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TEMPEST Zoning for Complex Platforms

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***Abstract*—The electromagnetic topology and electromagnetic zoning challenges for TEMPEST are compared to zoning as used in other pillars within the electromagnetic compatibility domain, like nuclear electromagnetic pulse, lightning and lightning electromagnetic pulses, and electromagnetic interference. The objectives are the same, but the development of procedures, requirements and methodology have been developed in separate pillars resulting in different approaches. However, this paper shows that the zoning is actually the same, and gives some recommendation for requirements and verification methods.**

Keywords—TEMPEST, topology, zoning

I. Introduction

TEMPEST is a codename referring to spying on information systems through leaking emanations like unintentional radio, or electrical signals, emission [1]. TEMPEST covers both methods to spy upon others and how to shield equipment against such spying. The protection efforts for TEMPEST are also known as emission security (EMSEC). Protecting equipment from spying is done with distance, shielding and filtering, and is largely equivalent of the standard electromagnetic compatibility (EMC) efforts to protect a system against lightning, prevent unwanted emission, prevent intra-EMC issues with other systems on a platform, or to prevent susceptibility issues, including those from intentional electromagnetic interference (I-EMI). The TEMPEST standards mandate measures such as equipment distance from walls, distance between wires carrying classified vs. unclassified information, filters on cables etc. These measures are similar to standard EMC measures. Due to the increased interest in cyber-security, the TEMPEST approaches are now applied to many systems.

Conventional standards have often been, unintentionally, developed in different stovepipes, by for instance lightning specialists, radio specialists, EMI specialists or TEMPEST specialists. The main reason are the different agencies dealing with the various domain areas. When developing complex platforms with an extended topology, the EM approach is the same, but the measures could be conflicting with other requirements. In this paper a basic overview of EM topology and zoning from different domains is given. Then the state of the art of TEMPEST zoning is described, and a comparison is made, and suggestions for use.

II. EM Topology and Zones

The electromagnetic zoning approach is very common and used explicitly, but in most cases implicitly, by hardware architects and designers. The most common approach is the external environment (zone 0), to platform or building (zone 1), to protected (zone 2), to cabinet (zone 3), to apparatus (zone 4), to modules (zone 5) to board level (zone 6). The zone numbers are just an example. A basic implicit example is a server rack with several hot-swappable processing units, installed in a (shielded) 19-inch cabinet, which is installed in a building with some, for instance, lightning protection. An explicit example is the STANAG 4370 which is referring to the AECTP-501 [2], where different levels for radiated emission, radiated susceptibility and conducted susceptibility are given for electromagnetic exposed (for instance a ship's topside) and electromagnetic protected (below deck) environments.

Carl Baum described the zoning as a result of electromagnetic topology in the EM architecture [3], [4]. His major driving force was protection of aerospace systems against nuclear electromagnetic pulses (N-EMP). The main concept of electromagnetic topology is to divide the space of interest into volumetric zones in order to break down a total complex electromagnetic problem into a group of small problems independent of each other. The NATO AEP 41 [5] provides a detailed description on how to apply the zoning principle to many platforms. In Fig. 1 the basic barrier protection concept is shown, while in Fig. 2 a basic figure of multiple barrier topology is shown.

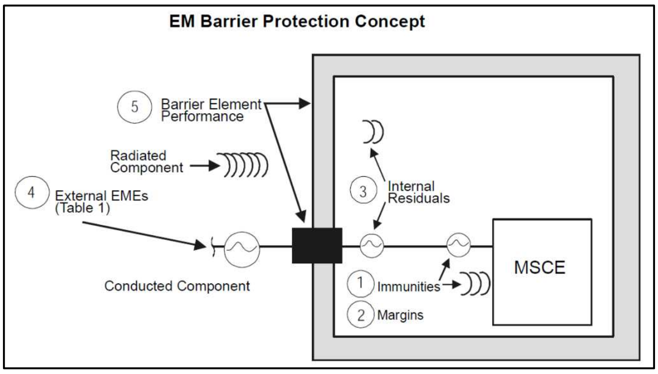

Fig. 1. EM Barrier Protection Concept Keyed to Allocation Equations, from NATO AEP 41 [5].

