EMC Performance and Alien Crosstalk Conformance for Cat8 Cables

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Abstract

With the recently released IEC 61156-9/-10 and TIA 568-C.2-1 standards, EMC and Alien Crosstalk testing became de facto a requirement for Cat8 cables. Even if still historical differences exist between these two standard families, both specifications came closer to each other given that the same Ethernet protocol, IEEE 802.3bq, better known as 25G/40GBase-T, must be supported by these cable types.

Alien crosstalk was first introduced back in 2008 when crosstalk between adjacent cables had to be quantified for the development of Cat6A. Though, it was used for unshielded cables only.

Regarding EMC (Electromagnetic Compatibility) testing for shielded cables, Coupling Attenuation (AC) is being used to differentiate different types of cables and screening efficiency levels. However, since Cat8 is aimed at shielded cables, both standardisation bodies had to revise and (re)adjust their own specifications.

The required parameters are the same, although on IEC side, an exclusion rule was introduced to avoid the timely consuming Alien Crosstalk testing. Nevertheless, regarding Transfer Impedance (TI), both committees have set requirements in their respective standards.

In this paper, we'll review the challenges of testing against EMC and Alien Crosstalk. We'll report measurement data and highlight the pitfalls in performing these types of tests.

Keywords: Electromagnetic Compatibility (EMC); Alien Crosstalk; Cat8; Coupling attenuation (AC); Transfer Impedance (TI); 40GBase-T, IEEE 802.3bq, Differential Mode Coupling, Common Mode Coupling.

1. Introduction

The demand for very high data bandwidth in the backbone interconnection network driven by new applications like IoT (Internet of Things), Industry 4.0 and others, leads to the requirement for cable types operating towards ever higher frequencies. Cat8 is the latest twisted pair cable specification for structured cabling in data centres.

Along with these new cable specifications come new standards requirements and thus new test challenges. It sets technological constraints for both cable designers and automatic test equipment (ATE) manufacturers.

For Cat8, the disturbance induced by the environment becomes more severe than for former lower speed applications like 10GBase-T. Although both standardisation bodies, IEC and TIA respectively, are still following their own historical way of approaching these issues, they recently came closer to each other with regards to Coupling Attenuation (AC) and Alien Crosstalk testing.

The much higher data bandwidth (4 times higher than for Cat6A (10GBase-T)) is a strong driver behind the introduction of new test requirements for cable manufacturers and their end customers.

By utilising balun-based and/or balunless automatic testing for EMC and Alien Crosstalk, cable manufacturers can significantly save time and money. Manual testing is not only time consuming but cost prohibitive. Hence, semi-automatic test equipment could be a good compromise for cable manufacturers.

2. EMC Testing

EMC testing consists of the below 3 different measurement parameters which have specific requirements depending on the type of cables:

AC: Coupling attenuation (symmetrical cables)

AS: Screening attenuation (coaxial cables)

TI: Transfer Impedance (coaxial and symmetrical cables)

Even though all these parameters are somehow linked to each other, fundamental differences exist as explained in the following paragraph.

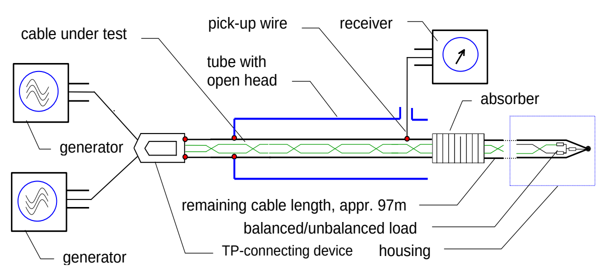

Figure 1: Triaxial test setup for balunless EMC testing [1]

AC and AS are measured both in an electrically long setup, whereas TI is measured in an electrically short setup. First of all, the EMC behaviour describes effects in both directions: immunity against disturbance from outside but also emission from a cable to its environment.

In principle, the same setup can be used to measure the 3 parameters. Depending on the type of signal sent in by the generators and the observed frequency range, another parameter can be recorded at the receiver side.

2.1 Coupling Attenuation (AC)

For AC the stimulus is a differential signal. It can be generated either by a true differential VNA or by using the modal decomposition method with separate sweeps.

AC can be measured with the triaxial method as shown in Fig. 1 by using a tube length of at least 3m, starting at 30MHz up to the maximum frequency of the higher modes. For the standard 40mm diameter tube that would mean 9GHz max frequency.

2.2 Screening Attenuation (AS)

For AS, a common mode stimulus has to be sent instead of a differential mode stimulus. Nevertheless, the experimental setup and the receiver remain the same as in Fig. 1.

2.3 Transfer Impedance (TI)

TI is a measurement similar to AS by applying a common mode stimulus. However, it focuses on low frequencies (few kHz) up to 100MHz normally. Therefore, the length of the tube must be much shorter in order to be able to reach the highest frequency within the electrical short restrictions. It is usually tested with a 45cm tube length.

