
Project: TEST

Title: On the Correlation Between Common-Mode and Differential-Mode Signals

Source: FTW (Telecommunications Research Center Vienna), Austria
Lund University of Technology, Sweden

Author: Thomas Magesacher (FTW/Infineon), Werner Henkel (FTW), Tomas Nordström (FTW),
Per Ödling (Lund Univ. of Techn.), Per Ola Börjesson (Lund Univ. of Techn.)

Contact: Thomas Magesacher
FTW (Telecommunications Research Center Vienna), Austria
Donau-City-Str. 1 / 3rd floor
A-1220 Vienna, Austria
voice: +43 1 505 2830 20
fax: +43 1 505 2830 99
email: thomas.magesacher@infineon.com

Status: For Information

Abstract:

This contribution investigates the correlation between common-mode (CM) and differential-mode (DM) signals caused by radio frequency interference (RFI) ingress. The question whether CM and DM signals are (partly) correlated or fully uncorrelated has been for further study. Time domain RFI ingress measurement results are presented and analyzed. We conclude that RFI ingress causes CM and DM signals that are highly correlated. This suggests that the CM signal can provide information that would be useful in combating the impact of RFI on the DM signal.

NOTICE

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1 Introduction

Radio transmitters operating in the same frequency bands as DSL systems cause two types of disturbing signals: A differential-mode (DM) signal that interferes additively with the signal to be transmitted and a common-mode (CM) signal, which is defined as the arithmetic mean of the two voltages measured between each wire and ground.

The question whether CM and DM signals are (partly) correlated or fully uncorrelated is for further study since frequency domain measurements of the coupling transfer function exhibit strong fluctuation over time [1],[2]. Our own frequency domain measurements confirm that the fluctuation is stronger compared to crosstalk transfer functions. However, this contribution shows that simultaneously measured CM and DM signals are strongly correlated. Thus, the DM signal can potentially support counter-measures to combat RFI-ingress.

2 RFI-Ingress Experiment

2.1 Setup

Figure 1 shows a block diagram of the experimental setup. The cable under test (CUT) is a typical in-house cable (type: DF-YY 5x0.5 EL, not shielded, not twisted) frequently used in Austria. It is placed approximately 10m away from the amateur radio antenna. The geometry of the setup, as shown in Figure 2, has been chosen to suit the conditions at the measurement site rather than aiming at particularly strong ingress levels. The cable is differentially terminated with $Z_t = 135\Omega$ at one end. The other end is connected to a balun that extracts the CM signal $c(t)$ and the DM signal $d(t)$.

