

Phantom Mode for DSL

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Abstract — The current technology used for data transmission over copper wires is DSL (Digital Subscriber Line). This technology supports the transmission of data and voice simultaneously over the same telephone channel because they use different frequency bands. Phantom-mode is a transmission mode that provides the creation of virtual channels that can be used both to attend new users and to increase the upstream/downstream rates (up to 300 Mbps for small distances with 2 twisted pairs) of a single user. Another advantage of the phantom-mode is the use of the existing telephony infrastructure in such a way that it can be implemented at low cost. The aim of this paper is to present the phantom-mode as a tool to improve signal transmission in DSL and exhibit the behavior of the phantom-mode transfer function and impedance characteristic curves simulated in CST Cable Studio and measured in a Network Analyzer and Impedance Analyzer.

Keywords — Phantom-mode, twisted wire pairs, DSL.

I. INTRODUCTION

Digital subscriber line (DSL) is a technology that supports telephony and Internet connection simultaneously. This is possible because DSL uses different frequency bands for data transmission/reception and for voice schemes, separating them by filtering [1]. Phantom-mode can help to achieve a downstream bit ratio of 300 Mbps over distances up to 400 meters on two twisted pairs in combination with vectoring and bonding techniques [2]. Higher speeds can be obtained with the use of more twisted pairs.

It is therefore important to know some Phantom-mode characteristics like transfer function and impedance characteristic. The transfer function determines the relation between the input and output signals of a system (in this case, the wire cable) and helps to forecast how the system will react to a given input signal. The characteristic impedance of a transmission line is the ratio between the voltage and de current for an infinitely long line [3] and knowing this feature of the transmission line and the source is possible reduce signal reflections with impedance matching.

II. PHANTOM-MODE

The phantom signal is a compound of a differential-mode and a common-mode signal. In Figure 1, the signal U_{d1} passes through the top left transformer and through the twisted pair, *Pair1*. The top right transformer extracts the differential signal U_{d1} from *Pair1* resulting in the signal $V_{d1} = U_{d1} + Noise$ at the far end. The same happens to the second twisted pair, *Pair2*.

A third signal is inserted at the center taps of the U_{d1} and U_{d2} transformers, the positive and negative parts of phantom signal being called U_{p+} and U_{p-} , respectively.

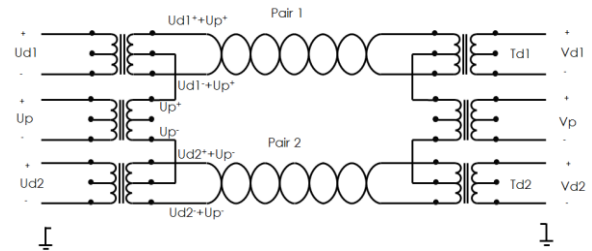


Figure 1 – Phantom-mode scheme

The phantom-mode signal, V_p , can be obtained as a differential-mode signal between the center taps of transformers T_{d1} and T_{d2} . [4]

In phantom-mode, a “virtual” pair can be derived from two twisted pairs. With N physical channels, one can create $N - 1$ virtual channels, totaling $2N - 1$ possible channels. Then, vectoring techniques can be applied to reduce the crosstalk created between the physical pairs and the new, virtual one. Finally, “bonding techniques” are used to create a DSL pipe composed by the two physical pairs and the virtual one.

III. SIMULATIONS WITH CST CABLE STUDIO

The CST Cable Studio is software dedicated to the three-dimensional analysis of signal integrity, conducted emissions, radiated emissions and electromagnetic susceptibility of complex cable structures in electrically large systems. The CST Cable Studio simulation for phantom mode presented in this paper focuses on the transfer function and characteristic impedance in a quad cable up to 300 MHz. The Table 1 presents the parameters used in the phantom mode simulations with CST Cable Studio.

TABLE 1. QUAD-CABLE DIMENSIONS – CST SIMULATIONS

Conductor diameter	0.5 mm
Total diameter	0.94 mm
Twisting rate	12 twists/m

Figure 2 shows how the wires touch each other’s dielectric in the cross-section of a quad cable, so the distances between their centers are 0.94 mm (PM edge) and $0.94 \times \sqrt{2}$ mm (PM diagonal). All dimensions were obtained at lab using a precision measure instrument and are the same independent of cable length.