3. Alien Crosstalk Testing

The test procedure is well known and has been described in former standards already. The test setup is illustrated in Fig. 2.

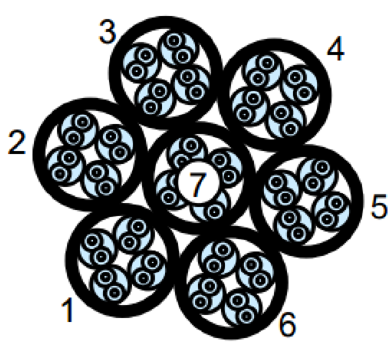

Figure 2: Test assembly cross-section; six cables around one cable [2]

The six-around-one worst case approach was defined in 2008. It ensures that any configuration is passing the minimum requirements, thus allowing the data transmission to run within the standards' defined limits.

Nevertheless, there is a big difference compared to Cat6A U/UTP Alien Crosstalk testing. For Cat6A (10GBase-T) only differential coupling had to be considered given that no screen is present. For Cat8, since all cabling is normally screened, common mode coupling and grounding has a major impact on the overall performance. With this new constraint, testing of cabling at components level becomes even more important to avoid expensive replacements after installation of non-complying systems.

4. Requirements for Cat8

The AC and Alien Crosstalk requirements are defined for Cat8 and Cat8.1/8.2, in TIA and in IEC, respectively.

For AC, in comparison with former editions, Type III was removed as it was for unshielded cables only, corresponding to the TIA Cat6A limit.

Type Ib sets the minimal requirement to meet in order to omit Alien Crosstalk testing in IEC.

TIA states a minimal requirement on AC whereas IEC is following the well-known types as in former standards:

Table 1 IEC: Overview of Coupling Attenuation specifications for Cat8.1 and Cat8.2

AC [dB]	IEC	
Frequency	30MHz-100MHz	100MHz-2000MHz
Type I	85	85-20*log (f/100)
Type Ib	70	70-20*log (f/100)
Type II	55	55-20*log (f/100)

Table 2 TIA: Overview of Coupling Attenuation specifications for Cat8

AC [dB]	TIA	
Frequency	30MHz-100MHz	100MHz-2000MHz
Category 8	55	55-20*log (f/100)

The TIA requirements are the same as Type II of IEC.

For Alien crosstalk, the requirements are also harmonised as shown in Table 3:

Table 3 Overview on Alien crosstalk specifications for Cat8.1/Cat8.2 and Cat8, for IEC and TIA respectively

Alien Crosstalk [dB]	IEC	TIA
PS ANEXT	117.5-15*log(f)	87.5-15*log(f/100)
PS AACR-F	102.2-20*log(f)	62.2-20*log(f/100)

Obviously the requirements are identical, only with differences in the notation of the formulas. For all requirements a low frequency plateau was introduced at 80dB.

5. Device under test (DUT)

As neither Cat8 (TIA) nor Cat8.1 (IEC) F/UTP cables were available at the time of the writing of this article, it has not been possible for us to report measurement data for such cable categories.

Nevertheless and in order to discuss the feasibility of such test measurements, we selected the Cat6A F/UTP cable type. It is the closest cable type to Cat8 and/or Cat 8.1, although limited up to 500MHz only: the construction principle is the same, i.e. 4 un-screened twisted pairs under an overall foil screen (Fig 3).

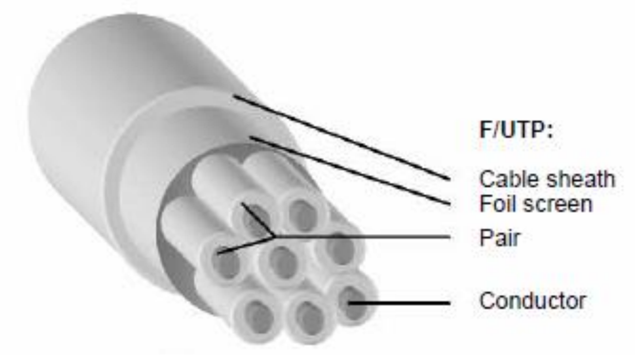

Figure 3: Common cable construction of an F/UTP type of cable [3]

The tested cables are all commercially available Cat 6A F/UTP.

6. AC measurements

6.1 General notes

The triaxial tube method according to IEC 62153-4-9 was used to evaluate the performance of the different cables (see Fig. 1). Four different cables were measured.

If the conductive side of the foil of the F/UTP cable is on the out-side, the short between the tube and the foil is easily done, making the test preparation simpler. And similarly, on the receiving side the pick-up wire can be readily connected to the drain wire.

