Measurement setup for differential-mode and common-mode channels

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Abstract

Since there is no model available for mixed differential-mode and common-mode transmission, this report gives a measurement setup to determine the channel transfert function of the differential-mode and common-mode channels, as well as the leaked channel from the differential-mode to the common-mode and conversely at the transmitting end and the receiving end. This measurement setup consists of determining 4 balanced functions as a ratio between wanted and unwanted signals.

Index Terms

VDSL, Common-mode, differential-mode, balance function

I. INTRODUCTION

When differential-mode and common-mode channels are used to transmit information, some leakage exists from the common-mode to the differential-mode at the transmitting end called Longitudinal Conversion Loss (LCL) and from differential-mode to the common-mode at the transmitting end called Transverse Conversion Loss (TCL). At the receiving end, the leakage from the common-mode to the differential-mode is called Longitudinal Conversion Transfer Loss (LCTL) and the leakage from the differential-mode to the common-mode the Transverse Conversion Transfer Loss (TCTL). The DM channel is determined by the variable h_d. The CM channel is determined by the variable h_c. The inverse of the LCTL balance function is determined by the varaible h^r_{d2c}. The inverse of the TCTL balance function is determined by the variable h^r_{c2d}. The inverse of the LCL balance function is determined by the variable h^t_{d2c}. The inverse of the TCL balance function is determined by the variable h^t_{c2d}.

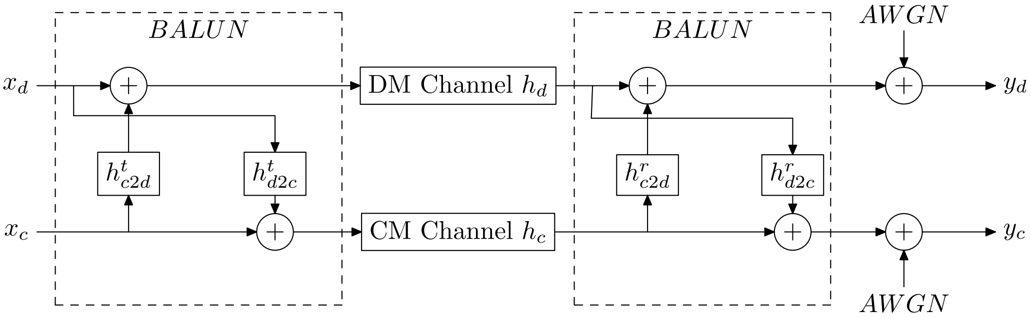

Fig. 1. Equivalent channel representation of a mixed DM and CM channel with leakage from one mode to the other at the transmitter and the receiver side

II. MEASUREMENT SETUP

In [1], Magesacher gives the measurement setup for differential-mode and common-mode channel determination. Figures 2 3 4 5 6 7 show the different measurement setups of the channels assuming that all the ports are terminated properly.

In order to assess the received signal, one can use probes, oscilloscopes or spectrum analysers. In the following section we describe the different possibilities to probe the different signals.

Close-field or near-field probes (magnetic field probes) are low-cost to buy and very quick and easy to make. They should always use 50 Ω cables, and the input impedance of the RF measuring instrument should also be 50 Ω. If there is no 50 Ω input option, one can use its high impedance input.

The pin probe (electric field probe) is a voltage probe which makes contact to the circuit or metalwork of interest via a 10 pF capacitor and picks up the common-mode voltage as well as the differential-mode voltage.

Ott and Paul's simple formula :

$$E = 1.26 f l i 10^7 \tag{1}$$

where E is the radiated emission in V/m, f is the frequency in MHz, l the length of the cable (m) and i the current measured in μA. In order to assess the radiated emission, one can use a bug detector which look at the radiated field that can be harmful