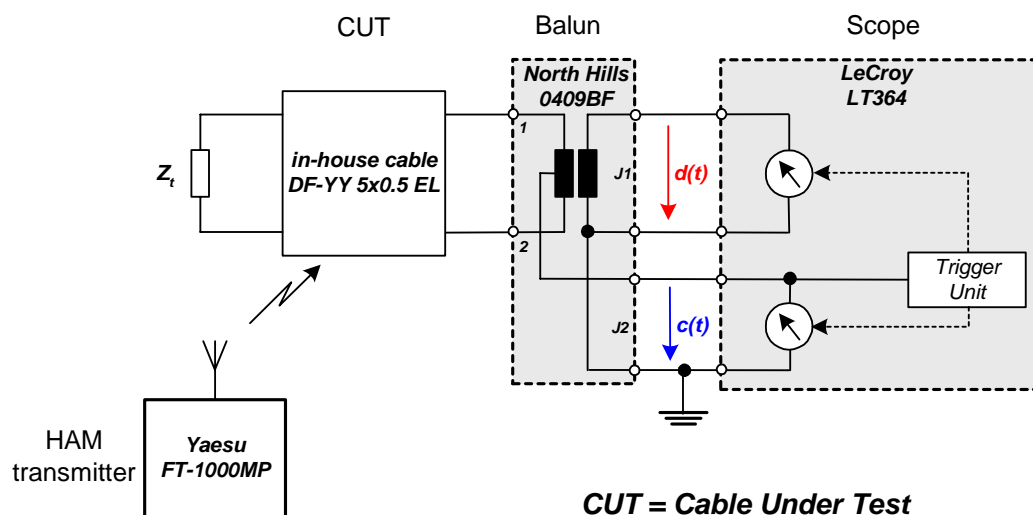


Figure 1: Block diagram

The scope samples and stores the two signals. Recording of the data is initiated by exceeding a specified voltage level at the CM input. In order to increase the recording time, the sampling frequency of the scope is reduced to 14.041MHz. The HAM transmitter, working in Morse-mode, generates a sequence of continuous wave (CW) pulses with a carrier frequency of $f_s = 1\text{MSamples/s}$ and a peak-envelope-power (PEP) of 100 W. Deliberate sub-sampling of a 14.041-MHz tone at 1 Msamples/s results in a 41-kHz tone distorted by all aliasing components at multiples of $1\text{ MHz} \pm 41\text{ kHz}$, that exist within the scope's measurement bandwidth of 0–25 MHz. This measurement method is adequate since we do not expect signals at any of these frequencies to be as strong as our HAM ingress.

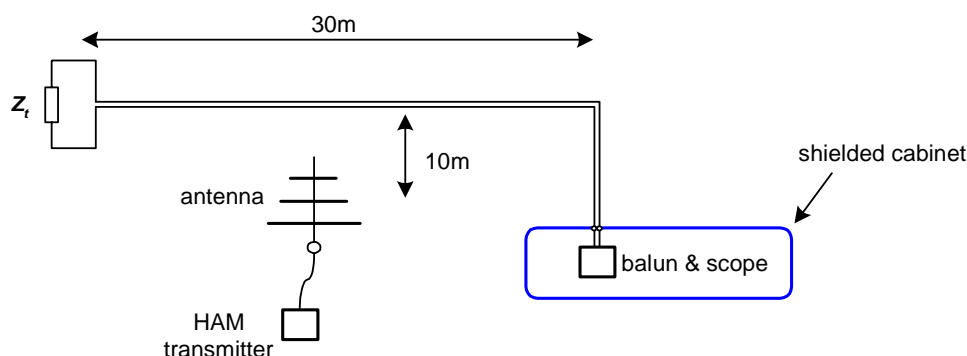


Figure 2: Geometry of the experimental setup

2.2 Measurement Results

Figure 3(a) shows the CM signal measured over a time interval of 170 ms (no. of samples $M = 170000$ at $f_s = 1\text{MSamples/s}$). The zero point of the time-scale coincides with the trigger event. A strong 50-Hz component $x_{50}[n]$ can be identified and removed from the CM signal, thus yielding $c'[n] = c[n] - x_{50}[n]$, as shown in Figure 3(b). The differential-mode signal is depicted in Figure 3(c). Generally, both CM and DM signals are rather noisy since the measurement bandwidth is 25 MHz.

2.3 Analysis and Discussion of Results

In order to assess the correlation between the post-processed CM signal $c'[n]$ and the DM signal $d[n]$ we evaluate the covariance function between the two $(M \times 1)$ vectors, i.e.,

$$\text{Cov}[k] = \frac{1}{\underbrace{\sum_{i=0}^{M-1} c'^2[i] \cdot \sum_{j=0}^{M-1} d^2[j]}_{\text{factor 1}}} \underbrace{\frac{M}{M-|k|}}_{\text{factor 2}} \sum_{n=0}^{M-1} (c'[n] - \bar{c}') \cdot (d[n+k] - \bar{d}), \quad k = -M+1 \dots M-1,$$

where \bar{c}' and \bar{d} are the mean values of $c'[n]$ and $d[n]$, respectively. Factor 1 normalizes the function such that the auto-covariance of both signals is equal to 1, and factor 2 compensates for the lag-dependent scaling.

The covariance reaches 0.98 for lag $k = 0$ as shown in Figure 4. Although there may be a fluctuation of the coupling transfer function it is stable enough to result in strong correlation between CM and DM pulses caused by HAM transmitters. The degree of fluctuation should be assessed on basis of long-term measurements of the frequency domain transfer function.

