Cross - Talk Measurements with Random Noise Source

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Abstract

We show that it is feasible to use random noise source for the measurements of cross talk. In fact, both the pair to pair cross talk as well as the power sum cross talk - we call it the integral power sum cross talk - can be measured. For the latter we use power splitters. We compare the measurements with those, which are obtained using the traditional method with sinusoidal disturbing signals and a network analyzer in conjunction with an S-parameter test set.

We develop a method, which should allow, to measure alien cross talk in installed cabling systems of local area networks, using hand held testers. By using random noise sources to energize over baluns and power splitters as many cables as deemed necessary, it is possible to assess the alien cross talk susceptibility of an installed base, cable by cable.

Keywords

Alien cross talk; channel; NEXT; FEXT; random noise; hand held tester.

1. Background

Cross talk is traditionally measured, using sinusoidal signals. Originally cross talk was measured at specific discrete frequencies. However, in the last two decades, it became more and more common to use "swept frequency" measurements. This is basically the same measurement method at discrete frequency measurements, the only difference being that the frequency point density has been substantially increased.

With the increased advent of digital transmission for telecommunications, it has been conjectured, that digital cross talk may have a somewhat different behavior than cross talk measurements with sinusoidal signals.

Thus cross talk measurements have been made with randomly selected signal patterns within the considered coding scheme. However, the obtained results confirmed the validity of the assumption, that the cross talk performance can be correctly assessed, using sinusoidal signals.

Our objective here is to indicate a way to obtain a signal, which can be used in the field, to assess alien cross talk of installed cabling systems. To achieve this we use random white noise generators to energize either the disturbing pair or all disturbing pairs within one cable over a power splitter simultaneously. Our goal is to demonstrate the feasibility of using broadband random white noise generators, based upon random noise diodes, to measure the cross talk with a spectrum analyzer.

The objective is to explore the possibility to use power splitters in conjunction with random noise generators and an amplifier, to energize pairs within an installed cabling system, which are not under direct measurement, but which generate due to their proximity an alien cross talk in the cable under measurement. For this reason we limit our measurements on 90 m of cable, and for easier comparison we do not consider the connecting hardware. However, it should be mentioned, that the connecting hardware has also an influence on the cross talk performance.

In this way, several circuits of an installed cabling system can be powered with random noise, whereas the cable under measurement is energized on the disturbing pair or pairs, while measuring the cross talk or the alien cross talk alone on the disturbing pair.

2. Introduction

We limit our reporting to 4 pair cables only, each having a length of 90 m. For our test we use a Noise/Com amplified noise module NC 1109A, which has a flat random noise power output in the frequency range from 100 Hz to 1 GHz. The output of the random noise generator is amplified with a broadband amplifier, in order to obtain a sufficiently high power level. We use furthermore a passive power splitter M/A-Com DS-4-4.

We use baluns from BH Electronics, having an operating frequency range from 3 MHz to 350 MHz. We use these baluns only for their ease of utilization in conjunction with the power splitters, having both SMA-connectors. Additionally they simplify our task of connecting the pairs to the baluns.

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The method for the pair to pair cross talk measurement, using the network analyzer is straight forward and does not require any schematics. In case of the pair to pair measurements with the random noise generator the output of the amplifier is directly connected over a 3 dB attenuator to the balun, which is connected to the disturbing pair.

For the measurement of the integral power sum NEXT we use the set-up shown in Fig. 1, whereas for the integral power sum IO-FEXT we use the set-up according to Fig. 2.

For termination of the pairs we use resistors supplied by JC Electronics Corp, which are especially designed for testing at higher frequencies.

The common mode port of all the baluns used is terminated with a 50 Ohm resistor.

For all our measurements we use an HP-4195A Spectrum/Network analyzer. The HP-4195A instrument allows both, the measurement of the S-parameters and the power spectrum measurement

3. Methodology

3.1 Normal pair to pair and power sum cross talk measurements

The measurements of pair to pair cross talk, using the network analyzer in conjunction with an S-parameter test set are straight forward: The loss of the baluns used for the measurements is determined, and is subtracted from the measured values of cross talk, which include the loss of the baluns.

