Some considerations concerning “alien crosstalk”

Dr.-Ing. J.-H. (Jo) Walling
Consultant
Beaconsfield, P.Q. Canada
jo.walling@sympatico.ca

0. Summary

Contrary to the simplified perception about alien crosstalk, it has to be stated that Alien NEXT or alien ACR – N**,** i.e. alien attenuation-to-crosstalk ratio at the near end **is not the most critical parameter in LAN cabling structures.** In fact **it is Alien FEXT**, or **ACR – F** which is the attenuation to crosstalk ratio at the far end, i.e. the **input-to-output FEXT minus the attenuation of the disturbed pair** (not to be confounded with **EL FEXT**, a term which is, this year, for exactly 100 years specified as the **input-to-output FEXT minus the attenuation of the disturbing pair**).

1. Background

In the 10GBase-T study group alien NEXT has been so far considered primarily. In this context alien NEXT has been in most contributions limited to “alien intra-family near end crosstalk”, as this crosstalk can be to some extend compensated for. However, the alien crosstalk generated by coupling from cables in the vicinity, carrying signals under totally different protocols can not be compensated for, as they are statistical in nature.

Therefore, it is primarily this “non-related alien crosstalk” which will have to be measured and limited in the standards.

On the other side the consideration of any kind of alien crosstalk has to be focused mainly on far end crosstalk, as this is really the limiting factor for installations. This has been already mentioned in two presentations at the 43rd IWCS in 1994 [1],[2]. The same conclusions were drawn in 1997 after an in depth investigation of the crosstalk behavior of loomed and hybrid cables (contributions to the TIA 41.7 group). More recently the same conclusion has been reached by Vanderlaan [3], though based only on loomed cables alone.

While these cited investigations considered only full length cables, it is much more important to focus on the geometries as occurring in real installations. This is done in the following, based on a four connector channel configuration, i.e. a cross-connect-consolidation point-telecommunication outlet channel (XC-CP-TO channel)

Each network is configured basically as tree, having its trunk in the equipment room (EQ). In fact, the basis of the trunk is at the cross-connect (XC). The main trunk is represented by the horizontal cable. It has eventually branched roots in the cross-connect and from there also to the equipment (EQ) itself. However, the trunk is branching out from the cross-connect to the consolidation points (CP), and from there over the telecommunication outlets (TO) to the telecommunication equipment (TE).

In order to simulate these conditions, we consider here for ease of calculation a loomed or multi-unit cable. Such a cable may be considered like a break-out cable where the branches represent virtual channels. In these cases each unit of the cable can have basically a different length.

The conditions for real channels composed of different cable components and connectors with varying electrical performances were as well calculated. The obtained results were absolutely comparable and are here therefore in view of keeping the results easy and transparent not represented.

2. Outline and Objective

The present report uses standardized performance parameter limits for cables as indicated in the international standards, and uses as well the therein contained channel configurations. Its main intention is the establishment of the random conditions to establish specification requirements primarily for cables and in a second step for channels.

The reporting is structured as follows:

3. Indication of the specification limits for Category 6 cables, including alien crosstalk according to IEC 61156-5 and to IEC 61156-6 [4]; [5].
4. Indication of the same limits for class E channels according to IS 11801 [6]
5. The expected “alien crosstalk” using a loomed cable of 100 m length with longitudinally distributed and equally spaced “consolidation point break-outs” (to simulate CP’s along the cable tree) will be derived. The alien FEXT based upon the same structure as in the preceding section will be derived.
6. The absolute worst case FEXT condition will be indicated.
7. Definition of NEXT, FEXT, EL FEXT, ACR-N and ACR-F and the corresponding power sum parameters [7] as annexed.

These precise definitions seem to be necessary, as the terms are frequently used incorrectly.

3. The IEC specification limits for cables

IEC 61156-5 specifies for the attenuation of category 6 UTP cables (assuming they are used in combination with patch cords with a 20 % de-rating):

$$\alpha = 1.820 \cdot \sqrt{f} + 0.0169 \cdot f + \frac{0.250}{\sqrt{f}} \qquad [\,dB\,] \qquad (1)$$

where:

f - is the frequency indicated in MHz.

Eq. (1) is valid from 4 MHz to 250 MHz. Values for 1 MHz are given only for information purposes.

The crosstalk performances are specified only in terms of power sums, with the stipulation that the pair-to-pair values shall be 3 dB better than the power sums.

We have for the PS NEXT:

$$\text{PS NEXT} = 72.3 - 15 \cdot \log_{10}(\,f\,) \qquad [\,dB\,] \qquad (2)$$

and for the PS EL FEXT:

$$\text{PS EL FEXT} = 65.0 - 20 \cdot \log_{10}(\,f\,) \qquad [\,dB \text{ for } 100\text{ m}\,] \qquad (3)$$

The crosstalk for bundled cables is specified and the power sum crosstalk of any pair in these cables shall be 5 dB better than the power sum requirements for the individual cable.

As to “Alien Crosstalk” it is referenced in IEC 61156-5, Section 3.3.11 completely, and for transparency the corresponding paragraph should be cited literally:

“ 3.3.11 Alien cross-talk

Alien cross-talk is only a consideration for unscreened cables. Alien cross-talk is the combined capacitive and inductive cross-talk coupling from neighbouring cables into the cable under consideration. The neighbouring cables may be used for data communication under the same protocol or for entirely different protocols. The alien cross-talk is, therefore, statistical in nature, and cannot be compensated for. The installation of these cables in open trays or ducts requires an additional cross-talk margin in order to guarantee sufficient cross-talk isolation. As the cables in the tray or duct are not as systematically laid up as in bundled cables, the required cross-talk margin is lower than the power sum cross-talk margin for bundled cables.

For any application where the cables are installed partially parallel, an additional power sum cross-talk margin (for PS NEXT and PS EL FEXT) may be required to compensate for alien cross-talk. **“**

Being editor of this standard, the author should like to make the following comments:

a. **Alien crosstalk is statistical in nature and cannot be compensated for** as far as it concerns non-extended family crosstalk. It is theoretical possible to compensate to some degree for intra-family and eventually even for extended family crosstalk, i.e. crosstalk coupled from cables running under the same or very similar protocols. Some previous presentations in the 10GBase-T study group [8] partially confirm this. In fact, it seems to be possible to correct this kind of alien crosstalk by 3-6 dB. This was to be expected and has been prior in depth investigated (cyclo-stationary crosstalk investigations). However, there will have to be devised strategies to improve these corrections and to use the potential of the DSPs more efficiently.
b. The "alien" intra-family crosstalk between different cables can be improved essentially in three ways or combinations thereof:
   i. Random strand-lay of the cables within boundary limits.
   ii. Loading of the jacketing material with conductive material. This gives a <u>substantial</u> improvement of the "alien crosstalk", however this maybe combined with deteriorating EMC performance. In fact it is a "pseudo-screening" without grounding.
   iii. Loading of the jacket with materials of high permeability (at best a permeability of the composite of about $\mu \approx 7$ is achievable with approximately 50-60 % loading). For the purposes here only aciculous ferrites seem to be feasible to use. These ferrites have an aspect ratio of approx. 10:1 length to diameter to compensate for the otherwise increased conductivity. Such cables will become relatively large in diameter and are additionally screened. They use generally other ferrite loadings, i.e. crushed sintered ferrite loading. The ferrite loading of the jacket material, will impact very strongly on the impedance, but is also has a detrimental impact on the propagation speed. Rough calculations indicate that the normalized velocity of propagation (NVP) is between 50 and 64% only.