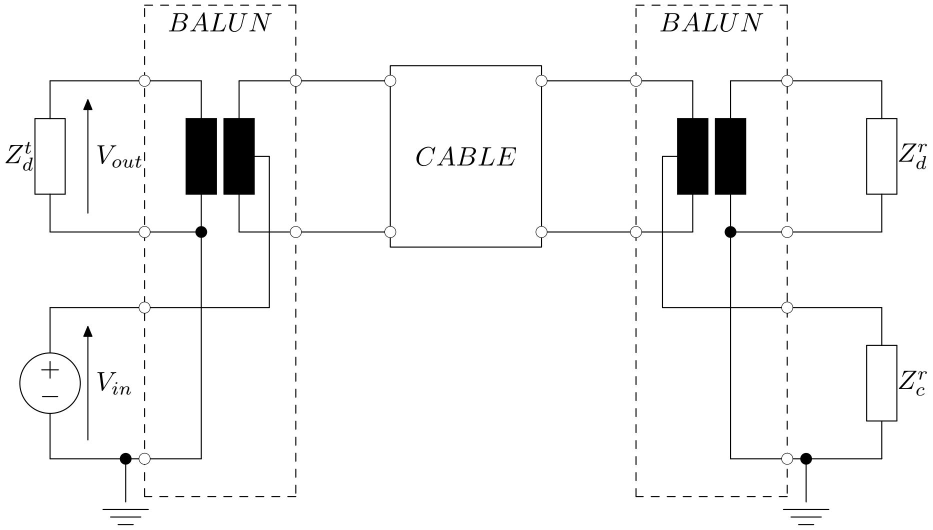

Fig. 2. Longitudinal Conversion Loss (LCL) measurement setup

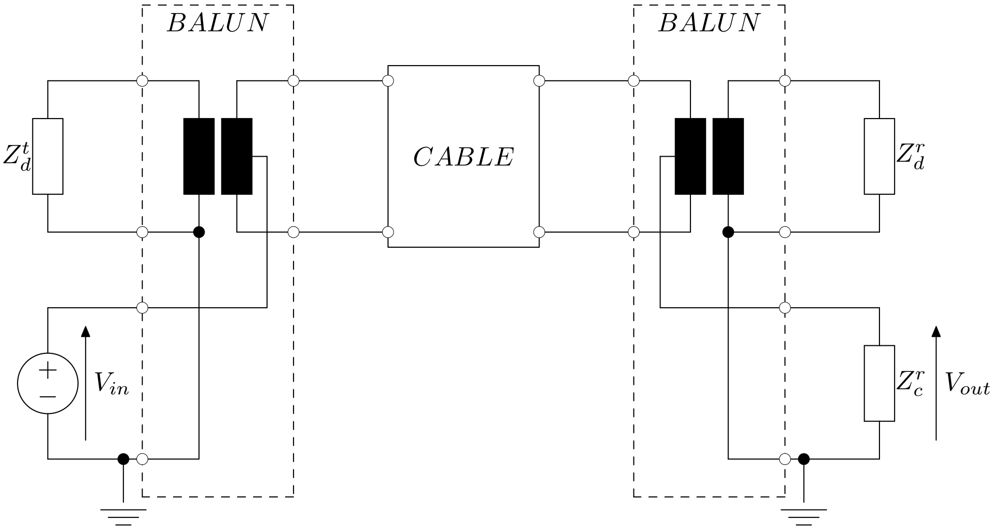

Fig. 3. Common-mode channel mesurement setup

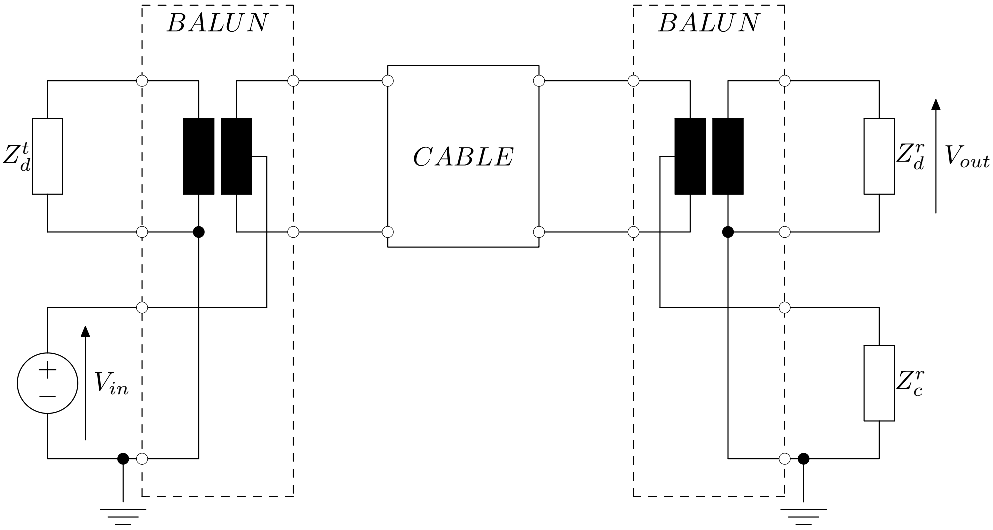

Fig. 4. Longitudinal Conversion Transfer Loss (LCTL) measurement setup

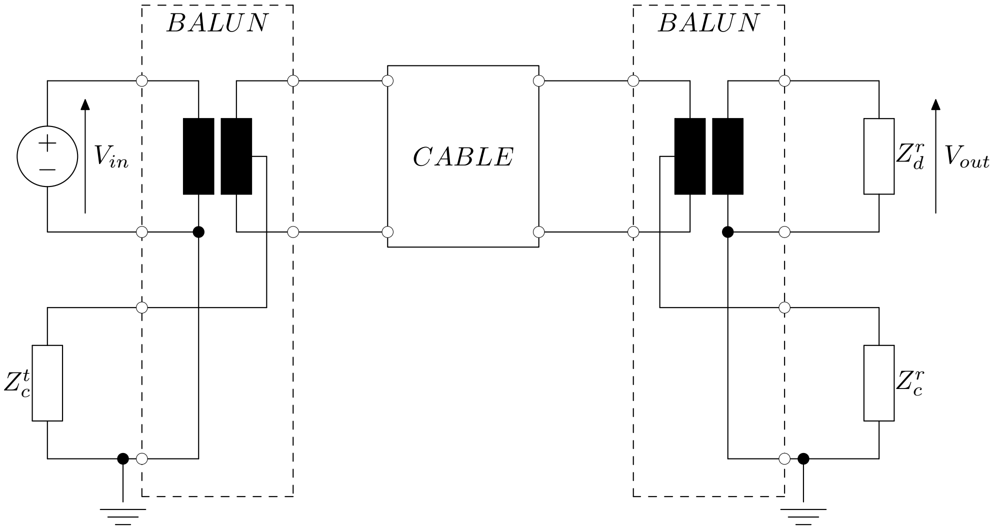

Fig. 5. Differential-mode channel measurement setup