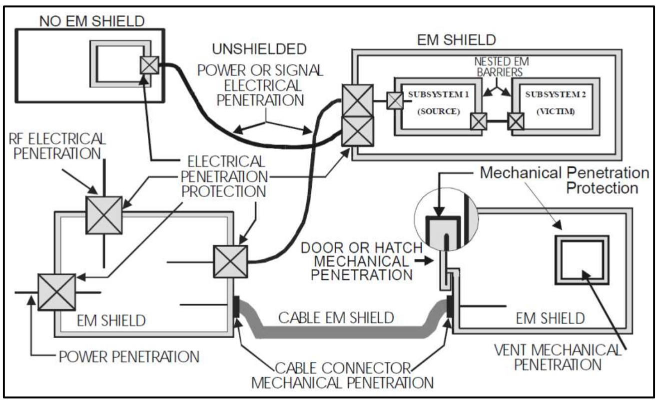

Fig. 2. Multiple Barrier Topology Design, from NATO AEP 41 [5].

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Only a few civil standards refer to zoning and EM topology. In IEC TR 61000-1-5 [6] the topology and zoning are mentioned, and a simple system is shown in Fig. 3, while the topological diagram for this system is shown in Fig. 4. A more detailed analysis is described in IEC TR 61000-5-6 [7]. This report is concerned with the arrangement of shielding and screening against radiated disturbances, and with mitigation of conducted disturbances. These arrangements include appropriate electromagnetic barriers.

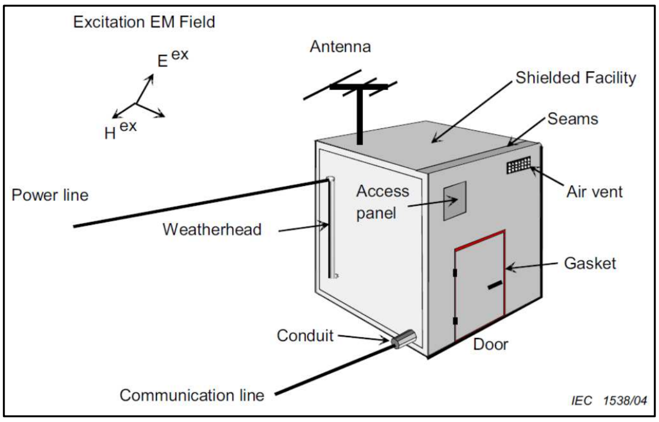

Fig. 3. Simplified illustration of a hypothetical facility excited by an external electromagnetic field, from IEC TR 61000-1-5 [6].

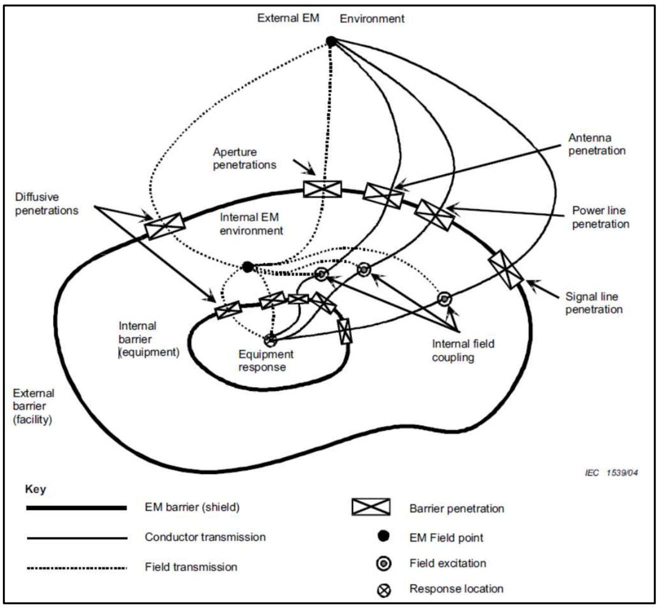

Fig. 4. The topological diagram for the simple system, from IEC TR 61000-1-5 [6].

The EM topology and its zoning has been applied also in the domain of lightning protection. In [8] the lightning protection zones (LPZ) are described and the EM barrier at the boundary [9] is called lightning equipotential bonding, as shown in Fig. 5. In Fig. 6 an example has been shown with the different lightning protection zones. An analysis and definition of the LPZ results in several protection levels with a fixed set of maximum and minimum lightning current parameters, such as shown in Table I. The maximum values are used in the design and the selection of appropriate surge protection devices (SPD).