Such cables are very heavy and have to be carefully handled. Such cables, though not with aciculous ferries, are used in aviation industry, to avoid NEMP (nuclear electromagnetic pulses) interferences and are available for instance from EMC/Eupen in New Jersey.

c. The IEC standard indicates PS EL FEXT performance requirements. However, it is obvious, that for the 10GBase-T protocol PS EL FEXT is of no interest. As a reminder: EL FEXT is defined as the difference of the input-to-output FEXT and the attenuation of the <u>**disturbing**</u> pair. What is interesting in this context is the ACR-F which is the difference of the input-to-output

FEXT and the attenuation of the **disturbed** pair (see Appendix 5). Therefore, henceforward the values indicated for PS EL FEXT are assumed to be valid also for PS ACR-F. This is in the context here justified, as the attenuations of all pairs can be assumed equal and equivalent to the maximum allowable value.

4. The ISO/IEC specification limits for channels

The ISO/IEC standard 11801 specifies for maximum channel length (here only cross-connect CP-TO channels, i.e. channels in a four connector configuration are reported on), but under the assumption of the utilization of the same types of cables mentioned in the previous section, for the insertion loss:

$$IL = 1.02 \cdot \left(1.820 \cdot \sqrt{f} + 0.0169 \cdot f + \frac{0.250}{\sqrt{f}} \right) + 4 \cdot 0.02 \cdot \sqrt{f} \qquad [\,dB\,] \qquad (4)$$

The pair to pair NEXT within a four pair channel is defined as:

$$NEXT = -20 \cdot \log_{10} \left[10^{-\frac{74.3 - 15 \cdot \log_{10}(f)}{20}} + 2 \cdot 10^{-\frac{94 - 20 \cdot \log_{10}(f)}{20}} \right] \qquad [\,dB\,] \qquad (5)$$

For the corresponding power sum there is specified:

$$PS\ NEXT = -20 \cdot \log_{10} \left[10^{-\frac{72.3 - 15 \cdot \log_{01}(f)}{20}} + 2 \cdot 10^{-\frac{90 - 20 \cdot \log_{10}(f)}{20}} \right] \ [\,dB\,] \qquad (6)$$

The ACR-N is specified as well as a pair to pair value:

$$ACR - N_j = NEXT_{ij} - IL_j\,, \qquad [\,dB\,] \qquad (7)$$

as is the power sum value for each pair of the channel:

$$PS\ ACR - N_j = PS\ NEXT_j - IL_j \qquad [\,dB\,] \qquad (8)$$

Though EL FEXT is formally correctly stated, what is meant is the ACR – F. Therefore, these specification values will be reported here:

$$ACR - F_{ij} = FEXT_{ij} - IL_j$$

$$ACR - F = -20 \cdot \log_{10} \left[10^{-\frac{67.8 - 20 \cdot \log_{10}(f)}{20}} + 4 \cdot 10^{-\frac{83.1 - 20 \cdot \log_{10}(f)}{20}} \right] \qquad [\,dB\,] \qquad (9)$$

and the power sum:

$$PS\ ACR-F = -10 \cdot \log_{10}\left(\sum_{\substack{i=1\\ i\neq j}}^{n} 10^{-\frac{ACR-F_{ij}}{10}}\right) \quad [\,dB\,]\ (10)$$

$$PS\ ACR-F = -20 \cdot \log_{10}\left[10^{-\frac{67.8-20\cdot\log_{10}(f)}{20}} + 4\cdot 10^{-\frac{83.1-20\cdot\log_{10}(f)}{20}}\right]$$

IS 11801 does not specify any alien crosstalk performance. It mentions only for "multi-unit cables" in Section 9.3.3 that they may be connected to more than one TO and that they will have to meet the PS NEXT requirement specified in IEC 61156-5, section 3.3.10.1.

In the implementation clause, Section 7.2.2.2 specifies furthermore:
a.) A minimum length of the horizontal cable between the floor distributor (FD) and the first consolidation point (CP) of 15 m.
b.) A maximum length of patch cord/jumper cables of 5 m.
c.) Where a multi-user TO assembly is used, the length of the work area cord should not exceed 20 m.

5. The "alien" crosstalk in a loomed cable

We consider first a loomed or multi-unit cable, having seven units, as shown in Fig. 1. The center unit is of course the most exposed to crosstalk coupling from the surrounding units. For cables having equal length of each unit we have the relations depicted in Fig. 2 and Fig. 3 for NEXT and ACR-F for a cable length of 100 m and 55 m, respectively. In both figures is shown the specified power sum NEXT, the specified alien power sum ACR-F as well as the alien power sum contribution of one peripheral unit onto the central unit.

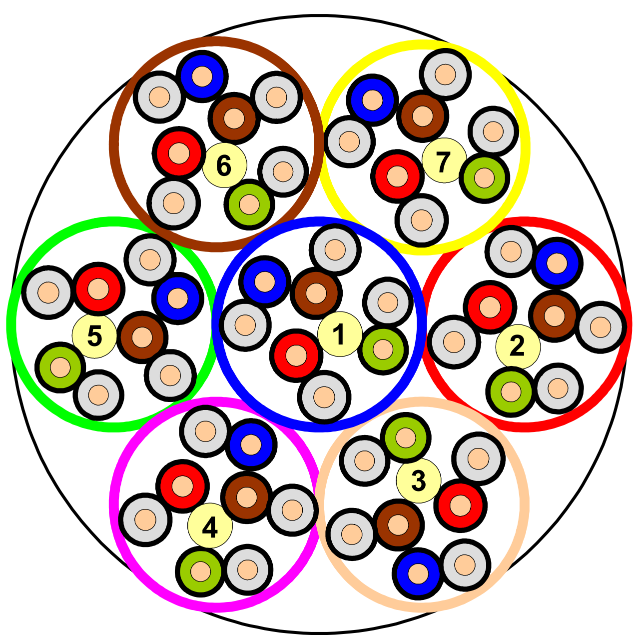

Figure 1: Loomed seven – unit cable

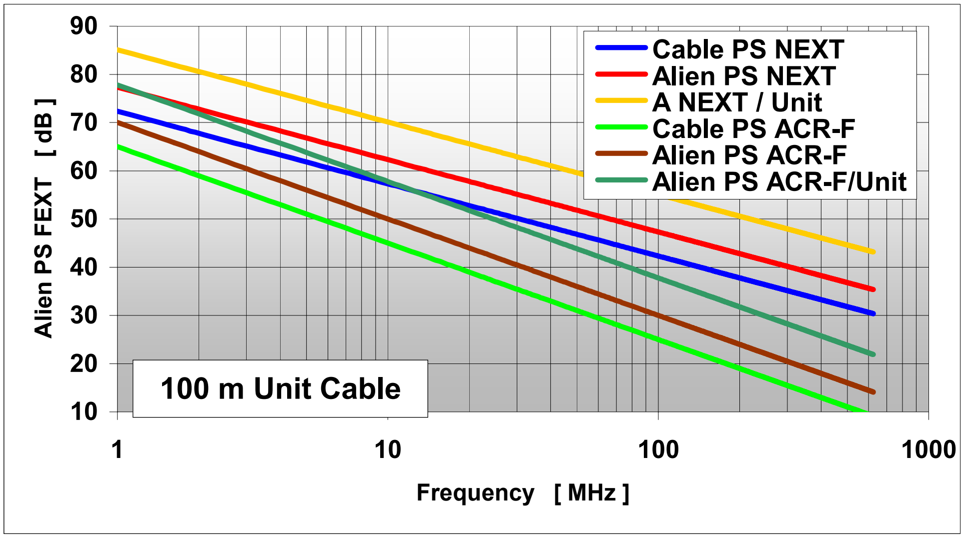

Figure 2: Power sum of NEXT, Alien NEXT, PS ACR-F and Alien PS ACR-F of a loomed or multi-unit cable of 100 m. Indicated is also the power sum impact of one unit on any pair of the center-unit.

The indicated values are based on the IEC 61156-5 standard for a Cat. 6 UTP cable. The length corrections of the corresponding power sum values are made according to Appendix 6.