On the other hand, if the conductive side of the foil and also the drain wire are both on the inside, a 'banana' type preparation, as shown in Fig. 4, has to be made to connect the tube, i.e. some parts of the foil have to be cut and folded back to provide a good contact by wrapping a wire around.

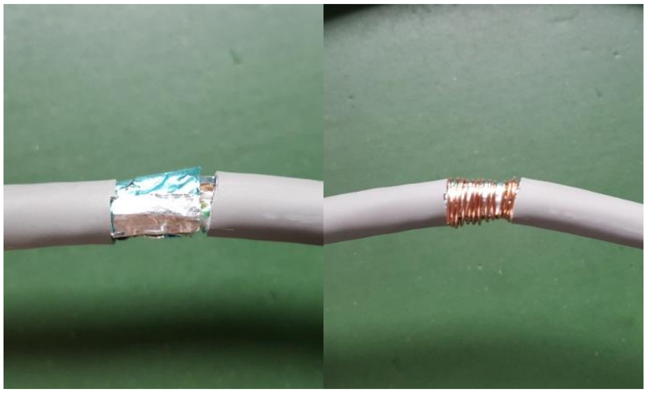

Figure 4: Example of a banana construction

The evaluation was done by setting the limit line at the worst case value. The resulting anchor value (@ f<100MHz) is used to classify the cables according to the requirements in the standards.

6.2 Cable 1

The resulted anchor value was found to be 68.1dB. It means that according to Table 1 & 2, this cable is meeting both the limit for Type II and Cat 8 of IEC and TIA, respectively. The value is very close to the 70dB for Type Ib of IEC, within the measurement accuracy.

For cable 1 it was needed to use the above explained 'banana' preparation as the conductive parts were on the inner side of the foil.

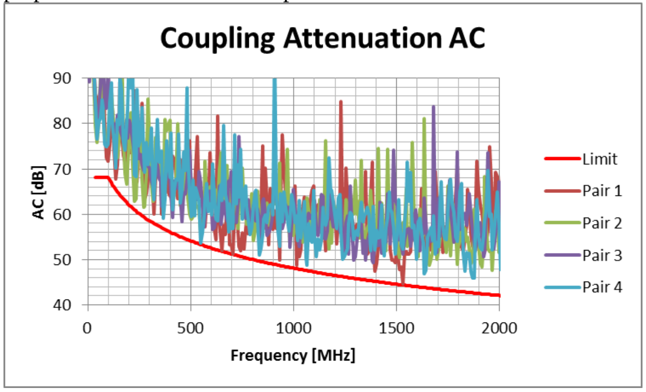

Figure 5: Coupling Attenuation of cable 1

6.3 Cable 2

Similarly to cable 1, cable 2 had the conductive side towards the core, i.e. a "banana" type preparation.

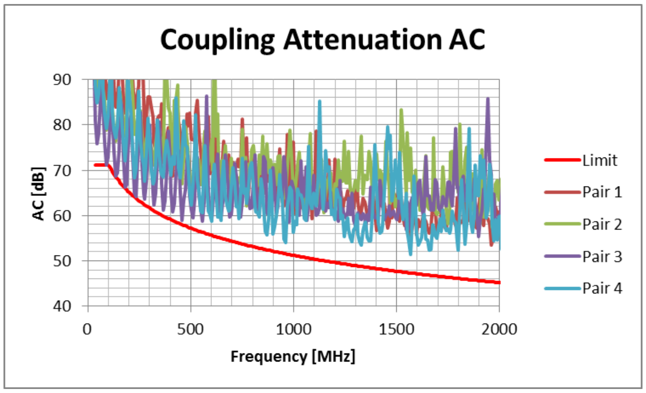

Figure 6: Coupling Attenuation of cable 2

The resulted anchor value was found to be 71.2dB. It is passing the limit for Cat8 and Type Ib of TIA and IEC, respectively. The value is very close to the limit for Type Ib of IEC, within the measure-ment accuracy.

6.4 Cable 3

Similarly to cable 1 & 2, cable 3 had the conductive side on the inner side, i.e. "banana" type preparation.

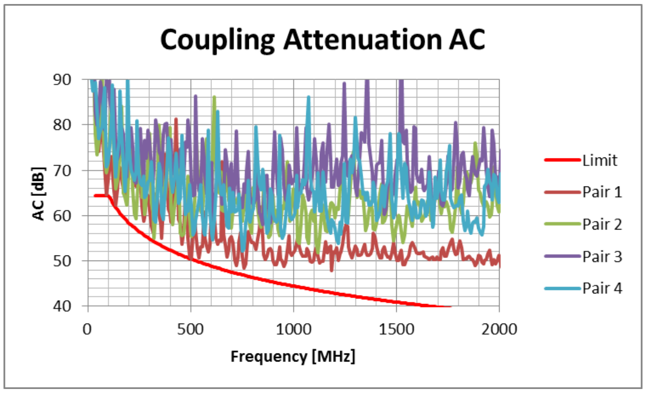

Figure 7: Coupling Attenuation of cable 3

The resulted anchor value was found to be 64.4dB. Hence, it is passing the limit for Cat8 and Type II of TIA and IEC, respectively.

