
Title: Proposed Method on Crosstalk Calculations in a Distributed Environment
Project: ADSL, SDSL, SpM
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Status: For discussion/decision

Abstract: So far ETSI TM6 considered in its simulation scenarios only scenarios where the victim system and the disturbing system are collocated. However, this assumption is longer valid in scenarios where victim and disturbing systems have different deployment reaches. This document describes a methodology how to calculate crosstalk in a distributed environment, i.e. when victim and disturbing terminals are no longer collocated.

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1. Introduction

Figure 1 shows a scenario where 3 lines generate crosstalk into the victim line. The crosstalk generated by line 2 (disturber D1 and D2) into the victim system is straight forward since all terminals are collocated. Crosstalk generated by lines 3 and 4 (disturber D3 to D6) emerge from not collocated terminals.

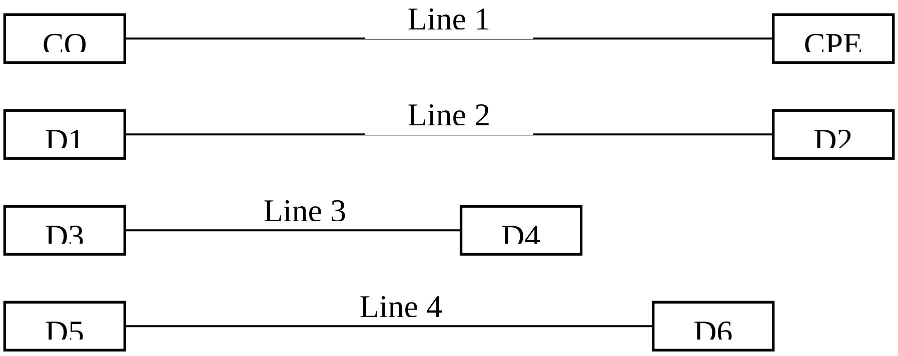

Figure 1 Distributed crosstalk scenario.

Each of the terminals on the left side of the disturbing lines generates NEXT into the CO terminal of the victim system and FEXT into the CPE terminal. The terminals connected to the right end of the disturber lines generate NEXT into the victim CPE and FEXT into the CO. Figure 2 and Figure 3 demonstrate this graphically. S_{NEXTi} and S_{FEXTi} are NEXT and FEXT PSDs generated by disturber i, respectively. These figures also show that the FSAN summation formula must be applied separately to NEXT and FEXT terms. The total crosstalk is then the sum of NEXT and FEXT.
Disturber D1 and D2 are collocated with the victim nodes and can therefore be calculated with the standard formulas. The methodology how to calculate the crosstalk from the non-collocated systems on lines 3 and 4 is described in Section 2.

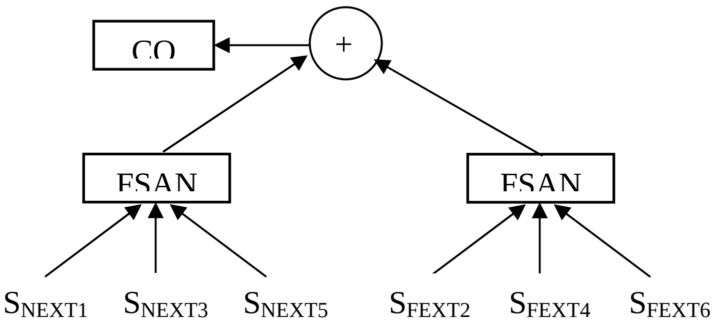

Figure 2 Equivalent crosstalk at the CO side.

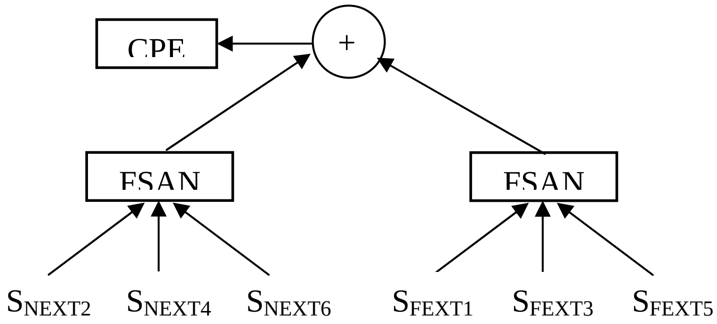

Figure 3 Equivalent crosstalk at the CPE side.

