Proficiency Testing for Conducted Immunity with a new Round Robin Test Device

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***Abstract*— Last year, a new round robin test device was proposed for inter-laboratory comparisons in conducted immunity testing according to IEC 61000-4-6[1]. The device has recently been successfully evaluated among all EMRP Project partners. The device is able to confirm or to deny the testing capability of a laboratory by recording a full set of parameters. The device is now ready for deployment as the first commercial proficiency testing device for conducted immunity.**

Keywords—Electromagnetic Compatibility (EMC), IEC 61000-4-6, EN ISO 17025, EN ISO 17043, proficiency testing, round robin, test device, conducted immunity, common mode, disturbance signal, Coupling-Decoupling Network (CDN), inter-laboratory comparison, Equipment under Test (EUT), Auxiliary Equipment (AE).

I. Introduction

An accredited test laboratory according to EN ISO 17025 [2] should fulfill a large set of requirements in order to assure the quality of the test results. One of these requirements is the participation of the laboratory to inter-laboratory comparisons or proficiency testing.

However, today, accredited EMC test laboratories only rarely participate in inter-laboratory comparisons. The main reason is that there are simply no adequate EMC devices available for comparisons; especially in the area of immunity testing. General requirements are given in ISO 17043 [3] but there is no precise reference document or technical standard that describes this problematic issue. Therefore a new round robin test device has been projected and developed last year [1], with a focus on the test of conducted immunity according to IEC 61000-4-6.

In contrast to immunity testing, inter-laboratory test devices for EMC testing of emissions have already been developed [4]. These devices are basically round robin test devices consisting of a stable disturbance source that is aimed to be measured by the laboratory. In the case of immunity, the task is somehow more difficult since the device should be able to validate the correct testing and to detect the incorrect testing of the laboratory having problems such as:

- A bad traceability of the measurement like a wrong or expired calibration.
- Mistakes coming from a wrong test setup, e.g. using a wrong number or type of CDN.
- Mistakes in the protocol testing, e.g. testing only a subset of all required frequencies.
- A poor connection between CDNs and ground plane

This contribution presents a complete evaluation of this unique test device aimed for conducted immunity, which is capable of doing the tasks explained above. The test device has been sent to the 10 laboratories participating to the EMRP Project (EMC Industry). All results are presented in details and they show that the device is now, with few modifications, ready for commercial deployment as the first proficiency testing device in EMC conducted immunity.

This paper is organized as follows. Section II explains the testing scheme and the details regarding the metrics observed during the measurements. Section III explains the test results and the reactions of the device for different errors in the setups. Finally, the conclusions are given in Section IV.

II. Testing scheme

The architecture and the operation principles of the device have already been presented [1]. The functionality of the test device for measuring the magnitude of the common mode disturbance signal flowing through its interfaces and the metallic housing versus frequency has been proven. Moreover,

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the stability and the repeatability of the measurements have been evaluated as quite high.

In order to assess the ability of the round robin test device to be used for proficiency testing, we defined 8 different testing scheme scenarios (See Table 1). Each scenario defines precisely the interface that should be used for the coupling (i.e. signal injection) and the interface for decoupling. Each participant was asked to measure 3 times each scenario in order to check the repeatability of the measurements and the stability of the device by every partner.

Scenario	Coupling Made On	Decoupling Made On
1	Channel 1 (CH 1)	Channel 2 (CH 2)
2	Channel 1 (CH 1)	Channel 3 (CH 3)
3	Channel 1 (CH 1)	Channel 4+5 (CH 4+5)
4	Channel 1 (CH 1)	Channel 6 (CH 6)
5	Channel 2 (CH 2)	Channel 1 (CH 1)
6	Channel 3 (CH 3)	Channel 1 (CH 1)
7	Channel 4+5 (CH 4+5)	Channel 1 (CH 1)
8	Channel 6 (CH 6)	Channel 1 (CH 1)

Table 1. The scenarios defined in the testing scheme

The IEC 61000-4-6 standard mentions that for the devices with more than two interfaces, only one of the interfaces should be chosen as the injection (i.e. coupling) interface, and the rest of the interfaces should be connected to decoupling CDNs, only one of these interfaces being terminated with 50Ω, thus providing only one return path [5]. According to the scenario definitions, each interface has to be separately tested. By this way, any phenomena related with the type of connector and cables (shielded or unshielded) could be evaluated. The channel 1 (i.e. CH 1) is the power interface of the device and therefore it was always selected to be connected to a CDN. Our round robin test device (see Figure 1) measures the frequency of the disturbance signal on this interface.