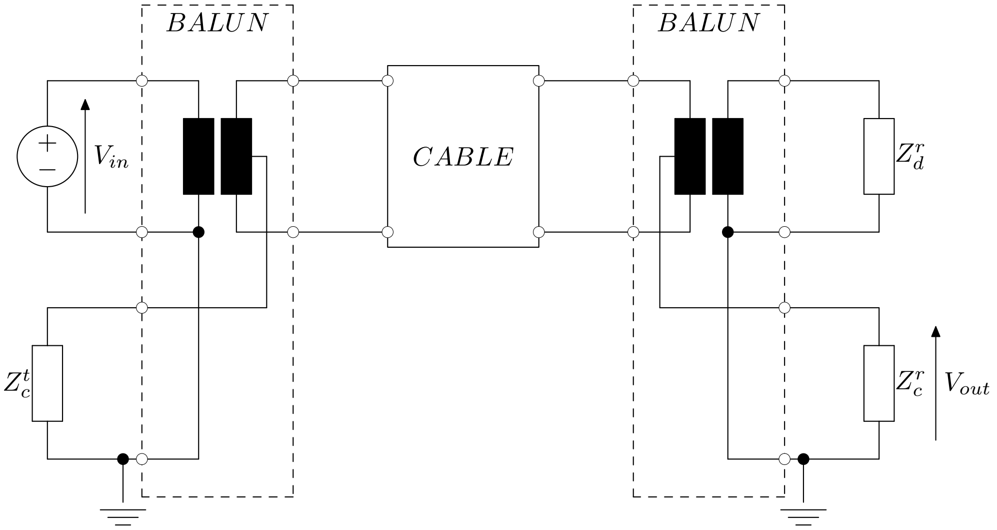

Fig. 6. Transverse Conversion Transfer Loss (TCTL) measurement setup

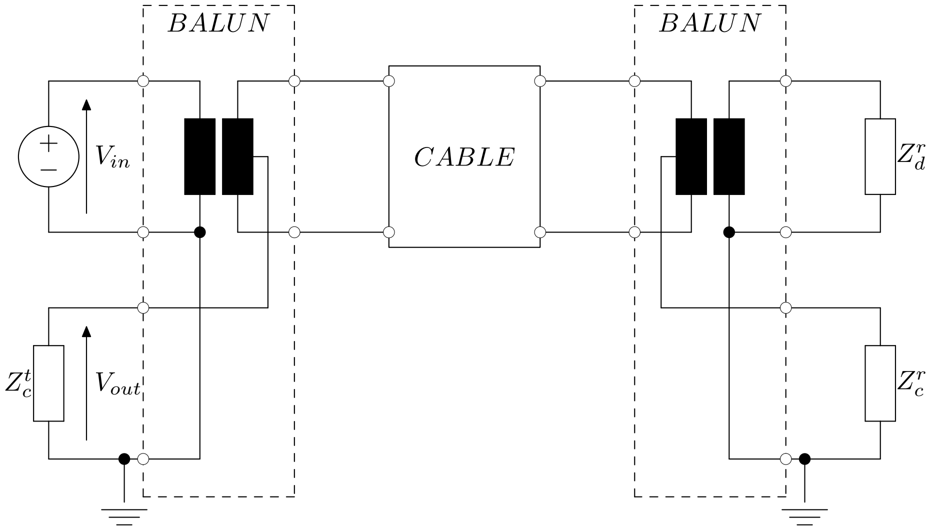

Fig. 7. Transverse conversion Loss (TCL) measurement setup

to human health. For frequencies under 30 MHz, it is almost impracticable to use antennas to asses the radiated emission since they assume far-field.