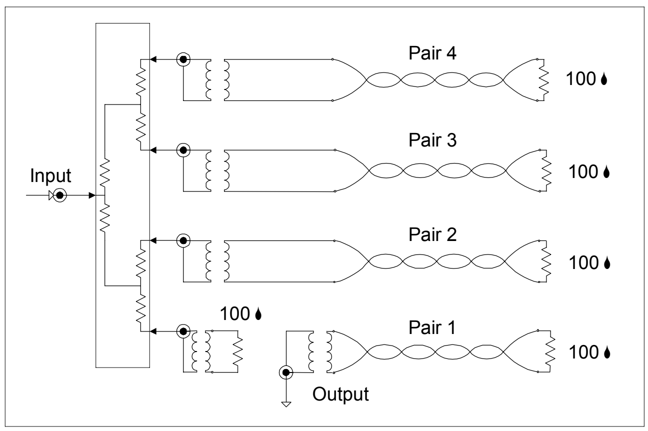

Fig. 1 : Set-up of Power splitter for measuring power sum NEXT for pair # 1

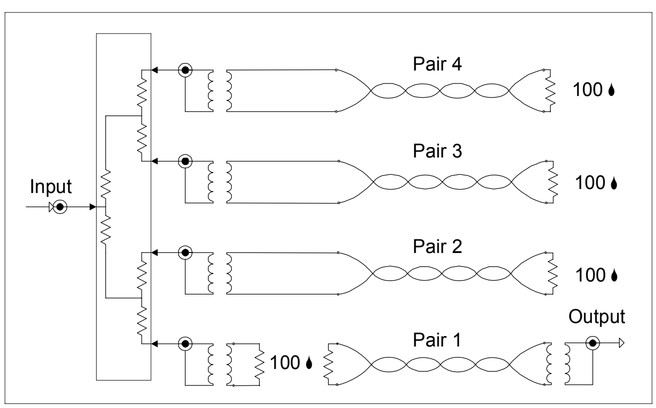

Fig. 2: Set-up of Power splitter for measuring power sum IO-FEXT for pair # 1

For the direct power sum cross talk measurement we use a power splitter. Though we are loosing some information on the S-parameters through the use of the power splitters, we can devise different ways to calibrate the set-up shown in the Fig. 1 and Fig. 2 [see also 1]. We indicate these in the following.

- We can calibrate the network analyzer with the S-parameter test set just prior to the power splitter. The losses for each path must to be measured. Both losses, i.e. the loss of the pair position on which the integral power sum is being measured and the power sum loss for the remaining positions, where the disturbing pairs are being connected, must to be subtracted from the result obtained.

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- Alternatively we can terminate all the baluns of the disturbing pairs with a 100 Ohm termination, and calibrate on the path for the disturbed pair. In this case only the power sum of the remaining position will have to be subtracted from the obtained result.

We explored both alternatives, and compared the results obtained with the power sums calculated from pair-to-pair measurements, which are taken directly, using two baluns on the network analyzer/S-parameter test-set.

We generally measure between 3 and 350 MHz with linear frequency division of this interval. We use 1601 points per sweep.

3.2 Pair to pair and power sum cross talk measurements with random noise sources

For the measurements, using the broadband random noise generator, we proceed as follows:

For pair to pair cross talk measurements we terminate the pairs not under measurement on both sides in 100 Ohm. The disturbing pair is connected, via a balun at its near end to the random noise generator, whereas the far end is terminated in 100 Ohm. For NEXT measurements, the disturbed pair is connected, again via a balun to the input of the spectrum analyzer, whereas the far end is terminated with a 100 Ohm resistor. The measurements of the IO-FEXT are done correspondingly.

