Influence of Terminal Units on the Radiation Properties on Ethernet Cables

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***Abstract*—In the design of network interface controllers, implementation of the so called Bob Smith terminations has become a de facto standard. Objective of this work is to assess the actual role of the Bob Smith terminations in the mitigation of emissions. This is done by resorting to modal analysis and focusing on the common-mode currents placed on the Ethernet cable.**

***Keywords*—Ethernet, termination, common mode, unshielded twisted wire pairs.**

I. Introduction

The Bob Smith termination, originally proposed in [1], is a common mode termination for Ethernet cables. It is composed of four resistors, each of them equal to 75 Ω. While over the years this value has become a de facto standard, later works have shown that 75 Ω may not always be the optimal value to mitigate common-mode emissions on Ethernet cables, [2], [3]. Starting from these analyses, this work investigates the generation of spurious emissions (of common-mode type) in the network interface controller by resorting to a distributed-parameter model of the Ethernet cable and modal decomposition of the noise currents.

II. Circuit Model

A simple transmission line circuit model is introduced to investigate the propagation of pairwise common mode currents, as shown in Fig. 1. It includes an Ethernet Cat.5 unshielded twisted-wire pair (UTP) cable with resistive transmission- and receiver-side terminations. The aim is to analyse the frequency behaviour of the Common Mode Return Loss (CMRL) and the Transverse Conversion Loss (TCL) at the input ports of the UTP used for transmission by varying the values of the terminations Z_{term}, considering the values proposed by R. Smith [1] (75 Ω) and J. Satterwhite [2] (52.3 Ω). The work conducts research on parameters derived from S-parameters, whose sources were originally defined as power waves in order to derive the representation. The first step in the analysis is to define the frequency behaviour of the cable as a function of its S-parameters matrix.

The S-parameters matrix of the cable is then embedded in a 2-by-2 matrix, by imposing the terminal conditions.

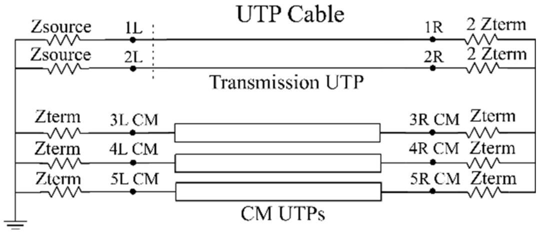

Fig 1. System for prediction of the CMRL and TCL at the physical ports 1L and 2L, respectively (L, R denoting the left and right end, respectively).

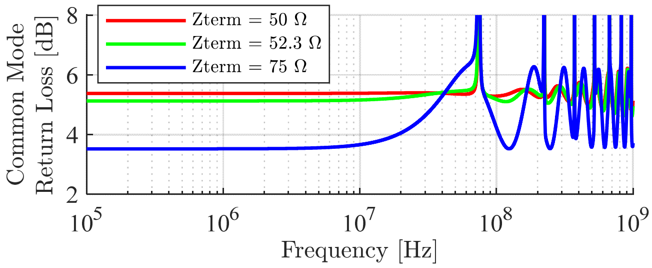

Fig 2. CMRL versus frequency.

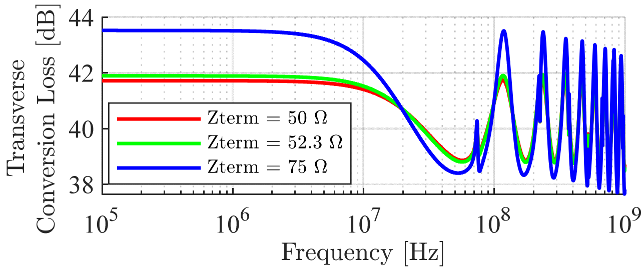

Fig 3. TCL versus frequency. An imbalance of 1 Ω in the left-end terminal unit of the transmission pair was considered.

Once the 2-by-2 S-parameters matrix has been obtained, the modal quantities as well as the parameters to be estimated are obtained through a straightforward modal transformation.

III. Results and Conclusion

As a simple and specific outcome, Fig. 2 and Fig. 3 report the frequency shape of the aforementioned parameters (i.e. CMRL, TCL). The final objective of investigation is to reduce radiated emissions, but here we consider a frequency range up to 1 GHz due to the limitation of TL theory. The plots point out that the 75 Ω termination value is optimal as far as the TCL is considered; instead, the low frequency behaviour of CMRL suggests that a 50 Ω termination is more effective in damping common-mode disturbance. Indeed, while the CMRL is mainly dependent on mismatching of the common-mode circuit, differential-to-common mode conversion (i.e., TCL) mainly depends on imbalance of the differential-mode circuit [4]. At the conference, it will be shown how the analysis can be extended to a more general configuration, involving a simulated Ethernet PHY board for the left termination of the cable. Since radiative properties of Ethernet cables are tightly related to the specific configuration adopted and nonideal behavior of the terminal units, further investigations are still needed to determine which of the two parameters is mainly affecting radiation, so to optimize the termination value.

References

[1] R. Smith, Apparatus and method for terminating cables to minimize emissions and susceptibility, US Patent US5321372A, June 14, 1994.

[2] J. Satterwhite, "Bob Smith Termination vs Proper Termination". Teltest Electronics Laboratories Inc., Austin, TX. [Online]. Available: http://teli.us/EN_BSTermination04.pdf (accessed Oct. 20, 2022).

[3] Z. Peterson, “Bob Smith termination: Is it correct for ethernet?”, *Altium*. [Online]. Available: https://resources.altium.com/p/bob-smith-termination-it-correct-ethernet (accessed Oct. 20, 2022).

[4] F. Grassi, X. Wu, Y. Yang, G. Spadacini, and S. A. Pignari, “Modeling of imbalance in differential lines targeted to spice simulation,” *Prog. Electromagn. Res. B*, vol. 62, pp. 225–239, 2015.