6.5 Cable 4

Cable 4 was the only cable with the conductive side of the foil on the outside, i.e. no need for "banana" type preparation.

The resulted anchor value was found to be 71.8dB. It is passing the limit for Cat8 and Type Ib of TIA and IEC, respectively. The value is very close to the limit for Type Ib of IEC, within the measurement accuracy.

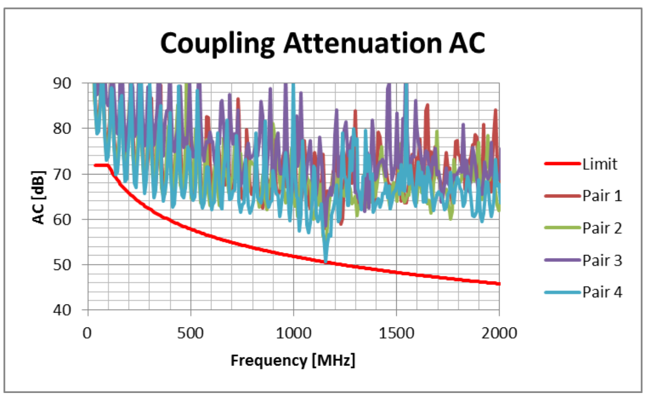

Figure 8: Coupling Attenuation of cable 4

7. Alien crosstalk

7.1 General testing requirements

Alien measurements, either PS ANEXT or PS AACR-F, consist of performing 96 crosstalk measurements from both sides, near and far end, which are then summed up (powersum) over the whole frequency range for the 4 pairs.

Alien Crosstalk measurement for Cat8 is much more demanding than for Cat6a:

- With screened Cat8 cables, the crosstalk signals are very weak and the summations are getting close to the noise limit of the ATE.
- The plateau has been further increased from 67dB to 80dB for Cat6A to Cat8, respectively.
- The dynamic range is further reduced by more than 13dB due to the powersum function of noise(N) as follows[4]:

$$Dynamic\ loss = \mathrm{N} + 10\log(24 * 10^{-N/10}) = 13.8dB \quad (1)$$

- As usual for RF measurements, the system should provide an accuracy margin of 20dB between the noise level and the limit line in order to reduce the error on the limit line below 1dB.

Consequently, the worst case noise level for Cat8 Alien Crosstalk testing for a single sweep is equal to:

$$Limit + Accuracy\ margin + Dynamic\ loss = 80dB + 20dB + 13.8dB = 113.8dB \quad (2)$$

With a corresponding noise level after powersum (see Figure 9) for lower frequencies of:

$$Limit + Accuracy\ margin = 80dB + 20dB = 100dB \quad (3)$$

7.2 Specific ATE requirements

As explained in 7.1, the first hurdle is to ensure that the performance of the ATE itself will have sufficient dynamic range.

The performance of AESA Cobalt ATE is shown in Figure 9, providing more than 23dB margin after powersum calculation. This leads to less than 1dB error on the limit line caused by the noise level.

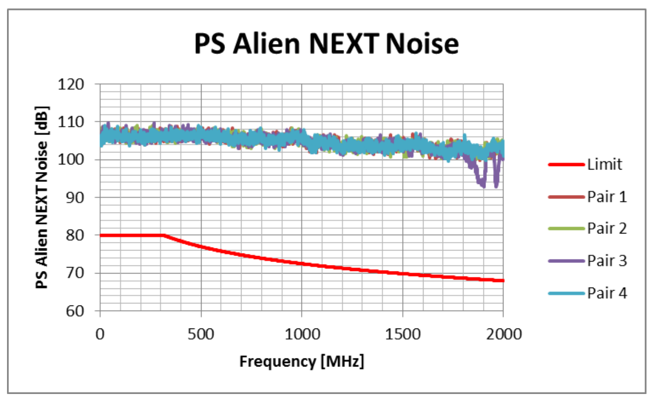

Figure 9: Powersum Alien NEXT Noise Cobalt

7.3 Specific connecting frame requirements

Similarly to the ATE itself, the cable connecting frame performance has to be verified. At higher frequencies, the crosstalk between the end of the cable sheet and the connection point becomes not negligible and the frame has to be optimised.