For the measurement of power sum NEXT and IO-FEXT the power splitter is connected via baluns to the disturbing pairs, whereas the disturbed pair is connected over a balun to the spectrum analyzer. The connections are done as well following the schematics as given in Fig. 1 and Fig. 2.

The calibration is done, using by measuring the power at each balun output. This power level serves as a reference power input. We use the same frequency window for the spectrum analyzer, which is used for of the network analyzer measurements. Thus the LF frequency of the network analyzer is equal to the frequency window for the spectrum measurement.

We limit, to save measurement time, the frequency range of the measurements from 10 to 350 MHz. For lower frequencies the window for the spectrum analyzer measurements will have to be decreased and this will also substantially increase the measurement time.

To obtain the ELFEXT from the IO-FEXT we measured the attenuation, both as the power decrease over the channel length and as the insertion loss, using the network analyzer.

4. Results

In the Figures 3, 5, 7 and 9 is shown the directly measured PS - NEXT for the four pairs, using a spectrum analyzer. In this case the integral power sum has been measured, using the power splitter. As a comparison, there are given in the same graphs also the traces of the measurements obtained using the power splitter in conjunction with a network analyzer.

The Figures 4, 6, 8 and 10 finally show the results of the power sum NEXT calculated from the pair to pair measurements. Here the results obtained with the spectrum analyzer for each pair combination and the same results using the network analyzer are shown, to allow a comparison.

In the Figure 11, we have the attenuation of one pair, measured with the random noise generator. The trace is relatively rough, such that for useful attenuation a curve fitting would be required. However, for the purposes pursued here, i.e. for the calculation of EL FEXT from IO-FEXT, the obtained results are sufficient.

The Figures 12, 14, 16 and 18 as well as Figures 13, 15, 17 and 19 finally show for the four pairs of the cable the measurements of the integral Power sum EL FEXT and for the calculated power sum EL FEXT, based upon pair to pair measurements. In each case there is given the result obtained with the spectrum analyzer and with the network analyzer.

5. Discussion of Results

The integral power sum NEXT measurements, using the power splitter, yield, in comparison to the results obtained under the same conditions, with the network analyzer absolutely comparable results. In fact, the deviations are so small, that they can be neglected. (see Fig. 3, 5, 7 and 9)

The same is also true for the calculated power sum NEXT measurements, which are based upon individual pair to pair measurements. (see Fig. 4, 6, 8 and 10) The measurements, using the network analyzer, can be used as reference measurement results. The results obtained with the random noise generator yield absolutely comparable results to the reference results.

However, there are differences when comparing the Fig. 3 and 4, 5 and 6, 7 and 8 and finally Fig. 9 and 10. The results, using the power splitter and the pair to pair measurements are significantly different. This difference has to be attributed either to the power splitter itself or to the used error correction method. As in a previous study, the use of

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power splitters for power sum cross talk measurements has been already validated [1], it seems, that these deviations have to be attributed to the specific power splitter used.

The Fig. 11 shows, as already mentioned the attenuation trace of one pair, using the random noise source and a spectrum analyzer. Here the spectral power of the noise sources at the input balun to the twisted pair is measured, and compared to the spectral power at the end of the same pair. The obtained trace is relatively rough. It should be mentioned that these measurements are not intended to measure the attenuation of the pairs. Therefore, the roughness of the results is of relatively low importance in the context of our investigation.

Our main objective is to verify, if it is feasible to measure the alien cross talk induced in one cable by adjacent and neighboring cables. It is not the intention to use the proposed method to replace existing measurement methods.

Hence, the precision of the attenuation measurement, and the resultant roughness, using the random noise generator is not essential. They are here used only for completeness. In practical applications, a multitude of cables is energized, using random noise generators, either with or without power splitters. For the actual cable under measurement the parameters, including the attenuation are known, thus that the PS-EL FEXT can be directly determined from the PS-IO-FEXT.

The attenuation, using random noise generators, if ever used, would require a curve fitting of the data to obtain useful and meaningful results.

