A NOVEL TIME-DOMAIN ELECTROMAGNETIC INTEREFENCE (TDEMI) MEASUREMENT SYSTEM

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ABSTRACT

In this paper, a novel ultra-fast, broadband time domain EMI measurement system is described. Measurements were performed in the 30 – 1000 MHz range. The signals from the antenna are digitized and processed by a computer in order to obtain the Fast-Fourier Transform (FFT). Correction of errors originating from the frequency characteristics of antenna, cable and oscilloscope is made by digital signal processing. With the presented time domain measurement system the measurement time can be reduced by a factor of 10. The results obtained with the described system have been compared with measurements performed with a conventional EMI receiver.

INTRODUCTION

In the past and currently, electromagnetic interference (EMI) are measured and characterized by superheterodyne radio receivers [1]. The disadvantage of this method is the quite long measurement time of typically 30 minutes for a frequency band from 30 to 1000 MHz [2]. Since conventional measurement systems are not evaluating the phase information of the measured EMI signal, important information is lost. In general the digital processing of EMI measurements allows to emulate in real-time the various modes of conventional analogous equipment, e.g. peak, average, RMS and quasi-peak detector and also introduces new concepts of analysis, e.g. phase spectra, statistical evaluation and time-frequency analysis methods.

The described TDEMI system is based on digital processing of sampled EMI signals. One of the advantages of this system is that the performance of the system may be improved via software. The TDEMI measurement system allows to emulate the modes of operation of conventional analogous EMI measurement systems. With the presented time domain measurement system the measurement time can be reduced by a factor of 10.

TIME-DOMAIN ELECTROMAGNETIC INTEREFENCE (TDEMI) MEASUREMENT SYSTEM

The block diagram of the experimental setup consisting of the time-domain measurement system and a conventional EMI receiver in Fig. 1 consists of a broad-band antenna (Antenna HL562, R&S), a switching unit (RSU, R&S), a low-pass filter (ZFL-1000LN, Mini-Circuits), an amplifier (SLP-1000, Mini-Circuits), an oscilloscope (TDS7104, Tektronix) and a personal computer. The EMI receiver (ESCS30, R&S). is used for comparison.

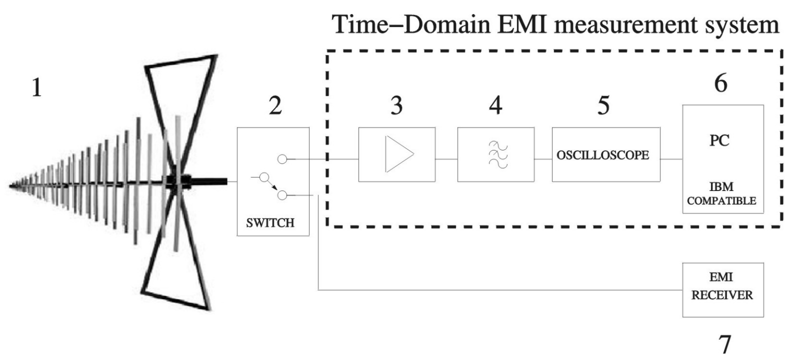

Fig. 1. Measurement system block diagram

The broad-band antenna combines the characteristics of a biconical and a log-periodic antenna to facilitate measurement from 30 to 1000 MHz. The anti-aliasing filter limits the signal bandwidth according to the requirement of the sampling theorem. The oscilloscope has an analogue bandwidth of 1 GHz. The equipment under test (EUT) is a commercial laptop with a 200 MHz clock frequency. The measurements are performed in the power-on mode of the EUT, supplied from the internal battery. All measurements have been made in an anechoic chamber. The distance between the vertically polarized antenna and the EUT was 1 m. The sampled EMI data are transformed to frequency-domain via the FFT [3].

ERROR CORRECTION OF THE MEASUREMENT SYSTEM

In order to determine the spectrum accurately from the time-domain measurements the frequency characteristics of the TDEMI measurement system has to be compensated. In Fig. 2 the antenna factor $H_{AF}(f)$ and the amplifier gain $H_{Amp}(f)$ are shown. The antenna factor depends on the effective antenna length, the antenna impedance and the input impedance of the amplifier. In Fig. 3 the measured filter frequency response $H_{LP}(f)$, and the cable losses $H_{Cable}(f)$ are shown. So the calculated spectrum from the time-domain data is corrected considering the total transfer function $H_{CF}(f)$ as follows:

$$H_{CF}(f) = H_{AF}(f) H_{Amp}(f) H_{LP}(f) H_{Cable}(f) \quad (1)$$

For comparison of the time-domain measurements with the EMI receiver measurements the IF filter characteristic and the detector type of the EMI receiver have to be taken into account.