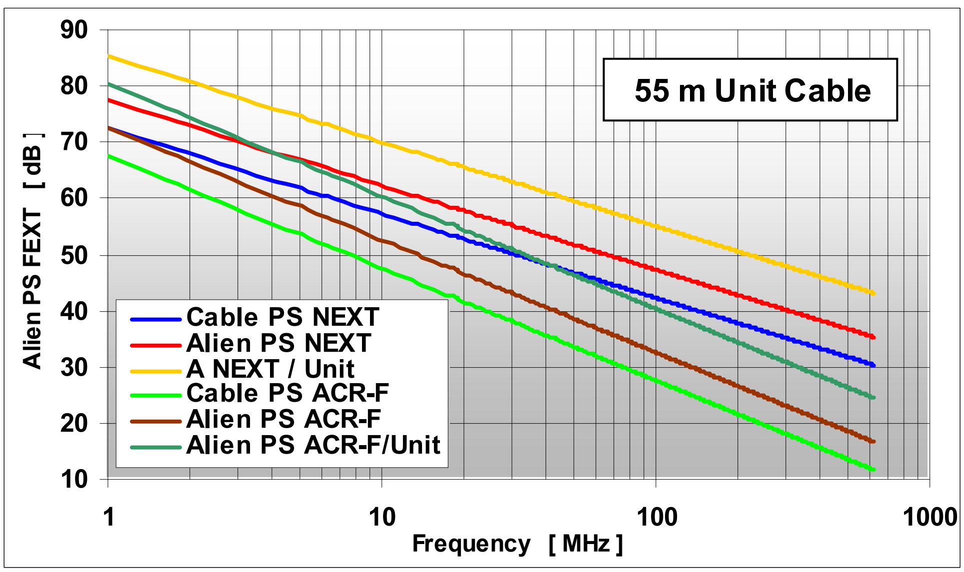

Figure 3: Power sum of NEXT, Alien NEXT, PS ACR-F and Alien PS ACR-F of a loomed or multi-unit cable of 55 m. Indicated is also the power sum impact of one unit on any pair of the center-unit.

Immediately apparent is the fact that NEXT at high frequencies barely changes with the length of the cable. Only at low frequencies there is a minor difference noticeable. However, PS ACR-F shows a marked change with length, which is nearly constant over frequency.

From these relations it seems that Alien PS NEXT is the most important issue. This is also true for loomed cables, where all units have the same length. However, this is in real installations not the case. In fact such cables are frequently used as break-out cables, having different unit lengths'.

As we use here such cables to simulate virtual channels, the "cable units" are either longitudinally in tight vicinity or directly loomed. Thus also the conditions in tightly filled trays are simulated. In these cases the units are, of course, of different lengths'.

.

In order to render the considerations closer to the field realities, we will consider a channel with a total length, which corresponds to what we can consider a "standard channel length for modeling purposes", i.e. a 5 m – 5 m – 85 m – 3 m – 2 m channel. Thus the total "virtual" channel length is 100 m. We also analyze a virtual channel of 55 m total length, thus that the horizontal cable has a length of only 40 m, while maintaining the minimal distance between the FD and CP. These channels are considered in their electrical performance and are assumed to run from the TO towards the equipment room. The units in the cable are distributed as indicated in Fig. 1 and Fig. 4.

The cable is assumed to be connected to longitudinally equally distributed consolidation points (CP), and from there to the equipment room. Hence the dimensions of the cable trees are installed as indicated in Fig. 4 and the individual units have the lengths' indicated in Table 1 and Table 2 for 100 m and 55 m of cable respectively, under consideration that the minimum distance between the CP and the FD is 15 m.

For these configurations we can determine the voltages at the junction points of the CP and the horizontal cables, which are spaced obviously 11.667 m (4.167 m) apart. Interesting in this context is definitely not the voltage of the cable unit 1 at the consolidation point 1, but the voltages at the CPs 2 to 7. These voltages indicate the input signal level.

Cable unit number	Work area cord	CP cable	Horizontal cable	Cross-connect of jumper cable	Equipment cord	Total length
5	5	5	85.000	3	2	100.000
5	5	5	73.333	3	2	88.333
5	5	5	61.667	3	2	76.667
5	5	5	50.000	3	2	65.000
5	5	5	38.333	3	2	53.333
5	5	5	26.667	3	2	41.667
5	5	5	15.000	3	2	30.000

Table 1: The length of the cables corresponding to the channel dimensions, if the break-out points are equally spaced along the horizontal cable of 85 m, but taking minimum distance between consolidation point and floor distributor into account.

We consider here only continuous cables, i.e. a aggregate channels having only virtual CPs, TOs, cross-connects etc. We can calculate then the power sum FEXT and ACR-F values easily from the specified limits, taking the length correction for FEXT and ACR-F into account. For the calculation of the attenuation we use Eq. (1) by assuming a normalized input voltage of 1 Volt.

The length values of the virtual channel cables are indicated in the Table 1 and Table 2. The results are compiled for a 100 m multi-unit cable in Table 3 and for a length of 55 m in Table 4. Here the total length of the units is indicated which contributes to FEXT.

In Fig. 5 we have the PS FEXT of the inner cable crosstalk of unit 1 with a length of 100 m. For the remaining units the PS FEXT for the cable length, parallel to unit 1 is shown. This allows the calculation of the noise voltage at then end of the cable.

Cable unit number	Work area cord	CP cable	Horizontal cable	Cross-connect of jumper cable	Equipment cord	Total length
5	5	5	40.000	3	2	55.000
5	5	5	35.833	3	2	50.833
5	5	5	31.667	3	2	46.667
5	5	5	27.500	3	2	42.500
5	5	5	23.333	3	2	38.333
5	5	5	19.167	3	2	34.167
5	5	5	15.000	3	2	30.000

Table 2: The length of the cables corresponding to the channel dimensions, if the break-out points are equally spaced along the horizontal cable of 40 m, but taking minimum distance between consolidation point and floor distributor into account.

Length of the cables for 100 m channel							
Cable Unit / CP #	1	2	3	4	5	6	7
TE - CP	10.000	10.000	10.000	10.000	10.000	10.000	10.000
CP - X-conn.	85.000	73.333	61.667	50.000	38.333	26.667	15.000
Cords in FD	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Total:	100.000	88.333	76.667	65.000	53.333	41.667	30.000
Unit 1 at the CPs	10.000	21.667	33.333	45.000	56.667	68.333	80.000

Table 3: Length' of the virtual cables to simulate channels with a multi-unit cable of 100 m length.

Towards this purpose we have to take the attenuated signal voltage over the first 10 m of cable, i.e. from the terminal equipment (TE) over the telecommunication outlet (TO) to the consolidation point (CP), into account. We get then the corrected noise voltage at the output, i.e. at the equipment (EQ) in the floor distributor (FD).

Note: The Fig. 4 represents also the installation scheme for a real channel configuration, taking attenuation de-rated work area cords, jumper cables and equipment cords into account, as well as the connectors at the TO, CP and the cross-connect. In so far the same configuration will be used to calculate the complete channel behavior.

Length of the cables for 55 m channel							
Cable Unit / CP #	1	2	3	4	5	6	7
TE - CP	10.000	10.000	10.000	10.000	10.000	10.000	10.000
CP - X-conn.	40.000	35.833	31.667	27.500	23.333	19.167	15.000
Cords in FD	5.000	5.000	5.000	5.000	5.000	5.000	5.000
Total:	55.000	50.833	46.667	42.500	38.333	34.167	30.000
Unit 1 at the CPs	10.000	14.167	18.333	22.500	26.667	30.833	35.000

Table 4: Length' of the virtual cables to simulate channels with a multi-unit cable of 55 m length.