Here, the attenuation measurements are used exclusively to calculate from the IO-FEXT measurements the EL FEXT.

Again, our measurements are very comparable between the results obtained with the spectrum analyzer and the network analyzer. (see Fig. 12 to 19) The results obtained for the pair to pair measurements are nearly identical for those obtained with the spectrum and network analyzer. (see Fig. 13, 15, 17 and 19).

However, comparing the results to those of the integral power sum EL FEXT (see Fig. 12, 14, 16 and 18) there are similar differences occurring as between the power sum NEXT results.

We can clearly state, that the measurement of cross talk, using random noise sources yields absolutely comparable results to those obtained, using sinusoidal signals, as used in a network analyzer. This is convincingly confirmed by the fact, that the results, obtained using a power splitter to energize all disturbing pairs simultaneously, are also absolutely comparable. In this case the results with the random noise generator and those obtained with a network analyzer yield very comparable results.

6. Conclusion

We show convincingly, that cross talk measurements using random white noise sources yield absolutely comparable results to those obtained in the classical way, using sinusoidal disturbing sources.

This renders the utilization of random noise sources feasible for alien cross talk measurements. Towards this purpose, it is proposed to energize in an installed system as many channels as deemed required, using random noise sources on one side, and terminations on the other side. This allows the evaluation of the impact of alien cross talk, on the channel or cable under test. The random noise sources may be easily realized, using commercially available random noise diodes.

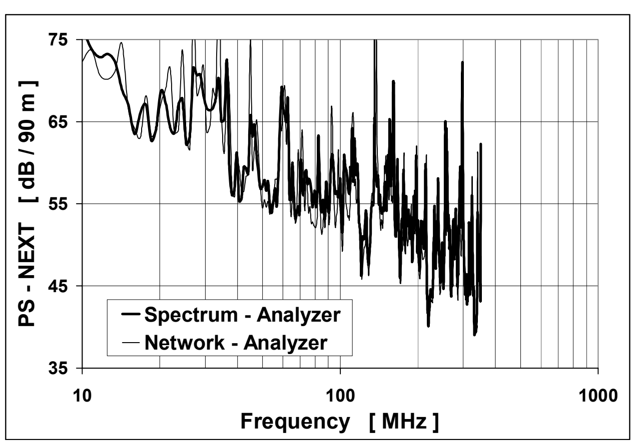

Fig. 3 : PS - NEXT for pair 1, measured directly with direct powering of all disturbing pairs over a power splitter.

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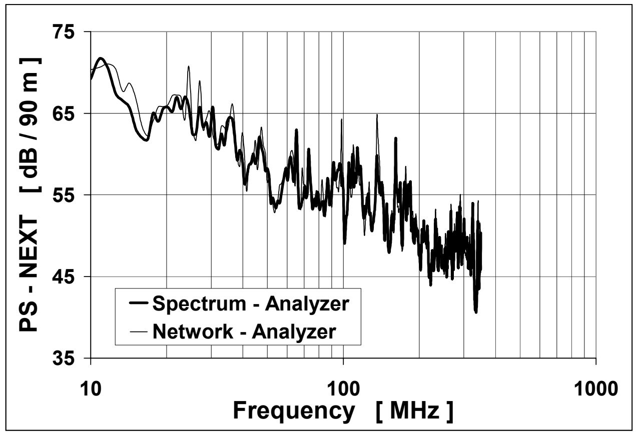

Fig. 4 : PS - NEXT for pair 1, calculated from pair to pair measurements.