2. Crosstalk Generated by Non-Collocated Terminals

Depending how the nodes of victim and disturber are located relative to each other we can distinguish 9 different scenarios depicted in Figure 4 to Figure 12. The described methodology assumes the same cable type for victim and disturber as well as the same termination impedances.

In the following the quantity S_{D1} denotes the transmit PSD of disturber D1. NEXT(H) and FEXT(H, l) are the standard (power) crosstalk functions with H and l being the relevant transfer function and coupling length, respectively. S_{NEXT1} and S_{FEXT1} denote the NEXT and FEXT PSDs generated by disturber D1 at nodes A and B, respectively.

For the calculation of the attenuation between nodes la and lb, i.e. the victim system, this (whole) line segment is terminated with Zterm on both sides.

Case 1

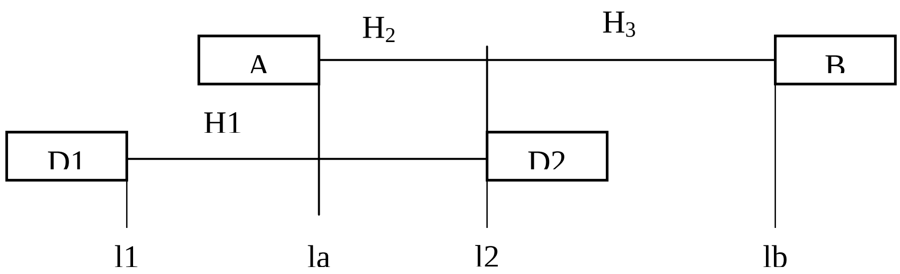

Figure 4 Case 1.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * \mathrm{abs}(H_1)^2 * \mathrm{NEXT}(H_2)$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * \mathrm{abs}(H_1)^2 * \mathrm{FEXT}(H_2, l2\text{-}la) * \mathrm{abs}(H_3)^2$
NEXT and FEXT from D2: See Case 9

H_1: Insertion loss between nodes l1 and la when this line segment is terminated with Zterm on both sides.
H_2: Insertion loss between nodes la and l2 when this line segment is terminated with Zterm on both sides[1].
H_3: Insertion loss between nodes l2 and lb when this line segment is terminated with Zterm on both sides.

[1] Since the same cables as well as the same termination impedances for both the victim and the disturbing system are assumed H_2 occurs on both the victim and the disturbing cable between nodes l2 and lb.

Case 2

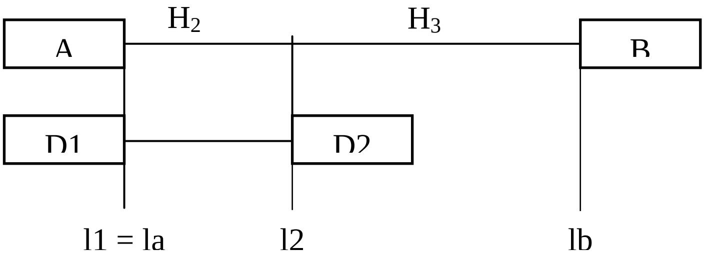

Figure 5 Case 2.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * NEXT(H_2)$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * FEXT(H_2, l2\text{-}la) * abs(H_3)^2$
NEXT and FEXT from D2: See Case 6

H_2: Insertion loss between nodes la and l2 when this line segment is terminated with Zterm on both sides.
H_3: Insertion loss between nodes l2 and lb when this line segment is terminated with Zterm on both sides.