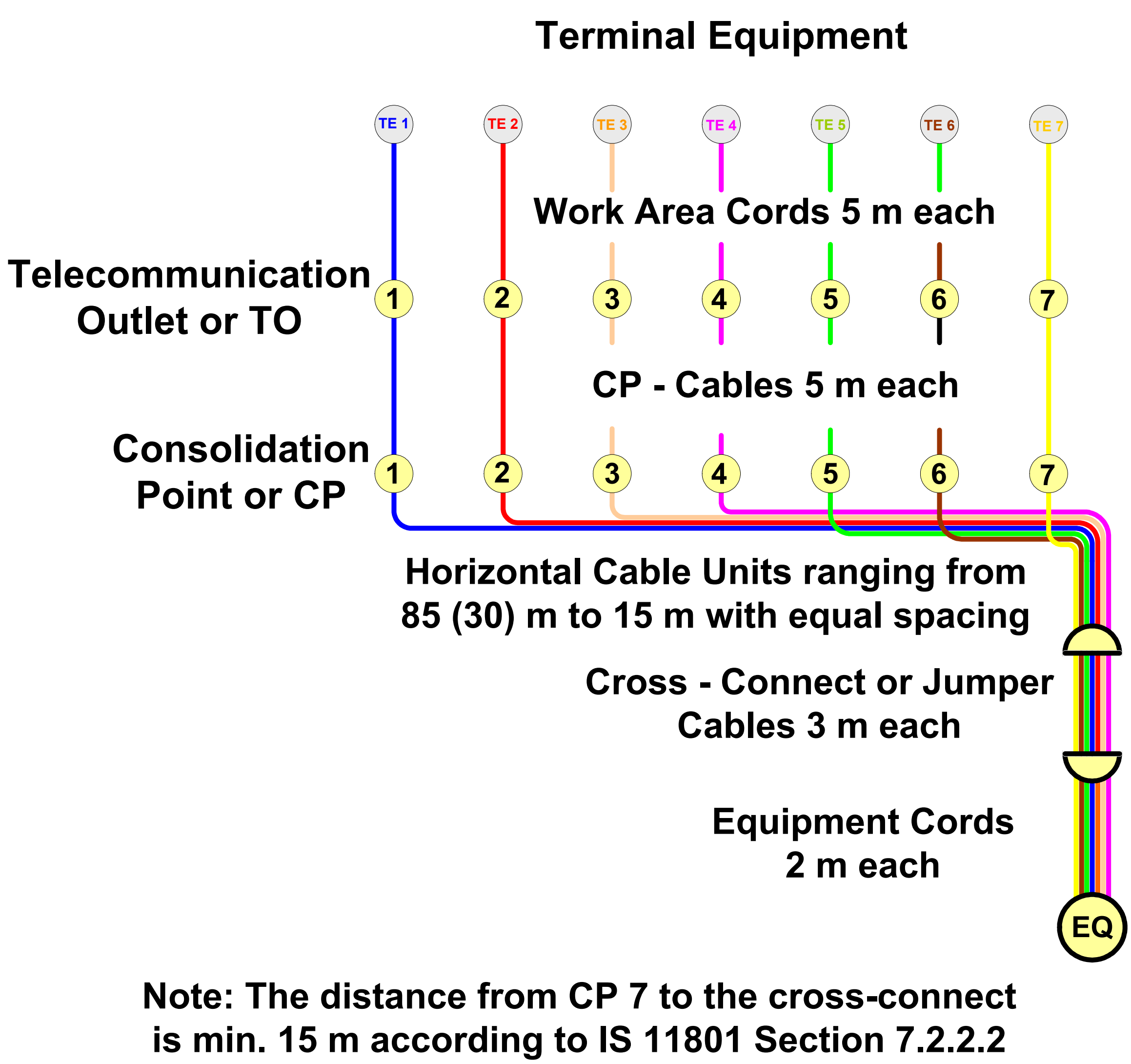

Figure 4: Tree structure of a loomed or multi-unit cable serving 7 consolidation points.

The Fig. 6 shows the same for a cable length of 55 m, as anticipated so far for the 10GBase-T protocol, using UTP cabling.

Based on these values, we can now calculate the output voltage, if the input voltage corresponds to the attenuated signal voltage. Attenuated by the work area cord and the CP cable, and can then calculate the corresponding PS FEXT, if the input voltage would be 1 V. The obtained results for the 100 m and 55 m virtual channels are shown in the fig. 7 and Fig. 8. These figures indicate the really occurring input-to-output FEXT of our virtual channels.

Note: If the loomed or multi-unit cable or any corresponding channel configuration using such cables has only a horizontal cable of 85 m and six horizontal cables of 15 m each, then we have obviously the worst case condition for FEXT. This case will be dealt with later on.

In so far the theoretically derived limits will have to be carefully checked in real installations or in “virtual channels”, representing the equivalent of deployed channel configurations.

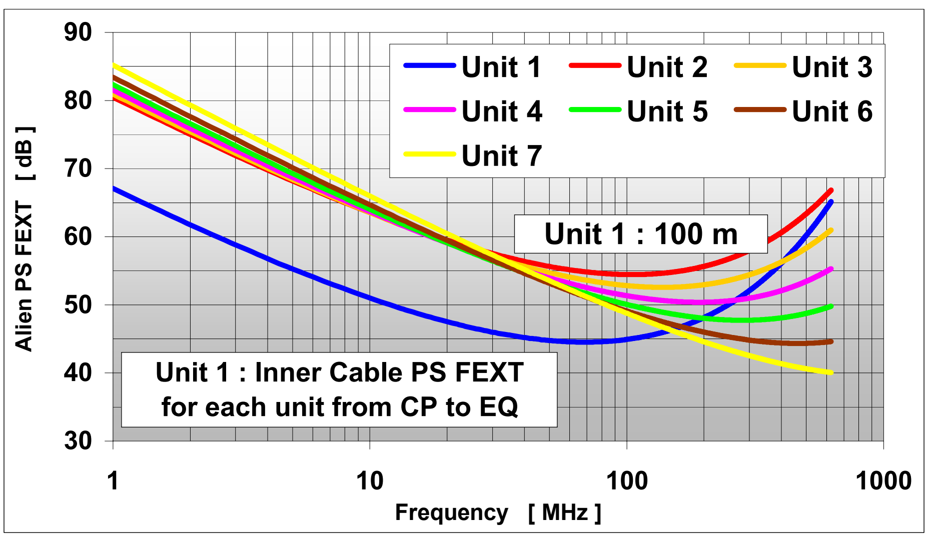

Figure 5: PS FEXT as a function of frequency for a 100 m unit cable, simulating a channel configuration as depicted in Fig. 4. The PS FEXT for the cable units is shown only for the shortened cables, i.e. by the unit length minus the combined length of the virtual work area cord and the CP cable.

Taking these values into account, we can now calculate the power sum of all these alien FEXT contributions and can determine, using the attenuation of the unit 1 the resultant power sum alien ACR-F.

The results are represented in the Fig. 9 and Fig. 10 for our virtual channels of 100m and 55 m, respectively.

The results are represented in the Fig. 9 and Fig. 10 for our virtual channels of 100m and 55 m, respectively. We see that both cases fail the allowable limit of ACR – F. It should be furthermore noted, that the considered case of the tree structure of the channels, as depicted in Fig. 4 is by far not the worst case. In fact, the worst cases occur, if by chance very long horizontal cables are placed in the vicinity of a multitude of short cables, which are close to the minimum allowable distance from the FD to the CP, i.e. 15 m.