In order to look at the radiated signal, appropriate probes and an oscilloscope is needed. The oscilloscope can look at the signal in time and frequency domain. It is the lowest-cost way but voltage probing suffers from the fact that the signal measured act as an antenna as well and pick up noise in the environment and oscilloscope have poor common-mode rejection.

Spectrum analysers are more accurate and can be used with close-field probes, current probes and antennas. Another solution is also a basic radio receiver.

However, some care should be taken with measurements since all uncertainties of the measure must be known. Indeed, measurements could easily be suffering from errors of +/-30 dB. Unless a good control of cables, antennas and especially the site and its local environment, the test repeatability is likely to be poor, and repeatability errors should be included. For instance, it is possible to measure at a closer distance than the usual 10 meters, but some care should be taken with coupling effect with the cable itself. Other problems for measurements are reflections on the ground plane, ambient noise by electrical equipment...

Low cost current probes use close-field magnetic probes as well as a ferrite cylinder. Current probes are simply clipped over the cable measured. The CM and DM are measured at the same time, therefore it is possible to clip another probe to cancel the CM and double the DM. Line Impedance Stabilisation Networks LISNs are the standard transducer for measuring conducted emissions in a great many test standards. LISNs create an artificial supply impedance of 50 Ω from each line to earth making the common-mode impedance 50 Ω and the differential-mode impedance 100 Ω. The output of the LISNs are neither CM or DM, but a mixture of two. CM can be measured by summing all the LISNs outputs, and DM by the difference between outputs. Impedance stabilizing Networks ISNs are similar to LISNs but they are designed to measure conducted CM emissions. ISNs create an impedance of 150 Ω because this is thought to more closely match the real impedance of signal and data cables. However, in [2], it is shown that this common-mode impedance was intended for frequency range 200 Hz to 4 kHz, giving a 600 Ω resistive impedance. Indeed, when the differential mode impedance is resistive, the commmon-mode impedance is equal to the quarter of the differential-mode impedance. This is due to the reference to earth which divide the differential-mode impedance into two parralel impedance of R/2, thus giving a common-mode impedance of R/4 (This common-mode impedance is the differential to common impedance conversion). When the reference is not the earth, a common-mode load impedance Z_L different than 0 [3].

In [3], MacFarlane proposed a probe for LCL measurement. The advantage is that it uses 50 Ω instruments to measure the electrical unbalance of wire pair networks and two-terminal devices instead of wide-band balanced voltmeters which should have an extremly good balance. Moreover, [4], [2] recensed the methods usually used to determine the unbalance functions in power cables (initially intended for 50 Hz signals) and the telecommunications cables (initially intended for 4 kHz signals). They recall the MacFarlane method and Van Maurik similar method. Finally [2] describes the paper of Tudziers and Paul where a method of calculating common-mode voltages on a telecommunication cable is given. The Tudziers model rely on the mode conversion which is done along the cable. A driving signal at the near-end is set into a lossless balun, then balance, far-end common-mode voltage are measured. Tudziers observed the relationship $Z_{cm} = Z_0/4$ but it must keep in mind that no voltage was transmitted in the common-mode at the transmitter side nor crosstlak nor RFI.

Indeed, in [5], [6], the characteristic impedances of the common-mode and differential-mode are separated. It appears in this article that the characteristic impedance in the common-mode is greater than the characteristic impedance of the differential-mode. The common-mode is less attenuated than the differential mode but the common-mode inductance is significantly higher than its differential counterpart.

Therefore, when transmitting signals in the differential-mode and common-mode (previously common-mode signals were unwanted since it was either crosstalk or RFI noise), the signals see different channels in the differential-mode and in the common-mode. As pointed out in [7], the leakage functions LCL or TCL depend on the telecommunication network, since the balance functions are different if a DECT device or a Fax Machine are plugged in the network. Therefore for xDSL applications, it can be difficult to set up a model for LCL and TCL as well as LCTL or TCTL since the balance functions will highly depend on the devices plugged into the network.

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