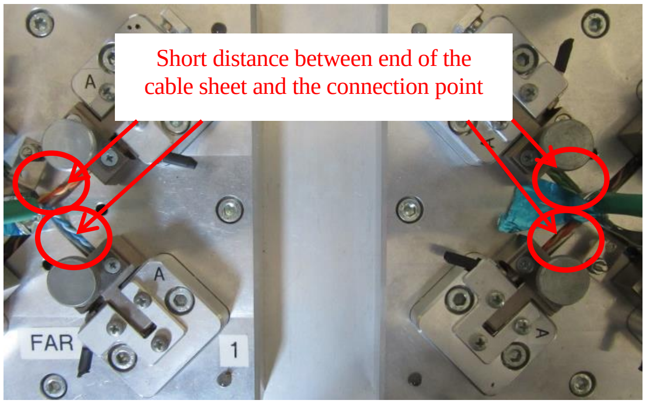

Figure 10: Short distance between end of the cable sheet and the connection point

This can be achieved by additional adapters improving the isolation between the near and far end connecting frame. No need to say that all this must come with a good grounding to reduce common mode coupling.

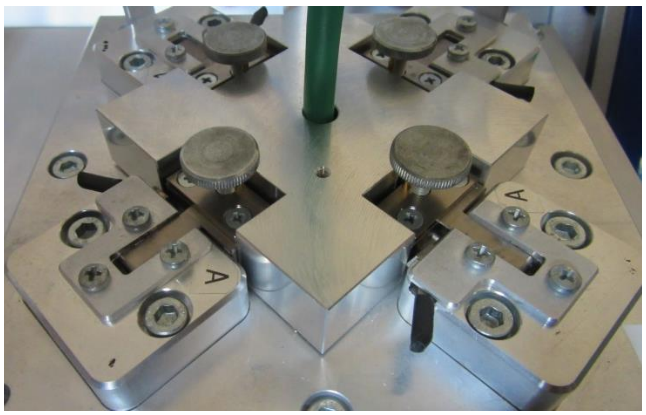

Figure 11: Adapter to improve the isolation of the connection frame for Alien Crosstalk measurements

7.4 Cable requirements

In Table 4, we show limits for Cat8 cables.

Table 4 Cat8 Alien Crosstalk requirements for information

Frequency [MHz]	Alien Crosstalk [dB]
317MHz*	80dB
500MHz	77dB
1000MHz	72.5dB
2000MHz	68dB

*: Last point of the plateau

Prior to discussing sample measurements for Cat8 Alien Crosstalk, we will first review past measurement to highlight how tricky it is to do such measurement and above all, how to properly interpret the results.

Worth noting that all cables in the bundle have to be properly terminated, i.e. 50//50-25 Ohm termination (100 Ohm differential and 50 Ohm common mode).

7.5 Coupling mechanisms

For Cat6A unscreened cables the main coupling mechanism is differential coupling between pairs with similar lay lengths. As Cat 8 cables are all shielded, the direct differential coupling is improved by several decades if it is well grounded.

As the cable construction symmetry is not perfect up to 2GHz, common mode coupling has to be considered for all cables.

The coupling between two cables (disturbing and disturbed) works as follows:

i) in the disturbing cable, mode conversion of the differential signal to the screen
ii) common mode coupling between the screen of the disturbing cable to the screen of the disturbed cable
iii) in the disturbed cable, mode conversion from the screen to the pair.

This mechanism shows that a proper grounding of the cable screens is of pivotal importance in order to reduce common mode coupling along a channel. And this has to be considered for all connections:

- horizontal cable to the jack
- flexible cable to the patchcord plug
- between the jack and a plug in a mated connection

It is illustrated in the following figures, taken from an outside source [5].

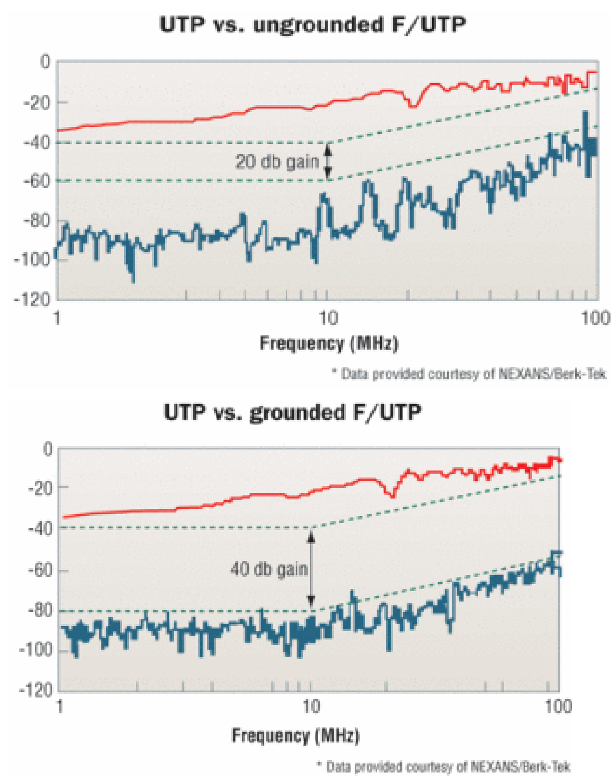

Figure 12: Difference between a grounded and an ungrounded F/UTP cable compared to a U/UTP cable [5]

These graphs speak by themselves: the grounding design improves the result by 20dB. It supports the common statement given by screening efficiency experts: "***grounding is essential***".

