Trabajo Fin de Máster

Máster Universitario en Electrónica, Tratamiento de Señal y
Comunicaciones

Construcción de una cámara semianecoica para test de componentes de automoción

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El tribunal nombrado para juzgar el Proyecto arriba indicado, compuesto por los siguientes miembros:

Presidente:

Vocales:

Secretario:

Acuerdan otorgarle la calificación de:

Sevilla, 2018

El Secretario del Tribunal

A mi familia
A mis maestros

Agradecimientos

Este trabajo final de máster no se podría haber llevado a cabo sin el apoyo de esas personas que me han enseñado durante mi etapa académica, mis profesores. Especialmente agradezco al tutor de este trabajo, Javier Reina, quien a pesar de la distancia a la que se realizó este TFM, fue paciente con mis errores y me ayudó a la realización de éste.

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Carmen Ramírez Perdigón

Barcelona, 2018

Resumen

En este trabajo fin de máster se presenta una solución al problema de la construcción de una cámara semianecoica para componentes de automoción, tratando de plasmar los requerimientos necesarios para construirla, un método para validarla y finalmente su puesta en marcha. Es un proyecto de ingeniería que se llevó a cabo entre 2017 y 2018 en la empresa Applus Laboratories, situada en Bellaterra (Barcelona).

Abstract

In this proyect, a solution is presented when building a semi-anechoic chamber for automotive components, trying to show the necessary requirements to build it, a method to validate it and finally its start-up. It was an engineering project that was carried out between 2017 and 2018 in the company Applus Laboratories, located in Bellaterra (Barcelona).

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Acrónimos

EUT	Equipment under test (equipo bajo test)
EMC	Electromagnetic compatibility (compatibilidad electromagnética)
EMI	Referente a los test de emisiones
EMS	Referente a los test de inmunidad
SAC	Semi-anechoic chamber (cámara semi-anecoica)
FAC	Faraday chamber (jaula de Faraday)
SR	Shielded room (sala apantallada)
ESD	Electrostatic discharge (descarga electrostática)
AP1	Panel de conectores 1
AP2	Panel de conectores 2
RF	Radio frecuencia

1 INTRODUCCIÓN

Desde los albores de las comunicaciones por medio de ondas electromagnéticas, se tuvo consciencia de la necesidad de evitar las interferencias entre distintas emisiones y de una sana convivencia entre los toscos receptores de la época. De los primeros aparatos de radio que carecían de selectividad y se podían escuchar varias emisoras al mismo tiempo se pasó a los receptores superheterodinos, que eran modelos más avanzados técnicamente, los cuales garantizaban estabilidad de funcionamiento y, sobre todo, selectividad de la emisora escuchada, con una mejor protección frente a interferencias.

Con el tiempo y el avance de la tecnología se fue abriendo paso a una nueva disciplina científico-tecnológica, la compatibilidad electromagnética (también conocida por sus siglas CEM o EMC) que se define como la rama de la tecnología electrónica y de las telecomunicaciones que estudia los mecanismos para eliminar, disminuir y prevenir los efectos de acoplamiento entre un equipo eléctrico o electrónico y su entorno electromagnético, intentando incorporar este conocimiento desde las primeras etapas de diseño de los dispositivos y sistemas.

Actualmente, la compatibilidad electromagnética se regula mediante normas y estándares con la finalidad de asegurar la confiabilidad y seguridad de los equipos y sistemas. Para cumplir con estos estándares se debe realizar la comprobación del funcionamiento electromagnético del equipo mediante las pruebas establecidas por el estándar regulador.

Posiblemente los pioneros de estos estudios hayan sido la industria militar y la aviación. La posibilidad de un fallo, debido a una deficiente compatibilidad electromagnética en ambas actividades, podría tener consecuencias catastróficas. En la electrónica de consumo y en automoción, los estándares que rigen el comportamiento de los productos electrónicos frente a la compatibilidad electromagnética se han ido ampliando y cobrando importancia con el paso de los años.

Un ejemplo de la importancia de la compatibilidad electromagnética en el sector de automoción es el siguiente. Imaginemos un vehículo que circula por la noche (éste será la víctima) y que, debido a una interferencia electromagnética generada por la señal radar (fuente de interferencia) de un aeropuerto cercano, acciona por error las luces de freno. El conductor de un vehículo que circule por detrás del anterior, al observar las luces de freno, para evitar una colisión, también frenará, posiblemente sin que le dé tiempo de ver si circulan coches por detrás. Esta situación puede causar un accidente y es perfectamente evitable. En España se vendieron, solo durante 2017, 1.462.230 vehículos nuevos (1) y todos están expuestos a campos electromagnéticos que podrían causar situaciones similares o peores que la anterior. La importancia de la compatibilidad electromagnética, en un sector que es además cada vez más electrónico, es innegable.

Como ya hemos dicho, la regulación de EMC se realiza mediante tests prestablecidos. Se distinguen dos grandes grupos de pruebas según la funcionalidad: de inmunidad, normalmente nombrados con las siglas EMS, y de emisiones, normalmente conocidos

por las siglas EMI. En los primeros se trata de comprobar la robustez que tiene el equipo ante posibles interferencias que provengan de su entorno. Para los test de emisiones sería el caso contrario, la norma establece unos niveles máximos de emisión que no se deben sobrepasar para que el equipo bajo prueba no interfiera en su entorno (véase la figura 1).

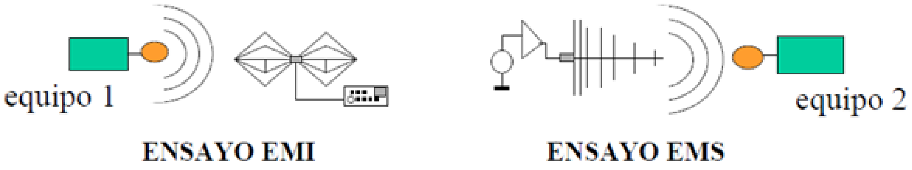


Figura 1:Esquema de test de EMI o EMS.

También pueden considerarse dos categorías según el tipo de propagación electromagnética: propagación conducida o radiada. Un test de inmunidad conducida, por ejemplo, consiste en inyectar una corriente mediante una pinza (transductor) al cableado de un equipo y comprobar cómo reacciona el equipo bajo prueba. Por su parte, un test de inmunidad radiada consiste en irradiar el equipo bajo prueba con un campo electromagnético mediante una antena.

Las pruebas de conformidad requieren un entorno caracterizado y seguro donde puedan realizarse. Para ello existen diferentes alternativas, dependiendo del grado de apantallamiento que sea preciso considerar:

- Cámara o jaula de Faraday, también conocida como cámara o sala apantallada o por sus siglas en inglés, FAC y SR (figura 2). Este tipo de cámaras proporcionan aislamiento electromagnético, es decir, las señales de RF que se encuentran en su interior no pueden salir y viceversa. Está compuesta básicamente por una estructura metálica con una puerta que garantiza un cierre con buen contacto metálico.
  En su interior, las ondas electromagnéticas pueden estar sometidas a reflexiones que son difíciles de controlar, por lo que este entorno no se considera apropiado para realizar tests de emisiones o inmunidad radiadas. Sin embargo, estos lugares son útiles para realizar tests conducidos, donde las componentes radiadas y reflejadas apenas tienen efecto.

Figura 2: Cámara de Faraday

- Cámaras semi-anecoicas (figura 3), normalmente conocidas por sus siglas en inglés, SAC (semi-anechoic chamber). Estas salas proporcionan no solo aislamiento electromagnético, sino que además simulan condiciones de espacio libre de influencias electromagnéticas. Se trata de las cámaras comúnmente usadas en la industria de automoción para tests de emisiones o inmunidad radiadas, ya que son capaces de absorber las señales reflejadas en paredes y techo, aunque no en el suelo. El suelo será un plano de masa que simulará las condiciones electromagnéticas reales, donde un vehículo circula sobre un plano de masa que será el suelo.

A lo largo de este trabajo se describirá este tipo de cámaras de forma más extensa, indicando cuáles son las características físicas de la cámara y de los materiales utilizados y por qué se usan de una manera y no de otra. Se abordarán los problemas que plantea el diseño, implementación y puesta en marcha de una SAC para componentes de automoción y cómo se pueden solucionar, llegando finalmente a la validación, lo que indicará que la cámara cumple los requisitos establecidos por los clientes y las entidades reguladoras.

Figura 3: Interior de una cámara semi-anecoica en Applus.

- Cámaras completamente anecoicas, normalmente conocidas como FAC (del inglés, Full Anechoic Chamber). Estas salas (figura 4), a diferencia de las anteriores, proporcionan un espacio completamente libre de reflexiones, incluidas las del suelo. Este entorno resulta útil para ciertos test de compatibilidad electromagnética en determinadas aplicaciones industriales y especialmente en el ámbito de la aeronáutica.

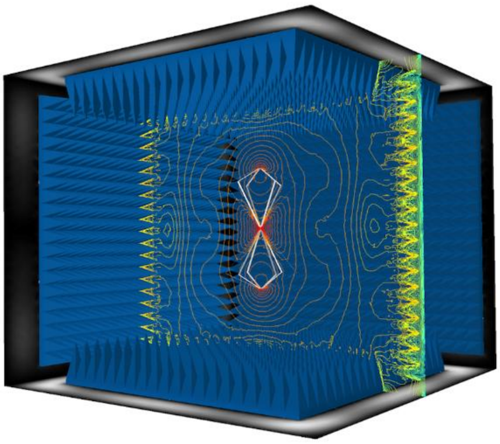


Figura 4: Cámara completamente anecoica.

1.1 MOTIVACIÓN

En el contexto de la automoción, la obligación de testear la compatibilidad electromagnética de cada equipo que se instale en un vehículo a motor, supone una gran cantidad de trabajo y también de tiempo, debido al enorme número de componentes. Sin embargo, no existen, al menos en España, suficientes laboratorios acreditados que proporcionen estos servicios a la industria.

Las principales empresas que realizan esta actividad en España se encuentran en Cataluña, ya que es el principal foco de la industria de automoción en nuestro país. Estas son Applus, donde se ha desarrollado este trabajo, e Idiada. Fuera de nuestro país encontramos importantes laboratorios de EMC para automoción, como 3Ctest en Reino Unido (recientemente adquirido por Applus).

Otra posibilidad para las empresas y fabricantes de estos productos es que realicen sus propias validaciones si disponen de los medios necesarios y consiguen las acreditaciones. Este es el caso de Lear, en Tarragona. Sin embargo, no solo es tremendamente costoso tener un laboratorio con todo el equipamiento necesario para realizar validaciones, sino que también es complicado, una vez montado el laboratorio, cumplir con todos los parámetros necesarios para que a ese laboratorio se le otorguen las acreditaciones. Por ello, la mayoría de las empresas optan por subcontratar estos servicios.

El problema que encuentran cuando solicitan un test de EMC es, en muchas ocasiones, el tiempo de espera. Aunque este tiempo depende del tipo de test, de lo complicado que pueda ser el montaje del setup o de si se trata o no una validación completa, es habitual que los tiempos oscilen entre 1 y 11 semanas. Esta amplitud lleva en ocasiones a tener que externalizar el test, si estos son urgentes, a otros países, en ocasiones mucho más costosos que en España.

El hecho de disponer de una nueva cámara SAC supondría reducir estos tiempos de espera y, obviamente, abarcar muchos más trabajos que poder facturar, razones que justifican la necesidad del presente Trabajo Fin de Máster.

Es preciso referirse al reto que supone, tanto empresarial como personal, la realización de este Trabajo Fin de Máster. Empresarial, debido al coste y a la inversión de recursos, y personal, ya que plantea una temática que requiere una alta cualificación científico-tecnológica y no existen directrices armonizadas a la hora de abordar el diseño de cámaras semianecoicas para automoción.

Cuando entré a formar parte del proyecto ya había terminado la fase de planteamiento y aceptación de la obra, pero aún quedaba realizar la obra, la validación y la compra de todos los equipos. Durante estos meses he combinado mi trabajo como ingeniera de test en una cámara de Faraday con el proyecto de la nueva cámara. Desde Applus realizamos el estudio de los equipos necesarios, los cálculos para las dimensiones del cableado y fibras, se realizó la supervisión de la construcción y la validación posterior y en todo momento Albatross, empresa encargada de la obra, trabajó bajo las directrices impuestas por Applus para la mejora de la cámara.

1.2 OBJETIVOS

El objetivo principal de este trabajo es plasmar de forma clara los procesos necesarios para diseñar y desplegar una cámara semianecoica para componentes de automoción (autocomponentes) completamente operativa, llamada SAC 4, proporcionando una metodología sistemática que ayude a la armonización de los procesos.

Para alcanzar este objetivo principal será necesario cumplir los siguientes objetivos particulares:

- Elegir la construcción que mejor se adapte a las necesidades de la empresa para la obtención de la SAC.

- Construcción de la SAC.
- Validación de la SAC, donde se explicará el método elegido y se pondrá en práctica, obteniendo finalmente unos resultados.
- Dotar del equipamiento necesario a la SAC para que esté completamente operativa.

1.3 ESTRUCTURA

La estructura de este proyecto está redactada enmarcando primero el marco teórico en el que se encuentra éste trabajo. Dónde primero se estudia la normativa aplicable a una cámara semianecoica del sector de la automoción y se proponen dos métodos de validación.

Después, también en un marco teórico, se indican los equipos y accesorios necesarios para trabajar con ésta cámara.

Una vez visto todo lo necesario para una nueva cámara semianecoica, lo siguiente es buscar, de entre las distintas opciones, que cámara se adecua mas a las necesidades del laboratorio, optándose por comprar y reciclar la cámara de otra empresa.

Debído a que la cámara original no se adecúa a los estándares de automoción es necesario hacer una readaptación, aprovechando el mayor material posible, para crear la núeva cámara.

Con la estructura de SAC4 ya planteada se realiza la construcción y de ésta, la posterior validación.

Finalmente, se hace un análisis de las conclusiones obtenidas del Trabajo Fin de Máster y una propuesta de líneas futuras.

1.4 ANTECEDENTES Y ESTADO DEL ARTE

No existen suficientes precedentes de estudios que se desarrollen la metodología seguida durante la construcción de una cámara semianecoica. Sin embargo, sí que se pueden citar estudios de rendimiento de estas cámaras, por ejemplo [2]. En este artículo se estudia la importancia del plano de masa y de su conexión a la cámara y cómo conseguir un plano de masa con menor resonancia. Además, en nuestro país existen publicación que los ingenieros de diseño toman como referencia para aprender a realizar diseños teniendo en cuenta la compatibilidad electromagnética, una de estas publicaciones viene a cargo del ingeniero Joan Pere Lopez Veragua., [3].

En Applus se realizó un proyecto similar un año antes de comenzar con el planteamiento de SAC 4, la construcción de SAC 3, que además, se convirtió en la primera cámara semi-anecoica de estas características, diseñada y planificada en España, ya que el proyecto se llevó a cabo íntegramente por Applus.

La construcción de SAC 3 tiene ciertas similitudes con la de SAC 4, ya que fue la readaptación de una cámara que poseía Applus desde hacía 30 años, pero que estaba en desuso. La empresa vio la oportunidad de utilizar los materiales y el espacio que poseían la antigua cámara, modificarla para que se adecuara a la normativa actual, e intentar ponerla en marcha, todo esto por un coste mucho menor que el de adquirir una cámara nueva.

Se tuvo que desmantelar completamente la cámara para comprobar el estado del blindaje, ya que con el paso del tiempo había sufrido corrosión por humedad. El blindaje exterior se reparó y se mejoró, ya que existían puntos de discontinuidad. Se incorporaron baldosas de ferritas a paredes y techo, ya que la antigua cámara no las tenía y se incorporaron los absorbentes que se habían desmontado. La planificación y construcción de SAC 3 se realizó entre 2016 y 2017, entrando en funcionamiento en mayo de 2017.

Durante la realización de la construcción de SAC 3 se llevó a cabo el estudio de la normativa, se comprendió cómo realizar una construcción de este tipo, se estudiaron los costes asociados y obviamente se cometieron errores. Todo este aprendizaje sirvió para adquirir experiencia que permitiera afrontar la realización de SAC 4.

Las construcciones se realizan basándose en el estándar regulador vigente, por ejemplo, en el caso de equipos industriales el estándar CISPR16, entendiendo por industriales los equipos comercializados que no requieran una seguridad especial como por ejemplo lavadoras, equipos de sonido, etc.

El último estándar regulador de automoción, la norma la CISPR 25 Ed.4 (15-05-2015), anexo 1 de esta memoria, incluye por primera vez un apartado con métodos para validar el correcto comportamiento de las cámaras, el Anexo J. Antes de la aparición de este anexo el estándar CISPR 25 se limitaba a ofrecer indicaciones sobre la construcción, pero no solicitaba ningún tipo de medición que caracterizara la cámara. Aunque el Anexo J no es de obligatorio cumplimiento es altamente recomendable tenerlo en cuenta para realizar nuevas cámaras. Además, se prevee que para conseguir las futuras acreditaciones de los fabricantes estos exijan la validación del Anexo J.

Para el cumplimiento de este anexo es necesario obtener un buen blindaje del exterior, siendo para ello muy importantes los paneles de ventilación o honeycombs, y un buen nivel de absorción de las ondas reflejadas en el interior de la cámara. Para esto último se utilizan absorbentes, este es el punto donde se ha visto el mayor el desarrollo tecnológico respecto al desarrollo de cámaras semianecoicas, ya que las primeras cámaras ni siquiera los incorporaban y su mejora es necesaria para bajar el nivel de ruido ambiental dentro de una cámara.

1.4.1 Honeycombs

Dentro de la cámara es necesario incluir ventilación, para ello se utilizan los paneles denominados honeycombs por la forma de su reja.

Estos paneles son tan importantes en el blindaje que normalmente determinan la frecuencia hasta la que la cámara está blindada. Tienen dos factores fundamentales, el primero es la cantidad de aire que dejan pasar y el segundo el blindaje que ofrecen. Estos factores suelen estar enfrentados, es decir, mientras mayor sea la cantidad de aire que dejen pasar menor será el blindaje.

Una opción que nos proporcionan los fabricantes para obtener una mejor atenuación, sobre todo en frecuencias altas donde el blindaje de los paneles deja de tener efectividad, es la de combinar paneles cruzados, aunque esto disminuiría considerablemente el flujo de aire. Para mejorar el flujo de aire en el caso que fuera necesario también es posible incorporar un ventilador al panel (fuera de la cámara).

1.4.2 Absorción de las ondas reflejadas dentro de cámara

Los absorbentes son los materiales encargados de absorber las ondas reflejadas en el interior de la cámara. Existen dos grupos fundamentales de absorbentes, las ferritas y absorbentes de poliuretano.

Centrándonos primero en los absorbentes de poliuretano, a los que normalmente se les conoce como absorbentes de RF, vemos que existe una gran tipología en el mercado, desde el material hasta la forma y tamaño, los diferentes absorbentes se comportan de manera distinta.

El poliuretano es un material plástico poroso formado por una agregación de burbujas. Se forma básicamente por la reacción química de dos compuestos, un poliol y un isocianato, aunque su formulación necesita y admite múltiples variantes y aditivos. El poliuretano al ser dopado con carbón ofrece una buena absorción de ondas electromagnéticas, dependiendo del porcentaje de carbón que tenga el poliuretano, absorberá más o menos energía.

Las prestaciones de las pirámides absorbentes de poliuretano dependen de su altura, en la figura 5 vemos distintos tipos de absorbentes según su altura. Cuanto mayor sea la altura de la pirámide (medida en longitudes de onda), mayor será su absorción. Las pirámides absorbentes más comúnmente utilizadas son las de 0.61 m, aunque su tamaño puede variar entre 0.1 m y 3m. La efectividad de las pirámides aumenta conforme aumenta la frecuencia, ya que disminuye su longitud de onda. La desventaja de utilizar estas pirámides es que, a frecuencias bajas, el tamaño de éstas para un correcto funcionamiento es demasiado grande (más o menos 3 m) y esto supone una reducción importante del área útil de la cámara, salvo que se usen en cámaras muy grandes.

Figura 5: Distintos tipos de absorbentes para cámaras semianecoicas

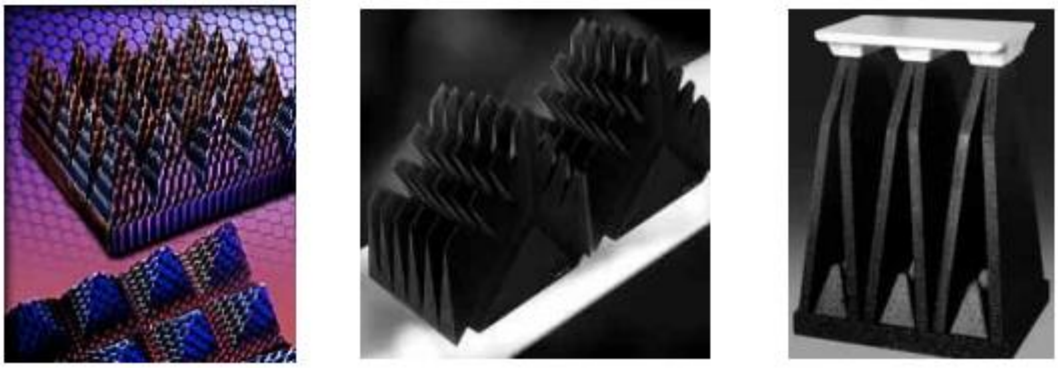
Otro factor que afecta a la absorción de la pirámide es el porcentaje de carbón, pues a medida que el porcentaje de carbón aumenta, mejor es la absorción en altas frecuencias, pero peor para frecuencias bajas.

Otro factor a tener en cuenta es la forma, generalmente los absorbentes son cónicos o piramidales, pero a veces se utilizan absorbentes de cuña, ejemplos de ello puede verse en la figura 6. Son utilizados generalmente en cámaras anecoicas y semi-anecoicas estrechas. Este absorbente se diseñó principalmente para dirigir la energía en un camino dado para que ésta pueda absorberse eficazmente por los otros materiales absorbentes (pirámides).

Figura 6: Absorbentes de tipo cuña.

Otra forma, aunque menos habitual, es la pirámide girada, su punta esta girada 45º. La ventaja de utilizar estos absorbentes es que utilizan menos material que la pirámide normal, y que sus puntas no se inclinan con el paso de los años. Sin embargo, su absorción no es tan buena como la absorción de la pirámide normal.

Actualmente se estudian los denominados absorbentes de nueva generación, en los que cambia básicamente su forma. En la figura 7 podemos ver nuevas formas diseñadas para absorbentes.



Pirámide corrugada

Absorbente de incidencia oblicua

Absorbente de cascada

Figura 7: Otros tipos de absorbentes.

Por otra parte, otro tipo de absorbente, quizás el más conocido, es el absorbente magnético o ferrita. Las baldosas de ferrita normalmente tienen buena absorción, (entre -10 dB y 30 dB) en el rango de frecuencias de 30 MHz a 600 MHz, a partir 600 MHz el comportamiento empieza a empeorar. Hay que destacar que se obtienen valores de absorción equivalentes a los que se obtendrían con pirámides de 3 m de longitud y una carga de carbón alta, pero ocupando apenas un par de centímetros de la cámara.

Según las necesidades, es posible combinar ambos absorbentes, a esto se le denomina absorbente híbrido. Teniendo en cuenta que los absorbentes de ferrita trabajan bien hasta más o menos 600 MHz y que los absorbentes piramidales de tamaño medio (típicamente 60 cm) se puede cubrir la banda de frecuencias altas (hasta 40 GHz).

2 MATERIAL Y MÉTODO

2.1 MATERIAL Y METODO

Se ha seguido la metodología de un proyecto de ingeniería llave en mano:

- Identificación de requisitos mediante el estudio de la normativa del sector. Analizando el estándar CISPR25, refente a lo ensayor de emisiones para componentes de automoción.
- Especificación formal de requisitos, tanto para la construcción como para la validación de una cámara semianecoica.
- Especificación del equipamiento necesario para la puesta en marcha de la cámara.
- Propuesta de solución tecnológica. Realización de planos para una cámara que se adaptase a los requisitos ya estudiados.
- Construcción y validación. Realización de la obra y posterior estudio del correcto apantallamiento mediante la validación estudiada en el estándar CIPS25.

2.2 NORMATIVA APLICABLE A LA CONSTRUCCION DE UNA SAC

Antes de comenzar a plantear cualquier construcción fue necesario estudiar detenidamente los requisitos exigidos por la normativa vigente, en este caso el estándar CISPR 25. Ésta es la norma fundamental que rige los test de medición de emisiones para automoción y que será adaptada por cada fabricante (Mercedes Benz, Renault-Nissan, Peugeot …) como base para establecer sus propias normas (igual o más exigentes que la CISPR 25). Es decir, la cámara deberá cumplir, al menos, con las restricciones de la CISPR 25 y una vez conseguido se deberá comprobar que también cumple con exigencias de cada fabricante para obtener la acreditación para poder realizar tests de cada uno.

Lo primero que la CISPR 25 establece respecto a lo que debe cumplir una cámara para automoción (vehículo y autocomponentes) son los niveles de ruido electromagnético ambiental que deben cumplirse en su interior. Estos tienen que estar al menos 6 dB por debajo de los especificados por la norma. La norma también proporciona unos límites de emisiones conducidas (punto 6.4.3 del anexo 1) y de emisiones radiadas (punto 6.5.4. del anexo 1) que los equipos bajo prueba deben superar.

Hay que tener en cuenta que dentro del blindaje habrá energía reflejada desde las superficies interiores. Este tipo de energía no causa un gran problema a la hora de realizar mediciones de emisiones conducidas, con lo que para este tipo de pruebas puede usarse, por ejemplo, una cámara de Faraday. Sin embargo, para mediaciones de emisiones radiadas, la energía reflejada puede causar errores de hasta 20 dB. Por lo tanto, es necesario aplicar algún material absorbente de RF a las paredes y al techo del blindaje. Como ya se vió, una solución típica son los absorbentes de RF, normalmente ferritas para bajas frecuencias y conos para frecuencias superiorres, estos son capaces de absorber la onda incidente (figura 8). No se debe colocar este material en el suelo.

El material de absorción debe tener un rendimiento mayor o igual a 6 dB en el rango entre 70 MHz a 2500 MHz. Este rendimiento se refiere a la capacidad de disminuir el ruido ambiente que tiene el absorbente. El estándar CISPR25 define, en el punto 4.1.4, que el ruido ambiente debe estar al menos 6 dB por debajo de los límites de emisiones, si el ruido fuera superior es posible que camuflara la emisión que se desea medir.

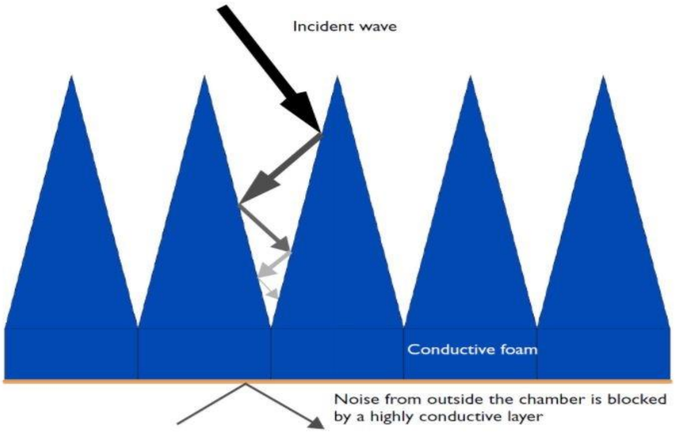


Figura 8: Efecto onda absorbida.

Respecto al tamaño máximo o mínimo, la norma no indica nada, pero sí establece que el recinto deberá ser de un tamaño lo suficientemente grande como para garantizar que tanto la antena como el equipo bajo prueba (EUT, del inglés equipment under test) pueda colocarse a una distancia de un metro, al menos, de cualquier punto de la sala, incluyendo el absorbente.

Para evitar posibles problemas, especialmente en tests de emisiones radiadas, dentro de la cámara no deberán colocarse elementos innecesarios como armarios, sillas, etc. Cuando se realicen los tests, esta restricción también incluye al personal que no participe activamente en su realización.

A diferencia de los tests para industria, todos los tests de componentes de automoción se realizan colocando el EUT sobre un plano de masa de referencia. Este deberá ser una superficie realizada en cobre, latón, bronce o acero galvánico, de al menos 0,5 mm de espesor. En nuestro caso, teniendo en cuenta que queremos poder realizar tanto medidas de emisiones radiadas como para emisiones conducidas, el tamaño mínimo del plano de tierra debe ser de 2,5 metros x 1 metro. El plano de masa tiene que estar elevado 0.9 ± 0.1 metros con respecto al suelo de la cámara.

El plano de masa de referencia deberá estar unido por medio de unas tiras (straps) al blindaje de la cámara. Las tiras estarán realizadas en uno de los materiales indicados anteriormente. La distancia entre las tiras no puede ser mayor a 30 cm y se debe guardar una proporción entre la longitud y el ancho de las tiras de 7:1. Para garantizar una conexión de baja impedancia a la sala blindada, es necesario un número suficiente de straps.

Las resonancias del plano de tierra de referencia, la ubicación, el ancho y la longitud de los straps influyen enormemente en los resultados de la medición. En la figura 9 se muestra la influencia del plano de masa.

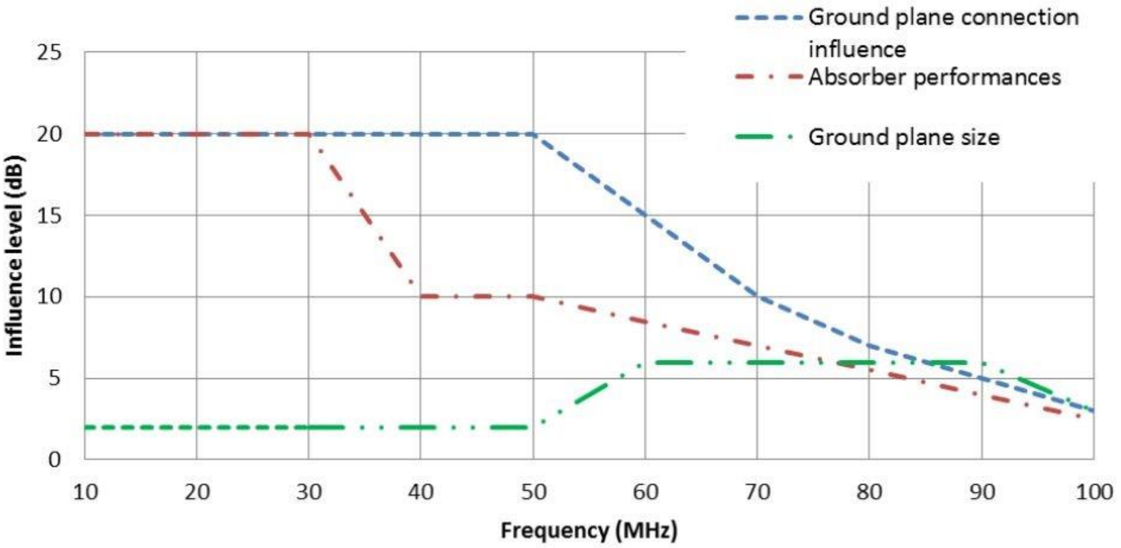


Figura 9: Influencia de la conexión del plano de masa, los absorbentes y el plano de masa (Anexo J de la CISPR25).

2.3 NORMATIVA DE VALIDACIÓN

Es necesario definir un método con el que comprobar el blindaje y, en general, el correcto funcionamiento de una cámara semianecoica. El anexo J de la CISPR25 proporciona dos métodos que, aunque no de obligado cumplimiento, son una buena práctica para validar una nueva SAC.

2.3.1 Anexo J.

La CISPR25 recomienda que se pruebe el rendimiento del blindaje de la cámara para configuraciones de test de emisiones radiadas, es decir, donde el blindaje es más crítico. Con este procedimiento se evaluarán las influencias de los absorbentes, el plano de tierra, la conexión al plano de tierra, etc.

La CISPR25 ofrece la opción o no de colocar baldosas de ferritas en el suelo. No será necesario poner suelo de ferrita si la cámara sin ellas cumple con la validación expuesta en este anexo.

Los dos métodos descritos son los siguientes.

- Método de medición de referencia. Este método utiliza un emplazamiento de referencia del cual ya se conoce que cumple con los requisitos de la norma CISPR 16-1-4. Se tomarán medidas de una señal emitida con una pequeña antena monopolo y luego se compararán las medidas del sitio de referencia con las del sitio a validar. Las medidas deben quedar dentro de una tolerancia definida en el anexo J de la CISPR25.
- Método de antena modelada de cable largo. En este método se utiliza como antena transmisora un cable de 50 cm. Se realizarán medidas a 30 MHz y superiores con test de emisiones radiadas. Las medidas deben quedar dentro de una tolerancia determinada.

En este Proyecto nos centraremos en detallar únicamente el segundo método, ya que fue el elegido para validar SAC 4. Todos los detalles de cómo realizar el primer método se encuentran bien definidos en el anexo J.

Para el método elegido es necesario disponer del equipo que actuará a modo de antena emisora, en este caso se trata de un alambre de 50 cm de longitud que se elevará 5 cm sobre el plano de masa y estará suspendido entre dos placas metálicas cuadradas terminadas, por un lado, en una carga de 50 ohms y después en un atenuador de 10 dB al que se le conectará el sistema de generación de señal (véanse las figuras 10, 11 y 12).

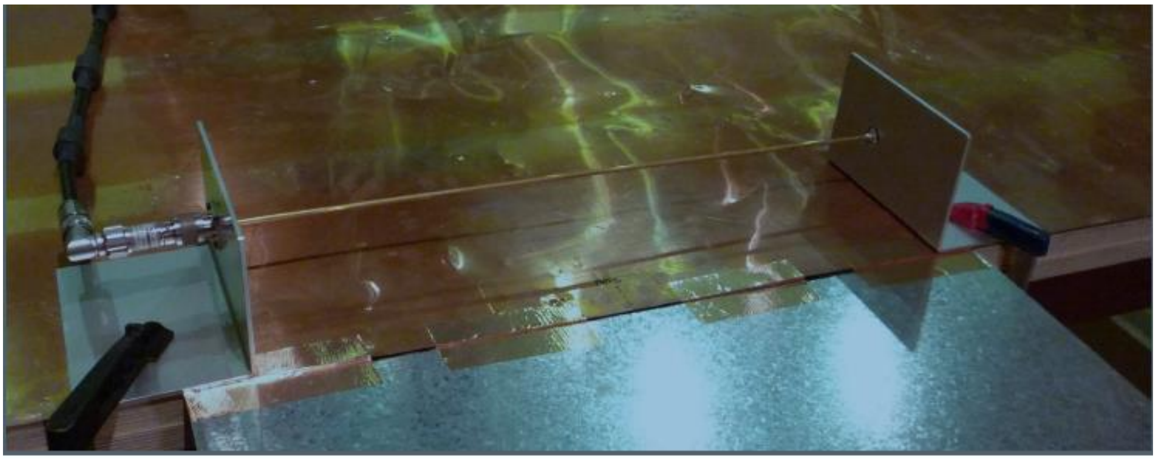


Figura 10: Equipo emisor de señal.

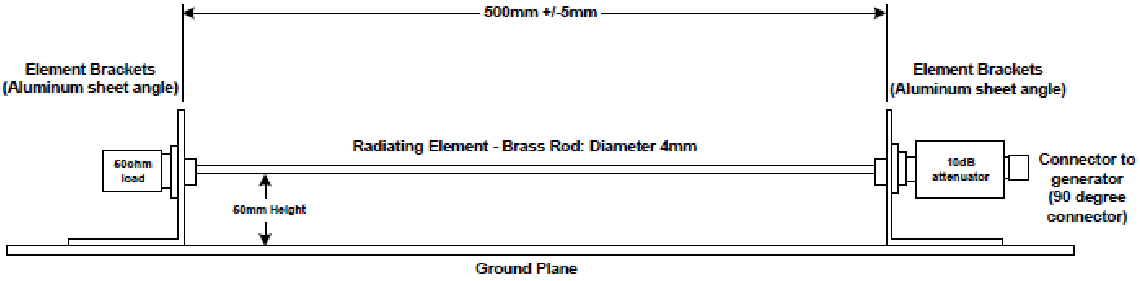


Figura 11: Plano para el montaje del equipo emisor.

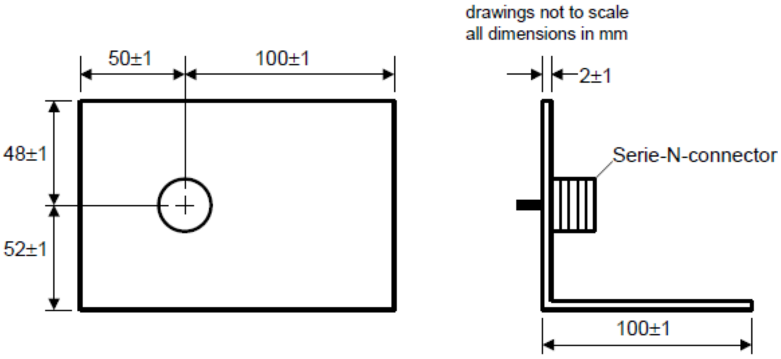


Figura 12: Plano de los conectores del equipo emisor.

Los tipos de antena receptoras (según el rango de frecuencia que se vaya a medir) se describen en el punto 6.5 de la CISPR25 y serán una antena monopolo, una antena bicónica y una antena logoperiódica. Los factores de antena (ganancia de cada antena) deben ser conocidos y considerados en los cálculos.

No es necesario que la potencia transmitida sea muy elevada, para evitar una sobrecarga del sistema de emisión se inserta el atenuador de 10 dB y este factor se incluye en los cálculos de medida.

La configuración o esquema físico de todos los equipos que intervienen en la medición debe ser el mismo que en un test de emisiones radiadas, las distancias, los caminos, etc.

El paso de frecuencias que se usará viene definido en el punto J.2.3.1.2 de la norma CISPR25.

2.3.2 Medición de intensidad de campo

El esquema de la configuración del test lo encontramos en la figura 13. La primera medida se debe hacer de forma directa, con el cable que alimentará a la antena emisora (8) directamente conectado al cable de salida de la antena receptora (7). El equipo que genere la señal debe estar configurado a 1 Vrms (120 dB(µV)). La medida leída se representará como M0 en dB(µV).

Para la medida del coeficiente de radiación, es decir, que intensidad de campo eléctrico que recibe la antena, se conecta el cable que transmite la señal de 1 Vrms (8) a la entrada del atenuador de 10 dB (3) y el cable del receptor (7) se conecta a la antena receptora (6), según se muestra en la figura 39. Se configura de nuevo la amplitud de la señal generada a 1 Vrms a la entrada del atenuador de 10dB. La lectura del receptor será registrada como MA en dB(µV) ya que la antena habrá convertido la señal de campo eléctrico a tensión y eso será lo que verá el receptor.

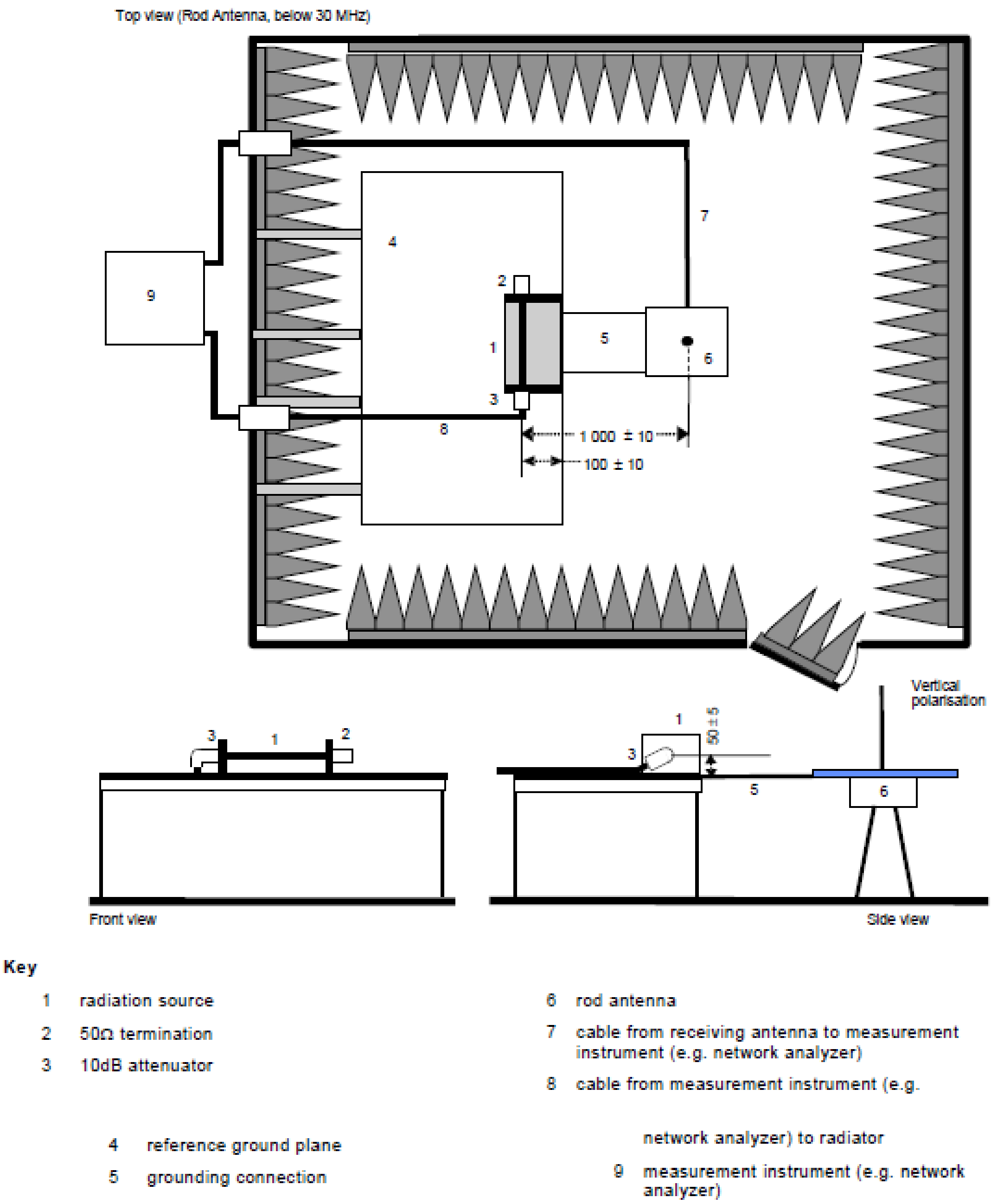


Figura 13: Esquema del test de validación con antena monopolo.

Es necesario tener las antenas que se usan caracterizadas con su factor de antena. Este factor se define como la relación entre la intensidad es campo eléctrico y la tensión que se genera en los terminales de la antena.

A partir de los dos valores calculados y el factor de antena de la antena receptora (kAF, en dB (1/m)), se puede obtener la intensidad de campo equivalente (Eeq, en dB (µV/m)) para cada frecuencia:

$$Eeq = 120\text{dB}(\mu V) + (MA - M0)\ kAF \qquad (1)$$

En el rango de frecuencia superior a 30 MHz, las mediciones se deben realizar tanto para polarizaciones horizontales como verticales. Los resultados se denorarán como Eeq, hor y Eeq, ver.

Para tener unos resultados fiables, el anexo indica que el nivel de ruido ambiente debe estar, al menos, 10 dB por debajo de los niveles de señal medidos. Para caracterizar los niveles de ambiente habría que realizar la medida con la antena receptora conectada al equipo receptor, teniendo la antena emisora desconectada de la fuente de señal.

El anexo indica los valores de referencia que se deben comparar con los datos de medición de intensidad de campo obtenidos en la tabla J.1. La norma permite una desviación de ± 6 dB con respecto a la tabla J.1 del anexo. La cámara y su instalación en general (diseño físico, tamaño del plano de referencia, absorbentes de RF, etc.) cumplirán con este método de validación si el resultado de la ecuación siguiente (Total %IT 150 KHz to 1000 MHz, Long Wire Method) es mayor o igual que el 90%, es decir, al menos el 90% de los puntos están dentro de los márgenes de desviación.

$$Total\ \%IT_{150\ kHz\ to\ 1000\ MHz,\ Long\ Wire\ Method} = \left(\frac{\text{data points } 150\ kHz\ to\ 1000\ MHz \text{ where } \Delta_{Long\ Wire\ Method} \text{ is within } \pm 6\ dB}{481} \right) \cdot 100 \qquad (2)$$

Ecuación 2

Los valores de desviación obtenidos no deben ser utilizados como factor de corrección para las mediciones de emisiones de un EUT.

2.4 ACCESORIOS Y EQUIPAMIENTO

Toda cámara necesita equiparse para poder ponerse en funcionamiento. Como en el laboratorio ya existían varias cáramas en uso se tomó su equipamiento como referencia. En los siguientes puntos se describen, a grandes rangos, los equipos y materiales usados para ello.

2.4.1 Cableado para RF

Para cualquier test es necesario transmitir la señal de RF, ya sea emitida por el equipo o inyectada a éste. Los cables son componentes pasivos destinados a la interconexión entre equipos. Hay que tener en cuenta que cada cable tiene una respuesta en frecuencia por lo que es necesario tener calibradas las pérdidas que produce en su rango de frecuencias. Para compensar la respuesta en frecuencia es necesario calibrar cada cable en su rango de funcionamiento e incluir estos datos en el software, EMC32, para que este los compense.

Cada test tiene características distintas por lo que se usará un cableado distinto para cada test. Podríamos clasificar los cables usados de la siguiente manera:

- Cables capaces de **transmitir potencia** y que posean **baja atenuación**. Este tipo de cableado está destinado a realizar test de inmunidad ya que interesa que sea capaz de transmitir la potencia generada por el amplificador y que se pierda la mínima energía para que no sea necesario un amplificador de mayor potencia. Son cables apantallados para que interfieran lo mínimo posible con el test. Se eligieron cables de diferentes longitudes que soportasen una inyección de hasta 1kW a 1GHz y 100W a 6GHz, y que su atenuación fuera inferior a 0,5 dB a 6GHz, todos del fabricante HUBER+SUHNER. Al ser cables que transmitirán potencia serán poco flexibles y por lo general mas delicados ya que la torsión podría romper su apantallamiento [4].
- Cables que posean **baja atenuación** y sean **flexibles**. Nuevamente se trata de cables apantallados. Están pensados para transmitir señales de baja potencia y por lo tanto se utilizan para realizar test de emisiones. Poseen un diámetro menor que los anteriores y por lo tanto mayor flexibilidad y soportan mayor torsión, esto resulta necesario para test en los que el cable tiene que ir conducido

por un mástil que le produce ándulos de 90º. Se requiere que posea poca atenuación ya que la señal que transmitirá ya tendrá un nivel bajo de potencia. Los cables elegidos soportan hasta 100 W a 1 GHz y poseen una atenuación interior a 0,75 dB a 6 GHz. Se eligieron cables de entre 0,5 metros y 4,7 metros del fabricante HUBER+SUHNER [5]

- Cables que posean **baja atenuación** y estén **envueltos en ferritas**. Las normas de algunos fabricantes exigen que para realizar test de emisiones radiadas el cableado esté apantallado con ferritas por lo que se solicitó al fabricante que uno de los cables de baja atenuación se forrase en ferritas y se envolviera en una funda plástica para protegerlo. Este cable se usará dentro de cámara para conectar la antena receptora con el pasamuros (bloque 7 en la imagen 39)
- Cables **RG223**. Se trata de cables que poseen doble apantallamiento pero que no son capaces de soportar potencias elevadas ni poseen baja atenuación. Se utilizan para realizar conexiones entre equipos, por ejemplo, un PWM con el EUT.

La cámara se equipó con estos tipos de cable, la lista de todos ellos con sus características se detalla en el Anexo 5.

2.4.2 Comunicaciones usadas en una cámara semianecoica

En la mayoría de las ocasiones que usamos una cámara semianecoica necesitamos comunicar elementos del interior y del exterior. Las comunicaciones pueden transmitir la señal de video monitoriza el test, de una señal analógica que nos interese obtener como por ejemplo, la monitorización de una tensión concreta, o comunicación propia que necesita el EUT para su funcionamiento.

Es innegable que los vehículos son ahora más electrónicos y menos mecánicos que hace 20 años y esta tendencia está creciendo cada año. Uno de los avances electrónicos más importantes para vehículos son las comunicaciones entre componentes, por ejemplo, el sensor que indica el nivel de aceite se comunica con la centralita de control del motor y con el cuadro de mandos.

Los principales protocolos de comunicación en vehículo son el CAN (Controller Area Network) y el LIN (Local Interconnect Network). Todos los vehículos que salen al mercado ya poseen comunicaciones con alguno o ambos protocolos. Otros protocolos de comunicación cada vez más integrados en vehículo son FlexRay, Most-bus y Ethernet. Las comunicaciones ayudan en gran medida a mejorar la seguridad de vehículo, sin embargo, son un nuevo punto a tener en cuenta a la hora de realizar test de EMC. Es fundamental, por ejemplo, comprobar la robustez de las comunicaciones cuando el elemento con el que se comunican es crítico.

En la práctica, cuando realizamos un test de EMC a un EUT que se controla mediante comunicación CAN o LIN es necesario tener el dispositivo con el que se comunicará, un PC, una caja de control que simule una centralita… fuera de cámara para que no se vea afecto. Es decir, necesitaremos un modo comunicar esa transmisión del interior al exterior. Esto se hace con un sistema de transceiver y fibras ópticas como el que vemos en la siguiente imagen. En la imagen 14 vemos el EUT comunicándose con un PC externo por medio de un sistema de transceiver (bloques rojos) y una fibra óptica (línea amarilla).

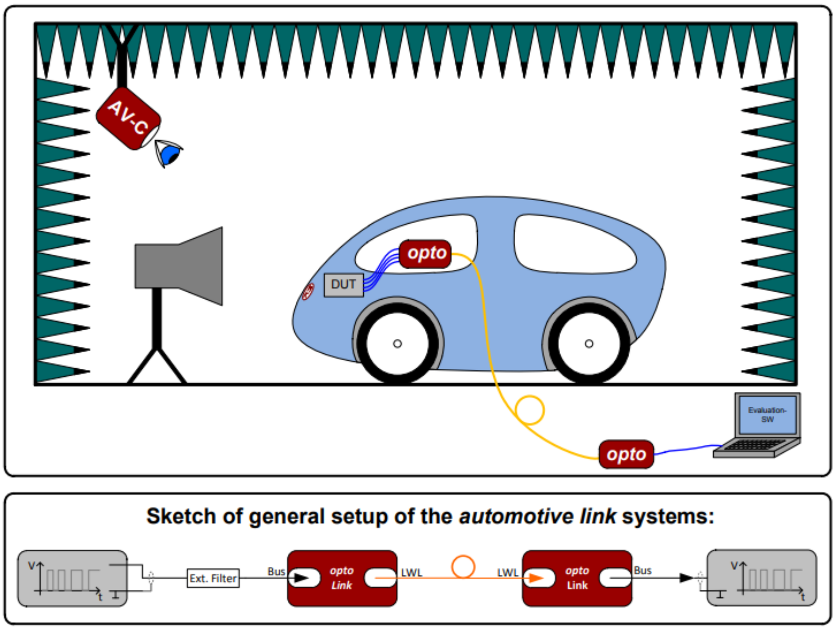


Figura 14: Estructura de comunicaciones LIN en una SAC.

2.4.3 Fibras ópticas

Debido a las características del tipo de test que se realizará dentro de la cámara el medio de soporte físico de las comunicaciones no debe ser un cable metálico. Cualquier tipo de cable metálico podría, por ejemplo, actuar a modo de antena si se coloca de fuera de la cámara a dentro y de este modo perderíamos el total aislamiento electromagnético que se busca. En el lugar de cables convencionales se deben de usar fibras ópticas, pues éstas no se verán afectadas por la RF y tampoco emitirán. Estas fibras se combinarán con módulos transceiver, de los que se hablará en la siguiente sección.

Además, las fibras se dejarán pasadas por debajo del suelo de la SAC, quedando accesibles solo sus conectores. De este modo se evitará el desgaste de las fibras, por ejemplo, por pisaduras o dobleces.

En el mercado encontramos distintos tipos de fibras según el tipo de transmisión que permiten, estas son:

- **Monomodo**. Tiene la peculiaridad de que dentro de su núcleo, la luz viaja sin reflejarse en sus paredes lo que permite mantener velocidades de transferencia más altas. Son también adecuadas para transmisiones de grandes distancias, hasta 10 km.
- **Multimodo**. permite que los haces de luz se reflejen en las paredes del revestimiento. Esta fibra no alcanza la velocidad de transmisión de la anterior y solo puede usarse para redes de cortas distancias, como por ejemplo dentro de un mismo edificio.

Para equipar SAC 4 se eligió fibras multimodo ya que la mayor distancia a cubrir sería de 10 metros y la velocidad de transmisión necesaria no era muy alta (hasta 1Mbits/s). Además, la diferencia económica es importante entre ambos tipos de fibras, siendo la multimodo mucho más económica.

2.4.4 Transceivers

Un transceiver óptico es un equipo capaz de transformar una comunicación recibida por el puerto y convertirlo a una señal de tensión analógica o a un protocolo de comunicación y viceversa. Para los test en una cámara semianecoica, los transceivers deben ir en parejas, uno en la sala de control y otro en el interior de la cámara.

Los módulos de comunicación óptica serían compartidos con SAC 3, esta ya disponía de varios por lo que no se adquirieron módulos nuevos, aunque, en ocasiones los proyectos tienen tales necesidades de comunicaciones que puede ser necesario compartir los módulos de todo el laboratorio. Estos módulos son del fabricante Messtecnik, (figura 15). Se trata de módulos diseñados para este tipo de test, ya que se ha comprobado que están totalmente apantallados.

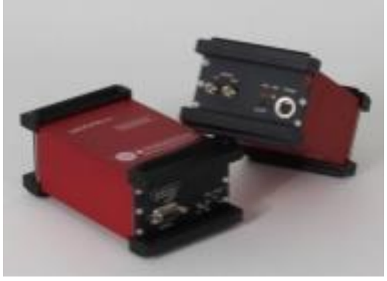


Figura 15: Modulos transceiver de Messtechnik.

Como ya se ha visto, los equipos bajo prueba pueden tener comunicación LIN, CAN o ambas a la vez y, cada pareja de módulos está dirigida a un tipo de comunicación por lo que encontramos módulos de LIN [6] y de CAN. Se dispone en el laboratorio de dos tipos de módulos CAN, HS (high-speed) [7] y FD (Flexible Data-Rate) [8] para poder cubrir las distintas necesidades de los clientes.

Además de las comunicaciones del propio EUT, es posible que necesitemos leer una señal analógica, frecuentemente el consumo de una corriente del EUT. Para ello se usan unos módulos distintos, módulos de señal. Estos funcionan leyendo hasta dos señales distintas. Son capaces de leer tensión, que se transmite al módulo exterior por fibra y de éste pasa a un receptor, por ejemplo, un osciloscopio o un sistema de adquisición de datos, el cual se conecta al software. El software es capaz de hacer la conversión de tensión a corriente.

Estos módulos poseen una batería interna que les permite funcionar sin tener que estar conectados a la red de alimentación. Sin embargo, en muchas ocasiones, están funcionando tantas horas que es necesario cargarlos de nuevo. Para no interrumpir el test (la carga dura aproximadamente 4 horas), se dispone también de varias baterías externas, battery pack de Messtechnik, también apantalladas.

2.4.5 Monitorización por video

Aunque cada vez en menor medida, la mayor parte de las señales y el comportamiento general del EUT siguen sin monitorizarse por software. Estas señales son luminosas, mediante LEDs que indiquen un mal funcionamiento, lámparas propias del EUT o sonoras, por ejemplo, el sonido de un motor interno. Por ello, resulta necesario poder ver y escuchar lo que sucede dentro de la SAC, y para eso se emplean cámaras de vigilancia. Estas cámaras deberán estar equipadas con transmisión óptica por las razones que se han comentado en el punto anterior. Además, deberán estar blindadas para que resistan los test inmunidad y para que no afecten en las medidas de emisiones.

Normalmente, este tipo de cámaras se instalan en posiciones fijas en las esquinas superiores del interior de las cámaras semianecoicas por lo que resulta muy útil que estén integradas en un sistema que pueda hacer que tengan algo de movimiento y se controlen desde el exterior [9]. En SAC 4 se han instalado dos cámaras en esquinas superiores de la sala (figura 16), que están controladas con el controlador externo (figura 17). Estas cámaras son capaces de tener cierto movimiento, pero en muchas ocasiones es necesario ver un punto que resulta invisible para las cámaras fijas, para ello también se dispone de una cámara portátil con trípode, imagen izquierda de la figura 46.

Las cámaras elegidas para equipar SAC 4 son también de la marca Messtechnik gracias al buen apantallamiento que proporcionan [10].

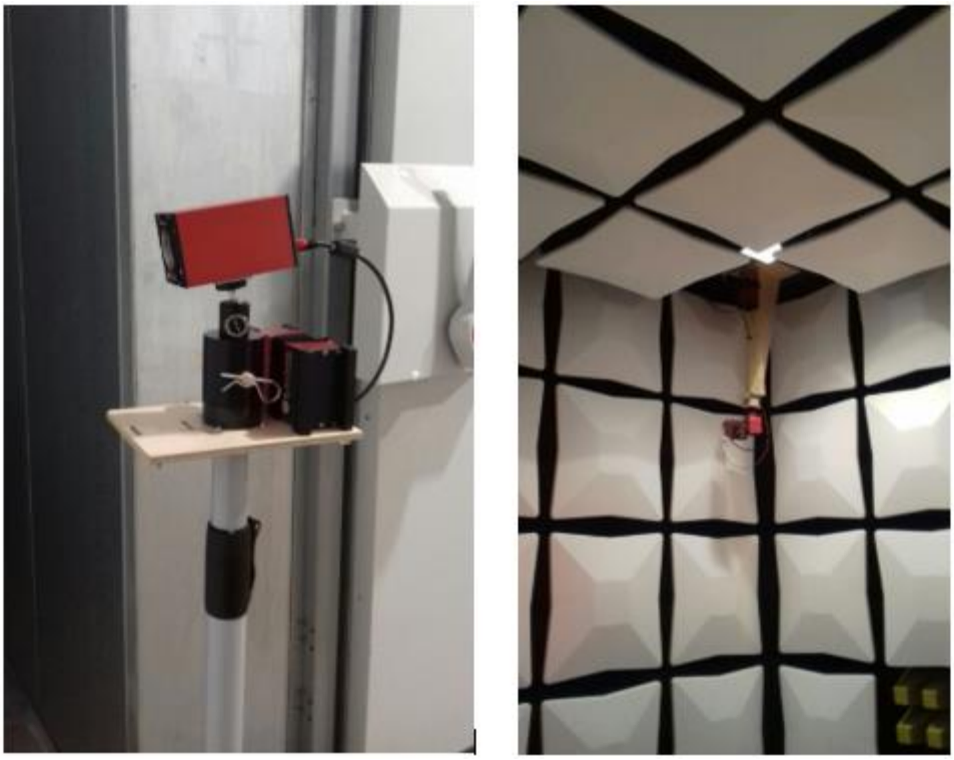


Figura 16: Cámara portátil y cámara fija de Messtechnik.

Figura 17: Distintos módulos controladores de cámara.

2.4.6 Transductores

Se trata de dispositivos que tienen la misión de recibir energía de una naturaleza eléctrica, mecánica, acústica, etc., y suministrar otra energía de diferente naturaleza, pero de características dependientes de la que recibió, generalmente tensión.

Podemos encontrar transductores activos y pasivos. Los transductores activos son aquellos a los que hay que conectar una fuente externa de energía eléctrica para que puedan responder a la magnitud física, mientras que los transductores pasivos son capaces de realizar esta conversión sin necesidad de alimentarlos.

Para los test de automoción se usan generalmente transductores pasivos, sondas para señales conducidas y antenas para señales radiadas. No obstante, en ocasiones se usan transductores activos, como por ejemplo pinzas de corriente para la monitorización del consumo.

En este Proyecto no se entrará a analizar las características de cada transductor, ya que existen y se usan una gran variedad dependiendo del rango de frecuencias, de si inyecta o recibe una señal y del tipo de señal (figura 18). SAC4 se equipará con los mismos transductores que SAC3.

Figura 18: Diferentes tipos de transductores.

2.4.7 Receptores de emisión

Son los equipos encargados de cuantificar el nivel de señal recibida que, como ya se ha dicho, es típicamente tensión, dando como resultado un valor numérico asociado a la magnitud relacionada (por ejemplo, 34 V). Los receptores son básicamente analizadores de espectro a los que se le ha añadido un preselector a la entrada (figura 19). Son equipos activos y se caracterizan por tener una gran precisión y sensibilidad. Para que no pierdan la precisión deben ser calibrados de manera periódica, normalmente una vez al año, aunque además suelen traer la opción de hacer una autocalibración por si existen dudas de su correcto funcionamiento. Hay una gran variedad de receptores, y normalmente se utiliza un receptor según las necesidades, por ejemplo, los receptores que trabajan a baja frecuencia suelen tener un nivel de ruido menor. Si necesitamos que trabajen a frecuencias altas, por ejemplo, superiores a 3 GHz, y un nivel de ruido bajo, los precios se elevan considerablemente.

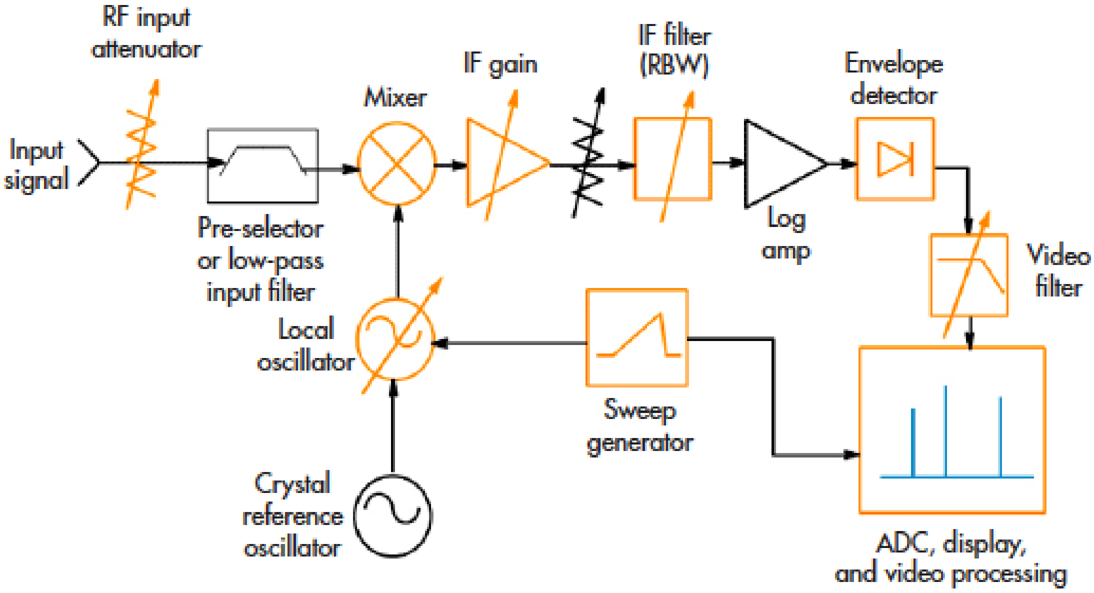


Figura 19: Estructura de un receptor de señal.

Para equipar SAC 4 se eligió uno de los últimos modelos de Rohde & Schwarz, el EMI Receiver ESW 8 (figura 48). Se trata de un equipo rápido que permite el análisis tanto en frecuencia, análisis clásico, como en tiempo, via FFT. Su principal característica es su rango frecuencial de trabajo, de 2 Hz a 8 GHz. Téngase en cuenta que en automoción, normalmente, no se superan los 6 GHz.

Este equipo no será compartido con otra sala, ya que no es conveniente moverlo debido a que es un equipo pesado muy sensible [11].

Figura 20: Receptor ESW 8 de Rohde & Schwarz.

2.4.8 Generadores de señal de RF

Cuando se va realizar un test de inmunidad es necesario generar la señal que se usará para perturbar el EUT Primero se aplicará una señal de baja potencia que será amplificada con un amplificador de señal. Las características de la señal de interferente están bien establecidas en cada norma y suelen atender a las siguientes características:

- Tipo de señal: sinusoidal, triangular, etc.
- Frecuencia
- Modulación

Este equipo no solo dispondrá de un conector de salida, RF OUTPUT, sino que debe tener varios canales de I/O (GPIB, LAN, etc.) que se usarán para ser conectado al PC de control.

Las señales más habituales para las normas de automoción son las siguientes (figura 21):

- Señal sin modulación (onda continua, CW)
- Señal modulada en amplitud (AM) por un tono de 1 kHz
- Señal modulada en fase (PM) con un tono de 577 µs y un periodo de 4600 µs.

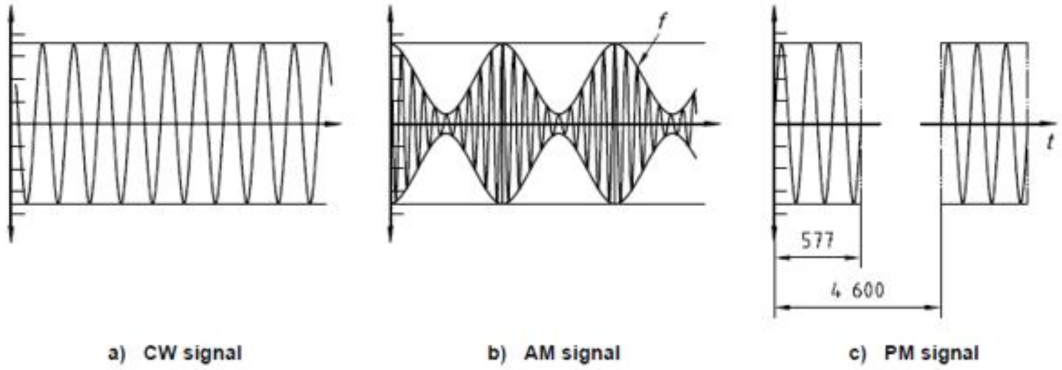


Figura 21: Señales generadas más usuales.

Para equipar SAC4, como ya se ha comentado, se utilizarán los racks de SAC3 y por lo tanto se usarán dos tipos de generadores de RF, uno que se usará en el rack del amplificador de señal que trabaja en baja frecuencia y otro para el rack de alta frecuencia.

Para el rack "de baja" se utiliza el generador de Rohde & Schwarz SMC100A [12], que genera señales de entre 9 kHz a 1.1 GHz. Para el rack "de alta" se utiliza el SMB100A [13] de la misma marca que el anterior y es capaz de generar señales de entre 9 kHz a 6 GHz (figura 22).

Figura 22: Generador de Rohde & Schwarz.

2.4.9 Amplificadores de señal

Suele ser, a la par del receptor, uno de los equipos más caros y sensibles de los laboratorios de EMC. Se encarga de amplificar la señal recibida desde el generador. Su característica principal es la potencia que son capaces de entregar, de hecho, los nombres de muchos de ellos suelen incluirla, por ejemplo, el BONN500 es capaz amplificar hasta 500W.

Tienen una zona lineal de trabajo (figura 23), en la que se puede realizar una interpolación correcta y de la cual no se debe salir. La zona lineal de trabajo la definen los fabricantes, estos han tomado como estándar delimitar esta zona hasta el punto de compresión de 1 dB. En el caso de saturar, la ganancia nominal sería distinta y las propiedades de la señal podrían verse modificadas (respuestas espurias, emisión de armónicos, etc.).

La calibración periódica de estos equipos asegura que la señal amplificada en su zona de trabajo no se distorsiona.

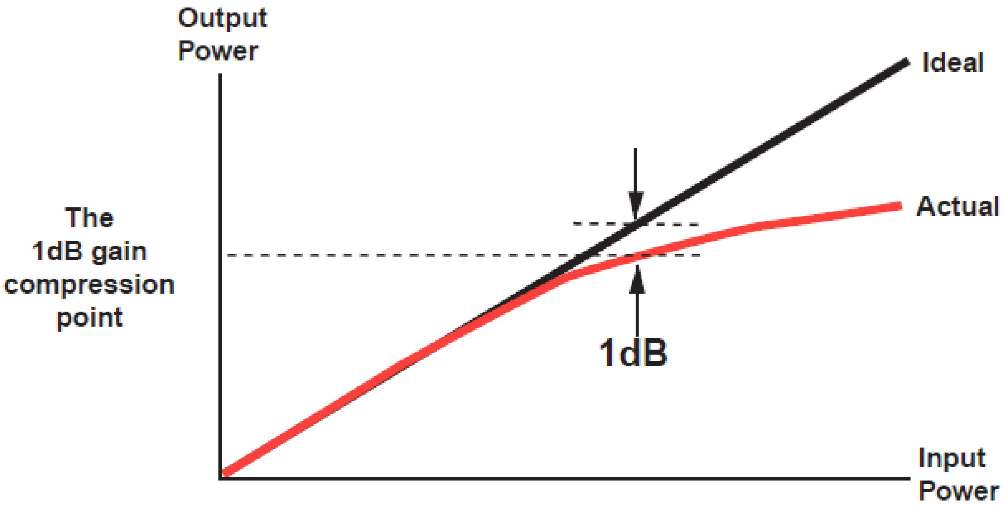


Figura 23: Zona lineal de trabajo del amplificador de señal.

2.4.10 Acoplador direccional

Es un componente que se usa para medir la cantidad de energía reflejada en un test de inmunidad. Como se trabaja con señales de alta potencia (tras ser amplificadas) los puertos de medida incluyen un acoplo para poder conectar equipos de medida (típicamente de entre 40 dB y 80 dB). El acoplador es un elemento imprescindible para conocer si el test se está realizando correctamente e incluso para proteger al propio amplificador de señal, ya que si obtenemos una señal reflejada muy potente, ésta se inyectará de vuelta al amplificador y es posible que no esté dimensionado para ello.

En SAC 4 se utilizarán los acopladores direccionales que poseen los racks de amplificadores, que incluyen un acoplo de 70 dB, figura 24.

Figura 24: Acoplador direccional de 40 dB.

Los acopladores direccionales poseen los siguientes conectores:

- Conexiones:
    - Entrada: RF in
    - Salida: RF out
- Puertos de medida:
    - Forward (FWD) / Onda incidente
    - Reverse (REV) / Onda reflejada

El acoplador direccional toma una pequeña porción de la señal, por ejemplo, un 1% de su potencia. Por el puerto de forward se lee la señal incidente, es decir, la señal que realmente se está aplicando, y por el puerto reverse la señal que se está reflejando, figura 25.

Un ejemplo del funcionamiento de este equipo es cuando al amplificador no se le conecta ningún transductor (circuito abierto). En este caso encontramos que la señal reflejada es el 100% de la señal emitida.

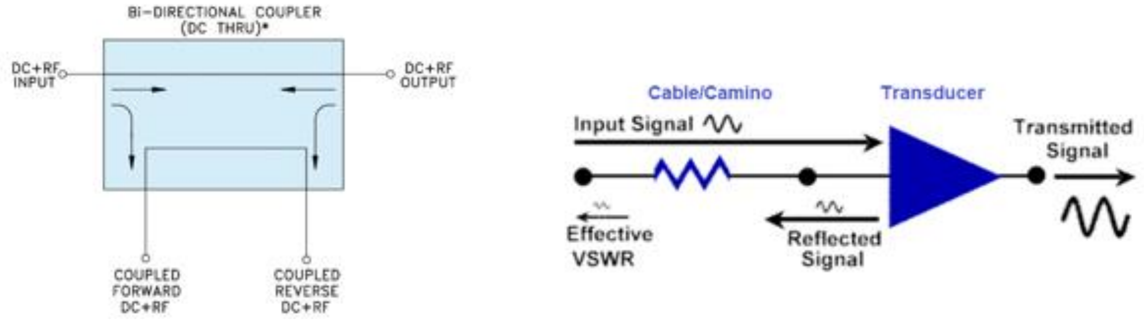


Figura 25: Esquema de funcionamiento del acoplador direccional.

2.4.11 Medidores de potencia y sensores de potencia

El sistema compuesto por el medidor de potencia y los sensores de potencia se encarga de medir el nivel de señal en el punto de conexión. Se asemeja a un sistema compuesto por un osciloscopio y una sonda.

Existen dos sensores de potencia, uno se conectará a la salida forward del acoplador direccional y otro a la salida reverse. Estos transmitirán la señal al medidor de potencia que será el encargado de traducir este mensaje. En el caso de los medidores de potencia tenemos que considerar el rango dinámico de funcionamiento que tienen (por ejemplo, de -67 dBm hasta +23 dBm) y el rango frecuencial de funcionamiento (por ejemplo de 9 kHz hasta 6 GHz). En la mayoría de los racks de amplificadores de potencia del laboratorio están integrados los mismos sensores de potencia, los R&S Z-91. Estas serán las que se usen también para SAC4 (ya integradas en el rack de SAC3), véase figura 56 [14].

Figura 26: Sensor de potencia de R&S Z-91.

2.4.12 Software

Para automatizar los test, consiguiendo reducir el número de errores que pueden ocurrir debido a la gran cantidad de variables que existen en cada equipo, y evitando realizar cálculos de atenuación, pérdidas o ganancias en cada frecuencia, es fundamental utilizar un software adecuado. Además, esto reducirá considerablemente el tiempo de test al mínimo posible.

Para la industria de la automoción, aunque existen más, generalmente se utiliza el software de Rohde Schwarz, EMC32, que resulta muy útil ya que casi todos los equipos que se suelen utilizar son de esta misma marca y eso permite que se interconecten fácilmente entre ellos.

EMC32 es un software especialmente preparado para test de EMC de industria y automoción, sirve para todos los test que se realicen en estos ámbitos, pero es modular, para poder realizar test de emisiones es necesario tener una licencia (Key) que desbloque esa opción y así con cada opción.

EMC32 nos permite realizar un hardware setup, es decir, nos permite realizar un setup virtual a semejanza del setup real, un ejemplo de ello se muestra en la figura 27. Además, podremos indicar el rango de frecuencias en el que se moverá, la atenuación que tendrán los caminos usados, etc. También se pueden configurar límites, distintos tipos de detectores (pico, quasi-pico y/o media). EMC32 nos proporciona un resultado en forma de gráficos y de valores en tablas.

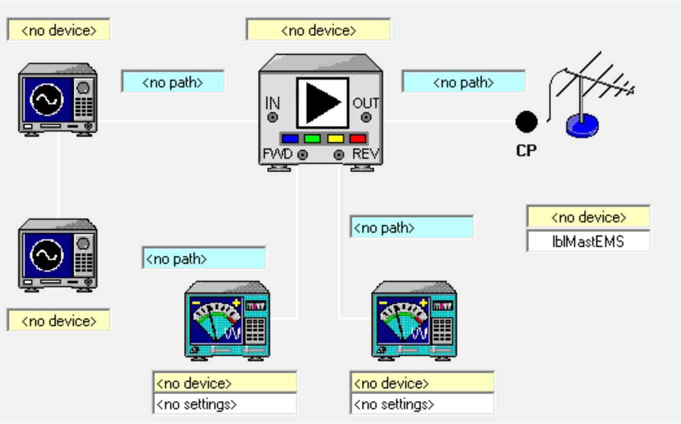


Figura 27: Vista de las conexiones de un Hardware setup en el EMC32.

2.4.13 LISN (Line Impedance Stabilization Network)

Una LISN es básicamente un filtro de paso bajo que se coloca entre la fuente de alimentación o la batería, es decir, aíslan las señales de RF no deseadas de la fuente de alimentación y el EUT Además, generan una impedancia conocida de 50 ohm. La adaptación de impedancia es fundamental en los test de EMC para que las señales sean conocidas, todos los sistemas deberán estar adaptados a 50 ohm.

Las LISN y sirven como puerto de medición del ruido conducido que genera el propio DUT. Son imprescindibles por cada línea de alimentación según la normativa, aunque en ocasiones también se aíslan algunas líneas como PWM con estos equipos. La estructura de filtro y el puerto de medida pueden verse en la figura 28.

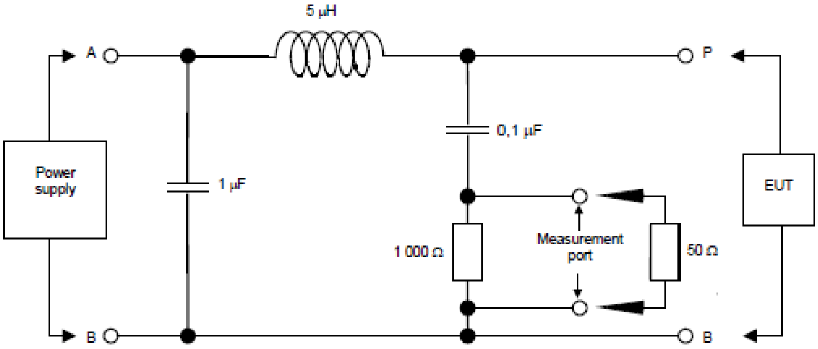


Figura 28: Esquema del interior de una LISN.