TABLE I. LIGHTNING CURRENT FOR EACH LIGHTNING PROTECTION LEVEL, FROM [8]

LPL	I	II	III	IV
Maximum current [kA]	200	150	100	100
Minimum current [kA]	3	5	10	16

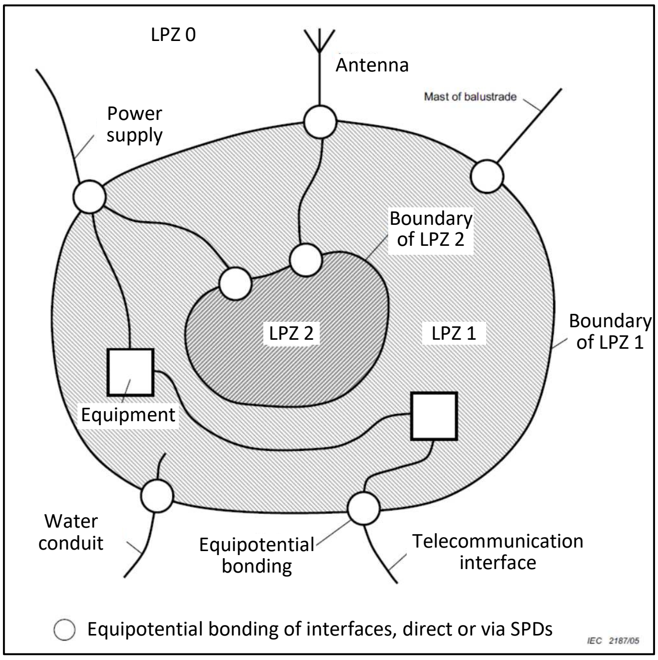

Fig. 5. General principle for zoning with various zones. The circles are lightning equipotential bonding.

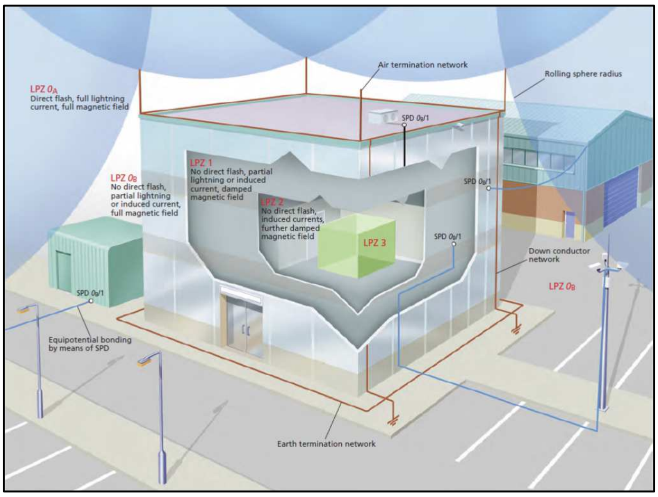

Fig. 6. The LPZ concept [10]. More detailed figures can be found in [10].

An example of mapping the LPZ to SPD is shown in Fig. 7, which is from IEC 62305-4 [8]. In Fig. 8 also the lightning electromagnetic pulse (L-EMP), or indirect lightning, is mentioned. SPD type 1 is for direct lightning, and designed for a waveform of 10/350 µs and a lightning current of 100 kA, while SPD type 2 is used for indirect lightning with a waveform of 8/20 µs and a level of 5 kA. Type 3 SPDs are used as a supplement in the vicinity of sensitive loads, and is characterized by a combination of the 8/20 µs current waveform and a 1.2/50 µs waveform. These SPDs are the standard devices in equipment which are tested against the IEC 61000-4-5