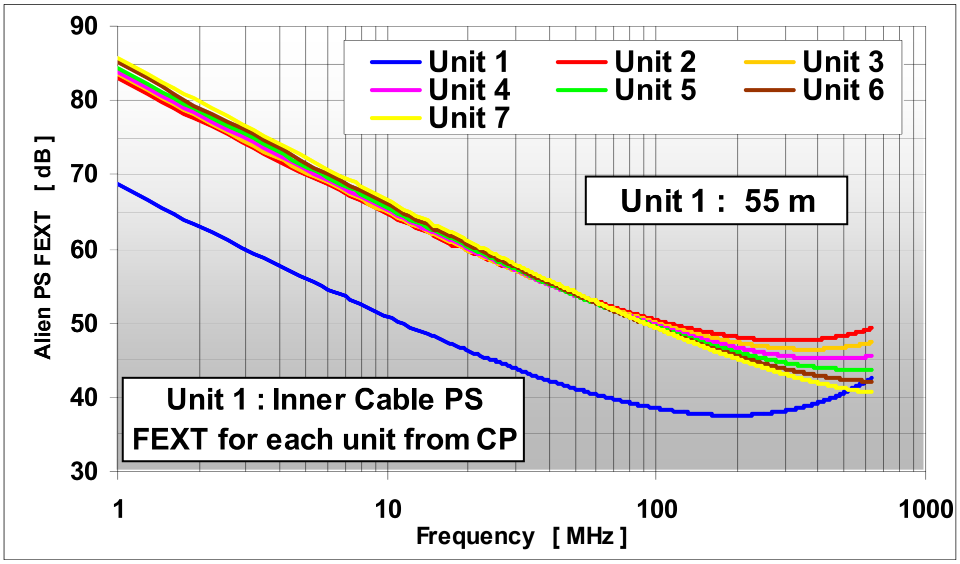

Figure 6: PS FEXT as a function of frequency for a 55 m unit cable, simulating a channel configuration as depicted in Fig. 4. The PS FEXT for the cable units is shown only for the shortened cables, i.e. by the unit length minus the combined length of the virtual work area cord and the CP cable.

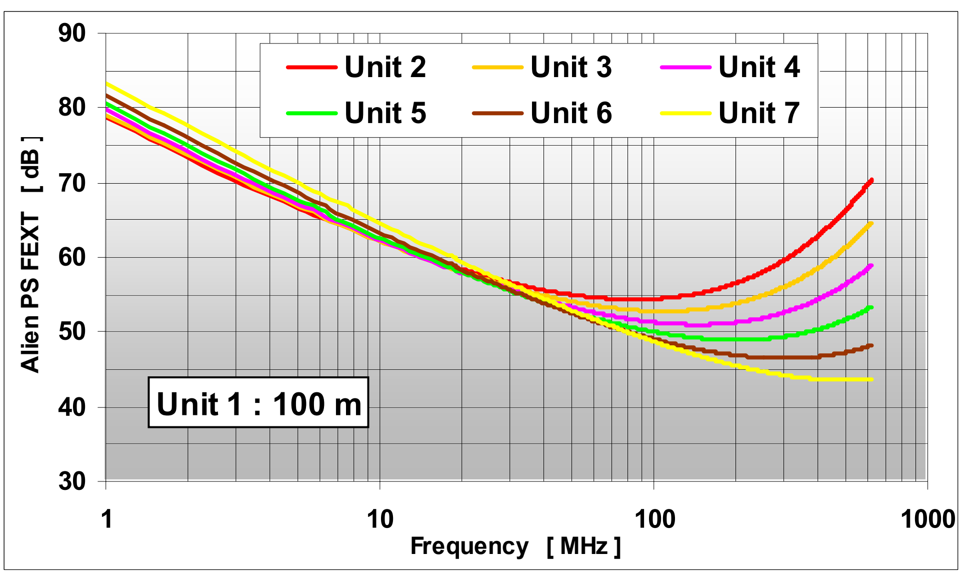

Figure 7: PS FEXT of the 100 m multi-unit cable for the different units, calculated from the values indicated in Fig. 4, but taking the attenuation of the virtual work area cord and the CP cable into account.

As a result we have to state, that alien FEXT is more important for real channel installations, than is alien NEXT. In fact, even the worst case alien NEXT, based upon power sum calculations will remain within the specified alien power sum limits, even if measured from the equipment side. This is convincingly demonstrated in the Fig. 11 and Fig. 12. Here for both lengths, i.e. 100 m and 55 m the effective alien power sum NEXT exceeds by a small margin, increasing at lower frequencies, the specification limit. Shown is also the PS NEXT of the unit 1 and the resultant total power sum NEXT for the pairs in the unit 1.

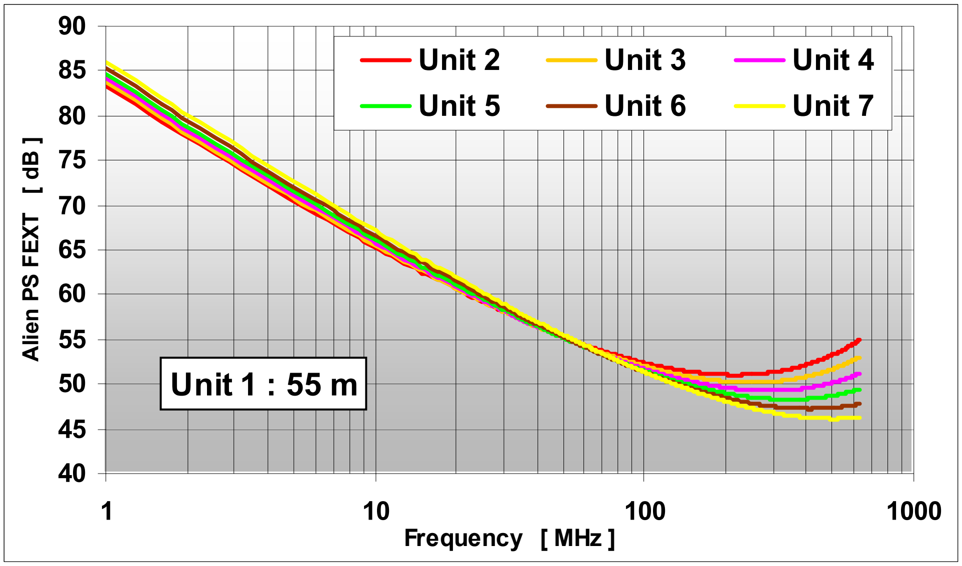

Figure 8: Figure 5: PS FEXT of the 55 m multi-unit cable for the different units, calculated from the values indicated in Fig. 4, but taking the attenuation of the virtual work area cord and the CP cable into account.

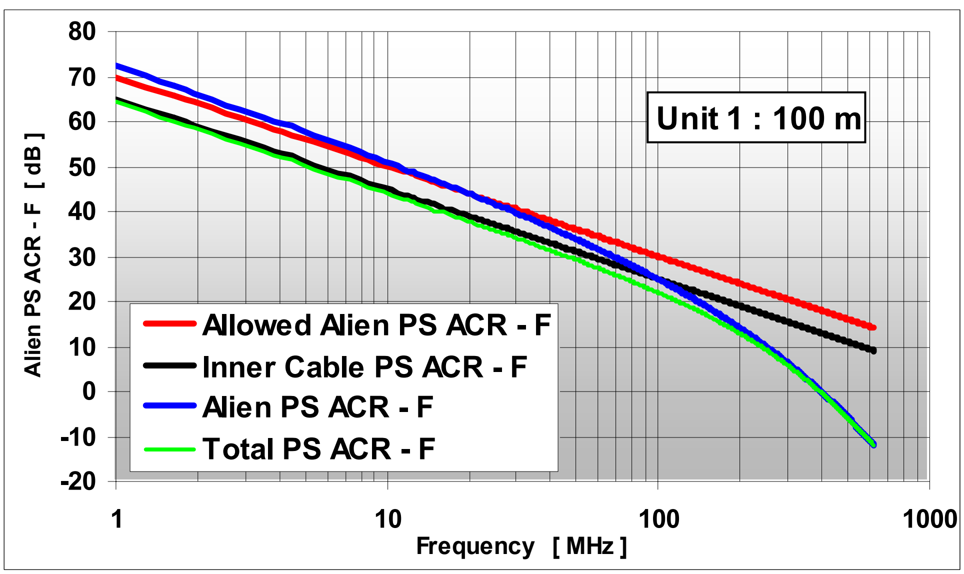

Figure 9: Resultant "Alien PS ACR – F" of a multi-unit cable of 100 m as depicted in Fig. 4. The "Alien PS ACR – F" of the units 2 to 7 on any pair in Unit 1 is

shown. There is, furthermore shown the inner unit PS ACR – F for the unit 1 and ultimately the total PS ACR – F noise.