Se suelen tener dos en el interior de la cámara, una para la línea positiva y otra para la negativa de la alimentación, y varias fuera de backup.

Para SAC 4 se ha utilizado el mismo modelo que se tiene en todo el laboratorio, las LISN de Schwarbeck Mess-Elektronik modelo NNBM 8124-200, figura 29 [15].

Figura 29: LISN de Schwarbeck Mess-Elektronik.

3 RESULTADOS

3.1 ELECCIÓN DE LA CÁMARA

Una vez conocidos los requisitos necesarios para tener una cámara según la CISPR25, el siguiente paso fue solicitar presupuesto a proveedores, en particular a Albatross y Inycom-Frankonia. Cada uno ofertó una cámara completamente nueva.

A su vez, Applus estaba en contacto con uno de sus clientes, el cual poseía una cámara semianecoicas que no había llegado a usar, puesto que este cliente no tenía equipamiento para ello. Applus propuso a este cliente un acuerdo comercial por el cual Applus se quedaría con la cámara y este cliente tendría privilegios (menores tiempos de espera y descuento en la realización de los tests durante 2 años).

El principal inconveniente de esta opción fue que esta cámara procedía de un sector distinto, tratándose de una SAC donde se realizaban test de precertificación del sector industrial, con lo que tenía características distintas a la de una cámara para autocomponentes (medidas, tipo de suelo, absorbentes…). Es decir, habría que realizar nuevos planos que se aprovecharan el máximo de materiales de esta cámara y se obtuviera finalmente una cámara que cumpliera con la normativa CISPR 25.

Para ello, se contactó con Albatross y se propuso realizar el proyecto conjuntamente. Los nuevos planos se llevaron a cabo con la ayuda de Albatross, aprovechando casi la totalidad de los materiales y teniendo que añadir el mínimo, como se detallará secciones posteriores y en el Anexo 2.

3.2 RESTRICCIONES RESPECTO AL ESPACIO DE CONSTRUCCIÓN

La construcción se llevaría a cabo en el sótano del edificio B. Ya se disponía de una sala para realizar test de ESD y de una cámara semianecóica, SAC3. Con la construcción de SAC4 y la de otra sala que servirá para realizar test eléctricos se obtendría un laboratorio completo, donde se podrían realizar todos los test necesarios para validar un EUT.

Para reducir al máximo los costes, se tendría que diseñar la cámara de manera que se pudiese compartir la sala de amplificadores con la SAC contigua (SAC 3), circunstancia que determinaría la disposición de las trampillas y de los filtros que no estaban contemplados en la SAC original. Podemos hacernos una idea de cómo quedaría la disposición del laboratorio con el plano de la figura 30.

Figura 30: Distribución del nuevo laboratorio para autocomponentes.

Por motivos de confidencialidad con nuestros clientes es necesario aislar cada sala e incluir un panel luminoso que indique si es posible el paso a la sala o no. En la imagen 10 podemos ver donde se situarían las entradas a cada sala. El espacio disponible, como puede verse en la figura 11, no es muy grande. La SAC4 será pequeña en comparación con el resto de cámaras del laboratorio, pero deberá cumplir con todo lo que se ha indicado en el punto anterior. De hecho, SAC 4 tendría finalmente las medidas mínimas para cumplir con todas las restricciones del punto anterior.

En la figura 31 se detallan las dimensiones de la zona donde se construiría la SAC4.

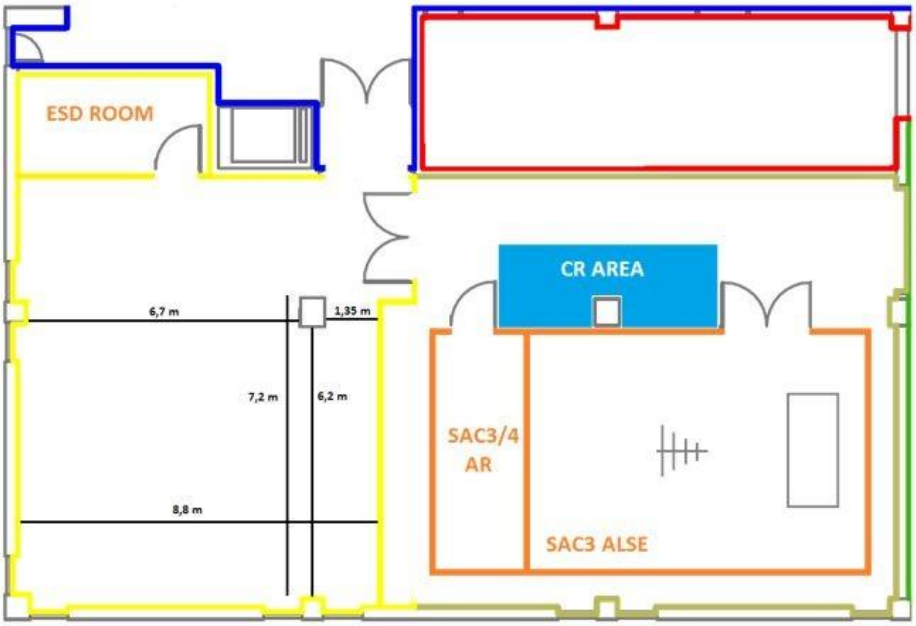


Figura 31: Espacio para la construcción de SAC4

La cámara podrá tener, como máximo, unas medidas exteriores de 6,2 x 6,7 metros. La altura no será un problema, ya que la ubicación (sótano del edificio B de Applus) tiene el techo a varios metros.

3.3 ADAPTACIÓN PARA SAC 4 DE LOS ELEMENTOS DE LA CÁMARA ANTIGUA

Durante la adaptación se intentó aprovechar la mayor cantidad de material de la cámara original. Ésta disponía de un tamaño de 7,3 metros de largo por 3,4 metros de ancho y 3,3 metros de alto. Poseía un suelo con superficie giratoria de 1,2 metros de diámetro. La estructura la conformaban varios paneles metálicos unidos, según se representa en las figuras 12 a 16, y que se describen a continuación.

3.3.1 Paneles metálicos para el blindaje

El principal cálculo para la adaptación de una cámara a otra fue el de los paneles metálicos que conformarían el blindaje. En las figuras 12 a 16, obtenidas de los planos de la SAC original, que se pueden consultar en el Anexo 3, aparecen todas las dimensiones de la cámara además de los respiraderos, trampillas y filtros de los que se disponía. Vemos en estas imágenes que la forma de la cámara era rectangular, típica para una cámara en industria. En las imagenes 32 y 36 aparecen los 6 paneles honeycombs de los que se disponía.

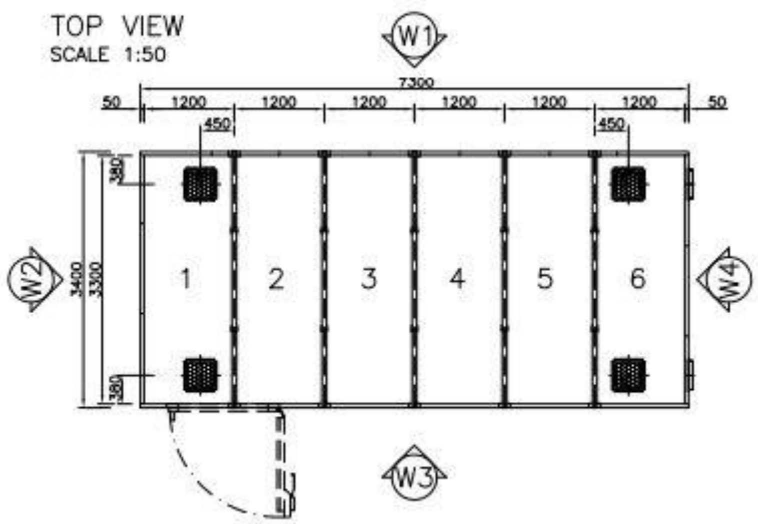


Figura 32: Vista de la planta de la SAC original (techo).

En la figura 33 aparece la plataforma rotatoria donde se instalaba una mesa aislante sobre la cual se disponía el EUT. Este sistema se utilizaba para obtener un diagrama de radiación en los test de industria.

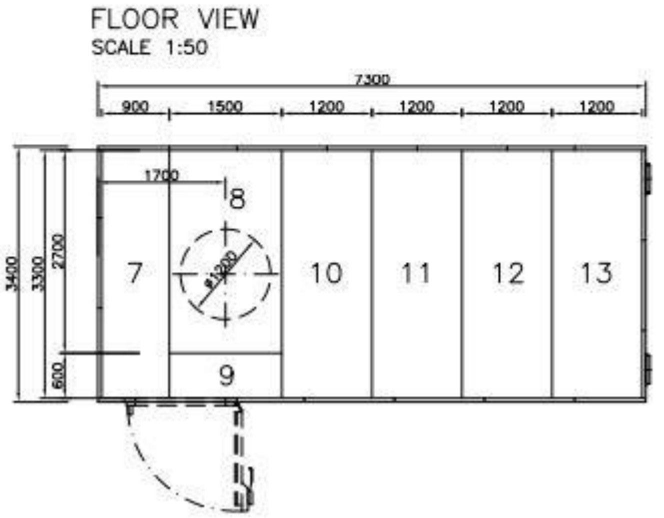


Figura 33: Vista de la planta de la SAC original (suelo)

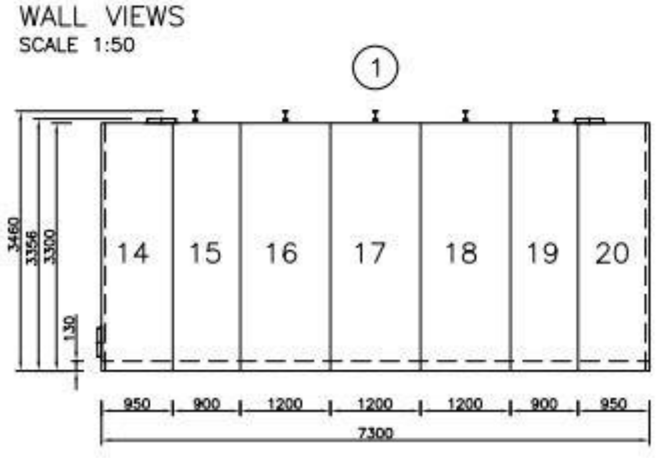


Figura 34: Vista trasera de la SAC original.

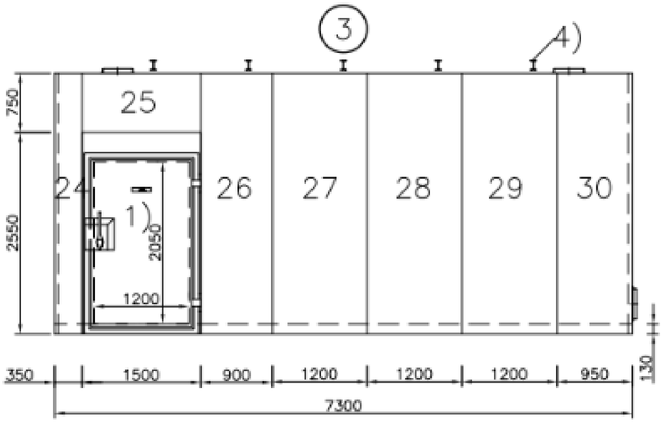


Figura 35: Vista frontal de la SAC original.

En la figura 36 vemos filtros en el panel 32 de tensión que posteriormente se reutilizarían. También aparecen paneles de conectores (AP1 y AP2) que también se reutilizarían, aunque habría que adaptarlos ya que muchos de estos conectores utilizaban una impedancia normalizada de 75 ohm, impedancia estándar para equipos de televisión que eran los que se testeaban, mientras que para automoción el estándar es de 50 ohm.

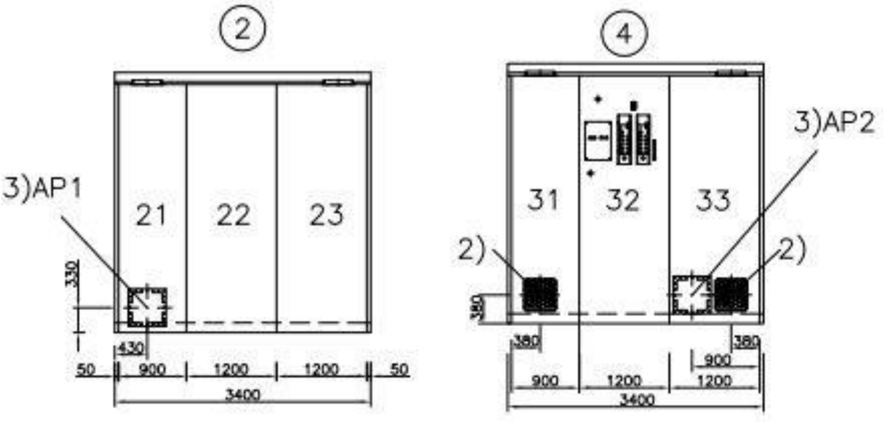


Figura 36: Vistas laterales de la SAC original.

El cálculo de la adaptación fue responsabilidad de Albatross, siguiendo las indicaciones de Applus, y se aprovechó casi la totalidad de las láminas de la estructura. Se obtuvo la estructura que aparece en los planos de las figuras 37 a 39.

La forma de SAC 4 sería casi cuadrada y aprovecharía casi por completo los paneles antiguos, en las siguientes figuras podemos ver la nueva ubicación de cada panel. Quedarían sin usar únicamente los 6 paneles que aparecen en la figura 20.

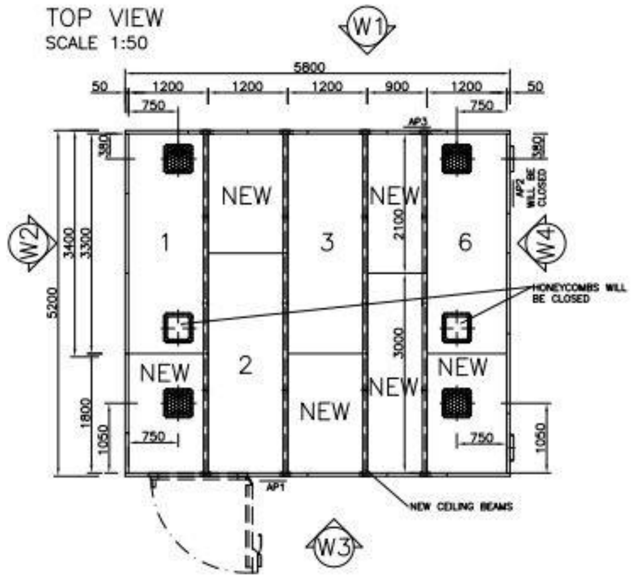


Figura 37: Vista de la planta de SAC4 (techo)

Se reutilizaron los respiraderos, ubicandolos entre el techo y uno de los laterales. Se reutilizaron también los filtros, los paneles de conectores y la puerta. De esto se hablará más detalladamente en puntos posteriores.

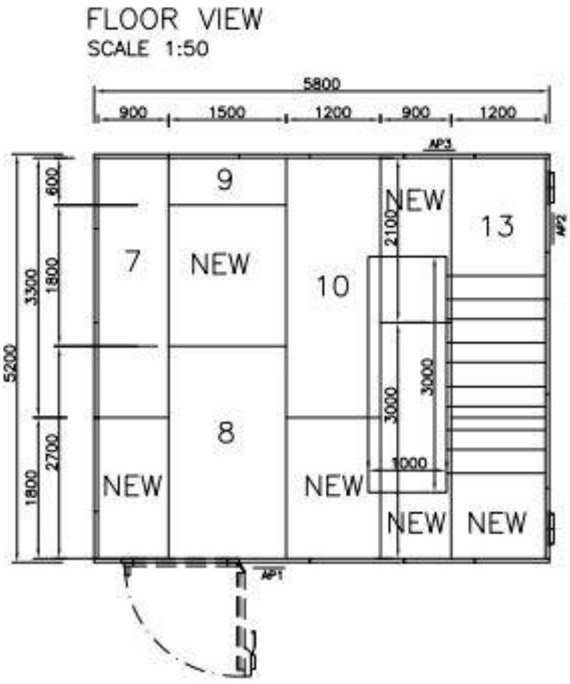


Figura 38: Vista de la planta de SAC 4 (suelo)

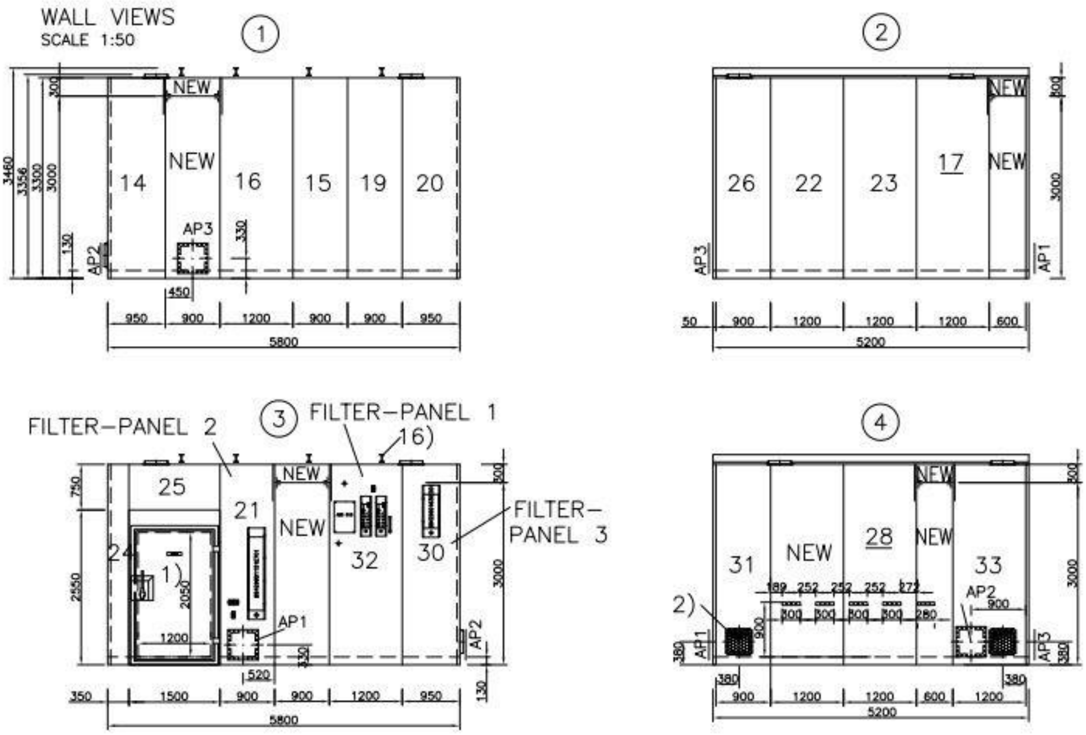


Figura 39: Vistas laterales de SAC 4.

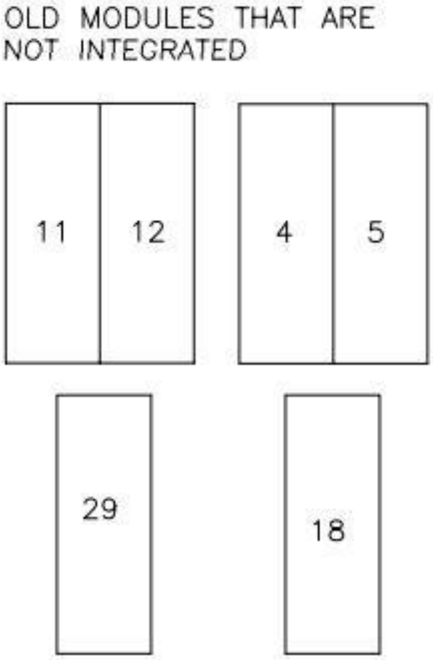


Figura 40: Paneles de la SAC original que no se reutilizaron.

3.3.2 Puerta

La puerta de una cámara semi-anecoica es un elemento importante en su blindaje, pues debe sellar perfectamente la entrada cuando esté cerrada. La puerta debe incluir ferritas y absorbentes iguales que los del resto de paredes para no presentar irregularidades cuando esté cerrada.

En este sentido, se reutilizó la puerta de la SAC original por completo. Aunque habría sido mejor cambiar la dirección de apertura de la puerta, ya que sería más accesible desde la posición del técnico que realice los test. No obstante, esta modificación presentaba dificultades y hubiera elevado el coste, ya que requeriría el cambio del sistema de bisagras.

En figura 41 se muestra la estructura de la puerta. En la figura vemos que el tipo de cierre de con manivela manual y está tanto en el interior como en el exterior. Como la función de esta área del edificio B no estaba originalmente pensada para este laboratorio ninguna de las dos cámaras semianecoicas posee cierre automático como las cámaras del edificio K. Incluir este cierre incrementaría considerablemente el presupuesto y supondría cambiar por completo de puerta.

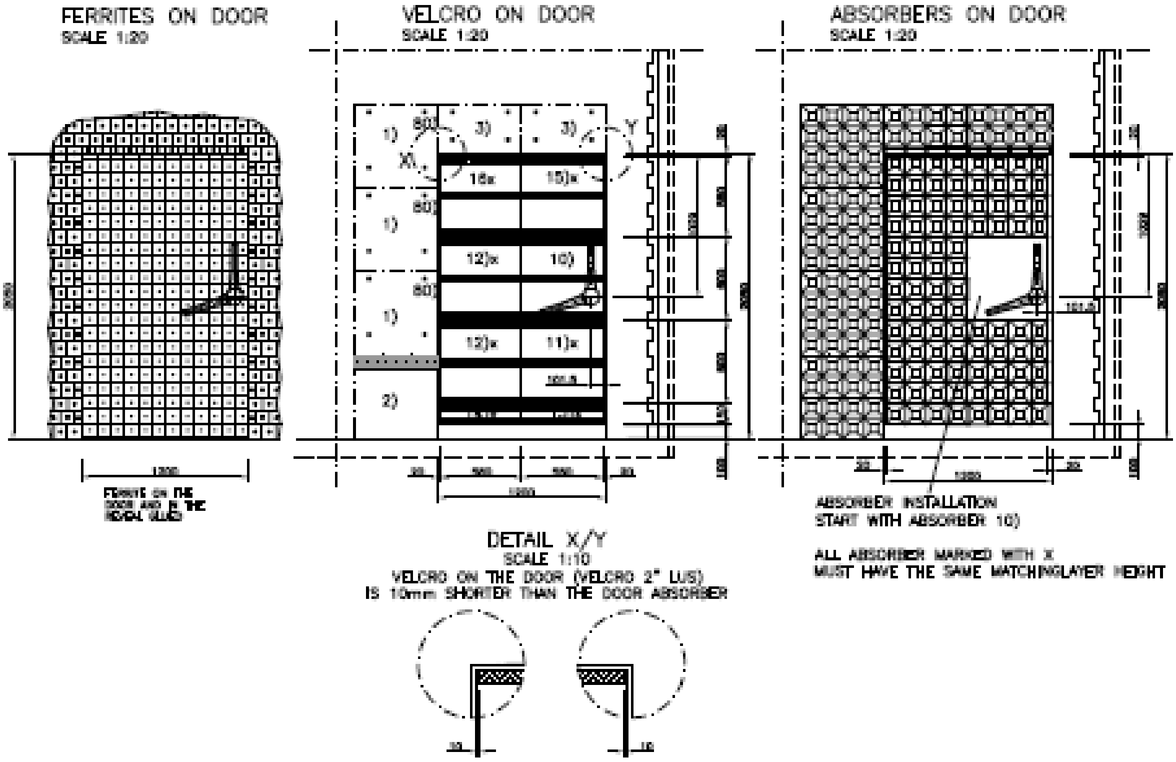


Figura 41: Puerta SAC original / SAC 4.

Aunque en la figura no se aprecie, la puerta queda elevada sobre el suelo del laboratorio 19 centímetros. Lo ideal sería que la puerta quedase al mismo nivel del suelo de la sala de control ya que muchas en ocasiones es necesario mover equipos pesados entre ellas con la ayuda de un carro.

3.3.3 Climatización de la sala

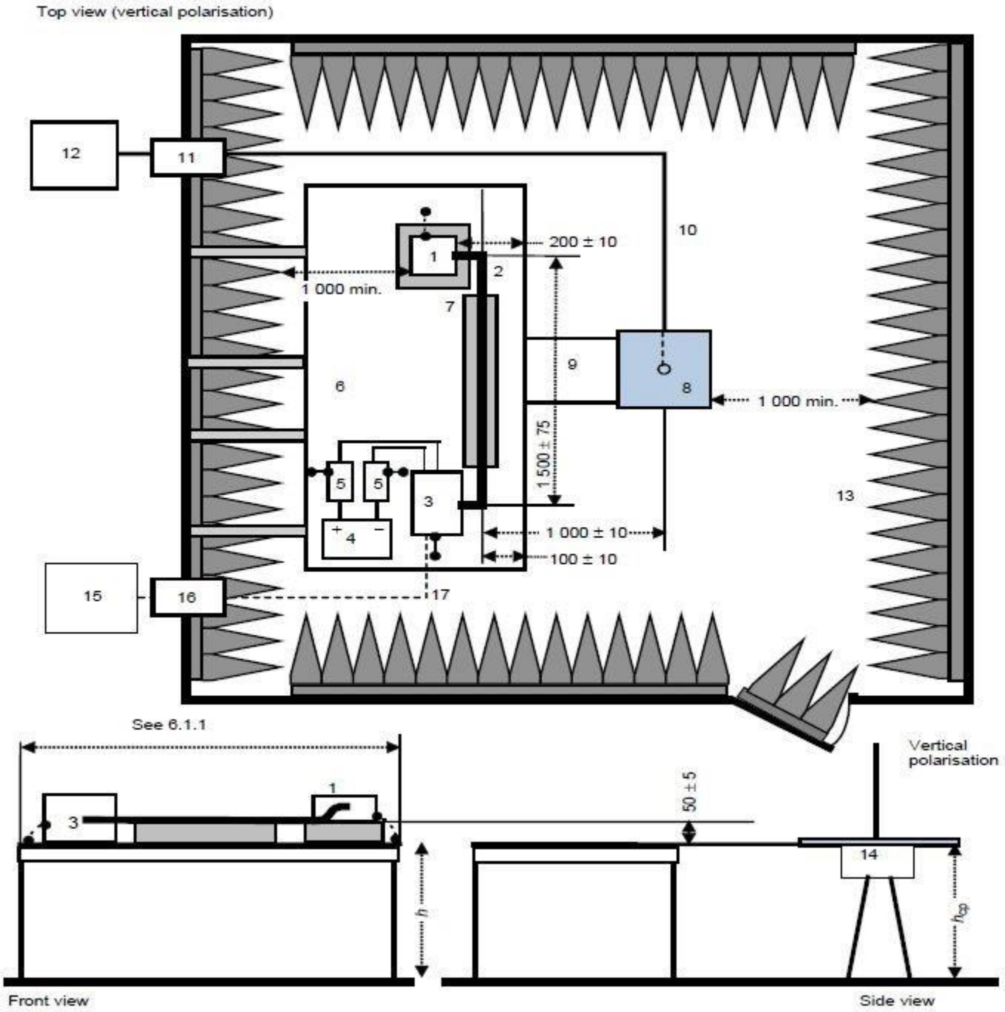
Para cualquier tipo de test es necesario tener caracterizadas todas las condiciones, incluidas las ambientales, temperatura y humedad, ya que se sabe que los cambios de estos parámetros afectan al funcionamiento de los componentes electrónicos. Aunque la CISPR25 no indica rangos de temperatura y humedad en los que se debe trabajar, estas condiciones sí suelen aparecer en las normas propias del fabricante, así que normalmente es necesario mantener la temperatura en 20º C ± 5ºC.

Como ya se ha indicado, la sala debe tener respiraderos, conectados a un sistema de climatización para regular estos parámetros. De la SAC original se disponía de 6 paneles de abeja, que se muestran en el anexo 3 y en las figuras 37 y 39 pueden verse dónde se dispusieron los paneles en la nueva cámara (paneles sombreados de los planos).

3.3.4 Filtros de tensión

Por lo general, los EUT se alimentan con la tensión de una batería, en el ejemplo de la figura 20 puede verse la estructura típica de un test de emisiones radiadas donde el módulo 1 es el EUT, se alimenta a través de una batería convencional de vehículo, módulo 4 en la figura 42. Al estar en uso, si la batería no se está alimentando continuamente se irá agotando; su autonomía dependerá del consumo del EUT. Si varía la tensión de alimentación del EUT, los resultados se verán afectados significativamente.

Para evitar que esto ocurra y obtener una tensión constante durante todo el test es necesario cargar la batería siempre que esté en uso. Esto se consigue conectando una fuente de alimentación a ella. La fuente deberá situarse fuera de la cámara para que no afecte a los test. Pasar directamente un cable del exterior al interior de la cámara por el pasamuros no es conveniente, ya que éste podría hacer de antena receptora de todas las señales exteriores y pasarlas al interior.



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Rod Antenna with counterpoise

(dimensions: 600 mm by 600 mm typical)

9 Grounding connection (full width bond between counterpoise and reference ground plane)

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Antenna matching unit (the preferred location is below the counterpoise; if above the counterpoise then the base of the antenna rod shall be at the height of the reference ground plane)

15 Stimulation and monitoring system

Figura 42: Setup típico para emisiones radiadas en bajas frecuencias (antena monopolo)

En el contexto de blindaje para RF, habrá que usar los llamados filtros pasamuros para pasar tensiones de alimentación del exterior al interior de la cámara, que evitarán el acoplo de la RF. Para el ejemplo anterior, la alimentación de la batería considera la reutilización de los filtros que la SAC original poseía, de hasta 32 A, que aparecen marcados en los planos de la SAC original como 6. En la figura 43 se muestra cómo quedarían ya integrados en el exterior de SAC 4.

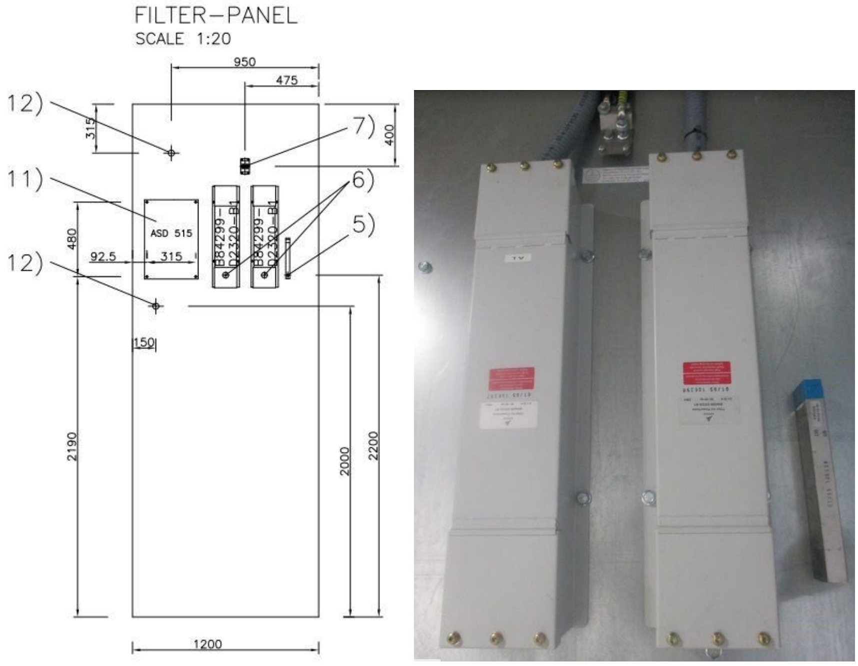


Figura 43: Filtros de 32 A.

En la mayor parte de los test no serán necesarios otros filtros, pero en algunos casos el consumo puede ser mayor o el EUT necesitar alimentación trifásica (en estos casos el EUT se alimentaría de forma directa, sin pasar por una batería). Por lo tanto, se considera necesario añadir nuevos filtros con mayor amperaje y trifásicos, número 15 y 18 de la figura 44. Los detalles de estos paneles se encuentran en el anexo 2.

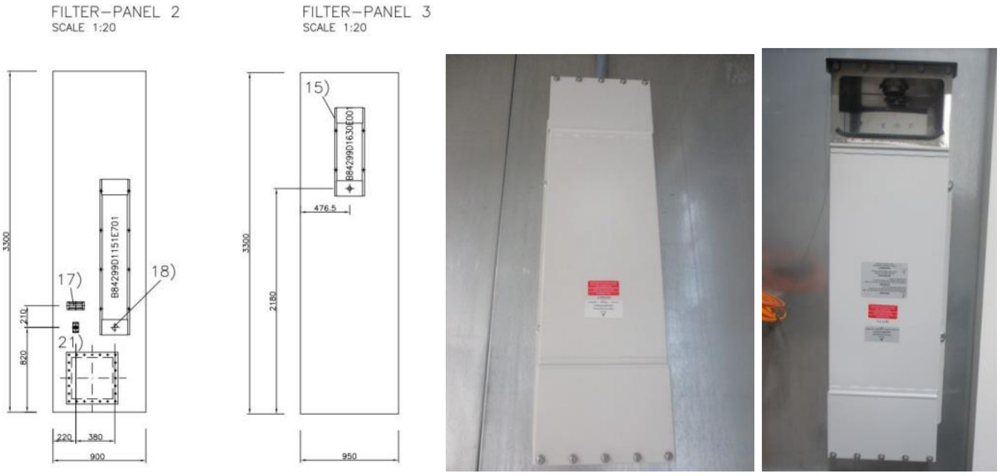


Figura 44: Paneles con filtros nuevos.

3.3.5 Caminos de RF (trampillas y conectores)

Un punto importante durante la planificación que tendría la distribución de SAC4 fueron los caminos de RF. Cuando hablamos de camino de RF nos referimos a los cables, atenuadores, conectores y pasamuros por donde transmitirá la señal de RF. De la distribución de estos caminos dependerá la posición de las trampillas con los conectores.

Para SAC 4 se estimaron necesarias dos trampillas (CP1 y CP2) y dos pasamuros (AP1 y AP3), según se muestra en la figura 45.

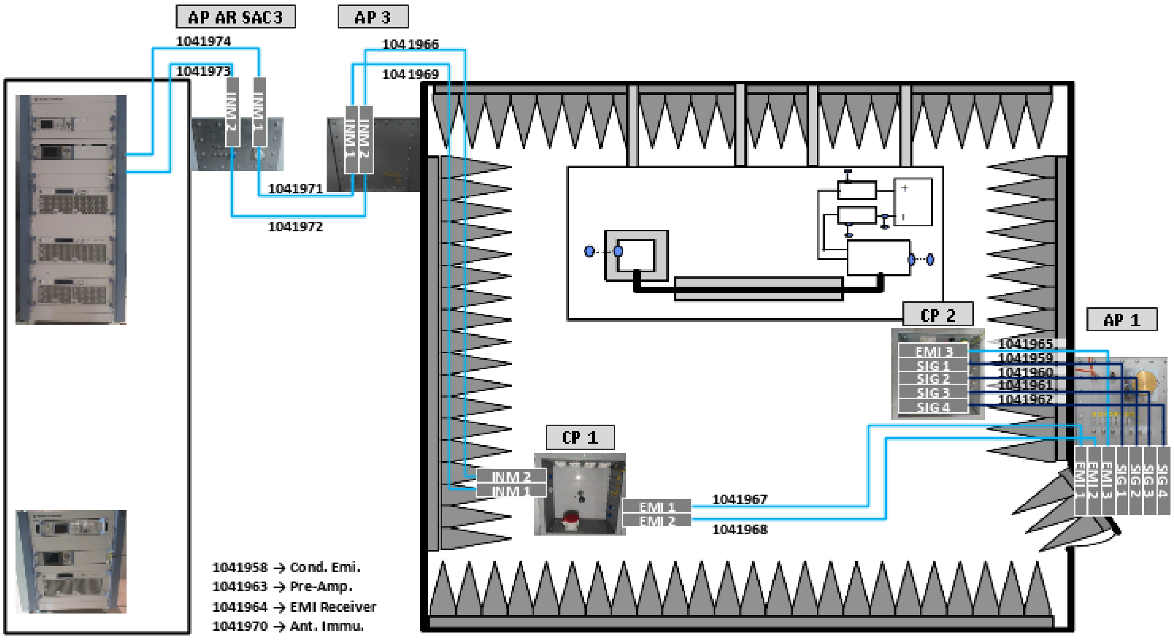
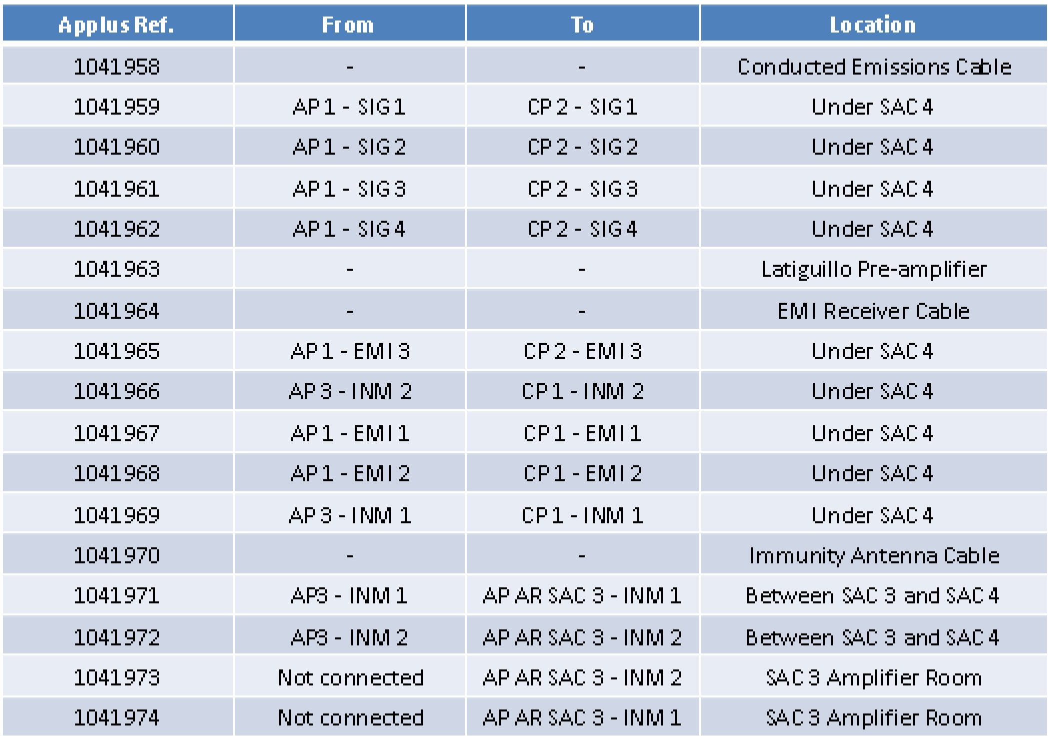


Figura 45: Plano de los caminos de RF.

Se decidió tener algunos caminos de RF cableados en el entresuelo de la SAC, ya que de esta manera los cables sufren menos torsiones y por lo tanto menos desgaste. Otro motivo es que al tener los cables fijos no existirá ninguna confusión respecto a qué cable se está usando, pues siempre se usará el mismo camino para el mismo tipo de test. Esto es importante ya que cuando se realiza el test se debe tener caracterizado el camino, los cables medirán varios metros lo que ocasionará perdidas que no son irrelevantes. Los caminos EMS-1, EMS-2, EMI-1, EMI-2 y EMI-3 serán caminos rutados en el entresuelo de la cámara. Los tipos de camino se indican en la figura 25 según el color, negro para un camino de emisiones y rosa para un camino de inmunidad. Vemos que los caminos de inmunidad salen desde la sala compartida de amplificadores.

Las conexiones y la situación de cada camino aparecen en la figura 46. Además, se le asignó un número de referencia, así el camino se mantendría como un único bloque, aunque posea varios tramos, y tendrá caracterizada su atenuación y potencia máxima.



Applus Ref.	From	To	Location
1041958	-	-	Conducted Emissions Cable
1041959	AP 1 - SIG 1	CP 2 - SIG 1	Under SAC 4
1041960	AP 1 - SIG 2	CP 2 - SIG 2	Under SAC 4
1041961	AP 1 - SIG 3	CP 2 - SIG 3	Under SAC 4
1041962	AP 1 - SIG 4	CP 2 - SIG 4	Under SAC 4
1041963	-	-	Latiguillo Pre-amplifier
1041964	-	-	EMI Receiver Cable
1041965	AP 1 - EMI 3	CP 2 - EMI 3	Under SAC 4
1041966	AP 3 - INM 2	CP 1 - INM 2	Under SAC 4
1041967	AP 1 - EMI 1	CP 1 - EMI 1	Under SAC 4
1041968	AP 1 - EMI 2	CP 1 - EMI 2	Under SAC 4
1041969	AP 3 - INM 1	CP 1 - INM 1	Under SAC 4
1041970	-	-	Immunity Antenna Cable
1041971	AP3 - INM 1	AP AR SAC 3 - INM 1	Between SAC 3 and SAC 4
1041972	AP3 - INM 2	AP AR SAC 3 - INM 2	Between SAC 3 and SAC 4
1041973	Not connected	AP AR SAC 3 - INM 2	SAC 3 Amplifier Room
1041974	Not connected	AP AR SAC 3 - INM 1	SAC 3 Amplifier Room

Figura 46: Localización de los caminos de RF

3.3.6 Absorbentes piramidales y baldosas de ferrita

Se utilizaron los absorbentes y las baldosas de ferrita de la SAC original para ser incorporados en SAC 4. Pero al tener SAC 4 unas dimensiones tan reducidas se tuvieron que sustituir algunos de los absorbentes por unos más pequeños, ya que en caso contrario no se cumpliría con la restricción por normativa de mantener a una distancia de al menos 1 metro de la cámara cualquier punto del test. En este caso el tamaño de la antena monopolo de la que se disponía estaba a menos de un metro de los absorbentes que quedaban justo encima de ella

En la figura 47 se muestran los absorbentes incorporados en el techo, las zonas marcadas en rojo fueron las que tuvieron que ser sustituidas con unos absorbentes de menor tamaño.

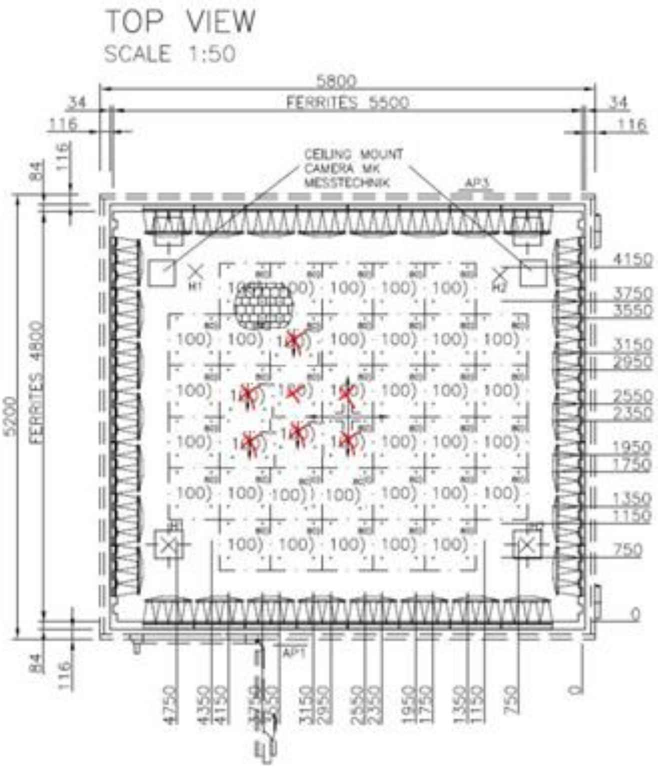


Figura 47: Vista superior la cámara con absorbentes reciclados y nuevos.

3.3.7 Plano de masa de referencia

La norma exige un plano de masa de referencia donde situar los equipos. Ya se disponía de un plano de masa, en la práctica una mesa de madera con superficie de cobre, por lo que se adaptaron los straps al tamaño de la mesa y se mantuvo la proporción entre la longitud y el ancho de las tiras de 7:1 exigida por la norma CISPR25. La mesa tenía un tamaño de 3 m de largo por 1 metro de ancho y 1 metro de alto, todos los planos de masa del laboratorio son iguales para mejorar la repetitividad de los tests. Se le añadirían cinco straps de 29 cm de ancho, cada uno con una separación entre ellos de 25 cm. Los straps tendrían una longitud de 1.08 metros y quedan unidos con tornillos al blindaje de la cámara (figuras 46 y 47).

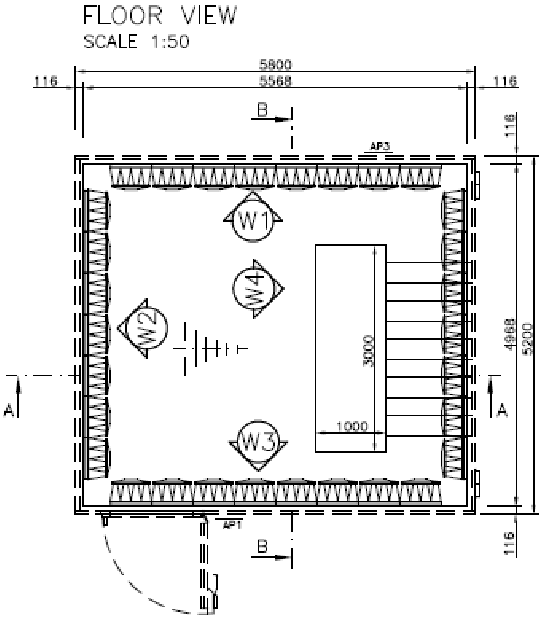


Figura 48: Vista superior de la cámara incluyendo la mesa.

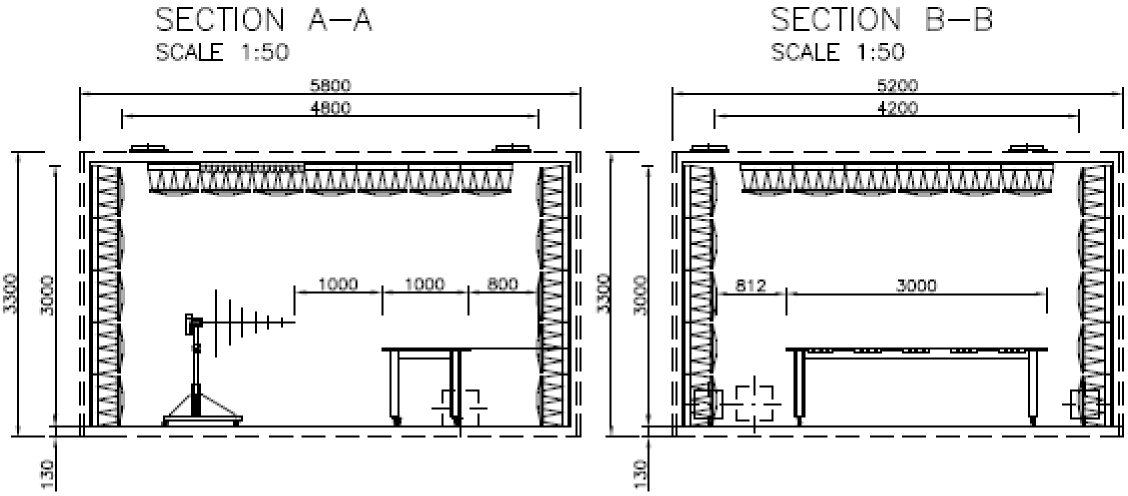


Figura 49: Vista lateral y vista frontal de la posición de la mesa dentro de la cámara.

3.4 OBRA

Antes de que comenzase el ensamblaje de SAC 4 se tuvo en cuenta el peso que tendría la estructura completa. Como se verá posteriormente, el interior de la estructura de la cámara posee baldosas de ferrita, material muy frágil y que se astilla rápidamente. Se comprobó que existía un desnivel en el suelo podría afectar a las ferritas, que podrían romperse con el tiempo. En prevención de ello se niveló el suelo donde iría emplazada para que tuviese el mínimo desnivel posible (figura 50).

Figura 50: Nivelado del emplazamiento de SAC 4.

Una vez hecho esto, se comenzó con el ensamblaje de la estructura metálica blindada siguiendo los planos del anexo 2. Este proceso lo llevaron a cabo los técnicos especializados de Albatross.

Figura 51: Montaje de la estructura blindada.

Sobre esta estructura metálica y en el interior de la cámara, se añadió un recubrimiento de paneles no conductores que servirían para disponer las baldosas de ferritas y los paneles de material absorbente. La razón de hacerlo de este modo, separando blindaje de ferritas, se justifica para dar solidez a la estructura. Al ser las ferritas tan frágiles, los impactos que es posible que reciba el blindaje metálico, o simplemente la vibración de los panes al abrir y cerrar la puerta, podría romperlas.

El siguiente paso fue recubrir esta estructura, excluyendo el suelo, con las baldosas de ferritas. Como se muestra en la figura 52 las ferritas están adheridas a un panel conductor. En realidad, al recubrimiento no conductor anteriormente indicado se le añadió una lámina flexible, parecida a una tela, de material metálico. Este revestimiento conductor es fundamental para la correcta respuesta en bajas frecuencias de las ferritas, y ayuda a que la conductividad de las ferritas sea uniforme.

Las baldosas de ferritas se atornillaron a las láminas conductoras, con el revestimiento metálico en medio, con unos tornillos no conductores. En la figura 52 vemos el proceso de recubrimiento de baldosas de ferrita del interior de la cámara.

Figura 52: Recubrimiento de baldosas de ferrita durante la obra.

A continuación, se colocaron los absorbentes de RF por medio de unas estructuras de madera que formaban unos rieles sobre las baldosas de ferritas. En la figura 53 se muestran tanto los absorbentes procedentes de la cámara antigua como los absorbentes más pequeños que se tuvieron que incorporar al techo. A los absorbentes se les añadieron unos protectores (en la figura 53 pueden verse en color blanco) para que los roces no los fueran desgastando.

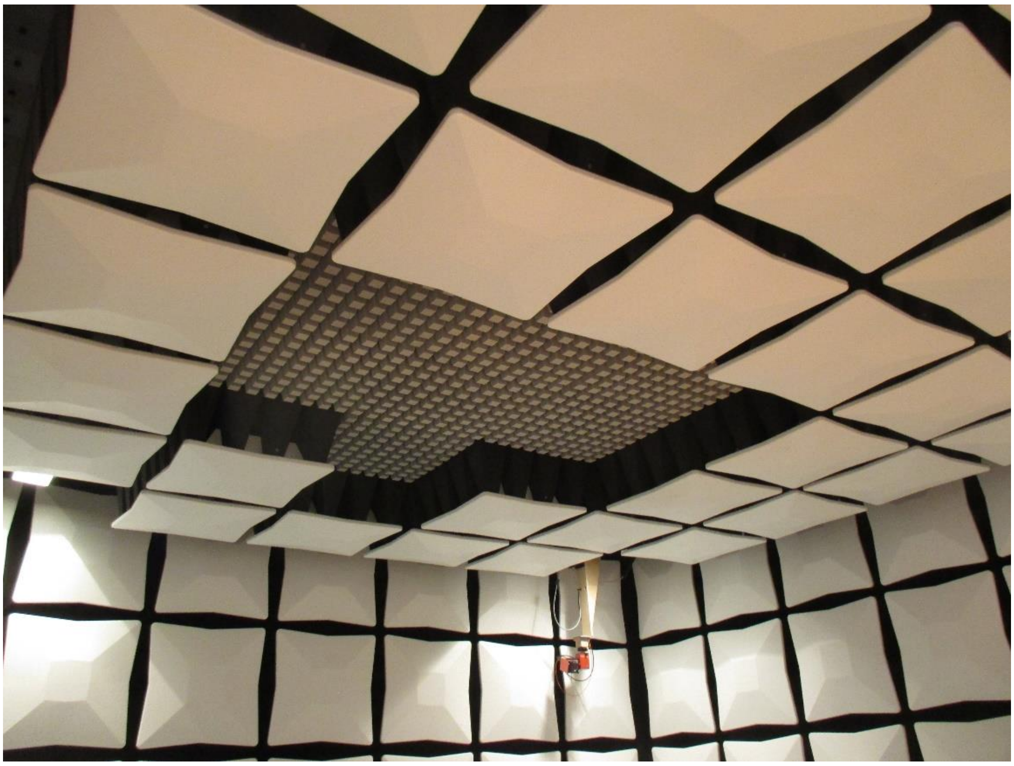


Figura 53: Absorbentes en el techo de SAC 4.

Para finalizar, se introdujo el plano de masa de referencia del que ya se disponía y se atornilló, junto a los straps, al blindaje de la cámara, de modo que la respuesta en frecuencia fuera lo mejor posible (figura 34).

Figura 54: Plano de masa de referencia atornillado al blindaje de SAC 4.

3.4.1 Mejora de la red de alimentación y aislamiento eléctrico

A la vez que se iba construyendo SAC 4 se subsanó un problema que databa de la fecha de construcción de SAC 3. La instalación eléctrica del edificio había quedado obsoleta y no estaba bien dimensionada.

Además, SAC 3 tenía una pica de tierra propia a la cual se conectaban los equipos de instrumentación. El problema que es que no se había aislado esta tierra de la del resto del edificio, de modo que existía un ruido procedente de los equipos electrónicos que se usaban en todo el edificio que acoplaba a los receptores de señal. Este ruido presentaba fluctuaciones y podía llegar a enmascarar la señal que se quería medir.

Para que esto no ocurriera, durante el redimensionamiento de la instalación eléctrica, se aisló una de las líneas y a ella se le incorporó la masa que poseía SAC 3, en lugar de la del edificio. En la figura 55 se aprecia la zona 1, es decir, la zona con masa aislada y la zona 2, conectada a la red del edificio. Con esta solución se obtuvo una red de alimentación donde conectar los equipos de medida totalmente aislada para evitar errores. A esta masa se conectó el blindaje de SAC 4 y se extendió la línea de alimentación para que sus equipos de medición estuvieran igualmente aislados.

Figura 55: Zonas de red de alimentación.

3.5 EJECUCIÓN DE LA VALIDACIÓN Y RESULTADOS

Una vez terminada la construcción se pasó a realizar la validación práctica de la cámara. El día anterior se preparó el test de emisiones radiadas que se lanzaría. Se introdujeron los caminos (cables de RF) con su atenuación y los datos que el generador necesita para generar una señal como la descrita en el punto anterior (señal sinusoidal de 120 dB(µV)) en el Software (EMC32).

Como SAC 4 aún estaba desprovista de equipos, se utilizaron los de SAC 3. Las antenas utilizadas fueron las mismas que para los test de emisiones radiadas usadas en SAC3, ya que éstas cumplían con el punto 6.5 de la CISPR25. Como se trata de un rango de frecuencias amplio, no se pudo realizar toda la medida con una sola antena. Para bajas frecuencias (entre 150 kHz y 30 MHz) se utilizó una antena monopolo (ROD) que se unió con un plano de masa a la mesa (bloque 5 de la figura 39), válida únicamente la polarización vertical. Para frecuencias de entre 30 y 200 MHz se utilizó una antena bicónica y aplicó polarización vertical y horizontal. Para frecuencias superiores (entre 200 MHz y 1 GHz) se utilizó una antena logoperiódica, también en ambas polarizaciones.

Con la configuración que indica el Anexo J, se realizó la primera parte del test para obtener el valor de M0 en cada frecuencia. El factor de antena era un valor conocido, con lo que para obtener el resultado de la ecuación 1 solo faltaría el valor de MA. Éste se obtuvo realizando las medidas de emisiones radiadas con cada antena. Se disponía de un software específico para realizar test de EMC llamado EMC32 del fabricante Rohde & Schwarz. En el software se introdujo la ecuación (1) para obtener directamente el campo equivalente (Eeq), los resultados de esta ecuación se presentan en el Anexo 4.

Finalmente, habría que comparar si cada punto cumple con que esté a menos de ± 2dB de los valores de comparación que aparecen en la tabla J.1 de la CISPR25. Como se ha indicado en el punto anterior, la validación será positiva si se cumple con (2), teniendo en cuenta que está permitido tener una variación mayor a 6 dB en algunos puntos.

3.5.1 Resultado de las mediciones

En las figuras 56-59, se presentan los resultados, presentados de forma gráfica, obtenidos tras las mediciones. Las tablas con los valores numéricos se detallan en el Anexo 4. Estos son los valores de la comparación entre Eeq max, es decir, el mayor valor entre los resultados de ambas polarizaciones y Eeq max ref.

- Antena ROD (150 kHz- 30 MHz)

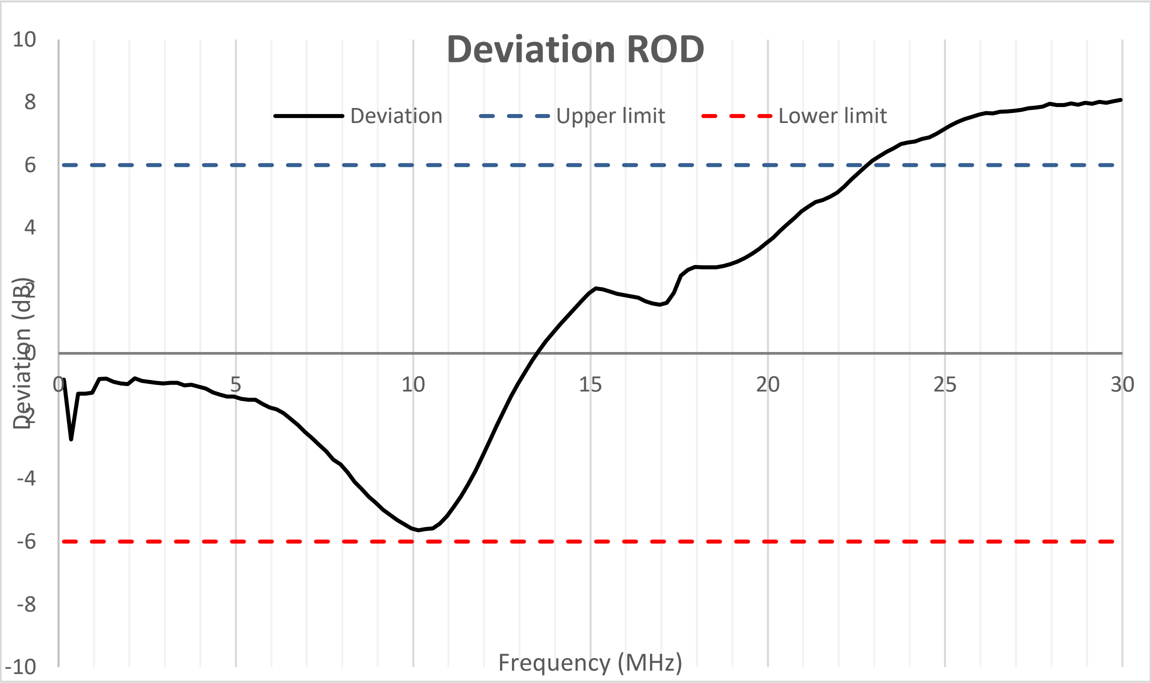


Figura 56: Desviación con la antena ROD (150 kHz- 30 MHz) (escala lineal).

- Antena Bicónica (30 MHz – 200 MHz)

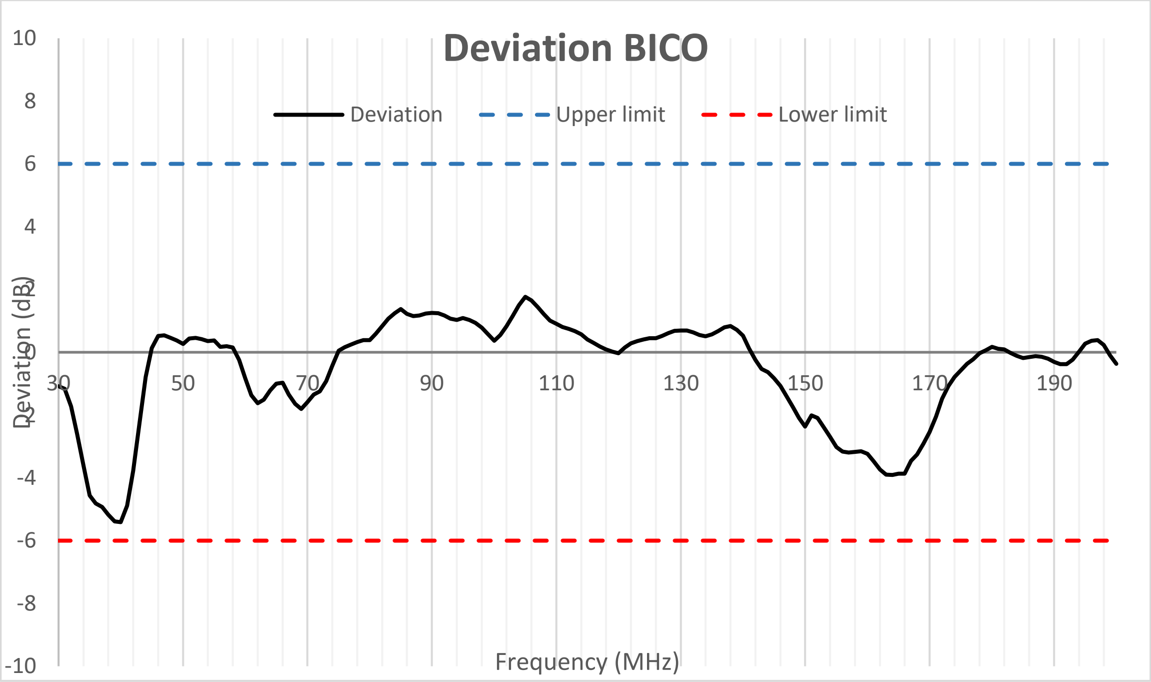


Figura 57: Desviación con la antena bicónica (30 MHz- 200 MHz) (escala lineal).

- Antena Logoperiódica (30 MHz – 1 GHz)

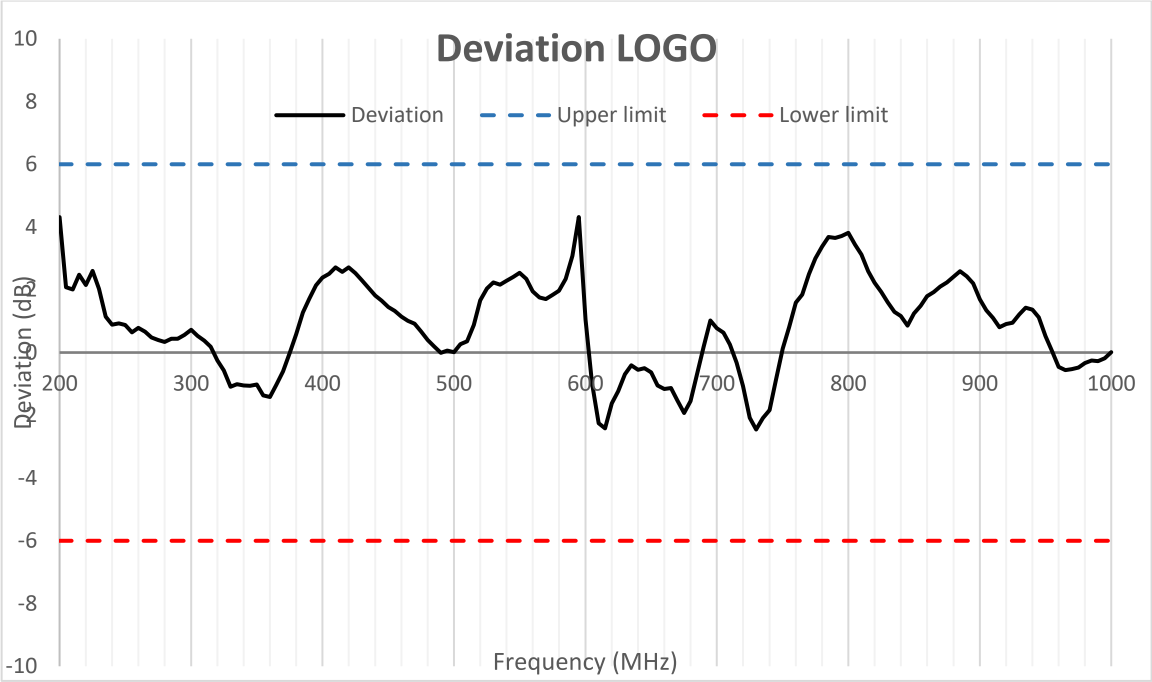


Figura 58: Desviación con la antena logo periódica (200 MHz- 1 GHz) (escala lineal).

- Rango completo (150 kHz- 1 GHz)

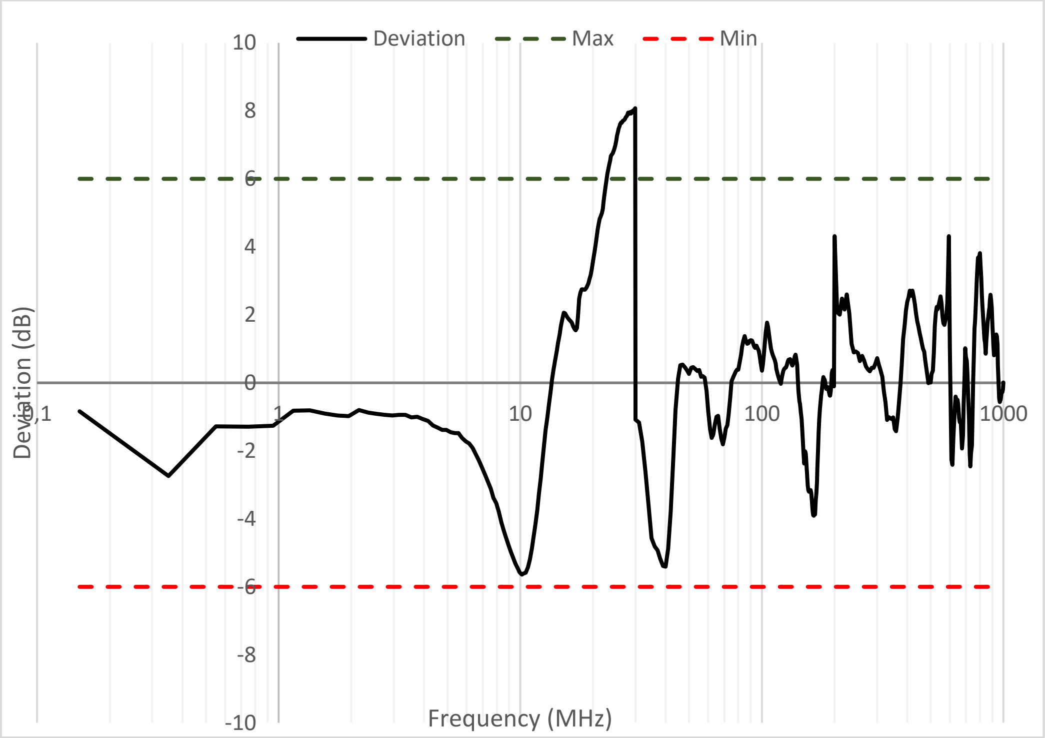


Figura 59: Resultado de la desviación total (escala logarítmica).

Para calcular en qué tanto por ciento se cumple con la validación se utiliza la ecuación (2).

$$Total\ \%IT_{150\ kHz\ to\ 1000\ MHz,\ Long\ Wire\ Method} = \left(\frac{\text{data points } 150\ kHz\ to\ 1000\ MHz \text{ where } \Delta_{Long\ Wire\ Method} \text{ is within } \pm 6\ dB}{481} \right) \cdot 100$$

(2)

Data points 150 kHz to 1000 MHz where $\Delta_{\text{long wire method}}$ is within de ± 6 dB = 445

$Total\ \%IT_{150\ KHz\ to\ 1000\ MHz,\ Long\ Wire\ Method=}$ (445/481)*100= 92.52% $\geq$ al 90%

A la vista de los resultados obtenidos, con esta validación se concluye que la cámara cumple con los requisitos del anexo J.

4 CONCLUSIONES

Como ya se indicó, el objetivo principal de este trabajo era plasmar una metodología para obtener una cámara semianecoicas para componentes de automoción que cumpliese con las restricciones de la norma CISPR 25.

Primero se planteó el problema que existía en el laboratorio, la necesidad de ampliar éste para reducir los tiempos de espera de los clientes y conseguir una mayor facturación. Ampliar el laboratorio pasaba por, entre otras cosas, instalar una nueva cámara semianecoicas.

Una vez aprobado el proyecto se solicitó presupuesto a los principales proveedores de cámaras semianecoicas. Finalmente se optó por algo distinto, reciclar una cámara que procedía del sector industrial, aprovechando al máximo los materiales de los que se disponía e incorporando materiales nuevos cuando fuera necesario. Este proyecto se llevaría a cabo conjuntamente con Albatross.

Tras el estudio de la planificación se realizó la construcción con personal de Albatross. A la vez, se redimensionó la red eléctrica del edificio y se aisló la masa de las dos cámaras, SAC 3 y SAC 4, para que el ruido procedente de los equipos electrónicos del resto del edificio no interfirieran en las medidas.

Cuando la obra concluyó, se realizó el test que validaría la cámara. El test se recoge en el anexo J de la CISPR25 y proporciona dos métodos. Se escogió el método de antena modelada de cable largo y se puso en práctica.

Los resultados de la medición se compararon con los resultados de referencia que proporciona el Anexo J y aunque en algunas medidas existen desviaciones mayores del máximo requerido, el anexo J lo permite siempre que se cumpla al menos con el 90% de las frecuencias medidas.

Se obtuvo un 92,52% de cumplimiento, con lo que la validación fue positiva.

Para finalizar se equipó la SAC con todo lo necesario para su puesta en marcha, equipos, cables, monitorización… Actualmente, la SAC 4 es una cámara operativa para medidas de emisiones según la CISPR25.

4.1 LINEAS FUTURAS

Durante los siguientes meses e incluso años después de la puesta en marcha de SAC4 será necesario realizarle mejoras para cumplir con los cambios que surjan en la normativa o incluso en los equipos bajo prueba.

Durante las primeras semanas de funcionamiento se vio la necesidad de incluir una plataforma elevadora a la entrada de la puerta para que sea mas facil meter y sacar equipos pesados de ella.

Por otra parte, para ciertos equipos es necesario el uso de aire comprimido, ya sea bien para refrijerar o para activar algun mecanismo del propio EUT, de momento no se ha incorporado este mecanismo en SAC4 ya que los equipos que lo han necesitado se han derivado a otras salas, pero se prevee incorporarlo en un futuro para que SAC4 sea completamente autonoma.

ANEXOS

Dado el volumen de datos generados para la realización del presente estudio, se ha optado por incluir la información más relevante en los anexos siguientes.

Anexo 1

CISPR25

CISPR/D/425A/CDV

COMMITTEE DRAFT FOR VOTE (CDV)
PROJET DE COMITÉ POUR VOTE (CDV)

Project number
Numéro de projet
CISPR 25 Ed. 4

IEC/TC or SC: **CISPR/D**
CEI/CE ou SC:

Secretariat / Secrétariat
Germany

☒ Submitted for parallel voting in CENELEC
Soumis au vote parallèle au CENELEC

Date of circulation
Date de diffusion
2015-02-20

Closing date for voting (Voting mandatory for P-members)
Date de clôture du vote (Vote obligatoire pour les membres (P))
2015-05-15*

Also of interest to the following committees
Intéresse également les comités suivants
CISPR/A, TC69

Supersedes document
Remplace le document
CISPR/D/419/CD, CISPR/D/424/CC

Proposed horizontal standard
Norme horizontale suggérée
☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the TC/SC secretary
Les autres CE/SC sont requis d'indiquer leur intérêt, si nécessaire, dans ce CDV à l'intention du secrétaire du CE/SC

Functions concerned
Fonctions concernées
☐ Safety / Sécurité
☒ EMC / CEM
☐ Environment / Environnement
☐ Quality assurance / Assurance qualité

Titre : CISPR 25: Véhicules, bateaux et moteurs á combustion interne - Caractéristique des pertubations radioélectriques - Limites et méthodes de mesure pour la protection des récepteurs embarqués

Title : CISPR 25: Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers

Introductory note

This draft contains test methods for vehicles in charging mode as well as specific methods needed to test components for a shielded high voltage board net as used in electric and hybrid electric vehicles.

It also contains the results of the CISPR/D-CISPR/A-project on chamber validation for ALSEs used for component testing.

***IEC CO Note:** Please be informed that an "A" version of the CDV is circulated due to a problem which occurred in the document during the pdf conversion with some figures and the formatting of the document. The closing date for voting remains unchanged.

ATTENTION
VOTE PARALLÈLE
IEC – CENELEC
L'attention des Comités nationaux de l'IEC, membres du CENELEC, est attirée sur le fait que ce projet de comité pour vote (CDV) de Norme internationale est soumis au vote parallèle.
Les membres du CENELEC sont invités à voter via le système de vote en ligne du CENELEC.

ATTENTION
IEC – CENELEC
PARALLEL VOTING
The attention of IEC National Committees, members of CENELEC, is drawn to the fact that this Committee Draft for Vote (CDV) for an International Standard is submitted for parallel voting.
The CENELEC members are invited to vote through the CENELEC online voting system.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES – RADIO DISTURBANCE CHARACTERISTICS – LIMITS AND METHODS OF MEASUREMENT FOR THE PROTECTION OF ON-BOARD RECEIVERS

FOREWORD

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International Standard CISPR 25 has been prepared by CISPR subcommittee D: Electromagnetic disturbances related to electric/electronic equipment on vehicles and internal combustion engine powered devices.

This fourth edition cancels and replaces the third edition published in 2008. This edition constitutes a technical revision.

The following significant changes were made with respect to the previous edition:

- inclusion of charging mode for EV and PHEV,
- overall improvement
- the methods for chamber validation have been included
- test methods for shielded power supply systems for high voltages for electric and hybrid electric vehicles have been included

The text of this standard is based on the following documents:

FDIS	Report on voting
XX/XX/FDIS	XX/XX/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

The National Committees are requested to note that for this publication the stability date is 2020.

THIS TEXT IS INCLUDED FOR THE INFORMATION OF THE NATIONAL COMMITTEES AND WILL BE DELETED AT THE PUBLICATION STAGE.

INTRODUCTION

This International Standard is designed to protect on-board receivers from disturbances produced by conducted and radiated emissions arising in a vehicle.

Test procedures and limits given are intended to provide provisional control of vehicle radiated emissions, as well as component/module conducted/radiated emissions of long and short duration.

To accomplish this end, this standard:

- establishes a test method for measuring the electromagnetic emissions from the electrical system of a vehicle;
- sets limits for the electromagnetic emissions from the electrical system of a vehicle;
- establishes test methods for testing on-board components and modules independent from the vehicle;
- sets limits for electromagnetic emissions from components to prevent objectionable disturbance to on-board receivers;
- classifies automotive components by disturbance duration to establish a range of limits.

NOTE Component tests are not intended to replace vehicle tests. Exact correlation between component and vehicle test performance is dependent on component mounting location, harness length, routing and grounding, as well as antenna location. Component testing, however, permits components to be evaluated prior to actual vehicle availability.

VEHICLES, BOATS AND INTERNAL COMBUSTION ENGINES –
RADIO DISTURBANCE CHARACTERISTICS –
LIMITS AND METHODS OF MEASUREMENT FOR THE PROTECTION OF ON-BOARD RECEIVERS

1 Scope

This International Standard contains limits and procedures for the measurement of radio disturbances in the frequency range of 150 kHz to 2 500 MHz. The standard applies to any electronic/electrical component intended for use in vehicles, trailers and devices. Refer to International Telecommunications Union (ITU) publications for details of frequency allocations. The limits are intended to provide protection for receivers installed in a vehicle from disturbances produced by components/modules in the same vehicle. The method and limits for a complete vehicle (whether connected to the power mains for charging purposes or not) are in Clause 5 and the methods and limits for components/modules are in Clause 6. Only a complete vehicle test can be used to determine the component compatibility with respect to a vehicle’s limit.

The receiver types to be protected are, for example, broadcast receivers (sound and television), land mobile radio, radio telephone, amateur, citizens' radio, Satellite Navigation (GPS etc.) and Bluetooth. For the purpose of this standard, a vehicle is a machine, which is self-propelled by an internal combustion engine, electric means, or both. Vehicles include (but are not limited to) passenger cars, trucks, agricultural tractors and snowmobiles. Annex A provides guidance in determining whether this standard is applicable to particular equipment.

The limits in this standard are recommended and subject to modification as agreed between the vehicle manufacturer and the component supplier. This standard is also intended to be applied by manufacturers and suppliers of components and equipment which are to be added and connected to the vehicle harness or to an on-board power connector after delivery of the vehicle.

This International Standard does not include protection of electronic control systems from radio frequency (RF) emissions, or from transient or pulse-type voltage fluctuations. These subjects are included in ISO publications.

Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, Clause 6 of this standard defines multiple limit levels. The level class to be used (as a function of frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

CISPR 25 defines test methods for use by Vehicle Manufacturers and Suppliers, to assist in the design of vehicles and components and ensure controlled levels of on-board radio frequency emissions.