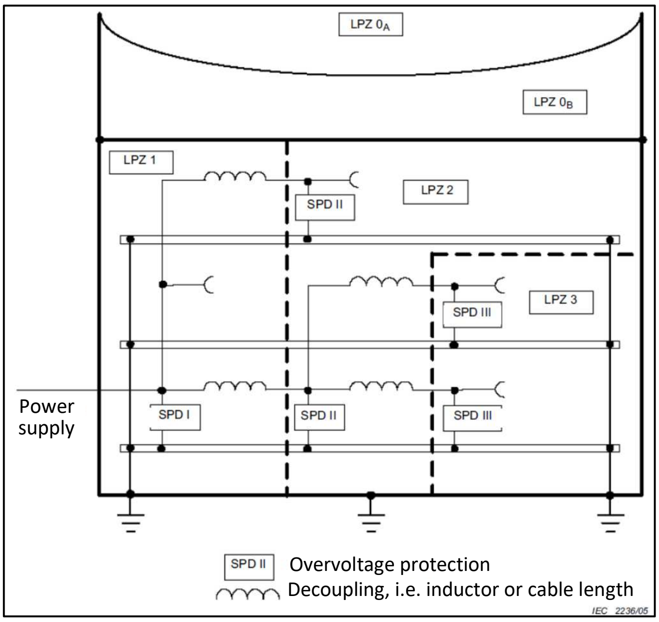

Fig. 7. LPZ and the SPDs, from IEC 62305-4 [8].

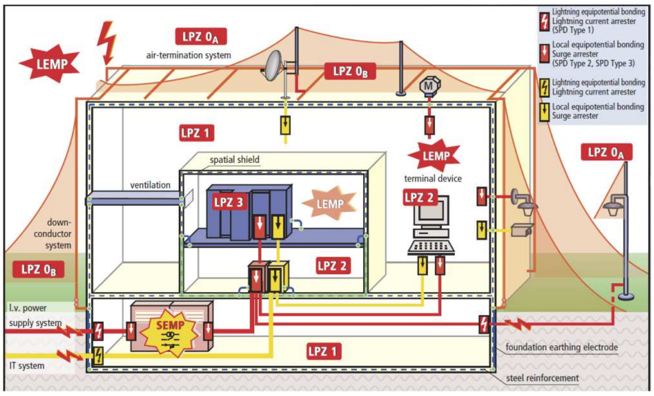

Fig. 8. Lightning protection zones and SPDs, from [11]

III. TEMPEST ZONING

Protecting complex platforms, like houses, offices, large plants, or mobile platforms like shelters, or even complete naval ships, for leakage of compromising emanation to achieve TEMPEST protection is very similar as the zoning approach used in the other pillars; Pillars like Nuclear EMP, Lightning or Lightning EMP, and basic EMI prevention.

This paper refers to information available only in the public domain, as most TEMPEST information is classified. In summary, the primary compromising emanation leakage paths are wireless communication systems and wired interfaces. Encryption of the information being communicated is the primary protective means, whilst in certain situations the use of a boundary protection device can be an alternative. The secondary compromising emanation leakage paths are the unwanted radiated electromagnetic fields. In this sense, an ‘attacker’ is a person who would like to receive compromising emanations, i.e. a radiated electromagnetic field which, after demodulation and interpretation, contains classified information, as shown in Fig. 9. To prevent unwanted radiated electromagnetic fields, the equipment can be hardened such that no unwanted electromagnetic fields are radiated. The other approach would be to put equipment in a controlled area, where no ‘attacker’ can be present. This controlled area is called ‘inspectable space’. Another approach is to place equipment in shielded enclosures, such that no unwanted electromagnetic field can be received outside such zone. The information itself can also be encrypted to decrease the likelihood of interpretation of data streams.

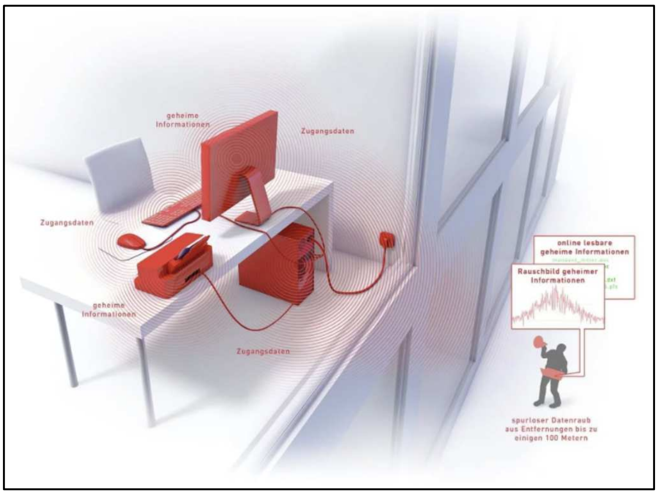

Fig. 9. Attacker outside a building receiving compromising emanations, from [13].