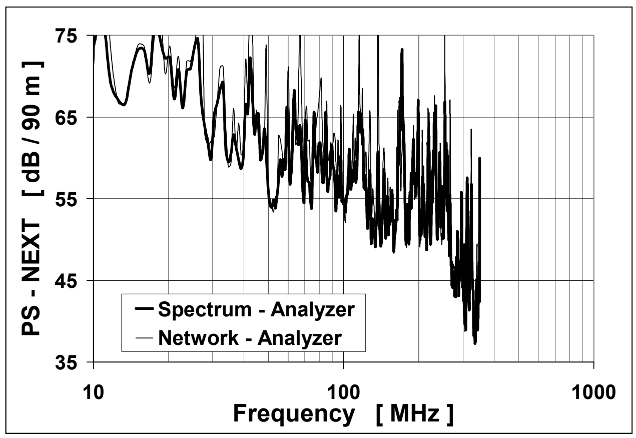

Fig. 5 : PS – NEXT for pair 2, measured directly with direct powering of all disturbing pairs over a power splitter.

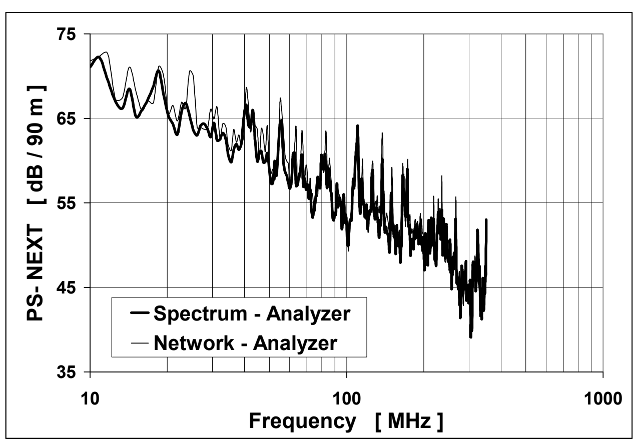

Fig. 6 : PS - NEXT for pair 2, calculated from pair to pair measurements.

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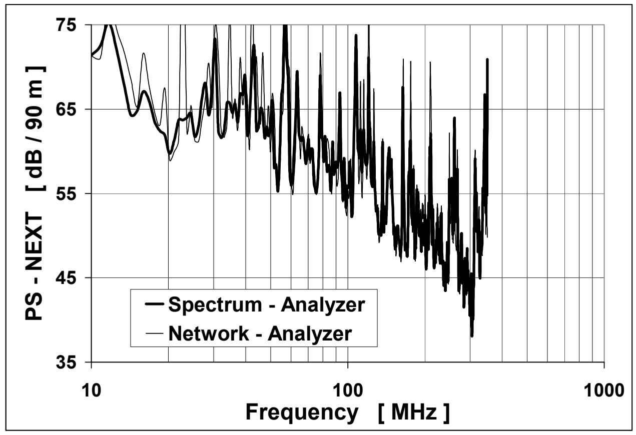

Fig. 7 : PS - NEXT for pair 3, measured directly with direct powering of all disturbing pairs over a power splitter.

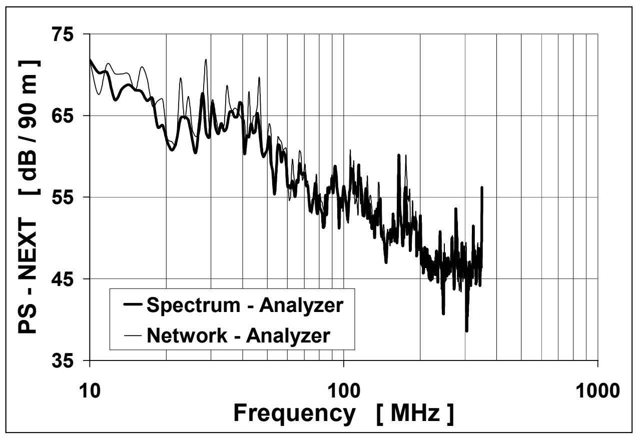

Fig. 8 : PS - NEXT for pair 3, calculated from pair to pair measurements.