Vehicle test limits are provided for guidance and are based on a typical radio receiver using the antenna provided as part of the vehicle, or a test antenna if a unique antenna is not specified. The frequency bands that are defined are not applicable to all regions or countries of the world. For economic reasons, the vehicle manufacturer must be free to identify what frequency bands are applicable in the countries in which a vehicle will be marketed and which radio services are likely to be used in that vehicle.

As an example, many vehicle models will probably not have a television receiver installed; yet the television bands occupy a significant portion of the radio spectrum. Testing and mitigating noise sources in such vehicles is not economically justified.

The vehicle manufacturer should define the countries in which the vehicle is to be marketed, then choose the applicable frequency bands and limits. Component test parameters can then be selected from CISPR 25 to support the chosen marketing plan.

The World Administrative Radio communications Conference (WARC) lower frequency limit in region 1 was reduced to 148,5 kHz in 1979. For vehicular purposes, tests at 150 kHz are considered adequate. For the purposes of this standard, test frequency ranges have been generalized to cover radio services in various parts of the world. Protection of radio reception at adjacent frequencies can be expected in most cases.

Annex E defines artificial networks used for the measurement of conducted disturbances and for tests on vehicles in charging mode.

Annex H defines a qualitative method of judging the degradation of radio communication in the presence of impulsive noise.

Annex I defines test methods for shielded power supply systems for high voltage networks in electric and hybrid vehicles.

Annex J defines methods for the validation of the ALSE and the reference ground plane used for component testing.

Annex K lists work being considered for future revisions.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*
Amendment 1 (1997)
Amendment 2 (1998)
Amendment 3 (2014)
Amendment 4 (2014)

CISPR 12:2009, *Vehicles, motorboats, and internal combustion engine-driven devices – Radio disturbance characteristics - Limits and methods of measurement for the protection of receivers except those installed in the vehicle/boat/device itself or in adjacent vehicles/boats/devices*

CISPR 16-1-1:2010, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*
Amendment 1 (2010)
Amendment 2 (2014)

CISPR 16-1-2:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-2: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Conducted disturbances*

CISPR 16-1-4:2010, Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-4: Radio disturbance and immunity measuring apparatus - Ancillary equipment - Radiated disturbances
Amendment 1 (2012)

CISPR 16-2-1:2014, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-1: Methods of measurement of disturbances and immunity - Conducted disturbance measurements*

CISPR 16-2-3:2010, *Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-3: Methods of measurement of disturbances and immunity - Radiated disturbance measurements*
Amendment 1 (2010)
Amendment 2 (2014)

ISO 11452-4:2011, *Road vehicles — Component test methods for electrical disturbances from narrowband radiated electromagnetic energy — Part 4: Bulk current injection (BCI)*

SAE ARP 958.1 Rev D: 2003-02 - Electromagnetic Interference Measurement Antennas; Standard Calibration Method

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1
absorber lined shielded enclosure (ALSE)
shielded enclosure/screened room with radio frequency-absorbing material on its internal ceiling and walls

3.2
antenna factor
the factor which is applied to the voltage measured at the input connector of the measuring instrument to give the field strength at the antenna

3.3
antenna matching unit
a unit for matching the impedance of an antenna to that of the 50 Ω measuring instrument over the antenna measuring frequency range

3.4
class
a performance level agreed upon by the purchaser and the supplier and documented in the test plan

3.5
component continuous conducted emissions
the noise voltages/currents of a steady-state nature existing on the supply or other leads of a component/module which may cause disturbance to reception in an on-board receiver

3.6

compression point

the input signal level at which the gain of the measuring system becomes non-linear such that the indicated output deviates from an ideal linear receiving system's output by the specified increment in dB

3.7

device

a machine driven by an internal combustion engine which is not primarily intended to carry persons or goods

Note **devices** include, but are not limited to, chainsaws, irrigation pumps, snow blowers, air compressors, and landscaping equipment.

3.8

receiver terminal voltage (antenna voltage)

the voltage generated by a source of radio disturbance and measured in dB(μV) by a radio disturbance measuring instrument conforming to the requirements of CISPR 16

3.9

RF boundary

an element of an EMC test setup that determines what part of the harness and/or peripherals are included in the RF environment and what is excluded. It may consist of, for example, ANs, filter feed-through pins, RF absorber coated wire, and/or RF shielding.

3.10

artificial network (AN)

a network inserted in the supply lead or signal/load lead of apparatus to be tested which provides, in a given frequency range, a specified load impedance for the measurement of disturbance voltages and which may isolate the apparatus from the supply or signal sources/loads in that frequency range

Note network inserted in the d.c power lines of the vehicle in charging mode which provides, in a given frequency range, a specified load impedance and which isolates the vehicle from the d.c power supply in that frequency range”

3.11

average detector

a detector, the output voltage of which is the average value of the envelope of an applied signal

Note The average value must be taken over a specified time interval.

[IEV 161-04-26]

3.12

bandwidth

bandwidth (of an equipment)

the width of a frequency band over which a given characteristic of an equipment or transmission channel does not differ from its reference value by more than a specified amount or ratio

Note The given characteristic may be, for example, the amplitude/frequency characteristic, the phase/frequency characteristic or the delay/frequency characteristic.

[IEV 161-06-09, modified]

bandwidth (of an emission or signal)

the width of the frequency band outside which the level of any spectral component does not exceed a specified percentage of a reference level

[IEV 161-06-10]

3.13

broadband emission

an *emission* which has a *bandwidth* greater than that of a particular measuring apparatus or receiver

Note An emission which has a pulse repetition rate (in Hz) less than the bandwidth of a particular measuring instrument can also be considered as a broadband emission.

[IEV 161-06-11, modified]

3.14

disturbance suppression

action which reduces or eliminates *electromagnetic disturbance*

[IEV 161-03-22]

3.15

disturbance voltage; interference voltage (deprecated in this sense)

voltage produced between two points on two separate conductors by an *electromagnetic disturbance*, measured under specified conditions

[IEV 161-04-01]

3.16

electromagnetic environment

the totality of electromagnetic phenomena existing at a given location

[IEV 161-01-01]

3.17

reference ground plane

a flat conductive surface whose potential is used as a common reference.

Note For the purpose of this standard, the reference ground plane is defined as the top metallic surface of the test bench/table.

[IEV 161-04-36]

3.18

narrowband emission

an *emission* which has a *bandwidth* less than that of a particular measuring apparatus or receiver

Note An emission which has a pulse repetition rate (in Hz) greater than the bandwidth of a particular measuring instrument can also be considered as a narrowband emission.

[IEV 161-06-13]

3.19

peak detector

a detector, the output voltage of which is the peak value of an applied signal

[IEV 161-04-24]

3.20

quasi-peak detector

a detector having specified *electrical time constants* which, when regularly repeated identical *pulses* are applied to it, delivers an output voltage which is a fraction of the peak value of the pulses, the fraction increasing towards unity as the pulse repetition rate is increased

[IEV 161-04-21]

3.21

shielded enclosure; screened room

a mesh or sheet metallic housing designed expressly for the purpose of electromagnetically separating the internal and the external environment

[IEV 161-04-37]

3.22

validation reference ground plane

an elevated reference ground plane with the dimensions of 2,5 m x 1 m which is used as the standard for the reference measurements/modelling per Annex J. The validation reference ground plane size and grounding used during the reference measurements and/or modelling may be different than what a laboratory would use during EUT measurements.

3.23

artificial mains network (AMN)

provides a defined impedance to the EUT at radio frequencies, couples the disturbance voltage to the measuring receiver and decouples the test circuit from the supply mains. There are two basic types of AMN, the V-network (V-AMN) which couples the unsymmetrical voltages, and the delta-network which couples the symmetric and the asymmetric voltages separately. The terms line impedance stabilization network (LISN) and V-AMN are used

Note network inserted in the power mains of the vehicle in charging mode or of a component (e.g. charger) which provides, in a given frequency range, a specified load impedance and which isolates the vehicle /component from the power mains in that frequency range”

3.24

Asymmetric artificial network (AAN)

network used to measure (or inject) asymmetric (common mode) voltages on unshielded symmetric signal (e.g. telecommunication) lines while rejecting the symmetric (differential mode) signal

Note This network is inserted in the communication/signal lines of the vehicle in charging mode or of a component (e.g. charger) to provide a specific load impedance and/or a decoupling (e.g. between telecommunication signal and power main)

3.25

measurement time

the effective, coherent time for a measurement result at a single frequency

- for the peak detector, the effective time to detect the maximum of the signal envelope,
- for the quasi-peak detector, the effective time to measure the maximum of the weighted envelope
- for the average detector, the effective time to average the signal envelope

3.26

bonded (ground connection and d.c. resistance)

when the term “bonded” is used to describe a grounding connection within this standard, the purpose of the bonding is to provide the lowest possible impedance (resistance and inductance) connection between two metallic parts (see 5.3 of CISPR 16-2-1). The d.c. resistance of this connection shall not exceed 2,5 mΩ.

Note A low current (≤100 mA) 4-wire milliohm meter is recommended for this measurements

3.27

low voltage (LV)

operating d.c. voltage below 60 V, e.g. nominal voltages of 12 V, 24 V or 48 V

Note The term low voltage may be defined with a different voltage range in other standards.

3.28

high voltage (HV)

operating voltage between 60 V to 1 000 V.

Note The term low voltage may be defined with a different voltage range in other standards.

4 Requirements common to vehicle and component/module emissions measurement

4.1 General test requirements and test plan

4.1.1 Categories of disturbance sources (as applied in the test plan)

Electromagnetic disturbance sources can be divided into two main types:

- Narrowband sources (examples of narrowband disturbance sources are vehicle electronic components which include clocks, oscillators, digital logic from microprocessors and displays)
- Broadband sources (examples of broadband disturbance sources are electrical motors and ignition system)

Note 1 While most vehicle or electrical/electronic components are a source of both narrowband and broadband disturbances, some may be a source of only one type of disturbance.

Note 2 Broadband sources can be classified in short-duration broadband (examples are washer pump, door mirror, electrical windows) and long-duration broadband (examples are front wiper motor, heater blower, engine cooling)

For the purposes of this standard, categorization of the disturbance type is used only in simplifying the testing demands by potentially reducing the number of detectors that must be used (i.e. eliminating the average detector if the device is known to be broadband-type of source, such as a d.c. brush commutated motor). Otherwise, this standard requires that sources comply with limits based upon both types of measurement detectors and not the type of disturbance.

4.1.2 Test plan

A test plan shall be established for each item to be tested. The test plan shall specify the

- frequency range to be tested,
- the emissions limits,
- antenna types and locations,
- test report requirements,
- supply voltage and other relevant parameters.

The test plan shall define for each frequency band whether the conformance can be obtained with average and peak limits or with average and quasi-peak limits.

4.1.3 Determination of conformance of equipment under test (EUT) with limits

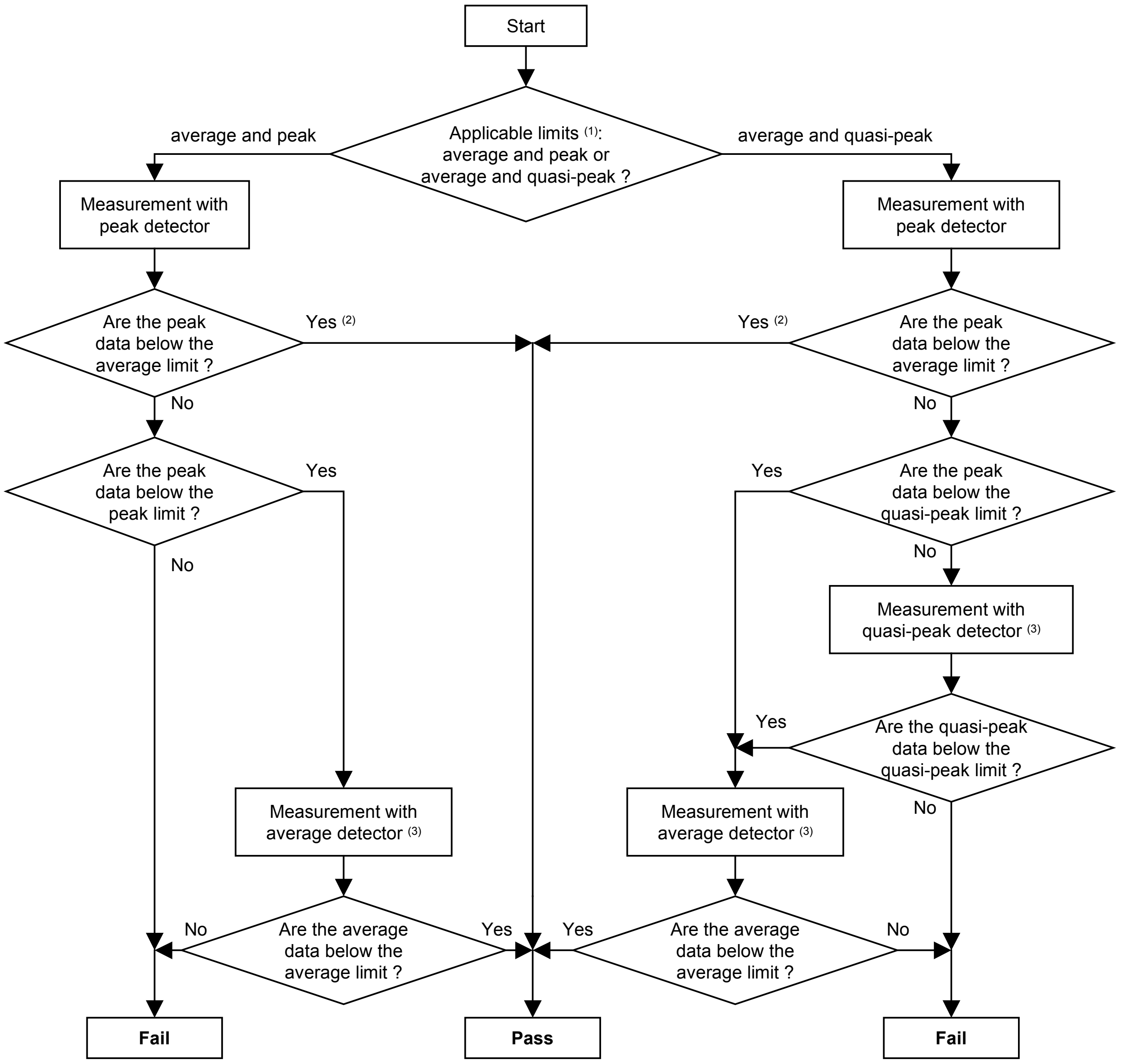
In all cases the EUT shall conform with the average limit.

The EUT shall also conform with either peak or quasi-peaks limits as follows.

- For frequencies where both peak and quasi-peak limits are defined, the EUT shall conform with either the peak or the quasi-peak limits (as defined in the test plan).
- For frequencies where only peak limits are defined, the EUT shall conform with the peak limit.

The general procedure applicable for all frequency bands is described in Figure 1.

The limits given in this standard take into account uncertainties.



Note 1 The conformance should normally be obtained by compliance to both average and peak limits or both average and quasi-peak limits, unless the test plan defines that conformance can be obtained by compliance to the single appropriate limit. *(depending on the case, peak, or average, or quasi-peak).*

Note 2 Because measurements with a peak detector are always higher than or equal to measurements with an average detector and the applicable peak limit is always higher than or equal to the applicable average limit, this single detector measurement can lead to a simplified and quicker conformance process.

Note 3 This flow-chart is applicable for each individual frequency, e.g. only frequencies that are above the applicable limit need to be remeasured with average or quasi-peak detector.

Figure 1 – Method of determination of conformance for all frequency bands

4.1.4 Operating conditions

Different operating conditions of the EUT can influence emission measurement results. When performing component/module tests, the EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. The operating conditions shall be specified in the test plan.

To ensure correct operation of components/modules during test, a peripheral interface unit shall be used which simulates the vehicle installation. Depending on the intended operating modes, all significant sensor and actuator leads of the EUT shall be connected to a peripheral interface unit. The peripheral interface unit shall be capable of controlling the EUT in accordance with the test plan.

The peripheral interface unit may be located internal or external to the shielded enclosure. If located in the shielded enclosure, the disturbance levels generated by the peripheral interface unit shall be at least 6 dB below the test limits specified in the test plan.

4.1.5 Test report

The report shall contain the information agreed upon by the customer and the supplier, e.g.

- sample identification,
- date and time of test,
- bandwidth,
- step size,
- required test limit,
- ambient data and test data.

4.2 Shielded enclosure

The ambient electromagnetic noise levels shall be at least 6 dB below the limits specified in the test plan for each test to be performed. The shielding effectiveness of the shielded enclosure shall be sufficient to assure that the required ambient electromagnetic noise level requirement is met.

NOTE Although there will be reflected energy from the interior surfaces of the shielded enclosure, this is of minimal concern for the measurement of conducted disturbances because of the direct coupling of the measuring instrument to the leads of the EUT. The shielded enclosure may be as simple as a suitably grounded bench-top screened cage.

4.3 Absorber-lined shielded enclosure (ALSE)

For radiated emission measurements, however the reflected energy can cause errors of as much as 20 dB. Therefore, it is necessary to apply RF absorber material to the walls and ceiling of a shielded enclosure that is to be used for radiated emission measurements. No absorber shall be placed on the floor for vehicle tests. For component testing, no absorber shall be placed on the floor, however, flat ferrite tiles with a maximum thickness of 25 mm may be utilised on the floor for component level testing if the chamber performance in this configuration meets the requirements of Annex J.

The following ALSE requirements shall also be met for performing radiated RF emissions measurements.

4.3.1 Size

For radiated emissions tests, the shielded enclosure shall be of sufficient size to ensure that neither the vehicle/EUT nor the test antenna shall be closer than 1 m from the walls or ceiling, or to the nearest surface of the absorber material used thereon.

4.3.2 Objects in ALSE

For radiated emissions measurements in particular, the ALSE shall be cleared of all items not pertinent to the tests. This is required in order to reduce any effect they may have on the measurement. Included are unnecessary equipment, cable racks, storage cabinets, desks, chairs, etc. Personnel not actively involved in the test shall be excluded from the ALSE.

4.3.3 ALSE performance validation

4.3.3.1 Vehicle ALSE

Performance of the absorption material shall be greater than or equal to 6 dB in the 70 MHz to 2 500 MHz frequency range.

Note 1 A test method is described in IEEE STD 1128-1998: IEEE recommended practice for radio frequency (RF) absorber – Evaluation in the range of 30 MHz to 5 GHz.”

4.3.3.2 Component ALSE

Performance of the absorption material shall be greater than or equal to 6 dB in the 70 MHz to 2 500 MHz frequency range.

Note 1 A test method is described in IEEE STD 1128-1998: IEEE recommended practice for radio frequency (RF) absorber – Evaluation in the range of 30 MHz to 5 GHz.”

Note 2 Additionally, it is recommended that the ALSE Performance Validation procedure described in Annex J be used to evaluate the performance of the shielded enclosure as configured for Clause 6.5 component radiated emissions testing. This performance verification procedure will evaluate the influences of the chamber, absorber, ground plane, ground plane grounding, and any other possible cause for measurement variation

4.4 Measuring instrument

The measuring instrument shall comply with the requirements of CISPR 16-1-1. Either manual or automatic frequency scanning may be used.

For the limits given in CISPR 25 the appropriate average detector is the linear detector with meter time constants defined in CISPR 16-1-1.

Note 1 Spectrum analysers and scanning receivers are particularly useful for disturbance measurements. The peak detection mode of spectrum analysers and scanning receivers provides a display indication which is never less than the quasi-peak indication for the same bandwidth. It may be convenient to measure emissions using peak detection because of the faster scan possible than with quasi-peak detection.

Note 2 A preamplifier may be used between the antenna and measuring instrument in order to achieve the 6 dB ambient noise requirements (see 4.2). If a preamplifier is used to achieve the 6 dB ambient noise requirement, the laboratory should establish a procedure to avoid overload of the preamplifier, such as using a step attenuator.

4.4.1 Spectrum analyser parameters

The scan rate of the spectrum analyser shall be adjusted for the CISPR frequency band and detection mode used.

Spectrum analysers may be used for performing compliance measurements to this standard providing the precautions cited in CISPR 16-1-1 on the use of spectrum analysers are adhered to and that the broadband emissions from the product being tested have a repetition frequency greater than 20 Hz.

The minimum scan time in Table 1 is applicable only for the measurement of emissions where the pulse repetition interval of the signal is shorter than the minimum observation time at each frequency based on a step size equal to half of the resolution bandwidth B_{res}. For the measurement of signals with a pulse repetition interval longer than the minimum observation time and for the measurement of intermittent signals the minimum scan time has to be increased.

If the pulse repetition interval of the signal is known the scan shall be performed with a scan time that allows an observation time at each frequency that is longer than the reciprocal of the pulse repetition frequency of the signal.

As alternative multiple faster scans with the use of a maximum hold function may be used if the total scanning time is equal to or greater than the time that would have been spent using the minimum scan time defined in Table 1. The following equation can be used to calculate the minimum scan time for multiple scans.

$$T_{s,\mathrm{min}} = 2 \times \frac{\Delta f}{B_{res}} \qquad (1)$$

where

$T_{s,min}$	is the minimum scan time for multiple scans,
Δf	is the frequency span,
B_{res}	is the resolution bandwidth.

For further guidance on the measurement of the duration of disturbance and the determination of the minimum scan time see CISPR 16-2-1 and CISPR 16-2-3.

4.4.2 Scanning receiver parameters

The dwell time of the scanning receiver shall be adjusted for the CISPR frequency band and detection mode used. The minimum measurement time, maximum step size and recommended bandwidth (BW) are listed in Table 2.

The minimum measurement time in Table 2 is applicable only for the measurement of emissions where the pulse repetition interval of the signal is shorter than the minimum measurement time in Table 2. For the measurement of signals with a pulse repetition interval longer than the minimum measurement time in Table 2 and for the measurement if intermittent signals the minimum measurement time has to be increased.

If the pulse repetition interval of the signal is known the scan shall be performed with a measurement time that is longer than the reciprocal of the pulse repetition frequency of the signal.

For further guidance on the measurement of the duration of disturbance and the determination of the minimum measurement time see CISPR 16-2-1 and CISPR 16-2-3.

Table 1 – Spectrum analyser parameters

Service / Band	Frequency MHz	Peak detection		Quasi-peak detection		Average detection	
		RBW at -3 dB	**Min. scan time**	**RBW at -6 dB**	**Min. scan time**	**RBW at -3 dB**	**Min. scan time**
BROADCAST							
LW	0,15 - 0,30	9 or 10 kHz	10 s / MHz	9 kHz	200 s / MHz	9 or 10 kHz	10 s / MHz
MW	0,53 - 1,8						
SW	5,9 - 6,2						
FM	76 - 108	100 or 120 kHz	100 ms / MHz	120 kHz	20 s / MHz	100 or 120 kHz	100 ms / MHz
TV Band I	41 - 88						
TV Band III	174 - 230						
DAB III	171 - 245						
TV Band IV/V	468 - 944						
DTTV	470 - 770	100 or 120 kHz	100 ms / MHz	Does not apply	Does not apply	100 or 120 kHz	100 ms / MHz
DAB L band	1 447 – 1 494						
SDARS	2 320 – 2 345						
MOBILE SERVICES							
CB	26 - 28	9 or 10 kHz	10 s / MHz	9 kHz	200 s / MHz	9 or 10 kHz	10 s / MHz
VHF	30 - 54	100 or 120 kHz	100 ms / MHz	120 kHz	20 s / MHz	100 or 120 kHz	100 ms / MHz
VHF	68 - 87						
VHF	142 -175						
Analogue UHF	380 - 512						
RKE	300 - 330						
RKE	420 - 450						
Analogue UHF	820 - 960						
GSM 800	860 - 895						
EGSM/GSM 900	925 - 960						
GPS L1 civil	1 567 – 1 583	Does not apply	Does not apply	Does not apply	Does not apply	9 or 10 kHz	1 s / MHz
GLONASS L1	1 591 – 1 613						
GSM 1800 (PCN)	1 803 – 1 882	100 or 120 kHz	100 ms / MHz	Does not apply	Does not apply	100 or 120 kHz	100 ms / MHz
GSM 1900	1 850 – 1 990						
3G / IMT 2000	1 900 – 1 992						
3G / IMT 2000	2 010 – 2 025						
3G / IMT 2000	2 108 – 2 172						
Bluetooth/802.11	2 400 – 2 500						

When a spectrum analyser is used for measurements, the video bandwidth shall be at least three times the resolution bandwidth (RBW).

Service / Band	**Frequency** MHz	**Peak detection**			**Quasi-peak detection**			**Average detection**		
		BW at -6 dB	**Step size**	**Min. measurement time**	**BW at -6 dB**	**Step size**	**Min. measurement time**	**BW at -6 dB**	**Step size**	**Min. measurement time**
BROADCAST										
LW	0,15 - 0,30	9 kHz	5 kHz	50 ms	9 kHz	5 kHz	1 s	9 kHz	5 kHz	50 ms
MW	0,53 - 1,8									
SW	5,9 - 6,2									
FM	76 - 108	120 kHz	50 kHz	5 ms	120 kHz	50 kHz	1 s	120 kHz	50 kHz	5 ms
TV Band I	41 - 88									
TV Band III	174 - 230									
DAB III	171 - 245									
TV Band IV/V	468 - 944									
DTTV	470 - 770	120 kHz	50 kHz	5 ms	Does not apply	Does not apply	Does not apply	120 kHz	50 kHz	5 ms
DAB L band	1 447 – 1 494									
SDARS	2 320 – 2 345									
MOBILE SERVICES										
CB	26 - 28	9 kHz	5 kHz	50 ms	9 kHz	5 kHz	1 s	9 kHz	5 kHz	50 ms
VHF	30 - 54	120 kHz	50 kHz	5 ms	120 kHz	50 kHz	1 s	120 kHz	50 kHz	5 ms
VHF	68 - 87									
VHF	142 -175									
Analogue UHF	380 - 512									
RKE	300 - 330									
RKE	420 - 450									
Analogue UHF	820 - 960									
GSM 800	860 - 895									
EGSM/GSM 900	925 - 960									
GPS L1 civil	1 567 – 1 583	Does not apply	Does not apply	Does not apply	Does not apply	Does not apply	Does not apply	9 kHz	5 kHz	5 ms
GLONASS L1	1 591 – 1 613									
GSM 1800 (PCN)	1 803 – 1 882	120 kHz	50 kHz	5 ms	Does not apply	Does not apply	Does not apply	120 kHz	50 kHz	5 ms
GSM 1900	1 850 – 1 990									
3G / IMT 2000	1 900 – 1 992									
3G / IMT 2000	2 010 – 2 025									
3G / IMT 2000	2 108 – 2 172									
Bluetooth/802.11	2 400 – 2 500									

Note For emissions generated by brush commutator motors without an electronic control unit, the maximum step size may be increased up to 5 times the bandwidth

Table 2 – Scanning receiver parameters

4.5 Power supply

The power supply shall have adequate regulation to maintain the supply voltage U_s within the ranges specified:

Vehicle tests: Ignition on, engine off

The vehicle battery voltage shall be recorded before and after the measurement with ignition off and battery disconnected from the vehicle electrical network. The values shall be within the following values:

$$U_s = \left(12^{+2}_{-1}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(24^{+4}_{-2}\right) \text{V for systems with 24 V nominal supply voltage}$$

Vehicle tests: Engine running

The vehicle battery voltage shall be recorded before and after the measurement with engine running in idle mode and battery connected to the vehicle electrical network. The values shall be within the following values:

$$U_s = \left(13^{+3}_{-0}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(26^{+6}_{-0}\right) \text{V for systems with 24 V nominal supply voltage}$$

NOTE Most of the vehicle tests will be performed without the engine running, but with the ignition switched on, therefore care must be taken to ensure that the battery is sufficiently well charged. A permanent recording of the battery voltage may be installed during the measurements as a complementary information.

Vehicle tests: Charging mode

The d.c. power supply voltage during the test shall be nominal ±10 %.

The a.c. power supply voltage during the test shall be nominal –15 % / +10 %. The rated value of the frequency shall be nominal ±1 %.

$$U_s = \left(14^{+1}_{-1}\right) \text{V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(24\begin{smallmatrix}+4\\-2\end{smallmatrix}\right) \text{ V for systems with 24 V nominal supply voltage}$$

Component/module tests:

The d.c. power supply voltage during the test shall be nominal ±10 %.

The a.c. power supply voltage during the test shall be nominal –15 % / +10 %. The rated value of the frequency shall be nominal ±1 %.

Unless otherwise stated in the test plan the values below shall be used.

$$U_s = \left(13\begin{smallmatrix}+1\\-1\end{smallmatrix}\right) \text{ V for systems with 12 V nominal supply voltage}$$

$$U_s = \left(26\begin{smallmatrix}+2\\-2\end{smallmatrix}\right) \text{ V for systems with 24 V nominal supply voltage}$$

$$U_s = \left(48\begin{smallmatrix}+4\\-4\end{smallmatrix}\right) \text{ V for systems with 48 V nominal supply voltage}$$

The power supply shall also be adequately filtered such that the RF noise produced by the power supply is at least 6 dB lower than the limits specified in the test plan.

When specified in the test plan, a vehicle battery shall be connected in parallel with the power supply.

5 Measurement of emissions received by an antenna on the same vehicle

5.1 Antenna measuring system

5.1.1 Type of antenna

An antenna of the type to be supplied with the vehicle shall be used as the measurement antenna for the bands for which it is designed to be used for radio reception.

If no antenna is to be furnished with the vehicle (as is often the case with a mobile radio system), the antenna types in Table 3 shall be used for the test. The antenna type and location shall be included in the test plan.

If an active antenna is used, the noise floor of the measured signal at the radio antenna connector may increase (see also the note in 5.4).

Table 3 – Antenna types

Frequency MHz	**Antenna type**
0,15 to 6,2	1 m monopole

26 to 54	Loaded quarter-wave monopole
68 to 1 000	Quarter-wave monopole
1 000 to 2 500	As recommended by the vehicle manufacturer

5.1.2 Measuring system requirements

5.1.2.1 Broadcast bands

For each band, the measurement shall be made with instrumentation which has the following specified characteristics.

5.1.2.1.1 AM broadcast:

Long wave (0,15 MHz to 0,3 MHz)

Medium wave (0,53 MHz to 1,8 MHz)

Short wave (5,9 MHz to 6,2 MHz)

The measuring system consisting of antenna element, antenna matching unit, coaxial cable(s) and preamplifier, if used, shall have the following characteristics:

- noise floor of the measurement system shall be at least 6 dB lower than the applicable limits.

Antenna matching unit

- input impedance shall have a resistance of at least 100 kΩ in parallel with a maximum capacitance of 10 pF;
- output impedance: 50 Ω resistive;
- gain: The gain (or attenuation) shall be known with an accuracy of ± 0,5 dB. The gain shall remain within a 6 dB envelope for each frequency band as shown in Figure 2. Verification shall be performed in accordance with Annex B;

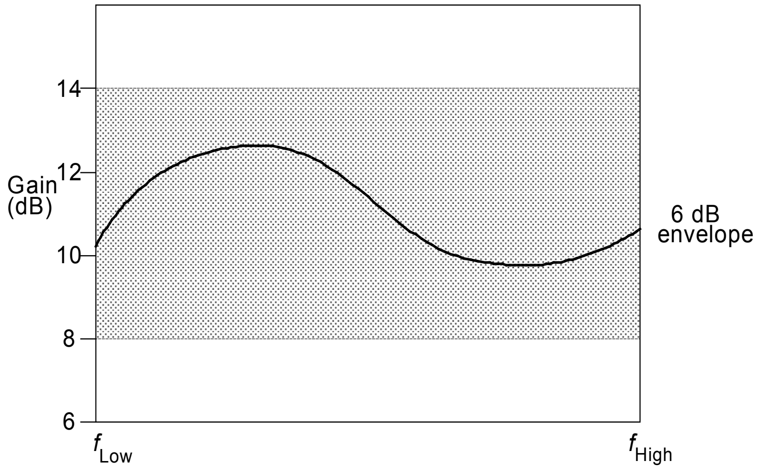


Figure 2 – Example of gain curve

- **compression point**: The 1 dB **compression point** shall occur at a sine wave voltage level (generator output level) greater than 60 dB(μV). Verification shall be performed in accordance with annex B;

5.1.2.1.2 FM broadcast (76 MHz to 108 MHz) and Digital audio and TV broadcast

Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω. If the voltage standing wave ratio (VSWR) of the antenna is greater than 2:1 an input matching network shall be used. Appropriate correction shall be made for any attenuation/gain of the matching unit.

5.1.2.2 Mobile services (26 MHz to 2 500 MHz)

Measurements shall be taken with a measuring instrument which has an input impedance of 50 Ω. If the voltage standing wave ratio (VSWR) of the antenna is greater than 2:1 an input matching network shall be used. Appropriate correction shall be made for any attenuation/gain of the matching unit.

5.2 Method of measurement

The disturbance voltage shall be measured at the receiver end of the antenna coaxial cable using the ground contact of the connector as reference. The antenna connector shall be grounded to the housing of the on-board radio. The radio housing shall be grounded to the vehicle body using the production harness. A coaxial bulkhead connector shall be used for connection to the measuring instrument outside the shielded room. In the case of an active vehicle antenna, which is fed by the radio via the antenna cable (phantom network), a decoupling network similar to that used in the radio shall be installed at the antenna connector to feed the active antenna from the vehicle supply voltage.

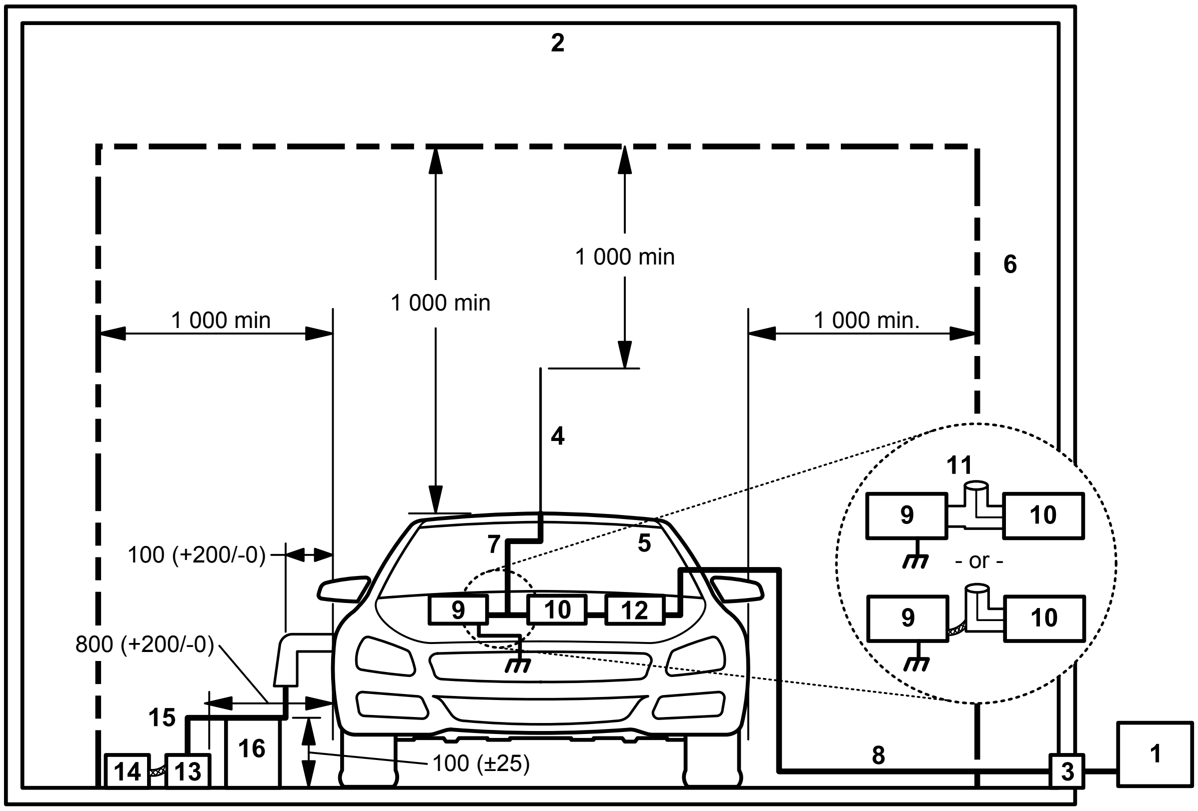
When making measurements in the AM broadcast bands (LW, MW, SW), the vehicle/matching unit ground and ground of the ALSE shall be electrically isolated from each other by means such as an isolation transformer, sheath-current suppressor, battery-powered measurement instrumentation, fiber optics, etc. Appropriate correction shall be made for the insertion loss of any isolation network. (See Annex C for an example of a sheath-current suppressor).

Note The use of a high-quality coaxial cable e.g. double-shielded cable for connection to the measuring instrument is recommended as well as the use of ferrite rings on the cable for suppression of surface currents.

Some vehicles may allow a receiver to be mounted in several locations (e.g. under the instrument panel, under the seat, etc.). In these cases a test shall be carried out as specified in the test plan for each receiver location.

The test setup is described in Figure 3.

Dimensions in mm



Key

1 Measuring instrument
2 ALSE
3 Bulkhead connector
4 Antenna (see 5.1)
5 Vehicle
6 Typical absorber material
7 Antenna coaxial cable
8 High-quality coaxial cable e.g. double-shielded (50 Ω)
9 Housing of on-board radio
10 Impedance matching unit (when required)
11 Modified coaxial "T" connector
12 AM broadcast band ground isolation network (when required)
13 Artificial Mains Network (only for Charging mode configuration)
14 Power mains (only for Charging mode configuration)
15 Charging cable (only for Charging mode configuration)
16 Insulating support (only for Charging mode configuration)

Figure 3 –Vehicle-radiated emissions – Example for test layout (end view with monopole antenna)

5.3 Test setup for vehicle in charging mode

The various configurations (a.c. or d.c., with or without communication) are considered in this clause.

5.3.1 a.c. power charging without communication

5.3.1.1 Power mains

The power mains socket can be placed anywhere in the test location with the following conditions:

- It shall be placed on the reference ground plane.
- The length of the harness between the power mains socket and the AMN(s) shall be kept as short as possible.
- The harness shall be placed on the reference ground plane.

5.3.1.2 Artificial mains network

Power mains shall be applied to the vehicle through 50 µH/50 Ω AMN(s) (see Annex E).

The AMN(s) shall be mounted directly on the reference ground plane. The case of the AMN(s) shall be bonded to the reference ground plane. The d.c. resistance between the ground of the AMN measurement port and the ground plane shall not exceed 2,5 mΩ

The measuring port of each AMN shall be terminated with a 50 Ω load.

The power charging cable shall be placed in a straight line between the AMN(s) and the vehicle charging plug and shall be routed perpendicularly to the vehicle longitudinal axis as shown in Figure 4 and 5.

For vehicles with plug located front/rear of the vehicle, the AMN shall be placed on one side of the vehicle and perpendicularly to the vehicle power charging plug and shall be aligned with the vehicle charging cable.

5.3.1.3 Power charging cable

The power charging cable shall be placed in a straight line between the AMN(s) and the vehicle charging plug. The projected cable length shall be 800 (+200 / -0) mm.

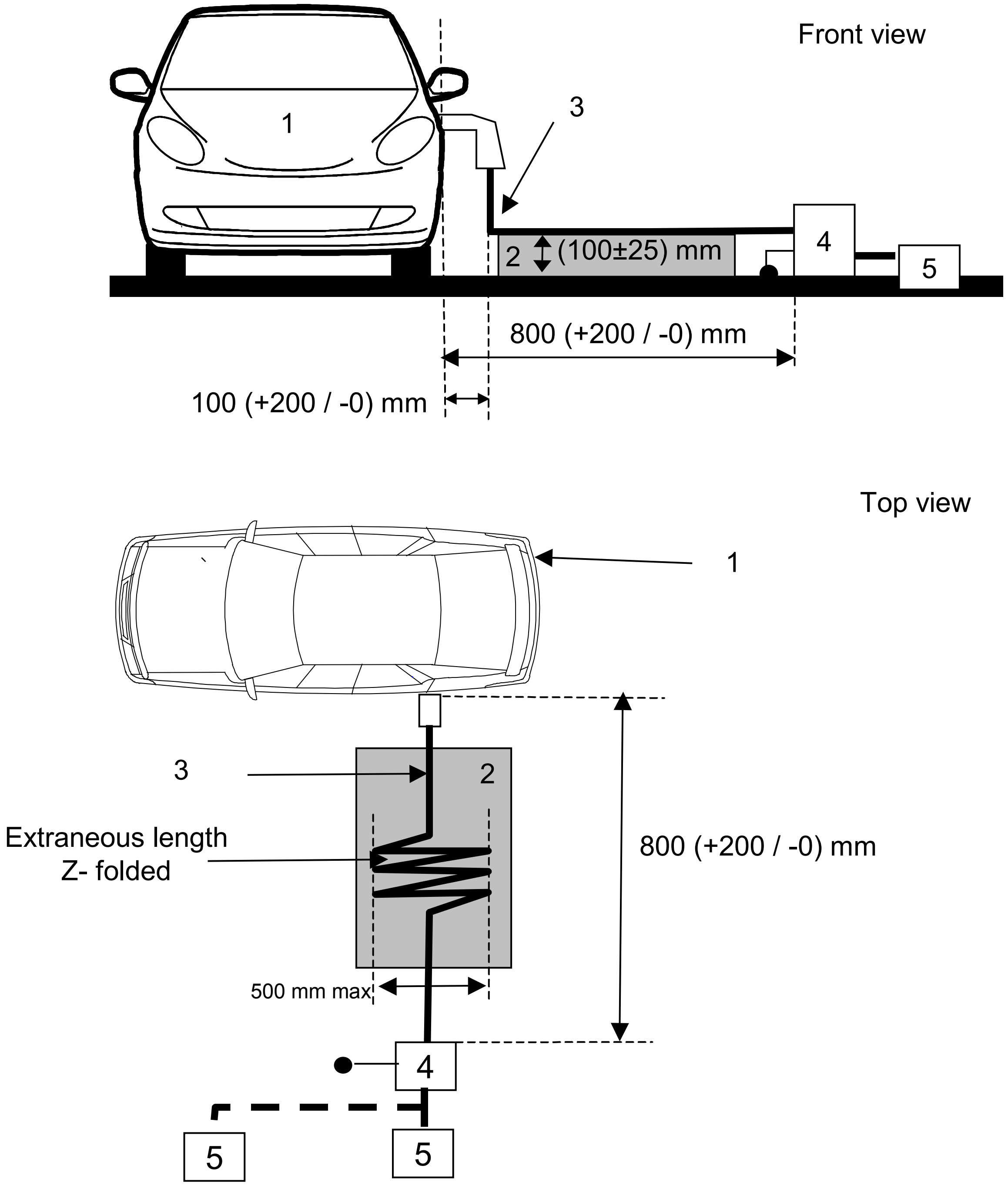
If the length of the cable is longer than 1 m, the extraneous length shall be “Z-folded” in less than 0,5 m width. If it is impractical to do so because of cable bulk or stiffness, or because the testing is being done at a user installation, the disposition of the excess cable shall be precisely noted in the test report.The charging cable at vehicle side shall hang vertically at a distance of 100 (+200 / -0) mm from the vehicle body.

The whole cable shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (100 ± 25) mm above the reference ground plane.

5.3.1.4 Measuring system

The measuring system (receiver, impedance matching unit, cable…) shall be placed as defined in Figure 3.

Examples of test setups are shown in Figures 4 and 5.



Key

1 Vehicle under test

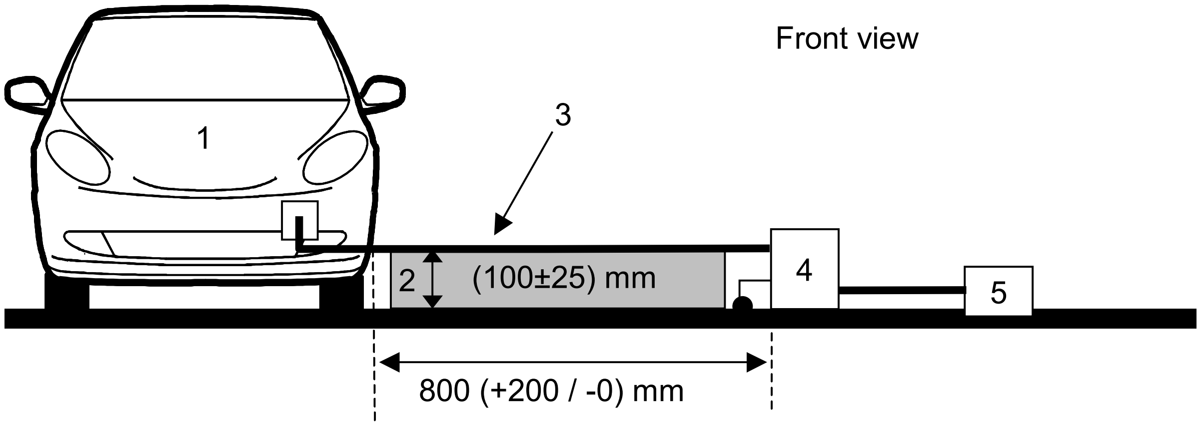
2 Insulating support

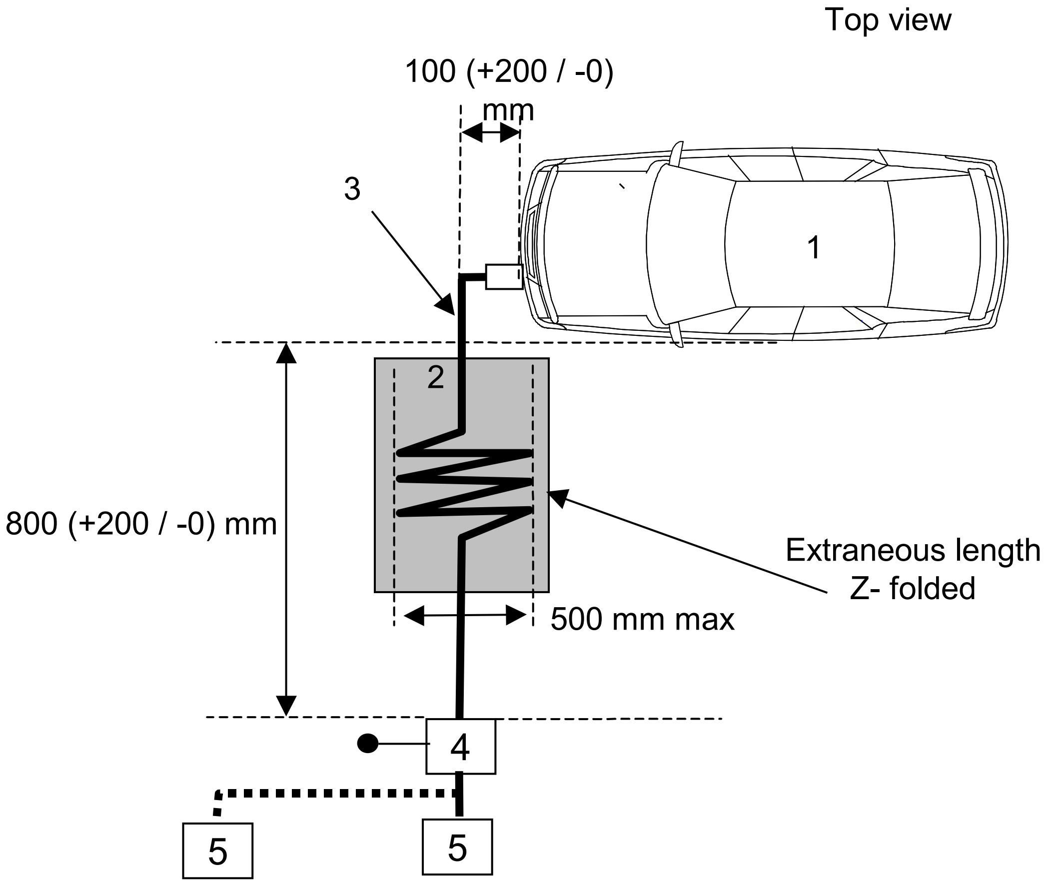
3 Charging cable

4 Artificial Mains Network(s) grounded

5 Power mains socket (see 5.3.1.1, alternative positions shown in the figure)

Figure 4 – Example of test setup for vehicle with plug located on vehicle side (a.c. powered without communication)





Key

1	Vehicle under test
2	Insulating support
3	Charging cable
4	Artificial Mains Network(s) grounded
5	Power mains socket (see 5.3.1.1, alternative positions shown in the figure)

Figure 5 – Example of test setup for vehicle with plug located front / rear of vehicle (a.c. powered without communication)

5.3.2 a.c. or d.c. power charging with communication line(s) or with signal line(s)

5.3.2.1 General

This configuration concerns charging mode for a.c. power and for d.c. power using communications or signal lines.

Note In some cases the lines used for communication between vehicle and charging station cannot be considered as “communication line” (as defined in CISPR 22) but rather as signal lines.

5.3.2.2 Charging station / Power mains

The charging station may be placed either in the test location or outside the test location.

Note If communications between the vehicle and the charging station can be simulated, the charging station may be replaced by the supply from power mains.

In both case duplicated power mains and communication or signal lines socket(s) shall be placed in the test location with the following conditions:

- It shall be placed on the reference ground plane.
- The length of the harness between the power mains / communication or signal lines socket and the AMN(s) / AN(s) / AAN(s) shall be kept as short as possible.
- The harness between the power mains / communication or signal lines socket and the AMN(s) / AN(s) / AAN(s) shall be placed on the reference ground plane.

Note The power mains and communication or signal lines socket(s) should be filtered.

If the charging station is placed inside the test location then harness between charging station and the power mains / communication or signal lines socket shall be placed with the following conditions :

- The harness at charging station side shall hang vertically down to the reference ground plane.
- The extraneous length shall be placed as close as possible of the reference ground plane and “Z-folded” if necessary.

5.3.2.3 Artificial mains networks / artificial networks

A.c. Power mains shall be applied to the vehicle through 50 µH/50 Ω AMN(s) (see Annex E).

D.c. power mains shall be applied to the vehicle through 5 µH/50 Ω High Voltage Artificial Networks (HV-AN(s))”. (see Annex E).

The AMN(s) / HV-AN(s) shall be mounted directly on the reference ground plane. The cases of the AMN(s) / HV-AN(s) shall be bonded to the reference ground plane. The d.c. resistance between the ground of the AMN / HV-AN measurement port and the ground plane shall not exceed 2,5 mΩ

The measuring port of each AMN / HV-AN shall be terminated with a 50 Ω load.

The AMN / HV-AN shall be placed in front, aligned and on the same side of the vehicle power charging plug.

5.3.2.4 Asymmetric artificial network

Communication lines shall be applied to the vehicle through AAN(s) (see Annex E).

Note Signal lines may be applied to the vehicle through AAN(s) (see Annex E).

The AAN(s) shall be mounted directly on the reference ground plane. The case of the AAN(s) shall be bonded to the reference ground plane.

The measuring port of each AAN shall be terminated with a 50 Ω load.

The power charging cable shall be placed in a straight line between the AMN/AAN or HV-AN/AAN and the vehicle charging plug and shall be routed perpendicularly to the vehicle longitudinal axis as shown in Figure 6 and 7.

5.3.2.5 Power charging / communication or signal cable

The power charging / communication or signal cable shall be placed in a straight line between the AMN(s) / HV-AN(s) / AAN(s) and the vehicle charging plug. The projected cable length shall be 0,8 (+0,2 / -0) m.

If the length of the cable is longer than 1 m, the extraneous length shall be “Z-folded” in less than 0,5 m width.

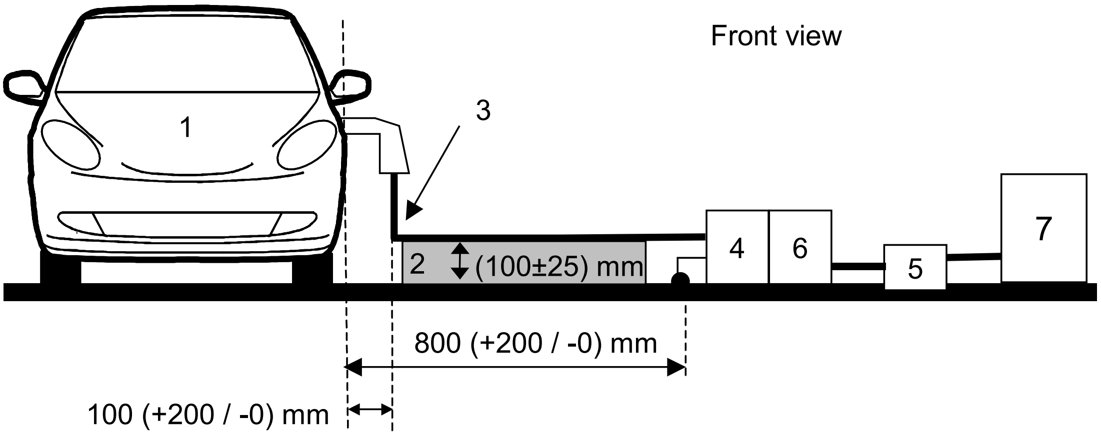
The charging / communication or signal cable at vehicle side shall hang vertically at a distance of 100 (+200 / -0) mm from the vehicle body.

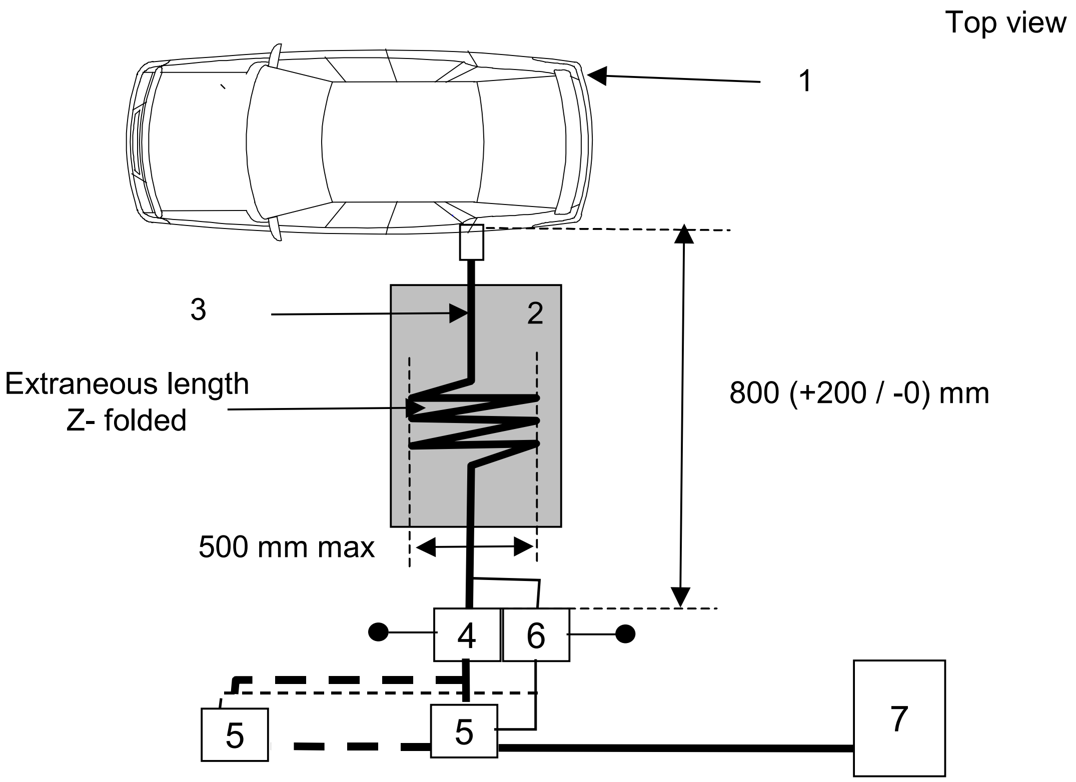
The whole cable shall be placed on a non-conductive, low relative permittivity (dielectric-constant) material ($\varepsilon_r \leq 1,4$), at (100 ± 25) mm above the reference ground plane.

5.3.2.6 Measuring system

The measuring system (receiver, impedance matching unit, cable…) shall be placed as defined in Figure 3

Examples of test setups are shown in Figures 6 and 7.





Key

1 Vehicle under test

2 Insulating support

3 Charging / communication or signal cable

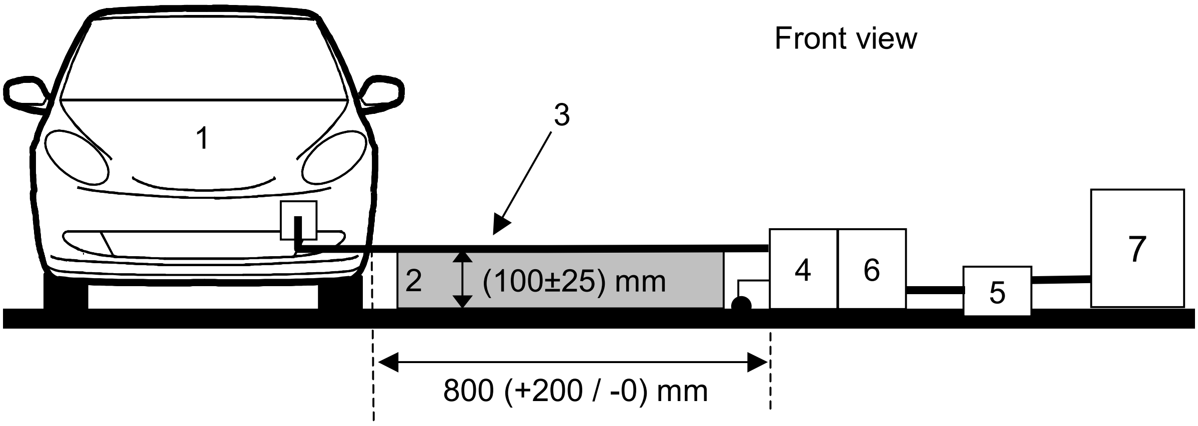
4 a.c.-AMN(s) or d.c. HV-AN(s) grounded

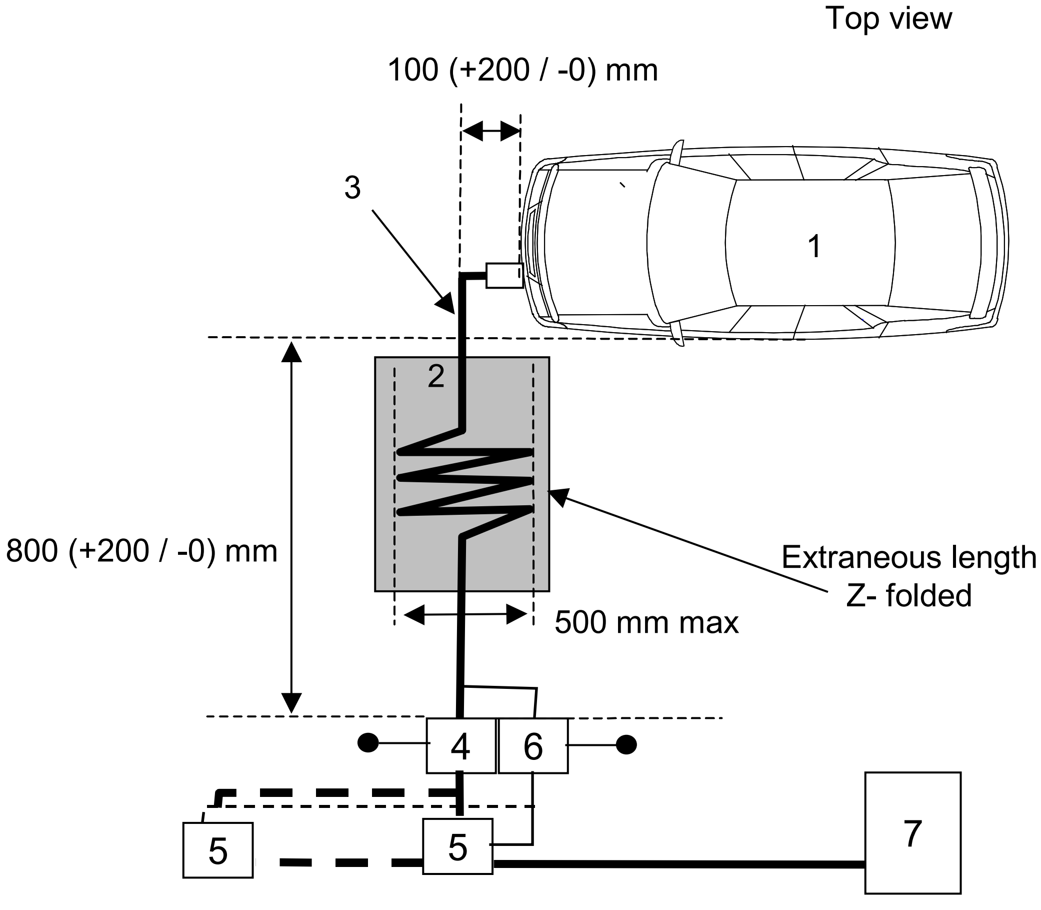
5 Power mains socket (alternative positions shown in the figure)

6 Asymmetric artificial network(s) grounded

7 Charging Station

Figure 6 – Example of test setup for vehicle with plug located on vehicle side (a.c. or d.c. powered with communication)





Key

1 Vehicle under test
2 Insulating support
3 Charging / communication or signal cable
4 a.c. AMN(s) or d.c. HV-AN(s) grounded
5 Power mains socket (alternative positions shown in the figure)
6 Asymmetric artificial network(s) grounded
7 Charging Station

Figure 7 – Example of test setup for vehicle with plug located front /rear of vehicle (a.c. or d.c. powered with communication)

5.4 Examples of limits for vehicle radiated disturbances

It is recommended for acceptable radio reception in a vehicle using typical radio receivers, that the disturbance voltage at the end of the antenna cable should not exceed the values shown in Table 4. Where different receivers are used or different coupling models for the propagation of disturbances are valid, the limits may be changed and detailed in the vehicle manufacturer’s own specification.

Table 4 – Example for limits of disturbance – Complete vehicle

Service / Band [a]	Frequency MHz	Terminal disturbance voltage at receiver antenna terminal in dB (µV)		
		Peak	Quasi-peak	Average
BROADCAST				
LW [b]	0,15 - 0,30	26	13	6
MW [b]	0,53 - 1,8	20	7	0
SW [b]	5,9 - 6,2	20	7	0
FM [b]	76 - 108	26	13	6
TV Band I [c]	41 - 88	16	-	6
TV Band III [c]	174 - 230	16	-	6
DAB III	171 - 245	10	-	0
TV Band IV/V [c]	468 - 944	16	-	6
DTTV	470 - 770	20 [d]	-	10 [d]
DAB L band	1 447 – 1 494	10	-	0
SDARS	2 320 – 2 345	16	-	6
MOBILE SERVICES				
CB [b]	26 - 28	20	7	0
VHF [b]	30 - 54	20	7	0
VHF [b]	68 - 87	20	7	0
VHF [b]	142 -175	20	7	0
Analogue UHF [b]	380 - 512	20	7	0
RKE [f]	300 - 330	20	-	6
RKE [f]	420 - 450	20	-	6
Analogue UHF [b]	820 - 960	20	7	0
GSM 800	860 - 895	26	-	6
EGSM/GSM 900	925 - 960	26	-	6
GPS L1 civil [e,g]	1 567 – 1 583	-	-	0
GLONASS L1 [e,h]	1 591 – 1 613	-	-	0
GSM 1800 (PCN)	1 803 – 1 882	26	-	6
GSM 1900	1 850 – 1 990	26	-	6
3G / IMT 2000	1 900 – 1 992	26	-	6
3G / IMT 2000	2 010 – 2 025	26	-	6
3G / IMT 2000	2 108 – 2 172	26	-	6
Bluetooth/802.11	2 400 – 2 500	26	-	6

[a] LW: Long wave, MW: Medium wave, SW: Short wave (amplitude modulation, AM)
VHF: Very high frequency, UHF: Ultra high frequency (frequency modulation, FM)
DAB: Digital audio broadcasting, TV: Television, DTTV: Digital Terrestrial Television
RKE: Remote keyless entry, GPS: Global positioning system, GSM: Global system mobile
3G: Third generation

[b] In this analogue service the peak and quasi-peak limits can be relaxed by 6 dB for short duration disturbances (e.g. short duration PK (or QPK) limit = PK (or QPK) limit + 6 dB)

[c] Analogue TV only

[d] This limit is less stringent than the analogue limit and should only be applied where analogue TV is no longer in use

[e] The bandwidth and frequency steps to be used for the GPS and GLONASS L1 civil band are respectively 9 kHz and 5 kHz rather than the bandwidth and frequency steps defined in Table 1 and Table 2 for services above 30 MHz.

[f] RKE limits are defined over a large frequency band. Any modification of the average limit around the operating frequency due to sensitivity of RKE systems should be defined in the test plan.

[g] The values given in the table apply for the 1 574,42 MHz to 1 576,42 MHz frequency range. The limits for the whole GPS L1 frequency range are given in Figure 8a.

[h] The values given in the table apply for the 1 598,065 MHz to 1 606,5 MHz frequency range. The limits for the whole GLONASS L1 frequency range are given in Figure 8b.

NOTE 1 Stereo signals may be more susceptible to disturbance than monaural signals in the FM broadcast band. This phenomenon has been factored into the FM (76 MHz to 108 MHz) limits.

NOTE 2 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of ambient noise requirements, then applicable limits should be defined in the test plan and the applied limits and bandwidths should be documented in the test report.

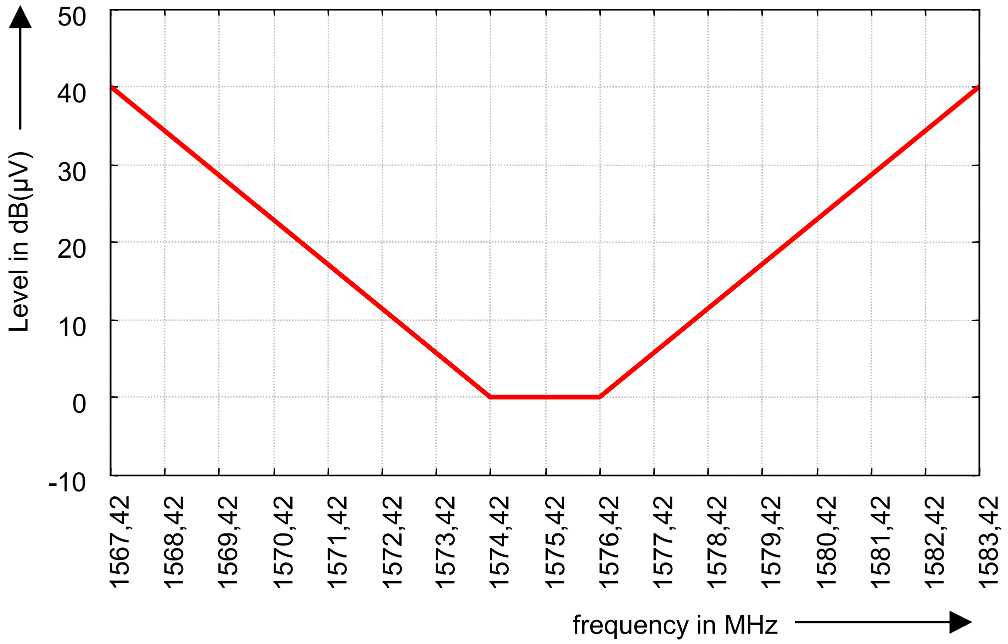


Figure 8a – Average limit for radiated disturbances from vehicles GPS band 1 567,42 to 1 583,42 MHz

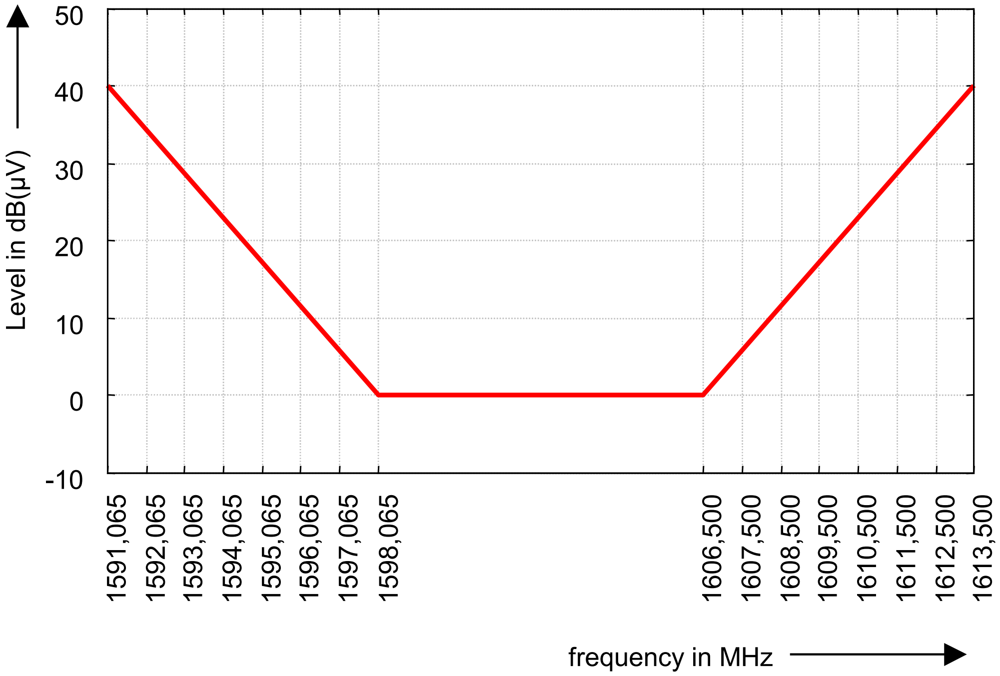


Figure 8b – Average limit for radiated disturbance from vehicles GLONASS band 1 591,065 to 1 613,5 MHz

NOTE - If an active antenna is used, the noise floor may increase. The additional noise floor depends on the type of antenna and must be subtracted from the measured value to determine the real value of the disturbance using the following formula (all terms in µV):

$$U_{real\ Disturbance} = \sqrt{U^2_{Measured} - U^2_{Antenna\ noise}} \qquad (2)$$

A relaxation of the limit because of the active antenna noise floor does not guarantee compliance. Subsequent changes to the active antenna design may result in non-compliance. This topic remains under study. Annex D describes a method to determine the noise floor of an active antenna.

6 Measurement of components and modules

6.1 General

For LV components test methods and requirements are defined in this clause.

For LV/HV components additional test methods and limits are defined in Annex I.

For LV/HV components:

- Conducted emission (voltage method) on LV lines shall be performed according to setup defined in clause I.3 and requirement in 6.2.3
- Conducted emission (voltage method) on HV lines shall be performed according to setup defined in clause I.3 and requirement in I.3.3

6.2 Test equipment

6.2.1 Reference ground plane

The reference ground plane shall be defined as the top metallic surface of the test bench/table.

The reference ground plane shall be made of 0,5 mm thick (minimum) copper, brass, bronze or galvanized steel.

The minimum size of the reference ground plane for conducted emissions (voltage method) shall be 1 000 mm x 400 mm.

The minimum size of the reference ground plane for conducted emissions (current probe method) shall be 2 500 mm x 400 mm.

The minimum width of the reference ground plane for radiated emissions shall be 1 000 mm. The minimum length of the reference ground plane for radiated emissions shall be 2 000 mm, or underneath the entire equipment plus 200 mm, whichever is larger.

The height of the reference ground plane (test bench) shall be (900 ± 100) mm above the floor.

The distance from the edge of the ground strap to the edge of the next strap shall not be greater than 300 mm. The maximum length to width ratio for the ground straps shall be 7:1.

Note 1 Because of resonances of the reference ground plane the location, width and length of the bond straps may influence the measurement results. A sufficient number of low inductive bond straps are necessary to ensure a low impedance connection to the shielded room.

6.2.2 Power supply and AN

For the tests defined in 6.3, 6.4, 6.5, 6.6 and 6.7, each positive EUT power supply lead shall be connected to the power supply through an artificial network. For the TEM cell emissions tests of 6.6, an AN with a coaxial connector will facilitate connection to the TEM cell EUT power connector. The AN shall have a nominal 5 μH inductance. The impedance characteristics and a suggested schematic are shown in Annex E.

Power supply is assumed to be negative ground. If the EUT utilizes a positive ground then the test setups shown in the figures need to be adapted accordingly. Depending on the intended EUT installation in the vehicle:

- EUT remotely grounded (vehicle power return line longer than 200 mm): two artificial networks are required, one for the positive supply line and one for the power return line.
- EUT locally grounded (vehicle power return line 200 mm or shorter): one artificial network is required, for the positive supply.

The AN(s) shall be mounted directly on the reference ground plane. The case(s) of the AN(s) shall be bonded to the reference ground plane. The d.c. resistance between the ground of the AN measurement port and the ground plane shall not exceed 2,5 mΩ

The power supply return shall be connected to the reference ground plane (between the power supply and the AN(s)).

The measuring port of the AN not connected to the measuring instrument shall be terminated with a 50 Ω load.

6.2.3 Load Simulator

The load simulator includes sensors and actuators, and terminates the test harness connected to the EUT.

To ensure sufficient reproducibility the same termination must be used for each measurement either by using special termination equipment (e.g. artificial networks, filters) – located at the RF boundary – or by using the same load simulator.

6.2.4 Signal/control line filters

In the TEM cell test method using the coaxial connectors for EUT leads each lead shall pass through a filter which has impedance characteristics similar to that of the AN defined above.

The attenuation of the filters shall be specified for the whole frequency range of the intended component/module test (see 6.3 to 6.7) according to the requirements shown in Figure 9. The minimum attenuation shall be more than 40 dB from 30 MHz up to the upper cut-off frequency (f_c), which depends on the intended test method. Figure 9 shows e.g. an upper cut-off frequency (f_c) of the chosen test method of 400 MHz.

NOTE Other low pass RF filter configurations may be used if the filter characteristics are not applicable to special wanted signals of the EUT's inputs or outputs (e.g. high speed network data interfaces). The filters shall be specified in the test plan.

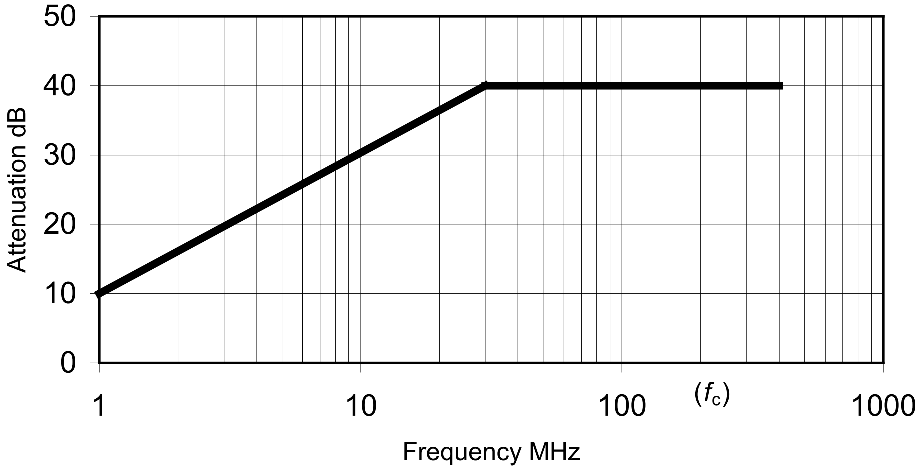


Figure 9 – Example for the required minimum attenuation of the Signal / Control line filters

The attenuation of such a filter can be determined by a two-port network analyser measurement (-s_{21}). The input and output impedance of the network analyzer shall be 50 Ω.

The test setup is shown in Figure 10.

Note Equivalent methods for measuring in a 50 Ω system such as a measuring receiver or equivalent equipment with built-in tracking generator can also be used for the measurement since only the magnitude of the attenuation is to be measured.

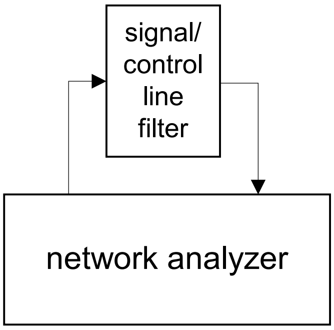


Figure 10 – Setup for measurement of the filter attenuation

6.3 Conducted emissions from components/modules – Voltage method

6.3.1 General

Voltage measurements are able to characterize the emissions on single leads only. The test method is not usable to characterize the radiated emission transmitted e.g. by different antenna structures on the printed board of electronic components or to characterize the efficiency of shielding. Therefore, voltage measurements are not able to characterize the complete EUT emission. At lower frequencies (e.g. in the AM-bands) voltage measurements usually ensure more dynamic range than radiated measurements.

6.3.2 Reference ground plane arrangement

6.3.2.1 Test setup

6.3.2.1.1 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the reference ground plane.

The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the actual vehicle configuration.

All sides of the EUT shall be at least 100 mm from the edge of the reference ground plane. In the case of a grounded EUT, the ground connection point shall also have a minimum distance of 100 mm from the edge of the reference ground plane.

6.3.2.1.2 Location of the test harness

The power supply line(s) between the connector of the AN(s) and the connector(s) of the EUT (l_p) shall have a standard length of $\left(200\ {}^{+200}_{\ \ 0}\right)$ mm.