Case 3

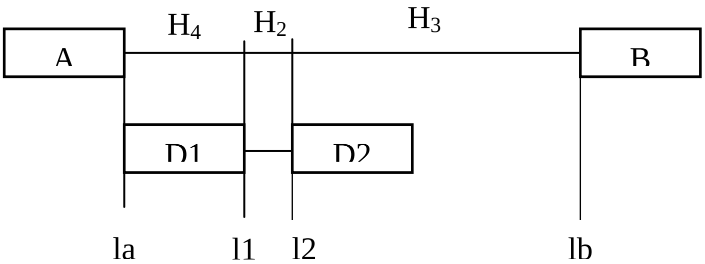

Figure 6 Case 3.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * NEXT(H_2) * abs(H_4)^2$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * FEXT(H_2, l2\text{-}l1) * abs(H_3)^2$
NEXT and FEXT from D2 into Node B: See Case 3

H_2: Insertion loss between nodes l1 and l2 when this line segment is terminated with Zterm on both sides.
H_3: Insertion loss between nodes l2 and lb when this line segment is terminated with Zterm on both sides.
H_4: Insertion loss between nodes l1 and la when this line segment is terminated with Zterm on both sides.

Case 4

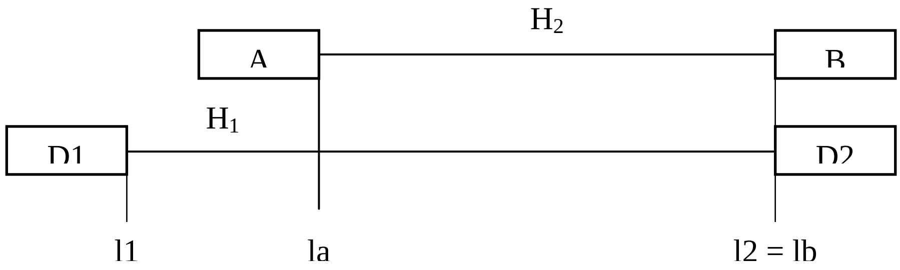

Figure 7 Case 4.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * abs(H_1)^2 * NEXT(H_2)$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * abs(H_1)^2 * FEXT(H_2, lb\text{-}la)$
NEXT and FEXT from D: See Case 8

H_1: Insertion loss between nodes l1 and la when this line segment is terminated with Zterm on both sides.
H_2: Insertion loss between nodes la and lb when this line segment is terminated with Zterm on both sides.

Case 5[2]

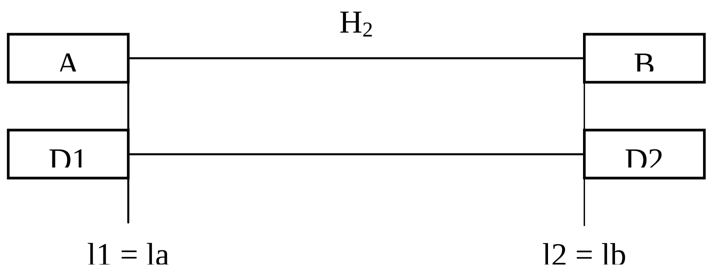

Figure 8 Case 5.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * NEXT(H_2)$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * FEXT(H_2, lb\text{-}la)$
NEXT and FEXT from D2: See Case 5

H_2: Insertion loss between nodes la and lb when this line segment is terminated with Zterm on both sides.

Case 6

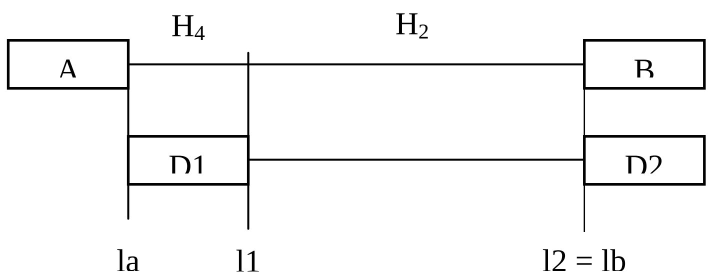

Figure 9 Case 6.

[2] This scenario actually corresponds to the well known collocated scenario.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * NEXT(H_2) * abs(H_4)^2$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * FEXT(H_2, lb-l1)$
NEXT and FEXT from D2: See Case 2

H_2: Insertion loss between nodes l1 and lb when this line segment is terminated with Zterm on both sides.
H_4: Insertion loss between nodes l1 and la when this line segment is terminated with Zterm on both sides.