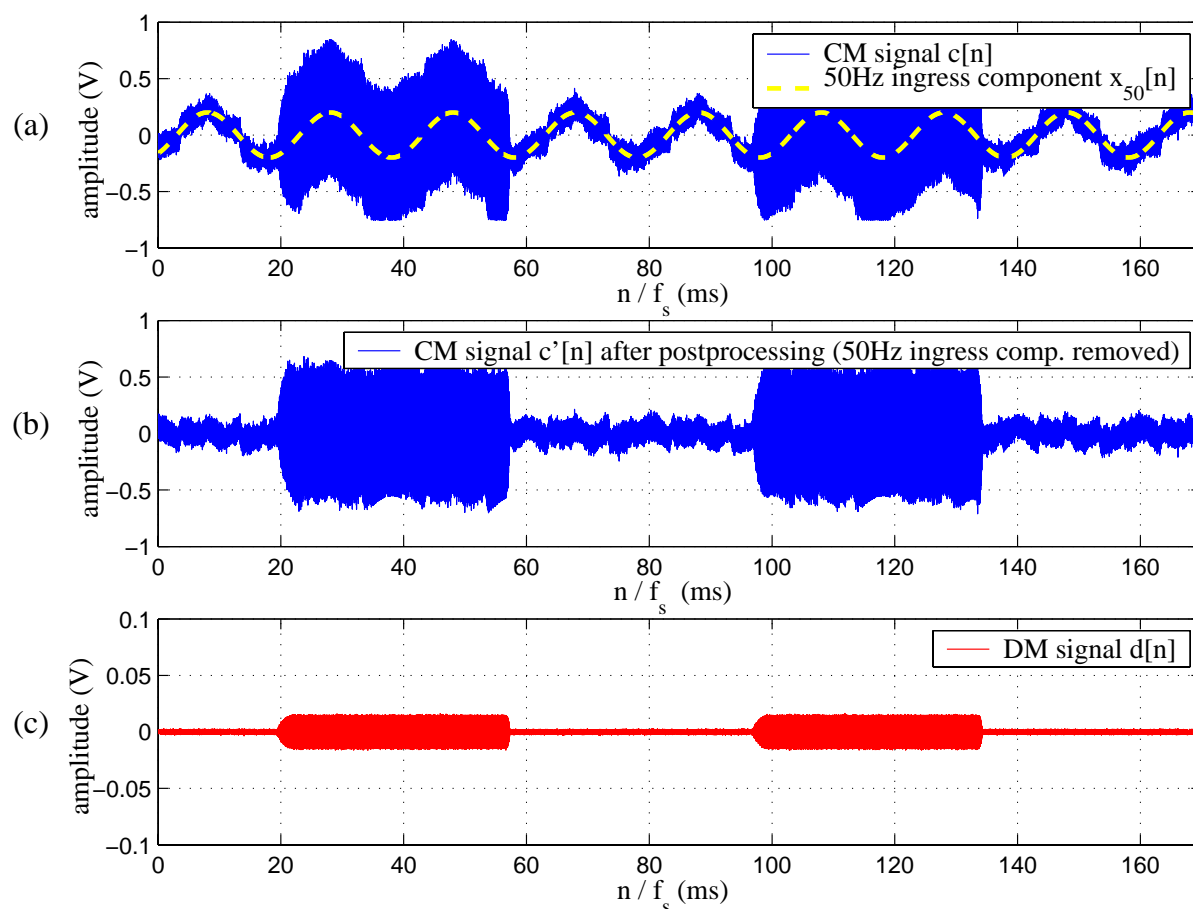


Figure 3: (a) CM ingress $c[n]$; (b) post-processed CM signal $c'[n]$, 50-Hz component eliminated; (c) DM ingress $d[n]$