The harness shall be placed in a straight line on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the reference ground plane.

To minimize the coupling between power and input/output leads, the space between those lead types shall be maximized (≥ 200 mm from or perpendicular to the power supply lines connecting the AN(s) and the EUT).

The total length of the test harness (excluding power lines) shall not exceed 2 m. The wiring type is defined by the actual system application and requirement.

All leads and cables shall be located at a minimum distance of 100 mm from the edge of the reference ground plane.

6.3.2.1.3 Location of the load simulator

Preferably, the load simulator shall be placed directly on the reference ground plane. If the load simulator has a metallic case, this case shall be bonded to the reference ground plane.

Note Alternatively, the load simulator may be located adjacent to the reference ground plane (with the case of the load simulator bonded to the reference ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an **RF boundary** bonded to the reference ground plane.

When the load simulator is located on the reference ground plane, the d.c. power supply lines of the load simulator shall be connected directly to the power supply and not through the AN(s).

6.3.2.2 Test procedure

The general arrangement of the disturbance source (EUT), connecting harnesses, etc. represents a standardised test condition. Any deviations from the standard test harness length etc. shall be agreed upon prior to testing and recorded in the test report.

The EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. These operating conditions must be clearly defined in the test plan to ensure supplier and customer are performing identical tests.

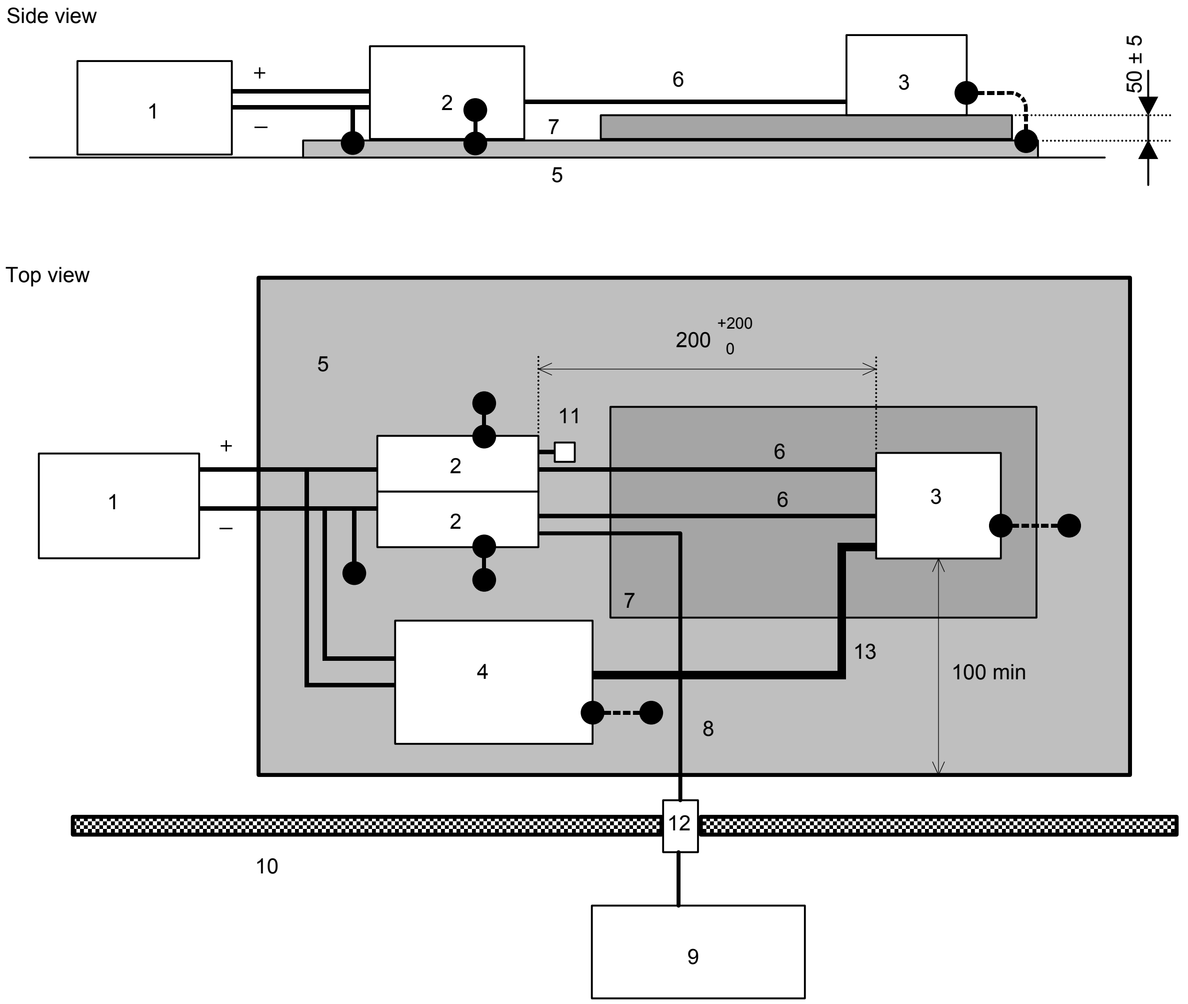
The conducted emissions on power lines are measured successively on positive power supply and power return by connecting the measuring instrument on the measuring port of the related AN, the measuring port of the AN in the other supply lines being terminated with a 50 Ω load.

For voltage measurements the following apply:

- For EUT remotely grounded (vehicle power return line longer than 200 mm), the voltage measurements shall be made on each lead (supply and return) relative to the reference ground plane (see Figure 11).
- For EUT locally grounded (vehicle power return line 200 mm or shorter), voltage measurements on power supply leads shall be made relative to the reference ground plane (see Figure 12).
- Generators/alternators shall be loaded with a battery and parallel resistor combination, and connected to the artificial network in the manner shown in Figure 13. The load current, operating speed, harness length and other conditions shall be defined in the test plan.
- For the tests of ignition systems refer to Figure 14.

Note For EUT's with multiple positive power supply connections and/or multiple power return connections, the measurements (on power supply and on power return) may be performed with all power supply connections tied together at the AN and all power return connections tied together at the other AN. The details of the AN connection should be defined in the test plan.

Dimensions in millimetres – not to scale



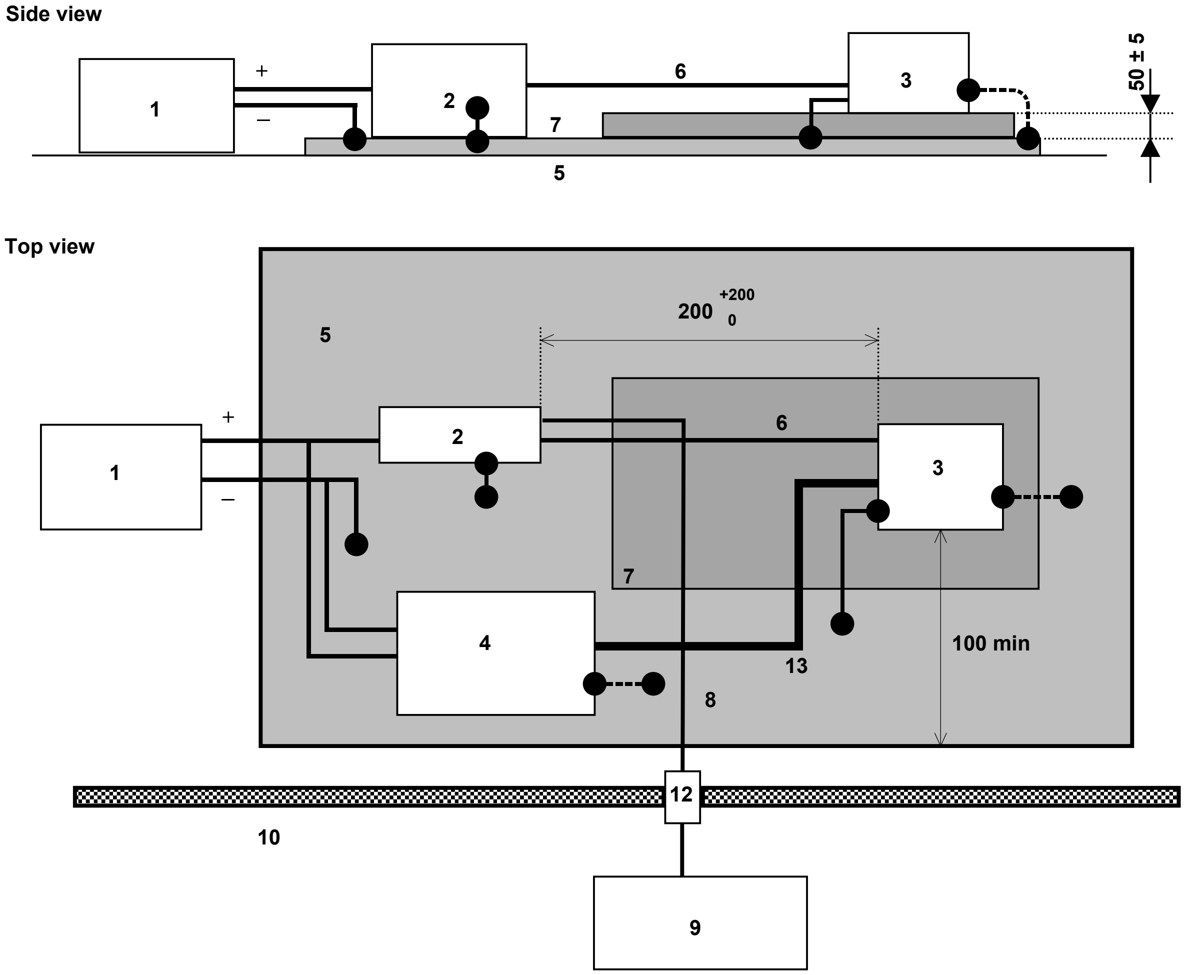
Key

1	Power supply (may be placed on the reference ground plane)
2	Artificial network
3	EUT (housing grounded if required in test plan)
4	Load simulator (metallic casing grounded if required in test plan)
5	Reference ground plane
6	Power supply lines
7	Low relative permittivity support ($\varepsilon_r \leq$ 1,4)
8	High-quality coaxial cable e.g. double-shielded (50 Ω)
9	Measuring instrument
10	Shielded enclosure
11	50 Ω load
12	Bulkhead connector
13	Test harness (excluding power lines)

Note The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 11 – Conducted emissions – Example of test setup for EUT with power return line remotely grounded.

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the reference ground plane)

2 Artificial network

3 EUT (housing grounded if required in test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Power supply line

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

12 Bulkhead connector

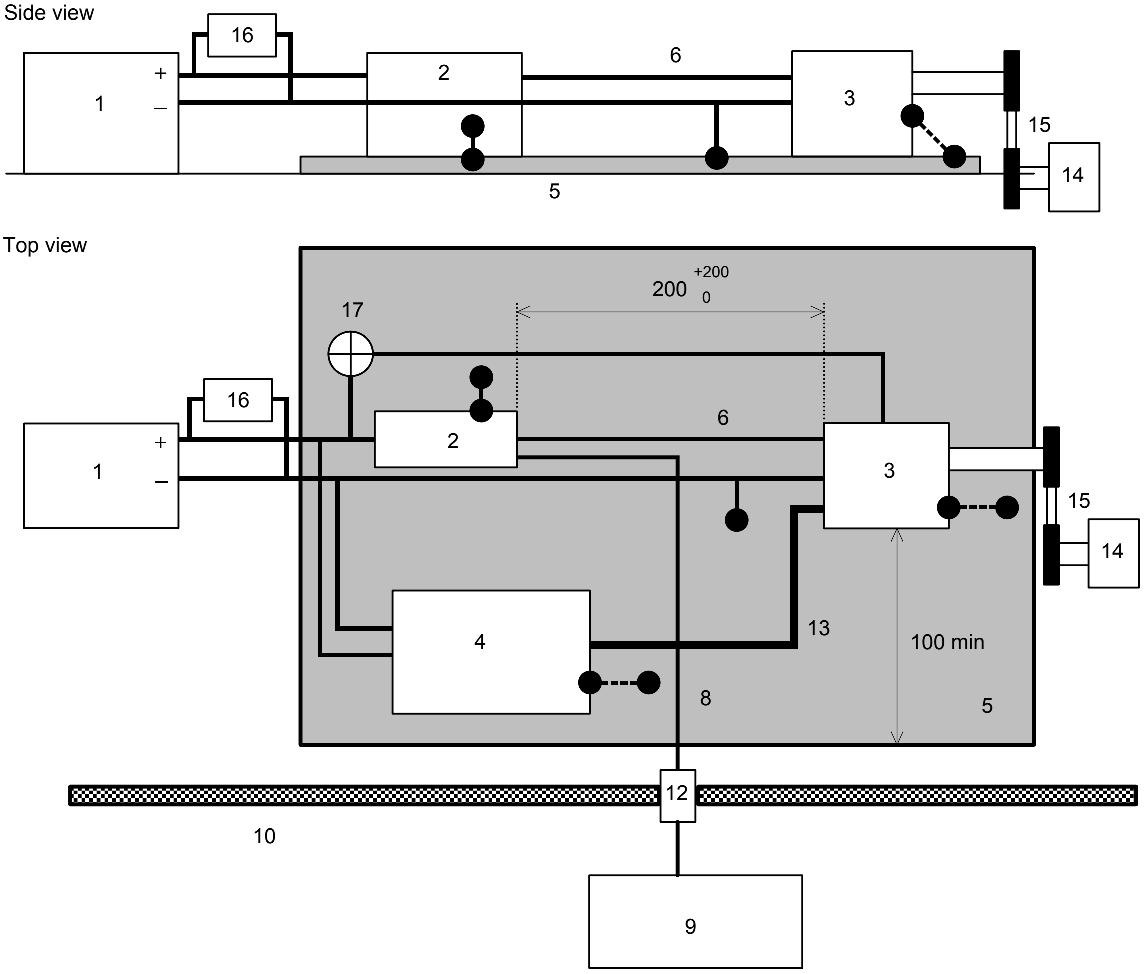
13 Test harness (excluding power lines)

Note The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 12 – Conducted emissions – Example of test setup for EUT with power return line locally grounded

959
960

Dimensions in millimetres – not to scale



961
962

Key

1 Battery (may be placed on the reference ground plane)

2 Artificial network

3 EUT

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Power supply lines

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 50 Ω load

12 Bulkhead connector

13 Test harness (excluding power lines)

14 Motor (Air/Low Emissions)

15 Non-conductive belt/coupler

16 Load resistor

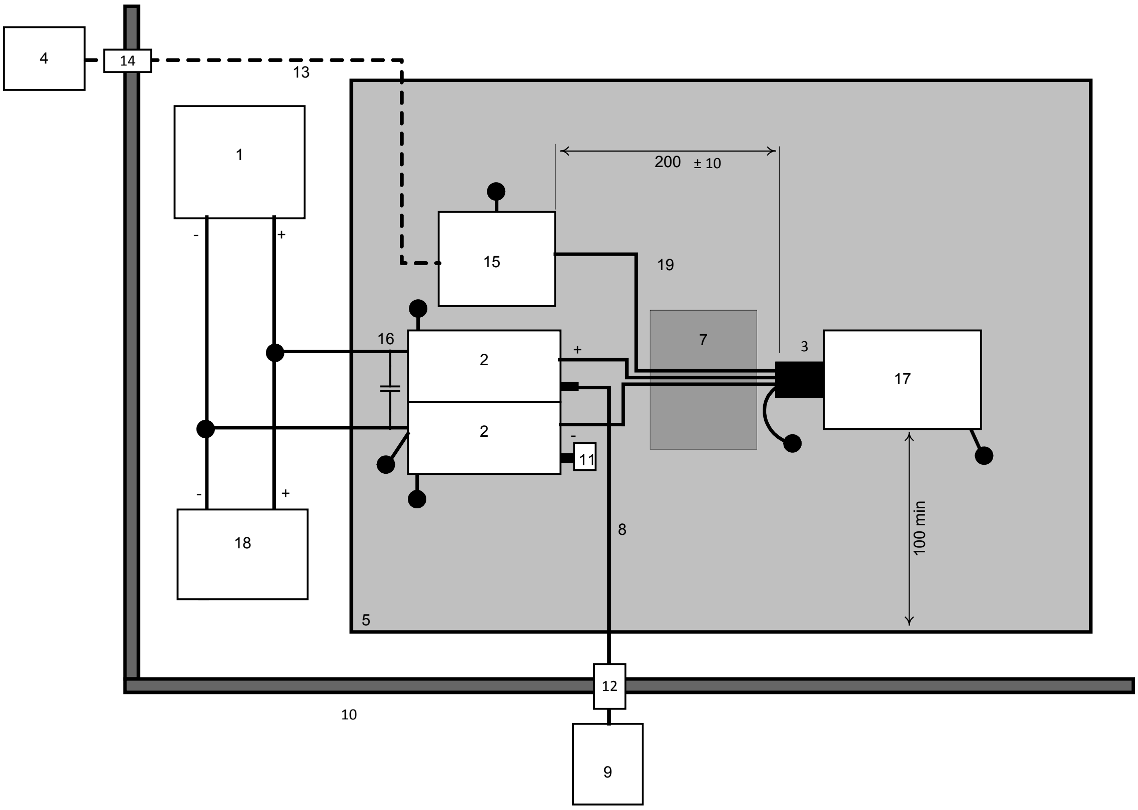
17 Indicator lamp/control resistor (if applicable)

Note The EUT housing ground lead, when required in the test plan, should not be longer than 150 mm.

963

Figure 13 – Conducted emissions – Example of test setup for alternators and generators

Dimensions in millimetres – not to scale



Key

1 Power supply (may be placed on the reference ground plane)

2 Artificial network

3 Pencil coil

4 ECU simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 High-quality coaxial cable e.g. double-shielded (50 Ω)

9 Measuring instrument

10 Shielded enclosure

11 50 Ω load

12 Bulkhead connector

13 Optical fibres

14 Fiber optic feed through

15 Optical fibre converter

16 1 000 µF capacitor

17 Engine simulator

18 Battery

19 Signal line

Note The pencil coil housing ground lead, when required in the test plan, should not be longer than 150 mm.

Figure 14 – Conducted emissions – Example of test setup for ignition system components

6.3.3 Limits for conducted disturbances from components/modules – Voltage method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note 1 The method to be used for characterisation of the Voltage Division Factor of the AN, sometimes referred to as insertion loss, is given in Annex A.8 of CISPR 16-1-2.

Note 2 It is recommended for acceptable radio reception in a vehicle that the conducted noise should not exceed the values shown in Table 5, peak and average or quasi-peak and average, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 5 – Examples of limits for conducted disturbances – Voltage Method

Service / Band	**Frequency** MHz	**Levels in dB(µV)**														
		Class 5			**Class 4**			**Class 3**			**Class 2**			**Class 1**		
		Peak	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**
BROADCAST																
LW	0,15 – 0,30	70	57	50	80	67	60	90	77	70	100	87	80	110	97	90
MW	0,53 – 1,8	54	41	34	62	49	42	70	57	50	78	65	58	86	73	66
SW	5,9 – 6,2	53	40	33	59	46	39	65	52	45	71	58	51	77	64	57
FM	76 – 108	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
TV Band I	41 – 88	34	-	24	40	-	30	46	-	36	52	-	42	58	-	48
TV Band III	174 – 230	Conducted emission – Voltage method Not Applicable														
DAB III	171 – 245															
TV Band IV	468 – 944															
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	44	31	24	50	37	30	56	43	36	62	49	42	68	55	48
VHF	30 – 54	44	31	24	50	37	30	56	43	36	62	49	42	68	55	48
VHF	68 – 87	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
VHF	142 – 175	Conducted emission – Voltage method Not Applicable														
Analogue UHF	380 – 512															
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

6.4 Conducted emissions from components/modules – current probe method

6.4.1 Test setup

6.4.1.1 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the actual vehicle configuration.

The EUT shall be at least 100 mm from the edge of the reference ground plane and at least 500 mm from the chamber wall. The test plan shall simulate the actual vehicle configuration and shall specify: remote versus local grounding, the use of an insulating spacer, and the electrical connection of the EUT case to the reference ground plane.

The measuring equipment shall be as shown in Figure 15.

6.4.1.2 Location of the test harness

The test harness shall be $\left(1700\ ^{+300}_{\ \ 0}\right)$ mm long (or as agreed upon in the test plan), and shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), positioned (50 ± 5) mm above the reference ground plane. The test harness wires shall be nominally parallel and adjacent unless otherwise defined in the test plan.

6.4.2 Test procedure

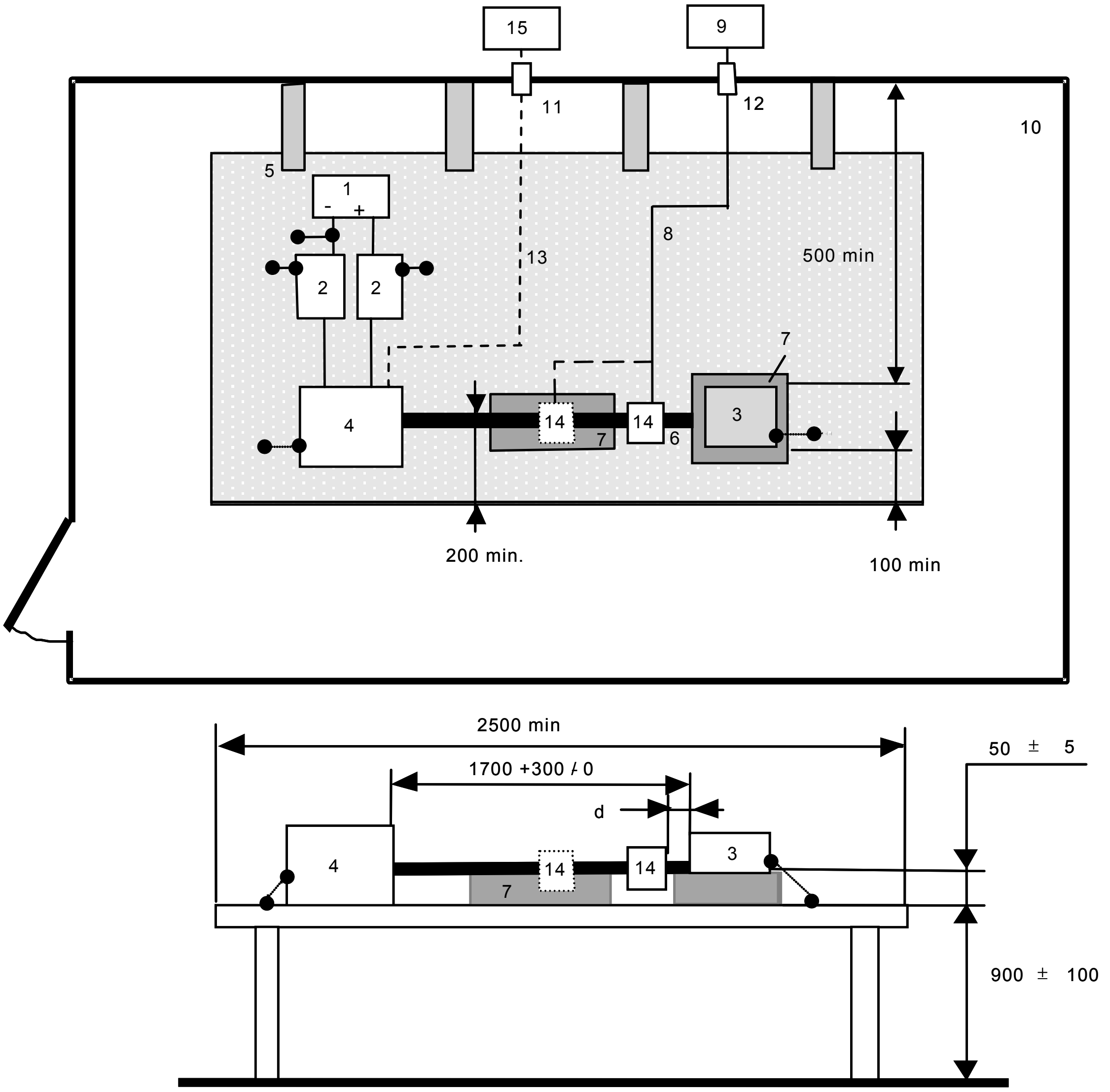
The probe (see CISPR 16-1-2) shall be mounted around the complete harness (including all wires). If the EUT has multiple connectors on the unit resulting in multiple wire bundles, the test plan shall define which wires shall be included in the probe for measurement. In the absence of any definition, measurements shall be made for each bundle (connector) independently and for all wires together.

If the EUT wiring has too many wires to be accommodated in the measurement probe, the test plan may define the wires to be measured and this shall be included in the test report.

Measure the emissions with the probe positioned 50 mm and 750 mm from the EUT.

In most cases, the position of maximum emission will be as close to the EUT connector as possible. Where the EUT is equipped with a metal shell connector, the probe shall be clamped to the cable immediately adjacent to the connector shell, but not around the connector shell itself. The EUT shall be at least 100 mm from the edge of the reference ground plane and at least 500 mm from the chamber wall. The test plan shall simulate the actual vehicle configuration and shall specify remote versus local grounding, the use of an insulating spacer and the electrical connection of the EUT case to the reference ground plane.

Note Some additional measurements may be defined in the test plan with only the positive supply wire in the probe and/or only the negative supply wire in the probe. For these test configurations limits are to be defined in the test plan.



Dimensions in millimetres – not to scale

Key

1 Power supply

2 Artificial network

3 EUT (connected to ground if specified in the test plan)

4 Load simulator (metallic casing grounded if required in test plan)

5 Reference ground plane

6 Wiring harness

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 High-quality coaxial cable e.g. double-shielded ($50\ \Omega$)

9 Measuring instrument

10 Shielded enclosure

11 Fiber optic feed through

12 Bulkhead connector

13 Optical fibers

14 Current probe (represented at 2 positions)

15 Stimulation and monitoring system

d The distance from the EUT to the closest probe position

Figure 15– Conducted emissions – Example of test setup for current probe measurements

6.4.3 Limits for conducted disturbances from components/modules – Current probe method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note It is recommended for acceptable radio reception in a vehicle that the conducted noise should not exceed the values shown in Table 6, peak and average or quasi-peak and average limits, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table 6 – Examples of limits for conducted disturbances - control/signal lines – Current probe method

Service / Band	**Frequency** MHz	**Levels** in **dB**(μA)														
		Class 5			**Class 4**			**Class 3**			**Class 2**			**Class 1**		
		Peak	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**
BROADCAST																
LW	0,15 – 0,30	50	37	30	60	47	40	70	57	50	80	67	60	90	77	70
MW	0,53 – 1,8	26	13	6	34	21	14	42	29	22	50	37	30	58	45	38
SW	5,9 – 6,2	19	6	-1	25	12	5	31	18	11	37	24	17	43	30	23
FM	76 – 108	4	-9	-16	10	-3	-10	16	3	-4	22	9	2	28	15	8
TV Band I	41 – 88	0	-	-10	6	-	-4	12	-	2	18	-	8	24	-	14
DAB III	171 – 245	-2	-	-12	4	-	-6	10	-	0	16	-	6	22	-	12
TV Band III	174 – 230	Conducted emission – control/signal lines Not Applicable														
TV Band IV	468 – 944															
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	10	-3	-10	16	3	-4	22	9	2	28	15	8	34	21	14
VHF	30 – 54	10	-3	-10	16	3	-4	22	9	2	28	15	8	34	21	14
VHF	68 – 87	4	-9	-16	10	1	-10	16	7	-4	22	13	2	28	15	8
VHF	142-175	4	-9	-16	10	1	-10	16	7	-4	22	13	2	28	15	8
Analogue UHF	380 – 512	Conducted emission – control/signal lines Not Applicable														
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

6.5 Radiated emissions from components/modules - ALSE method

6.5.1 General

Measurements of radiated field strength shall be made in an ALSE to eliminate the high levels of extraneous disturbance from electrical equipment and broadcasting stations.

Note 1 Conducted emissions will contribute to the radiated emissions measurements because of radiation from the wiring in the test setup. Therefore, it is advisable to establish conformance with the conducted emissions requirements before performing the radiated emissions test.

Note 2 Disturbance to the vehicle on-board receiver can be caused by direct radiation from one or more leads in the vehicle wiring harness. This coupling mode to the vehicle receiver affects both the type of testing and the means of reducing the disturbance at the source.

Note 3 Vehicle components which are not effectively grounded to the vehicle by short ground leads, or which have several harness leads carrying the disturbance voltage, will have radiated emissions that do not correlate well with its conducted emissions. This has been shown to give better correlation with the complete vehicle test for components installed in this way.

Examples of component installations for which this test is applicable include, but are not limited to:

- electronic control systems containing microprocessors;
- two speed wiper motors with negative supply switching;
- suspension control systems with strut-mounted actuator motors;
- engine cooling and heater blower motors mounted in plastic or other insulated housings.

6.5.2 Test setup

For radiated emissions measurements, the arrangement of the EUT, test harness, load simulator and measuring equipment shall be equivalent to the examples shown in Figures 17 to 20.

6.5.2.1 Antenna systems

Measurements shall be made using linearly polarised electric field antennas that have a nominal 50 Ω output impedance.

Note 1 To improve consistency of results between laboratories, the following antennas are recommended:

a) 0,15 MHz to 30 MHz	1 m vertical monopole (where this is not 50 Ω, a suitable antenna matching unit shall be used);
b) 30 MHz to 300 MHz	a biconical antenna;
c) 200 MHz to 1 000 MHz	a log-periodic antenna;
d) 1 000 MHz to 2 500 MHz	a horn or log periodic antenna.

The method to be used for characterization of the vertical monopole (rod) antenna is given in CISPR 16-1-4.

Note 2 Use the 1 m method in SAE ARP 958.1 Rev D February 2003 for determining biconical, log periodic and horn antenna factors.

Note 3 Biconical antennas usually have a SWR of up to 10:1 in the frequency range of 30 MHz to 80 MHz. Therefore an additional measurement error may occur when the receiver input impedance differs from 50 Ω. The use of an attenuator (3 dB minimum) at the receiver's input or the input of an additional preamplifier (if possible) will keep this additional error low.

6.5.2.2 Antenna matching unit for monopole antenna

Correct impedance matching between the antenna and the measuring instrument of 50 Ω shall be maintained in the frequency ranges selected for the test. There shall be a maximum SWR of 2:1 at the output port of the matching unit. Appropriate correction shall be made for any attenuation/gain of the antenna system from the antenna to the receiver.

Note Care should be taken to ensure that input voltages do not exceed the pulse input rating of the unit or overloading may occur. This is particularly important when active matching units are used.

6.5.2.3 Location of the EUT

The EUT shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the actual vehicle configuration.

The side of the EUT, which is nearest to the front edge of the reference ground plane, shall be located at a distance of (200 ± 10) mm from the front edge of the reference ground plane.

6.5.2.4 Test harness and location

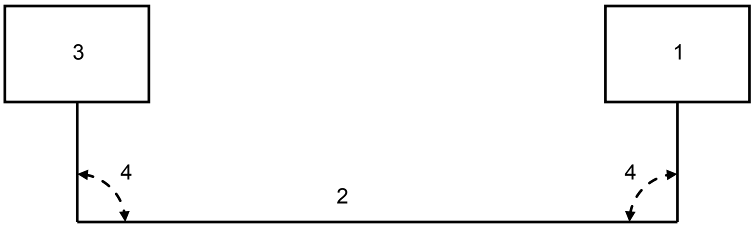
The total length of the test harness between the EUT and the load simulator (or the RF boundary) shall not exceed 2 000 mm (or as defined in the test plan). The wiring type is defined by the actual system application and requirement.

Care shall be taken with the power lines that these are also not exceeding 2 000 mm. Where the power is taken separately from the load box, the AN shall be located such that the power lines can be maintained at less than 2 000 mm. If the power is derived from the load box, the line between the load box and the AN shall be kept as short as is practically possible to avoid excessive length being added to the power lines.

The test harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), at (50 ± 5) mm above the reference ground plane.

The length of test harness parallel to the front of the reference ground plane shall be (1 500 ± 75) mm.

The long segment of test harness shall be located parallel to the edge of the ground plane facing the antenna at a distance of (100 ± 10) mm from the edge. Location of the EUT and load simulator requires that the harness bend angle shall be $\left(90\ {}^{+45}_{\ 0}\right)$ degrees as shown in Figure 16.



Key

1 EUT

2 Test harness

3 Load simulator

4 Angle $\left(90\ ^{+45}_{\ \ 0}\right)$ degrees

Figure 16 – Test harness bending requirements

6.5.2.5 Location of the load simulator

Preferably, the load simulator shall be placed directly on the reference ground plane. If the load simulator has a metallic case, this case shall be bonded to the reference ground plane.

Alternatively, the load simulator may be located adjacent to the reference ground plane (with the case of the load simulator bonded to the reference ground plane) or outside of the test chamber, provided that the test harness from the EUT passes through an RF boundary bonded to the reference ground plane. The layout of the test harness that is connected to the load simulator shall be defined in the test plan and recorded in the test report.

When the load simulator is located on the reference ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s).

6.5.2.6 Location of the measuring antenna

The phase centre of the measuring antenna shall be (100 ± 10) mm above the reference ground plane for the biconical, log-periodic and horn antenna.

The height of the counterpoise of the rod antenna shall be (+10 / -20) mm relative to the reference ground plane and shall be bonded to the reference ground plane.

For radiated emissions tests, the shielded enclosure shall be of sufficient size to ensure that neither the EUT nor the test antenna shall be closer than 1 m from the walls or ceiling, or to the nearest surface of the absorber material used thereon. No part of any antenna radiating element shall be closer than 250 mm to the floor.

The distance between the longitudinal part (1 500 mm length) of the wiring harness and the reference point of the antenna shall be (1 000 ± 10) mm. For a biconical or other antenna (e.g. biconilog) no part of the antenna shall be closer to the wiring harness or EUT than 700 mm.

The reference point of the antenna is defined as:

– the vertical monopole element for rod antennas,
– the phase centre (mid-point) for biconical antennas,
– the tip for antennas with log-periodic elements (including biconilog antennas),
– the front aperture for horn antennas.

Each antenna (excluding the rod antenna) shall be calibrated for this reference point for a 1 000 mm measuring distance (see 6.5.2.1).

Note 1 The rod antenna is excluded because calibration is achieved by using the method defined in CISPR 16-1-4.

The phase centre of the antenna shall be in line with the centre of the longitudinal part of the wiring harness for frequencies up to 1 000 MHz.

The phase center of the antenna for frequencies above 1 000 MHz shall be in line with the EUT.

Note 2 The users of this standard should be aware that antenna manufacturers may give:

- independent antenna factors for horizontal and vertical polarisations: in this case the appropriate antenna factor should be used for measurement in each polarisation.

- A single antenna factor: in this case this antenna factor should be used for measurements in both polarisations.

6.5.3 Test procedure

The general arrangement of the disturbance source and connecting harnesses, etc. represents a standardised test condition. Any deviations from the standard test harness length, etc. shall be agreed upon prior to testing and recorded in the test report.

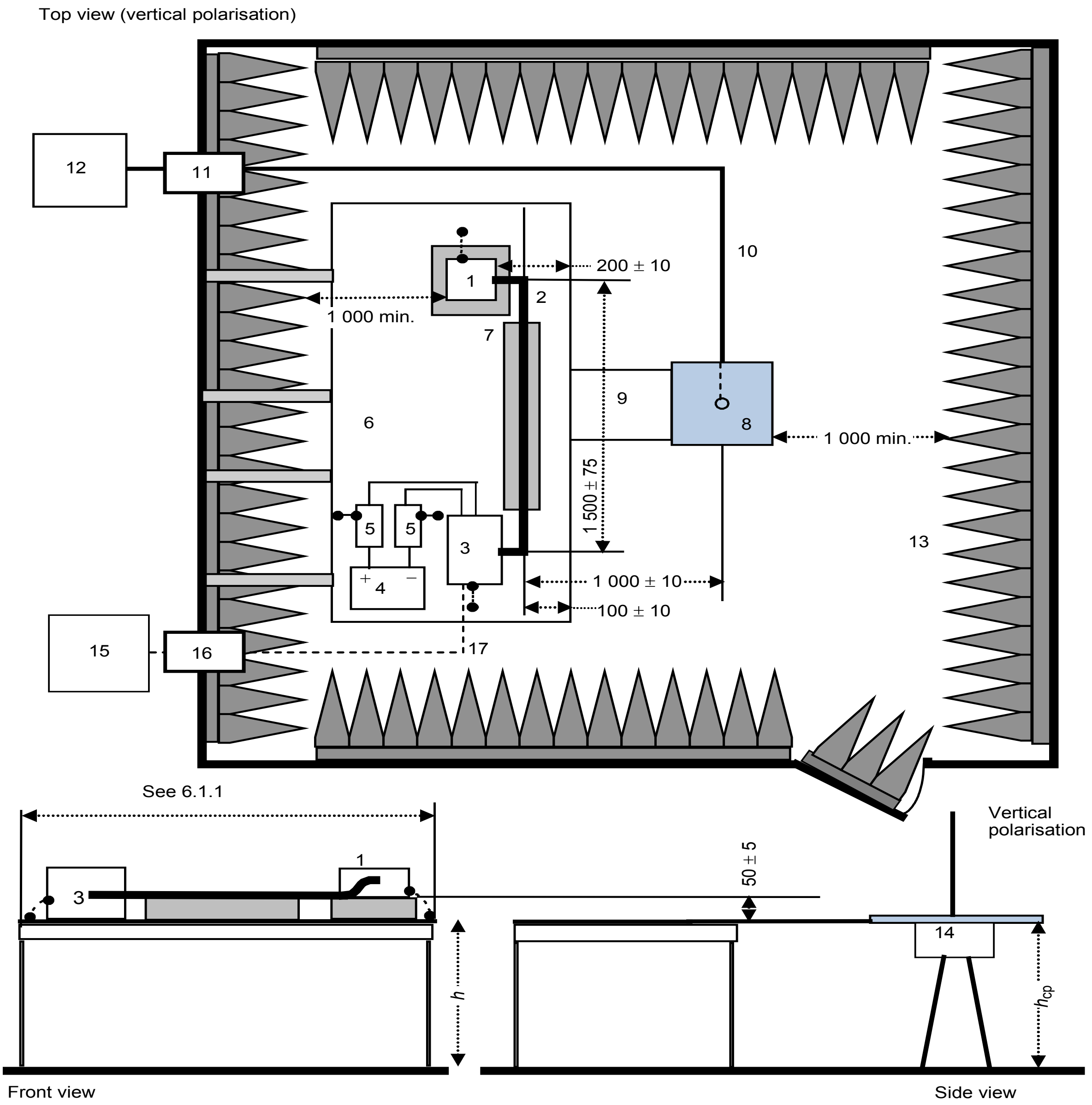
The EUT shall be made to operate under typical loading and other conditions as in the vehicle such that the maximum emission state occurs. These operating conditions must be clearly defined in the test plan to ensure supplier and customer can perform identical tests. The orientation(s) of the EUT for radiated emission measurements shall be defined in the test plan.

From 150 kHz to 30 MHz measurements shall be performed in vertical polarisation only.

From 30 MHz to 2 500 MHz measurements shall be performed in vertical and horizontal polarisations.

For radiated emission measurements, the arrangement of the EUT and measuring equipment shall be functionally equivalent to the examples shown in Figures 17 to 20.

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

8 Rod Antenna with counterpoise

(dimensions: 600 mm by 600 mm typical)

9 Grounding connection (full width bond between counterpoise and reference ground plane)

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

14 Antenna matching unit (the preferred location is below the counterpoise; if above the counterpoise then the base of the antenna rod shall be at the height of the reference ground plane)

15 Stimulation and monitoring system

h = (900 ± 100) mm

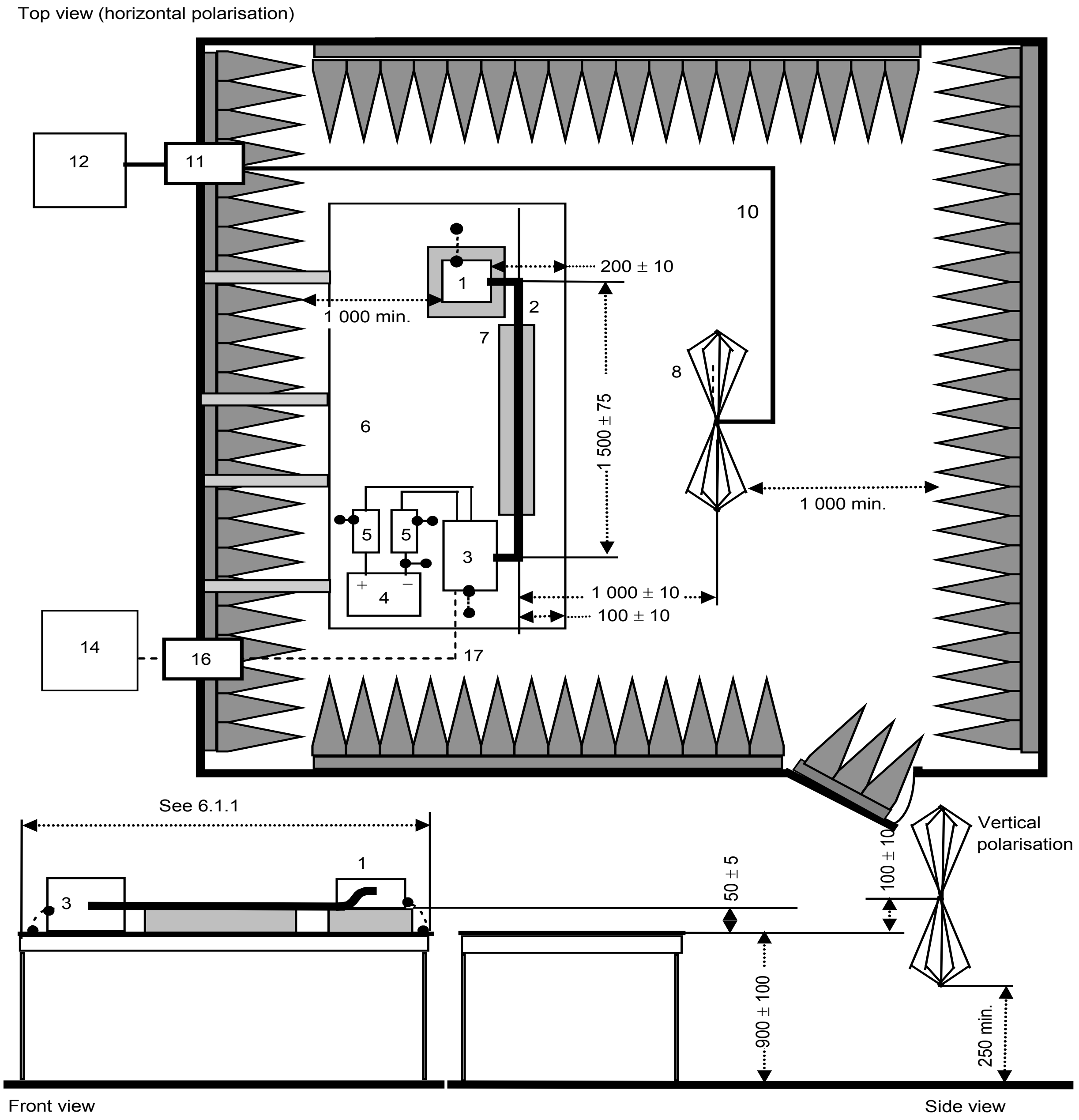
h_{cp} = $h + (+10 / -20)$ mm

16 Fiber optic feed through

17 Optical fibers

Figure 17 – Example of test setup – rod antenna

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded enclosure)

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Biconical antenna (no part of the antenna closer than 700 mm to the wiring harness or EUT)

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

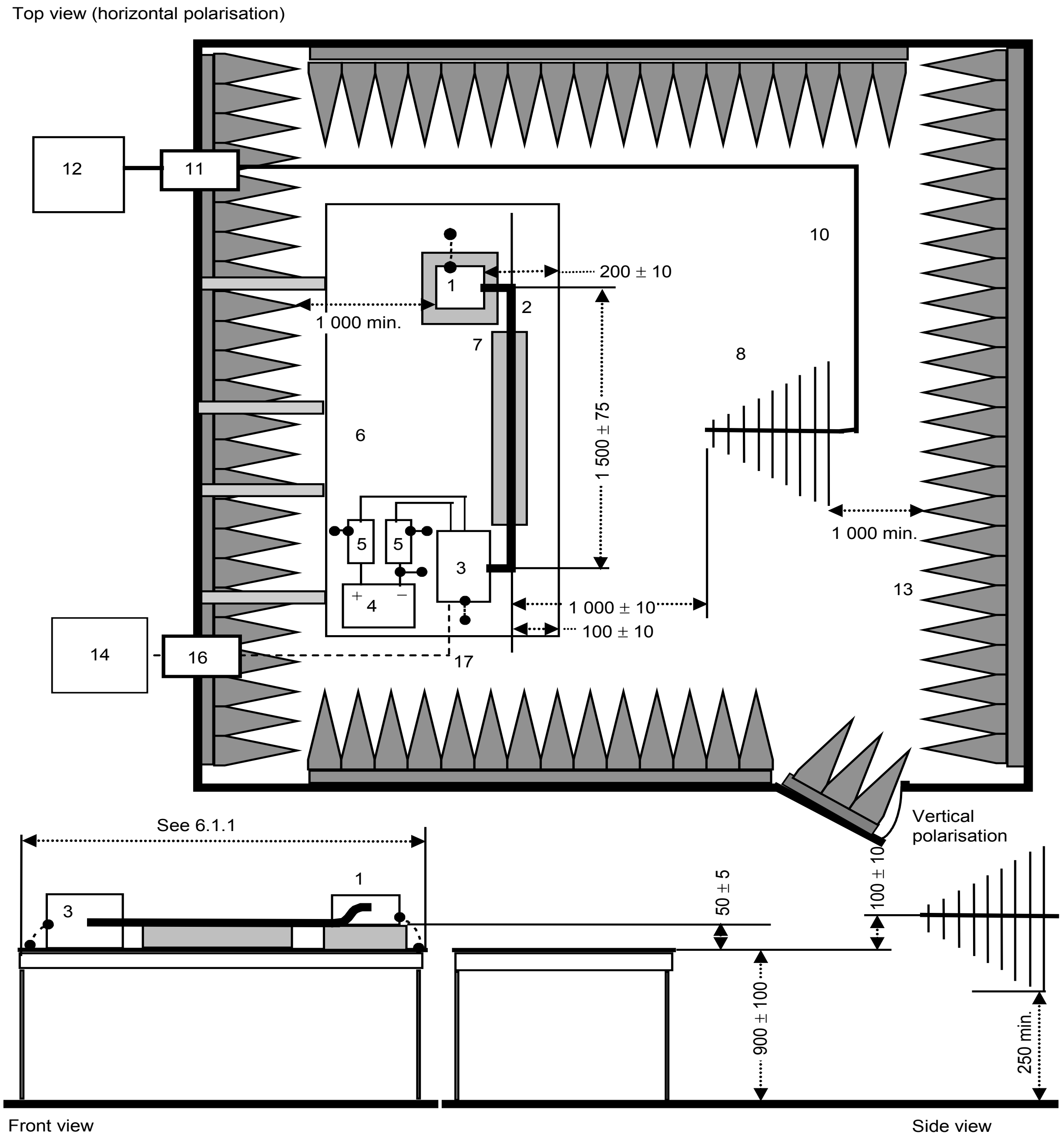
14 Stimulation and monitoring system

16 Fiber optic feed through

17 Optical fibers

Figure 18 – Example of test setup – biconical antenna

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)

2 Test harness

3 Load simulator (placement and ground connection according to 6.5.2.5)

4 Power supply (location optional)

5 Artificial network (AN)

6 Reference ground plane (bonded to shielded

8 Log-periodic antenna

10 High-quality coaxial cable e.g. double-shielded (50 Ω)

11 Bulkhead connector

12 Measuring instrument

13 RF absorber material

enclosure)

7 Low relative permittivity support (ε_r ≤ 1,4)

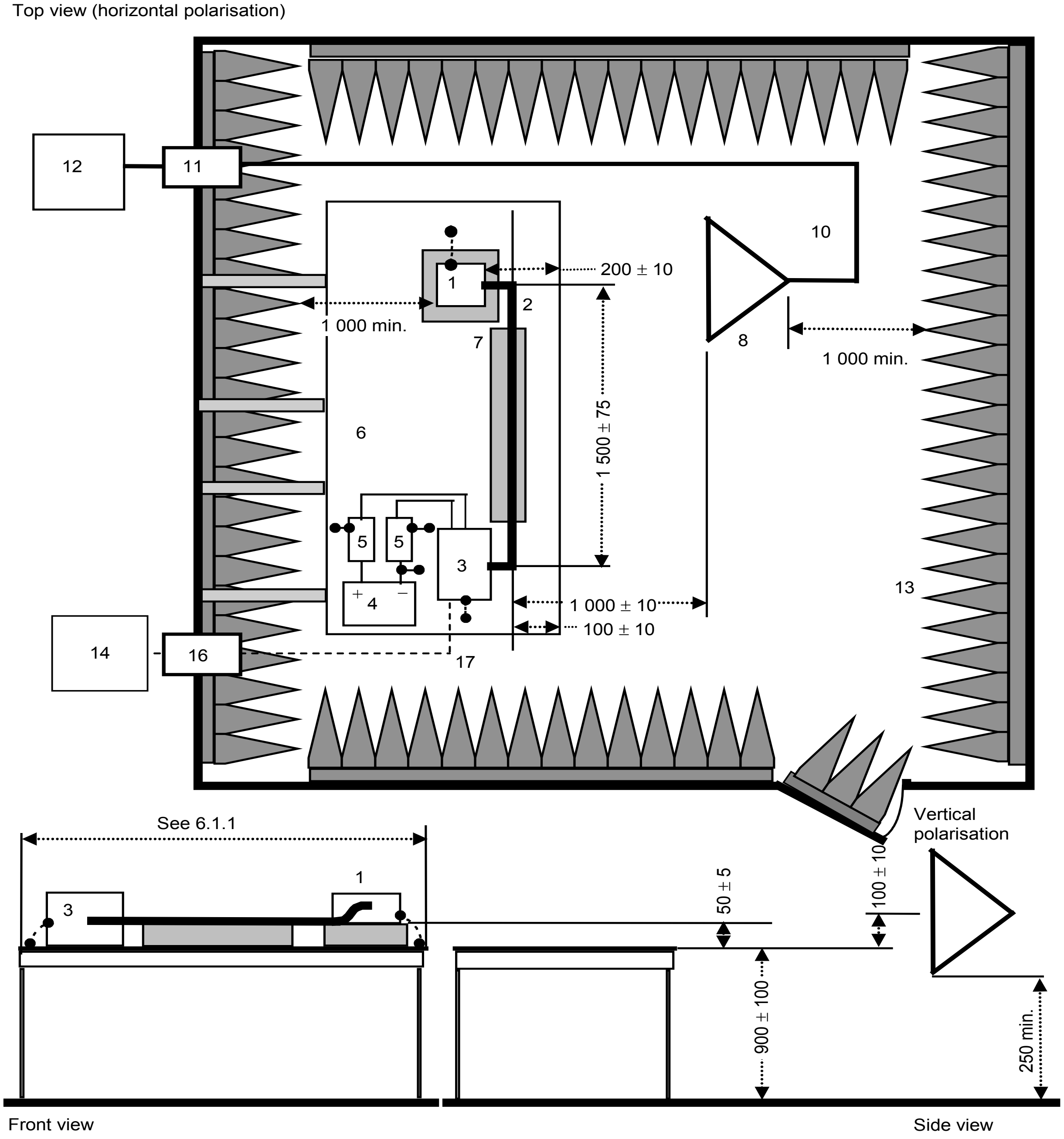
14 Stimulation and monitoring system

16 Fiber optic feed through

17 Optical fibers

Figure 19 – Example of test setup – log-periodic antenna

Dimensions in millimetres – not to scale



Key

1 EUT (grounded locally if required in test plan)
2 Test harness
3 Load simulator (placement and ground connection according to 6.5.2.5)
4 Power supply (location optional)
5 Artificial network (AN)
6 Reference ground plane (bonded to shielded enclosure)
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)
8 Horn antenna
10 High-quality coaxial cable e.g. double-shielded (50 Ω)
11 Bulkhead connector
12 Measuring instrument
13 RF absorber material
14 Stimulation and monitoring system
16 Fiber optic feed through
17 Optical fibers

Figure 20 – Example of test setup – above 1 GHz

6.5.4 Limits for radiated disturbances from components/modules – ALSE method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note It is recommended for acceptable radio reception in a vehicle that the radiated noise should not exceed the values shown in Table 7, peak and average or quasi-peak and average limits, respectively. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined. For the GPS band a specific limit characteristic is recommended. This is shown in Figure 21.

Table 7 – Examples of Limits for radiated disturbances – ALSE method

Service / Band	**Frequency** MHz	**Levels** in **dB**(µV/m)														
		Class 5			**Class 4**			**Class 3**			**Class 2**			**Class 1**		
		Peak	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**
BROADCAST																
LW	0,15 – 0,30	46	33	26	56	43	36	66	53	46	76	63	56	86	73	66
MW	0,53 – 1,8	40	27	20	48	35	28	56	43	36	64	51	44	72	59	52
SW	5,9 – 6,2	40	27	20	46	33	26	52	39	32	58	45	38	64	51	44
FM	76 – 108	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
TV Band I	41 – 88	28	-	18	34	-	24	40	-	30	46	-	36	52	-	42
TV Band III	174 – 230	32	-	22	38	-	28	44	-	34	50	-	40	56	-	46
DAB III	171 – 245	26	-	16	32	-	22	38	-	28	44	-	34	50	-	40
TV Band IV	468 – 944	41	-	31	47	-	37	53	-	43	59	-	49	65	-	55
DTTV	470 – 770	45	-	35	51	-	41	57	-	47	63	-	53	69	-	59
DAB L Band	1447 – 1494	28	-	18	34	-	24	40	-	30	46	-	36	52	-	42
SDARS	2320 – 2345	34	-	24	40	-	30	46	-	36	52	-	42	58	-	48
MOBILE SERVICES																
CB	26 – 28	40	27	20	46	33	26	52	39	32	58	45	38	64	51	44
VHF	30 – 54	40	27	20	46	33	26	52	39	32	58	45	38	64	51	44
VHF	68 – 87	35	22	15	41	28	21	47	34	27	53	40	33	59	46	39
VHF	142 – 175	35	22	15	41	28	21	47	34	27	53	40	33	59	46	39
Analogue UHF	380 – 512	38	25	18	44	31	24	50	37	30	56	43	36	62	49	42
RKE	300 – 330	32	-	18	38	-	24	44	-	30	50	-	36	56	-	42
RKE	420 – 450	32	-	18	38	-	24	44	-	30	50	-	36	56	-	42
Analogue UHF	820 – 960	44	31	24	50	37	30	56	43	36	62	49	42	68	55	48
GSM 800	860 – 895	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
EGSM/GSM 900	925 – 960	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
GPS L1 civil	1567 – 1583	-	-	10	-	-	16	-	-	22	-	-	28	-	-	34
GLONASS L1	1 591 – 1 613	-	-	10	-	-	16	-	-	22	-	-	28	-	-	34
GSM 1800 (PCN)	1803 – 1882	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
GSM 1900	1850 – 1990	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
3G / IMT 2000	1900 – 1992	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
3G / IMT 2000	2010 – 2025	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
3G / IMT 2000	2180 – 2172	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48
Bluetooth/802.11	2400 – 2500	44	-	24	50	-	30	56	-	36	62	-	42	68	-	48

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 The values given in the table apply for the 1 574,42 MHz to 1 576,42 MHz frequency range. The limits for the whole GPS L1 frequency range are given in Figure 21a.

Note 4 The values given in the table apply for the 1 598,065 MHz to 1 606,5 MHz frequency range. The limits for the whole GLONASS L1 frequency range are given in Figure 21b.

Note 5 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

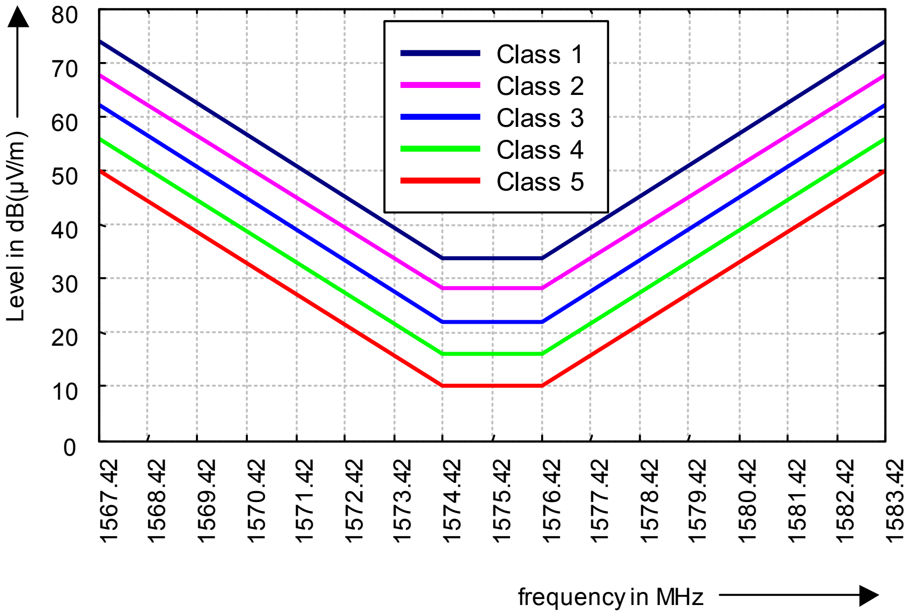


Figure 21a – Example of average limit for radiated disturbances from components GPS band 1 567,42 to 1 583,42 MHz

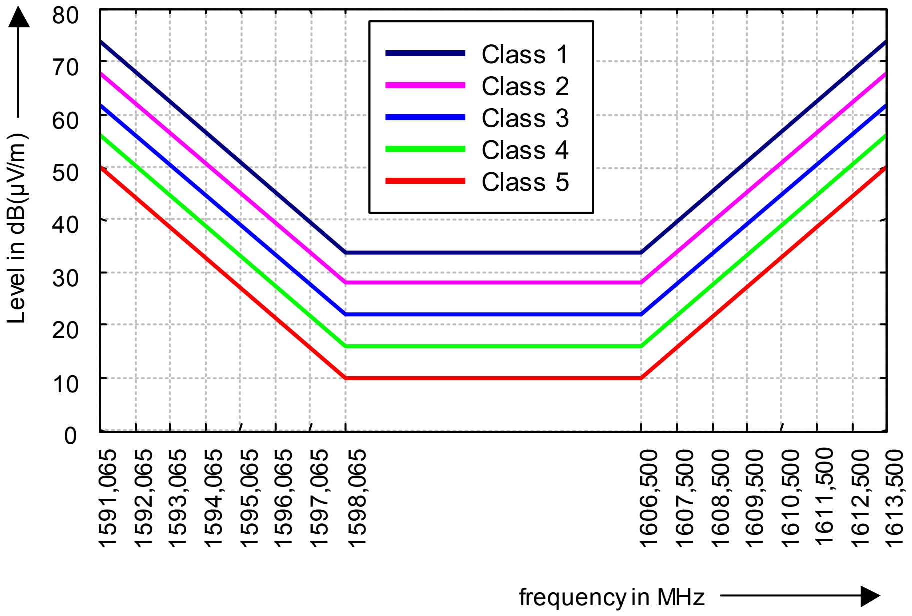


Figure 21b – Example of average limit for radiated disturbances from components GLONASS band 1 591,065 MHz to 1 613,5 MHz

6.6 Radiated emissions from components/modules – TEM cell method

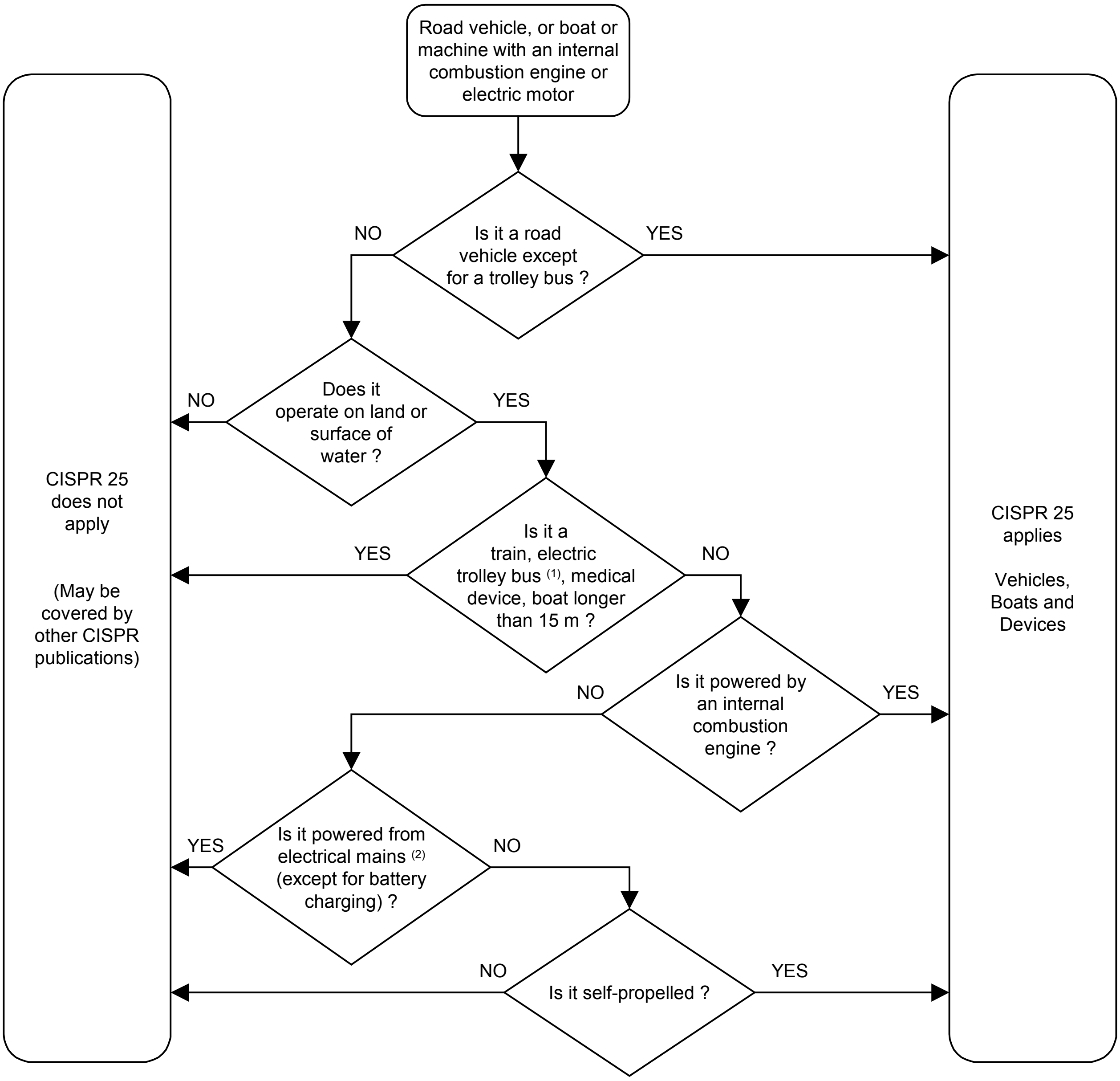
Refer to Annex F

6.7 Radiated emissions from components/modules – Stripline method

Refer to Annex G

Annex A
(informative)

Flow chart for checking the applicability of CISPR 25



(1) In the case of a dual-mode trolley bus (e.g. propelled by power from either a.c./d.c. mains or an internal combustion engine), the a.c./d.c. mains portion of the vehicle propulsion system shall be excluded from this standard.

(2) Connection to the electrical mains is the work of another CISPR subcommittee

This chart is intended to assist with determining whether a particular product is covered by this publication. In case of conflict between this chart and Clause 1, Scope, Clause 1 shall take precedence.

Annex B

(normative)

Antenna matching unit – Vehicle test

B.1 Antenna matching unit parameters (150 kHz to 6,2 MHz)

The requirements for the measurement equipment are defined in 5.1.2.1.

B.2 Antenna matching unit – verification

The 10 pF and 60 pF values for the artificial antenna network of Figure B.1 are used to represent a conventional antenna, e.g., 1 m rod, 2 m coax. The 60 pF capacitor represents the capacitance of the coaxial cable between the vehicle antenna and the input of the vehicle radio.

Note Actual values with on-glass antennas and diversity systems may vary greatly.

B.2.1 Gain measurement

The antenna matching unit and artificial antenna adapter (AAA) shall be measured to determine whether its gain meets the requirements of 5.1.2.1 using the test arrangement shown in Figure B.1.

B.2.2 Test procedure

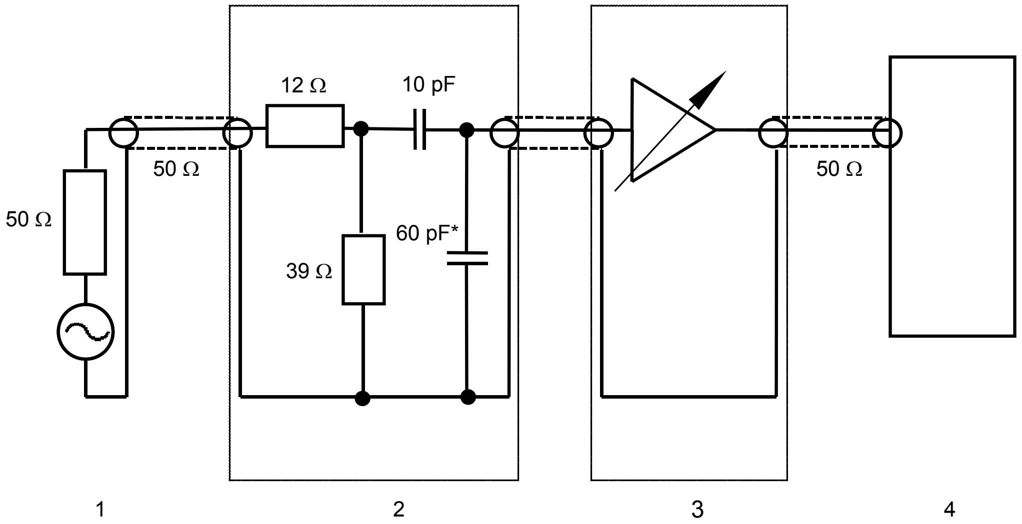
1) Set the signal generator 40 dB(μV) output level.
2) Plot the gain curve for each frequency segment.

Note For more precise calibration, the actual values of the components used in the AAA and the input parameters of the matching network may be measured. The actual attenuation for the specific measuring equipment can be calculated and used to obtain the matching network gain with greater precision.

The gain of the antenna matching unit shall be evaluated. This can be obtained either by calculation (with the actual values of the components used in the AAA the input parameters of the antenna matching unit) or by complimentary measurement (using two identical AAA head to tail).

B.3 Impedance measurement

Measurement of the output impedance of the antenna matching unit with the antenna attached shall be made with a vector impedance meter (or equivalent test equipment). The output impedance shall lie within a circle on a Smith chart crossing (100 + j0) Ω, having its centre at (50 + j0) Ω (e.g. SWR less than 2:1).



Key

1 Signal generator
2 Artificial antenna adapter
3 Antenna matching unit
4 Measuring instrument

* Includes connector capacitance and, if used, cable capacitance

Figure B.1 –Verification setup

Annex C
(informative)

Sheath-current suppressor

C.1 General Information

This Annex provides information on the proposed performance and verification of a sheath-current suppressor recommended for use when measuring vehicle antenna terminal voltage in the AM broadcast bands (LW, MW, SW). This suppressor electrically-isolates the ALSE from the vehicle ground.

C.2 Suppressor Construction

The performance curve below (Figure C.1) shows the attenuation of the sheath currents using 20 turns of a coaxial cable around a ferrite toroidal core:

Material:	N30; Al = 5 400 nH
Size:	Toroidal core 58,3 x 40,8 x 17,6 mm
Manufacturer:	TDK EPCOS Order No.: B64290L0040X830
Number of turns:	20 (coaxial cable)

Note To increase the attenuation, two sheath-current suppressors may be placed in series or more turns may be added to the single core.

Figure C.1 – Characteristic S_{21} of the ferrite core

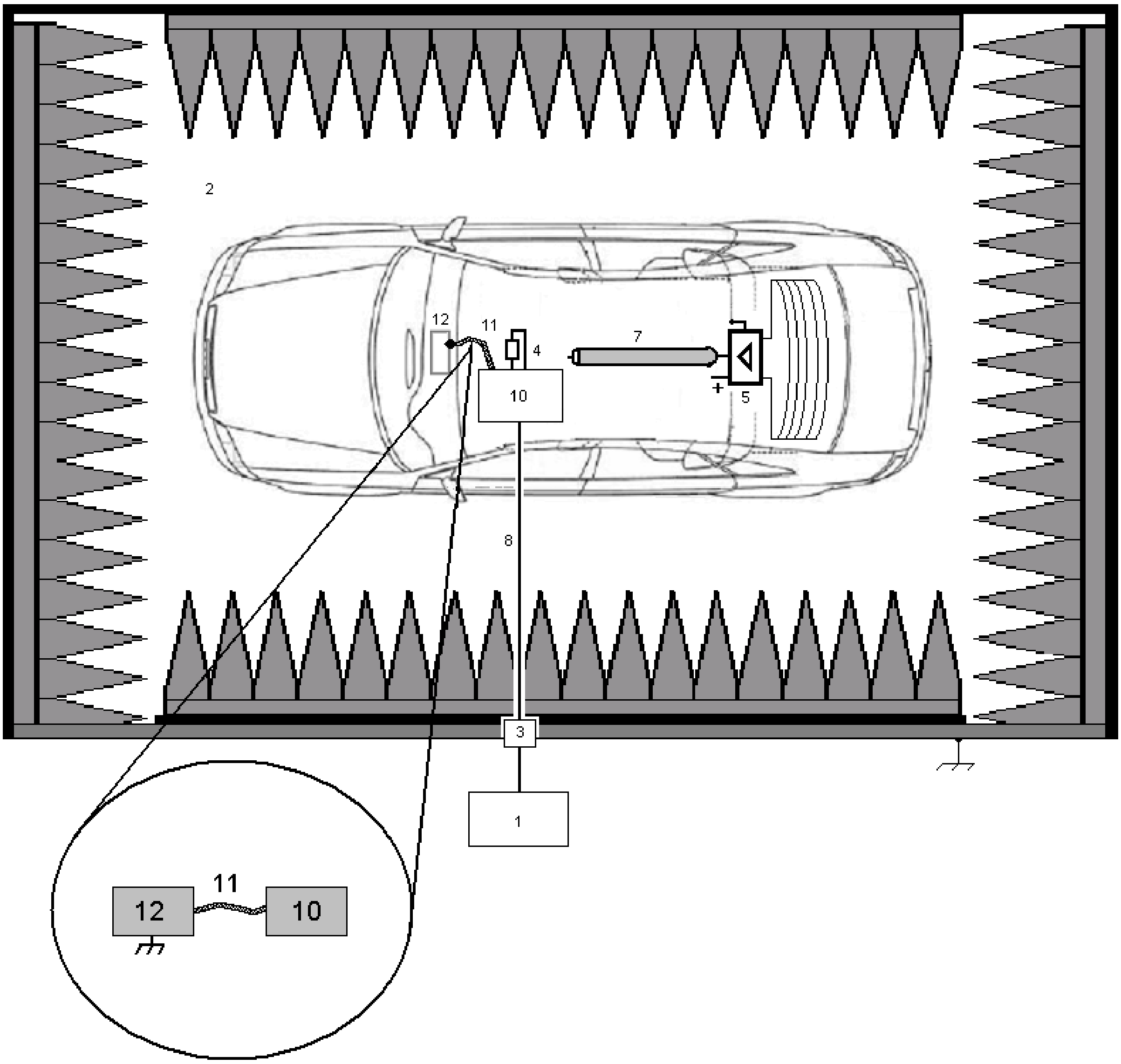
Annex D
(informative)

Guidance for the determination of the noise floor of active vehicle antennas in the AM and FM Range

Three steps are necessary to determine the noise floor of an active antenna installed in the vehicle:

1) Measurement of the noise floor of the test equipment (measuring receiver plus impedance converter) with coaxial cable impedance termination at the Impedance converter RF-Input in the AM- and FM-Range. ($U_{\text{Equipment noise}}$) (Test setup see Figure D.1).
2) Measurement of the noise floor of the active vehicle antenna including the noise floor of the test equipment. ($U_{\text{Equipment noise plus antenna noise}}$)(Test setup see Figure D.2).
3) Calculation of the active antenna noise floor with formula (D.1) (all terms in µV):

$$U_{\mathit{Antenna\ noise}} = \sqrt{U^2_{\mathit{Equipment\ noise\ plus\ antenna\ noise}} - U^2_{\mathit{Equipment\ noise}}} \qquad \text{(D.1)}$$



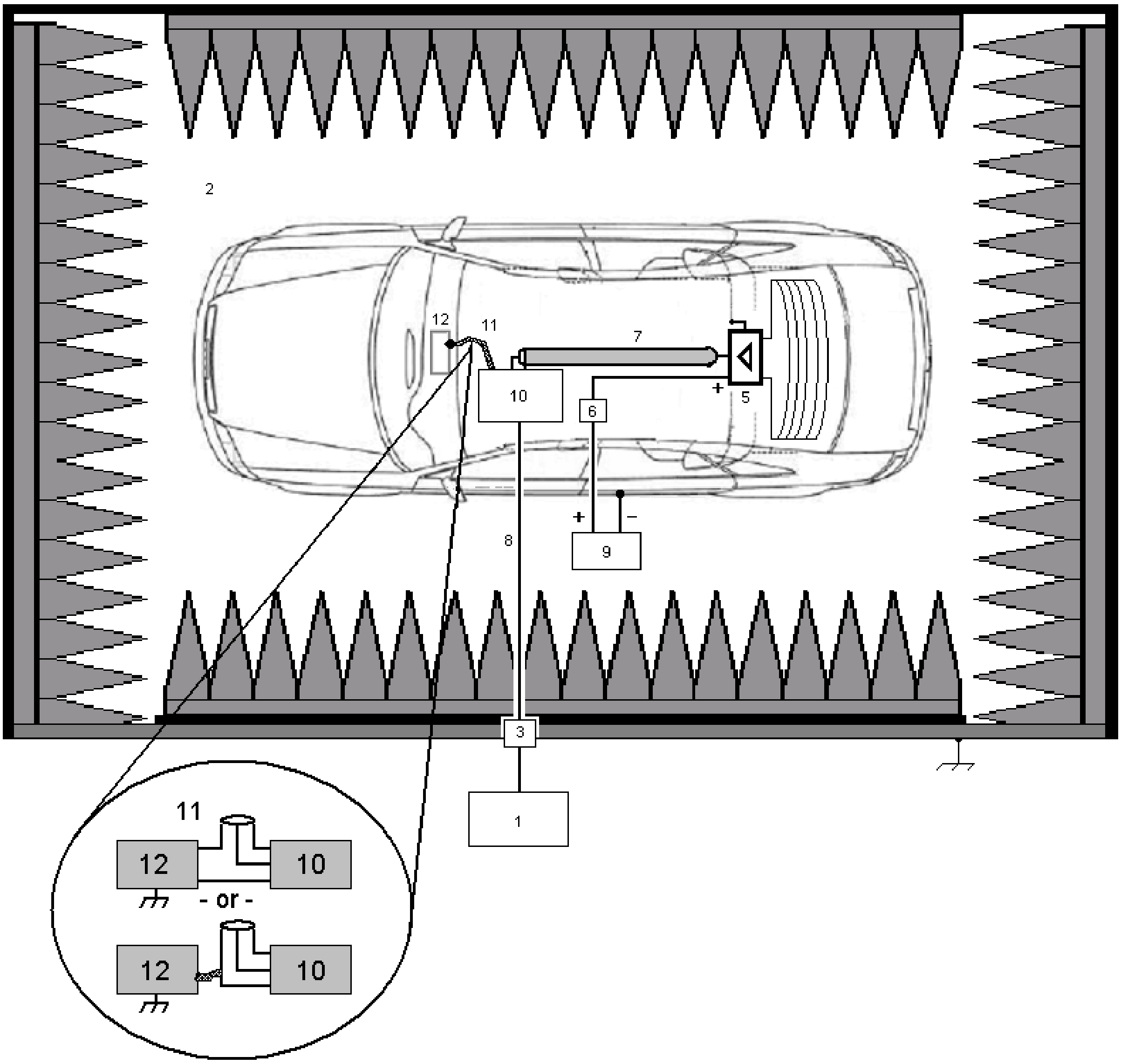
Key

1 Measuring instrument
2 ALSE
3 Bulkhead connector
4 Resistor according to coaxial cable impedance
5 Vehicle antenna amplifier
-
7 Antenna coaxial cable
8 High-quality double-shielded coaxial cable (50 Ω)
-
10 Impedance matching unit
11 Short connection to the housing of the on-board radio

1337 12 Housing of on-board radio

1338 **Figure D.1 – Vehicle test setup for equipment noise measurement in the AM/FM range**

1339



Key

1	Measuring instrument
2	ALSE
3	Bulkhead connector
	-
5	Vehicle antenna amplifier
6	Antenna amplifier power plug
7	Antenna coaxial cable
8	High-quality coaxial cable e.g. double-shielded (50 Ω)
9	External 12V battery
10	Impedance matching unit
11	Modified coaxial "T" connector or short connection to the housing of the on-board radio

12 Housing of on-board radio

Figure D.2 - Vehicle test setup for antenna noise measurement in the AM/FM range

Annex E
(normative)

Artificial Networks (AN), Artificial Mains Networks (AMN) and Asymmetric Artificial Networks (AAN)

E.1 General

Currently different types of power supplies and power supply cabling are used for a component powered by low voltage (LV) and/or high voltage (HV) and/or connected to the power grid (a.c. power mains, d.c. power supply). Therefore, it is necessary to use networks which provide specific load impedance and isolate the component from the power supply:

- Artificial networks (AN) : used for d.c. power supplies;
- Artificial Mains Networks (AMN) : used only for a.c. power mains;
- Asymmetric artificial network (AAN): used only for communication/signal lines.