Figure 1. The front view of the conducted immunity round robin device

The selected test parameters of the conducted common mode current are given in Table 2. These values correspond to Level 3 in IEC 61000-4-6 standard. Only one level was selected in order to avoid too many scenarios and thus to reduce the testing time. Furthermore, the signal duration for each frequency was recommended to be at least 1 second. By this way, the device can have at least 3 measurements (i.e. amplitude of each channel including the frequency information) at every frequency point.

The device can also simulate a failure by changing a LED's color from green to red, depending on the amplitude or on the frequency of the signal observed on the metaling housing of the device (The threshold for the red LED can be freely programmed). All participants have therefore been asked to identify this "failure signal" and to report any kind of changes they would observe during their measurements.

Environmental Phenomenon	Test Specification	Units	Performance Criterion
Radio – Frequency Common Mode	0.15 to 80 10 80	MHz V % AM (1 kHz)	Green Light Expected (Red Light means device failure)

Table 2. Test parameters of the conducted current

METAS first calibrated the device by repeating the testing 5 times for every scenario and obtained so called "Expectation Values" in device units for each scenario. These expectation values were reported in forms of mean values with standard deviations.

Even though the device is very stable (typical deviation of less than 0.5 dB), a so called "Acceptance Tolerance" (of the typical order ±2.5 dB) has been defined in order to take into account the variations in the test infrastructures or in the test setups of the laboratories.

METAS included 3 different cables in the test package. These 3 cables are shielded and they have 3 different interfaces on one end; namely, USB, Ethernet and 4 pin OB connector. The other ends of the cables are banana socket with integrated 150 ohms common mode termination impedance. The motivation for these terminations is to simulate the auxiliary equipment (AE) in the setups. Another functionality of these cables is that in case a participant does not have the required CDN to test the interfaces, these cables can be used for coupling/decoupling. The discrepancy which would yield from this replacement was also taken into account.

In order to guarantee the stability of the device during the comparison, the device returned back to METAS after 4 partners for a control measurement. After this control measurement, the device was sent to the remaining 5 partners. The testing of the last partner (i.e. Partner 10) was still ongoing during the writing of this contribution. Moreover, Partner 7 measurements are also omitted due to some technical unclarity. Therefore, both Partner 7 and Partner 10 are excluded from the analysis of the results reported in this publication.

III. TEST RESULTS

The comparison generated an important number of values. For this contribution, the emphasis has been made on the most interesting and didactic cases. In order to protect the anonymity of the laboratories, the laboratories have been numbered arbitrarily in the results, tables and graphics.

A. Detection of Improper Decoupling

Scenario 1 is the default setup for applying conducted immunity test on the device. The signal injection is performed on CH1 which is the mains connector used for powering up the device. Decoupling is performed on CH2 that is a banana socket used for earth connection. The other interfaces are left open.

Figure 2, Figure 3 and Figure 4 provide an overview of the measurements of Partners 1,3,4,5 and 8 in Scenario 1. They show the signal level versus frequency observed on CH1, CH2 and CH7 respectively. The channel CH7 which is the signal channel connected to the metallic housing of the device is intended to assess the correct isolation in the setup.

The results of these three figures show a significant difference in Partner 1 measurements. The signals coupled on CH1 and decoupled on CH2 are significantly lower (about 2 units to 6 units, corresponding to about 5dB to 15 dB depending on the frequency) than expected, especially for frequencies from 150 kHz up to approximately 20 MHz. On the other hand, the signal flowing on CH7 is higher than expected for this frequency sub-band. This shows an imperfection in the coupling/decoupling mechanism in Partner 1's setup resulting in that the signal mostly flows over the housing, not inside the device.

After much effort to find the reason of this deviation, we noticed that for decoupling, the Partner 1 used a decoupling clamp [5] whereas all other participants used CDNs. The use of decoupling clamp is of course allowed according to IEC 61000-4-6. However, in the case of Partner 1, the termination of the cable used for decoupling was not properly done. It was left open (See Figure 5). This violates the requirement of having 150 Ohm at the AE side. As expected, especially for lower frequencies, the signal indeed faces more resistance on the path from CH1 to CH2 and less resistance on the path from CH1 to CH7, resulting from the open circuit conditions in the CH2. Therefore, the amount of signal flowing on CH7 is significantly higher. This also explains why the observed signal level is higher in CH7 for lower frequencies.