8. Alien crosstalk measurements

All measurements were executed as shown in Figure 11 above to improve the isolation between near and far connection frame. The termination of all unused pairs was done on the recently designed Alien termination frame (see Figure 13).

As these cables are all Cat6A rated, impedance and insertion loss above 500MHz is out of range. Hence, it was decided to deduct the maximum Cat8 insertion loss from PS AFEXT without explicitly measuring it to calculate PS AACR-F.

This simplification was needed to compare the real Alien far end crosstalk of the cables and rating them in a comparable form.

Figure 13: Alien termination frame

The Alien termination frame consists of 2 times 7 termination blocks. Each block is prepared to terminate one 4 pair cable. This allows for maximum flexibility to execute Alien measurements of 6-around-1 cable bundles.

The termination frame is fixed with screws to the ATE and rest on a stable stand to avoid mechanical stress. The frame can be easily removed if not used for normal operation.

8.1 Cable 1

Cable 1 achieved for PS ANEXT a 7.5dB margin. The worst case PS AACR-F margin was found to be 8.4dB.

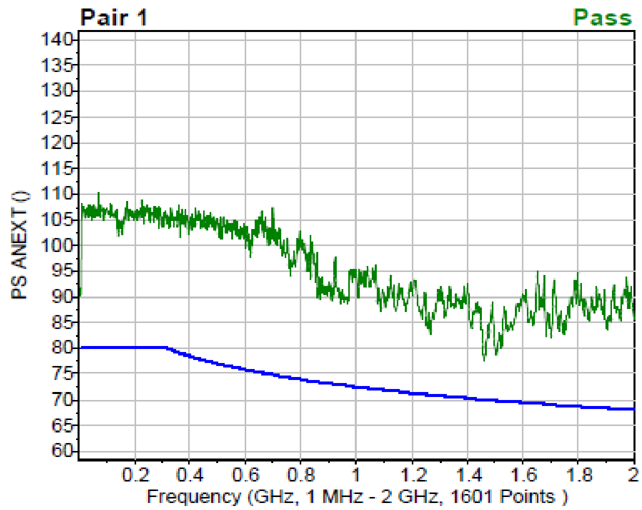

Figure 14: PS ANEXT of cable 1

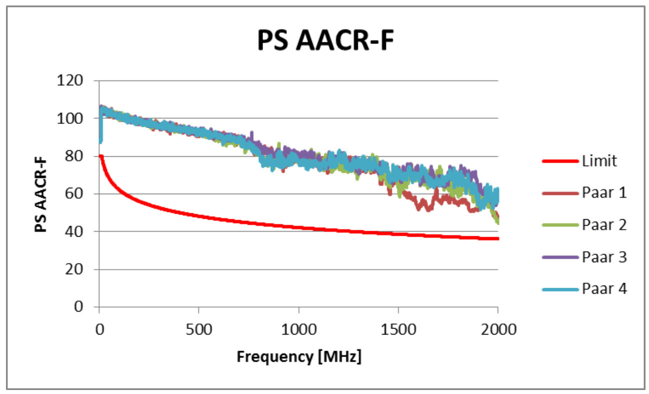

Figure 15: PS AACR-F of cable 1

8.2 Cable 2

Cable 2 has shown a PS ANEXT margin of 5.8dB. The worst case PS AACR-F margin was found to be 14.6dB.