The margin of the effective alien power sum NEXT compared to the specification limit is slightly higher at low frequencies for the virtual channel length of 55 m.

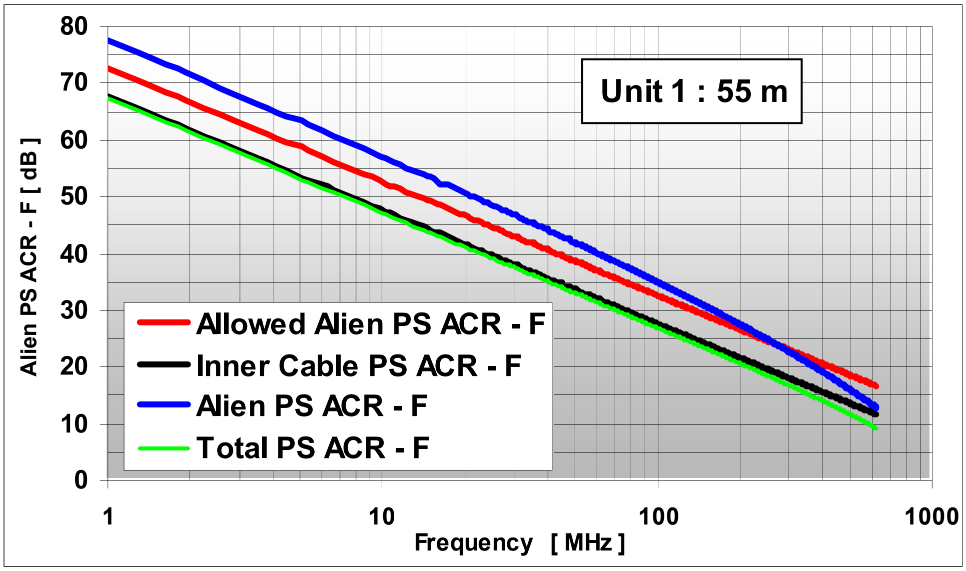

Figure 10: Resultant "Alien PS ACR – F" of a multi-unit cable of 55 m as depicted in Fig. 4. The "Alien PS ACR – F" of the units 2 to 7 on any pair in Unit 1 is shown. There is, furthermore shown the inner unit PS ACR – F for the unit 1 and ultimately the total PS ACR – F noise.

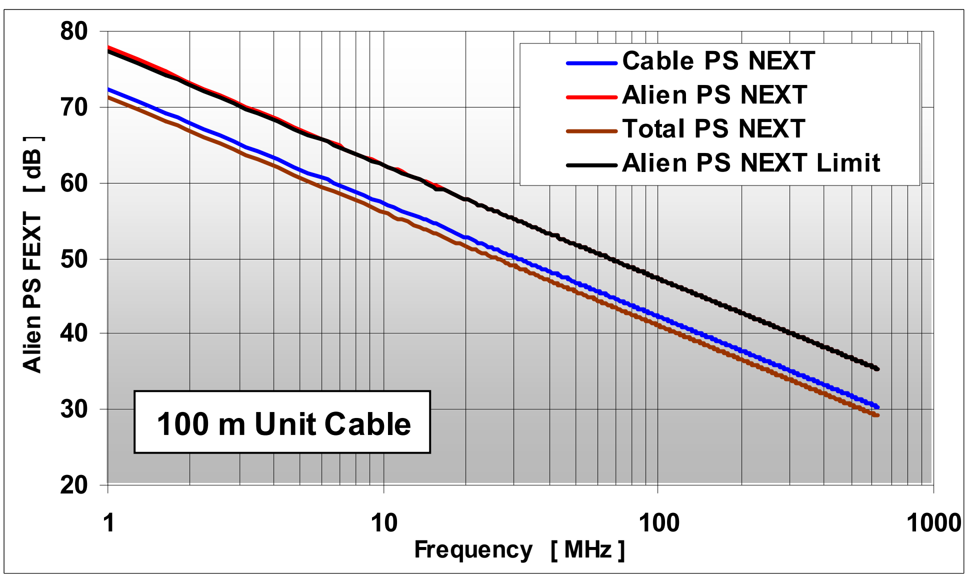

Figure 11: Alien power sum NEXT limit and alien power sum NEXT for a virtual channel of 100 m length configured as shown in Fig. 4, but viewed from the equipment side.

6. The absolute worst case FEXT condition

The worst case condition for FEXT is shown in Fig. 12. Here the "horizontal cable" of 85 m of the channel is surrounded by six "horizontal cables" of 15 m lengths' only. Thus the signal in the unit 1 is already strongly attenuated, when it is hit by the crosstalk coupling of the adjacent pairs, which have a substantially higher signal level.

The obtained result for the worst case condition of PS ACR – F are shown in Fig. 13 for a total virtual channel length of 100 m, and in Fig. 14 for a virtual channel length of 55 m. While the results on a 100 m virtual channel are totally unacceptable, the results for the 55 m virtual channel fall below the specification limit at approximately 185.7 MHz. It should be noted that the specification limits are set based upon a full channel length of 100 m.

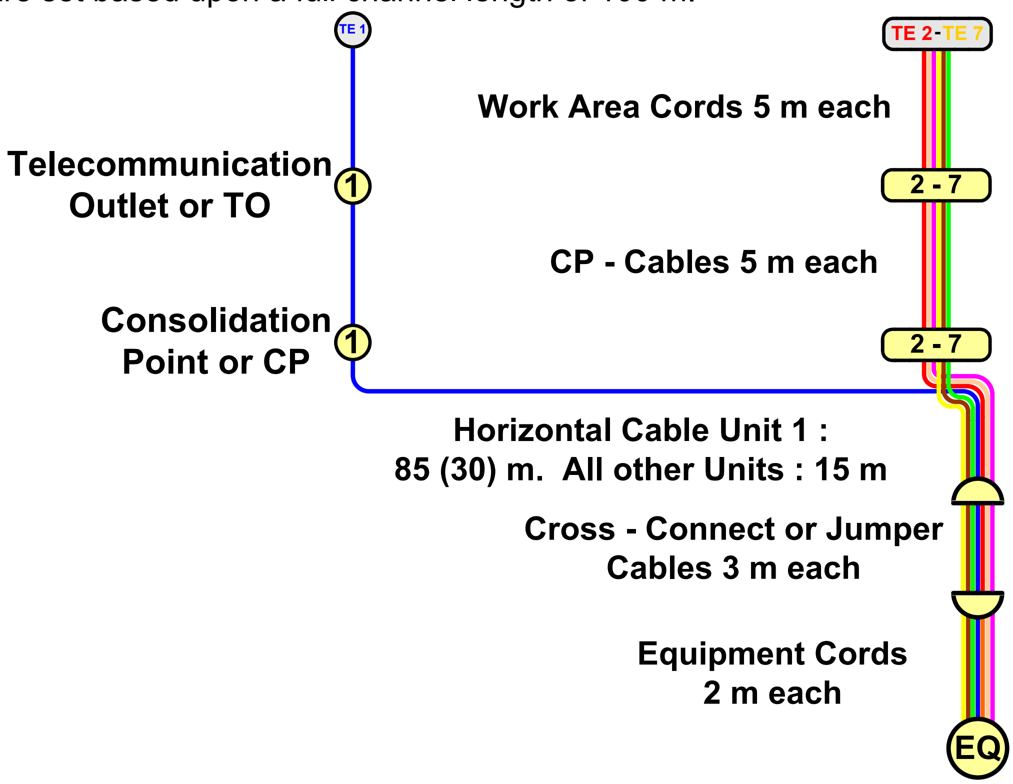

Figure 12: Worst case condition for the FEXT in a virtual channel represented by a loomed or multi-unit cable

7. Conclusion

We can conclude based on this preliminary study that Alien PS ACR – F is the predominant alien crosstalk component. There is a marked reduction in alien PS ACR – F noticeable, if the channel length is reduced to 55 m.