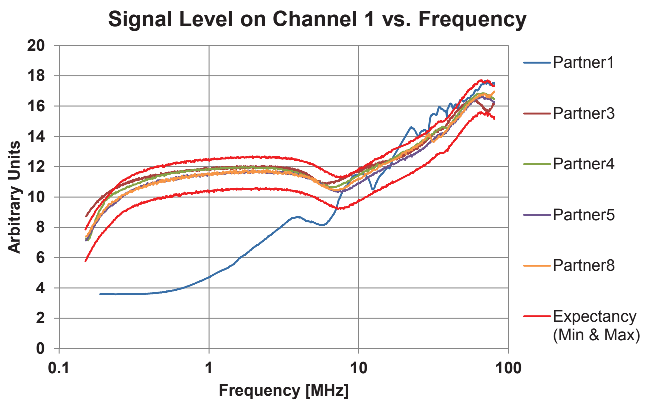

Figure 2. Signal level measured on CH1 versus frequency for Scenario 1 for Partners 1,3,4,5 and 8 and expectancy curves (1 unit ≈ 2.5 dB)

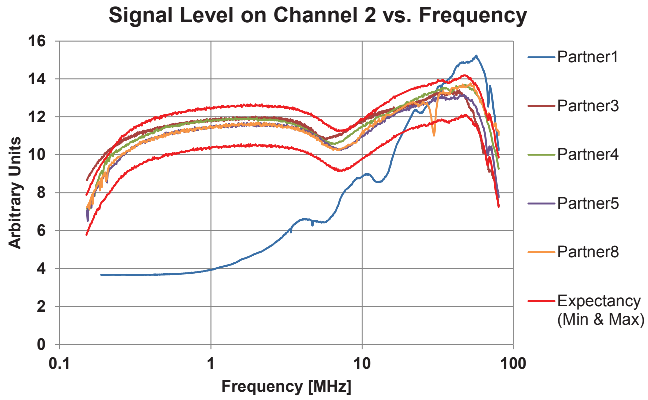

Figure 3. Signal level measured on CH2 versus frequency for Scenario 1 for Partners 1,3,4,5 and 8 and expectancy curves (1 unit ≈ 2.5 dB)

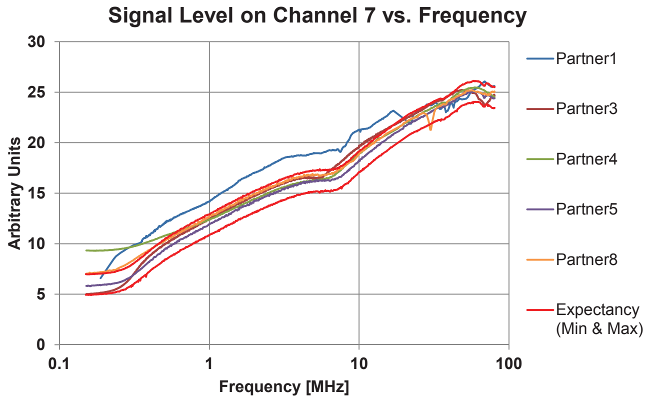

Figure 4. Signal level measured on CH7 versus frequency for Scenario 1 for Partners 1,3,4,5 and 8 and expectancy curves (1 unit ≈ 2.5 dB)

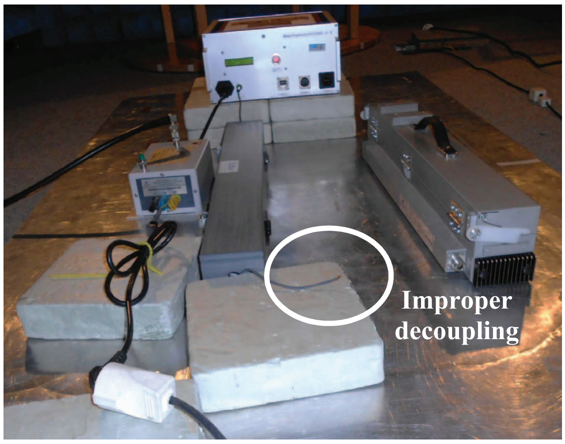

Figure 5. The improper decoupling in Scenario 1 at Partner 1

B. Compensation for Decoupling Problems

A similar incident occurred with Partner 3 on Scenario 4. Partner 3 performed the measurements for Scenario 4 several times with different setups. In their first setup, they used a CDN on CH1 for coupling the common mode current on the device and an EM clamp for decoupling it over CH6. Like Partner 1, the termination of the cable used for decoupling was left open. This arrangement is shown in Figure 6, and further denoted as Setup A in the figures. In order to improve the measurements, Partner 3 also tested another setup. The EM Clamp was omitted and a jig with a termination of 150 Ω was considered as a replacement of a CDN. This arrangement is denoted as Setup B (See Figure 7).