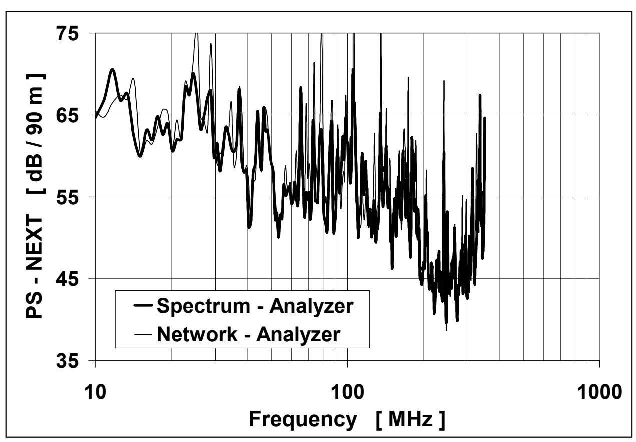

Fig. 9 : PS - NEXT for pair 4, measured directly with direct powering of all disturbing pairs over a power splitter.

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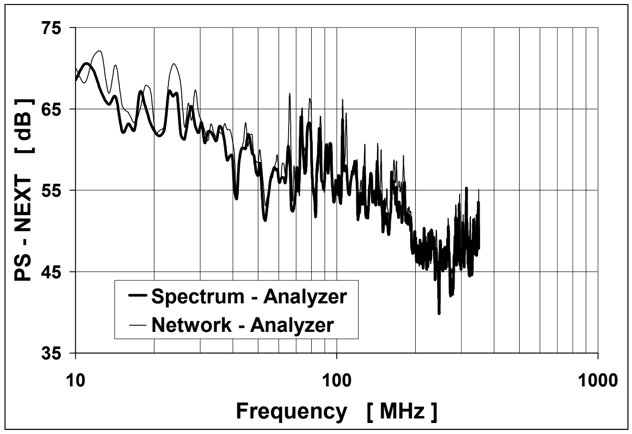

Fig. 10 : PS - NEXT for pair 4, calculated from pair to pair measurements

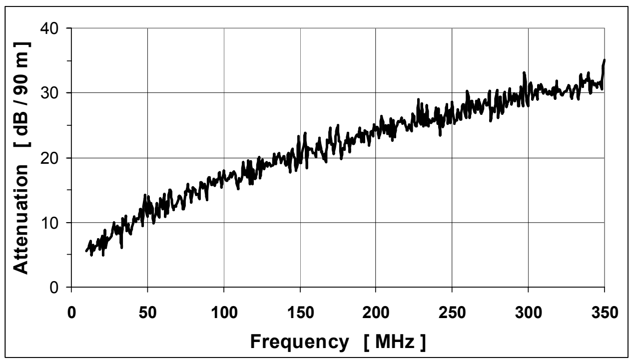

Fig. 11 : Attenuation of one pair, measured with the random noise generator.

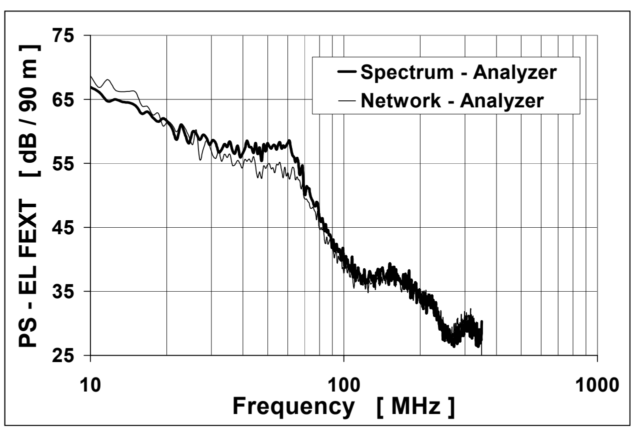

Fig. 12 : PS - EL FEXT for pair 1, measured directly with direct powering of all disturbing pairs over a power splitter.