The results obtained in this study will have to be confirmed experimentally, either on real channels or on loomed or multi-unit cables used as "virtual channels".

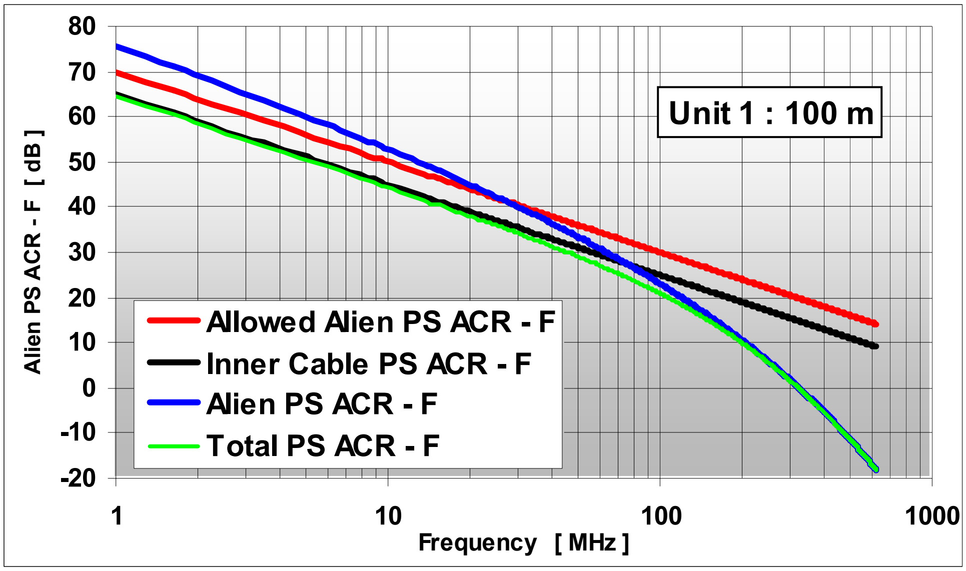

Figure 13: Worst case PS ACR – F for the virtual channel of Fig. 12 for a 100 m virtual channel length

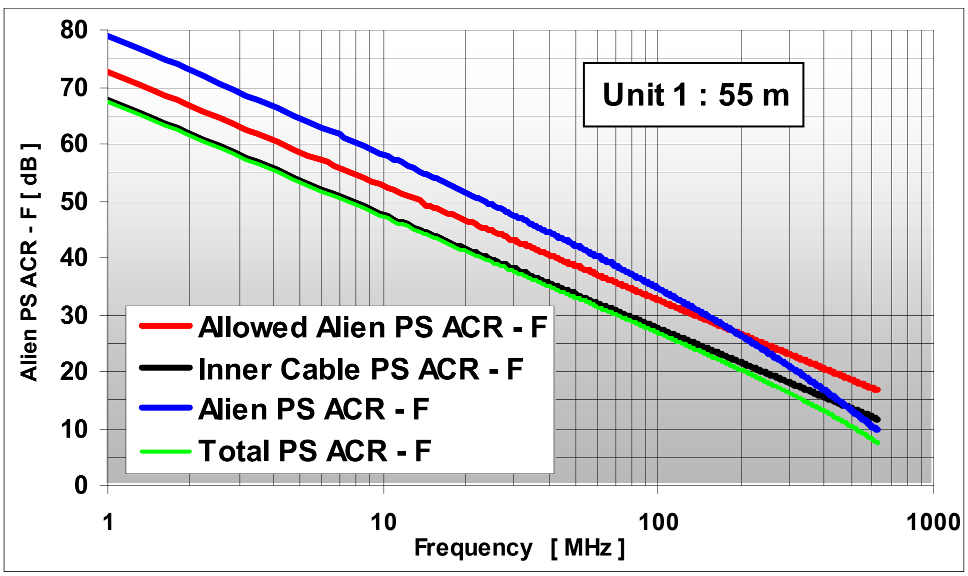

Figure 14: Worst case PS ACR – F for the virtual channel of Fig. 12 for a 55 m virtual channel length

In this case the only alternative would be to use FTP of SFTP cables, i.e. cables with an overall screen which needs to be grounded (ISO/IEC Class E overall screened cables – TIA Category 6 with an overall screen) or individually screened cables (ISO/IEC Class E overall screened cables – Category 7 cables).

It seems also to be impossible to improve the alien properties of UTP cabling by loading the jacket with either ferrites or conductive materials, as this will have serious impacts on propagation velocity in the first case and EMC performance in the second case.

References

[1] - S, Hinoshita et al: Analysis and Improvement of Crosstalk (NEXT & FEXT)for Multi-unit Backbone UTP Cable applied to FDDI/ATM Data Speed
Proc. 43rd IWCS 1994, p. 341-350

[2] - J.-H. Walling et al: Performance evaluation of Multiple Pair Category 5 Backbone Cable for High Speed Data Services
Proc. 43rd IWCS 1994, p. 328-340

[3] P. Vanderlaan: Alien Crosstalk and Network Performance
Contribution to the 10GBase-T Study Group, March 12, 2003

[4] - IEC 61156-5: IEC International Standard: Multicore and symmetrical pair/quad cables for digital communications – Symmetrical pair/quad cables with transmission characteristics up to 600 MHz - Horizontal floor wiring – Sectional specification
1st Ed. 2002-03

[5] - IEC 61156-6: IEC International Standard: Multicore and symmetrical pair/quad cables for digital communications – Symmetrical pair/quad cables with transmission characteristics up to 600 MHz - Work area wiring – Sectional specification
1st Ed. 2002-03

[6] - IS 11801: ISO/IEC International Standard: Information Technology – Generic cabling for customer premises
2nd Ed. 2002-09

[7] - ASTM D 4566-20XX Draft: Standard Test Methods for Electrical Performance Properties of Insulations and Jackets for Telecommunications Wire and Cable.

[8] C. Aldana et al: Receiver based alien crosstalk mitigation
Contribution to the 10GBase-T Study Group, July, 2003

Appendix

0. Definition of the crosstalk and related parameters

In the Fig. A-1 we have the voltages on two pairs which are capacitive and inductive loosely coupled. If we consider only the input to output voltages, we have:

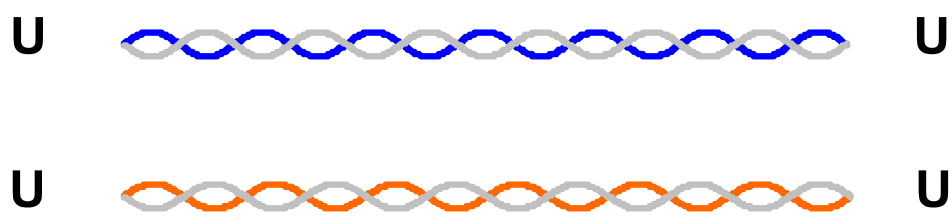

Figure A-1 : Voltage relations on two pairs for crosstalk assessment

1. Attenuation

Using the symbols given in Fig. A-1 we get for the attenuation:

$$\alpha_1 = -20 \cdot \log_{10} \left| \frac{U_{1F}}{U_{1N}} \right| \quad \text{and} \quad \alpha_2 = -20 \cdot \log_{10} \left| \frac{U_{2F}}{U_{2N}} \right| \qquad \text{(A-1)}$$

Note: Generally the attenuations of different pairs of a cable are slightly different for the same length.