Case 7

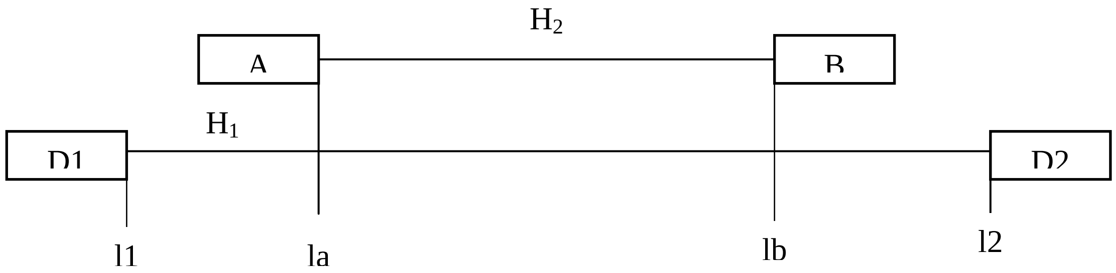

Figure 10 Case 7.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * abs(H_1)^2 * NEXT(H_2)$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * abs(H_1)^2 * FEXT(H_2, lb-la)$
NEXT and FEXT from D2: See Case 7

H_1: Insertion loss between nodes l1 and la when this line segment is terminated with Zterm on both sides.
H_2: Insertion loss between nodes la and lb when this line segment is terminated with Zterm on both sides.

Case 8

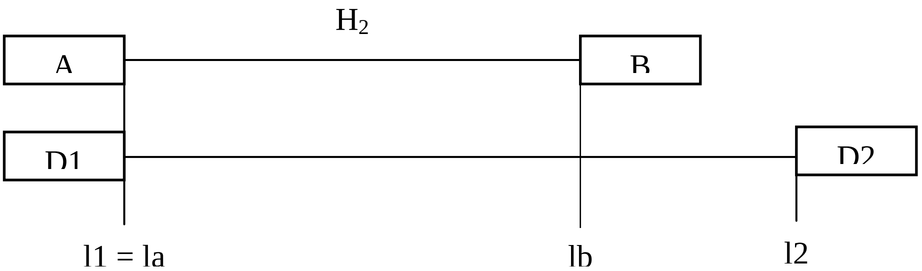

Figure 11 Case 8.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * NEXT(H_2)$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * FEXT(H_2, lb-la)$
NEXT and FEXT from D2: See Case 4

H_2: Insertion loss between nodes la and lb when this line segment is terminated with Zterm on both sides.

Case 9

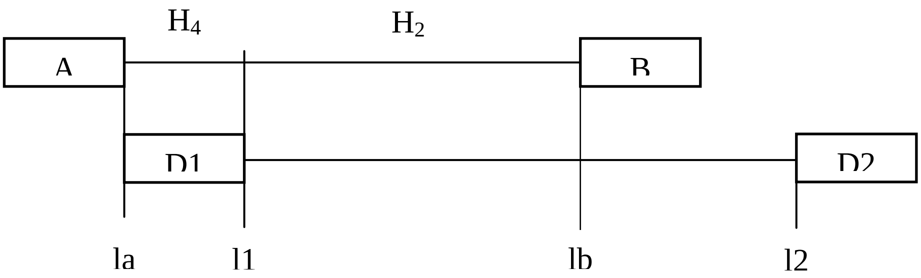

Figure 12 Case 9.

NEXT fromD1 into Node A: $S_{NEXT1} = S_{D1} * NEXT(H_2) * abs(H_4)^2$
FEXT from D1 into Node B : $S_{FEXT1} = S_{D1} * FEXT(H_2, lb\text{-}l1)$
NEXT and FEXT from D2: See Case 1

H_2: Insertion loss between nodes l1 and lb when this line segment is terminated with Zterm on both sides.
H_4: Insertion loss between nodes l1 and la when this line segment is terminated with Zterm on both sides.