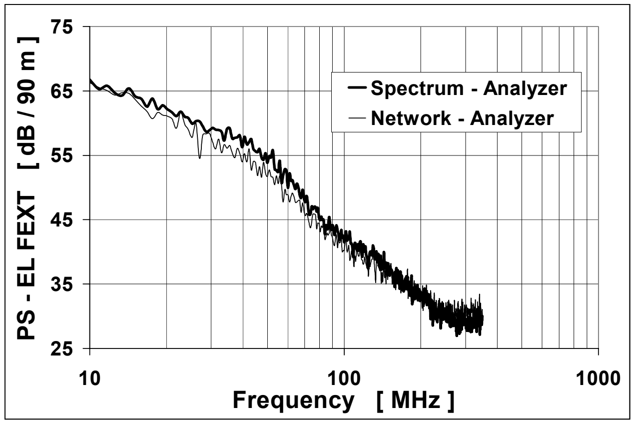

Fig. 13 : PS - EL FEXT for pair 1, calculated from pair to pair measurements.

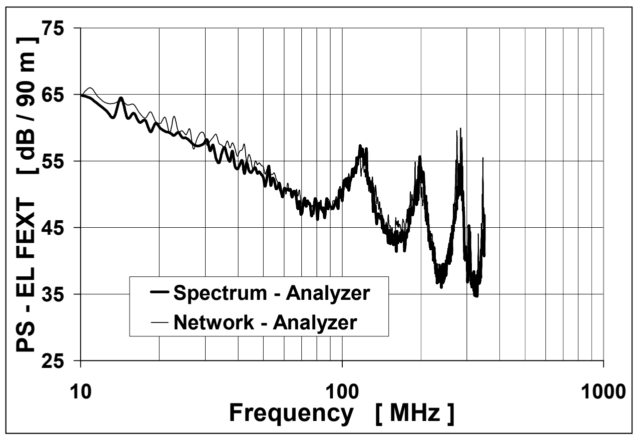

Fig. 14 : PS - EL FEXT for pair 2, measured directly with direct powering of all disturbing pairs over a power splitter.

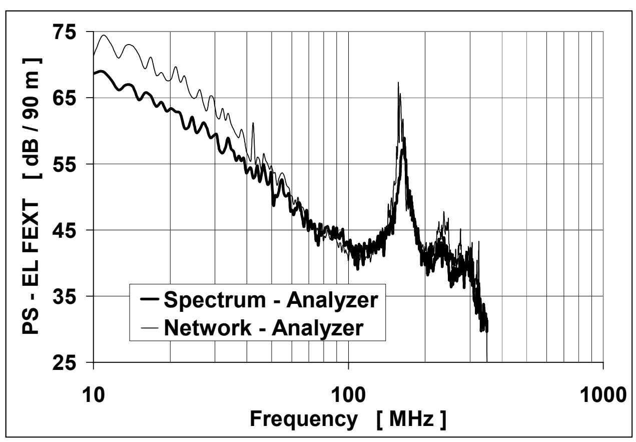

Fig. 15 : PS - EL FEXT for pair 2, calculated from pair to pair measurements.

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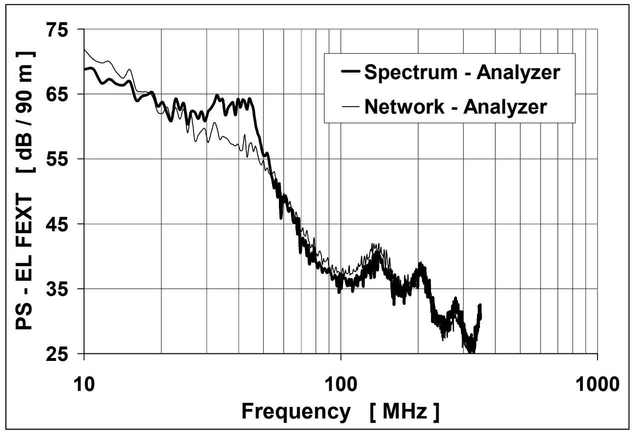

Fig. 16 : PS - EL FEXT for pair 3, measured directly with direct powering of all disturbing pairs over a power splitter.