E.2 Artificial networks (AN)

E.2.1 Component powered by LV

For a component powered by LV, a 5µH/50Ω-AN as defined in Figure E.1 shall be used.

The AN(s) shall be mounted directly on the ground plane. The grounding connection of the AN(s) shall be bonded to the ground plane.

Measurement ports of AN(s) shall be terminated with a 50 Ω load.

The AN impedance Z_{PB} (tolerance ± 20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is specified in Table E.1 and shown in Figure E.2. It is measured between the terminals P and B (of Figure E.1) with a 50 Ω load on the measurement port with terminals A and B (of Figure E.1) short circuited.

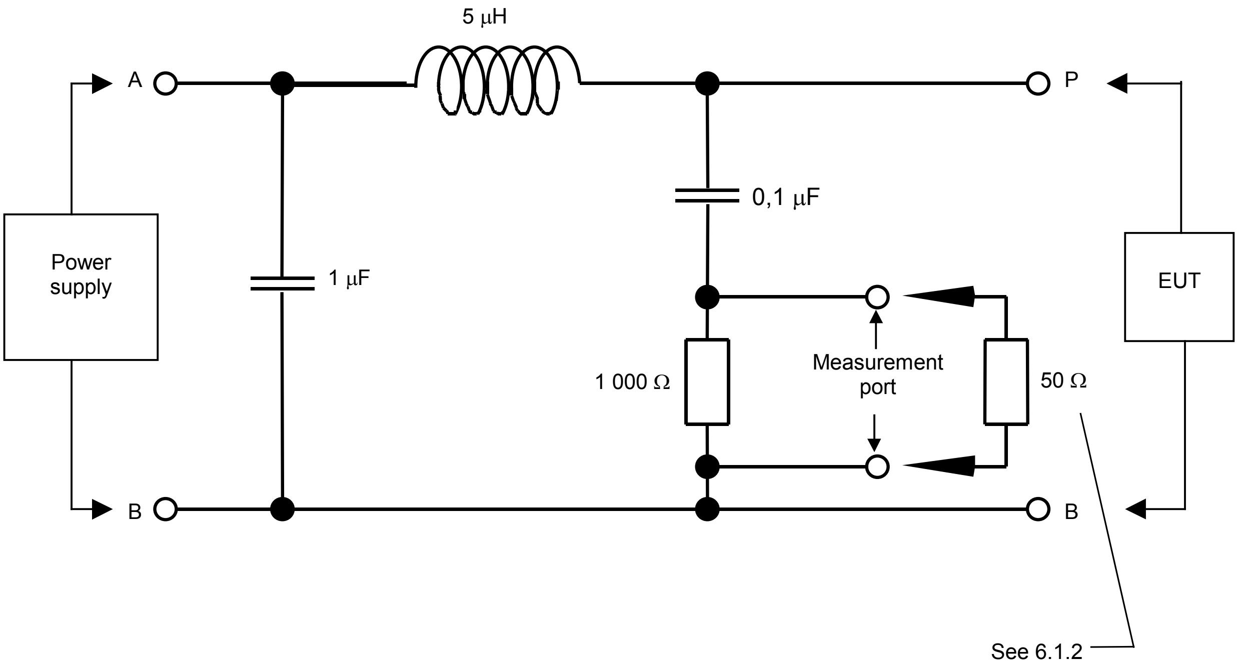


Figure E.1 – Example of 5 µH AN schematic

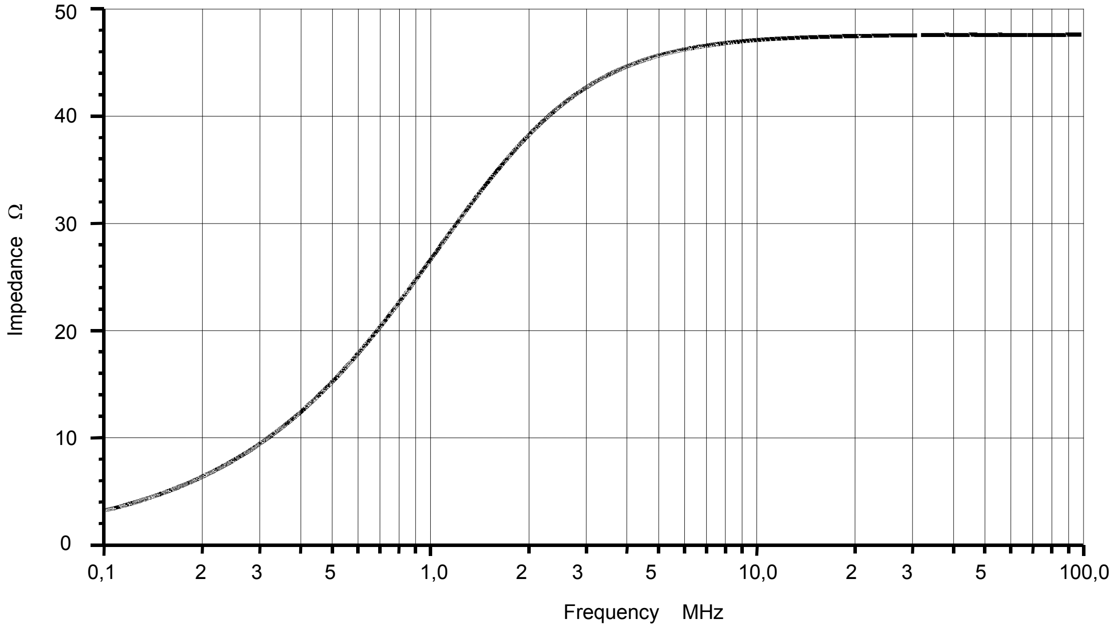


Figure E.2 – Characteristics of the AN impedance Z_{PB}

Table E.1 Magnitude of the AN impedance Z_{PB}

frequency MHz	magnitude of the impedance		
	nominal value Ω	lower tolerance Ω	upper tolerance Ω
0,10	3.20	2,56	3,84
0,15	4.79	3,83	5,75
0,20	6.37	5,09	7,64
0,30	9.45	7,56	11,34
0,40	12.41	9,93	14,89
0,50	15.23	12,18	18,27
0,70	20.34	16,27	24,41
1,00	26.64	21,31	31,97
1,50	33.88	27,10	40,65
2,00	38.26	30,61	45,92
2,50	40.97	32,77	49,16
3,00	42.70	34,16	51,24
4,00	44.65	35,72	53,59
5,00	45.66	36,53	54,79
7,00	46.59	37,27	55,90
10,00	47.10	37,68	56,53
15,00	47.39	37,91	56,87
20,00	47.49	37,99	56,99
30,00	47.56	38,05	57,07
50,00	47.60	38,08	57,12
100,00	47.61	38,09	57,14

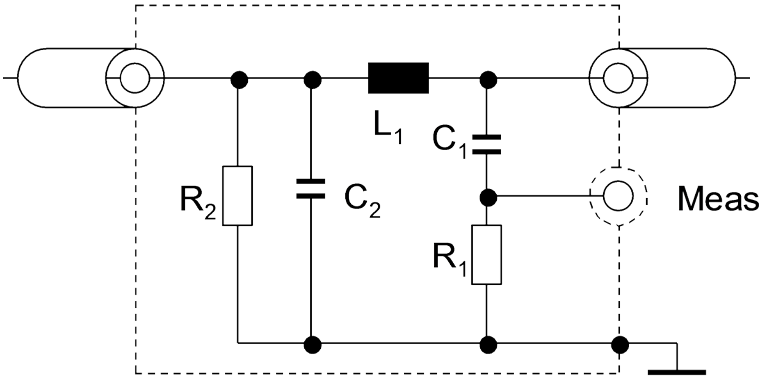
E.2.2 Component powered by HV

For a component powered by HV (e.g. 60 V – 1 000 V), a 5 µH / 50 Ω HV-AN as defined in Figure E.3 shall be used.

The HV-AN(s) shall be mounted directly on the ground plane. The grounding connection of the HV-AN(s) shall be bonded to the ground plane.

Measurement ports of HV-AN(s) shall be terminated with a 50 Ω load.

The HV-AN impedance Z_{PB} (tolerance ± 20 %) in the measurement frequency range of 0,1 MHz to 100 MHz is shown in Figure E.4. It is measured between the terminals P and B (of Figure E.3) with a 50 Ω load on the measurement port with terminals A and B (of Figure E.3) short circuited.



L_1: 5 µH
C_1: 0,1 µF
C_2: 0,1 µF (default value)
R_1: 1 kΩ
R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure E.3 – Example of 5 µH HV AN schematic

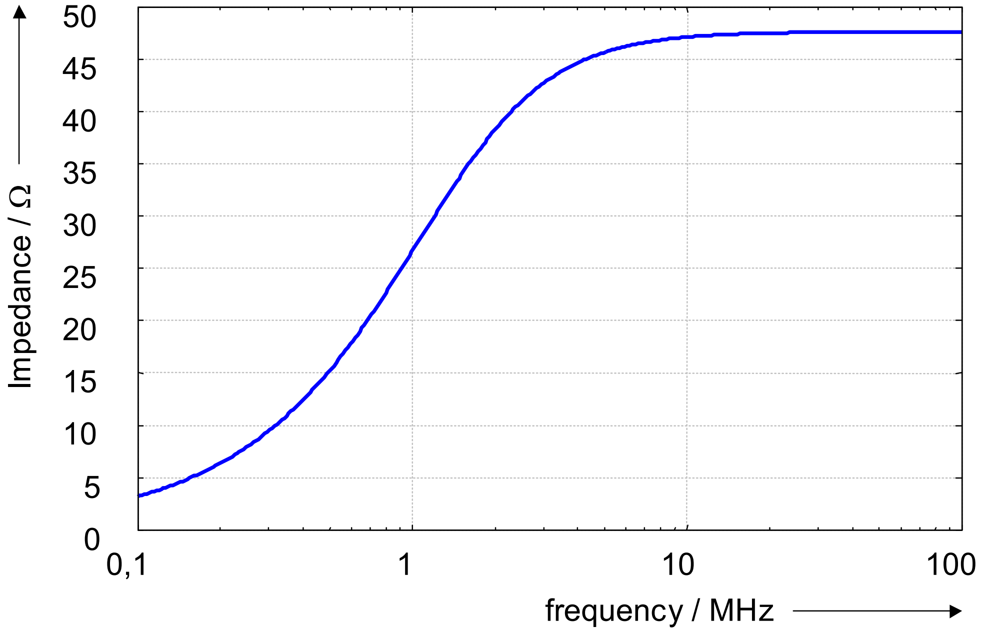
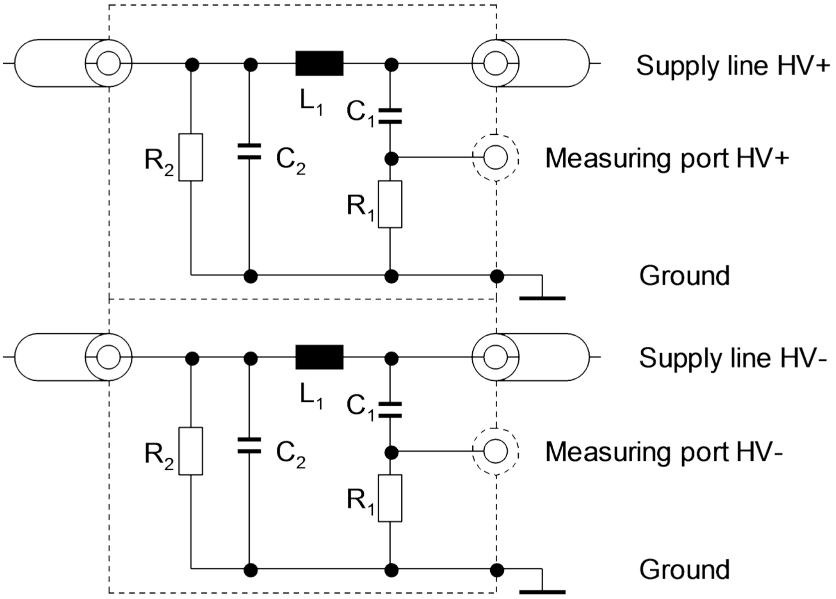


Figure E.4 – Characteristics of the HV AN impedance

See Table E1 for the nominal impedance and upper/lower tolerances in tabular form.

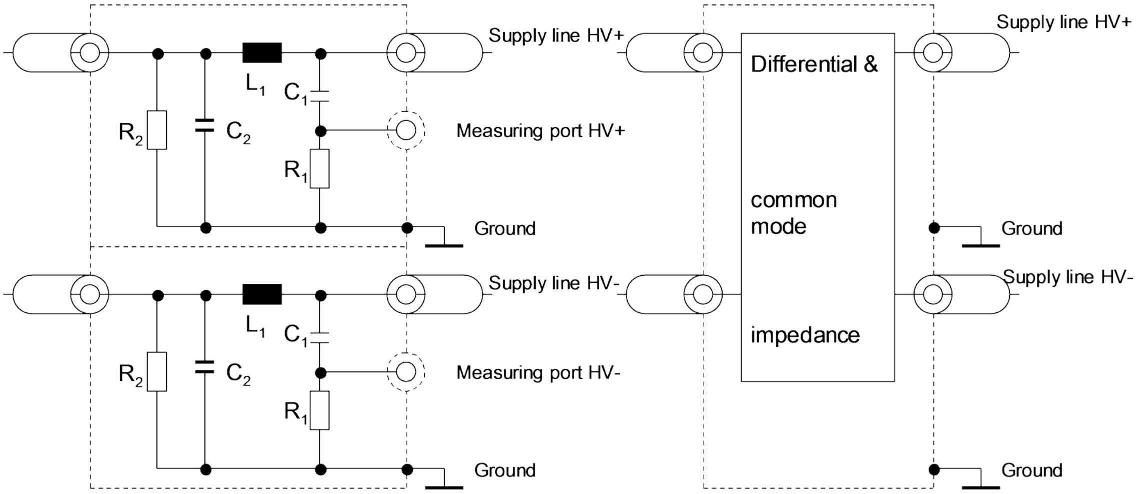
If unshielded HV AN´s are used in a single shielded box, then there shall be an inner shield between the HV AN´s as described in Figure E.5.



L_1: 5 µH
C_1: 0,1 µF
C_2: 0,1 µF (default value)
R_1: 1 kΩ
R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure E.5 – Example of 5 µH HV AN combination in a single shielded box

An optional impedance matching network may be used to simulate common mode / differential mode impedance seen by the EUT plugged on HV power supply (see Figure E.6).



L_1: 5 µH
C_1: 0,1 µF
C_2: 0,1 µF (default value)
R_1: 1 kΩ
R_2: 1 MΩ (discharging C_2 to < 50 V_{dc} within 60 s)

Figure E.6 – Impedance matching network attached between HV ANs and EUT

E.2.3 Component involved in charging mode connected to d.c. power mains

For a component involved in charging mode (e.g. charger) connected to a d.c. power mains, a 5 µH / 50 Ω-d.c.-AN as defined in clause E.2.1 shall be used.

E.2.4 Vehicle in charging mode connected to d.c. power mains

For a vehicle in charging mode connected to a d.c. power mains, a 5 µH / 50 Ω-d.c.-AN as defined in clause E.2.1 shall be used.

E.3 Artificial Mains networks (AMN)

E.3.1 Component AMN

For a component involved in charging mode (e.g. charger) connected to a a.c. power mains, a 50 µH / 50 Ω-AMN as defined in CISPR 16-1-2 clause 4.3 shall be used.

The AMN(s) shall be mounted directly on the ground plane. The grounding connection of the AMN(s) shall be bonded to the ground plane.

Measurement ports of AMN(s) shall be terminated with a 50 Ω load.

E.3.2 Vehicle in charging mode connected to a.c. power mains

For a vehicle in charging mode connected to a a.c. power mains, a 50µH/50Ω-AMN as defined in clause E.3.1 shall be used.

E.4 Asymmetric artificial network (AAN):

Currently different types of communication system and communication cabling are used for the communication between charging station and component (e.g. charger) or vehicle. Therefore a distinction between some specific cabling/operation types is necessary.

The AAN(s) shall be mounted directly on the ground plane. The grounding connection of the AAN(s)) shall be bonded to the ground plane.

Measurement ports of AAN(s) shall be terminated with a 50 Ω load.

E.4.1 Symmetric communication lines

An asymmetric artificial network (AAN) to be connected between component (e.g. charger) or vehicle and charging station or any associated equipment (AE) used to simulate communication is defined in CISPR 16-1-2 Annex E clause E.2 (T network circuit) (see example in Figure E.7).

The AAN has a common mode impedance of 150 Ω. The impedance Z_{cat} adjusts the symmetry of the cabling and attached periphery typically expressed as longitudinal conversion loss (LCL). The value of LCL should be predetermined by measurements or be defined by the manufacturer of the charging station/charging cable. The selected value for LCL and its origin shall be stated in the test report.

Note ´For some networks (e.g. CAN) this AAN cannot be used for conducted emission and/or radiated emission measurements on these lines. Alternative methods (current and voltage measurements) should be used.

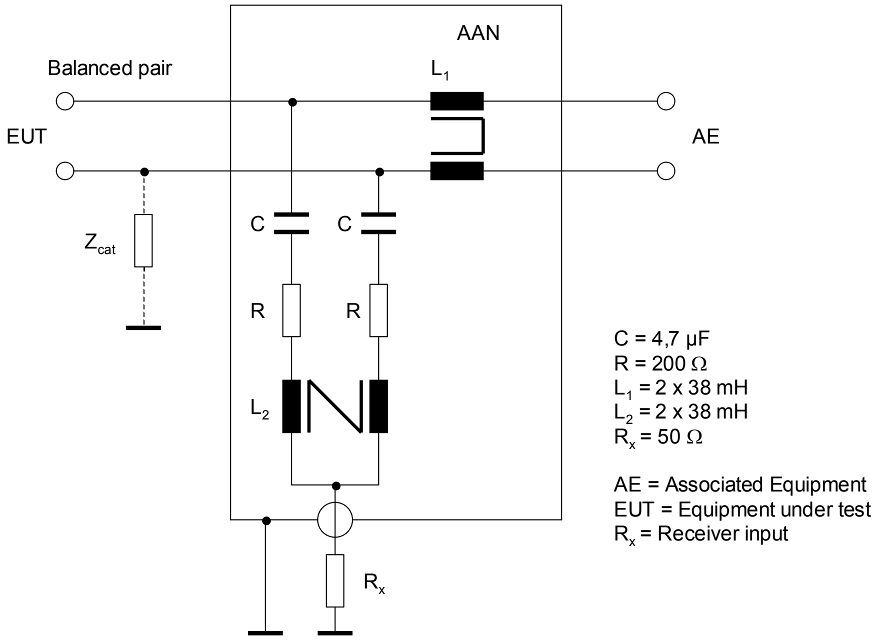


Figure E.7 Example of an AAN for symmetric communication lines

E.4.2 PLC on power lines

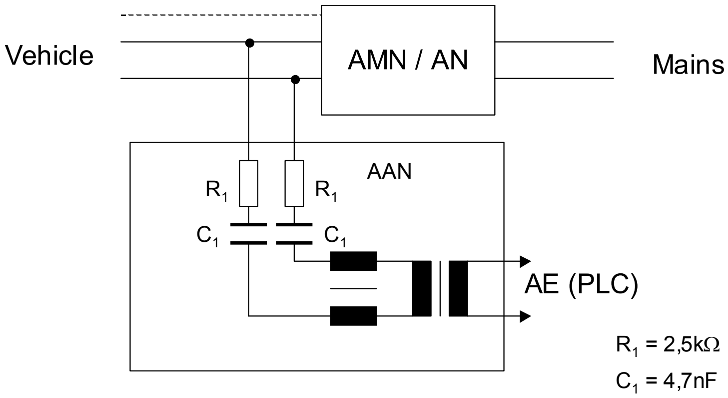
If an original charging station can be used for the test, it might be not necessary to add any AAN for PLC communication.

If PLC communication cannot be ensured with original charging station and AMN, or shall be simulated with use of an associated equipment (AE) (e. g. as a PLC modem) instead of an original charging station, it is necessary to add an AAN for PLC communication between PLC modem and the AMN (component or vehicle side) as defined in Figure E.8.

Note This AAN is not intended for any conducted emission measurement, but only to ensure adequate decoupling between PLC modem and power mains.

The circuits shown in Figures E.8 allow at least emission measurements for out-of-band emissions. For in-band emission measurements a disturbance current (common mode) measurement (as defined in CISPR 16-2-1) on the charging cable may be performed. In case of in-band emission measurements the disturbance current should fulfil the requirements for conducted disturbance currents on network and telecommunication access.

The circuit in Figure E.8 provides a common mode termination by the AN/AMN. For emission testing only the emissions from the PLC modem of the EUT should be measured. Therefore, an attenuator is located between powerline and the PLC modem at the AE side in the circuit for emission tests. This attenuator consists of two resistors in combination with the input/output impedance of the PLC modem. The value of the resistors depends on the design impedance of the PLC modems and the allowed attenuation for the PLC system.



The value of the resistors depends on the allowed attenuation and the design impedance of the PLC modem (here: 40dB attenuation, 100Ω PLC design impedance)

Figure E.8 Example of AAN circuit of PLC on a.c. or d.c. powerlines

E.4.3 PLC (technology) on control pilot

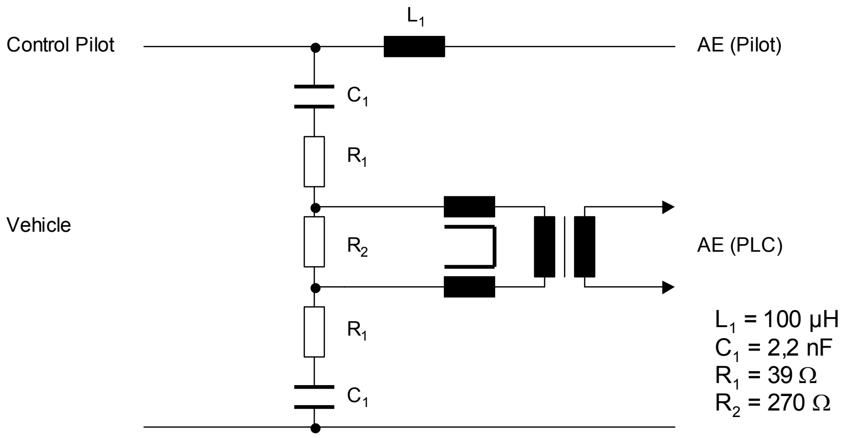
Some communication systems use the control pilot line (versus PE) with a superimposed (high frequency) communication. Typically the technology developed for powerline communication (PLC) is used for that purpose. On one hand the communication lines are operated unsymmetrically, on the other hand two different communication systems operate on the same line. Therefore a special AAN must be used as defined in Figure E.9.

It provides a common mode impedance of 150 Ω ± 20 Ω (150 kHz to 30 MHz) on the control pilot line (assuming a design impedance of the modem of 100 Ω). Both types of communications (control pilot, PLC) are separated by the network.

Therefore, typically a communication simulation is used in combination with this network. The attenuator built by the resistors and the design impedance of the PLC modem makes sure that the signal on the charging cable is dominated by the EUT’s communication signals rather than the AE PLC modem.

The values of inductance and capacitance in the networks added for PLC on control pilot shown in Figure E.9 shall not induce any malfunction of communication between component (e.g. charger) or vehicle and AE or charging station. It may therefore be necessary to adapt these values to ensure proper communication.

Note This AAN is not intended for any conducted emission measurement, but only to ensure a controlled impedance of the pilot line (and PLC) seen from the component or vehicle side.



The values of the three resistors depend on the design impedance of the PLC modem connected at AE side. The values given in the schematic are valid for a design impedance of 100 Ω.

Figure E.9 Example of AAN circuit for PLC on pilot line

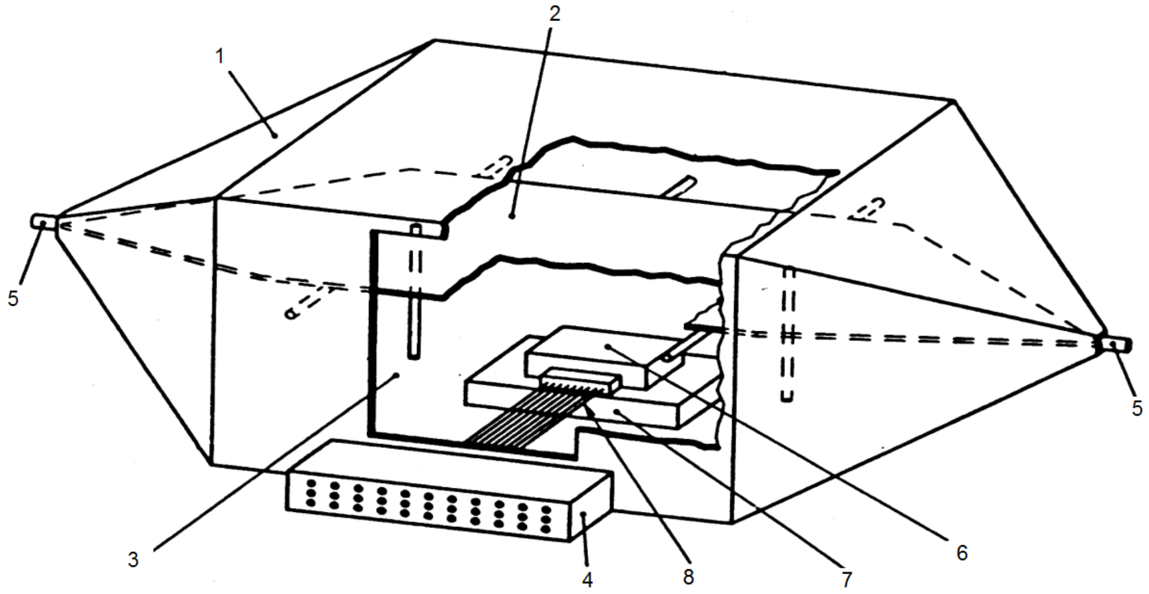
Annex F

(informative)

Radiated emissions from components/modules – TEM cell method

F.1 General

Measurements of radiated field strength shall be made in a shielded enclosure to eliminate the high levels of extraneous disturbance from electrical equipment and radiated fields from nearby broadcast and other radio transmitters. The TEM cell works as a shielded enclosure. An example of a TEM cell is shown in Figure F.1. Information relating to the size and construction of a TEM cell for component measurement is given in F.5.



Key

1 Outer shield

2 Septum (inner conductor)

3 Access door

4 Connector panel (optional)

5 Coaxial connectors

6 EUT

7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

8 Artificial harness

Note The connectors on the connector panel should be coaxial RF connectors if the RF boundary extends outside of the TEM cell

Figure F.1 - TEM cell (example)

The upper frequency limit of this test method is a direct function of the TEM cell dimensions, the dimensions of the components/module (arrangement included), and the RF filter characteristic. Measurements shall not be made near the TEM cell resonance frequencies.

A TEM cell is recommended for testing automotive electronic systems in the frequency range from 150 kHz to 200 MHz. The TEM cells boxed in Table F.2, are typical of those used in automotive work.

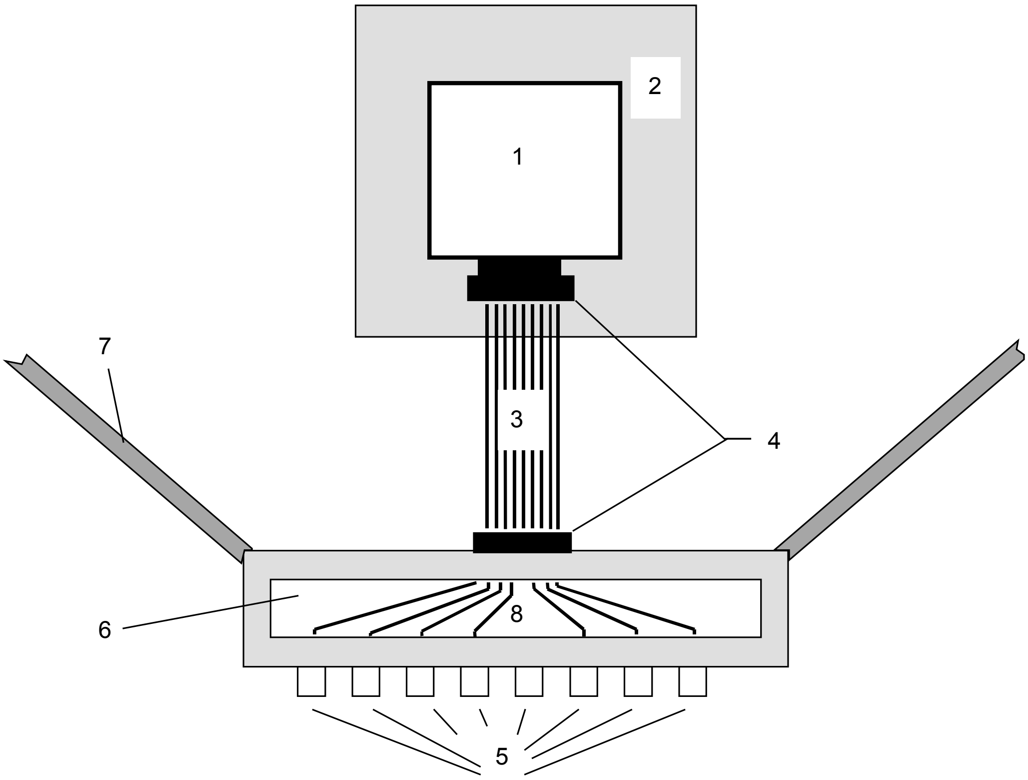
In order to achieve reproducible test results the EUT and the test harness shall be placed in the TEM cell in the same position for each repeated measurement.

For the purpose of this test, the septum of the TEM cell functions in a similar way to a receiving antenna.

F.2 Test setup

F.2.1 Setup with major field emission from the wiring harness

The TEM cell shall have a connector panel connected as close as possible to a plug connector (see Figures F.2 and F.3).



Key

1 EUT

2 Low relative permittivity support ($\varepsilon_r \le 1,4$)

3 Printed circuit board or wiring harness

4 Connector

5 Coaxial connectors

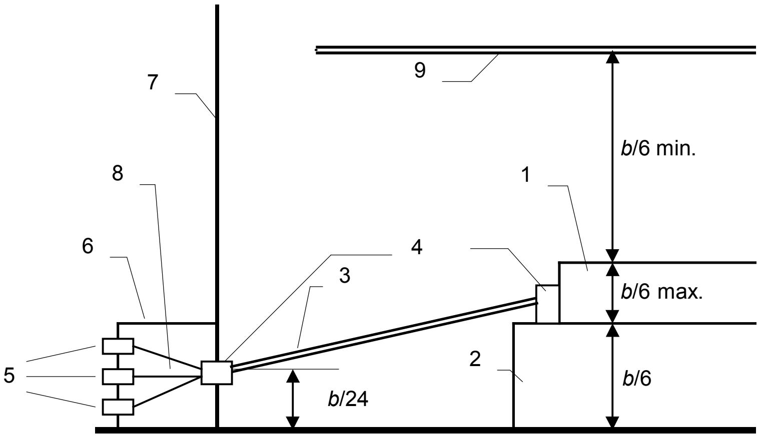
6 Connector panel (optional)

7 TEM cell wall

8 RF coaxial cables

Note All leads to the EUT shall pass through an RF boundary. The RF boundary is either at the wall of the TEM cell or extended through RF coaxial cable (8) and coaxial connectors (5). The boundary is terminated by RF-filters which can be connected inside the connector panel (6) or directly outside to the coaxial connectors (5). The cables in the connector panel should be coaxial if the RF-filters are connected to the coaxial connectors (5)

Figure F.2 – Example of arrangement of leads in the TEM cell and to the connector panel



Key

1 EUT

2 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

3 Printed circuit board (no ground plane) or wiring harness, not shielded

4 Connector

5 Coaxial connectors

6 Connector panel (optional)

7 TEM cell wall

8 Cables

9 Septum

b is the TEM cell height (see Annex F.5)

NOTE The connectors on the connector panel should be coaxial RF connectors if the RF boundary extends outside of the TEM cell.

Figure F.3 – Example of the arrangement of the connectors, the lead frame and the dielectric support

All supply and signal leads from the EUT are directly connected to the artificial harness (e.g. a lead frame). The plugs at the connector panel which are not required shall be sealed so that they are RF-tight.

The connection of the positive power lead shall be through the AN (6.2.2), direct at the connector panel.

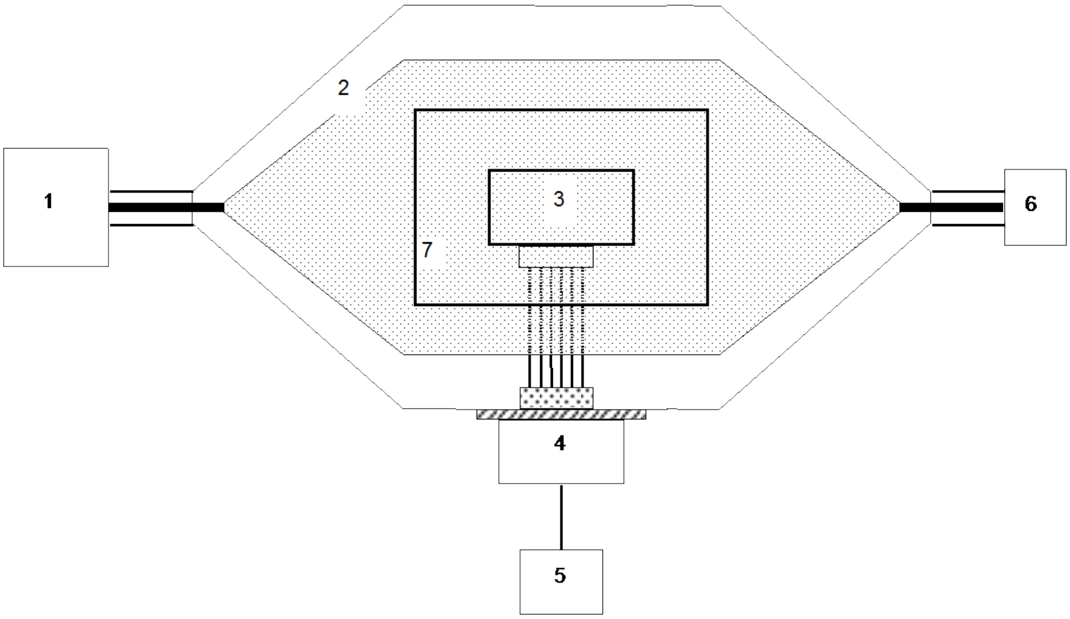
It is not permitted to ground the EUT directly to the TEM cell floor. The grounding shall be done at the connector panel.

F.2.2 Setup with major field emissions from the EUT

The test setup is similar to the method shown above, except that the leads to the EUT are positioned and shielded to minimise electromagnetic radiation from the leads. This is accomplished by positioning the leads flat across the bottom of the TEM cell and bringing them vertically to the EUT. The use of a sealed battery and shielded wiring in the TEM cell will further reduce the electromagnetic radiation from power and signal leads. To minimise the radiation from the wiring further, shielding foil tape can be applied over the leads.

F.3 Test procedure

An example of the TEM cell method test layout is given in Figure F.4. The general arrangement of the EUT, the harness, the filter system at the TEM cell's wall, etc. represent a standardised test condition. Any deviations from the standard test configuration shall be agreed upon prior to testing and recorded in the test report.



Key

1 Measuring instrument
2 TEM cell
3 EUT
4 AN (see 6.2.2)
5 Power supply
6 50 Ω termination resistor
7 Low relative permittivity support ($\varepsilon_r \leq 1,4$)

Figure F.4 – Example of the TEM cell method test setup

The EUT shall be supported *b*/6 (see Figure F.3) above the TEM cell floor by non-conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$) in the allowed working region. The length of the artificial harness (e.g. a lead frame) shall be 450 +/- 45 mm and positioned as shown in Figures F.2 and F.3.

The wiring arrangement of the artificial harness, the design and the overall height of the EUT's connector constitute electrical coupling loops and dipoles which have influence on the test results. All connections between the plug and contacts of the EUT's (multipole) connector and the artificial harness shall be as short as possible. Repeat measurements shall be performed using the same arrangement of the artificial harness, the same overall height of the EUT's connector and the same pin assignment on both connectors. Care shall be taken, if the size of the EUT and the allowed working region is nearly the same. In such a case, special care should be taken to define and document the test layout in the test plan.

The EUT shall be installed to operate under typical loading and other conditions in the vehicle in such a way that the maximum emission state occurs. These operating conditions must be defined in the test plan to ensure supplier and customer can perform identical tests.

Note Different orthogonal orientations of the EUT could lead to different levels of measured electromagnetic energy.

The positive supply line shall have an RF filter at the TEM cell input. The artificial network (AN) of 6.2.2 shall be used as this filter. The AN shall be connected directly to the TEM cell and shall be screened, so that the negative supply line is grounded at the connector panel. The RF sampling port of the AN shall be terminated with a 50 Ω load.

All sensor and actuator leads of the EUT shall be connected to a peripheral interface, which simulates the operation in the vehicle.

To minimise influences of the wiring outside the TEM cell, low pass filters shall be used, which shall be connected directly to the BNC panel. The performance of the filters depends on the frequency range of the EUT's wanted signals. If no other configuration is specified in the test plan the filters shall perform like the artificial network with a 50 Ω impedance as described in Annex E.

To eliminate influences of its length and arrangement the wiring inside the connector panel shall be as short as possible via 50 Ω coaxial cables if a BNC connector panel is used. The shielding (outer conductor) of the cables shall be grounded at both ends.

Repeat measurements shall be performed using the same RF port of the TEM cell, with the opposite port terminated by a 50 Ω impedance.

F.4 Limits for radiated disturbances from components/modules – TEM cell method

The level class to be used (as a function of the frequency band) shall be agreed upon between the vehicle manufacturer and the component supplier.

Note Recommended limits for radiated disturbances from components (both the setup with major field coupling to the wiring harness (F.2.1) and the setup with major coupling to the EUT (F.2.2) are given in Table F.1. Since the mounting location, vehicle body construction and harness design can affect the coupling of radio disturbances to the on-board radio, multiple limit levels are defined.

Table F.1 – Examples of limits for radiated disturbances – TEM cell method

Service / Band	Frequency MHz	Levels in dB(µV)														
		Class 5			Class 4			Class 3			Class 2			Class 1		
		Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average	Peak	Quasipeak	Average
BROADCAST																
LW	0,15 – 0,30	26	13	6	36	23	16	46	33	26	56	43	36	66	53	46
MW	0,53 – 1,8	20	7	0	28	15	8	36	23	16	44	31	24	52	39	32
SW	5,9 – 6,2	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
FM	76 – 108	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
TV Band I	41 – 88	16	-	6	22	-	12	28	-	18	34	-	24	40	-	30
TV Band III	174 – 230	16	-	6	22	-	12	28	-	18	34	-	24	40	-	30
DAB III	171 – 245	10	-	0	16	-	6	22	-	12	28	-	18	34	-	24
TV Band IV	468 – 944	Radiated emission – TEM cell Not Applicable														
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
VHF	30 – 54	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
VHF	68 – 87	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
VHF	142 – 175	20	7	0	26	13	6	32	19	12	38	25	18	44	31	24
Analogue UHF	380 – 512	Radiated emission – TEM cell Not Applicable														
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

F.5 TEM Cell design

The dimensions of a TEM cell are shown in the Figure F.5a and F.5b and given in Table F.2.

Dimensions in millimetres

Drawing not to scale

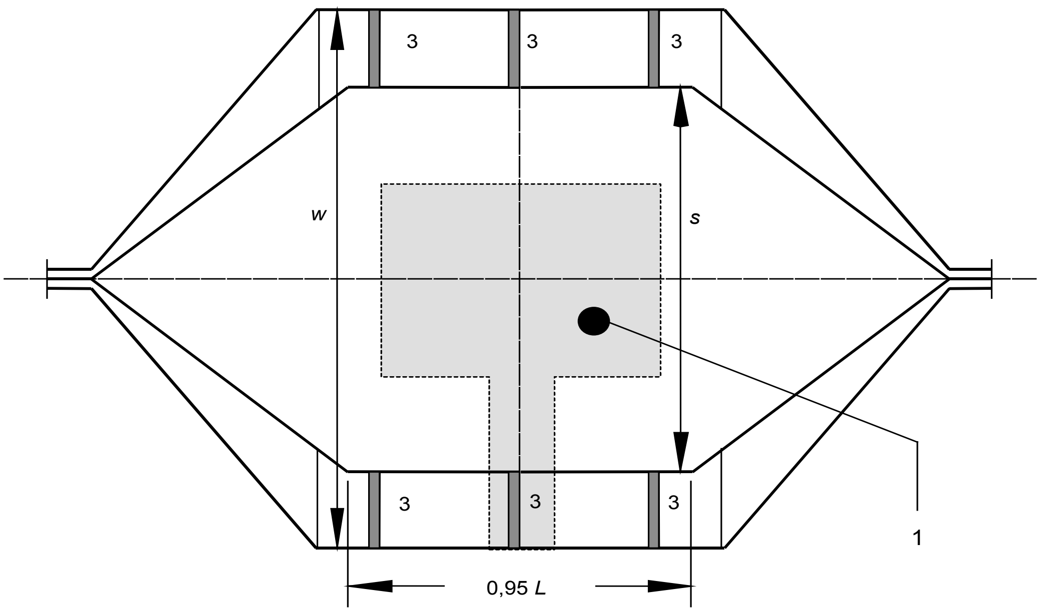


Figure F.5a – Horizontal section view at septum

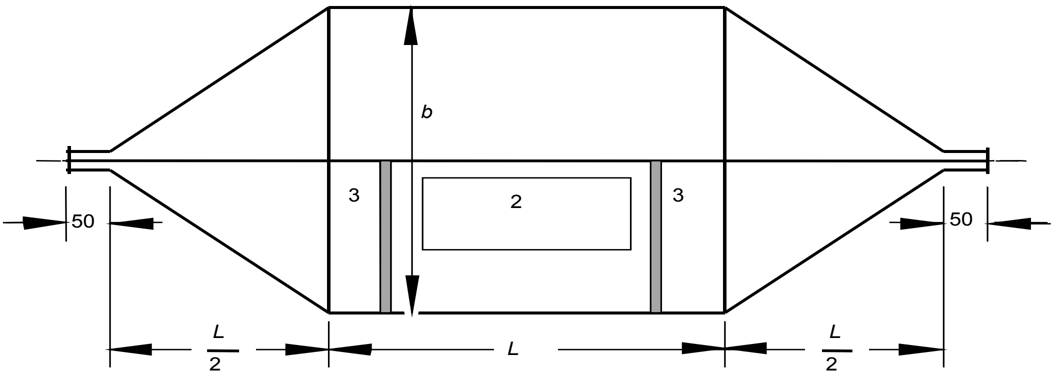


Figure F.5b – Vertical section view at septum

Key

1 Allowed working region: 0,33 *W*, 0,60 *L*
2 Access door
3 Dielectric supports

Figure F.5 – TEM cell

Table F.2 shows the dimensions for constructing TEM cells with specific upper frequency limits.

Table F.2 – Dimensions for TEM cells

Upper frequency MHz	**Cell form factor** *W*/*b*	**Cell form factor** *L*/*W*	**TEM cell height** *b* mm	**Septum width** *S* mm
100	1,00	1,00	1 200	1 000
200	1,69	0,66	560	700
200	1,00	1,00	600	500
300	1,67	1,00	300	360
500	1,50	1,00	200	230

NOTE The TEM cells in the box are typical for automotive component testing. For integrated circuit testing, even smaller TEM cells may be applicable for testing up to and above 1 GHz.

Annex G
(informative)

Radiated emissions from components/modules – Stripline method

G.1 General

The stripline is an open waveguide, which consists of a reference ground plane and an active conductor (septum) and has characteristic impedance. Commonly used values for characteristic impedances are 50 Ω and 90 Ω. Information relating to the size and construction of a stripline is given in Figure G.2 and Figure G.3.

Users are encouraged to study and experiment with the test method to increase the body of knowledge with the aim of reaching consensus on including it in the main body of this standard at a future date.

The stripline may be used in the frequency range from 150 kHz to 400 MHz where the harness is the primary radiating/coupling element.

The limits of the frequency range can be extended up to 1 000 MHz, if:

- – the dominance of TEM mode can be shown 1);
- – and the EUT is located under the septum;
- – and the height of the EUT is limited to 1/3 of the septum height.

Measurements shall be made in a shielded enclosure to eliminate high levels of external disturbances. For further details see Figure G.1.

Note The influence of the shielded enclosure on the measured impedance (i.e. reflection coefficient as measured with a network analyser) of the stripline should be less than 6 dB compared with an open field test site. To realize this it might be necessary to equip the shielded enclosure partially with absorbers. An example is shown in Figure G.1.

G.2 Test setup

For radiated emissions measurements, the arrangement of the EUT, test harness, load simulator and measuring equipment shall be equivalent to the example shown in G.1.

Deviations of the location and length of the test harness (e.g. the original vehicle harness) and the location of the EUT have to be agreed between customer and supplier.

In order to achieve reproducible test results the EUT and the test arrangement shall be located at the same position in the stripline for each repeated measurement.

G.2.1 Stripline impedance matching

Correct impedance matching between the stripline and the measuring instrument of 50 Ω shall be maintained for all frequencies. This can be achieved by using lossless transmission line transformers (non-linear shape of the septum tapers or an additional external waveguide) or lumped passive network.

---

1) For the design shown in Figure G.2 it is presumed that the TEM mode is dominant up to 400 MHz. For the design shown in Figure G.3 it is presumed that the TEM mode is dominant up to 1 000 MHz.

If the matching unit is a lumped passive network, appropriate correction of measurement results shall be made for any insertion loss.

G.2.2 Location of the EUT

The EUT shall be placed (50 ± 5) mm above the reference ground plane on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$) and must be located on the same side as the 50 Ω load of the stripline as shown in Figure G.1. The case of the EUT shall not be grounded to the reference ground plane unless it is intended to simulate the real vehicle configuration. In the case that the EUT is not located under the septum, the EUT shall be located at a distance of $\left(200\ {}^{+50}_{\ \ 0}\right)$ mm from the edge of the septum.

G.2.3 Location and length of the test harness

The length of test harness parallel to the septum shall be (1 000 ± 50) mm.

The total length of the test harness between the EUT and the load simulator (or the RF boundary) is typical 1 700 mm and shall not exceed 2 000 mm. The same test harness can be used as with the ALSE test method (see 6.5).

The long segment of the test harness shall be within the inner one-third of the width of the septum. Ideally, it is placed under the centreline of the septum.

The wiring type is defined by the intended system application and requirement. The test harness shall be placed on a non-conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$), (50 ± 5) mm above the reference ground plane. The locations of the EUT and load simulator require a harness bend angle of (90 ± 15) degrees.

G.2.4 Location of the load simulator

The load simulator should be located at a distance of $\left(200\ {}^{+50}_{\ \ 0}\right)$ mm from the edge of the septum. If this cannot be met, the actual location of the load simulator shall be documented in the test report.

The load simulator shall be placed directly on the reference ground plane. If the load simulator has a metallic case, this case shall be bonded to the reference ground plane. Alternatively, the load simulator may be located adjacent to the reference ground plane (with the case of the load simulator bonded to the reference ground plane) or outside of the test chamber, provided the test harness from the EUT passes through an RF boundary bonded to the reference ground plane. When the load simulator is located on the reference ground plane, the d.c. power supply lines of the load simulator shall be connected through the AN(s) (see 6.2.2).

G.3 Test procedure

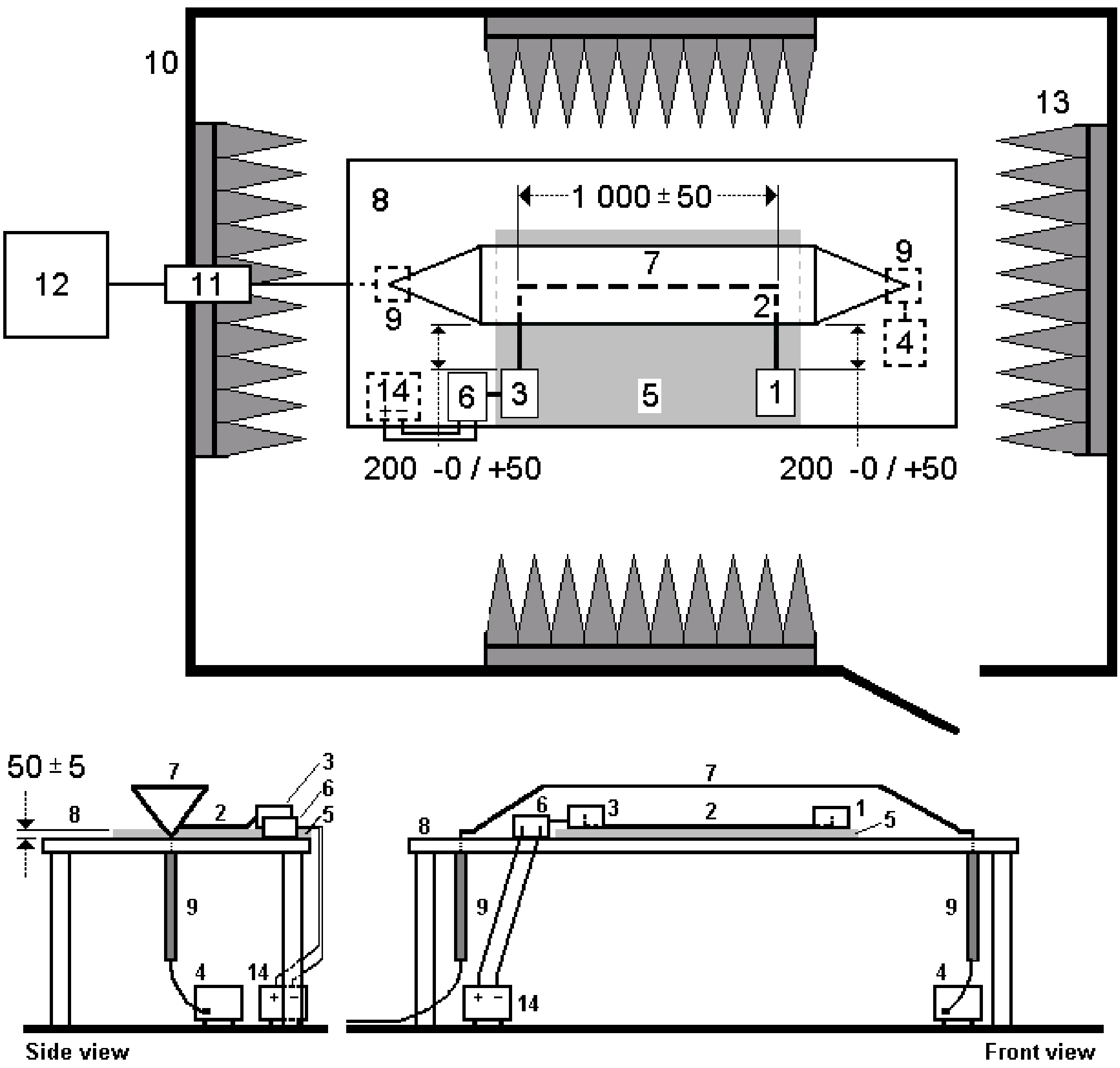
The general arrangement of the EUT, the harness and the peripherals, represents a standardized test condition. Any deviations from the standard test configuration shall be agreed between customer and supplier prior to testing and recorded in the test report.

The EUT shall be installed to operate under typical loading and operating conditions in the vehicle in such a way that the maximum emission state occurs. These operating conditions have to be defined in the test plan to ensure that customer and supplier are performing identical tests.

The arrangement of the EUT as well as the measuring equipment shall be functionally equivalent to the example shown in Figure G.1 and shall be defined in the test plan.

Top view

Dimensions in millimetres



Key:

1 EUT

2 Test harness

3 Load simulator

4 50 Ω load (location optional)

5 Low relative permittivity support ($\varepsilon_r \leq 1{,}4$)

6 Artificial network (AN)

7 Septum

8 Reference ground plane

9 Matching unit (if necessary)

10 Wall of shielded room

11 Bulkhead connector

12 Measuring instrument

13 Absorbers (if necessary)

14 Power supply (location optional)

Figure G.1 – Example of a basic stripline test setup in a shielded enclosure

G.4 Limits for radiated emissions from components/modules – Stripline method

Some disturbance sources are continuous emitters and require a lower limit than a disturbance source which operates only periodically or for short intervals.

The limits of the radiated electromagnetic energy may be different for each disturbance source and arrangement (coupling between antenna and electronic equipment in the vehicle).

For evaluation of radiated emissions from components/modules the RF voltage at the stripline output is to be measured.

Table G.1 – Examples of limits for radiated disturbances – Stripline method

Service / Band	**Frequency** MHz	**Levels** in **dB**(µV)														
		Class 5			**Class 4**			**Class 3**			**Class 2**			**Class 1**		
		Peak	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**
BROADCAST																
LW	0,15 – 0,30	47	34	27	57	44	37	67	54	47	77	64	57	87	74	67
MW	0,53 – 1,8	41	28	21	49	36	29	57	44	37	65	52	45	73	60	53
SW	5,9 – 6,2	41	28	21	47	34	27	53	40	33	59	46	39	65	52	45
FM	76 – 108	32	19	12	38	25	18	44	31	24	50	37	30	56	43	36
TV Band I	41 – 88	22	-	12	28	-	18	34	-	24	40	-	30	46	-	36
TV Band III	174 – 230	22	-	12	28	-	18	34	-	24	40	-	30	46	-	36
DAB III	171 – 245	16	-	6	22	-	12	28	-	18	34	-	24	40	-	30
TV Band IV	468 – 944	22	-	12	28	-	18	34	-	24	40	-	30	46	-	36
DTTV	470 – 770	26	-	16	32	-	22	38	-	28	44	-	34	50	-	40
DAB L Band	1447 – 1494	Radiated emission – Stripline Not Applicable														
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	40	28	21	46	34	27	52	40	33	58	46	39	64	52	45
VHF	30 – 54	32	19	12	38	25	18	44	31	24	50	37	30	56	43	36
VHF	68 – 87	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
VHF	142 – 175	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
Analogue UHF	380 – 512	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
RKE	300 – 330	20	-	6	26	-	12	32	-	18	38	-	24	44	-	30
RKE	420 – 450	20	-	6	26	-	12	32	-	18	38	-	24	44	-	30
Analogue UHF	820 – 960	26	13	6	32	19	12	38	25	18	44	31	24	50	37	30
GSM 800	860 – 895	32	-	12	38	-	18	44	-	24	50	-	30	56	-	36
EGSM/GSM 900	925 – 960	32	-	12	38	-	18	44	-	24	50	-	30	56	-	36
GPS L1 civil	1567 – 1583	Radiated emission – Stripline Not Applicable														
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

Note 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

Note 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

Note 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

These limits have been established for a 90 Ω stripline design as shown in Figure G.3. In case of using other stripline impedance characteristics than 90 Ω, the limits have to be adapted in accordance with the following formula G.1:

$$K_{\frac{90\Omega}{Z_2}} = 20\lg\sqrt{\frac{90\Omega}{Z_2}}\ \text{dB} \tag{G.1}$$

Example for a stripline with 50 Ω characteristic impedance:

$$K_{\frac{90\Omega}{50\Omega}} = 20\lg\sqrt{\frac{90\Omega}{50\Omega}} = 2{,}54\ \text{dB} \tag{G.2}$$

Limits $Z_{50\Omega}$ = Limits $Z_{90\Omega}$ - $K_{90\Omega/50\Omega}$ = Limits $Z_{90\Omega}$ - 2,54 dB

where

K is the correction factor for limits in dB;

Z is the characteristic impedance of stripline in Ω.

G.5 Stripline design

An example of a 50 Ω stripline construction is shown in FigureG.2 and for a 90 Ω stripline in Figure G.3. The ratio of *b*/*h* determines the characteristic impedance. If dimension *b* is greater than *h*, the following equation G.3 applies:

$$Z = \frac{120\times\pi}{\frac{b}{h} + 2{,}42 - 0{,}44\times\frac{h}{b} + \left[1 - \frac{h}{b}\right]^6} \tag{G.3}$$

where

Z is the characteristic impedance of the stripline in Ω;

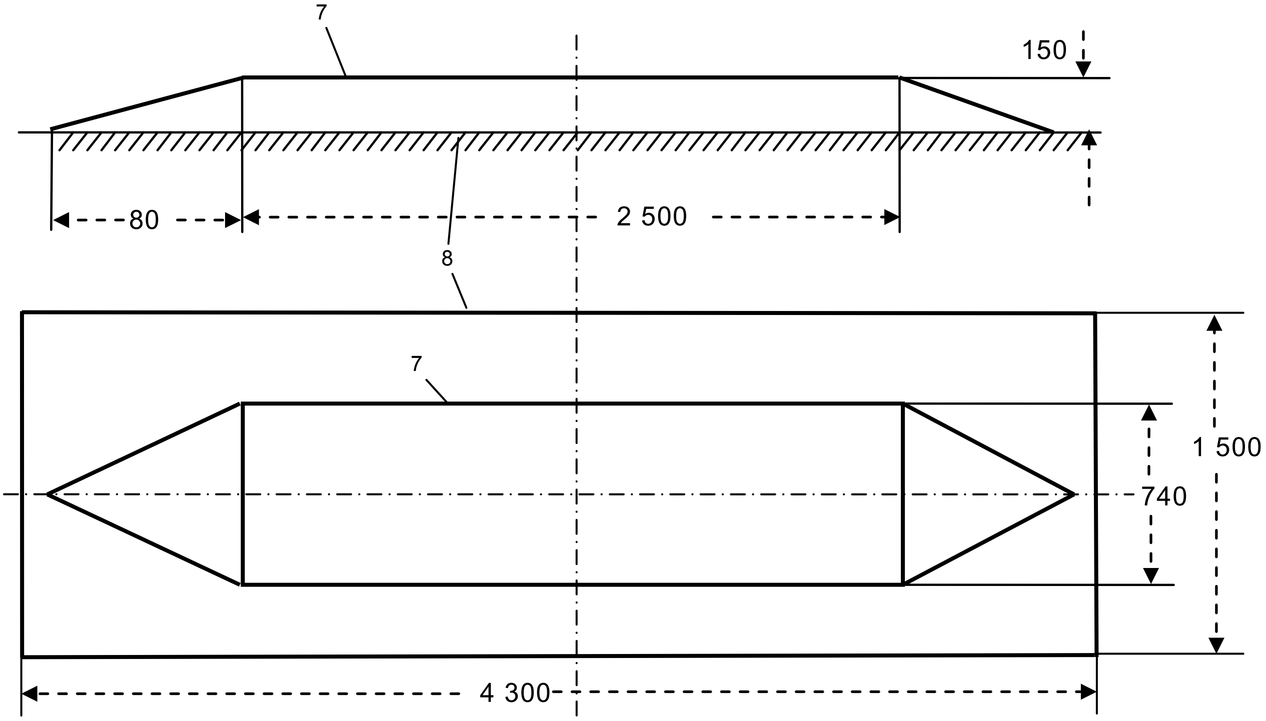
b is the stripline septum width in mm;

h is the stripline septum height above the reference ground plane in mm;

π = 3,14159

NOTE Typical striplines are constructed to have an impedance of either 50 Ω or 90 Ω with b/h equal to 5 and 1,83, respectively. The termination may be either a resistive load or a tapered matching section terminated in a 50 Ω coaxial resistive load. A resistive load may be constructed of carbon resistors, conductive strips, thick film on a ceramic substrate, etc. in such a way that it matches the characteristic impedance of the stripline and minimizes the standing waves ratio.

Dimensions in millimetres

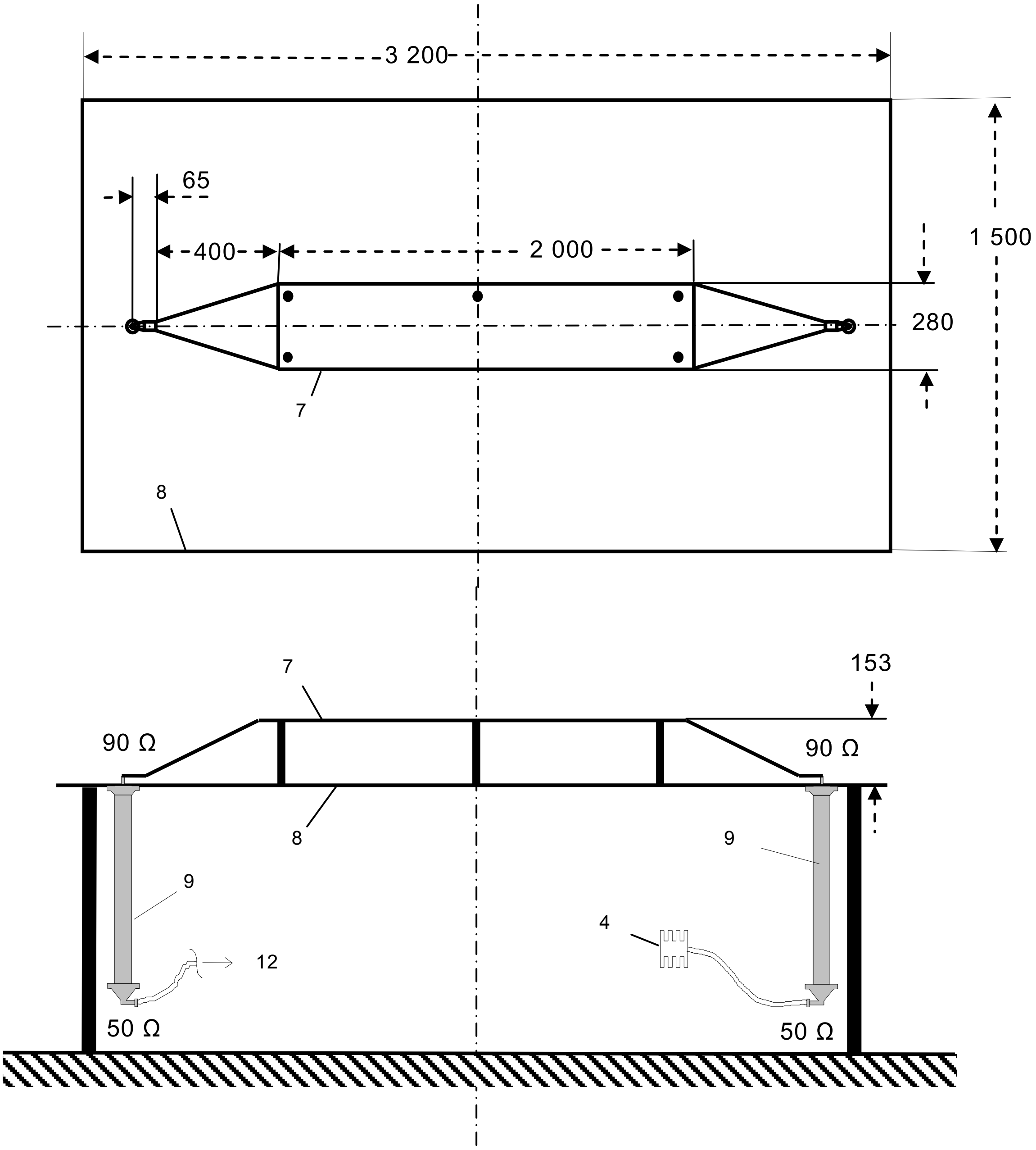


Key:

7	Septum
8	Reference ground plane

Figure G.2 – Example for a 50 Ω stripline

Dimensions in millimetres



Key:

4	50 Ω load
7	Septum
8	Reference ground plane
9	Matching unit
12	Measuring instrument

Figure G.3 – Example for a 90 Ω stripline

Annex H
(informative)

Interference to mobile radio communication in the presence of impulsive noise – Methods of judging degradation

H.1 Introduction

This annex provides methods of judging the degradation of radio communication in the presence of impulsive noise.

H.2 Survey of methods of judging degradation to radio channel

Test programs have been conducted in the United States of America by the Federal Communications Commission (FCC) and the Motor Vehicle Manufacturers Association (MVMA, later the American Automobile Manufacturers Association, AAMA, now disbanded). These test programs were directed toward providing a better understanding of the effects of motor vehicles on mobile communications reception.

The tests measured the degradation to communications systems subjectively and objectively at numerous receiver frequencies using several classes of automotive ignition noise sources such as a traffic stream and a controlled matrix of vehicles. Correlation between various objective and subjective measures of degradation was studied using rating scales employed by the FCC and MVMA for grading communication quality.

H.2.1 Subjective tests

H.2.1.1 Subjective tests of annoyance

Subjective degradation tests were conducted by the FCC using a single vehicle and groups of vehicles simulating traffic patterns. The FCC proposed and used a subjective jury rating scale based upon annoyance which had been used traditionally to determine the effects of ambient noise on job performance, accident rate, and fatigue of personnel.

Grade	Interfering effect was
5	almost nil
4	noticeable
3	annoying
2	very annoying
1	so bad the presence of speech was barely discernible

This grade system is very nearly the same as that given in ITU-R Recommendation ITU-R BS.1284 which should be used for future work if annoyance testing is conducted.

Quality		Impairment	
5	excellent	5	imperceptible
4	good	4	perceptible, but not annoying
3	fair	3	slightly annoying
2	poor	2	annoying
1	bad	1	very annoying

Annoyance is a highly subjective psychological reaction. The degree of annoyance caused by audible noise has been found to be influenced by a large number of variable physical and psychological factors (including illness, fatigue, status of interpersonal relations, and family problems).

H.2.1.2 Subjective tests of intelligibility

H.2.1.2.1 General

Since land mobile communication systems are used primarily to transmit voice messages, the performance of such systems should be based primarily on the intelligibility of the received signal in the presence of ignition noise.

The most common procedure for determining the intelligibility of a voice channel is a subjective method involving trained speakers and listener jury panels that directly score the percentage of speech that is intelligible. These schemes have the merit of producing repeatable results. Unfortunately, subjective scoring methods are expensive and time-consuming. As a result, they are not widely used.

The subjective scale for intelligibility proposed by the MVMA is:

Grade	Description
5	could understand the message extremely well
4	could understand the message fairly well
3	think I understood, but had to guess at some words
2	could barely discern the message
1	could not detect speech at all

H.2.1.2.2 Intelligibility test method

Beginning at 20 dB quieting with the vehicle ignition noise source off, the radio frequency input level was reduced by 1 dB decrements and scored at each decrement by the jury until the jury reached

Grade 1 (worst). Then the radio frequency input level was increased by 1 dB increments until the 20 dB quieting level was again reached.

The radio frequency input level was then increased by 3 dB increments until the jury rated the quality Grade 5 (best). The radio frequency input level was then decreased by 3 dB decrements until the 20 dB quieting level was reached.

The entire process was repeated with the vehicle noise source in operation.

The results of the two tests (noise source off / noise source on) were then compared and the difference in radio frequency level for a particular quality grade (in decibels) was reported as the subjective degradation.

H.2.2 Objective tests

H.2.2.1 General

Uncertainty in subjective measurements arises from ambiguity of the rating scale definition, and variability of juror judgement. The latter source of error is largely caused by psychological factors. Objective measurements should have uncertainties less than those obtained from subjective tests.

A study carried out by the Institute for Telecommunication Sciences [1] develops a method of obtaining an objective intelligibility measure giving good results for speech sent through both analogue and digital noise-corrupted communication channels. The distortion measure is obtained using Linear Predictive Coding (LPC), a mathematical technique widely known for its application to the analysis and synthesis of speech.

H.2.2.2 Objective test method

To develop an objective intelligibility measure for corrupted speech, a comparison must be performed between the distorted speech and the original noise-free speech. A subjective intelligibility measure of the distorted speech must also be available in order to judge the quality of the objective measure being used. Both of these requirements are met by first making a noise-free master tape of preselected speech, then sending it through the voice communication channels to be tested and making a recording of the speech at the channel outputs. The latter recording can be subjectively scored for intelligibility, and also compared with the original speech by a mathematical technique to obtain an objective score.

The preselected speech to be sent over a voice channel for intelligibility scoring consists of phonetically balanced groups of isolated words, as opposed to complete sentences or nonsense syllables. These phonetically balanced words were used because subjective scores have been shown to be repeatable, which is a necessary criterion for this study. (During tests employing vehicles as a noise source, subjective scoring by listener panels was conducted and compared to the objective scores, resulting in good correlation.)

H.2.3 Conclusions relating to judgement of degradation

Numerous studies have been conducted over the years to develop a simple, inexpensive, objective method of measuring land mobile receiver degradation in the presence of ignition noise. Linear Predictive Coding (LPC) is neither simple nor inexpensive (when compared to the equipment used for CISPR 12 and CISPR 25 measurements), but it is technically a good objective method for measuring receiver degradation.

Subjective tests have proved to be effective in rating mobile receiver degradation. Of the two subjective rating methods in use, intelligibility was determined to be superior to annoyance in characterizing the effect of radio noise on a communication link. Most objective measurements taken during the subjective testing, however, showed poor correlation. The Linear Predictive Coding (LPC) method showed good correlation with the subjective intelligibility test method. Subjective tests are preferred, however, because of their reduced complexity and resulting lesser cost.

Considering only the subjective test methods, and as a result of the numerous tests conducted, it is recommended that intelligibility be used as the index of communications system performance rather than annoyance.

H.3 Bibliography

[1] GAMAUF K. J. and HARTMAN W. J., *Objective Measurement of Voice Channel Intelligibility*, October 1977; available from the National Technical Information Service, Springfield, Virginia 22151, USA, reference number FAA-RD-77-153.

Annex I
(normative)

Test methods for shielded power supply systems for high voltages in electric and hybrid vehicles

I.1 General

Components/modules used in electric vehicles are electronic components connected with LV network and/or HV power supply systems in the sense of CISPR 25. Therefore the requirements regarding emissions apply to them in their functions. The test methods, procedures and limit lines are defined in accordance with CISPR 25 requirements for vehicles.

This document gives additional test set-up methods and limits for emission measurement according to the main part when considering the HV power supply system parts, which are typically fully shielded.

Examples of HV power supply system parts are:

- inverter with electrical motor
- onboard charger
- DC-DC-converter
- electrical heater
- high voltage battery
- all devices which have in addition to the LV power supply a HV power connection

The limits in Table I.1 are derived taking into account the overall high voltage shielding and attenuation performance, see I.5.3.5.

For unshielded systems limits of the main body have to be applied.

The present electric vehicle technology provides two categories of electric systems. The first category consists of the common LV systems (typically unshielded) and the second of the HV systems (typically shielded).

The limits given when testing the HV systems are based on the limits already defined for the LV systems in the main part and on the coupling factor identified between the both networks.

This annex specifies the following tests:

- conducted RF voltage measurements on shielded power supply lines with shielded artificial networks
- conducted RF current measurements on shielded cables of power supply systems
- radiated RF emission measurements of components/modules
- interaction between HV and LV ports of the system due to coupling (decoupling factor)

I.2 Conducted emission from components/modules on HV power lines – Voltage method

I.2.1 Ground plane arrangement

The location of the EUT, test harness and load simulator on the ground plane is shown in Figures I.1, I.2 and I.3. The reference ground plane conditions defined in 6.2.1 (radiated emissions) apply.

I.2.2 Test set-up

The set-up is adapted from 6.3.2.1 and is shown in Figure I.1. The shielding configuration and any protective ground connection should be representative of the vehicle application and shall be defined in the test plan. The battery charger ground connection shall also be defined in the test plan. EUTs and loads shall be connected to ground using impedance as defined in the test plan. The vehicle HV battery should be used; otherwise the external HV power supply shall be connected via feed-through-filtering.

Unless otherwise specified in the test plan (e.g. use of original vehicle harnesses), the length of harnesses shall be as follows:

- 200^{+200}_{0} mm for the LV lines
- 1700^{+300}_{0} mm for the HV lines and the length of the HV test harness parallel to the front of the ground plane shall be (1500 ± 75) mm.
- less than 1000 mm for the three phase lines between EUT and electric motor(s)

All of the harnesses shall be placed on a non conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$) at (50 ± 5) mm above the ground plane.

HV lines shall be placed at a minimum distance of 100 mm from the edge of the reference ground plane.

Shielded supply lines for the positive HV d.c. terminal line (HV+), the negative HV d.c. terminal line (HV-) and three phase HV a.c. lines may be separate coaxial cables or in a common shield depending on the connector system used. The original HV harness from the vehicle may be used optionally.

Unless otherwise specified in the test plan the EUT case shall be connected to the ground plane either directly or via defined impedance.

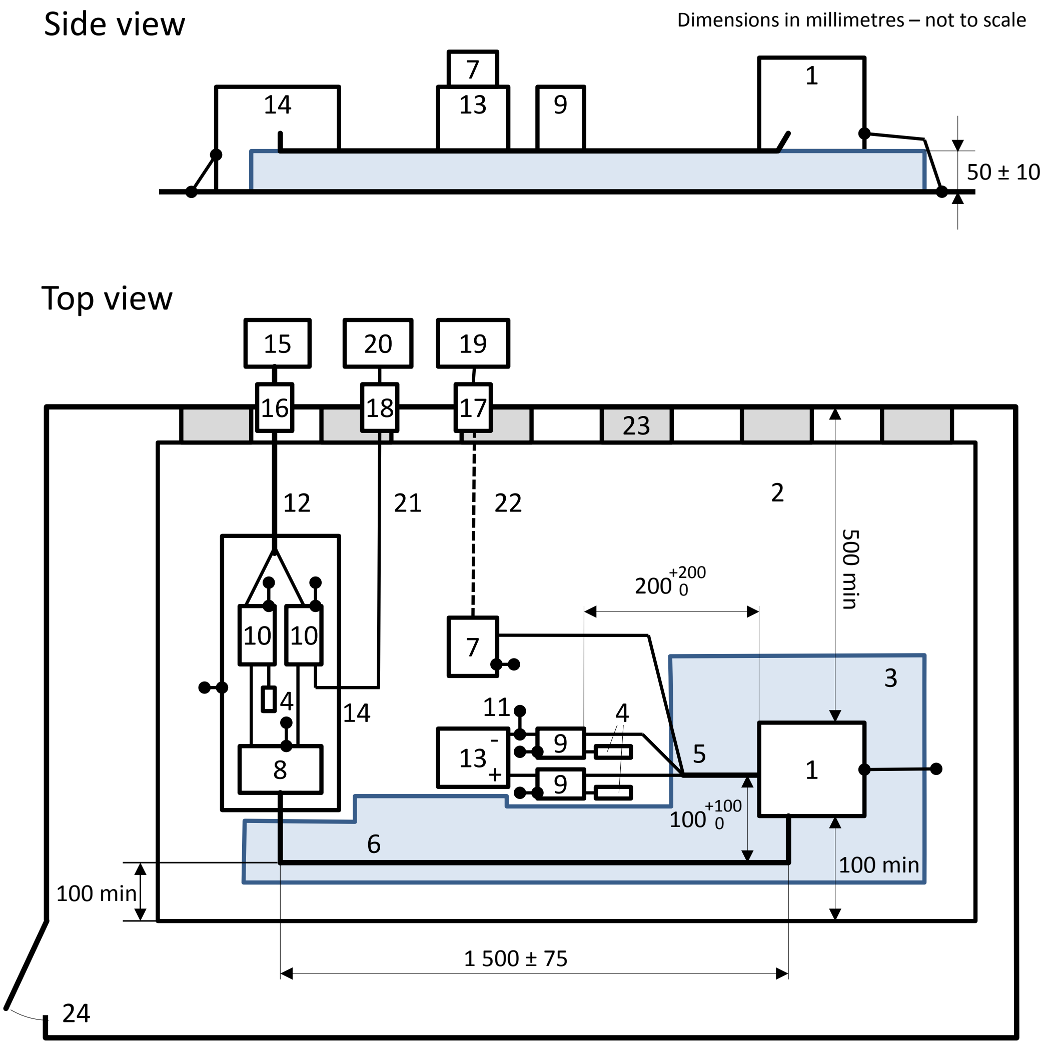
Figure I.2 shows a more complex configuration adding an electric motor or load machine emulation to the setup, e.g. in case the EUT is an electric power unit. The electric motor shall be mounted on a non-conductive insulating support and its housing bonded to the ground plane, if applicable. The load machine emulation shall be placed outside the shielded room. In case of using a load machine emulation, the test plan shall define the connection conditions between the EUT and the load machine emulation and also the necessary grounding conditions. The load machine emulation will replace the “electric motor”, the “mechanical connection”, the “filtered mechanical bearing” and the “brake or propulsion motor”. The three phase motor supply lines will be fed through a power line filter.