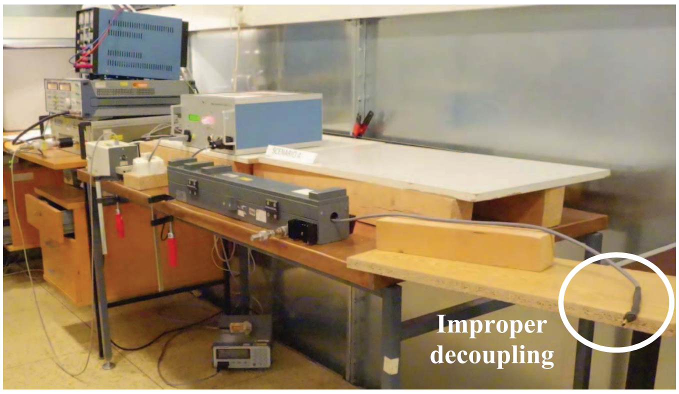

Figure 6. The improper decoupling in Setup A for Scenario 4 at Partner 3

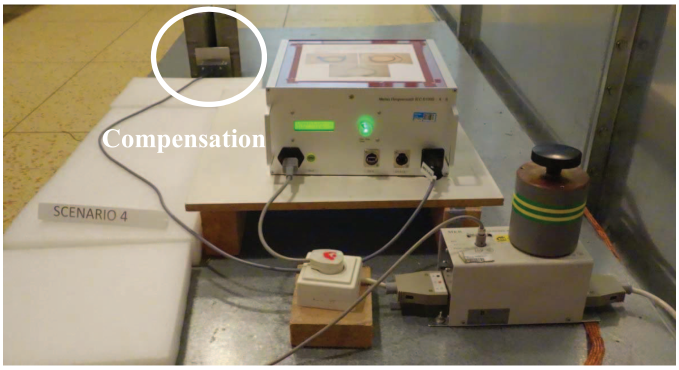

Figure 7. Decoupling over CH6 with a jig having 150Ω termination (i.e. Compensation) in Setup B for Scenario 4 at Partner 3

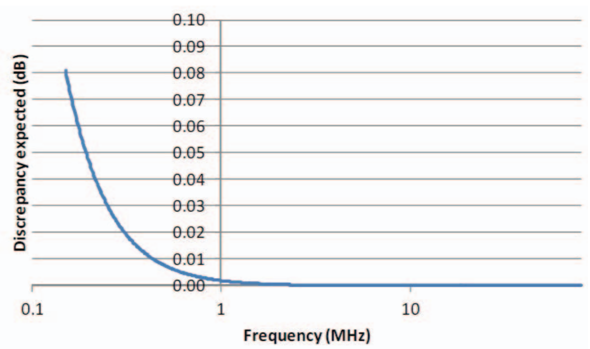

Figure 8. Simulation of the discrepancy brought by 150Ω termination with a jig instead of a CDN

In order to assess the validity of the second setup, a quick simulation was performed based on the variation of total impedance of the common closed loop, including the round robin test device. For this simulation, the round robin device was modelled by a 21 nF capacitor, confirmed by previous evaluations. As depicted in Figure 8, the discrepancy between Setups A and B is very low (0.08 dB in worst case). Therefore, it was concluded that the Setup B is valid. This demonstrated that the use of 150 Ω termination was applicable and that it should give the same results as using a CDN.

Figure 9, Figure 10 and Figure 11 depict the corresponding analysis for the measurements done using these 2 different setups of Partner 3 for Scenario 4. They show the signal level versus frequency observed on CH1, CH6 and CH7 respectively. This analysis shows that the significant deviation of Setup A could be acceptably improved with the Setup B.