Zoning Procedures define attenuation measurement procedures, according to which individual rooms within a security perimeter can be classified into Zone 0, Zone 1, Zone 2, or Zone 3, which then determines what shielding test standard is required for equipment that processes classified data in these rooms [1]. The levels are described in classified standards, but in [1] it is written:

- Level A: This is the strictest standard for devices that will be operated in Zone 0 environments, where it is assumed that an attacker has almost immediate access (e.g. neighboring room, about 1 meter distance).
- Level B: This is a slightly relaxed standard for devices that are operated in Zone 1 environments, where it is assumed that an attacker cannot get closer than about 20 meters, or where building materials ensure an attenuation equivalent to the free-space attenuation of this distance.
- Level C: An even more relaxed standard for devices operated in Zone 2 environments, where attackers have to deal with the equivalent of 100 meters of free-space attenuation, or equivalent attenuation through building materials.

Mapping these zones to protection of equipment is shown in Fig. 10

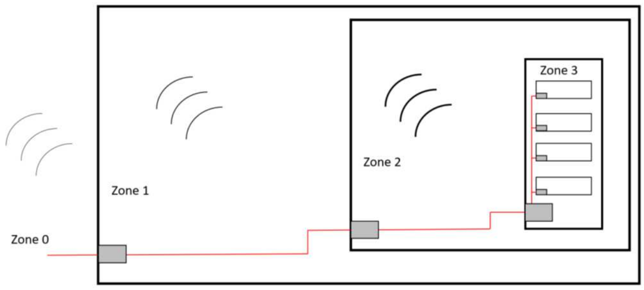

Fig. 10. Conceptual TEMPEST zoning model

Other standards define the installation requirements, for example in respect to grounding and cable distances. Based on the separation distance one can derive the required attenuation between the boundaries.

IV. Zoning requirements for complex systems

Electromagnetic topology is to divide the space of interest into zones in order to break down a total complex electromagnetic problem into a group of small problems independent of each other. For a naval ship, the zones are (in general):

- Zone 0: external to the platform, lightning, nuclear electromagnetic pulse, intentional EMI, EMI due to another platform: STANAG 4370, AECTP-250 series [14]
- Zone 1: on-platform, electromagnetically exposed, STANAG 4370, AECTP-500 series [2]
- Zone 2: on-platform, electromagnetically protected environment, STANAG 4370, AECTP-500 series [2]
- Zone 3: on-platform, inside cabinet in an electromagnetically protected environment, STANAG 4370, AECTP-500 series [2]

Only for EMC Zone 1 to Zone 2 we can find an attenuation, or shielding effectiveness of 26 dB, based on the levels for NCS07 and NRS02, although for NRE02 a SE of 20 dB is given. For Zone 2 to Zone 3 no clear SE can be found, although a 20 dB minimum is often assumed.

In MIL-STD 464D [15] a link with TEMPEST is made: 'In some cases, the RE102 limits of MIL-STD-461 are considered an acceptable risk level for TEMPEST control of unintentional radiated electromagnetic emissions.' The MIL-STD-461 levels are similar or equal to the AECTP-500 levels.

An overall approach to EMC and TEMPEST could involve the creation of a zone-equipment level overview combining the generic EMI requirements with the TEMPEST requirements. This will however require access to classified information.

V. Zoning verification

The shielding effectiveness can be measured using the SE techniques as described in IEEE 299 [16] for buildings and large rooms, and IEEE 299.1 [17] for cabinets. Measurements can be performed with empty cabinets, or partially filled to investigate the effect of cavity resonance. In another paper more detail is given [18]. The attenuation of filters can be verified using the techniques described in IEC CISPR 17 [19], or IEEE STD 1560 [20]. As the installation of filters can decrease its performance, the actual or emphasized way of installation should be taken into account. The influence of electrical parts like an uninterruptable power supply can also be verified, such as shown in [21]. The attenuation of cable transits, cable feedthrough and glands can be verified using the methods described in [22].

VI. Conclusion

TEMPEST zoning is compared with zoning as used in other EMC pillars, like N-EMP, lightning, L-EMP and EMI. In essence there are no differences. Only the levels, i.e. the required attenuation, are different and sometimes unclear, and a rationale for the levels is not obvious. When designing complex and extensive platforms, where all EMC measures have to be taken into account simultaneously, the EMC architect has to be able to combine the requirements into single and clear requirements. To verify the performance of the EM zoning, several measurement techniques have been used, and can be used to verify the performance of complex systems with respect to all requirements.

Acknowledgement

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