The electric motor may be placed on a separate ground plane. In this case, the test plan shall define the connection configuration between this separate motor ground plane and the EUT ground plane (representing the vehicle grounding configuration).

The setup in Figure I.3 is an example for further HV- and LV load simulators and supplies attached to the EUT like e.g. for testing an on-board charger and its communication links. Various combinations of the shown setups are possible based on the true application of the HV component under study (EUT).

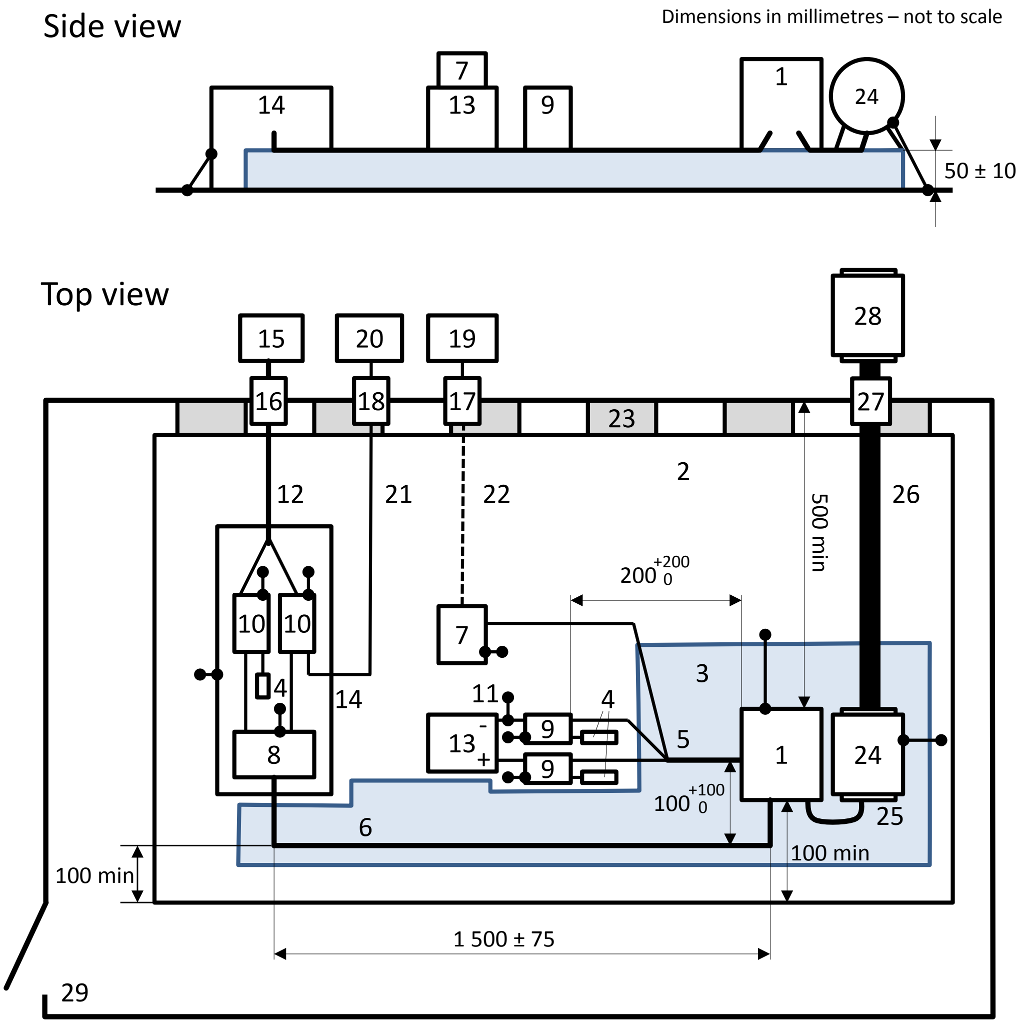
Note 1 Care shall be taken when using a power line filter (Key 16) on the HV supply line. This filter will increase the common mode capacitance between HV+ and ground reference or HV- and ground reference and may lead to the generation of extra resonances.

Note 2 Depending on the package situation in the vehicle and the material used for the chassis (e. g. metal or alternative material) the impedance of the connection of the shielding to the vehicle chassis may vary drastically.



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm
4	50 Ω load
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
15	HV power supply (shielded if placed inside shielded enclosure)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e. g. double shielded (50 Ω)
22	Optical fibre
23	Ground straps
24	Shielded enclosure

Figure I.1 – Conducted emission – example for test setup for EUTs with shielded power supply systems

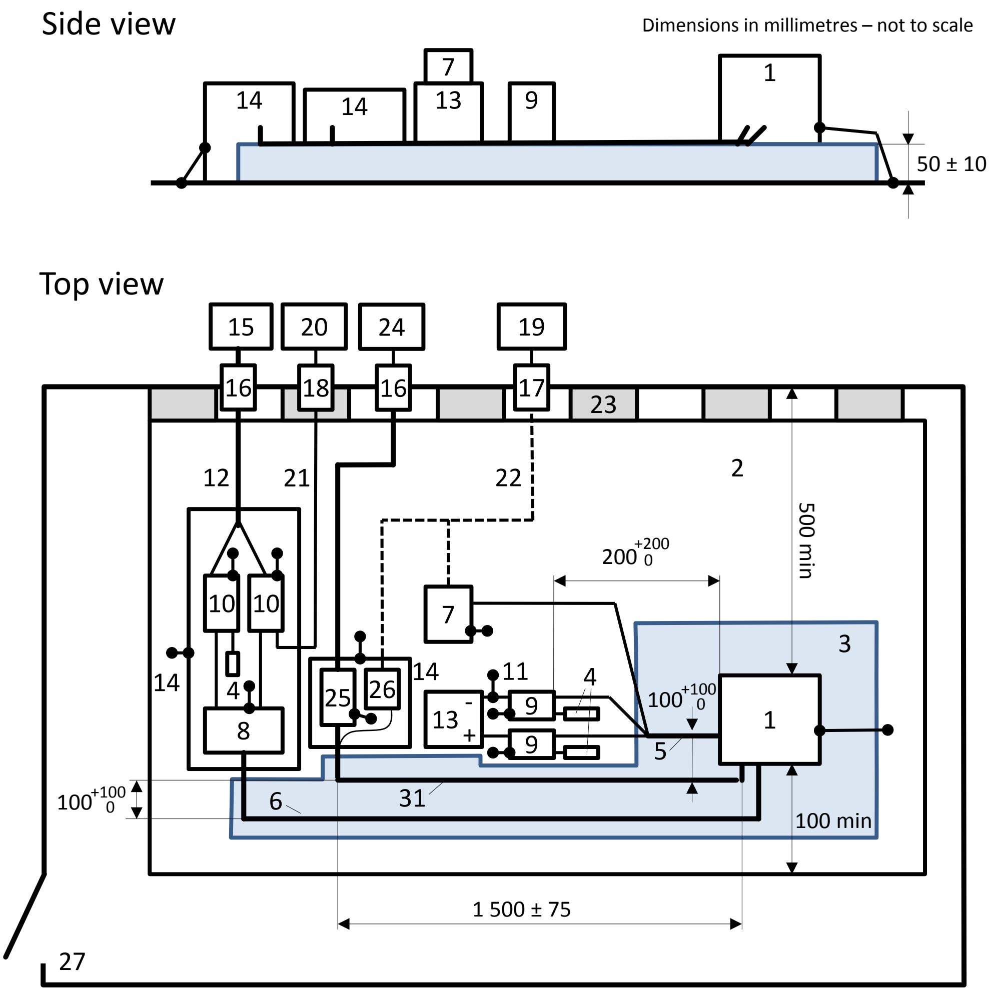


1	EUT	15	HV power supply (should be shielded if placed inside the shielded enclosure)
2	Ground plane	16	Power line filter
3	Low relative permittivity support ($\varepsilon_r \le 1,4$) thickness 50 mm (a non-conductive support can be used for the electric motor)	17	Fiber optic feed through
		18	Bulk head connector
4	50 Ω load	19	Stimulating and monitoring system
5	LV harness	20	Measuring instrument
6	HV lines (HV+, HV-)	21	High quality coaxial cable e. g. double shielded (50 Ω)
7	LV load simulator	22	Optical fibre
8	Impedance matching network (optional)	23	Ground straps
9	LV AN	24	Electric motor
10	HV AN	25	Three phase motor supply lines
11	LV supply lines	26	Mechanical connection (e.g. non-conductive)
12	HV supply lines	27	Filtered mechanical bearing
13	LV power supply 12 V / 24 V / 48 V		

	(should be placed on the bench)
14	Additional shielded box
28	Brake or propulsion motor
29	Shielded enlosure

Note The electric motor, mechanical connection, filtered mechanical bearing and brake or propulsion motor may be replaced by a load machine emulation.

Figure I.2 – Conducted emission – example of test setup for EUTs with shielded power supply systems with electric motor attached to the bench



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm
4	50 Ω load
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
14	Additional shielded box
15	HV power supply (should be shielded if placed inside shielded enclosure)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double shielded (50 Ω)
22	Optical fibre

10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
23	Ground straps
24	a.c. power mains
25	AMN for a.c. power mains
26	a.c. charging load simulator
27	Shielded enclosure
31	a.c. lines

Figure I.3 – Conducted emission - example of test setup for EUTs with shielded power supply systems and inverter/charger device

I.2.3 Limits for conducted emission – Voltage method

The applicable limits are defined taking into account the shielding performance of the overall HV systems. It is determined by coupling between HV- and LV networks. This coupling can be internal to the component or external to the enclosure. Less HV shielding performance results in more severe HV limit classes. HV limit classes from Tables 1 and 2 are determined by the OEM based on his overall HV system knowledge. HV-LV decoupling can be tested according to I.5.

For unshielded systems CISPR25 main body voltage limits of clause 6.3 shall be used.

Basis for limits of Table I.1 are the limits (class 5) from 6.3.3, Table 5 modified by the addition of the required decoupling factors (attenuation) between HV and LV part, see I.5.3.

Table I.1 – Example for limits for conducted voltage measurements at shielded power supply devices

Service / Band	**Frequency** MHz	**Levels in dB(µV)**														
		Class 5			**Class 4**			**Class 3**			**Class 2**			**Class 1**		
		Peak	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**	**Peak**	**Quasipeak**	**Average**
BROADCAST																
LW	0,15 – 0,30	107	94	87	117	104	97	127	114	107	136	123	116	146	133	126
MW	0,53 – 1,8	86	73	66	94	81	74	103	90	83	112	99	92	121	108	101
SW	5,9 – 6,2	81	68	61	89	76	69	97	84	77	106	93	86	114	101	94
FM	76 – 108	57	44	37	64	51	44	71	58	51	78	65	58	85	72	65
TV Band I	41 – 88	53	-	43	60	-	50	67	-	57	75	-	65	82	-	72
TV Band III	174 – 230	Conducted emission – Voltage method Not Applicable														
DAB III	171 – 245															
TV Band IV	468 – 944															
DTTV	470 – 770															
DAB L Band	1447 – 1494															
SDARS	2320 – 2345															
MOBILE SERVICES																
CB	26 – 28	67	54	47	74	61	54	82	69	62	90	77	70	97	84	77
VHF	30 – 54	65	52	45	72	59	52	79	66	59	87	74	67	94	81	74
VHF	68 – 87	57	44	37	64	51	44	71	58	51	79	66	59	86	73	66
VHF	142 – 175	Conducted emission – Voltage method Not Applicable														
Analogue UHF	380 – 512															
RKE	300 – 330															
RKE	420 – 450															
Analogue UHF	820 – 960															
GSM 800	860 – 895															
EGSM/GSM 900	925 – 960															
GPS L1 civil	1567 – 1583															
GLONASS L1	1 591 – 1 613															
GSM 1800 (PCN)	1803 – 1882															
GSM 1900	1850 – 1990															
3G / IMT 2000	1900 – 1992															
3G / IMT 2000	2010 – 2025															
3G / IMT 2000	2180 – 2172															
Bluetooth/802.11	2400 – 2500															

NOTE 1 All values listed in this table are valid for the bandwidths in Tables 1 and 2. If measurements have to be performed with different bandwidths than those specified in Tables 1 and 2 because of noise floor requirements, then applicable limits should be defined in the test plan.

NOTE 2 Where multiple bands use the same limits the user must select the appropriate bands over which to test. – When the test plan includes bands that overlap the test plan shall define the applicable limit.

NOTE 3 Although the limits for Peak, Quasi-Peak and Average detectors are shown, measurements with all three detectors are not required. See Figure 1.

I.3 Conducted emission from components/modules on HV power lines – current probe method

I.3.1 Ground plane arrangement

The location of the EUT, the test harness and the load simulator on the ground plane (table with metal plane) are shown in Figures I.4, I.5 and I.6.

I.3.2 Test setup

The setup shall be as described in 6.4.1 with the extensions according to Figure I.4. The shielding configuration shall be according to the vehicle series configuration. Generally all shielded HV parts shall be properly connected with low impedance to ground (e.g. AN, cables, connectors etc.). EUTs and loads shall be connected to ground using impedance as defined in the test plan. The vehicle HV battery should be used; otherwise the external HV power supply shall be connected via feed-through-filtering.

Unless otherwise specified in the test plan (e.g. use of original vehicle harnesses), the length of harnesses shall be as follows:

- $1700\ ^{+300}_{\ \ 0}$ mm for the LV lines
- $1700\ ^{+300}_{\ \ 0}$ mm for the HV lines and the length of the HV test harness parallel to the front of the ground plane shall be (1500 ± 75) mm.
- less than 1000 mm for the three phase lines between EUT and electric motor(s)

All of the harnesses shall be placed on a non conductive, low relative permittivity material ($\varepsilon_r \leq 1{,}4$) at (50 ± 5) mm above the ground plane. HV lines shall be placed at a minimum distance of 200 mm from the edge of the reference ground plane.

Shielded supply lines for HV+ and HV- lines and three phase lines may be coaxial cables or in a common shield depending on the plug system used. The original HV harness from the vehicle may be used optionally.

Unless otherwise specified in the test plan the case shall be connected to the ground plane either directly or via defined impedance.

– The electric motor may be placed on a separate ground plane. In this case, the test plan shall define the connection configuration between this separate motor ground plane and the EUT ground plane (representing the vehicle grounding configuration). The electric motor shall be mounted on a non-conductive insulating support and its housing bonded to the ground plane, if applicable. In case of using a load machine emulation, the test plan shall define the connection conditions between the EUT and the load machine emulation and also the necessary grounding conditions. The load machine emulation will replace the “electric motor”, the “mechanical connection”, the “filtered mechanical bearing” and the “brake or propulsion motor”. The three phase motor supply lines will be fed through a power line filter.

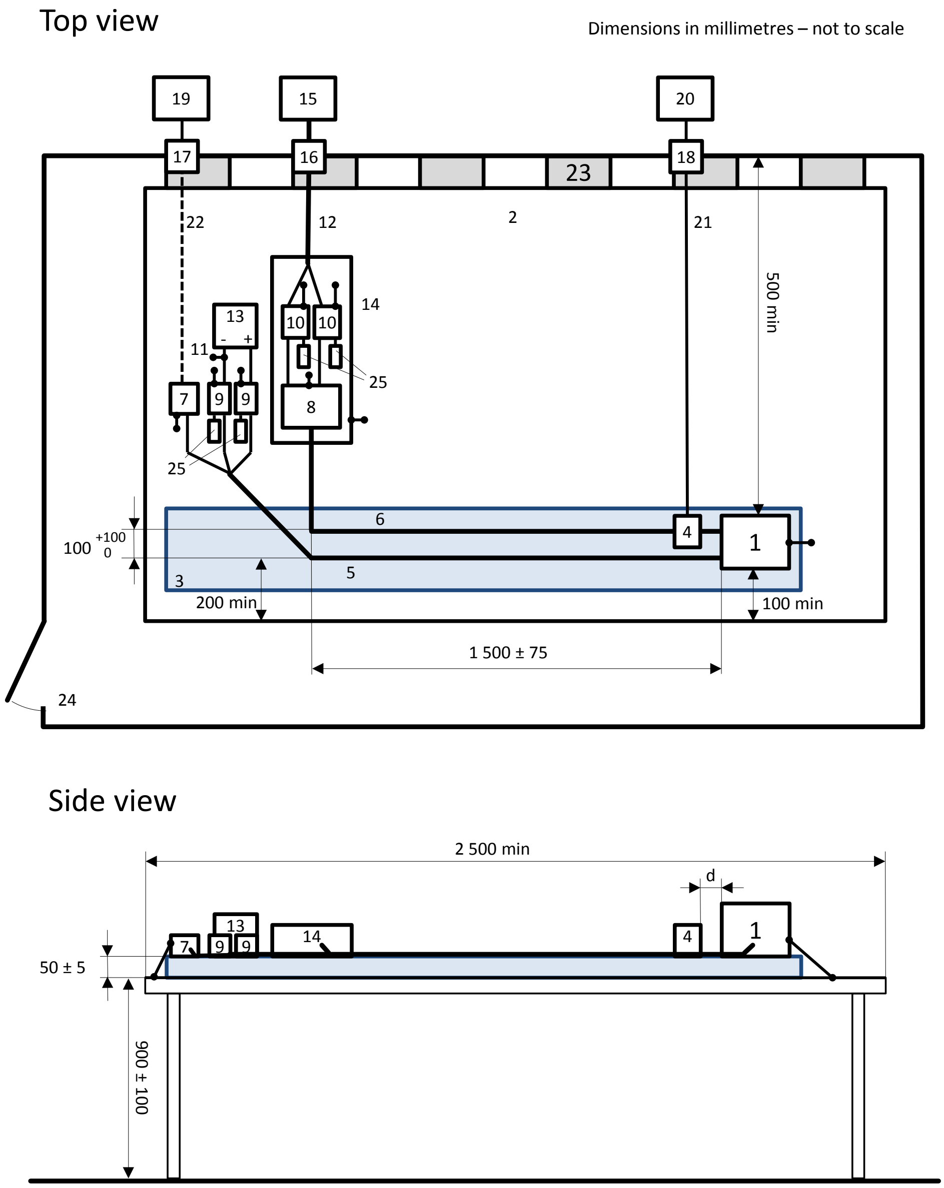
Note 1 Care shall be taken when using a power line filter (Key 16) on the HV supply line. This filter will increase the common mode capacitance between HV+ and ground reference or HV- and ground reference and may lead to the generation of extra resonances.

Note 2 Depending on the package situation in the vehicle and the material used for the chassis (e. g. metal or alternative material) the impedance of the connection of the shielding to the vehicle chassis may vary drastically.

Current probe measurements have to be performed on HV+ and HV- power supply lines, and the three phase lines of the electric motor, separately (if applicable) and commonly. Measure the emission with the probe positioned d = 50 mm and d = 750 mm (depending on harness length) from the EUT.

The deviations of the common test setup have to be defined in the test plan and/or in the test report. If electric motor and power unit is one unit measurement according to Figure I.5 is not applicable (not needed).

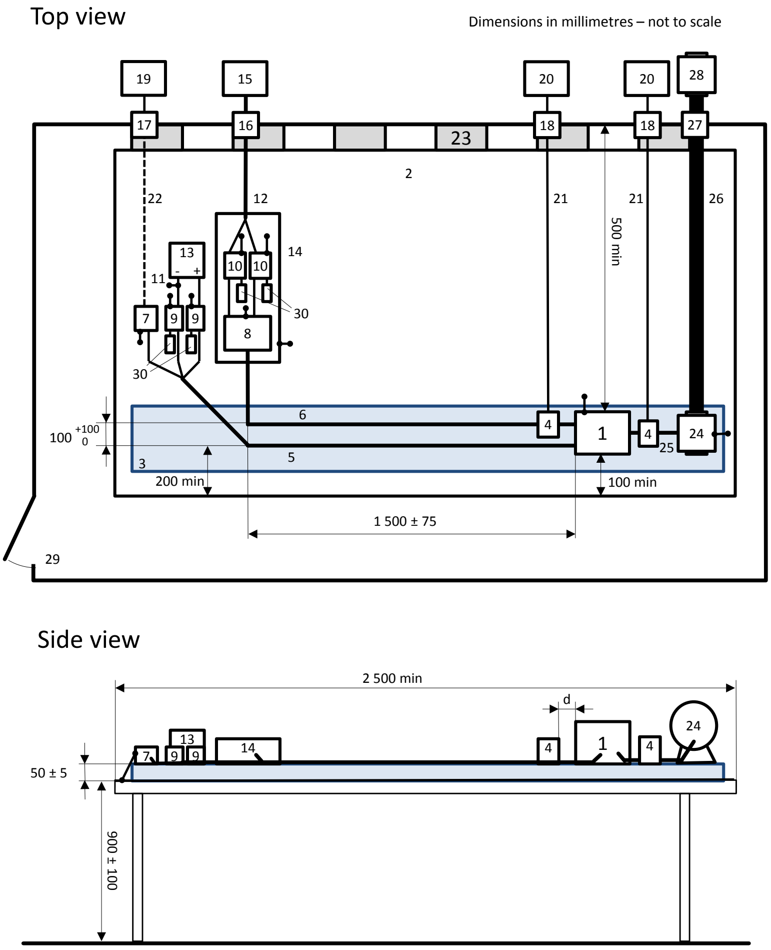
Note 3 Care shall be taken by using a protection earth line which can influence the test result.



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50 mm
4	Current probe (“d” see clause I.4.2)
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
14	Additional shielded box
15	HV power supply (should be shielded if placed inside the shielded enclosure)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double shielded (50 Ω)
22	Optical fibre
23	Ground straps
24	Shielded enclosure

13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)	25	50 Ω load

Figure I.4 – Conducted emission - example of test setup current probe measurement on HV lines for EUTs with shielded power supply systems

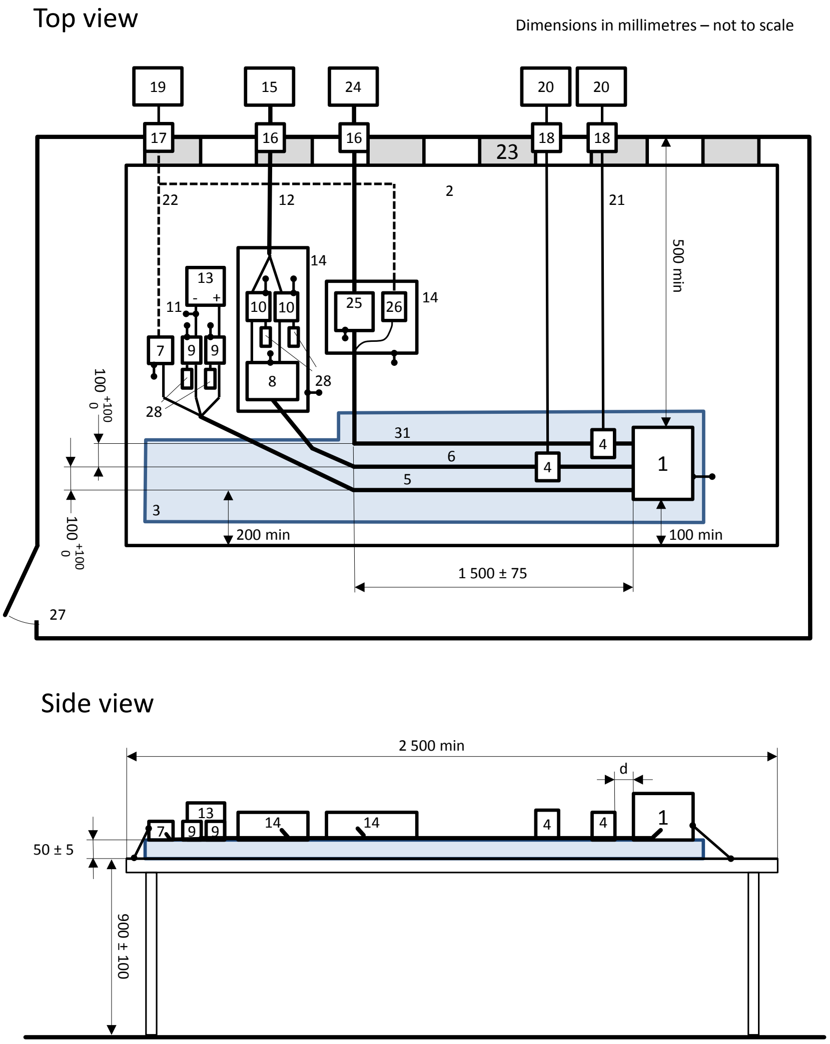


1	EUT	16	Power line filter
2	Ground plane	17	Fiber optic feed through
3	Low relative permittivity support ($\varepsilon_r \leq \leq 1,4$) thickness 50 mm (a non-conductive support can be used for the electric motor)	18	Bulk head connector
		19	Stimulating and monitoring system
4	Current probe (“d” see clause I.4.2)	20	Measuring instrument
5	LV harness	21	High quality coaxial cable e. g. double shielded (50 Ω)
6	HV lines (HV+, HV-)	22	Optical fibre
7	LV load simulator	23	Ground straps
8	Impedance matching network (optional)	24	Electric motor
9	LV AN	25	Three phase motor supply lines
10	HV AN	26	Mechanical connection (e.g. non-conductive)
11	LV supply lines	27	Filtered mechanical bearing
12	HV supply lines	28	Brake or propulsion motor
13	LV power supply 12 V / 24 V / 48 V		

	(should be placed on the bench)
14	Additional shielded box
15	HV power supply (should be shielded if placed inside the shielded enclosure
29	Shielded enclosure
30	50 Ω load

Note The electric motor, mechanical connection, filtered mechanical bearing and brake or propulsion motor may be replaced by a load machine emulation.

Figure I.5 – Conducted emission - example of test setup current probe measurement on HV lines for EUTs with shielded power supply systems with electric motor attached to the bench



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50 mm
4	Current probe (“d” see clause I.4.2)
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e. g. double shielded (50 Ω)
22	Optical fibre

8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
15	HV power supply (should be shielded if placed inside the shielded enclosure
23	Ground straps
24	a.c. power mains
25	AMN for a.c. power mains
26	a.c. charging load simulator
27	Shielded enclosure
28	50 Ω load
31	a.c. lines

Figure I.6 – Conducted emission - example of test setup current probe measurement on HV lines for EUTs with shielded power supply systems and inverter/charger device

I.3.3 Limits for conducted emission – current probe method

For limits see 6.4, Table 6.

I.4 Radiated emissions from components/modules – ALSE method

I.4.1 Ground plane arrangement

The location of the EUT, the test harness and the load simulator on the ground plane are shown in Figures I.7, I.8 and I.9.

I.4.2 Test setup

The setup shall be as described in 6.5.2, Figures 17, 18, 19 and 20 with the extensions according to Figures I.7, I.8 and I.9. The shielding configuration shall be according to the vehicle series configuration. Generally all shielded HV parts shall be properly connected with low impedance to ground (e. g. AN, cables, connectors etc.). EUTs and loads shall be connected to ground using impedance as defined in the test plan. The external HV power supply shall be connected via feed-through-filtering.

Unless otherwise specified in the test plan (e.g. use of original vehicle harnesses), the length of harnesses shall be as follows:

- 1700^{+300}_{0} mm for the LV lines
- 1700^{+300}_{0} mm for the HV lines and the length of the HV test harness parallel to the front of the ground plane shall be (1500 ± 75) mm.
- not larger than 1000 mm for the three phase lines between EUT and electric motor(s)

All of the harnesses shall be placed on a non conductive, low relative permittivity material ($\varepsilon_r \leq 1,4$), at (50 ± 5) mm above the ground plane. The long segment of LV lines test harness shall be located parallel to the edge of the ground plane facing the antenna at a distance of (100 ± 10) mm from the edge. The long segment of the HV lines test harness shall be located at 100^{+100}_{0} mm from the LV lines test harness (as shown in Figures I.7, I.8 and I.9).

Unless otherwise specified in the test plan, the configuration with the long segment of HV lines test harness at a distance of (100 ± 10) mm from the edge and the LV lines test harness located at 100^{+100}_{0} mm from the HV lines shall also be tested.

Shielded supply lines for HV+ and HV- line and three phase lines may be coaxial cables or in a common shield depending on the used plug system. The original HV harness from the vehicle may be used optionally.

Unless otherwise specified in the test plan, the EUT case shall be connected to the ground plane either directly or via defined impedance.

The electric motor may be placed on a separate ground plane. In this case, the test plan shall define the connection configuration between this separate motor ground plane and the EUT ground plane (representing the vehicle grounding configuration). The electric motor shall be mounted on a non-conductive insulating support and its housing bonded to the ground plane, if applicable. In case of using a load machine emulation, the test plan shall define the connection conditions between the EUT and the load machine emulation and also the necessary grounding conditions. The load machine emulation will replace the “electric motor”, the “mechanical connection”, the “filtered mechanical bearing” and the “brake or propulsion motor”. The three phase motor supply lines will be fed through a power line filter.

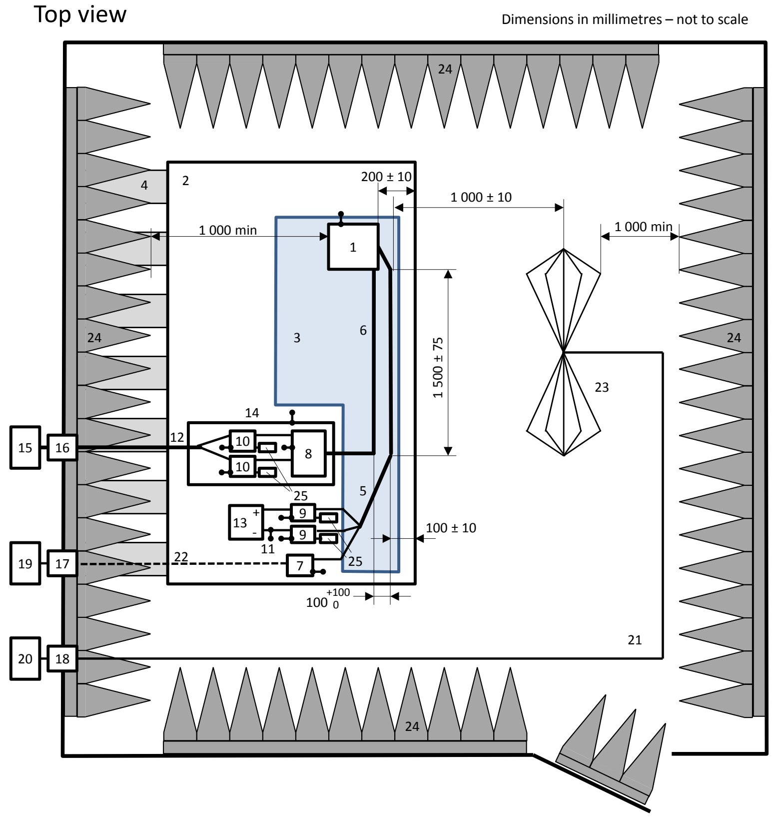
For onboard chargers (see Figure I.9) the a.c. power lines shall be placed the furthest from the antenna (behind LV and HV harness). The distance between the a.c. power lines and the closest harness (LV or HV) shall be 100^{+100}_{0} mm.

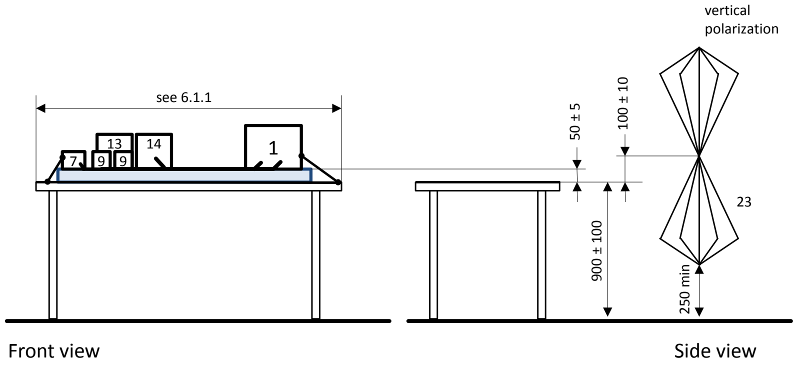
Note 1 Care shall be taken when using a power line filter (Key 16) on the HV supply line. This filter will increase the common mode capacitance between HV+ and ground reference or HV- and ground reference and may lead to the generation of extra resonances.

Note 2 Depending on the package situation in the vehicle and the material used for the chassis (e. g. metal or alternative material) the impedance of the connection of the shielding to the vehicle chassis may vary drastically.

NOTE 3 Care shall be taken by using a protection earth line which can influence the test result.

In this clause the test setup is shown with a biconical antenna. All other antenna types described in this document can be used for the corresponding frequency ranges and antenna configurations (e.g. rod, log-periodic, horn etc.).

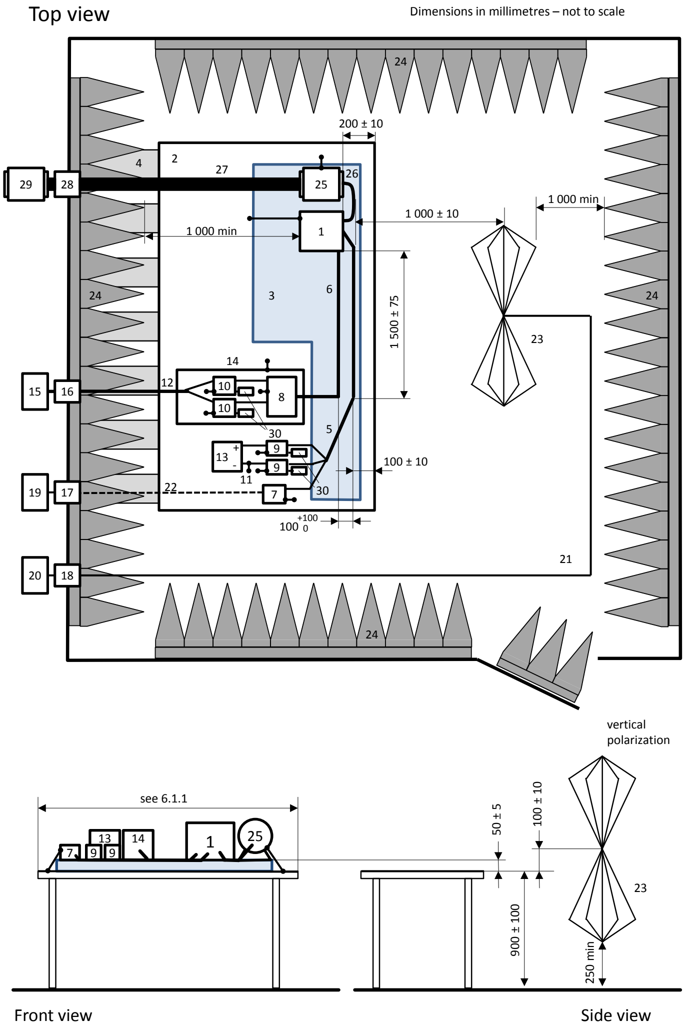




1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50 mm
4	Ground straps
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
14	Additional shielded box
15	HV power supply (should be shielded if placed inside ALSE)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double shielded (50 Ω)
22	Optical fibre
23	Biconical antenna
24	RF absorber material

12	HV supply lines
13	LV power supply 12 V / 24 V / 48 (should be placed on the bench)
25	50 Ω load

Figure I.7 – Radiated emission - example of test setup measurement with biconical antenna for EUTs with shielded power supply systems

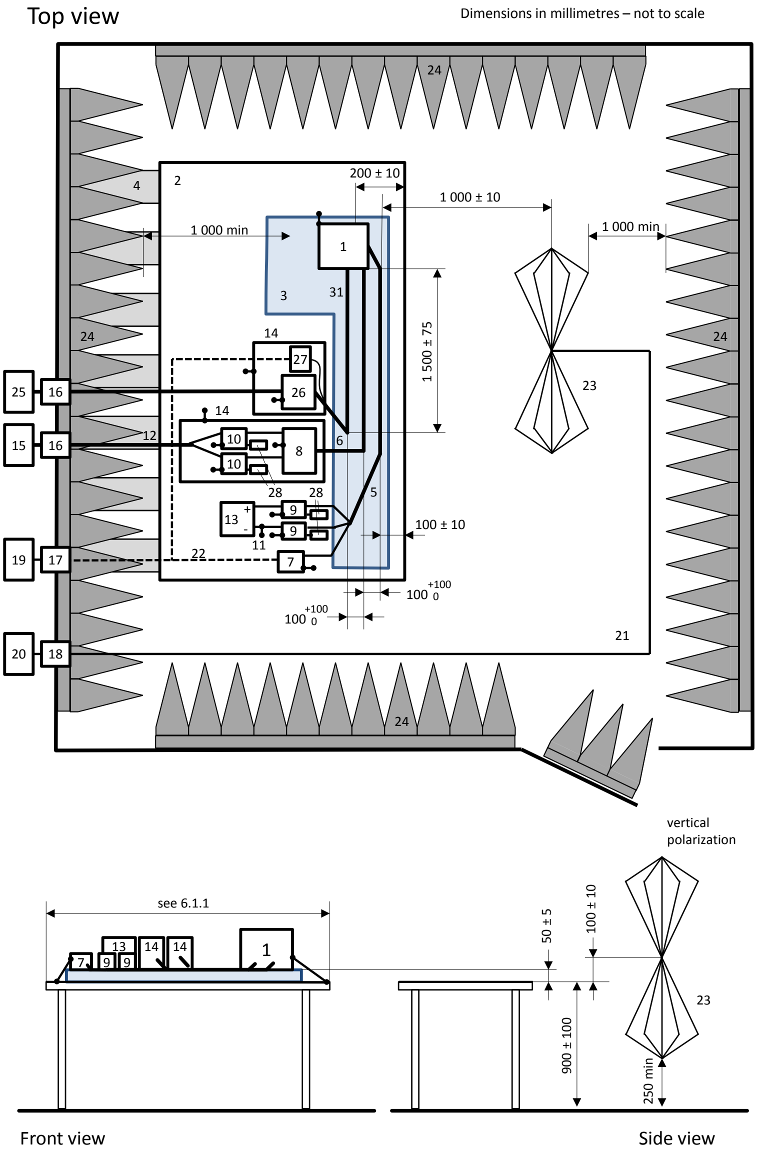


Note The electric motor, mechanical connection, filtered mechanical bearing and brake or propulsion motor may be replaced by a load machine emulation.

1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm (a non-conductive support can be used for the electric motor)
4	Ground straps
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double shielded (50 Ω)
22	Optical fibre
23	Biconical antenna
24	RF absorber material
25	Electric motor
26	Three phase motor supply lines

11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
15	HV power supply (should be shielded if placed inside the ALSE)
27	Mechanical connection (e.g. non-conductive)
28	Filtered mechanical bearing
29	Brake or propulsion motor
30	50 Ω load

Figure I.8 – Radiated emission - example of test setup measurement with biconical antenna for EUTs with shielded power supply systems with electric motor attached to the bench



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm
4	Ground straps
5	LV harness
15	HV power supply (should be shielded if placed inside ALSE)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system

6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
20	Measuring instrument
21	High quality coaxial cable e. g. double shielded (50 Ω)
22	Optical fibre
23	Biconical antenna
24	RF absorber material
25	a.c. power mains
26	AMN for a.c. power mains
27	a.c. charging load simulator
28	50 Ω load
31	a.c. lines

Figure I.9 – Radiated emission - example of test setup measurement with biconical antenna for EUTs with shielded power supply systems and inverter/charger device

I.4.3 Limits for radiated emissions – ALSE method

For limits see 6.5, Table 7.

I.5 Coupling between HV and LV systems

I.5.1 General

In the previous sub clauses HV component limits and corresponding test methods have been described. This sub clause provides test methods to determine the influence of disturbances from the HV side to the LV side.

The coupling between HV and LV systems can be determined

- with measurements (voltage, current, electric field) based on the test setup as defined in I.5.2
- with direct measurement of scattering parameters as defined in I.5.3

The test method to be used shall be agreed between the vehicle manufacturer and the equipment supplier and documented in the test plan.

I.5.2 Measurement based on CISPR 25 test setup defined in the main part

These test setups are based on CISPR 25 test setups defined in the main part. The LV side remains unchanged. The HV side is modified. The EUT shall be in an operational mode as defined in the test plan.

In general, a test signal is injected at the HV+ and the HV- port consecutively. The test level is set to meet the specified HV limits from Table I.1 (average). Signal calibration and monitoring is mandatory.

The test signal shall be applied either by current probe or capacitive coupling. On the LV side the emission is determined using both conducted methods (voltage method and current probe method) and ALSE method.

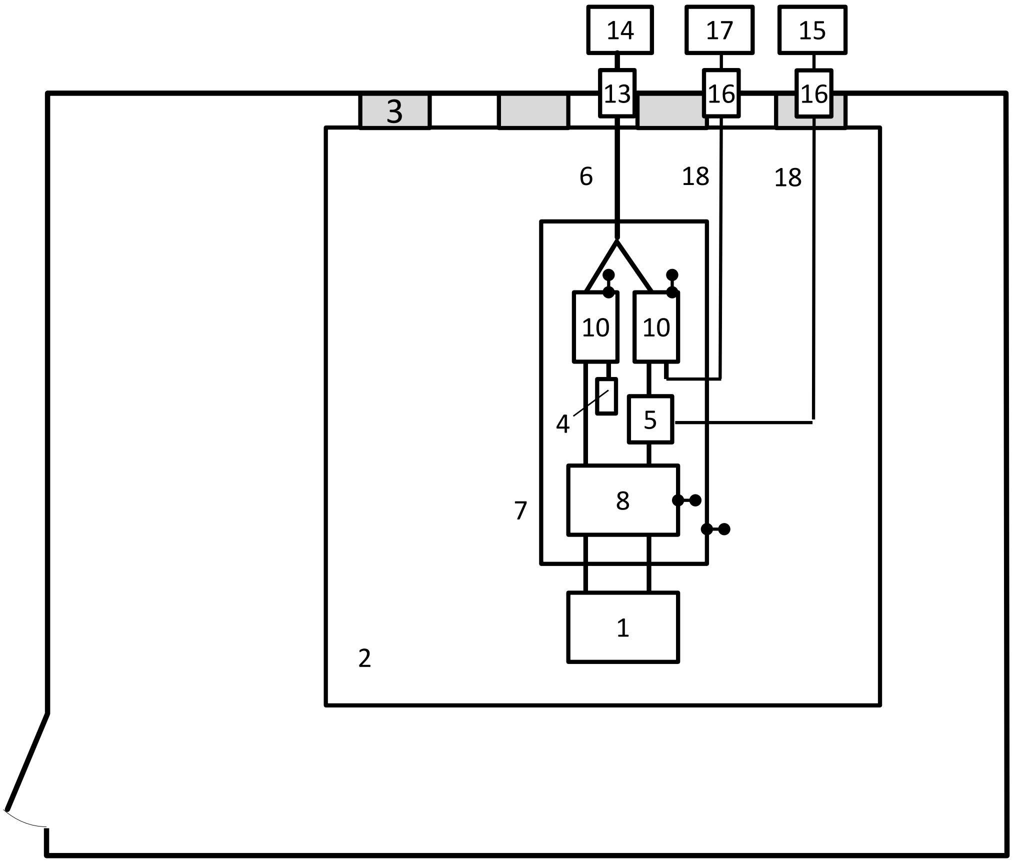
I.5.2.1 describes the calibration procedure to ensure that the test levels on the HV-side are met according to the HV limit class from Table I.1 (average). Test setups for conducted and radiated emission are described in I.5.2.2, I.5.2.3 and I.5.2.4. Coupling measurements shall be performed with all three test setups and the associated requirements.

I.5.2.1 Test Signal Injection and Calibration

The setup for the calibration of the test signal is shown in Figure I.10. The RF power of the test signal is supplied to the coupling element between HV AN and optional impedance matching network, either by injection probe (as defined in ISO 11452-4) or capacitive coupling (as defined in DCC method in ISO 7637-3). For calibration the EUT shall be unpowered.

Measure the output level at the measuring port of the HV AN. Terminate the measuring port of the other HV AN with 50 Ω. The measurement shall be performed in the frequency range from 150 kHz to 108 MHz with a bandwidth of 9 kHz using AV or PK detector. The test signal is set to the specified limit from Table I.1 (average).

Calibration of the test signal shall be performed at the HV+ and HV- ports consecutively.



1	EUT (or EUT simulator)
2	Ground plane
3	Ground straps
4	50 Ω load
5	Test signal coupling element
13	Power line filter
14	Shielded HV power supply (may be placed inside the shielded enclosure)
15	Tracked RF test generator (may be placed inside the shielded box)

(may be current clamp or capacitor)

6 HV supply lines (HV+, HV-)

7 Additional shielded box

8 Impedance matching network (optional)

10 HV AN

16 Bulk head connector

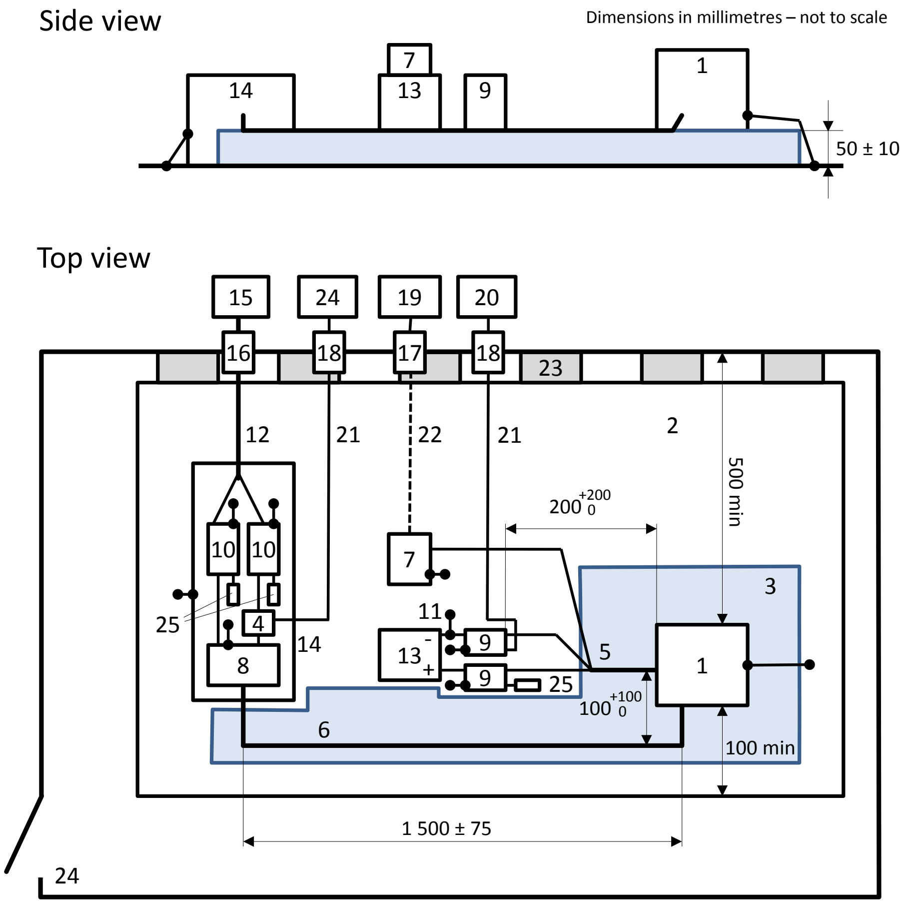
17 Measuring instrument

18 High quality coaxial cable e.g. double shielded (50 Ω)

Figure I.10 – Test setup for calibration of the test signal

I.5.2.2 Conducted Emission – Voltage Method

This method consists of measuring disturbance voltages at the LV side of the power supply. The emission level shall be measured on LV+ and LV- for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits defined in 6.3, Table 5 (average). The setup is shown in Figure I.11. The reference ground plane conditions defined in 6.2.1 (radiated emissions) apply.



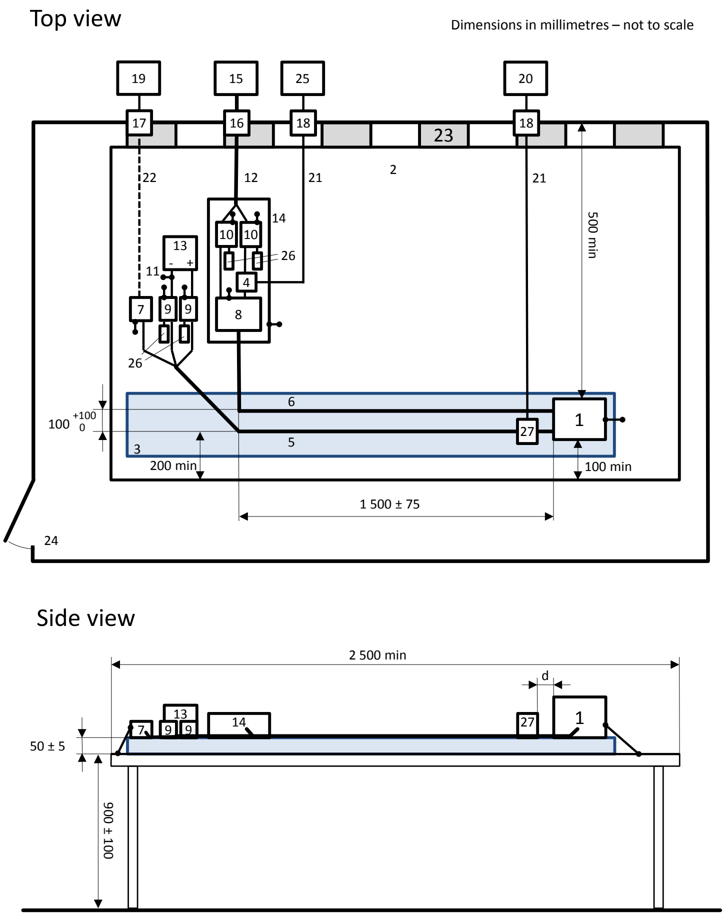
1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1,4$) thickness 50 mm
4	Test signal coupling element (may be current clamp or capacitor)
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
14	Additional shielded box
15	HV power supply (should be shielded if placed inside the shielded enclosure)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double shielded (50 Ω)
22	Optical fibre
23	Ground straps
24	RF generator (may be placed inside the shielded box (14))

13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
25	50 Ω load

Figure I.11 – Conducted emission – test setup for measurement decoupling factor between HV supply ports and LV port

I.5.2.3 Conducted Emission – Current Probe Method

This method consists of measuring disturbance currents at the LV harness side. The emission level shall be measured for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits defined in 6.4, Table 6 (average). The setup is shown in Figure I.12.



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50mm
4	Test signal coupling element (may be current clamp or capacitor)
5	LV harness
6	HV lines (HV+, HV-)
15	HV power supply (should be shielded if placed inside the shielded enclosure)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double

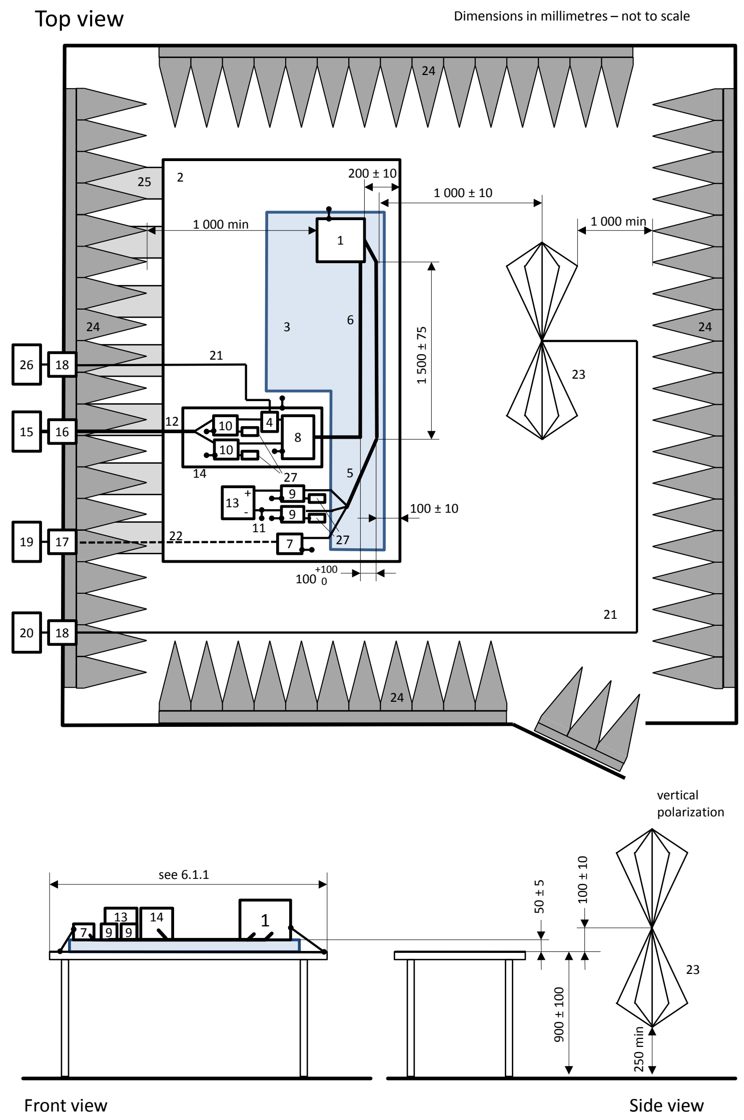
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V (should be placed on the bench)
14	Additional shielded box
	shielded (50 Ω)
22	Optical fibre
23	Ground straps
24	Shielded enclosure
25	RF generator (may be placed inside the shielded box (14))
26	50 Ω load
27	Current clamp

Figure I.12 – Conducted emission - test setup for measurement decoupling factor between HV supply ports and LV ports with current probe

I.5.2.4 HV-specific Radiated Emission Test

This method consists of measuring radiated emissions from the whole set up. The emission level shall be measured for each test signal injection configuration. The measured level shall not exceed the corresponding LV emission limits defined in 6.5, Table 7 (average). The setup is shown in Figure I.13.

The antenna to be used for the measurements shall be as defined in 6.5.2.1. In this clause the test setup is shown with a biconical antenna as an example.



1	EUT
2	Ground plane
3	Low relative permittivity support ($\varepsilon_r \leq 1{,}4$) thickness 50mm
4	Test signal coupling element (may be current clamp or capacitor)
5	LV harness
6	HV lines (HV+, HV-)
7	LV load simulator
8	Impedance matching network (optional)
9	LV AN
10	HV AN
11	LV supply lines
12	HV supply lines
13	LV power supply 12 V / 24 V / 48 V
15	HV power supply (should be shielded if placed inside ALSE)
16	Power line filter
17	Fiber optic feed through
18	Bulk head connector
19	Stimulating and monitoring system
20	Measuring instrument
21	High quality coaxial cable e.g. double shielded (50 Ω)
22	Optical fibre
23	Biconical antenna
24	RF absorber material
25	Ground straps
26	RF generator (may be placed inside the shielded box (14))

	(should be placed on the bench)	27	50 Ω load
14	Additional shielded box		

Figure I.13 – Radiated emission - test setup measurement decoupling factor between HV supply ports and LV ports with biconical antenna

I.5.3 Measurement of the HV-LV Scattering parameters

I.5.3.1 General

Clause I.5.3 describes the measurement of the decoupling factors between high voltage d.c. lines and the low voltage lines of electric/electronic components.

This part provides information on how the decoupling factor (attenuation level) can directly be measured.

The measurements shall be performed with a network analyser in two steps

- full-port calibration
- measurement with the EUT unpowered

I.5.3.2 Network analyser parameter

The following parameters should be used for a network analyser

- power level: 0 dBm (recommended; depending on needed dynamic range, higher values may be necessary)
- minimum averaging factor: 8
- minimum number of points (with logarithmic sweep) : 401
- maximum IF bandwidth : 1 kHz

I.5.3.3 Calibration

A full-port calibration shall be performed including only the network analyser coaxial measuring cables.

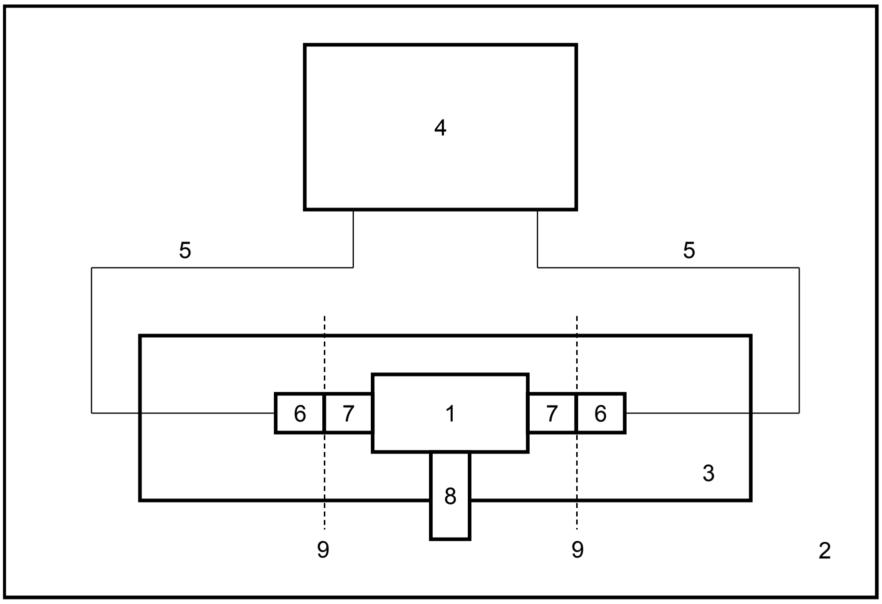
I.5.3.4 EUT measurement

The EUT measurement shall be performed according to Figure I.14 with the EUT unpowered (with only network analyzer measuring coaxial cables and without any LV/HV lines).

The EUT is placed on an insulating support (50 ± 5) mm above the ground plane.

Unless otherwise specified in the test plan the EUT case shall be bonded to the ground plane with a copper strap (maximum length to width ratio of 4:1). The d.c. resistance between the EUT case and ground plane shall not exceed 2,5 mΩ.

Care shall be taken concerning the adaptors used between the EUT terminals and the network analyser coaxial measuring cables particularly to ensure the lowest possible impedance between the coaxial measuring cable shield and the EUT case.



1 EUT
2 Ground plane
3 Low relative permittivity support ($\varepsilon_r \le 1,4$) thickness 50 mm
4 Network analyzer
5 High quality coaxial measuring cable e.g. double shielded (50 Ω),
6 Network analyzer coaxial measuring cable connector
7 Adaptors
8 EUT Bonding connection
9 Reference plane for network analyzer calibration

Figure I.14 – Test setup for EUT measurements

Coupling attenuation measurements S_{21EUT} shall be performed for the configurations defined in Table I.2 (for equipment without negative LV line) or to Table I.3 (for equipment with negative LV line).

The test plan shall define the EUT internal configuration(s) to be tested in order to ensure that the S_{21EUT} worst case is measured (e.g. mechanical or electronic switches state)

Table I.2 – Configurations for equipment without negative LV line

Measuring configuration		
	Port 1	**Port 2**
Configuration 1	Positive d.c. HV line	Positive LV line
Configuration 2	Negative d.c. HV line	Positive LV line

Table I.3 – Configurations for equipment with negative LV line

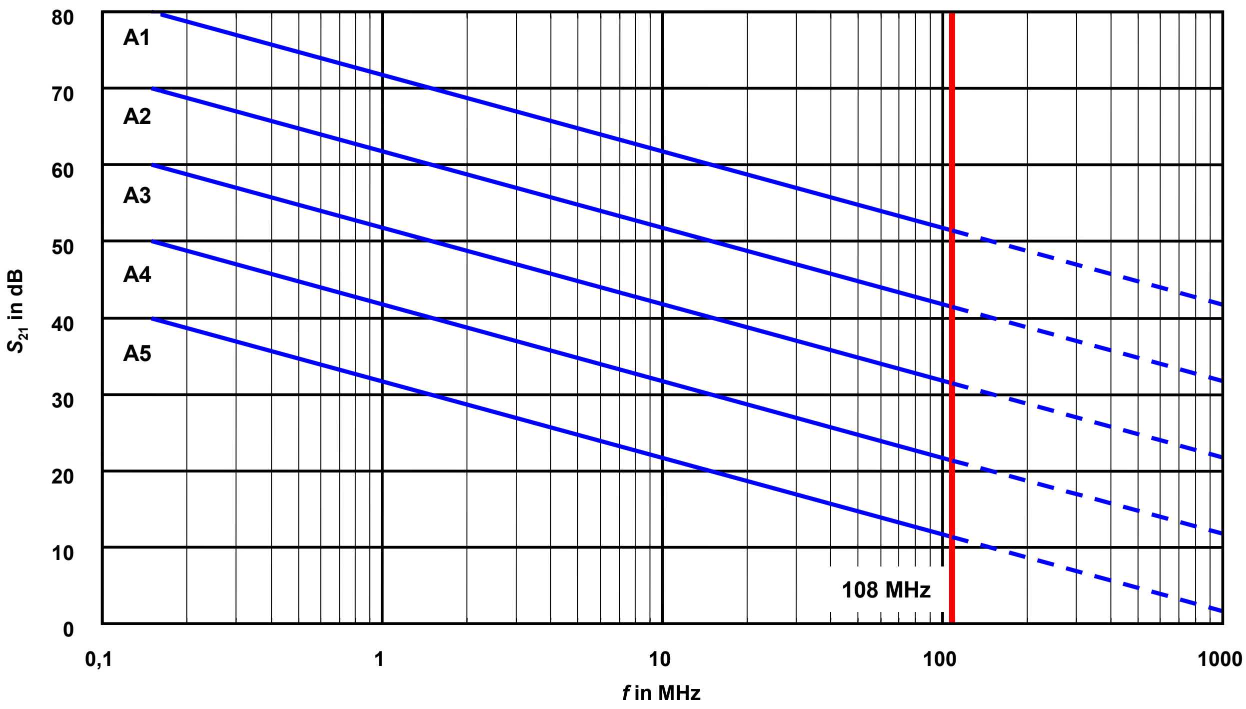
Measuring configuration		
	Port 1	**Port 2**
Configuration 1	Positive d.c. HV line	Positive LV line
Configuration 2	Negative d.c. HV line	Positive LV line
Configuration 3	Positive d.c. HV line	Negative LV line
Configuration 4	Negative d.c. HV line	Negative LV line

I.5.3.5 Requirement

Examples for requirements are given Table I.4 and Figure I.15.

Table I.4 – Examples of requirements for S_{21EUT}

Frequency in MHz	Class	Minimum attenuation S_{21} in dB
0,15 - 1000	A1	80 - 10 × lg (f_{MHz}/0,15)
	A2	70 - 10 × lg (f_{MHz}/0,15)
	A3	60 - 10 × lg (f_{MHz}/0,15)
	A4	50 - 10 × lg (f_{MHz}/0,15)
	A5	40 - 10 × lg (f_{MHz}/0,15)



The decoupling factor above 108 MHz is informative

2316 **Figure I.15 – Examples of requirements for S_{21EUT}.**

2317

2318

Annex J
(informative)

ALSE Performance Validation 150 kHz – 1 GHz

J.1 Introduction

This annex contains requirements for the validation of the ALSE used for component tests described in 6.5. This annex contains two procedures, either of which can be used for validation of the ALSE (both methods are not required). See flowchart in Figure J.2 for a visual representation of the ALSE validation process. The validation procedures are designated as follows:

Reference Measurement Method: This method uses a reference test site for the reference measurements. A reference test site is an OATS or alternative test site, (e.g. weather-protected OATS or semi-anechoic chamber) which meets the requirements of CISPR 16-1-4. Reference measurements, which are similar to Normalized Site Attenuation (NSA) measurements, are made on the reference test site with a standard ground plane (site or ALSE floor ground plane below 30 MHz, elevated 2,5 m x 1 m validation reference ground plane at 30 MHz and above). Corresponding measurements are then made in the ALSE. The reference measurements are compared to the ALSE measurements to determine if the ALSE measurements are within a defined tolerance (see J.2.4).

Modelled Long Wire Antenna Method: This method uses a 50 cm “long wire” antenna as the transmitting antenna. At frequencies below 30 MHz, the long-wire antenna was modelled using a floor (non-elevated) ground plane. At frequencies 30 MHz and above, the long-wire antenna was modelled with an elevated validation reference ground plane of a standard size (2,5 m x 1 m). Measurements are made on the long-wire antenna in the ALSE. The ALSE measurements are compared to the modelled fields in order to determine if the ALSE measurements are within a defined tolerance (see J.3.4).

Both the Reference Measurement Method and Modelled Long Wire Antenna Method utilize a standard size validation reference ground plane for the reference measurements and modelling. At frequencies below 30 MHz, a floor (non-elevated) ground plane (e.g. the floor of an ALSE, OATS or alternative test site is the standard. The decision to use the same type of validation reference ground plane for both methods was based on the research work described in the first reference document of section J.4, where a standard environment using a TEM cell was investigated, and found to give the same results as those from measurements using the floor ground plane approach. At frequencies above 30 MHz, an elevated validation reference ground plane with the dimensions of 2,5 m x 1 m is the standard. The validation reference ground plane size and grounding used during the reference measurements and modelling will be different than what a laboratory would use in the ALSE during EUT measurements. Not all ALSEs are constructed and setup identically and will therefore be different from the standardized validation reference setup in some way. The purpose of this validation procedure is to compare the standardized validation reference setup data (either measured or modelled) with the results from an ALSE used for CISPR 25 radiated emissions testing on an EUT to assure that the deviations due to the ALSE setup differences are within a reasonable tolerance.

The ALSE configured as it normally used during EUT test may not initially meet the requirements specified in this annex.

The following setup parameters have a significant influence on the results obtained for chamber validation:

- Reference ground plane size
- Reference ground plane bonding straps (number, size, horizontal versus vertical)

– Absorber performance

If the chamber validation requirements are not met, modifications on one or more of the previous influent parameters should help to improve the ALSE performance within the tolerance specified in this annex.

Some parameters, their specifications and tolerances defined in CISPR25 are known to be influent in the setup and could lead to excessive deviations. On the frequency range between 10 MHz and 100 MHz, the ground plane size, its connections and the absorbers performances, even with the CISPR specifications are the most important ones. Figure J.1 summarizes the influence levels of these parameters over the particular 10 – 100 MHz frequency range.

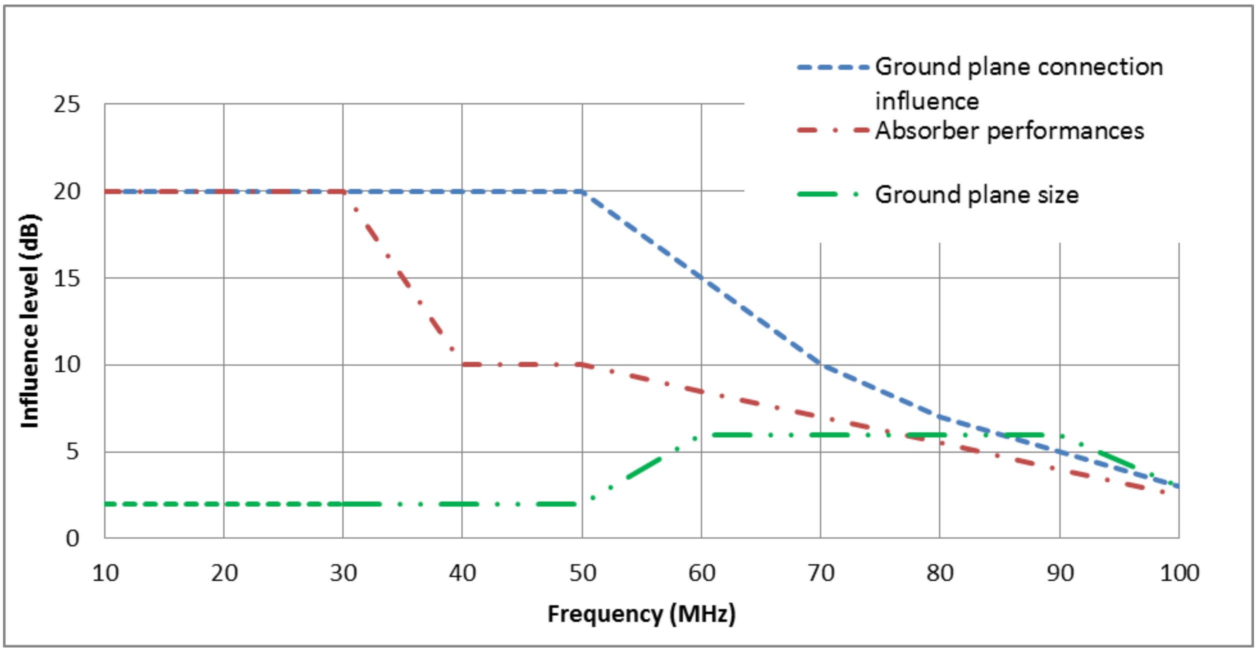


Figure J.1 – ALSE influence parameters over the 10 – 100 MHz frequency range

Note 1 Between 10 and 30 MHz the most important parameters are the ground plane connection and the absorbers performances. The influence of the ground plane size is more a shift in the resonances observed linked to the first previous parameters.

Note 2 The influence of each parameter had been evaluated individually. When mixed together their influence can be more important.

The validation procedures of this annex have intentionally been limited to the frequency range of 150 kHz to 1 GHz. Studies performed during the development of this annex showed that the absorber materials and reference ground plane grounding utilized in the ALSE will generally create the largest measurement deviations at frequencies below 200 MHz. Therefore, it was decided to limit the chamber validation upper frequency to 1 GHz. Validation methods above 1 GHz are being considered as future work.

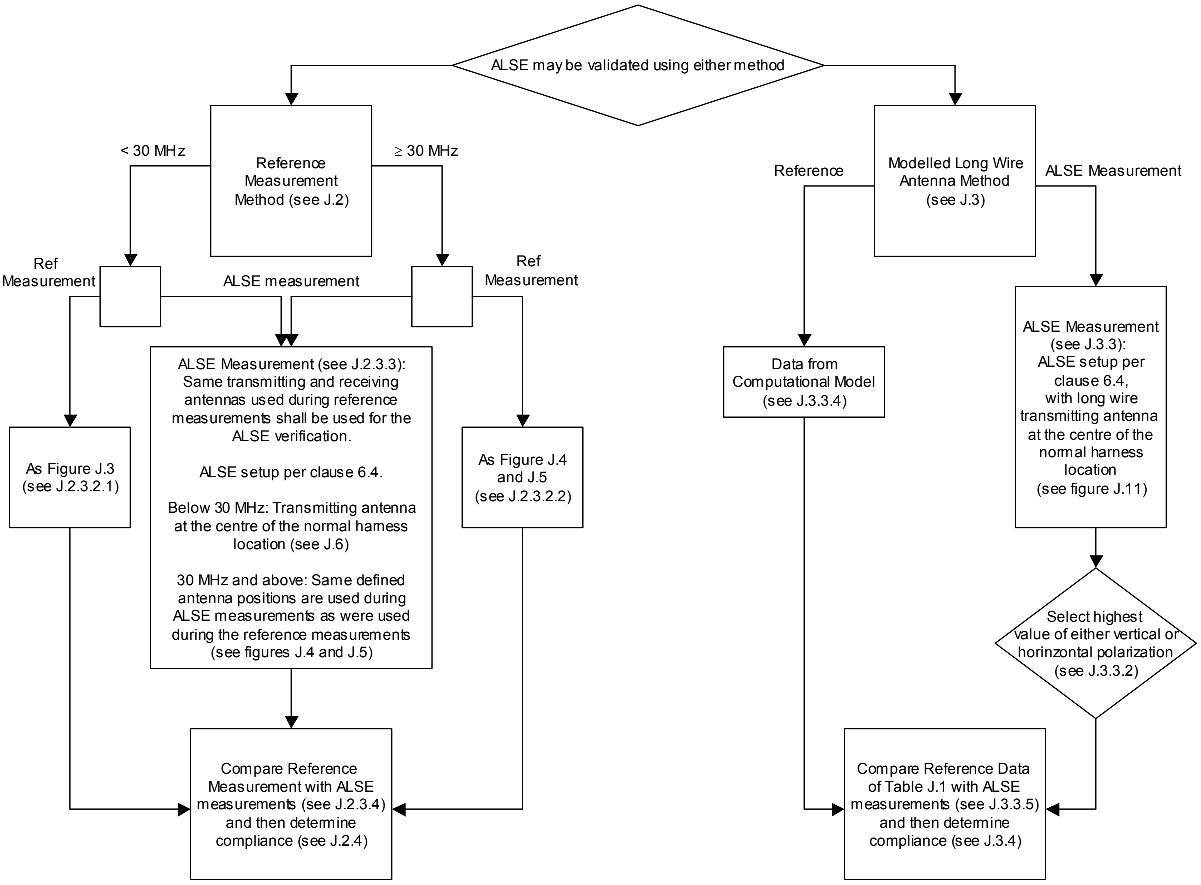


Figure J.2 – Visual Representation of ALSE Performance Validation Process

J.1.1 Purpose

During a component test, the measured electric field should be characteristic of the EUT only and the impact of the ALSE should be minimized. The EUT measurement data should vary as little as possible if the measurements are performed in different ALSEs and/or at different locations. The aim of this annex is to control the effects of the ALSE. ALSEs which meet the requirements of this annex will show less deviation in EUT data.

J.1.2 Repetition period of ALSE validation measurements

The measurements described in this annex should be performed after any major changes to the ALSE, EUT reference ground plane bonding, and/or test facility layout.

J.2 Reference measurement method

J.2.1 Overview

The validation method described below has the following aspects:

- A small monopole, biconical or shortened dipole transmitting antenna is used.

- A reference (ideal) measurement is taken in an Open Area Test Site (or similar) environment with a standardized setup that differs from the setup used in the ALSE that is to be evaluated as defined in J.2.3.2 (see J.1 for more information).
- An ALSE measurement is taken with the setup as described in 6.5
- The deviation of the reference and ALSE measurements are to be within a defined tolerance (see J.2.4).

J.2.2 Equipment

J.2.2.1 Transmission and measuring equipment

The methods in this annex define measurements of the transmission coefficient (see J.2.3.1.1) between a transmitting and receiving antenna. These measurements should be made with RF instrumentation having a nominal output or input impedance of 50 Ω. Examples include:

- a network analyser,
- a spectrum analyser or measurement receiver with a tracking generator,
- a signal generator and a spectrum analyser or measurement receiver,

J.2.2.2 Transmitting antenna

The cable connecting the transmitting antenna to the signal source may affect the verification results of the ALSE. Ferrites are to be used on the cable to minimize coupling effects. The cable should also be routed immediately towards the back of the reference ground plane, away from the receiving antenna and placed directly on the reference ground plane.

Note It is highly recommended that ferrites, with a minimum impedance of 50 Ω at 25 MHz and 110 Ω at 100 MHz, be placed on the transmitting and receiving antenna cables every 20 cm along its entire length within the ALSE being validated.

In the frequency range below 30 MHz, a short passive monopole transmitting antenna is used in vertical polarization as the transmitting antenna. It should have the following characteristics:

- Overall height of monopole, including drive unit < 500 mm
- Monopole diameter < 10 mm
- Optional top loading disc diameter < 120 mm

Note It is possible to construct a suitable transmitting monopole using the photographs in Figure J.3. Three ports are shown on this antenna base. During use as a radiator, the third port may be terminated with 50 Ω or may be unterminated. Leaving the third port un-terminated will result in an increase of the reference signal by approximately 6 dB. This could be useful in cases where reference signal amplitude adjustments are needed to overcome ambient or measurement system sensitivity issues. In either case, the same transmitting antenna loading is used during the reference and ALSE measurements.