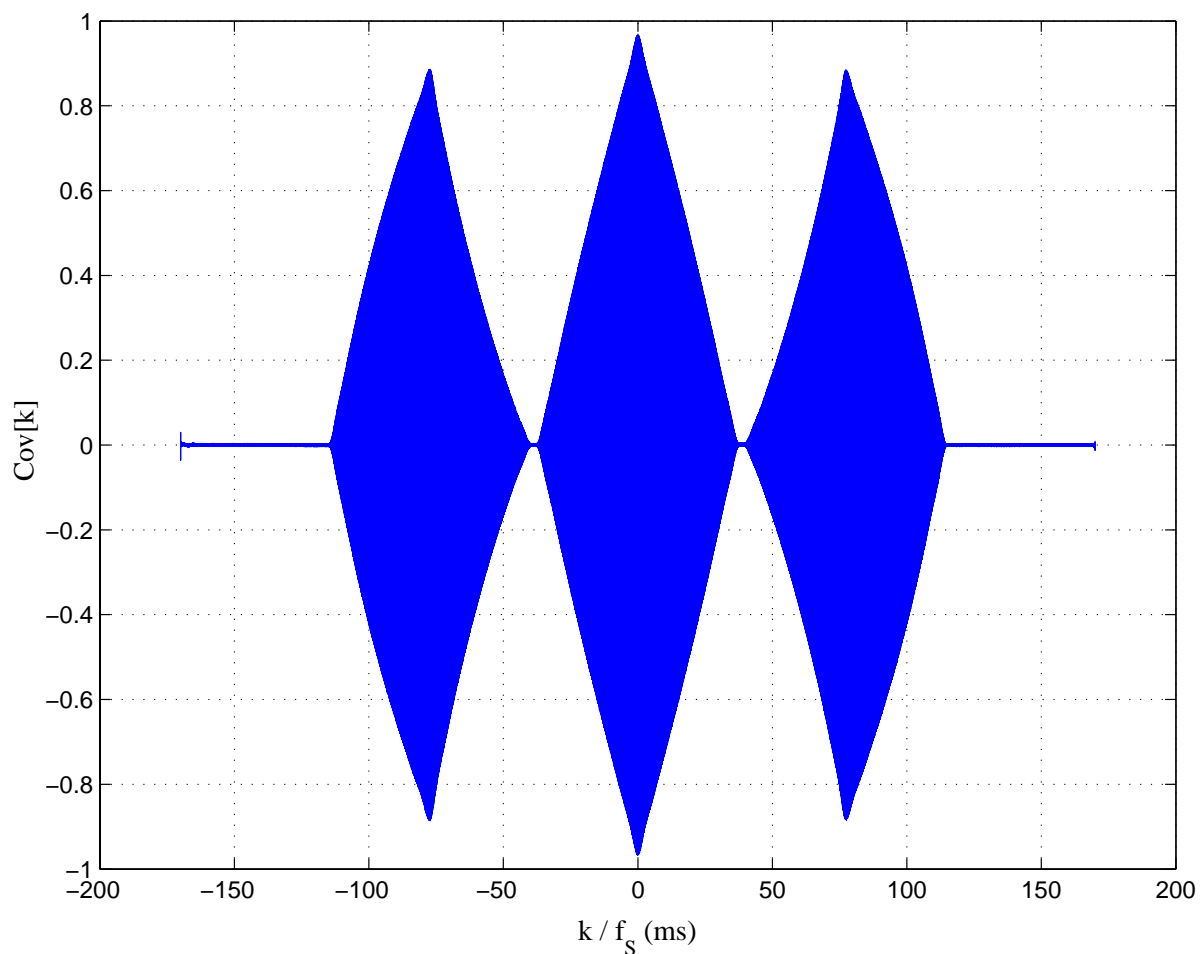


Figure 4: Covariance between CM and DM signals

3 Conclusion

This contribution investigates the correlation between CM and DM signals caused by RFI ingress. The question if CM and DM signals are correlated has been for further study so far [1],[2]. Time domain RFI ingress measurements show a strong correlation between CM and DM signals. We conclude that the CM signal contains information that could be used to combat RFI ingress. Thus, we recommend the use of correlated CM and DM test signals.

4 References

- [1] Rob F.M. van den Brink, "Text proposal for modulation the ingress noise generator", Temporary Document TD 04, 011t04a0, ETSI STC TM6, Sophia Antipolis, France, 12-16/02,2001
- [2] Rob F.M. van den Brink, "Laboratory performance tests for xDSL systems", Permanent Document TM6(98)10, 980p10a5, ETSI STC TM6, Sophia Antipolis, France, 12-16/02, 2001