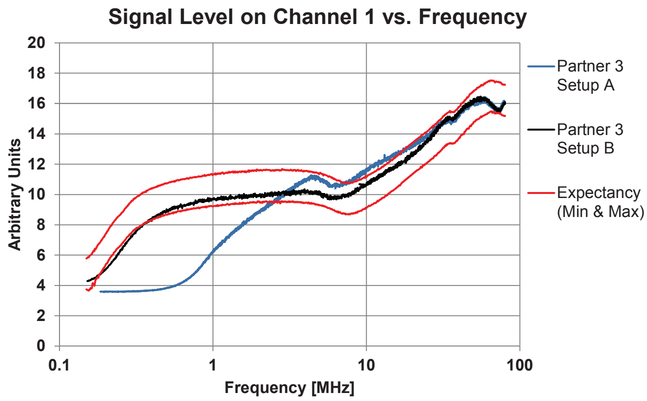

Figure 9. Signal level measured on CH1 versus frequency for Scenario 4 for Setups A and B at Partners 3 and expectancy curves (1 unit ≈ 2.5 dB)

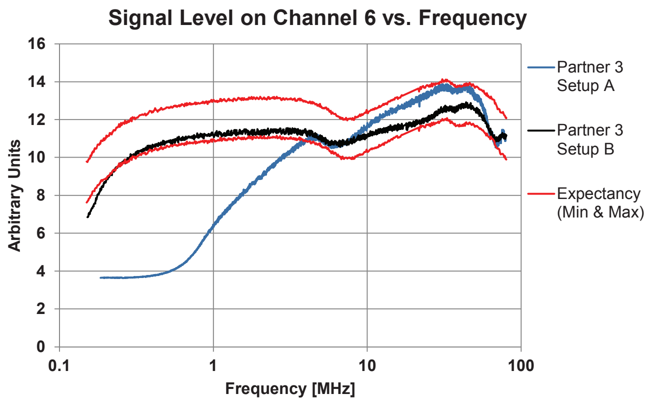

Figure 10. Signal level measured on CH6 versus frequency for Scenario 4 Setups A and B at Partners 3 and expectancy curves (1 unit ≈ 2.5 dB)

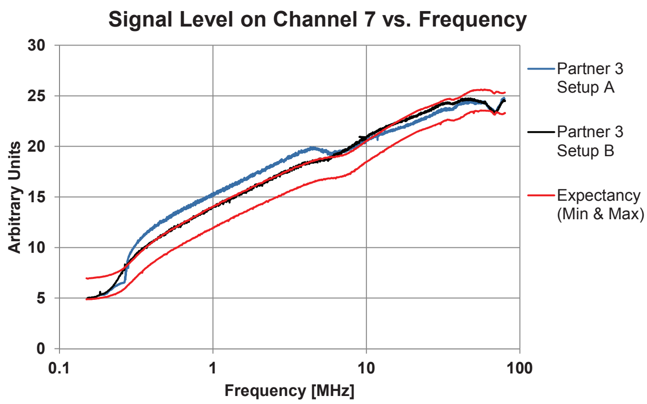

Figure 11. Signal level measured on CH7 versus frequency for Scenario 4 Setups A and B at Partners 3 and expectancy curves (1 unit ≈ 2.5 dB)

It is important to note here that the cable used for Setup B is a specially designed cable. It has 150Ω in between its ends. This resistance also contributes to the overall slight decrease in the signal level observed in the channels. However, the slight decrease in signal level resulted from this effect was considered as being within the expectancy curves defined by METAS.

This analysis applied on the measurements of the participants can be used not only for evaluating the coupling/decoupling mechanism, but also in order to assess the general condition of the setup so that it functions as required. The next case depicts this situation.

C. Detection of Generic Errors

The capability of the device for detecting some generic errors was proven in the Partner 9 measurements for Scenario 1. Partner 9 used two CDNs as required in the standard, one for coupling and one for decoupling. Nevertheless, the values they have reported were out of the expectancy curves. After a quick check on the setup, it was found that there was a broken connection in the connector of the cable used with M1 CDN for the decoupling. Partner 9 identified the problem and corrected it by changing the cable with a proper (i.e. normal) one. The test was repeated again. The second test showed similar results as expectancy curves (see Figure 12, Figure 13 and Figure 14). These pictures demonstrate the effect of a broken wire on the immunity test. In the case of the faulty setup, the CH2 signal level was almost at the noise level (around 4 units) and it increased only above 10 MHz. On the other hand, on CH7, the level of the signal is much higher than expected (around 5 dB) up to 10 MHz. These observations are fully explained by the broken connection on CH2: No signal was able to flow on that channel and the signal primarily flew through the metallic housing of the device.