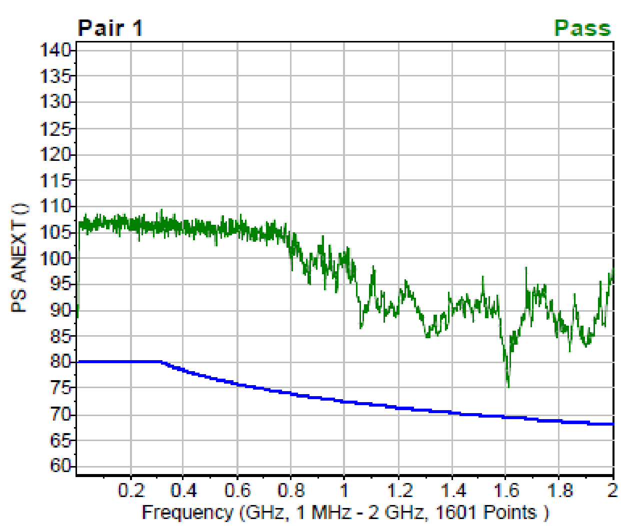

Figure 16: PS ANEXT of cable 2

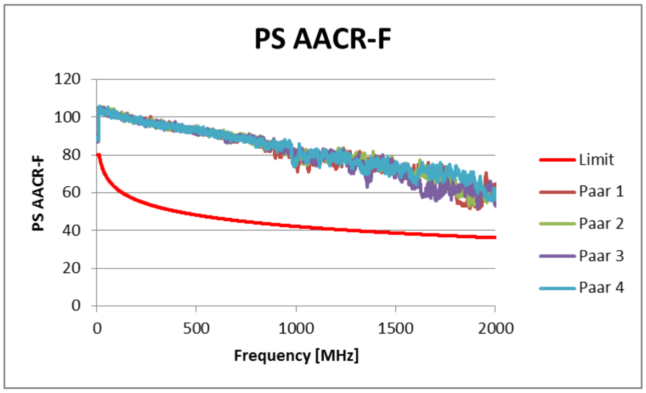

Figure 17: PS AACR-F of cable 2

8.3 Cable 3

PS ANEXT of cable 3 resulted in a 3.5dB margin. The worst case PS AACR-F margin was found to be 16.9dB.

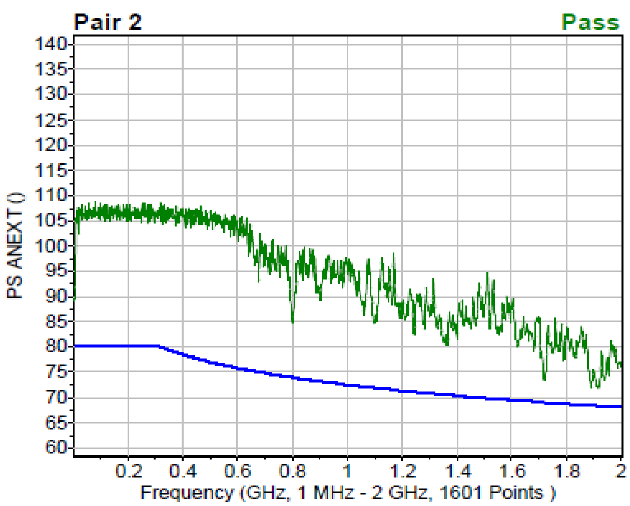

Figure 18: PS ANEXT of cable 3

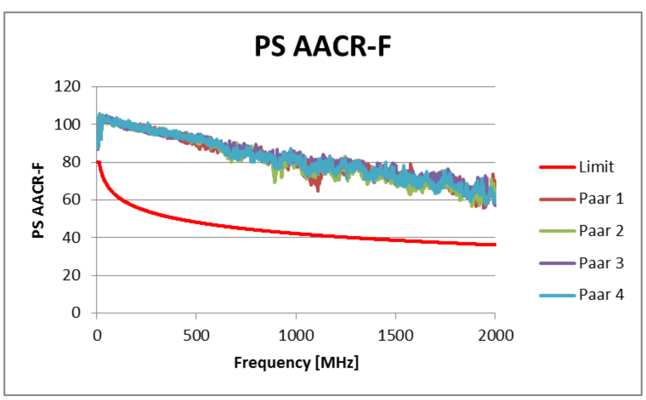

Figure 19: PS AACR-F of cable 3

8.4 Cable 4

The worst case margin for PS ANEXT was found at 1.3dB For PS AACR-F the found margin was 11.6dB.

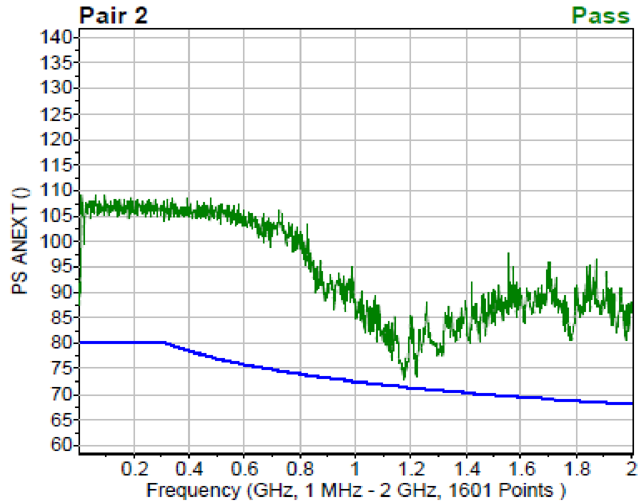

Figure 20: PS ANEXT of cable 4

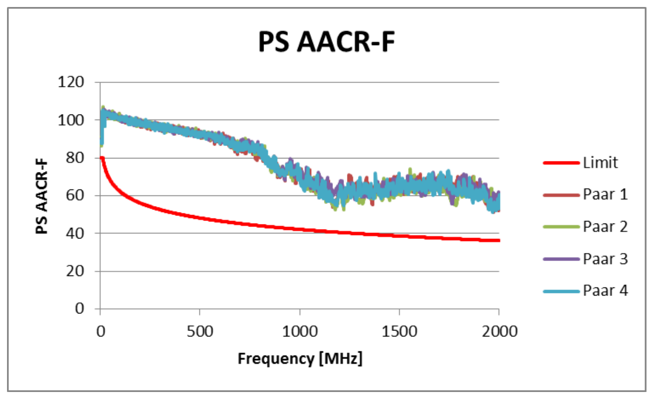

Figure 21: PS AACR-F of cable 4

8.5 Discussion

Finally all Cat6A F/UTP cables passed the Cat8 Alien requirements with a small margin for PS ANEXT and a good margin for PS AACR-F.