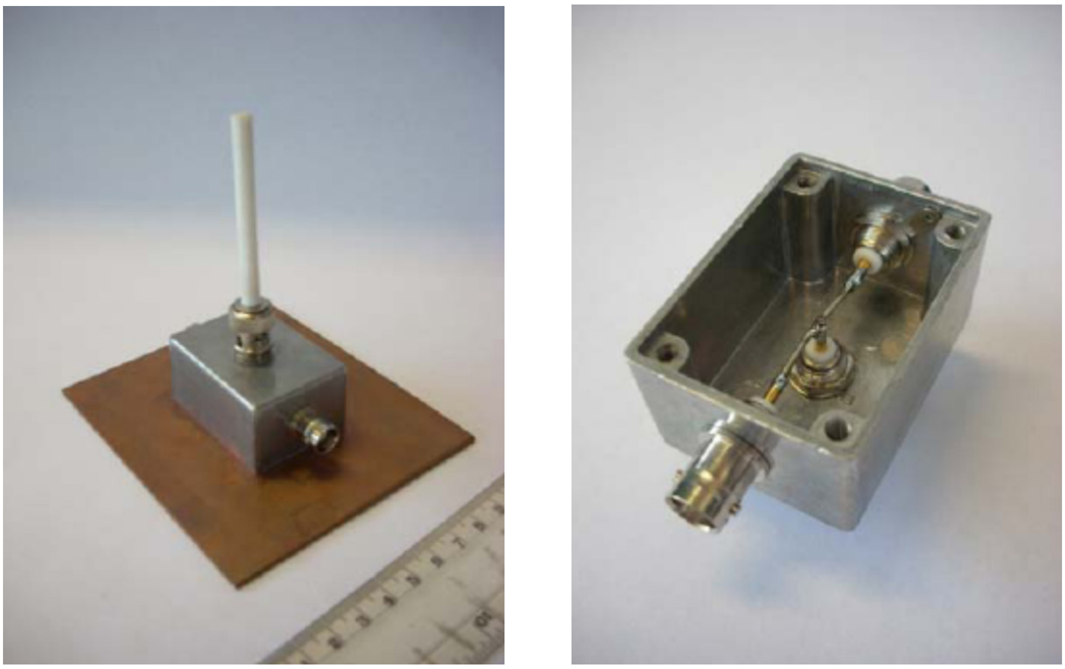


Figure J.3 – Example of construction of a transmitting monopole

In the frequency range 30 MHz and above, a small transmitting antenna (e.g. small biconical or shortened dipole) is used in the same location as the EUT harness is normally placed during component measurements. Verification measurements are made in horizontal and vertical polarization. The maximum dimension (tip to tip) of the small transmitting antenna shall be ≤ 40 cm.

Note Care should be taken to use the same element orientation for both the reference and validation testing.

J.2.2.3 Receiving antenna

The receiving antenna used is the same as described in 6.5. Because relative measurements are performed, the antenna factors of the transmitting and receiving antenna do not need to be considered.

The transmitted power should be chosen such that an overload condition does not occur in the measurement system. This can be verified by reducing the transmitted power by 10 dB and verifying that the transmission coefficient does not vary.

J.2.3 Procedure

J.2.3.1 General requirements

J.2.3.1.1 Transmission coefficient measurement

The measurements described in this annex serve the purpose to determine the transmission coefficient (C_T in dB) between the input of a transmitting antenna and the output of a receiving antenna. This includes a “direct” measurement (M_0 in dB(μV)) with the RF feed cable and receiving antenna cable connected directly together. A separate measurement (M_A in dB(μV)) is then made with the RF feed cable connected to the transmitting antenna and the receiving antenna cable connected to the receiving antenna. The transmission coefficient is then calculated as follows:

$$C_T = M_A - M_0 \tag{J.1}$$

Note 1 The magnitude of an S21 network analyser measurement that has a valid “thru” calibration has the same value as C_T.

Note 2 C_T has the same magnitude but opposite sign to insertion loss.

J.2.3.1.2 Frequency step size

The frequencies to be used for the measurements are given in Table J.1. The same frequencies will be used for the reference and ALSE measurements. A total of 481 frequencies are used during the measurements; 150 frequencies 150 kHz – 29.95 MHz (step size: 200 kHz), 170 frequencies 30 MHz – 199 MHz (step size: 1 MHz), and 161 frequencies 200 MHz – 1000 MHz (step size: 5 MHz).

J.2.3.1.3 Noise floor

An initial “noise floor” transmission coefficient measurement will be made. For this measurement the receiving antenna will be connected to the test instrumentation, but the transmitting antenna will be disconnected from the RF feed cable. All subsequent transmission measurements will be made with the same measurement instrumentation settings (e.g. transmitted power level, resolution bandwidth, video bandwidth, detector, input attenuation, etc.) and must be at least 10 dB above the level measured in this “noise floor” measurement.

J.2.3.2 Reference measurements

A reference transmission coefficient measurement ($C_{T\ Reference}$) will be made with the antennas setup as shown in Figures J.4, J.5 and J.6.

J.2.3.2.1 Reference measurements below 30 MHz

Because the decay of the electric field at these frequencies in the vicinity of the monopole is proportional to $1/r^3$, it is permissible in the following circumstances to use the conductive floor (non-elevated ground plane) of an ALSE, instead of an OATS, to make the reference measurement. If the floor is covered with some type of material (e.g. floor tiles or carpeting), then a minimum 1,5 m x 1 m ground surface is placed on and grounded to the ALSE floor (d.c. resistance ≤ 2,5 mΩ). The transmitting and receiving monopole antenna counterpoises are bonded to the conductive floor or ground surface during the reference measurements in an ALSE and/or OATS. If a receiving monopole antenna with elevated counterpoise is used, then the counterpoise shall be grounded to the floor at the front of the counterpoise nearest the transmitting monopole antenna (for the entire width of the counterpoise). When the reference measurements are performed in an ALSE, then the following sequence applies:

1) With the monopole antennas on the grounded floor surface, at least three transmission coefficient reference measurements will be made with each measurement having the pair of antennas moved more than 0,3 m from any other measurement position.
2) If the difference (Δ) of the three reference measurements is less than 2 dB, any one of them can be used as the reference measurement.
3) If the difference (Δ) of the three reference measurements is greater than 2 dB, then the ALSE site cannot be used for the reference measurements. The reference measurements must then be made at a different site (ALSE and/or OATS) which meets the conditions of #2.

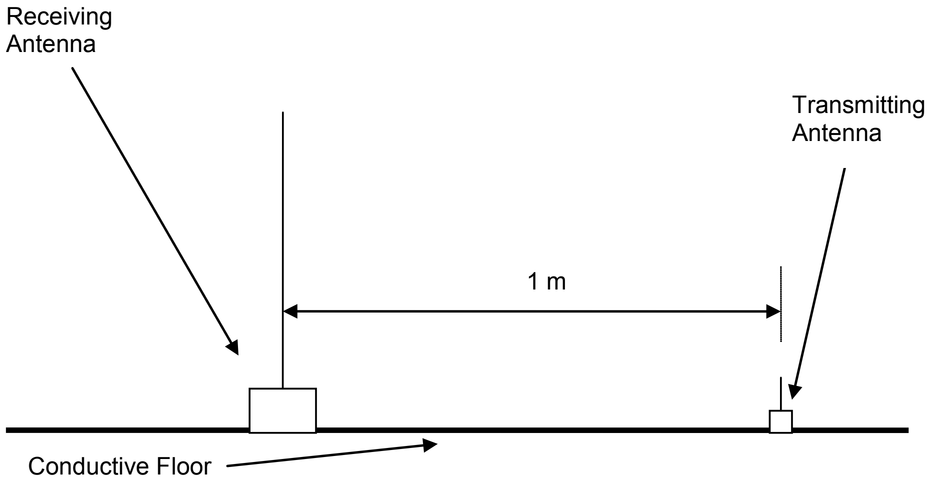


Figure J.4 – Side view of antenna configuration for reference measurement below 30 MHz

J.2.3.2.2 Reference measurements at 30 MHz and above

The reference measurements at 30 MHz and above will be made on a reference test site. A reference test site is an OATS or alternative test site (e.g. weather-protected OATS or semi-anechoic chamber) which meets the requirements of CISPR 16-1-4, Clauses 5.6.2 and 5.3.2 respectively.

An elevated validation reference ground plane (see 3.27) is required for the reference measurements at 30 MHz and above. The elevated validation reference ground plane will have a standard dimension of 2,5 m x 1 m and is bonded to the reference test site ground plane floor surface. Grounding of the elevated validation reference ground plane to the reference test site ground plane will be achieved by using single strap with a width of 100 -0/+100 mm which is centred on the centre point of the rear length of the validation reference ground plane (see Figure J.13 for a drawing of the validation reference ground plane and the single strap grounding). The bond between the validation reference ground plane and the reference test site ground plane should be less than 2.5 mΩ. The 2,5 m x 1 m elevated validation reference ground plane is a standard size that is used for all reference measurements. This is not necessarily the same reference ground plane which is used during EUT testing and the ALSE measurements of J.2.3.3 (see J.1 for more information). The transmitting and receiving antennas will remain in one location (centred on the centre point of the elevated reference ground plane) for all measurements.

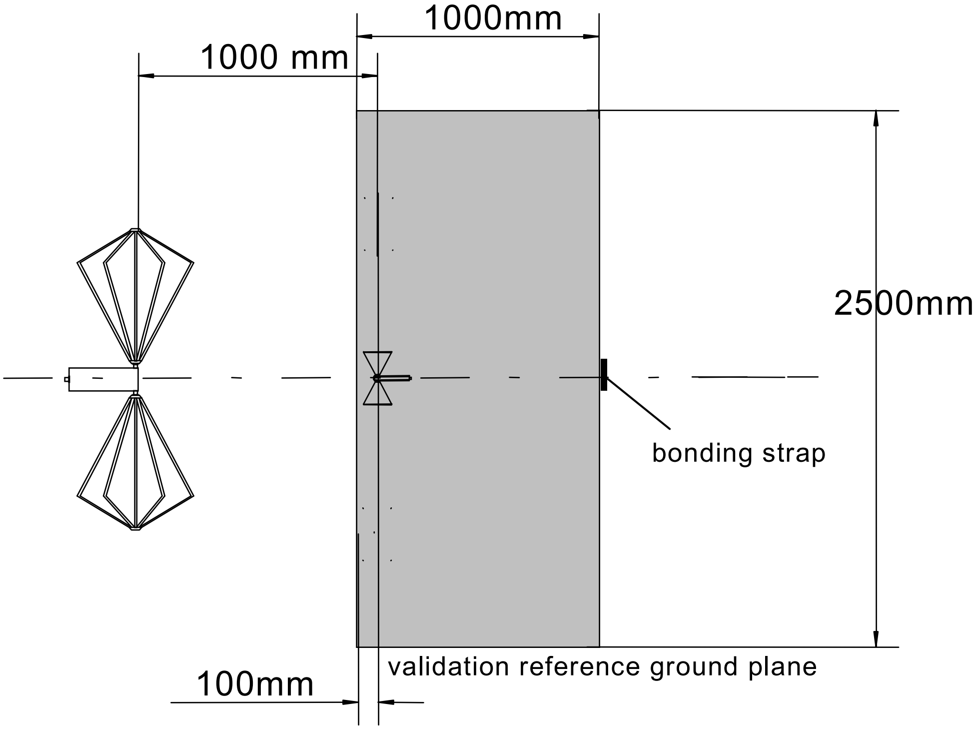


Figure J.5 – Top view of antenna configuration for reference measurement 30 MHz and above (with the biconical antenna shown as example)

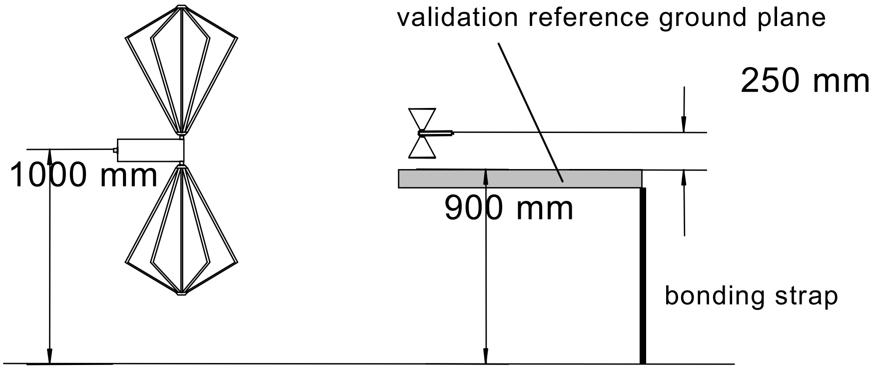


Figure J.6 – Side view of antenna configuration for reference measurement 30 MHz and above (with the biconical antenna shown as example)

J.2.3.3 ALSE measurements

The ALSE transmission coefficient ($C_{T\,ALSE}$) measurements are made with the same ALSE configuration (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) that will be used during measurements of an EUT. It also includes the connection between antenna counterpoise and table for monopole antenna measurements below 30 MHz.

NOTE The battery and AN(s) will not be part of the validation setup and therefore are not placed on the elevated reference ground plane during the ALSE validation.

At frequencies below 30 MHz, the transmitting antenna will be positioned directly on the reference ground plane at the position where the centre of the test harness would normally be, opposite the receiving antenna. This is shown in Figure J.7.

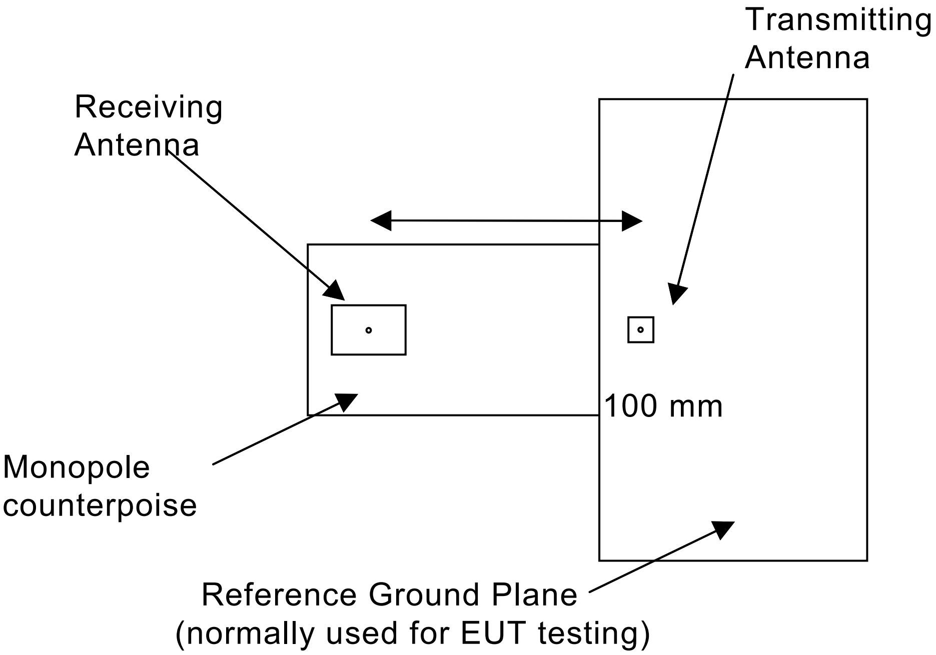


Figure J.7 – Top view of antenna configuration for the ALSE measurement below 30 MHz

At 30 MHz and above, the transmitting antenna should be positioned as in the reference measurements. This is shown in Figure J.5 and Figure J.6. The transmitting and receiving antennas will remain in one location (centred on the centre point of the ALSE reference ground plane) for all measurements.

J.2.3.4 Deviation of the ALSE measurement and reference data

At frequencies below 30 MHz, the reference measurement (with antennas on the ALSE floor) is compared to the ALSE (typical EUT test setup) measurement.

The delta of the measurement data obtained in J.2.3.3 from the reference data obtained in J.2.3.2 will be calculated for each frequency below 30 MHz.

$$\Delta_{<30\ MHz} = C_{T\ Reference} - C_{T\ ALSE} \qquad \Delta \text{ in dB} \qquad (J.2)$$

At each frequency 30 MHz and above, the reference data obtained at each antenna polarization in J.2.3.3, will be compared to the corresponding antenna polarization data obtained in the ALSE. This will result in two Δ data sets at 30 MHz and above:

$$\Delta_{\geq 30\ MHz\ Vert} = C_{T\ Reference\,Vertical} - C_{T\ ALSE\ Vertical} \qquad \Delta \text{ in dB} \qquad (J.3)$$

$$\Delta_{\geq 30\ MHz\ Horiz} = C_{T\ Reference\ Horizontal} - C_{T\ ALSE\ Horizontal} \qquad \Delta \text{ in dB} \qquad (J.4)$$

J.2.4 Requirements

To determine compliance, first calculate the % In Tolerance ($\%IT$) data points for each data set:

$$\%IT_{<30\ MHz} = \left(\frac{\text{data points of } \Delta_{<30\ MHz} \text{ within } \pm 6\text{ dB}}{481} \right) \cdot 100 \tag{J.5}$$

$$\%IT_{\geq 30\ MHz\ Vert} = \left(\frac{\text{data points of } \Delta_{\geq 30\ MHz\ Vert} \text{ within } \pm 6\text{ dB}}{481} \right) \cdot 100 \tag{J.6}$$

$$\%IT_{\geq 30\ MHz\ Horiz} = \left(\frac{\text{data points of } \Delta_{\geq 30\ MHz\ Horiz} \text{ within } \pm 6\text{ dB}}{481} \right) \cdot 100 \tag{J.7}$$

Next, find the minimum % In Tolerance ($\%IT$) data points for the two data sets at ≥ 30 MHz:

$$\%IT_{\geq 30\ MHz\ \min} = \min\left(\%IT_{\geq 30\ MHz\ Vert}, \%IT_{\geq 30\ MHz\ Horiz}\right) \tag{J.8}$$

Finally, calculate the total percentage of data points within the ±6 dB requirement over the entire frequency range of 150 kHz to 1 000 MHz ($Total\ \%IT_{150\ kHz\ to\ 1000\ MHz\ Ref\ Method}$) by:

$$Total\ \%IT_{150\ kHz\ to\ 1000\ MHz\ \mathrm{Re}f\ Method} = \%IT_{<30\ MHz} + \%IT_{\geq 30\ MHz\ \min} \tag{J.9}$$

The ALSE and its installation (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) is compliant with the requirements of this validation method if $Total\ \%IT_{150\ kHz\ to\ 1000MHz\ Ref\ Method}$ is ≥ 90 %. This compliance may be included in a statement in the test report.

Note Only those frequency ranges (Table J.1) are to be evaluated in which the ALSE is used for component testing in which case the value 481 in eq. J.5 through eq. J.9 will be replaced by the total number of points for the reduced frequency range.

The difference between the reference and ALSE measurements will not be used

- as a correction factor for emissions measurements of an EUT, or
- to produce an antenna factor for the Receiving antenna.

J.3 Modelled long wire antenna method

J.3.1 Overview

The validation method described below has the following aspects:

- a line source based on a rod between two metallic sheet angles is used in the location of the cabling harness,
- the reference values are determined through numerical simulations,
- an ALSE measurement is performed with the setup as described in 6.5,
- the reference and ALSE measurements should be similar, within a defined tolerance.

J.3.2 Equipment

J.3.2.1 Transmission and measuring equipment

Examples of transmission and measuring equipment are described in J.2.2.1.

J.3.2.2 Transmitting antenna

The cable connecting of the transmitting antenna to the signal source may affect the verification results of the ALSE. Ferrites are to be used on the cable to minimize coupling effects. The cable should also be routed immediately towards the back of the reference ground plane, away from the receiving antenna and placed directly on the reference ground plane.

Note It is highly recommended that ferrites, with a minimum impedance of 50 Ω at 25 MHz and 110 Ω at 100 MHz, be placed on the transmitting and receiving antenna cables every 20 cm along its entire length within the ALSE being validated.

The radiation source consists of a brass rod with (4 ± 0,2) mm diameter located at (50 ± 2) mm height (between the ground plane and the closest point of the rod) above the ground reference plane parallel to the front edge. The horizontal distance between the edge of the ground reference plane and the rod is (100 ± 2) mm. The rod is held by two metallic sheet angles (see Figure J.8), which are separated by (500 ± 5) mm. Type-N-connectors are integrated in the angles as support for the rod. The centre of the rod is located at the same position as the centre of the cabling harness used for EUT testing.

The metallic sheet angles are mounted on the ground reference plane to establish a low inductive, low resistive connection between angle and ground (see Figure J.10).

Note It is recommended to use mounting clamps made of plastic or to screw the sheet angles directly to the ground plane.

At the load end of the radiator, the rod is terminated with a (50 ± 7,5) Ω RF load (max VSWR 1.2:1 over the frequency range of 150 kHz to 1000 MHz) through the Type-N-connector mounted in the metallic sheet angle. At the RF feed end of the radiator, the rod is connected to a 10 dB, 50 Ω attenuator (max VSWR 1.2:1 over the frequency range of 150 kHz to 1000 MHz) through the Type-N-connector mounted in the other metallic sheet angle. See Figure J.9 for a side view of the radiator and the RF terminations.

The RF feed cable is used to connect the signal source to the 10 dB, 50 Ω attenuator at the source end of the radiator using an angle connector as shown in Figure J.9.

The construction of the radiation source allows a reliable modelling for numerical calculations, which establishes the reference data. It is important that the construction of the radiation source is followed closely. Typical VSWR curves (without the 10 dB attenuator) of a properly constructed radiation source are shown in Figure J.11.

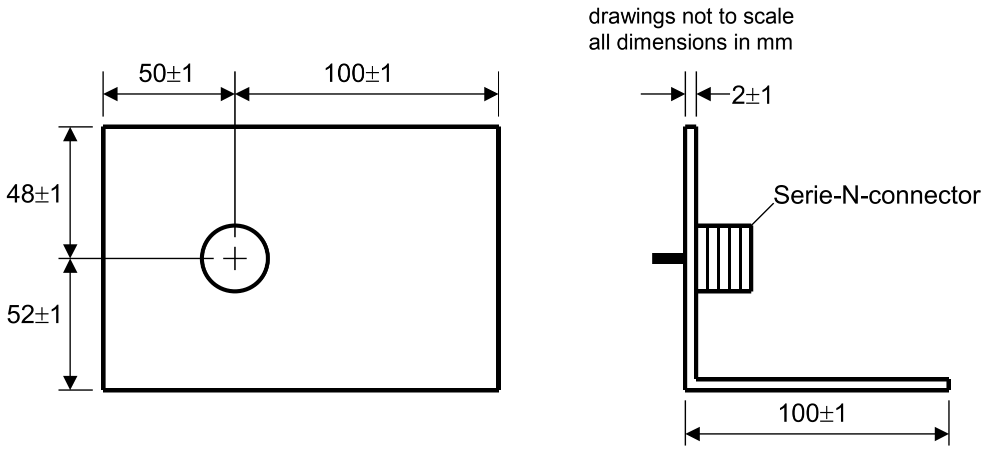


Figure J.8 - Metallic sheet angles used as support for the rod

Note The two metallic sheet angles are mirror-inverted to each other.

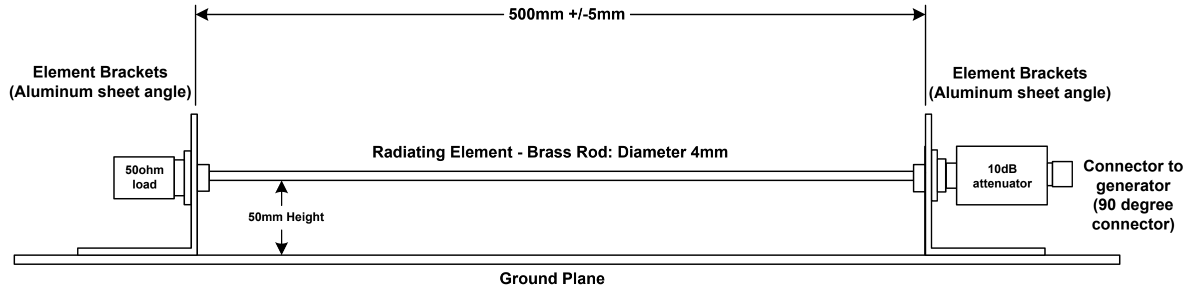


Figure J.9 - Radiator side view 50 Ω terminations

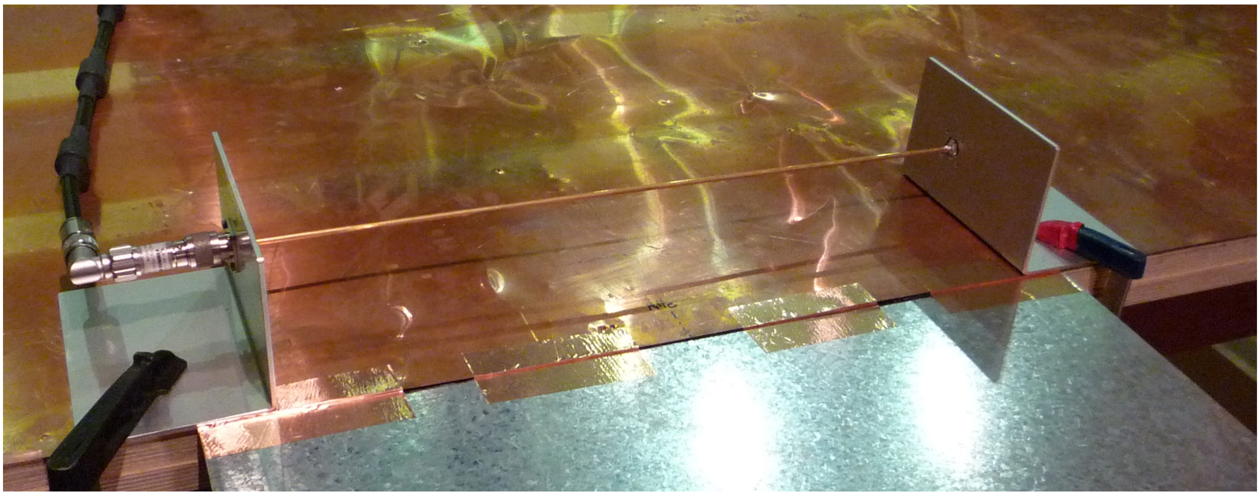


Figure J.10 - Photo of the radiator mounted on the ground reference plane

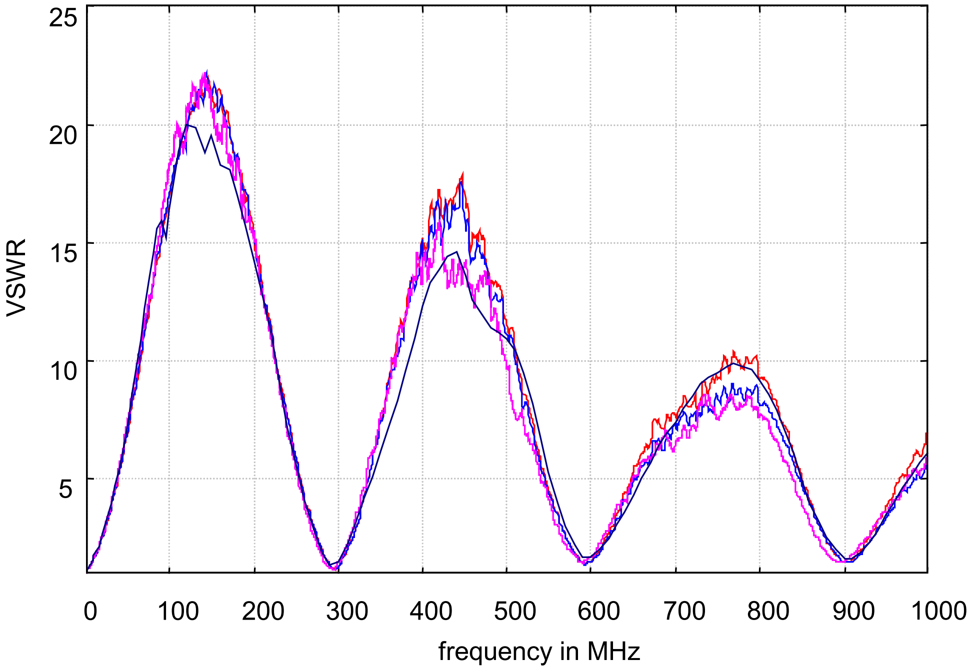


Figure J.11 - Example VSWR measured from four radiation sources (without 10 dB)

J.3.2.3 Receiving antenna

The receiving antennas used are the same as described in 6.5. The antenna factor(s) must be known and considered in the calculations below.

The transmitted power should be chosen so that an overload condition does not occur in the measurement system. This can be verified by reducing the transmitted power by 10 dB and checking that the received power is also reduced by 10 dB.

J.3.2.4 ALSE configuration

The measurements are made with the same ALSE configuration (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) that will be used during measurements of a DUT. This also includes the connection between antenna counterpoise and table for monopole antenna measurements.

Note The battery and AN(s) will not be part of the validation setup and therefore are not placed on the elevated reference ground plane during the ALSE validation.

J.3.3 Procedure

J.3.3.1 Frequency step size

The frequency step size requirements are described in J.2.3.1.2.

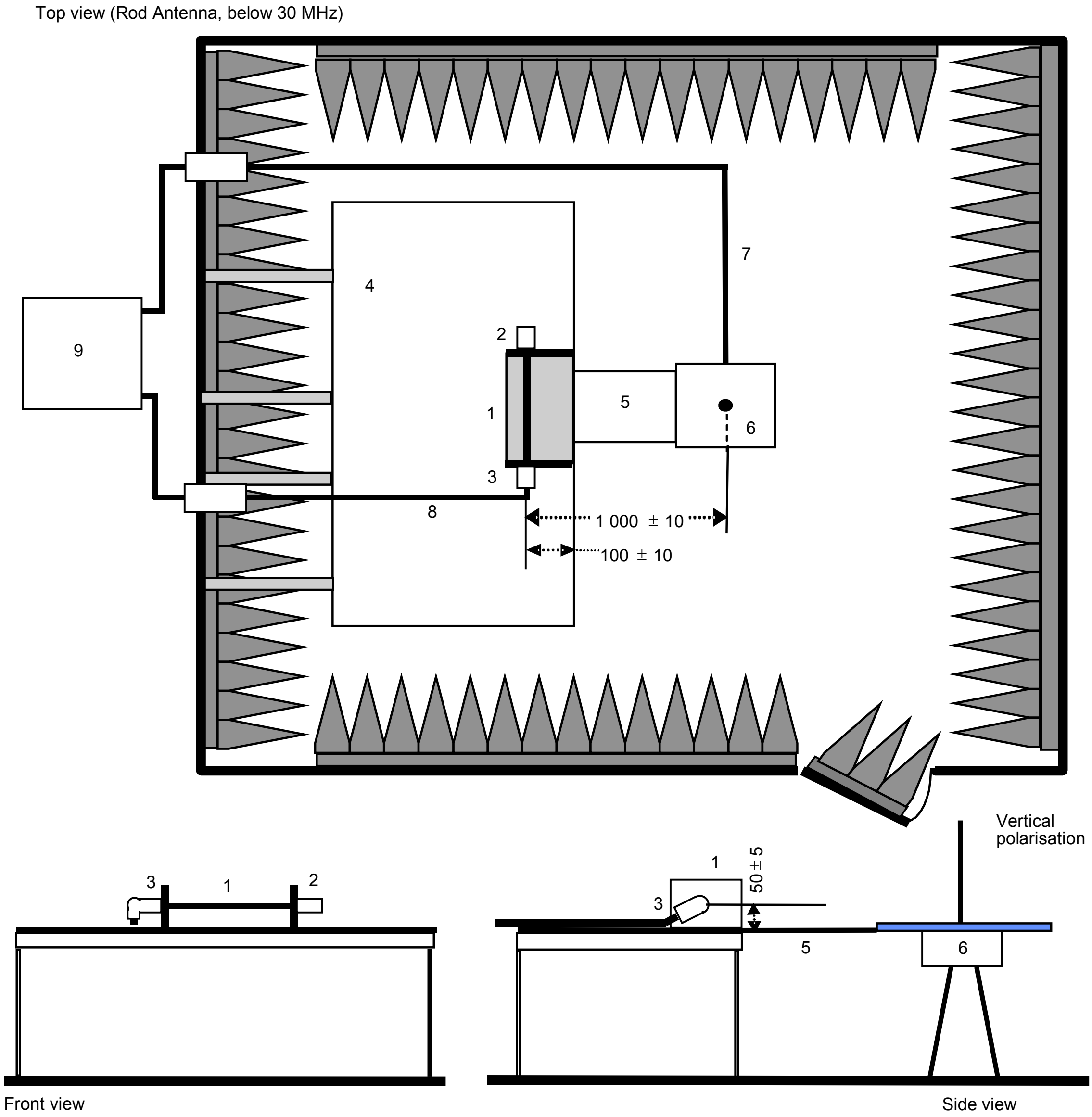
J.3.3.2 ALSE equivalent field strength measurements

An initial “direct” measurement is made with the radiator feed cable directly connected to the receiving antenna output cable. The amplitude of signal generation equipment is set to deliver 1 Vrms (120 dB(µV)). The reading of the receiving instrument is recorded as quantity M_0 in dB(µV).

Note Since the difference between the initial measurement M_0 and the measurement M_A is calculated in equation J.18 the absolute value of the generator output will not directly influence the result. However, it is recommended to use the level of 1 V to obtain sufficient measurement dynamic range.

If a network analyser is used, the “direct” measurement is replaced by a full two-port calibration with the end of the radiator RF feed cable and the end of the antenna cable defining the reference plane.

For the measurement of the transmission coefficient, the radiator feed cable is connected to the input of the 10 dB attenuator and the antenna cable is connected to the receiving antenna (see Figure J.12). Again the amplitude of signal generation equipment is set to deliver 1 Vrms (120 dB(µV)) to the input of the 10 dB attenuator. The reading of the receiving instrument is recorded as quantity M_A in dB(µV).



Key

1	radiation source
2	50Ω termination
3	10dB attenuator
6	rod antenna
7	cable from receiving antenna to measurement instrument (e.g. network analyzer)
8	cable from measurement instrument (e.g.

4 reference ground plane

5 grounding connection

network analyzer) to radiator

9 measurement instrument (e.g. network analyzer)

Figure J.12 - Example setup for ALSE equivalent field strength measurement (rod antenna shown for the frequency range below 30 MHz).

From the two values and the antenna factor of the receiving antenna (k_{AF}, in dB(1/m)), the equivalent field strength (E_{eq}, in dB(µV/m)) can be derived for each frequency:

$$E_{eq} = 120\text{dB}(\mu\text{V}) + \left(M_A - M_0\right) + k_{AF} \qquad \text{(eq. J.10)}$$

Note The equivalent field strength is the field strength that would be received, when a signal with 1 Vrms is injected in the input of the 10 dB attenuator.

In case of the network analyser, which measures the scattering parameter S_{21} (in dB), the equivalent field strength ($E_{\text{eq in dB(µV/m)}}$) can be derived as

$$E_{eq} = 120\text{dB}(\mu\text{V}) + S_{21} + k_{AF} \qquad \text{(eq. J.11)}$$

In the frequency range above 30 MHz, the measurements should be performed both for horizontal and vertical polarisations. The results are $E_{eq,hor}$ and $E_{eq,ver}$.

For each frequency, the maximum equivalent field strength $E_{eq,max}$ is derived as maximum of the $E_{eq,hor}$ and $E_{eq,ver}$.

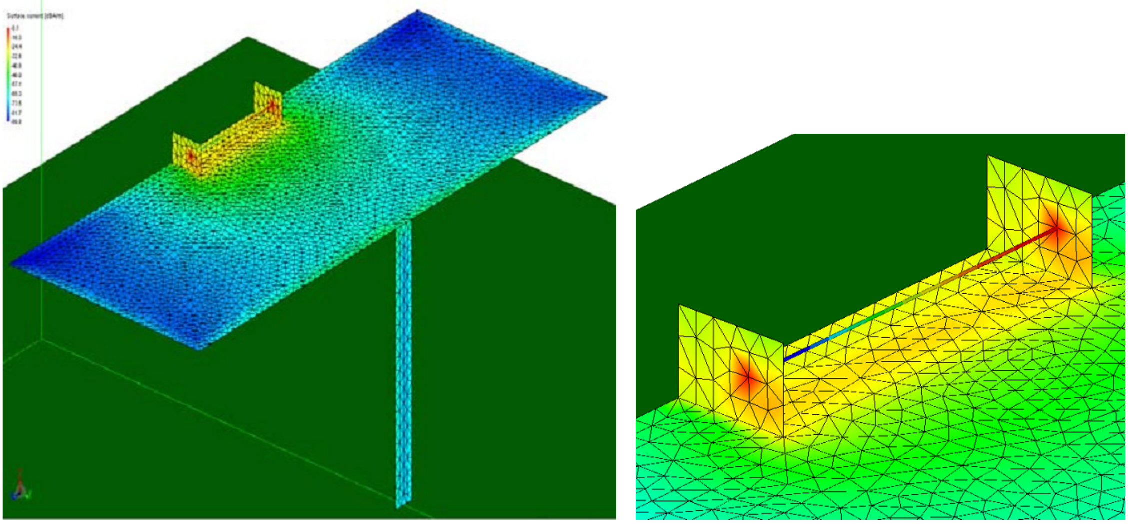
For reliable results the noise floor should be at least 10 dB below the measured signal levels. This can be verified by connecting the receiving antenna to the receiving instrument but disconnecting the signal source from the radiation source.

J.3.3.3 Techniques used to generate the reference data

In the model below 30 MHz, the ground plane is a non-elevated ground plane (e.g. the floor of an ALSE, OATS or alternative test site) which is similar to the setup shown in Figure J.4 (using the long wire transmitting antenna instead of the transmitting monopole). In the model for 30 MHz and above, the standard size 2,5 m x 1 m reference ground plane is elevated and located in an ideal free field with perfectly conducting ground properties. Grounding of the elevated reference ground plane to the floor is achieved by using a single strap with a width of 100 mm which is centred on the centre point of the rear length of the reference ground plane. Calculations were done with a Method of Moments (MoM) code. Figure J.13 shows the computer model used for MoM in the frequency range 30 MHz to 200 MHz.

Note Comparative simulations have been done in the past with FDTD.

At frequencies below 30 MHz, the monopole antenna was part of the model since the connection between monopole antenna and the ground plane has an influence on the antenna factor. At frequencies above 30 MHz, the electric field strength at the point where the receiving antennas reference point is located has been used and is the maximum of vertical and horizontal polarisations.



a) Complete model b) Detail of the radiator

Figure J.13 - MoM-Modell for the frequency range 30MHz to 200 MHz

J.3.3.4 Reference data

The numbers shown in Table J.1 are used as the standard set of reference data. The information shown in Table J.1 is the numerical reference data that is compared to the equivalent field strength measurement data obtained in the ALSE being validated. This reference data is also applicable to evaluations of ALSEs that deviate in their setup from the configuration the modelling was based on. Hence, no further modelling is required and users need not perform their own simulations. Although modelling of a user’s chamber is possible, only the numbers shown in Table J.1 are allowed to be used to determine chamber acceptance.

The simulation data already includes the 10 dB attenuator.

Table J.1 Reference data to be used for chamber validation

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	**$E_{eq,max,ref}$ in dB(µV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(µV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(µV/m)**
0,15	61,14	30	71,24	200	87,9
0,35	61,14	31	71,39	205	88,58
0,55	61,14	32	71,51	210	89,59
0,75	61,14	33	71,62	215	90,61
0,95	61,14	34	71,71	220	91,47
1,15	61,14	35	71,81	225	92,24
1,35	61,14	36	71,92	230	93,05
1,55	61,14	37	72,09	235	93,96
1,75	61,13	38	72,36	240	94,94
1,95	61,13	39	72,84	245	95,9
2,15	61,13	40	73,61	250	96,81
2,35	61,13	41	74,76	255	97,66
2,55	61,12	42	76,28	260	98,46
2,75	61,12	43	78,03	265	99,22
2,95	61,12	44	79,76	270	99,92
3,15	61,11	45	81,16	275	100,53
3,35	61,11	46	82,04	280	101,03
3,55	61,11	47	82,43	285	101,4
3,75	61,10	48	82,48	290	101,65
3,95	61,10	49	82,37	295	101,76
4,15	61,09	50	82,2	300	101,74
4,35	61,09	51	82,03	305	101,59
4,55	61,08	52	81,87	310	101,34
4,75	61,08	53	81,75	315	100,99
4,95	61,07	54	81,65	320	100,55
5,15	61,07	55	81,57	325	100,05
5,35	61,06	56	81,52	330	99,62
5,55	61,05	57	81,48	335	99,38
5,75	61,05	58	81,47	340	99,17
5,95	61,04	59	81,46	345	98,93
6,15	61,03	60	81,47	350	98,61
6,35	61,02	61	81,49	355	98,14
6,55	61,02	62	81,52	360	97,67
6,75	61,01	63	81,55	365	97,48
6,95	61,00	64	81,59	370	97,49
7,15	60,99	65	81,63	375	97,58

Frequency range 150 kHz – 30 MHz		**Frequency range 30 MHz – 200 MHz**		**Frequency range 200 MHz – 1000 MHz**	
Frequency in MHz	**$E_{eq,max,ref}$ in dB(µV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(µV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(µV/m)**
7,35	60,98	66	81,68	380	97,68
7,55	60,98	67	81,73	385	97,73
7,75	60,97	68	81,79	390	97,74
7,95	60,96	69	81,85	395	97,74
8,15	60,95	70	81,91	400	97,78
8,35	60,94	71	81,97	405	97,86
8,55	60,93	72	82,03	410	97,96
8,75	60,92	73	82,1	415	98,07
8,95	60,91	74	82,17	420	98,19
9,15	60,90	75	82,24	425	98,33
9,35	60,89	76	82,31	430	98,48
9,55	60,88	77	82,38	435	98,64
9,75	60,86	78	82,45	440	98,8
9,95	60,85	79	82,53	445	98,95
10,15	60,84	80	82,61	450	99,06
10,35	60,83	81	82,69	455	99,11
10,55	60,82	82	82,77	460	99,09
10,75	60,81	83	82,85	465	98,99
10,95	60,79	84	82,94	470	98,86
11,15	60,78	85	83,03	475	98,72
11,35	60,77	86	83,12	480	98,59
11,55	60,76	87	83,22	485	98,49
11,75	60,74	88	83,32	490	98,38
11,95	60,73	89	83,42	495	98,25
12,15	60,72	90	83,53	500	98,12
12,35	60,70	91	83,64	505	97,97
12,55	60,69	92	83,75	510	97,74
12,75	60,67	93	83,87	515	97,54
12,95	60,66	94	83,99	520	97,55
13,15	60,65	95	84,11	525	97,43
13,35	60,63	96	84,23	530	97,24
13,55	60,62	97	84,35	535	97,15
13,75	60,60	98	84,47	540	97,22
13,95	60,59	99	84,59	545	97,36
14,15	60,57	100	84,71	550	97,33
14,35	60,56	101	84,83	555	96,96
14,55	60,54	102	84,94	560	96,3
14,75	60,52	103	85,05	565	95,59

Frequency range 150 kHz – 30 MHz		Frequency range 30 MHz – 200 MHz		Frequency range 200 MHz – 1000 MHz	
Frequency in MHz	$E_{eq,max,ref}$ in dB(μV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(μV/m)	Frequency in MHz	$E_{eq,max,ref}$ in dB(μV/m)
14,95	60,51	104	85,15	570	94,92
15,15	60,49	105	85,25	575	94,26
15,35	60,48	106	85,35	580	93,6
15,55	60,46	107	85,43	585	92,94
15,75	60,44	108	85,52	590	92,33
15,95	60,43	109	85,59	595	91,8
16,15	60,41	110	85,67	600	91,34
16,35	60,39	111	85,73	605	90,95
16,55	60,38	112	85,79	610	91,06
16,75	60,36	113	85,85	615	91,81
16,95	60,34	114	85,9	620	92,51
17,15	60,33	115	85,95	625	93,15
17,35	60,31	116	85,99	630	93,7
17,55	60,29	117	86,03	635	94,15
17,75	60,28	118	86,06	640	94,5
17,95	60,26	119	86,09	645	94,74
18,15	60,24	120	86,12	650	94,88
18,35	60,22	121	86,15	655	94,92
18,55	60,21	122	86,17	660	94,88
18,75	60,19	123	86,18	665	94,76
18,95	60,17	124	86,2	670	94,51
19,15	60,15	125	86,21	675	94,08
19,35	60,14	126	86,22	680	94,55
19,55	60,12	127	86,22	685	95,18
19,75	60,10	128	86,22	690	95,8
19,95	60,08	129	86,22	695	96,14
20,15	60,07	130	86,22	700	95,98
20,35	60,05	131	86,21	705	95,85
20,55	60,03	132	86,2	710	95,83
20,75	60,02	133	86,18	715	95,69
20,95	60,00	134	86,16	720	95,28
21,15	59,98	135	86,14	725	94,8
21,35	59,96	136	86,12	730	94,65
21,55	59,95	137	86,09	735	94,71
21,75	59,93	138	86,06	740	94,86
21,95	59,91	139	86,03	745	95,23
22,15	59,90	140	85,99	750	95,8
22,35	59,88	141	85,95	755	96,4

Frequency range 150 kHz – 30 MHz		**Frequency range 30 MHz – 200 MHz**		**Frequency range 200 MHz – 1000 MHz**	
Frequency in MHz	**$E_{eq,max,ref}$ in dB(μV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(μV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(μV/m)**
22,55	59,87	142	85,9	760	96,89
22,75	59,85	143	85,85	765	97,24
22,95	59,83	144	85,8	770	97,47
23,15	59,82	145	85,75	775	97,61
23,35	59,80	146	85,69	780	97,7
23,55	59,79	147	85,63	785	97,73
23,75	59,77	148	85,56	790	97,71
23,95	59,76	149	85,49	795	97,63
24,15	59,74	150	85,41	800	97,49
24,35	59,73	151	85,33	805	97,3
24,55	59,72	152	85,24	810	97,08
24,75	59,70	153	85,14	815	96,84
24,95	59,69	154	85,04	820	96,61
25,15	59,68	155	84,93	825	96,39
25,35	59,67	156	84,82	830	96,19
25,55	59,66	157	84,69	835	96
25,75	59,65	158	84,55	840	95,86
25,95	59,63	159	84,41	845	95,56
26,15	59,62	160	84,25	850	96,51
26,35	59,62	161	84,07	855	97,5
26,55	59,61	162	83,88	860	98,42
26,75	59,60	163	83,68	865	99,23
26,95	59,59	164	83,45	870	99,9
27,15	59,58	165	83,21	875	100,51
27,35	59,58	166	83,02	880	101,09
27,55	59,57	167	83,28	885	101,61
27,75	59,56	168	83,54	890	102,09
27,95	59,56	169	83,8	895	102,54
28,15	59,56	170	84,05	900	102,95
28,35	59,55	171	84,29	905	103,31
28,55	59,55	172	84,53	910	103,6
28,75	59,55	173	84,77	915	103,84
28,95	59,55	174	85	920	104,03
29,15	59,55	175	85,22	925	104,18
29,35	59,55	176	85,44	930	104,26
29,55	59,55	177	85,65	935	104,28
29,75	59,55	178	85,86	940	104,24
29,95	59,55	179	86,06	945	104,14

Frequency range 150 kHz – 30 MHz		**Frequency range 30 MHz – 200 MHz**		**Frequency range 200 MHz – 1000 MHz**	
Frequency in MHz	**$E_{eq,max,ref}$ in dB(µV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(µV/m)**	**Frequency in MHz**	**$E_{eq,max,ref}$ in dB(µV/m)**
		180	86,26	950	104
		181	86,44	955	103,84
		182	86,62	960	103,68
		183	86,78	965	103,53
		184	86,94	970	103,39
		185	87,07	975	103,27
		186	87,2	980	103,17
		187	87,31	985	103,08
		188	87,4	990	102,98
		189	87,48	995	102,86
		190	87,54	1000	102,69
		191	87,6		
		192	87,64		
		193	87,67		
		194	87,69		
		195	87,72		
		196	87,74		
		197	87,77		
		198	87,81		
		199	87,87		

J.3.3.5 Deviation of the ALSE measurement from the reference data

The deviation of the measurement data obtained in J.3.3.2 from the reference values given in Table J.1 is calculated for each frequency.

$$\Delta_{\text{Long Wire Method}} = E_{eq,max} - E_{eq,max,ref} \qquad \Delta \text{ in dB} \qquad \text{(J.12)}$$

J.3.4 Requirements

To determine compliance, calculate the total percentage of data points within the ± 6 dB requirement over the entire frequency range of 150 kHz to 1000 MHz ($Total\ \%IT_{150\ kHz\ to\ 1000MHz\ Long\ Wire\ Method}$) by:

$$Total\ \%IT_{150\ kHz\ to\ 1000\ MHz,\ Long\ Wire\ Method} = \left(\frac{\text{data points 150 } kHz \text{ to } 1000\ MHz \text{ where } \Delta_{Long\ Wire\ Method} \text{ is within } \pm 6\ dB}{481}\right) \cdot 100 \qquad \text{(J.13)}$$

The ALSE and its installation (physical layout, reference ground plane size, reference ground plane grounding, RF absorber, etc.) is compliant with the requirements of this validation method if $Total\ \%IT_{150\ kHz\ to\ 1000MHz\ Long\ Wire\ Method}$ is ≥ 90 %. This compliance may be included in a statement in the test report.

Note Only those frequency ranges (Table J.1) need to be considered, for which the ALSE is to be used in which case the value 481 in eq. J.13 will be replaced by the total number of points for the reduced frequency range..

The difference between the reference and ALSE measurement is not to be used as a correction factor for emissions measurements of an EUT.

J.4 References

"THE GROUNDPLANE RESONANCE – PROBLEMS WITH RADIATED EMISSIONS MEASUREMENTS BELOW 30 MHz". Dr Luke Turnbull, 2007 Automotive EMC Conference, Newbury UK. (http://www.conekt.co.uk/news-and-events/92-emc-groundplane-paper)

"MESSTECHNISCHE UNTERSUCHUNG DES EINFLUSSES DER ERDUNG VON CISPR-25-EMISSIONSMESSPLÄTZEN". Alexander Kriz, Wolfgang Müllner, Friedrich-Wilhelm Trautnitz, Jochen Riedelsheimer , Herbert Seitle, Test Kompendium 2004, Messen-Prüfen-Verifizieren, publish-industry Verlag GmbH, München, 2003. http://www.seibersdorf-rf.com

"AN ACCURATE VALIDATION PROCEDURE FOR COMPONENT TESTING CHAMBERS". Alexander Kriz, Wolfgang Müllner, Compliance Engineering, 2002 November/December 2002, Page 40-43. http://www.seibersdorf-rf.com

"ANALYSIS OF THE CISPR 25 COMPONENT TEST SETUP". Alexander Kriz, Wolfgang Müllner, 2003 International Symposium on Electromagnetic Compatibility (EMC), Istanbul, Turkey. http://www.seibersdorf-rf.com

"Proposal for the Validation of Absorber Lined Shielded Enclosures for CISPR 25 Emission Tests", Bongartz, Deckers, Heina, Hirsch, Mooser, Nickel, Seiger, IEEE Symposium on EMC, Austin, USA, August, 17th-21st, 2009

Annex K
(informative)

Items Under Consideration

K.1 Introduction

This annex contains future work items that are under consideration.

K.1.1 Measurement techniques and limits

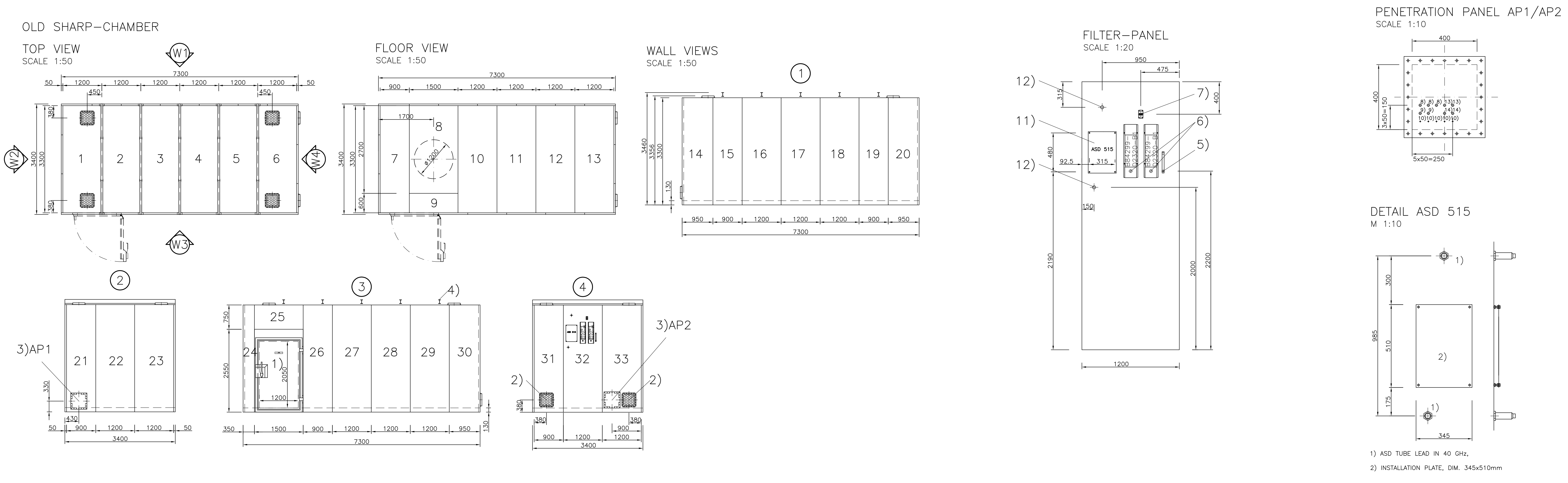
As further work progresses in CISPR A, CISPR H and TC 69 this will be reviewed and CISPR 25 updated accordingly.

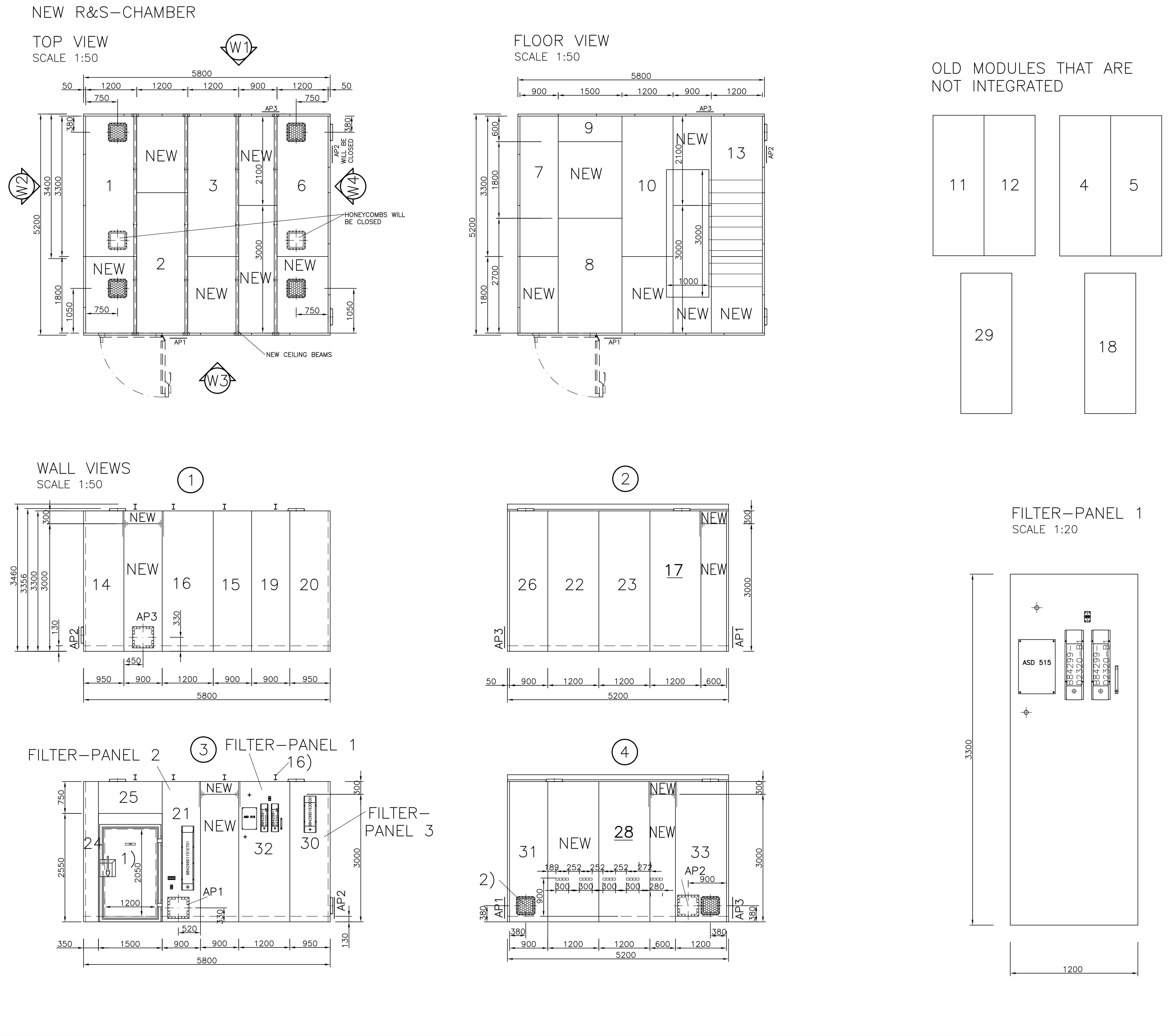
K.1.2 Measurement Uncertainty

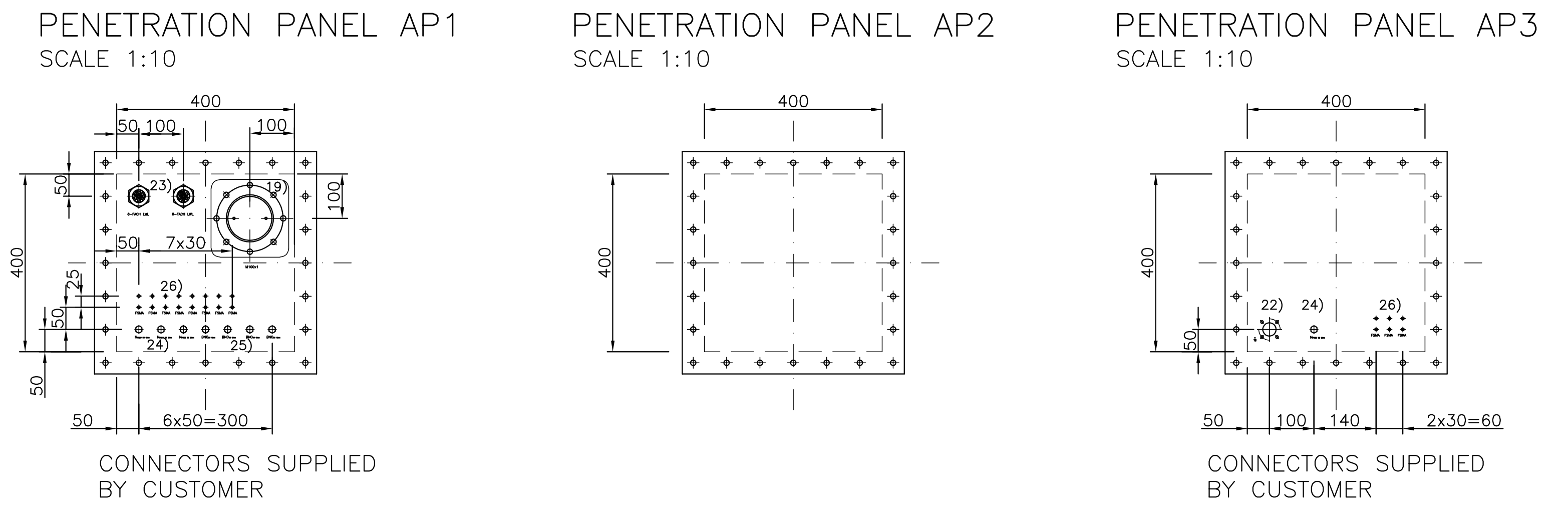
This topic will be considered for future revisions of this standard.

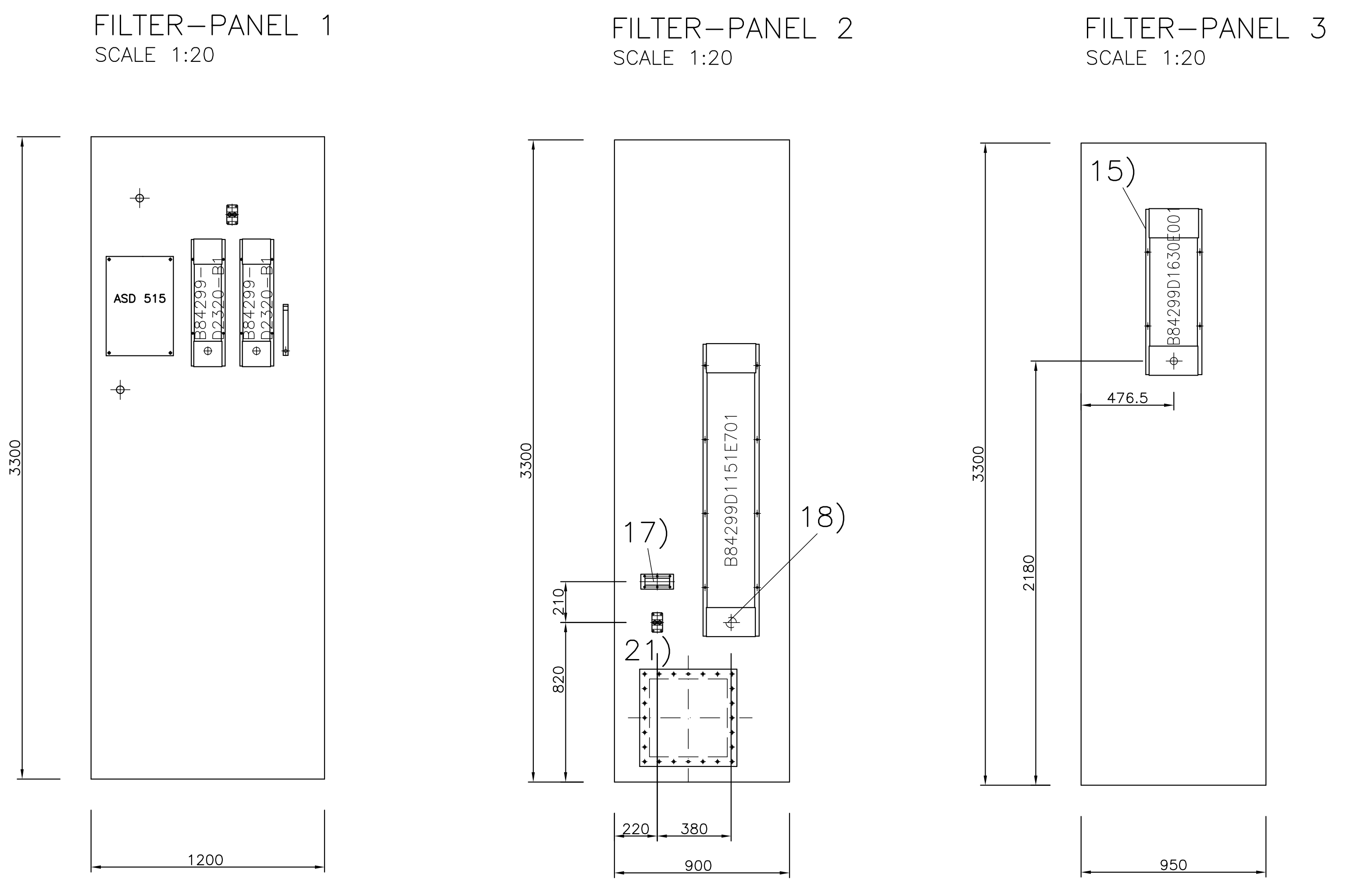
Anexo 2

Planos SAC 4









HOT GALVANIZED SHEET STEEL, 2mm THICK CONTINOUSLY CANTED, UNLACQUED.
ONLY THE DOOR PANEL IS LACQUER COATED RAL 7035.

	QUANTITY		TYPE
1)	1	BLADE CONTACT DOOR, SINGLE LEAF, CWxCH = 1200x2050mm	B83117–B1432–T161
2)	6	HONEYCOMB 20 GHz, 330x330mm, BOLTED	B83316–C1–Z12
3)	2	PENETRATION PANEL, 400x400mm, BOLTED	B83313–B1008
4)	5	ROOF BEAM, L = 3100mm	B83204–A–Z501
5)	1	FILTER FOR TELEPHONE LINE 2x0,1A	B84312–F20–B3
6)	2	FILTER FOR POWERLINES, 2x32A	B84299–D2320–B1
7)	1	GROUNDING BOLT	B83208–A–Z830
8)	6	N–CONNECTOR, 50 OHM	B83207–A50–Z732
9)	4	BNC–CONNECTOR, 50 OHM	B83207–A50–Z738
10)	10	FSMA–FIBEROPTIC CABLE CONNECTOR	B83207–A–Z734
11)	1	SMOKEDETECTION – SYSTEM (ONLY TUBES)	. . .
12)	2	TUBE LEAD IN FOR SMOKEDETECTION	B83208–A–Z846
13)	4	BNC–CONNECTOR, 75 OHM	B83207–A75–Z738
14)	4	N–CONNECTOR, 75 OHM	B83207–A75–Z732
		NEW PARTS P28231	
15)	1	FILTER FOR POWERLINES, 4x63A	B84299–D1630–E1
16)	4	ROOF BEAM 120, L = 5200mm	B83204–A–Z508
17)	1	FILTER FOR TELEPHONE LINE 20x1A	B84312–C100–H3
18)	1	FILTER FOR POWERLINES, 1000Vdc, 4x100A	B84299–D1151–E701
19)	1	FEED–THROUGH WITH MESH SLEEVE, DIAM. 100mm	B83208–D150–Z840
20)	3	PENETRATION PANEL, 400x400mm, BOLTED	B83313–B1008
21)	1	GROUNDING BOLT	B83208–A–Z830
22)	1	FEED THROUGH 7/16	SUPPLIED BY CUSTOMER
23)	2	MULTIPLE FIBRE OPTIC FEED THROUGH	B83207–A–Z801
24)	4	N–CONNECTOR, PREC, 50 OHM	SUPPLIED BY CUSTOMER
25)	4	BNC–CONNECTOR, 50 OHM (N WITH ADAPTER)	SUPPLIED BY CUSTOMER
26)	22	FSMA–FIBEROPTIC CABLE CONNECTOR	SUPPLIED BY CUSTOMER

PERMITTED FLOOR LEVEL DEVIATION FOR THE ERECTING AREA OF THE ENCLOSURE ACCORDING TO DIN 18202 (TOLERANCES FOR STRUCTURAL ENGINEERING), TABLE 3, LINE 4, HALF VALUES:

DISTANCE OF MEASURING POINTS IN m	1	4	10	15
TOLERANCE IN mm	1.5	4.5	6.0	7.5

P28231 B83117–S20–X835

Scale 1:50 1:20 1:10

Rev	Announcement	Date	Name
6	Connectors AP1 and AP3	09.10.17	S.–B,
5	AP3,Honeycomb new pos.	18.09.17	S.–B.
4	div. modification	07.09.17	S.–B.
3	Table, AP3	04.09.17	Berger
8	as built	02.01.18	S.–B.
7	QTY FSMA AP1	11.10.17	S.–B.

	Date	Name
Drawn	02.01.18	Schön–Bürger
Check	02.01.18	Berger
Norm		

AlbatrossProjects

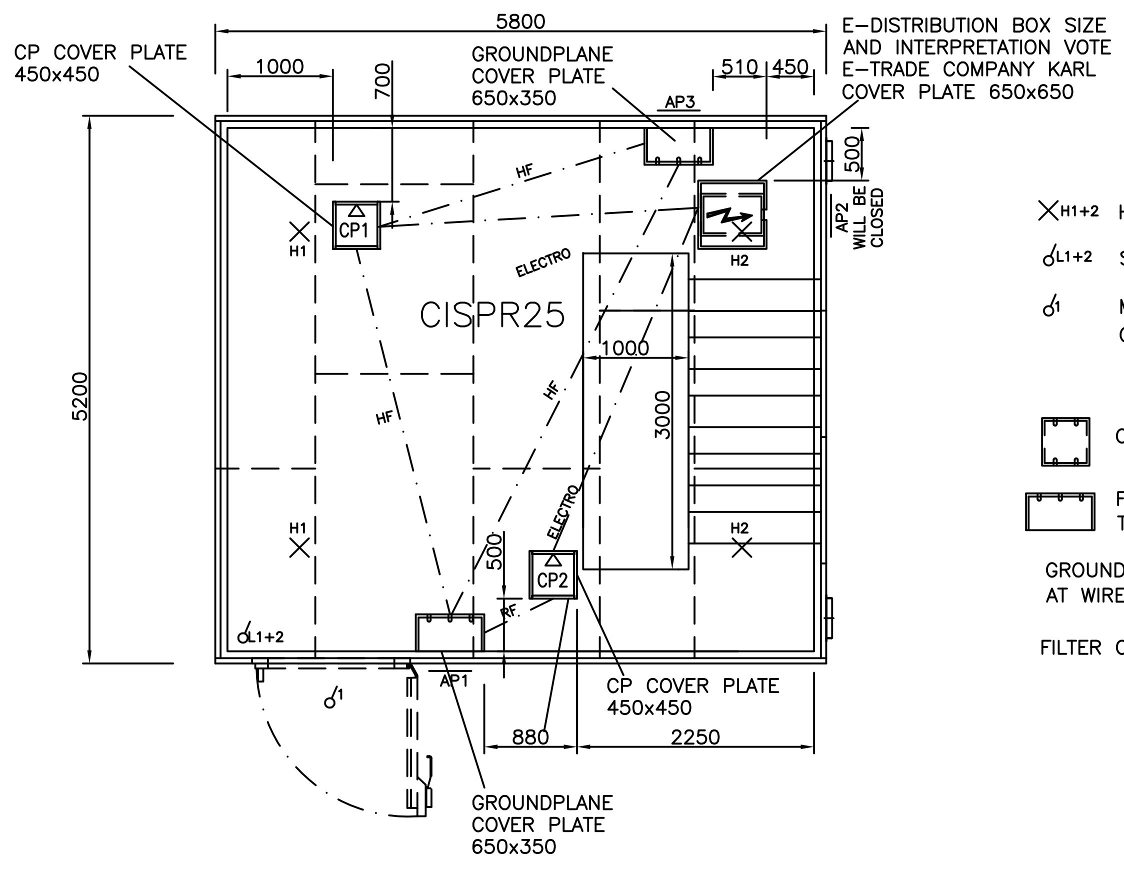
LGAI Barcelona / R&S Spain
C–CDC RELOCATION AND ENHANC.
SHIELDING 20 GHz

Revision 8

Page No 1

C62128–A520–A740–8–7606

E-INSTALLATION
SCALE 1:50



× H1+2 HALOGEN LAMP 300W – FILTER 6)

L1+2 SWITCH FOR LAMP

1 MICROSWITCH FOR DOOR STATUS INDICATION, CONNECTED BY CUSTOMER

☐ CONNECTION POINT

▭ FLOOR OPENINGS TO AP'S

GROUNDING RESISTANCE 1 OHM AT WIRE CROSS SECTION 16MM²

FILTER CONNECTED FROM OUTSIDE BY CUSTOMER

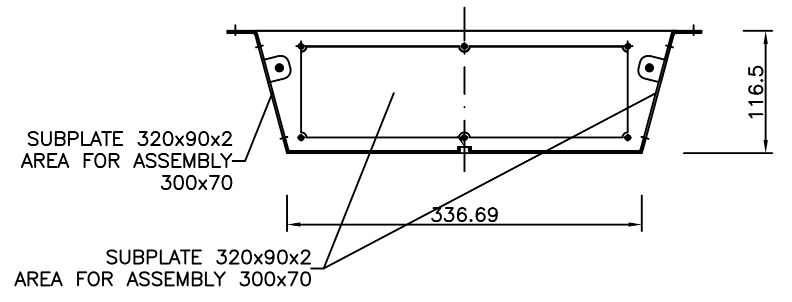
NUMBERING CORRESPONDS TO THE LEGEND ON THE SHIELDING DRAWING PAGE 01

NR.	TYPE	POS./USED FOR	B-NUMBER:
5)	FILTER 2x0,1A	SIGNAL LINE	B84312-F20-B3
6)	FILTER FOR POWERLINES 2x32A	CHAMBER SUPPLY	B84299-D2320-B1
6)	FILTER FOR POWERLINES 2x32A	SCHUKO-SOCKET	B84299-D2320-B1
15)	FILTER FOR POWERLINES 4x63A	CEE-SOCKET	B84299-D1630-E001
17)	FILTER 20x1A	BANANA SOCKETS	B84312-C100-H3
18)	FILTER FOR POWERLINES 100V DC, 4x100A	DC-SUPPLY	B84299-D1151-E701

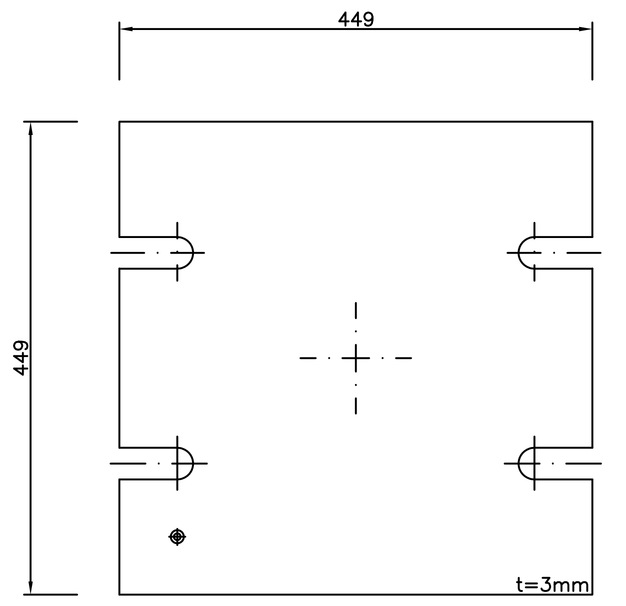
CONNECTION:

NR.	TYP	
2)	SCHUKO SOCKET, 230V, 1PH, 16A, WITH RCD	– FILTER 6)
3)	CEE SOCKET, 400V, 32A, 3PH WITH RCD	– FILTER 15)
6)	BANANA SOCKET	– FILTER 17)

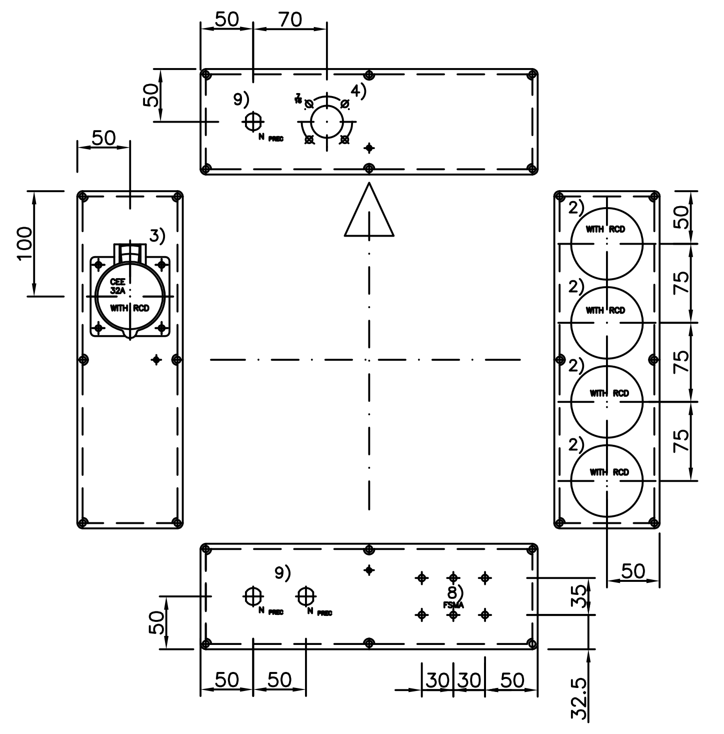
FLOOR CONNECTION POINT
SCALE 1:5



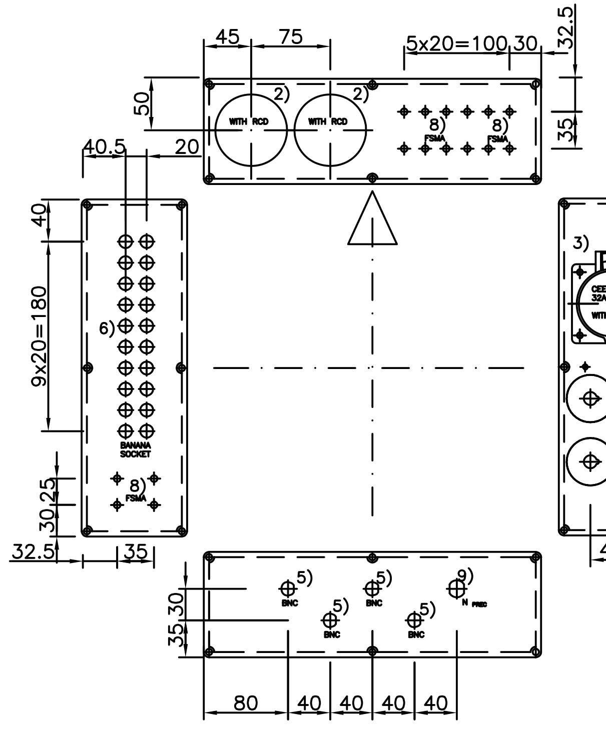
COVER PLATE CONNECTION POINT
SCALE 1:5



CP 1
SCALE 1:5



CP 2
SCALE 1:5



CONNECTORS SUPPLIED BY CUSTOMER!!!