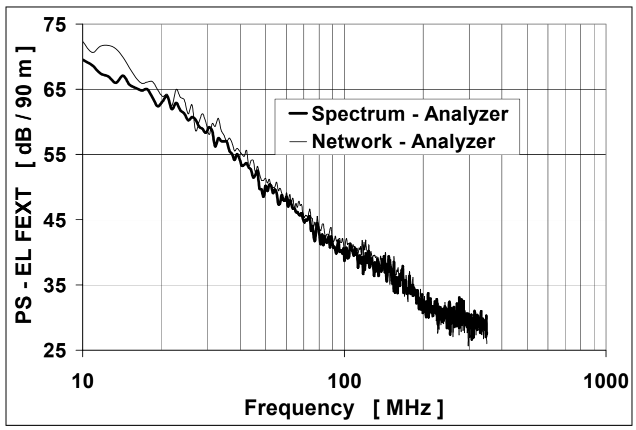

Fig. 17 : PS - EL FEXT for pair 3, calculated from pair to pair measurements.

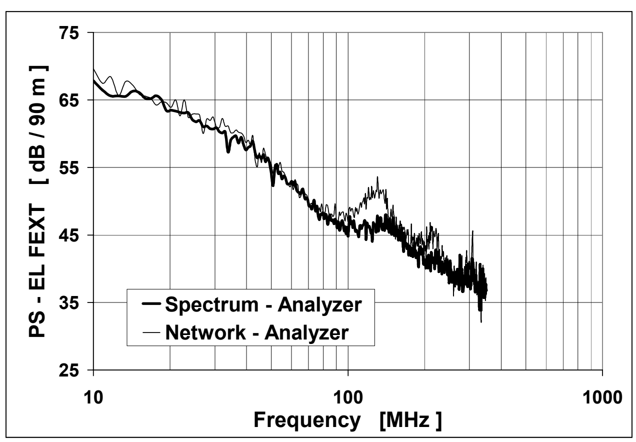

Fig. 18 : PS - EL FEXT for pair 4, measured directly with direct powering of all disturbing pairs over a power splitter.

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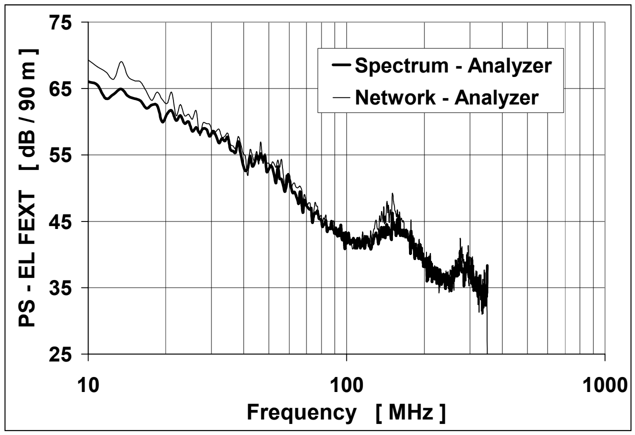

Fig. 19 : PS - EL FEXT for pair 4, calculated from pair to pair measurements.

7. References

[1] M. Belanger et al: Power Sum, Integral Power Sum and Vector Sum - Crosstalk.
47th IWCS (1998) p. 768-775

8. Authors

Jörg-Hein (Jo) Walling received his diploma in Mechanical Engineering in 1966 at the Technical University of Berlin. In 1974 he obtained a Doctor's degree (Dr.-Ing.) at the same University. In 1974 he joined Northern Telecom in the Research and Development department. Since 1976 he has been senior engineer at the NORTEL, Lachine Cable Plant. Later on he continued to work at the NORDX/CDT facilities, responsible for the design of Outside Plant and Data Grade Wires and Cables. Since 1999 he is an independent consultant for cables, standards and machinery.

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