IV. Conclusion and Future Work

This study shows that the new conducted immunity round robin test device is an extremely useful tool in order to investigate and evaluate the testing capabilities of a laboratory equipped to perform conducted immunity tests according to IEC 61000-4-6. The affirmation is even stronger. All participants are National Metrology Institutes or Laboratories with extensive experience and established recognition. Despite this fact, we could identify some weaknesses in their setups and in there testing procedure.

This demonstrates that EMC testing is not a very easy task. Especially for conducted immunity testing, it is essential to arrange the experiment setup according to the IEC standard. Here, the common mode circuit through the device plays a crucial role, and this strongly depends on the way the coupling and decoupling is performed. Even for a setup that looks correct at first glance, faulty components like a broken cable might totally change the testing conditions. Proficiency testing is therefore extremely important to assess the capabilities of a testing laboratory.

This study finally demonstrates that this novel test device is now ready for deployment as the first commercial proficiency testing device for conducted immunity.

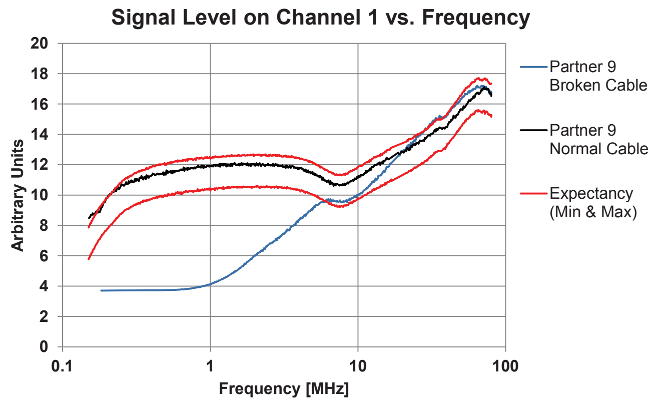

Figure 12. Signal level measured on CH1 versus frequency for Scenario 1 for broken and normal cables at Partner 9 and expectancy curves (1 unit ≈ 2.5 dB)

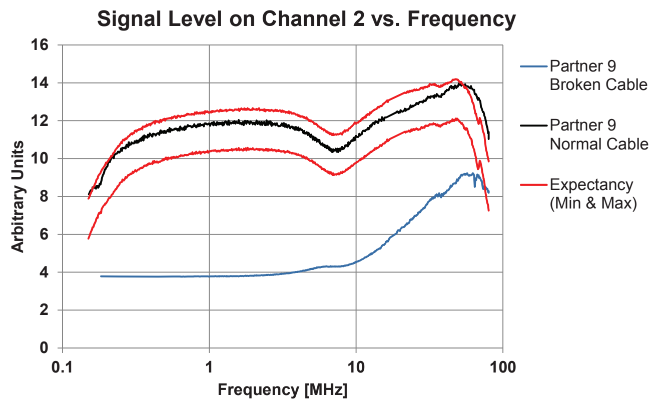

Figure 13. Signal level measured on CH2 versus frequency for Scenario 1 for broken and normal cables at Partner 9 and expectancy curves (1 unit ≈ 2.5 dB)

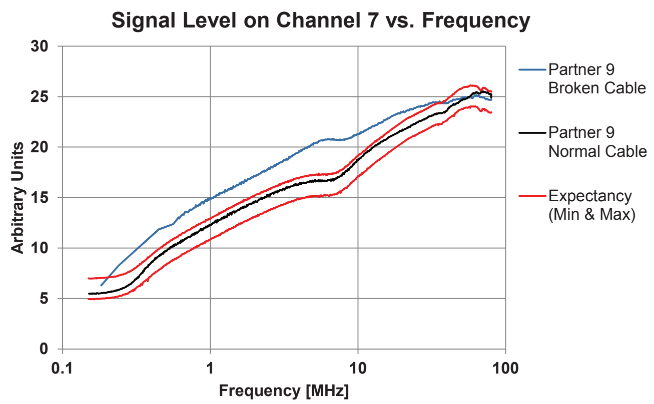

Figure 14. Signal level measured on CH7 versus frequency for Scenario 1 for broken and normal cables at Partner 9 and expectancy curves (1 unit ≈ 2.5 dB)

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