Figure 3 shows the circuit models generated and the source and load configurations for simulating the Phantom Mode (PM) edge and PM diagonal, respectively. The small yellow boxes represent differential sources/loads (external ports),

while the big white and blue box represents the quad cable model with 8 inputs/outputs, each one representing one end of each wire of the cable (4 wires = 8 ends).

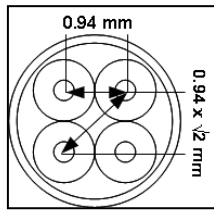


Figure 2 – Distances between wire centers in a quad cable

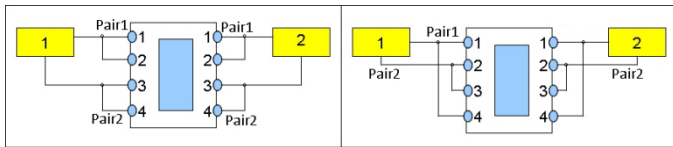


Figure 3 – Block diagram of PM edge and PM diagonal

The external ports have their impedances fixed set to 100 ohms. To simulate the common-mode transmission for each part of phantom mode, each termination of the external ports (differentials) was connected to two wires. The CST simulation generates the S-parameters for the circuit and the impedance, admittance and other curves can be obtained from them.

IV. RESULTS

A. Transfer Function

Figure 4 compares all TF curves of the diagonal and edge curves PM, obtained both by simulation in CST Cable Studio and measurements with the Network Analyzer. The simulated phantom mode transfer function curves were generated from the S-Parameters and it are a little different than the measured ones. As can be seen in the figure, the simulated TF for edge PM is almost 10 dB higher than the measured one up to 300 MHz. The behavior of the simulated TF for diagonal PM is peculiar in lower frequencies.

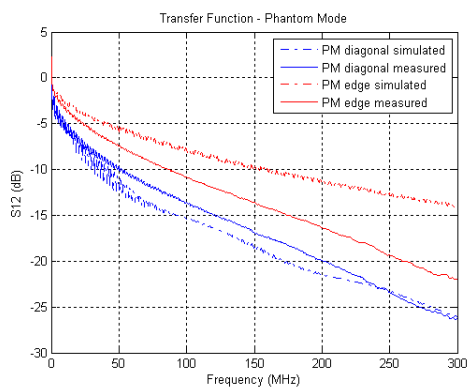


Figure 4 – The measured and simulated phantom mode transfer functions

B. Characteristic Impedance

To simulate the characteristic impedance is required the open and short impedances, which are generated in accordance with the wire connections in CST Cable Studio. It is possible to obtain the impedance corresponding to the type of connection from the S-Parameters and then the characteristic impedance is obtained according the Equation 1 [5].

$$Z_c = \sqrt{Z_{open} * Z_{short}} \quad (1)$$

The behavior of the phantom mode characteristic impedance curves are similar and converge to a value close to the expected, as shown in Figure 5. The simulated results are not identical to the measured ones, probably because CST does not consider all real environmental losses.

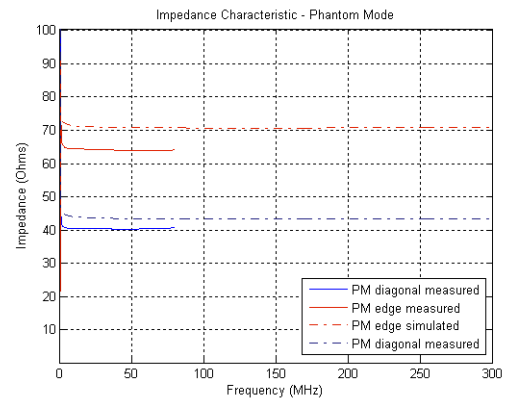


Figure 5 – Characteristic Impedance measured and simulated

V. CONCLUSIONS

Today, the Internet connects almost the entire world. Business, interpersonal relationships, knowledge and entertainment demand ever and ever higher speeds. A low-cost alternative for those needs can be the use of Phantom Mode. Using phantom mode is possible to obtain with N physical channels, N – 1 virtual channels, totaling 2N – 1 possible channels. Thus, it is essential to understand the phantom mode behavior.

This paper presented the Phantom Mode Transmission scheme and its basic formulation. Besides, a comparison between simulated and measured transfer functions and impedance curves of a phantom mode transmission over a quad-cable is presented.

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