3. Limitations of the Proposed Method

It is unclear how to generalize the proposed method to the case when the cables of the victim and the disturbing system are terminated with different impedances. In this case the insertion loss between identical nodes measured on victim cable and a disturbing wire are different. In this case it is unclear how the crosstalk functions for NEXT and FEXT shall de defined.
In order to avoid this problem each line segment is terminated with the same impedance Zterm. For the purpose of the simulations in the context of [1] this impedance shall be set to 135 Ω. In the scenario of case 1 for example the insertion loss H_2 is calculated under the assumption that both ends of the segment la->l2 are terminated by Zterm. However, in reality the termination impedance at node l2 on the upper line is Zterm transformed over the line segment l2->lb rather than Zterm. Taking this into account would result in different insertion losses H_2 when measured on the victim and on the disturbing wire. In this case we would be faced with above described problem how to construct the crosstalk functions. The error introduced by this simplification is that the product of the insertion losses H_2 and H_3 is no longer equivalent to the insertion loss between nodes la and lb.

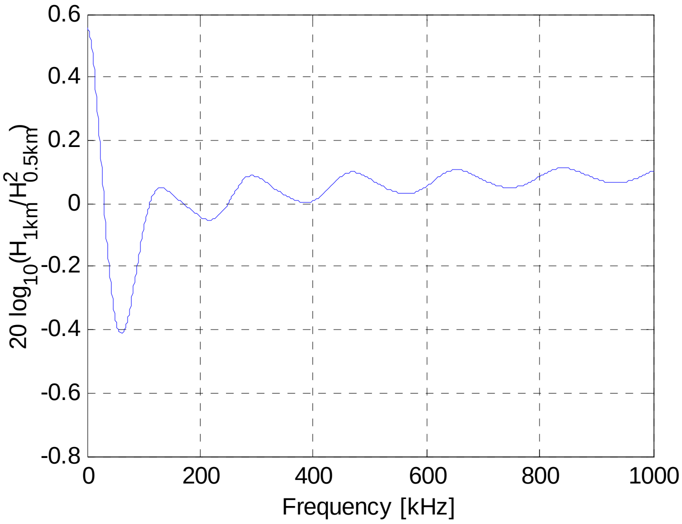

Figure 13 and
Figure 14 demonstrate this effect for a 1 km long ETSI 0.5 mm cable. The graph in

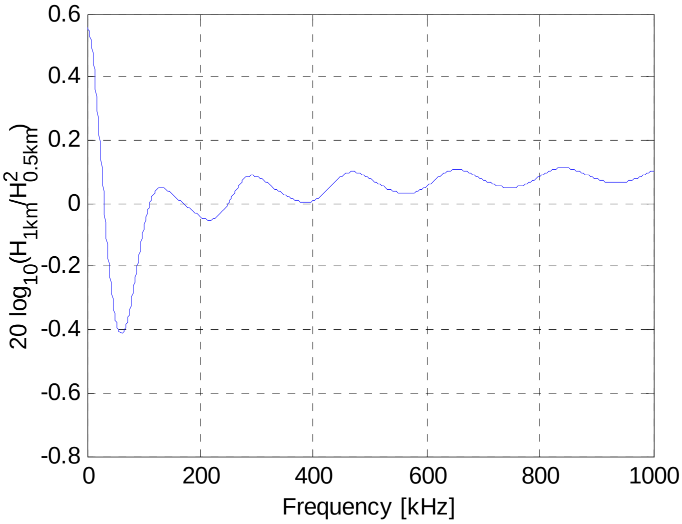

Figure 14 shows the difference in dB between the “true” insertion loss H_{1km} of this 1 km long cable and the following model: According to Figure 13 the 1 km long line is split (cut) into two identical 500 m long segments and both segments are terminated with Zterm on each side. The new total insertion loss is then the product of these tow (identical) insertion losses $H_{0.5km}$. The difference between abs(H_{1km}) and abs($H_{0.5km}$)^2 is depicted in