As this is not the final design cables can shift in both directions, getting better or worse. Therefore a frequent checking of Alien crosstalk is recommended till all effects are completely understood.

Table 5 Overview on Cat8 Alien Crosstalk margins

	PS ANEXT	PS AACR-F
Cable 1	7.5	8.4
Cable 2	5.8	14.6
Cable 3	3.5	16.9
Cable 4	1.3	11.6

9. Conclusions

In this paper we reviewed new requirements imposed by the recent publication of the Cat8 standards by both TIA and IEC.

After discussing the experimental setup and the limits set by the standards, we went on to measurement results for AC and Alien Crosstalk. Without Cat8 cable available, these measurements were performed on commercially available Cat6A cables, with similar construction (F/UTP) as expected for Cat 8.

For AC, we demonstrated that cable preparation must be done with great care to avoid artefacts. The measured cables met the expected performance within the limits set by the standards.

With regards to Alien Crosstalk testing, it is far from being straightforward given the new requirement of frequencies up to 2GHz. At such high frequencies, the various part of the ATE must be optimised. With Cat8, the powersum is now made over signals with order of magnitude lower that it used to be with Cat6A. Consequently, it puts stringent limits to the ATE.

The obtained results on Cat6A cables indicate that well designed Cat8 or Cat8.1 cables should theoretically pass the Alien Crosstalk requirements. Nevertheless, testing is strongly recommended especially during development and after material or mechanical changes.

These newly published standards are pushing cable manufacturers to enhance their testing capabilities in order to avoid the extra costs of poor quality (COPQ). In this respect, we demonstrated that the performances of AESA ATEs are fully meeting the needs for properly characterising Cat8 cables against EMC and/or Alien Crosstalk.

10. Acknowledgments

We want to thank IWCS staff for supporting us during the process of writing this paper. This paper would not have been possible without the support of 4 leading cable manufacturers which provided cable samples to conduct the tests.

11. References

[1] IEC 62153-4-9 Ed.2: Metallic communication cable test methods – Part 4-9: Electromagnetic compatibility (EMC) – Coupling attenuation of screened balanced cables, triaxial method; under consideration

[2] IEC 61156-1: Multicore and symmetrical pair/quad cables for digital communications - Part 1: Generic specification

[3] IEC 61156-5 Ed2.1: Multicore and symmetrical pair/quad cables for digital communications –Part 5: Symmetrical pair/quad cables with transmission characteristics up to 1 000 MHz – Horizontal floor wiring – Sectional specification

[4] Decibel Addition and Subtraction, https://www.noisemeters.com/apps/db-calculator.asp

[5] The myths and realities of shielded, screened cabling, July 1st 2007, found on http://www.cablinginstall.com/articles/print/volume-15/issue-7/features/design/the-myths-and-realities-of-shielded-screened-cabling.html

12. Authors

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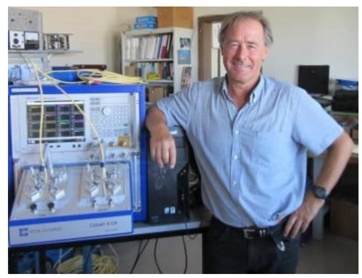
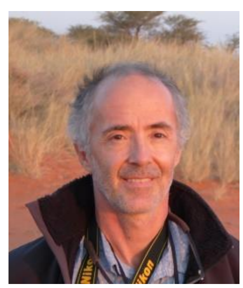
In 2016, he received a MBA from both the University of Applied Science Zurich (HWZ) and the University of Southern Queensland (USQ) in International Business.



Dick Gigon received his Microelectronic Engineering diploma in Neuchatel University and Ecole Polytechnique Fédérale de Lausanne (EPFL) in 1978. After 10 years in CMOS/TTL chip design and micro packaging technologies in Switzerland and USA, he joined AESA in May 1991 as Lab supervisor and telecom test equipment designer for copper and fibre optic cables. Specialist in RF passive components, baluns, filter, HF multiplexers, he has a significant experience in testing telephone, DSL, data LAN and coaxial cables to 6 GHz.

His knowledge on extrusion process, experience in debugging and customer training were on great importance for the company worldwide.



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