CONNECTORS WILL BE SUPPLIED BY CUSTOMER!
HOLES IN CP's MADE BY ALBATROSS/KARL

POS. NR.	QUANTITY	DESIGNATION	TYPE
1)	2	CONNECTION POINT	B83205-A-E200
2)	8	SOCKET SCHUKO TYPE, 230V, 16A WITH RCD	B83207-A-Z737
3)	2	CEE-SOCKET SCHUKO TYPE, 440V, 32A WITH RCD	
4)	1	RF-FEED THROUGH TYPE $\frac{7}{16}$"	SUPPLIED BY CUSTOMER
5)	4	RF-CONNECTOR BNC 50 OHM	SUPPLIED BY CUSTOMER
6)	20	BANANA SOCKET, MULTI CONTACT, 32A	
7)	4	DC-CLAMP, 100A, RUHSTRAT	
8)	22	FSMA-FIBEROPTIC CABLE CONNECTOR	SUPPLIED BY CUSTOMER
9)	4	RF-CONNECTOR N PREC; 50 OHM	SUPPLIED BY CUSTOMER

P28231	B83117-S20-X835				Scale 1:50 1:5	
				Date	Name	
5	Legend modifies	24.10.17	S.-B.	Drawn 12.10.2017	Schön-Bürger	Revision 5
4	Details	12.10.17	Berger	Check 12.10.2017	Berger	
3	Connectors	11.10.17	S.-B.	Norm		
2	Connectors CP1 / CP2	09.10.17	S.-B.	AlbatrossProjects		Page No 3
1	Zeichnung erstellt	07.09.17	S.-B.			
Rev	Announcement	Date	Name			

R&S SPAIN
CISPR 25 RELOCATION AND ENHANC.
E-INSTALLATION

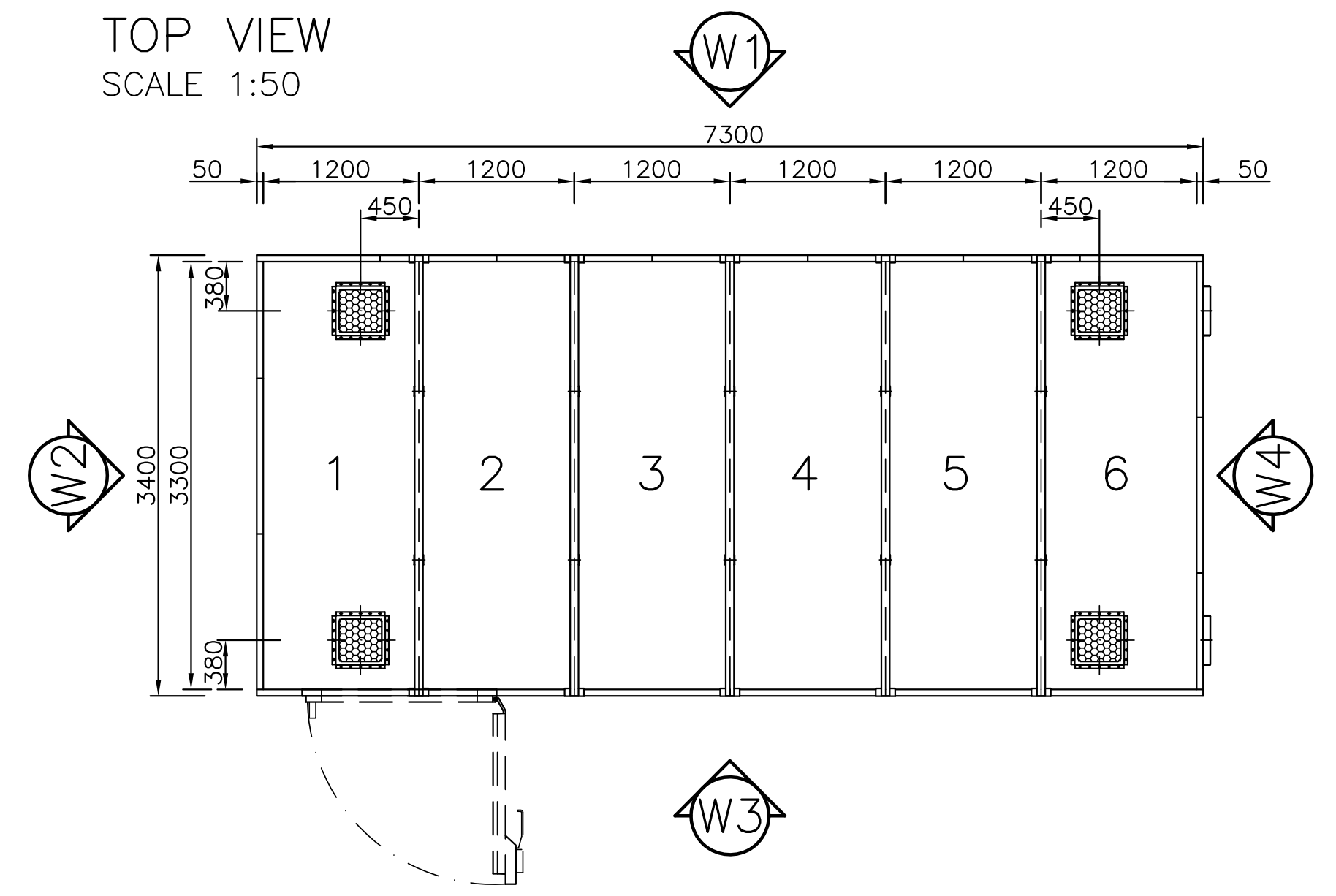
C62128-A520-A740-5-7606

Anexo 3

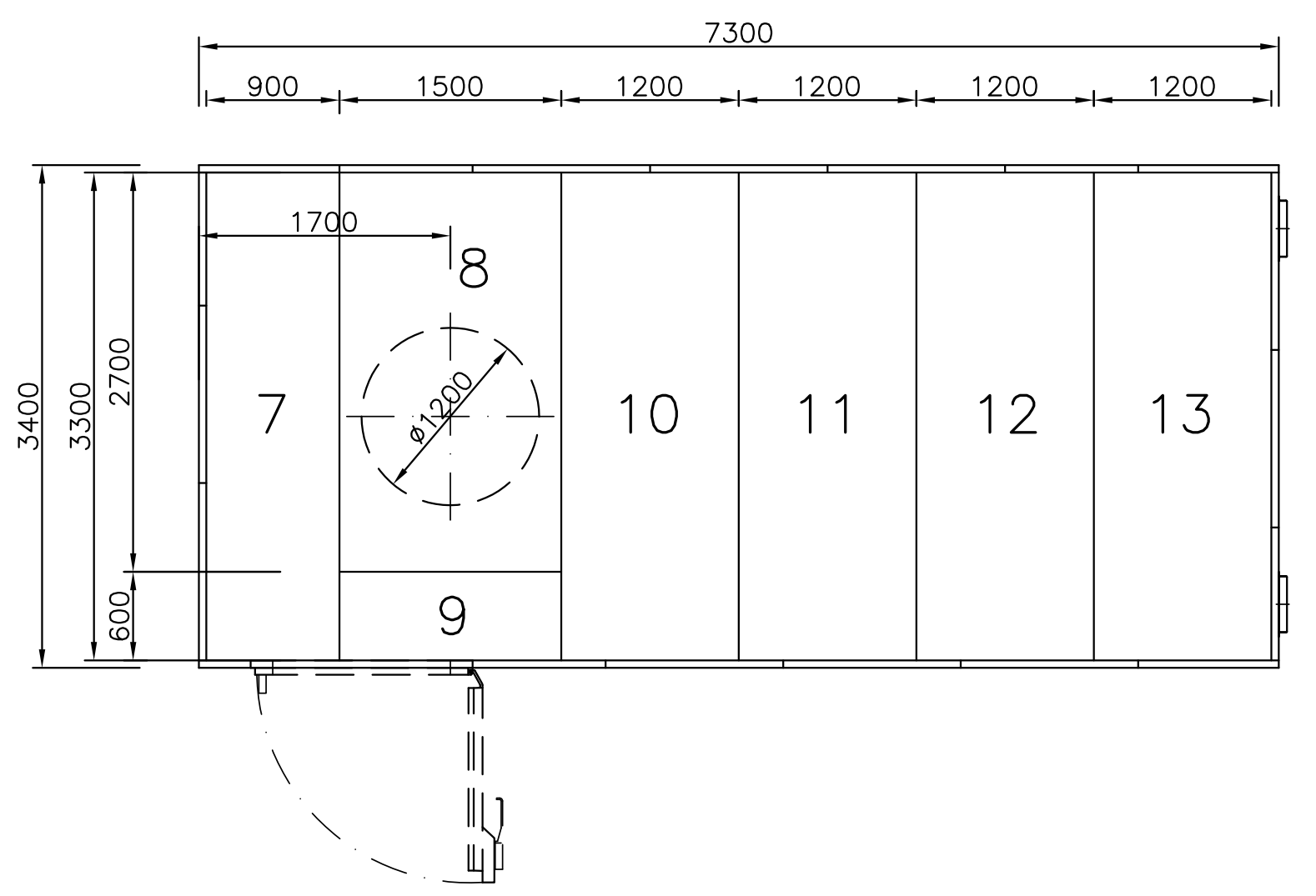
Planos SAC original

OLD SHARP-CHAMBER

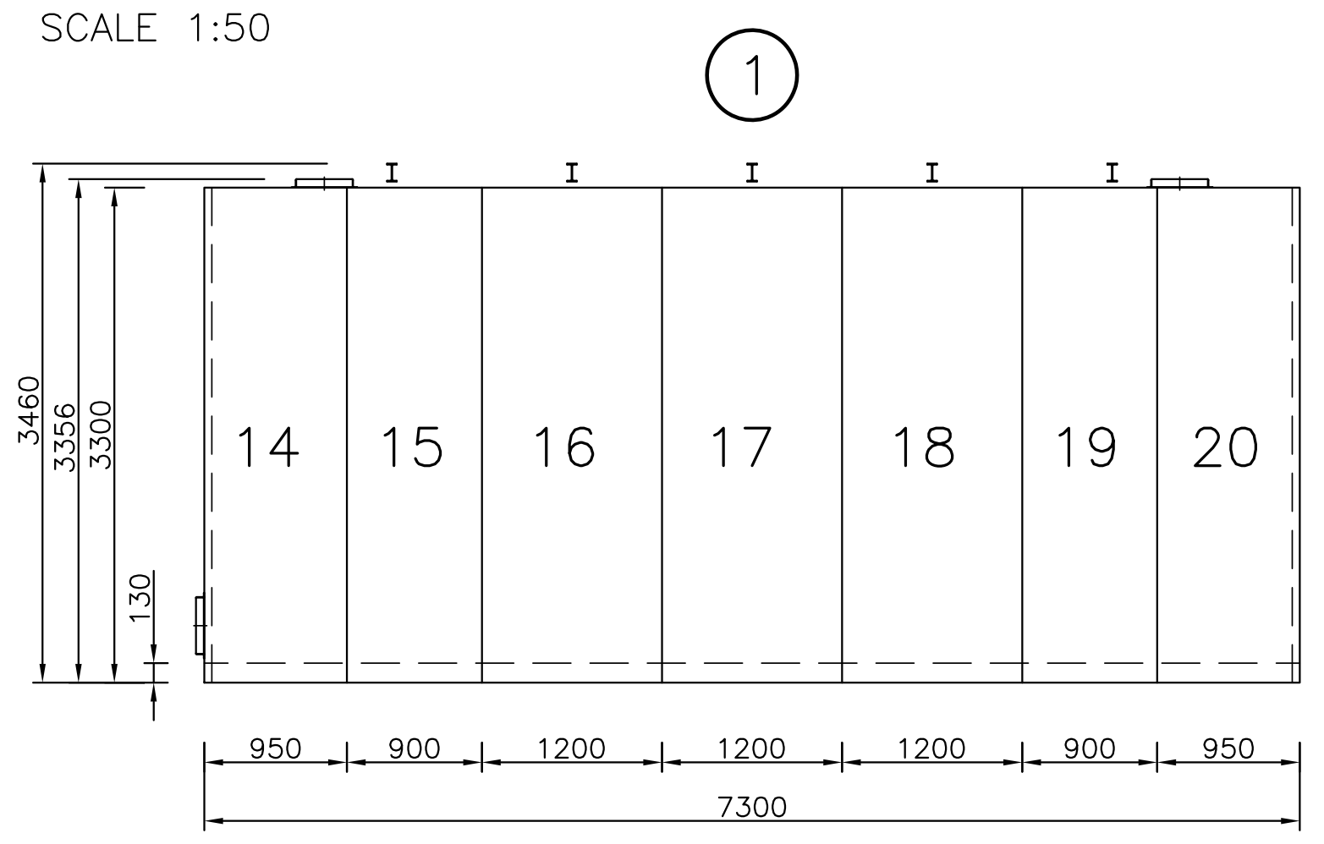
TOP VIEW
SCALE 1:50

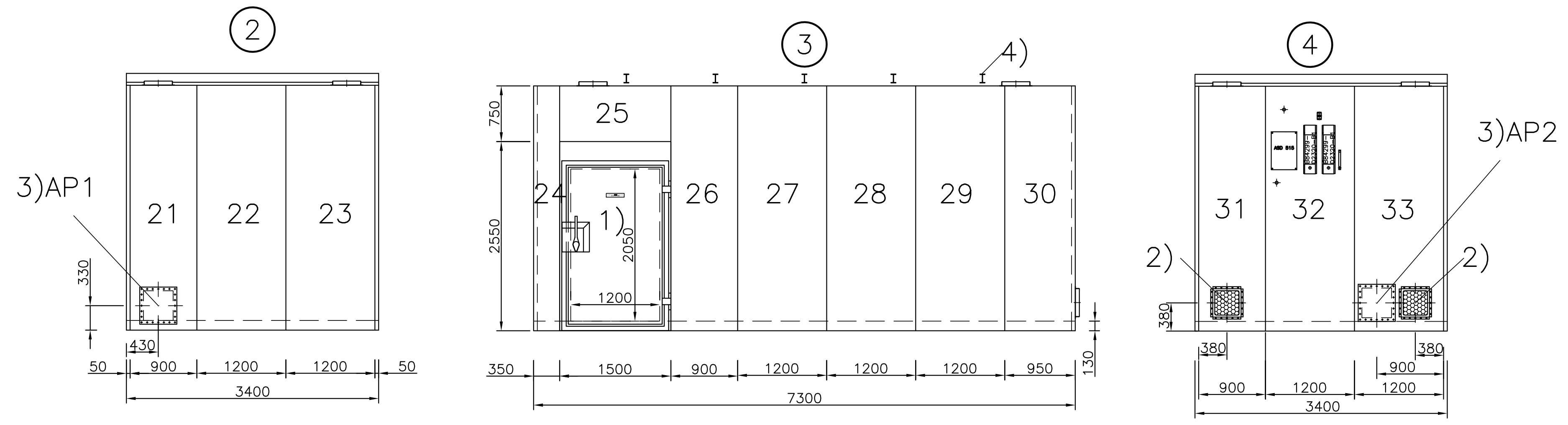


FLOOR VIEW
SCALE 1:50



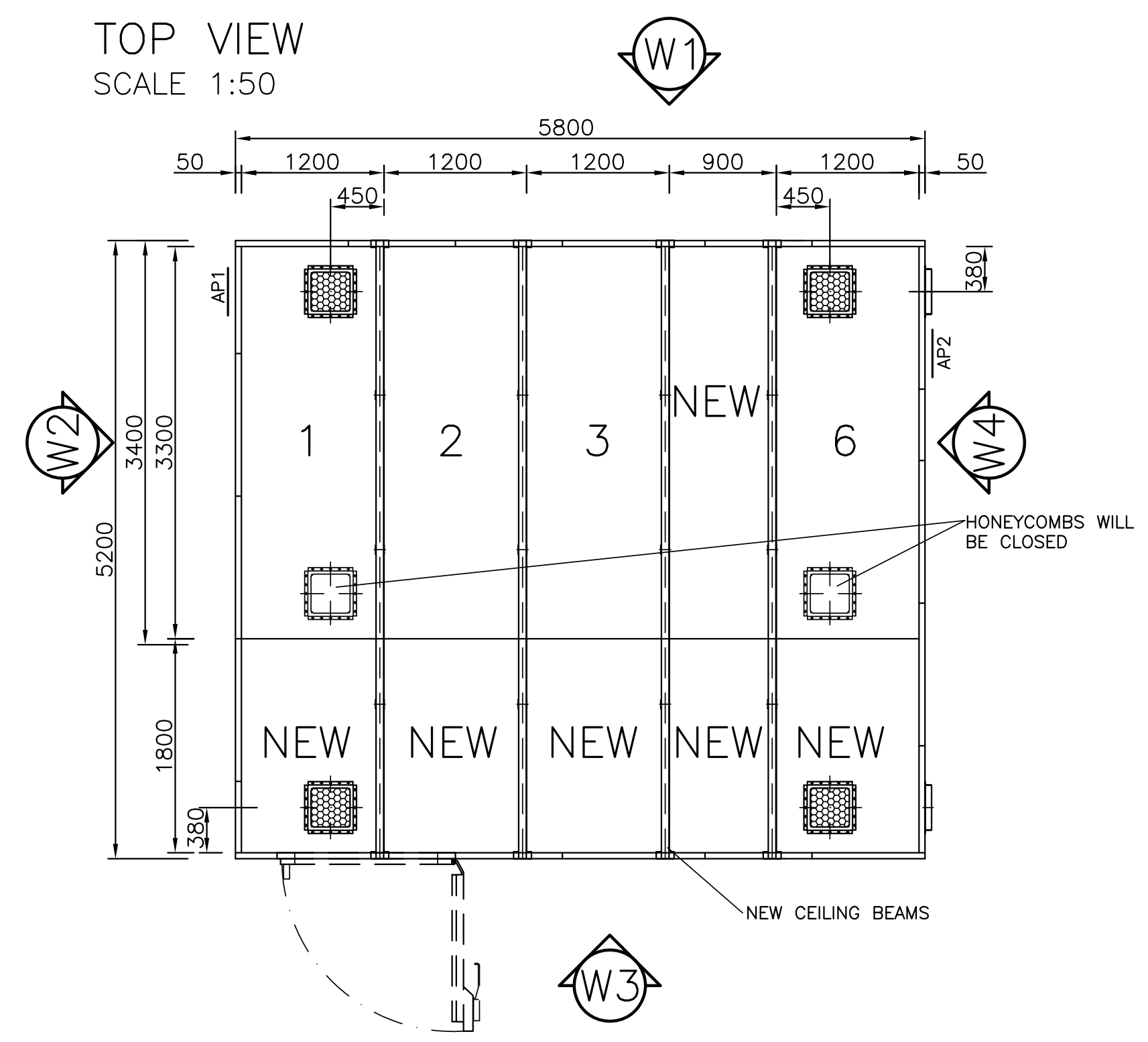
WALL VIEWS
SCALE 1:50



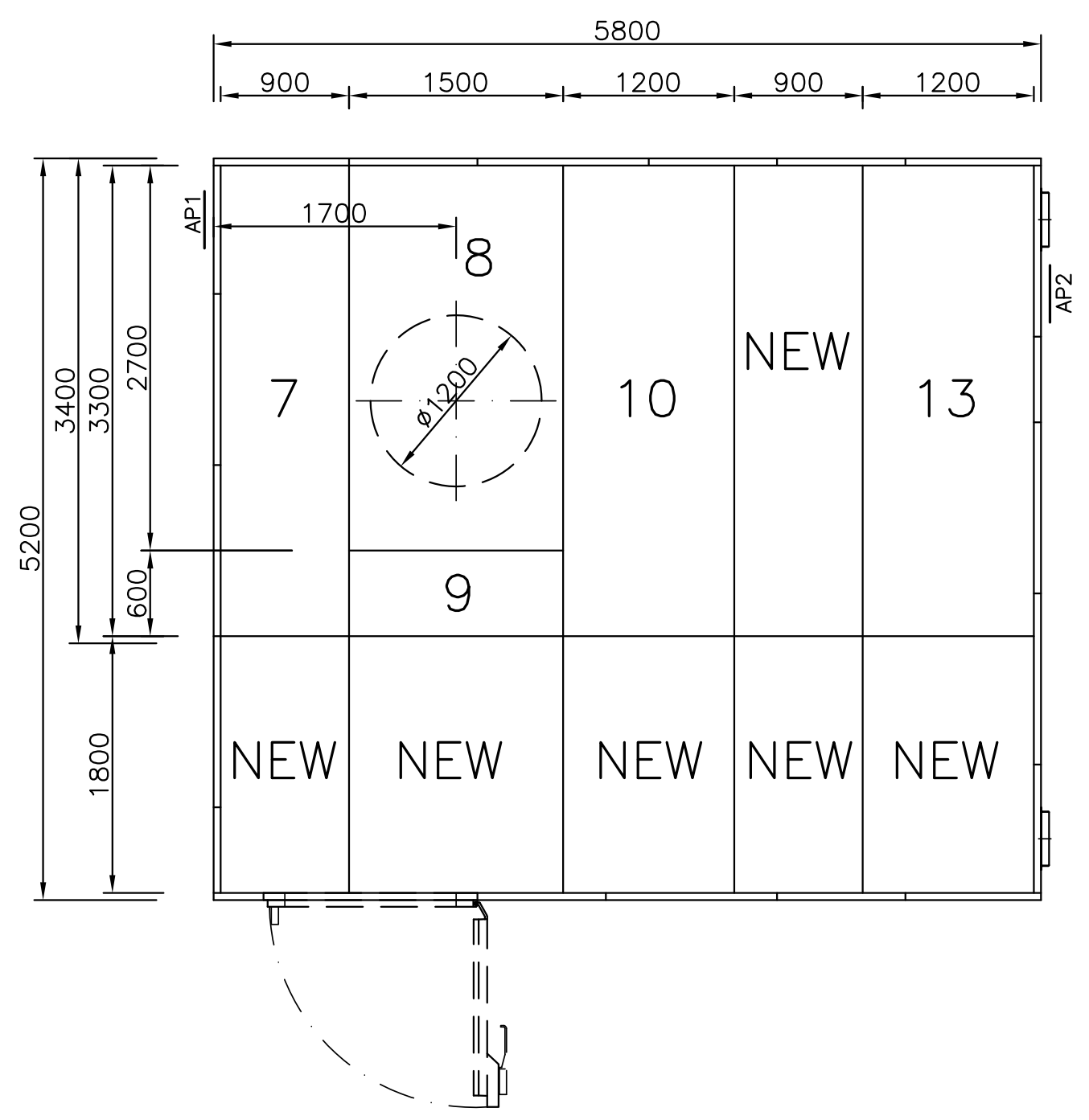


NEW R&S-CHAMBER

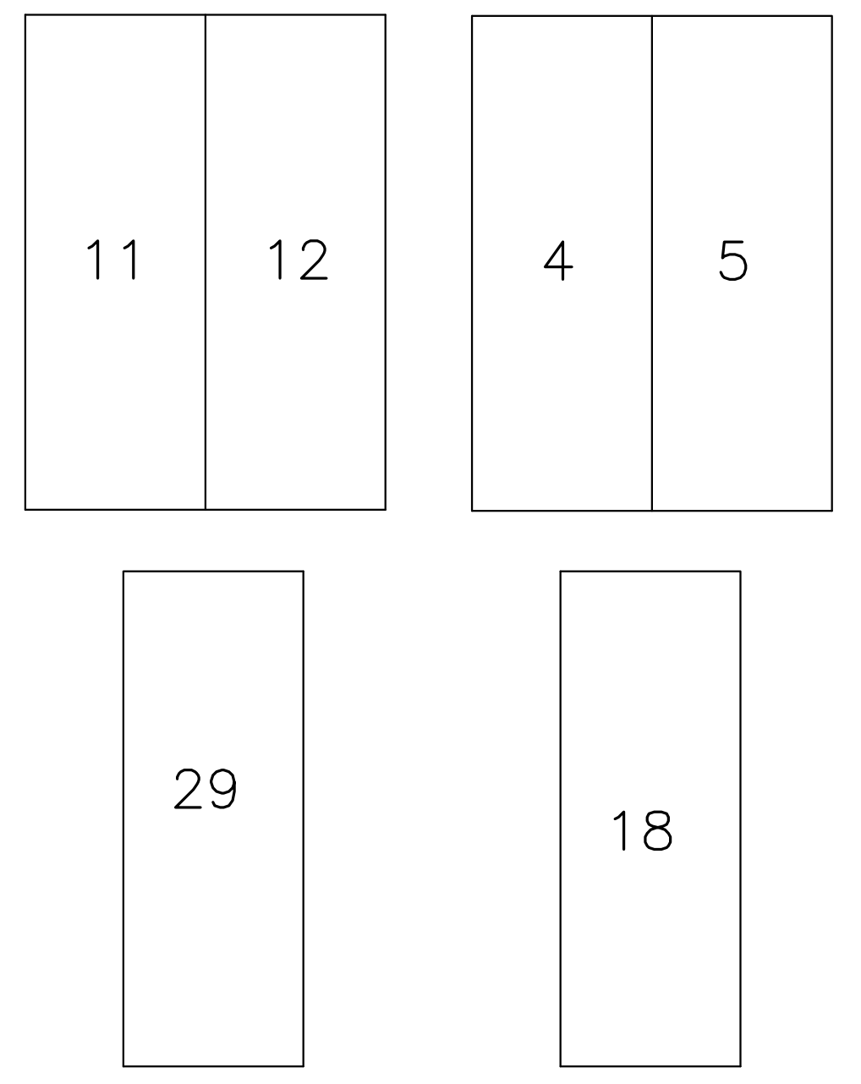
TOP VIEW
SCALE 1:50



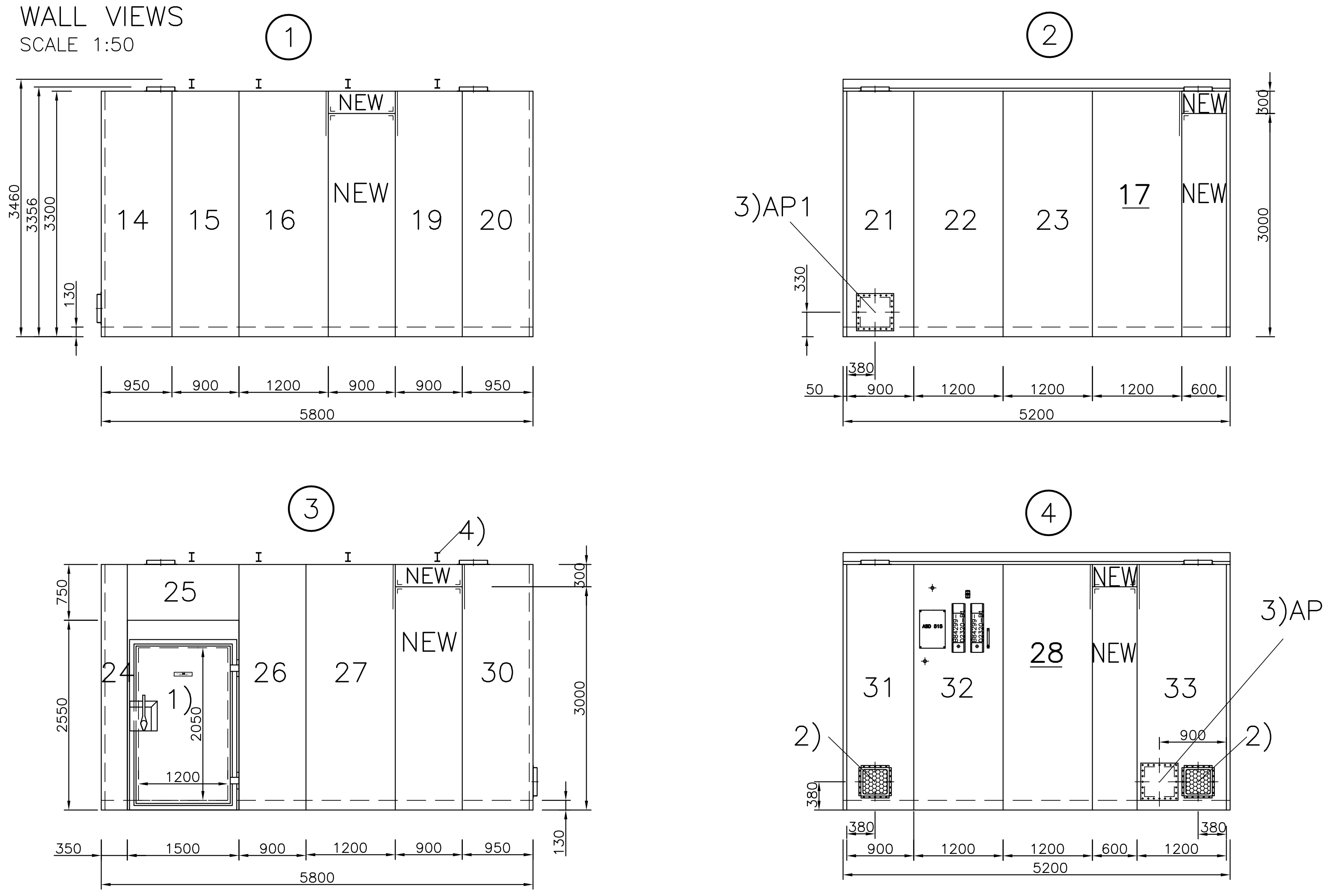
FLOOR VIEW
SCALE 1:50



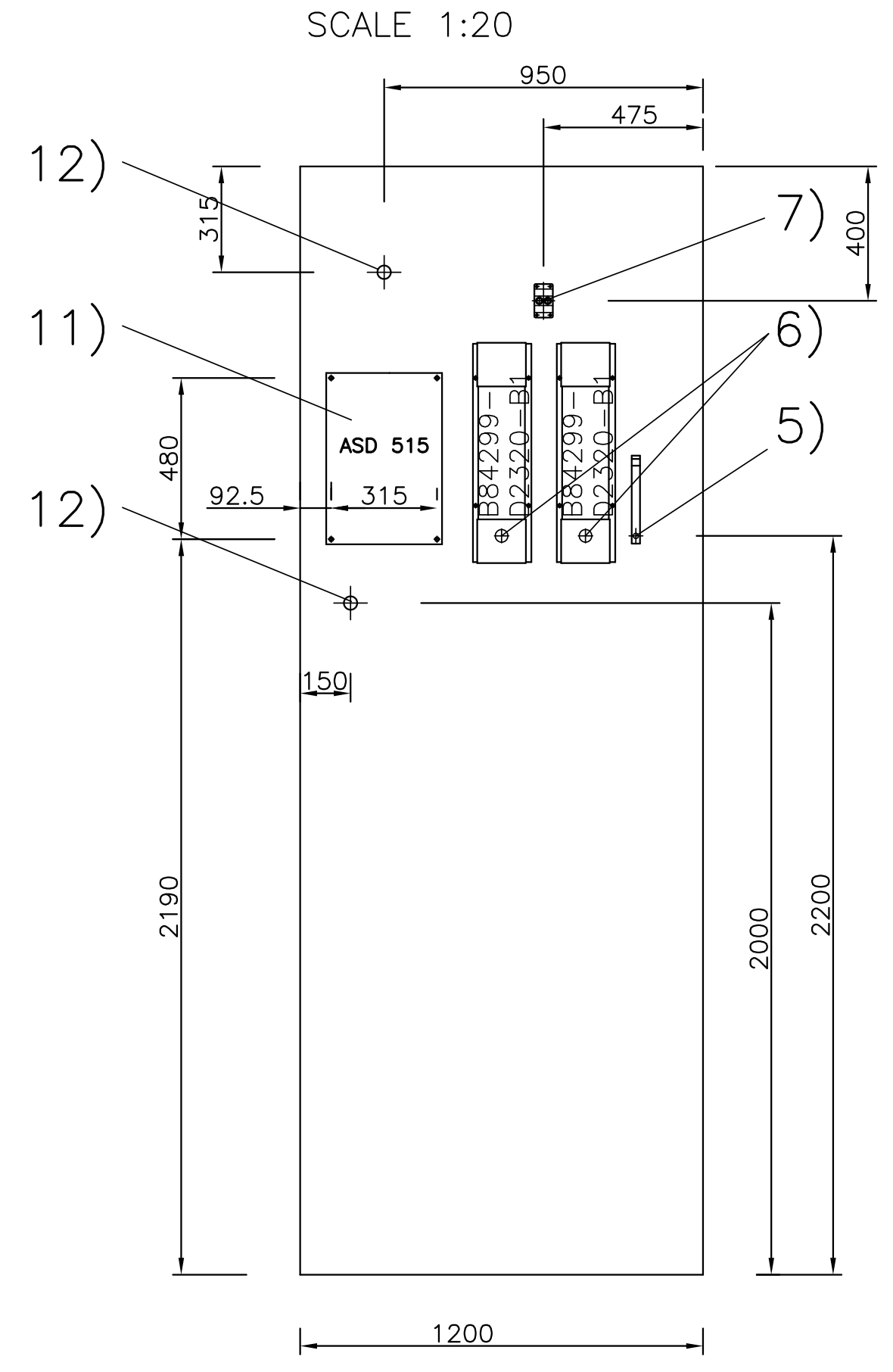
OLD MODULES THAT ARE NOT INTEGRATED



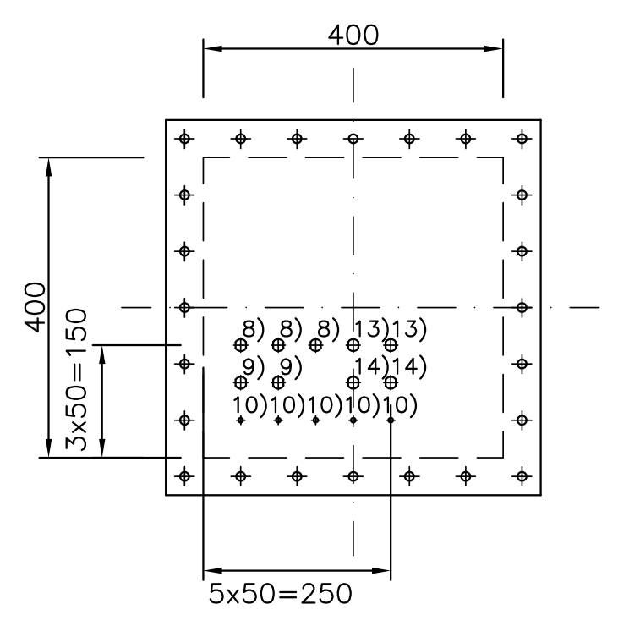
WALL VIEWS
SCALE 1:50



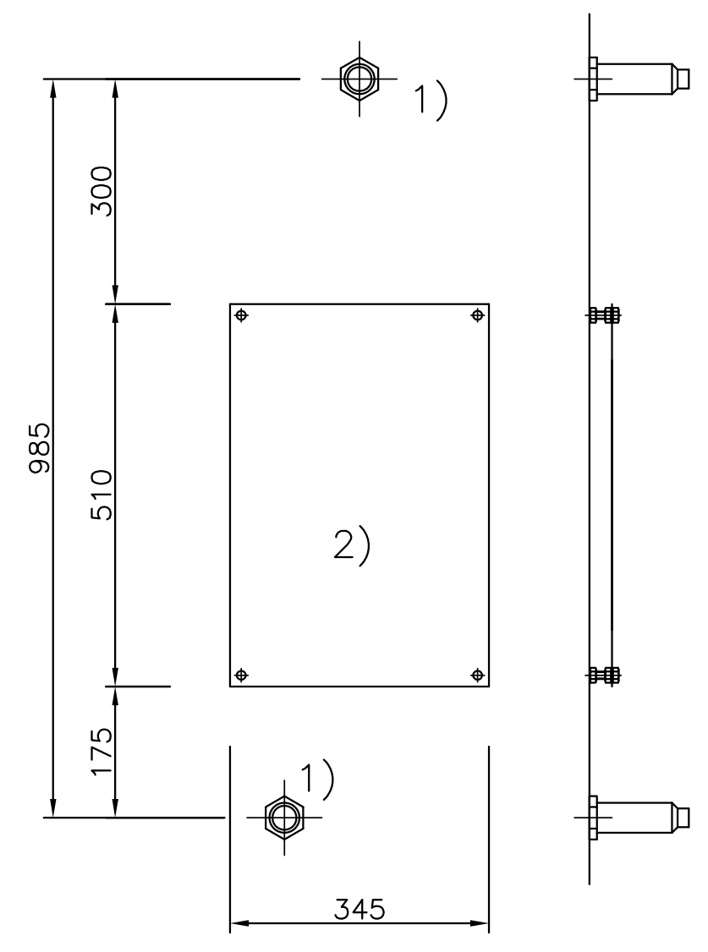
FILTER-PANEL
SCALE 1:20



PENETRATION PANEL AP1/AP2
SCALE 1:10



DETAIL ASD 515
M 1:10



1) ASD TUBE LEAD IN 40 GHz,

2) INSTALLATION PLATE, DIM. 345x510mm

HOT GALVANIZED SHEET STEEL, 2mm THICK CONTINOUSLY CANTED, UNLACQUED.
ONLY THE DOOR PANEL IS LACQUER COATED RAL 7035.

	QUANTITY		TYPE
1)	1	BLADE CONTACT DOOR, SINGLE LEAF, CWxCH = 1200x2050mm	B83117-B1432-T161
2)	6	HONEYCOMB 20 GHz, 330x330mm, BOLTED	B83316-C1-Z12
3)	2	PENETRATION PANEL, 400x400mm, BOLTED	B83313-B1008
4)	5	ROOF BEAM, L = 3100mm	B83204-A-Z501
5)	1	FILTER FOR TELEPHONE LINE 2x0,1A	B84312-F20-B3
6)	2	FILTER FOR POWERLINES, 2x32A	B84299-D2320-B1
7)	1	GROUNDING BOLT	B83208-A-Z830
8)	6	N-CONNECTOR, 50 OHM	B83207-A50-Z732
9)	4	BNC-CONNECTOR, 50 OHM	B83207-A50-Z738
10)	10	FSMA-FIBEROPTIC CABLE CONNECTOR	B83207-A-Z734
11)	1	SMOKEDETECTION - SYSTEM (ONLY TUBES)	. . .
12)	2	TUBE LEAD IN FOR SMOKEDETECTION	B83208-A-Z846
13)	4	BNC-CONNECTOR, 75 OHM	B83207-A75-Z738
14)	4	N-CONNECTOR, 75 OHM	B83207-A75-Z732
15)			. . .

PERMITTED FLOOR LEVEL DEVIATION FOR THE ERECTING AREA OF THE ENCLOSURE ACCORDING TO DIN 18202 (TOLERANCES FOR STRUCTURAL ENGINEERING), TABLE 3, LINE 4, HALF VALUES:

DISTANCE OF MEASURING POINTS IN m	1	4	10	15
TOLERANCE IN mm	1.5	4.5	6.0	7.5

P28231	B83117-S20-X835		Scale 1:50 1:20	1:10		
			Date	Name		Revision
		Drawn	09.08.17	Raab	LGAI Barcelona / R&S Spain C-CDC RELOCATION AND ENHANC. SHIELDING 20 GHz	1
		Check	09.08.17	Berger		
		Norm				Page No
1 created	09.08.17 Raab	AlbatrossProjects				
Rev Announcement	Date Name				C62128-A520-A740-1-7606	1

Anexo 4

En este anexo se presentan los datos numéricos resultados de la validación.

Desviación antena ROD:

Frequency (MHZ)	$E_{0\ ref}$ dB(μV/m)	E_{eq} dB(μV/m)	Deviation (dB)
0,15	58,13	57,2932391	-0,83676087
0,35	61,14	58,3977863	-2,74221371
0,55	61,14	59,8547201	-1,2852799
0,75	61,14	59,8492217	-1,29077835
0,95	61,14	59,8811745	-1,25882554
1,15	61,14	60,3247192	-0,81528077
1,35	61,14	60,330164	-0,80983603
1,55	61,14	60,2317308	-0,90826917
1,75	61,13	60,1694494	-0,96055063
1,95	61,13	60,1526547	-0,97734527
2,15	61,13	60,3324874	-0,79751258
2,35	61,13	60,2549292	-0,87507078
2,55	61,12	60,2073545	-0,91264549
2,75	61,12	60,1803653	-0,93963471
2,95	61,12	60,1602797	-0,95972032
3,15	61,11	60,1712519	-0,93874812
3,35	61,11	60,167157	-0,94284297
3,55	61,11	60,0882607	-1,02173927
3,75	61,1	60,1029304	-0,99706957
3,95	61,1	60,0336946	-1,06630543
4,15	61,09	59,9706685	-1,11933147
4,35	61,09	59,8401458	-1,24985419
4,55	61,08	59,7635073	-1,31649272
4,75	61,08	59,6984803	-1,38151969
4,95	61,07	59,6880584	-1,38194163
5,15	61,07	59,6190723	-1,45092768
5,35	61,06	59,5790782	-1,48092175
5,55	61,05	59,5686153	-1,4813847
5,75	61,05	59,4346544	-1,61534555
5,95	61,04	59,3198037	-1,72019633

6,15	61,03	59,2452832	-1,78471684
6,35	61,02	59,1124651	-1,90753491
6,55	61,02	58,9240469	-2,09595312
6,75	61,01	58,7222342	-2,28776579
6,95	61	58,4923144	-2,50768562
7,15	60,99	58,2856198	-2,70438017
7,35	60,98	58,0656439	-2,91435615
7,55	60,98	57,8615757	-3,11842428
7,75	60,97	57,5849488	-3,38505122
7,95	60,96	57,4213945	-3,53860552
8,15	60,95	57,1499054	-3,80009459
8,35	60,94	56,8350588	-4,10494116
8,55	60,93	56,6018221	-4,32817792
8,75	60,92	56,3531639	-4,56683615
8,95	60,91	56,147113	-4,76288699
9,15	60,9	55,915868	-4,98413199
9,35	60,89	55,7355855	-5,15441447
9,55	60,88	55,5608183	-5,31918172
9,75	60,86	55,4087554	-5,45124459
9,95	60,85	55,2721839	-5,57781611
10,15	60,84	55,1998876	-5,64011244
10,35	60,83	55,2289825	-5,60101754
10,55	60,82	55,2361969	-5,58380306
10,75	60,81	55,3804255	-5,42957454
10,95	60,79	55,5937367	-5,19626329
11,15	60,78	55,8890905	-4,8909095
11,35	60,77	56,2053954	-4,56460459
11,55	60,76	56,5788165	-4,1811835
11,75	60,74	56,9830793	-3,75692066
11,95	60,73	57,4464069	-3,28359314
12,15	60,72	57,9145595	-2,80544048
12,35	60,7	58,3839763	-2,31602374
12,55	60,69	58,8317785	-1,85822151
12,75	60,67	59,2720102	-1,39798981
12,95	60,66	59,6683421	-0,99165788
13,15	60,65	60,0515077	-0,59849228

13,35	60,63	60,3894659	-0,24053413
13,55	60,62	60,7066748	0,08667479
13,75	60,6	60,9976171	0,39761712
13,95	60,59	61,2546583	0,66465828
14,15	60,57	61,5017532	0,93175321
14,35	60,56	61,7412277	1,18122769
14,55	60,54	61,9668167	1,42681668
14,75	60,52	62,1956014	1,67560139
14,95	60,51	62,4139736	1,90397361
15,15	60,49	62,5551522	2,06515219
15,35	60,48	62,5203927	2,04039267
15,55	60,46	62,4228838	1,96288378
15,75	60,44	62,3382891	1,89828909
15,95	60,43	62,2845826	1,85458259
16,15	60,41	62,2238415	1,81384148
16,35	60,39	62,1619816	1,77198156
16,55	60,38	62,0452491	1,66524912
16,75	60,36	61,9506581	1,59065815
16,95	60,34	61,8885536	1,54855358
17,15	60,33	61,9406988	1,61069879
17,35	60,31	62,2328217	1,92282165
17,55	60,21	62,6900047	2,48000471
17,75	60,28	62,9376784	2,65767843
17,95	60,26	63,0084272	2,74842725
18,15	60,24	62,9874747	2,74747467
18,35	60,22	62,9610553	2,74105526
18,55	60,21	62,9541661	2,74416613
18,75	60,19	62,9753324	2,78533241
18,95	60,17	63,0191179	2,84911792
19,15	60,15	63,0779345	2,9279345
19,35	60,14	63,1823145	3,04231449
19,55	60,12	63,29297	3,17296995
19,75	60,1	63,4216077	3,3216077
19,95	60,08	63,5857366	3,50573658
20,15	60,07	63,7545276	3,68452758
20,35	60,05	63,9546476	3,90464763

20,55	60,03	64,1382153	4,10821532
20,75	60,02	64,3375106	4,31751064
20,95	60	64,5237255	4,5237255
21,15	59,98	64,6632104	4,68321042
21,35	59,96	64,7861477	4,82614765
21,55	59,95	64,8360455	4,88604546
21,75	59,93	64,9173008	4,98730084
21,95	59,91	65,0333206	5,12332064
22,15	59,9	65,209755	5,30975503
22,35	59,88	65,4147973	5,53479726
22,55	59,87	65,6132378	5,74323778
22,75	59,85	65,7965586	5,94655856
22,95	59,83	65,9710922	6,14109217
23,15	59,82	66,0980205	6,27802048
23,35	59,8	66,2223074	6,4223074
23,55	59,79	66,3314676	6,54146765
23,75	59,77	66,4356409	6,66564087
23,95	59,76	66,4775303	6,7175303
24,15	59,74	66,4890081	6,74900812
24,35	59,73	66,5586858	6,82868585
24,55	59,72	66,6022056	6,88220563
24,75	59,7	66,6919856	6,99198558
24,95	59,69	66,8183061	7,12830605
25,15	59,68	66,9424215	7,26242149
25,35	59,67	67,0460517	7,37605171
25,55	59,66	67,1273545	7,46735451
25,75	59,65	67,1900378	7,5400378
25,95	59,63	67,2418075	7,61180754
26,15	59,62	67,2806762	7,66067622
26,35	59,62	67,2694583	7,64945832
26,55	59,61	67,3120663	7,7020663
26,75	59,6	67,3103405	7,71034049
26,95	59,59	67,3240841	7,73408413
27,15	59,58	67,3373288	7,75732875
27,35	59,58	67,3941268	7,81412682
27,55	59,57	67,4063396	7,83633963

27,75	59,56	67,425813	7,86581298
27,95	59,56	67,5134105	7,95341048
28,15	59,56	67,4734343	7,91343429
28,35	59,55	67,4676622	7,91766218
28,55	59,55	67,519234	7,96923398
28,75	59,55	67,4739904	7,92399045
28,95	59,55	67,5313486	7,98134859
29,15	59,55	67,508947	7,95894697
29,35	59,55	67,5632074	8,01320738
29,55	59,55	67,5337638	7,98376375
29,75	59,55	67,5829812	8,03298124
29,95	59,55	67,6269021	8,07690207

Desviación antena BICO:

Frequency (MHz)	$E_{0\ ref}$ dB(µV/m)	$E_{eq\ Hor}$ dB(µV/m)	$E_{eq\ Ver}$ dB(µV/m)	$E_{eq\ max}$ dB(µV/m)	Deviation max (dB)
30	71,24	72,3232345	58,0416793	72,3232345	-1,08323448
31	71,39	72,5545758	58,3644245	72,5545758	-1,16457576
32	71,51	73,2352239	58,9678899	73,2352239	-1,7252239
33	71,62	74,2291549	59,9463027	74,2291549	-2,60915487
34	71,71	75,3321978	60,7981211	75,3321978	-3,62219781
35	71,81	76,3749219	60,7564832	76,3749219	-4,56492192
36	71,92	76,7352806	60,0848328	76,7352806	-4,81528061
37	72,09	77,0174743	59,3032295	77,0174743	-4,92747434
38	72,36	77,5348054	58,5296822	77,5348054	-5,17480538
39	72,84	78,2276897	57,6986598	78,2276897	-5,38768967
40	73,61	79,0208994	56,7293879	79,0208994	-5,41089939
41	74,76	79,6433741	55,565188	79,6433741	-4,88337406
42	76,28	80,0587314	54,67009	80,0587314	-3,77873139
43	78,03	80,2661597	55,0050208	80,2661597	-2,23615974
44	79,76	80,5471757	56,2450059	80,5471757	-0,78717572
45	81,16	81,0330296	57,7799283	81,0330296	0,1269704
46	82,04	81,5182538	59,2306676	81,5182538	0,52174623
47	82,43	81,8914782	60,464831	81,8914782	0,53852185
48	82,48	82,021166	61,2468168	82,021166	0,45883403
49	82,37	81,9987821	61,8114041	81,9987821	0,37121793

50	82,2	81,9318449	62,7193929	81,9318449	0,26815513
51	82,03	81,5897983	63,0314716	81,5897983	0,44020172
52	81,87	81,4117113	63,3259531	81,4117113	0,45828868
53	81,75	81,3339938	63,7521151	81,3339938	0,41600621
54	81,65	81,298383	63,2449887	81,298383	0,351617
55	81,57	81,1963242	62,8141144	81,1963242	0,3736758
56	81,52	81,3430125	63,3493182	81,3430125	0,17698754
57	81,48	81,2830235	63,3262249	81,2830235	0,19697651
58	81,47	81,3176232	63,0992089	81,3176232	0,15237677
59	81,46	81,703308	63,1866264	81,703308	-0,24330804
60	81,47	82,2934605	63,7978894	82,2934605	-0,82346049
61	81,49	82,857436	64,2544048	82,857436	-1,36743597
62	81,52	83,142789	64,2443324	83,142789	-1,62278897
63	81,55	83,0656416	64,0819456	83,0656416	-1,51564157
64	81,59	82,8044673	63,9509555	82,8044673	-1,21446732
65	81,63	82,630726	64,0637056	82,630726	-1,00072604
66	81,68	82,6481495	63,7098217	82,6481495	-0,96814954
67	81,73	83,0754817	63,9490092	83,0754817	-1,3454817
68	81,79	83,4333517	64,1432783	83,4333517	-1,64335168
69	81,85	83,6587482	63,7673678	83,6587482	-1,80874815
70	81,91	83,5024113	62,5010266	83,5024113	-1,5924113
71	81,97	83,3160006	60,9169527	83,3160006	-1,34600059
72	82,03	83,2778041	59,7114208	83,2778041	-1,24780412
73	82,1	83,0190713	58,8444611	83,0190713	-0,91907126
74	82,17	82,5959429	58,4548983	82,5959429	-0,42594288
75	82,24	82,1940113	58,1306873	82,1940113	0,0459887
76	82,31	82,1496077	57,8432494	82,1496077	0,1603923
77	82,38	82,1385831	57,6202916	82,1385831	0,24141692
78	82,45	82,1243031	57,4606754	82,1243031	0,32569695
79	82,53	82,1474404	57,2251534	82,1474404	0,38255959
80	82,61	82,2274796	56,8876053	82,2274796	0,38252042
81	82,69	82,1027282	56,6116317	82,1027282	0,5872718
82	82,77	81,9338225	56,5711936	81,9338225	0,83617748
83	82,85	81,7848417	57,0050299	81,7848417	1,06515826
84	82,94	81,6951239	57,6871398	81,6951239	1,24487606
85	83,03	81,6588047	58,3214596	81,6588047	1,37119527

86	83,12	81,893854	59,1027315	81,893854	1,22614605
87	83,22	82,0714883	60,0586824	82,0714883	1,14851166
88	83,32	82,1525819	61,0115488	82,1525819	1,16741806
89	83,42	82,1883083	62,4165836	82,1883083	1,23169169
90	83,53	82,2800867	63,5747797	82,2800867	1,24991326
91	83,64	82,393737	65,3038207	82,393737	1,24626304
92	83,75	82,5789878	66,8745963	82,5789878	1,17101223
93	83,87	82,8044165	68,1051061	82,8044165	1,06558354
94	83,99	82,9655478	69,1175788	82,9655478	1,02445218
95	84,11	83,0209022	69,7756324	83,0209022	1,0890978
96	84,23	83,2049082	70,3544176	83,2049082	1,02509184
97	84,35	83,4079591	70,8433038	83,4079591	0,94204092
98	84,47	83,6812334	71,3648806	83,6812334	0,78876655
99	84,59	84,0072434	72,0405495	84,0072434	0,58275663
100	84,71	84,3480296	72,7326388	84,3480296	0,36197041
101	84,83	84,2796121	73,0003991	84,2796121	0,55038792
102	84,94	84,1119335	73,1644466	84,1119335	0,8280665
103	85,05	83,8836704	73,1802898	83,8836704	1,16632963
104	85,15	83,6482012	73,1160433	83,6482012	1,50179881
105	85,25	83,4837464	73,1097535	83,4837464	1,76625363
106	85,35	83,7016125	73,486639	83,7016125	1,64838753
107	85,43	83,9953543	73,947045	83,9953543	1,43464566
108	85,52	84,303715	74,4351161	84,303715	1,21628501
109	85,59	84,5773691	74,8908228	84,5773691	1,01263085
110	85,67	84,7612604	75,1967005	84,7612604	0,9087396
111	85,73	84,9220615	75,3711391	84,9220615	0,80793848
112	85,79	85,0450822	75,4815256	85,0450822	0,74491777
113	85,85	85,177048	75,6214984	85,177048	0,67295195
114	85,9	85,3346922	75,8965514	85,3346922	0,56530776
115	85,95	85,5478315	76,3626928	85,5478315	0,40216852
116	85,99	85,6986356	76,8254094	85,6986356	0,29136439
117	86,03	85,8444779	77,2199318	85,8444779	0,1855221
118	86,06	85,9702264	77,4905206	85,9702264	0,08977359
119	86,09	86,0657838	77,6393426	86,0657838	0,0242162
120	86,12	86,1525544	77,7148217	86,1525544	-0,03255441
121	86,15	85,9996244	77,570181	85,9996244	0,1503756

122	86,17	85,8888385	77,5785205	85,8888385	0,28116145
123	86,18	85,8198347	77,7385702	85,8198347	0,36016528
124	86,2	85,7881616	78,00991	85,7881616	0,41183835
125	86,21	85,7650993	78,1876533	85,7650993	0,4449007
126	86,22	85,7702217	78,2598686	85,7702217	0,44977834
127	86,22	85,6964328	78,13893	85,6964328	0,52356722
128	86,22	85,6127383	78,0028979	85,6127383	0,60726172
129	86,22	85,5414747	78,0089735	85,5414747	0,67852526
130	86,22	85,531102	78,1576088	85,531102	0,68889798
131	86,21	85,5150399	78,2879128	85,5150399	0,6949601
132	86,2	85,5691311	78,416383	85,5691311	0,63086891
133	86,18	85,6325278	78,4542403	85,6325278	0,54747224
134	86,16	85,6511645	78,281795	85,6511645	0,50883546
135	86,14	85,5703434	78,0394634	85,5703434	0,5696566
136	86,12	85,4454839	77,8624837	85,4454839	0,67451608
137	86,09	85,2995944	77,8341975	85,2995944	0,79040558
138	86,06	85,2274337	77,9886947	85,2274337	0,83256633
139	86,03	85,3135981	78,2953943	85,3135981	0,71640194
140	85,99	85,4567329	78,5036155	85,4567329	0,53326712
141	85,95	85,8279041	78,7968716	85,8279041	0,12209586
142	85,9	86,1460566	79,052524	86,1460566	-0,24605659
143	85,85	86,3842273	79,3206058	86,3842273	-0,53422731
144	85,8	86,4339175	79,5445361	86,4339175	-0,63391753
145	85,75	86,5750177	79,9334925	86,5750177	-0,82501774
146	85,69	86,7617969	80,3325443	86,7617969	-1,07179694
147	85,63	87,0289749	80,6825851	87,0289749	-1,39897489
148	85,56	87,3070834	80,9061358	87,3070834	-1,74708336
149	85,49	87,5808076	81,0615663	87,5808076	-2,09080759
150	85,41	87,7795957	81,2186369	87,7795957	-2,36959574
151	85,33	87,3456165	81,1236469	87,3456165	-2,01561655
152	85,24	87,3344514	81,297197	87,3344514	-2,09445137
153	85,14	87,5432152	81,5234703	87,5432152	-2,40321521
154	85,04	87,7337674	81,581088	87,7337674	-2,69376744
155	84,93	87,9477836	81,6144554	87,9477836	-3,01778362
156	84,82	87,9828607	81,616932	87,9828607	-3,16286068
157	84,69	87,8878537	81,5778562	87,8878537	-3,19785371

158	84,55	87,7262205	81,5575727	87,7262205	-3,1762205
159	84,41	87,5612589	81,5979029	87,5612589	-3,15125892
160	84,25	87,4866087	81,7044965	87,4866087	-3,23660866
161	84,07	87,5406244	81,8893716	87,5406244	-3,47062438
162	83,88	87,6100499	82,0467488	87,6100499	-3,73004988
163	83,68	87,572724	82,143479	87,572724	-3,89272402
164	83,45	87,3561072	82,1922964	87,3561072	-3,90610716
165	83,21	87,0800886	82,2507124	87,0800886	-3,8700886
166	83,02	86,8866242	82,3881119	86,8866242	-3,86662421
167	83,28	86,7389253	82,4909089	86,7389253	-3,45892528
168	83,54	86,7941716	82,7187245	86,7941716	-3,25417158
169	83,8	86,7121448	82,8291034	86,7121448	-2,9121448
170	84,05	86,5888828	82,9606937	86,5888828	-2,53888283
171	84,29	86,3373938	83,0439596	86,3373938	-2,04739375
172	84,53	86,0133309	83,0409951	86,0133309	-1,48333095
173	84,77	85,839193	83,1237008	85,839193	-1,06919303
174	85	85,7818559	83,2295183	85,7818559	-0,78185591
175	85,22	85,7985743	83,2964991	85,7985743	-0,57857431
176	85,44	85,8070141	83,2036282	85,8070141	-0,36701412
177	85,65	85,8734756	82,9079452	85,8734756	-0,22347558
178	85,86	85,8942066	82,2621494	85,8942066	-0,03420657
179	86,06	85,9992276	81,8812695	85,9992276	0,06077244
180	86,26	86,087457	81,9120954	86,087457	0,17254298
181	86,44	86,3324011	82,2433737	86,3324011	0,10759886
182	86,62	86,5303145	82,4931975	86,5303145	0,0896855
183	86,78	86,799038	82,7641564	86,799038	-0,01903798
184	86,94	87,0526238	83,0171624	87,0526238	-0,11262379
185	87,07	87,2527082	83,2101209	87,2527082	-0,18270816
186	87,2	87,3554641	83,3575012	87,3554641	-0,15546411
187	87,31	87,4346721	83,5470531	87,4346721	-0,12467208
188	87,4	87,5421144	83,8155595	87,5421144	-0,14211439
189	87,48	87,6854295	84,1296281	87,6854295	-0,20542953
190	87,54	87,8431346	84,4592082	87,8431346	-0,30313458
191	87,6	87,9766754	84,8410248	87,9766754	-0,37667541
192	87,64	88,0158789	85,4534781	88,0158789	-0,37587892
193	87,67	87,9100644	85,8110959	87,9100644	-0,2400644

194	87,69	87,669205	86,0139926	87,669205	0,02079495
195	87,72	87,4446464	86,258596	87,4446464	0,2753536
196	87,74	87,3763699	86,6614803	87,3763699	0,36363014
197	87,77	87,3810015	87,1172457	87,3810015	0,38899846
198	87,81	87,3883948	87,5725837	87,5725837	0,23741634
199	87,87	87,316028	87,975345	87,975345	-0,10534503
200	87,9	87,0676084	88,2722059	88,2722059	-0,37220591

Desviación antena LOGO:

Frequency (MHz)	E_0 ref dB(µV/m)	E_{eq} Hor dB(µV/m)	E_{eq} Ver dB(µV/m)	E_{eq} max dB(µV/m)	Deviation max (dB)
200	87,9	83,3252986	83,5876734	83,5876734	4,31232656
205	88,58	84,6526736	86,4955233	86,4955233	2,08447668
210	89,59	83,7250094	87,5844989	87,5844989	2,00550113
215	90,61	82,3868072	88,1293151	88,1293151	2,48068488
220	91,47	82,0136637	89,3134837	89,3134837	2,15651632
225	92,24	81,7804606	89,6417735	89,6417735	2,59822649
230	93,05	82,9147315	91,0175452	91,0175452	2,03245476
235	93,96	83,2730445	92,8139075	92,8139075	1,14609248
240	94,94	83,4977158	94,047902	94,047902	0,89209803
245	95,9	84,6544474	94,975912	94,975912	0,92408803
250	96,81	85,5572937	95,9315765	95,9315765	0,87842351
255	97,66	85,2527653	97,0214268	97,0214268	0,6385732
260	98,46	84,5472846	97,6710029	97,6710029	0,78899711
265	99,22	84,6598191	98,5603928	98,5603928	0,65960721
270	99,92	84,4509522	99,4425217	99,4425217	0,4774783
275	100,53	84,4427972	100,13225	100,13225	0,39774963
280	101,03	85,4687406	100,691374	100,691374	0,33862605
285	101,4	85,6140793	100,959714	100,959714	0,44028629
290	101,65	85,6165997	101,211502	101,211502	0,43849828
295	101,76	86,0559284	101,201818	101,201818	0,5581823
300	101,74	85,9738987	101,018485	101,018485	0,72151516
305	101,59	85,7528823	101,055434	101,055434	0,53456646
310	101,34	85,5627707	100,957744	100,957744	0,38225552
315	100,99	85,5510159	100,809492	100,809492	0,18050788

320	100,55	85,5494212	100,808027	100,808027	-0,25802713
325	100,05	85,1763848	100,622773	100,622773	-0,57277304
330	99,62	85,1154655	100,710261	100,710261	-1,09026076
335	99,38	84,8495342	100,391595	100,391595	-1,01159501
340	99,17	85,0033616	100,219777	100,219777	-1,04977696
345	98,93	84,8753943	99,990415	99,990415	-1,06041503
350	98,61	84,9482166	99,6313526	99,6313526	-1,02135257
355	98,14	86,1374006	99,5021773	99,5021773	-1,36217725
360	97,67	87,0056031	99,0911897	99,0911897	-1,42118968
365	97,48	87,8712506	98,5140348	98,5140348	-1,03403476
370	97,49	88,8108831	98,0871968	98,0871968	-0,59719683
375	97,58	89,0864737	97,5891288	97,5891288	-0,00912877
380	97,68	89,0554014	97,1001936	97,1001936	0,5798064
385	97,73	89,1228302	96,4515198	96,4515198	1,27848019
390	97,74	89,1584956	96,0223261	96,0223261	1,71767388
395	97,74	89,0434331	95,6004018	95,6004018	2,13959823
400	97,78	89,1468833	95,3934196	95,3934196	2,38658042
405	97,86	89,3208077	95,346	95,346	2,51400002
410	97,96	89,0671028	95,2515129	95,2515129	2,70848715
415	98,07	89,3388964	95,5042635	95,5042635	2,56573646
420	98,19	89,0658475	95,475958	95,475958	2,71404202
425	98,33	88,610844	95,7954296	95,7954296	2,5345704
430	98,48	88,8857668	96,1789034	96,1789034	2,30109665
435	98,64	89,0942262	96,5807604	96,5807604	2,05923964
440	98,8	89,2850772	96,9854938	96,9854938	1,8145062
445	98,95	89,1870976	97,2975331	97,2975331	1,6524669
450	99,06	88,7110675	97,6095736	97,6095736	1,45042638
455	99,11	88,1189315	97,7863356	97,7863356	1,32366438
460	99,09	87,5582524	97,952158	97,952158	1,137842
465	98,99	86,8261371	97,9779773	97,9779773	1,01202269
470	98,86	86,0797543	97,9463314	97,9463314	0,91366857
475	98,72	85,7295124	98,0510571	98,0510571	0,66894292
480	98,59	85,7303981	98,1915339	98,1915339	0,39846606
485	98,49	85,6517724	98,2953156	98,2953156	0,19468439
490	98,38	85,2683841	98,3922931	98,3922931	-0,01229307
495	98,25	84,7494136	98,1870891	98,1870891	0,0629109

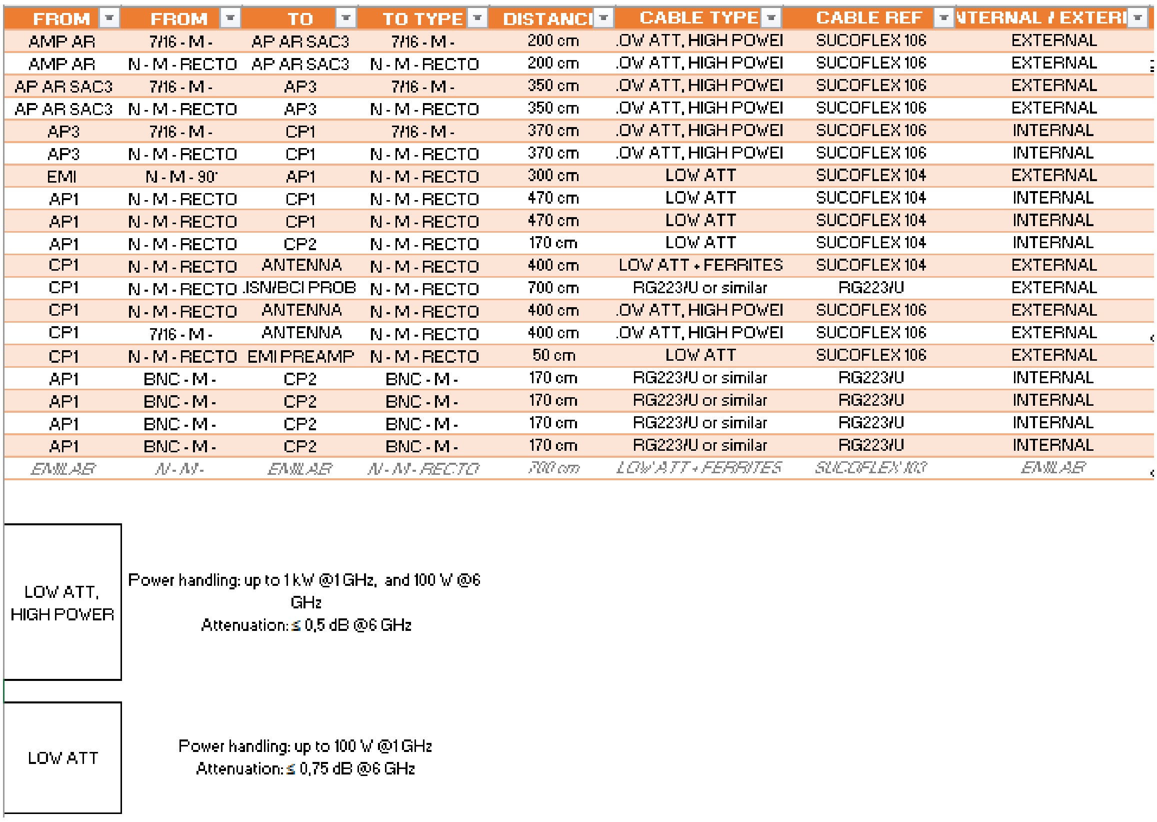
500	98,12	83,9684517	98,114032	98,114032	0,00596797
505	97,97	83,1948477	97,706204	97,706204	0,26379596
510	97,74	82,6360304	97,3825666	97,3825666	0,35743339
515	97,54	81,7798028	96,6613869	96,6613869	0,87861306
520	97,55	81,7036361	95,8841819	95,8841819	1,66581806
525	97,43	81,7502025	95,3877414	95,3877414	2,04225861
530	97,24	81,1470427	95,0055022	95,0055022	2,2344978
535	97,15	80,7730702	94,9856633	94,9856633	2,16433672
540	97,22	80,5405427	94,934044	94,934044	2,28595605
545	97,36	80,6404771	94,9478158	94,9478158	2,41218423
550	97,33	80,1772403	94,7873629	94,7873629	2,54263706
555	96,96	79,0130843	94,6133955	94,6133955	2,34660446
560	96,3	77,5077926	94,3511344	94,3511344	1,94886559
565	95,59	76,6775252	93,8388564	93,8388564	1,75114357
570	94,92	76,4968404	93,2147778	93,2147778	1,70522216
575	94,26	76,6910346	92,424868	92,424868	1,83513205
580	93,6	76,2398064	91,6308243	91,6308243	1,96917569
585	92,94	79,1579503	90,5934933	90,5934933	2,34650668
590	92,33	84,2060339	89,2540647	89,2540647	3,07593527
595	91,8	87,4826489	87,349947	87,4826489	4,31735114
600	91,34	90,2849296	85,0121368	90,2849296	1,05507041
605	90,95	91,9034038	82,7854839	91,9034038	-0,95340379
610	91,06	93,3168331	83,3845135	93,3168331	-2,2568331
615	91,81	94,2234537	83,1662637	94,2234537	-2,41345369
620	92,51	94,1312629	82,8649742	94,1312629	-1,62126293
625	93,15	94,3844396	81,6503736	94,3844396	-1,23443957
630	93,7	94,3891808	81,1146295	94,3891808	-0,68918085
635	94,15	94,5592023	81,2305165	94,5592023	-0,40920227
640	94,5	95,049484	81,5056646	95,049484	-0,54948404
645	94,74	95,2383499	81,8398705	95,2383499	-0,49834994
650	94,88	95,5148853	81,381348	95,5148853	-0,63488528
655	94,92	95,9656453	81,7346425	95,9656453	-1,04564529
660	94,88	96,0412596	83,0696295	96,0412596	-1,16125956
665	94,76	95,8897624	84,5304827	95,8897624	-1,12976235
670	94,51	96,0380804	85,9614011	96,0380804	-1,52808036
675	94,08	96,0098097	86,8204672	96,0098097	-1,92980971

680	94,55	96,1048831	87,0094051	96,1048831	-1,55488314
685	95,18	95,8428564	87,3317709	95,8428564	-0,66285641
690	95,8	95,6152632	87,5808699	95,6152632	0,18473682
695	96,14	95,1218905	87,9039531	95,1218905	1,01810947
700	95,98	95,2034937	88,3528735	95,2034937	0,77650628
705	95,85	95,2130726	88,5434101	95,2130726	0,63692738
710	95,83	95,5752406	88,1361193	95,5752406	0,25475941
715	95,69	96,0179298	87,5848091	96,0179298	-0,32792983
720	95,28	96,3523396	87,9173039	96,3523396	-1,07233957
725	94,8	96,884238	88,2565944	96,884238	-2,08423798
730	94,65	97,1035539	88,3302652	97,1035539	-2,45355392
735	94,71	96,7967405	87,5665883	96,7967405	-2,08674047
740	94,86	96,6962348	86,6206771	96,6962348	-1,83623483
745	95,23	96,0942636	85,665011	96,0942636	-0,8642636
750	95,8	95,6811061	85,4364315	95,6811061	0,11889385
755	96,4	95,5978497	85,8613308	95,5978497	0,80215031
760	96,89	95,3034827	85,6916739	95,3034827	1,58651731
765	97,24	95,3952659	85,0620979	95,3952659	1,84473408
770	97,47	94,9730365	83,5844028	94,9730365	2,49696347
775	97,61	94,6132125	81,2987556	94,6132125	2,99678749
780	97,7	94,3266367	78,9303621	94,3266367	3,37336329
785	97,73	94,0472828	77,3920666	94,0472828	3,68271715
790	97,71	94,0532439	77,729296	94,0532439	3,65675608
795	97,63	93,9160801	78,6471134	93,9160801	3,71391995
800	97,49	93,6734312	80,0573652	93,6734312	3,8165688
805	97,3	93,858377	83,1636902	93,858377	3,44162297
810	97,08	93,9613591	86,1692639	93,9613591	3,11864092
815	96,84	94,2521083	88,5510585	94,2521083	2,58789169
820	96,61	94,3909501	90,3167619	94,3909501	2,2190499
825	96,39	94,4638834	91,5488138	94,4638834	1,92611661
830	96,19	94,5889564	92,7115532	94,5889564	1,60104357
835	96	94,7077119	93,5822999	94,7077119	1,29228809
840	95,86	94,6924326	94,355305	94,6924326	1,16756736
845	95,56	94,4340619	94,7064618	94,7064618	0,85353821
850	96,51	93,9987572	95,2670372	95,2670372	1,24296276
855	97,5	93,6749321	96,0056663	96,0056663	1,49433368

860	98,42	93,7265784	96,6196067	96,6196067	1,80039333
865	99,23	93,9050025	97,2982596	97,2982596	1,93174038
870	99,9	94,3925034	97,7958237	97,7958237	2,10417633
875	100,51	94,9851464	98,2757653	98,2757653	2,23423471
880	101,09	95,4407124	98,6694187	98,6694187	2,42058129
885	101,61	95,6840468	99,0213576	99,0213576	2,58864245
890	102,09	95,5228876	99,6572565	99,6572565	2,43274346
895	102,54	95,3911335	100,340673	100,340673	2,19932728
900	102,95	95,3524434	101,259517	101,259517	1,69048267
905	103,31	95,0140696	101,968095	101,968095	1,3419051
910	103,6	94,839218	102,494079	102,494079	1,10592056
915	103,84	94,7298677	103,02952	103,02952	0,81048015
920	104,03	94,6394584	103,118417	103,118417	0,91158347
925	104,18	94,5491642	103,234696	103,234696	0,94530413
930	104,26	93,896667	103,045677	103,045677	1,21432327
935	104,28	93,174822	102,85335	102,85335	1,4266502
940	104,24	92,3064044	102,874043	102,874043	1,36595726
945	104,14	92,0692924	103,020045	103,020045	1,11995532
950	104	92,0732201	103,474541	103,474541	0,52545853
955	103,84	91,796525	103,807385	103,807385	0,03261453
960	103,68	91,4094437	104,135724	104,135724	-0,45572391
965	103,53	90,593079	104,093827	104,093827	-0,56382665
970	103,39	89,6142116	103,924526	103,924526	-0,53452581
975	103,27	88,729234	103,751989	103,751989	-0,48198863
980	103,17	88,5875783	103,501202	103,501202	-0,33120214
985	103,08	89,4092374	103,33043	103,33043	-0,25042953
990	102,98	90,7892039	103,251335	103,251335	-0,27133537
995	102,86	91,4158372	103,044778	103,044778	-0,18477778
1000	102,69	91,3246988	102,682929	102,682929	0,00707059

Anexo 5

En la siguiente imagen pueden verse los detalles, longitudes, localización y conectores, de los cables elegídos para equipar SAC 4.



FROM	FROM	TO	TO TYPE	DISTANCI	CABLE TYPE	CABLE REF	NTERNAL / EXTERI
AMP AR	7/16 - M -	AP AR SAC3	7/16 - M -	200 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	EXTERNAL
AMP AR	N - M - RECTO	AP AR SAC3	N - M - RECTO	200 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	EXTERNAL
AP AR SAC3	7/16 - M -	AP3	7/16 - M -	350 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	EXTERNAL
AP AR SAC3	N - M - RECTO	AP3	N - M - RECTO	350 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	EXTERNAL
AP3	7/16 - M -	CP1	7/16 - M -	370 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	INTERNAL
AP3	N - M - RECTO	CP1	N - M - RECTO	370 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	INTERNAL
EMI	N - M - 90'	AP1	N - M - RECTO	300 cm	LOW ATT	SUCOFLEX 104	EXTERNAL
AP1	N - M - RECTO	CP1	N - M - RECTO	470 cm	LOW ATT	SUCOFLEX 104	INTERNAL
AP1	N - M - RECTO	CP1	N - M - RECTO	470 cm	LOW ATT	SUCOFLEX 104	INTERNAL
AP1	N - M - RECTO	CP2	N - M - RECTO	170 cm	LOW ATT	SUCOFLEX 104	INTERNAL
CP1	N - M - RECTO	ANTENNA	N - M - RECTO	400 cm	LOW ATT + FERRITES	SUCOFLEX 104	EXTERNAL
CP1	N - M - RECTO	.ISN/BCI PROB	N - M - RECTO	700 cm	RG223/U or similar	RG223/U	EXTERNAL
CP1	N - M - RECTO	ANTENNA	N - M - RECTO	400 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	EXTERNAL
CP1	7/16 - M -	ANTENNA	N - M - RECTO	400 cm	.OW ATT, HIGH POWEI	SUCOFLEX 106	EXTERNAL
CP1	N - M - RECTO	EMI PREAMP	N - M - RECTO	50 cm	LOW ATT	SUCOFLEX 106	EXTERNAL
AP1	BNC - M -	CP2	BNC - M -	170 cm	RG223/U or similar	RG223/U	INTERNAL
AP1	BNC - M -	CP2	BNC - M -	170 cm	RG223/U or similar	RG223/U	INTERNAL
AP1	BNC - M -	CP2	BNC - M -	170 cm	RG223/U or similar	RG223/U	INTERNAL
AP1	BNC - M -	CP2	BNC - M -	170 cm	RG223/U or similar	RG223/U	INTERNAL
EMILAB	N - M -	EMILAB	N - M - RECTO	700 cm	LOW ATT + FERRITES	SUCOFLEX 103	EMILAB

LOW ATT, HIGH POWER	Power handling: up to 1 kW @1 GHz, and 100 W @6 GHz Attenuation: ≤ 0,5 dB @6 GHz
LOW ATT	Power handling: up to 100 W @1 GHz Attenuation: ≤ 0,75 dB @6 GHz

Figura 1: Cableado de RF para equipar SAC 4

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