2. NEXT

NEXT is defined as a power ratio. We have for the near end crosstalk:

$$NEXT_{12\,N} = 10 \cdot \log_{10} \left| \frac{U_{1N} \cdot \sqrt{Z_2}}{U_{2N} \cdot \sqrt{Z_1}} \right| \quad \text{and} \quad NEXT_{12\,F} = 10 \cdot \log_{10} \left| \frac{U_{1F} \cdot \sqrt{Z_2}}{U_{2F} \cdot \sqrt{Z_1}} \right|$$

or (A-2)

$$NEXT_{12\,N} = 20 \cdot \log_{10} \left| \frac{U_{1N}}{U_{2N}} \right| \quad \text{and} \quad NEXT_{12\,F} = 20 \cdot \log_{10} \left| \frac{U_{1F}}{U_{2F}} \right| \quad \text{if} \quad Z_1 = Z_2$$

Pair 1

By assuming that the characteristic impedances of all pairs are identical, we can replace the power ratios by the equivalent voltage ratios.

1N

Note: NEXT is reciprocal, i.e. NEXT $_{12\,N}$ = NEXT $_{21\,N}$

3. FEXT

Ne

The far end crosstalk is defined as input-to-output far end crosstalk we have then:

Pair 2

2N

$$FEXT_{12\,N} = 10 \cdot \log_{10} \left| \frac{U_{1\,N} \cdot \sqrt{Z_2}}{U_{2\,F} \cdot \sqrt{Z_1}} \right| \quad \text{and} \quad FEXT_{12\,F} = 10 \cdot \log_{10} \left| \frac{U_{1\,F} \cdot \sqrt{Z_2}}{U_{2\,N} \cdot \sqrt{Z_1}} \right|$$

or (A-3)

$$FEXT_{12\,N} = 20 \cdot \log_{10} \left| \frac{U_{1\,N}}{U_{2\,F}} \right| \quad \text{and} \quad FEXT_{12\,F} = 20 \cdot \log_{10} \left| \frac{U_{2\,N}}{U_{1\,F}} \right| \quad \text{if} \quad Z_1 = Z_2$$

Note: FEXT is also reciprocal, i.e. FEXT $_{12\,N}$ = FEXT $_{21\,F}$

4. EL FEXT

EL FEXT is defined as the output-to-output far end crosstalk. Hence:

$$EL\ FEXT_{12\,N} = -10 \cdot \log_{10} \left| \frac{U_{1\,F} \cdot \sqrt{Z_2}}{U_{2\,F} \cdot \sqrt{Z_1}} \right|$$

and

$$EL\ FEXT_{12\,F} = -10 \cdot \log_{10} \left| \frac{U_{1\,N} \cdot \sqrt{Z_2}}{U_{2\,N} \cdot \sqrt{Z_1}} \right|, \tag{A-4}$$

or

$$EL\ FEXT_{12\,N} = -20 \cdot \log_{10} \left| \frac{U_{1\,F}}{U_{2\,F}} \right|$$

$$EL\ FEXT_{12\,F} = -20 \cdot \log_{10} \left| \frac{U_{2\,F}}{U_{1\,F}} \right| \quad \text{if} \quad Z_1 = Z_2,$$

a fact which we will assume henceforward. Then we get with the definitions of appendix 1 and 3.

$$EL\ FEXT_{12\,N} = 20 \cdot \log_{10} \left| \frac{U_{1\,F}}{U_{2\,F}} \right| == 20 \cdot \log_{10} \left| \frac{U_{1\,N}}{U_{2\,F}} \right| - \alpha_1$$

$$= 20 \cdot \log_{10} \left| \frac{U_{1\,N}}{U_{2\,F}} \right| + 20 \cdot \log_{10} \left| \frac{U_{1\,F}}{U_{1\,N}} \right|$$

$$EL\ FEXT_{12\,F} = 20 \cdot \log_{10} \left| \frac{U_{2\,F}}{U_{1\,F}} \right| = 20 \cdot \log_{10} \left| \frac{U_{2\,N}}{U_{1\,F}} \right| - \alpha_2 \tag{A-5}$$

$$= 20 \cdot \log_{10} \left| \frac{U_{2\,N}}{U_{1\,F}} \right| + 20 \cdot \log_{10} \left| \frac{U_{2\,F}}{U_{2\,N}} \right|$$

Note 1: EL FEXT is no more reciprocal. The cause is the difference of the attenuations of the pairs. The “equal level” concept for this far end crosstalk parameter has its origin in the traditional telephone transmission lines, where only this parameter could be measured between different pairs far away from the central office.

Note 2: For bi-directional data traffic, where the attenuations of the pairs of a cable are different, this parameter is of no interest. We are mainly interested in ACR-F.

5. ACR (ACR-N and ACR-F)

We have to differentiate between ACR at the near end and at the far end, the difference being the directivity of the traffic. If we have bi-directional traffic on both considered pairs, then we talk about ACR-N (ACR at the near end) and if the traffic is uni-directional, then we talk about ACR-F (ACR at the far end). Formally both parameters have the same definition:

$$ACR = 20 \cdot \log_{10} \left| \frac{U_{1N}}{U_{2F}} \right| \tag{A-6}$$

We get then for the ACR-N:

$$\begin{aligned} ACR - N &= 20 \cdot \log_{10} \left| \frac{U_{1N}}{U_{2N}} \right| + 20 \cdot \log_{10} \left| \frac{U_{2N}}{U_{2F}} \right| = 20 \cdot \log_{10} \left| \frac{U_{1N}}{U_{2N}} \right| - \alpha_2 \\ &= NEXT_{12} - \alpha_2 \end{aligned} \tag{A-7}$$

and the ACR-F:

$$\begin{aligned} ACR - F &= 20 \cdot \log_{10} \left| \frac{U_{1N}}{U_{2F}} \right| - 20 \cdot \log_{10} \left| \frac{U_{2N}}{U_{2F}} \right| = 20 \cdot \log_{10} \left| \frac{U_{1N}}{U_{2F}} \right| - \alpha_2 \\ &= FEXT_{12} - \alpha_2 \end{aligned} \tag{A-8}$$

Note: Here the change in sign of the attenuation is mandatory due to the change of direction.

6. The power sum concept

All of the above parameters are defined as power ratios. If we want to evaluate the impact of any crosstalk coupling of multiple pairs to one pair, then we have to have to calculate the power sum:

$$PS\ X - talk_j = -20 \cdot \log_{10} \sum_{\substack{i=1 \\ i \neq j}}^{n} \left[10^{-\frac{X - talk_{ij}}{10}} \right] \tag{A-9}$$

7. The length correction for crosstalk

If we assume strictly length correlated crosstalk coupling, then we can derive the length correction for the crosstalk parameters. We obtain then:

$$NEXT_x = NEXT_y - 10 \cdot \log_{10}\left[\frac{1-10^{-\frac{x \cdot \alpha}{5}}}{1-10^{-\frac{y \cdot \alpha}{5}}}\right]$$

(A-10)

where:

x - is the length of the cable whose NEXT has to be determined

y - is the measured cable length, i.e. the cable with known NEXT

For EL FEXT and for ACR-F we have then:

$$EL\ FEXT_x = EL\ FEXT_y - 10 \cdot \log_{10}\frac{x}{y}$$

and (A-11)

$$(ACR-F)_x = (ACR-F)_y - 10 \cdot \log_{10}\frac{x}{y}$$

For the input to output FEXT we have then correspondingly:

$$FEXT_x = FEXT_y + 10 \cdot \log_{10}\frac{x}{y} + \alpha \cdot \left(\frac{y}{x} - 1\right) \qquad \text{(A-12)}$$

or as a combination of the above:

$$EL\ FEXT_x = FEXT_y + 10 \cdot \log_{10}\frac{x}{y} - \alpha \cdot \frac{y}{x}$$

and (A-13)

$$(ACR-F)_x = (ACR-F)_y + 10 \cdot \log_{10}\frac{x}{y} - \alpha \cdot \frac{y}{x}$$

Note: In the above the attenuation of all pairs is considered equal, which is generally not the case. However, here, for specification purpose calculations, we can make this assumption as a base line value for the attenuations of the pairs.