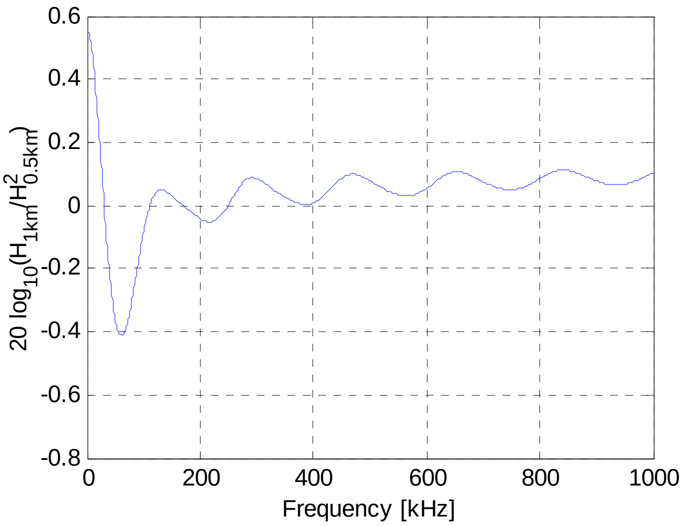

Figure 14. It can be seen that the difference is a few fractions of a dB.

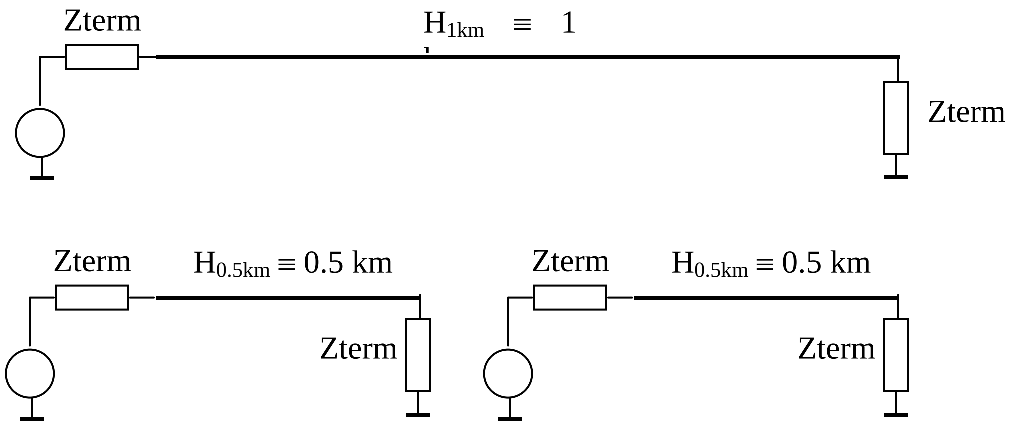

Figure 13 A 1 km long line is split into two 500 m long lines.

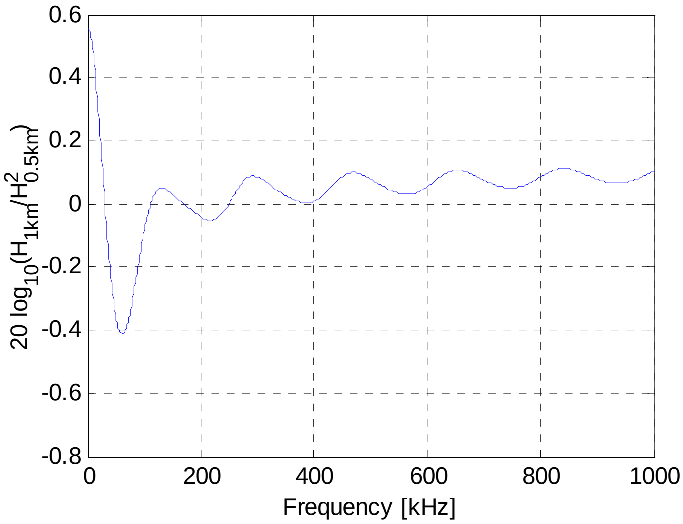

Figure 14 Difference between H_{1km} and $H_{0.5km}$ * $H_{0.5km}$.

4. Summary

The authors of this contribution ask to agree on the proposed method for the calculation of distributed crosstalk for the simulations in the European SpM Framework [1].

5. References

[1] R. Persico, "Framework for spectral management studies on e-SDSL and ADL-64", Sophia Antipolis, September 2003, contribution 033t04