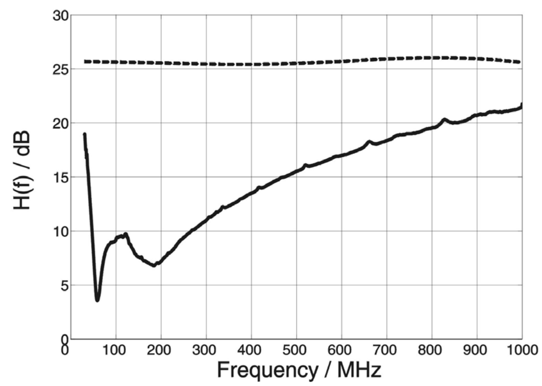

Fig. 2. ─ Antenna Factor $H_{AF}(f)$ in dB/m, ---Amplifier Gain $H_{Amp}(f)$

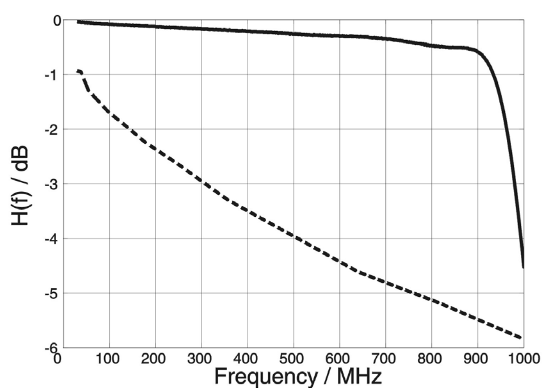

Fig. 3. ─ Filter Frequency Response $H_{LP}(f)$, ---Cable losses $H_{Cable}(f)$

COMPARISON OF THE TDEMI MEASUREMENT SYSTEM WITH AN EMI RECEIVER

To analyse the TDEMI measurement system performance, the measurements performed with the TDEMI measurement system are compared with the results obtained with a conventional EMI receiver in the peak detector mode and the average detector mode. The Fast-Fourier Transform (FFT) signal processing algorithm has been used for processing of the data measured with the TDEMI system. The results obtained thereby has been compared with the results obtained with a commercial EMI receiver using the peak detector.

To emulate the behaviour of conventional analogue EMI receivers with the TDEMI measurement system a model of an analogue EMI receiver is required. The block diagram of a conventional EMI receiver is shown in Fig. 4. The conventional EMI receiver in Fig. 4 consists of a voltage divider (1), a RF selection filter (2), an amplifier (3), a mixer (4), an IF filter (5), a detector (6), a display unit (7) and a local oscillator (8).

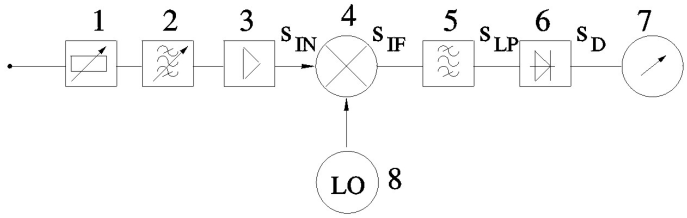

Fig. 4. EMI receiver block diagram

The digital signal processing in the TDEMI measurement system allows to emulate in real-time the various modes of conventional anagoges EMI measurement systems. The detector output signal for peak detection is given by:

$$s^{(p)}{}_{D}(t) = MAX\{s_D(t) \big| n \in \{1...N\}\} \tag{2}$$

The detector output signal for average detection is given by:

$$s^{(m)}{}_{D}(t) = \frac{1}{N\Delta t}\int_{0}^{N\Delta t} s_D(t)\,dt \tag{3}$$

SIGNAL PROCESSING WITH FAST-FOURIER TRANSFORM (FFT)

A comparison between the classical Fast-Fourier Transform (FFT), and the measured results of an commercial EMI receiver using the peak detector (100 msec./step dwell-time) is shown in Fig. 5.

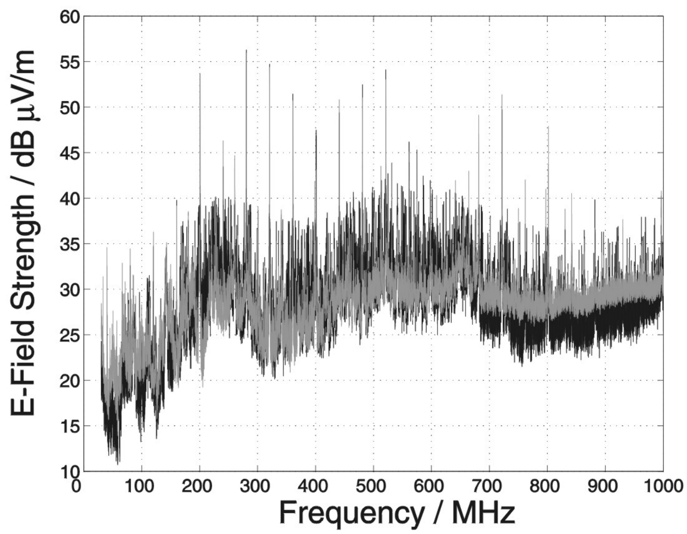

Fig. 5. Comparison: FFT (black line) and EMI receiver (gray line)

MEASUREMENT EVALUATION

The average deviation between the spectrum calculated from the time domain data and spectrum from the EMI receiver is below 3 dB over a frequency range of 30 MHz up to 1 GHz. The measurement error depends on the statistical properties of the interferences. In Fig. 6 the FFT calculated spectrum for 30 independent measurements is shown. At 200 MHz a steady E-Field amplitude over 30 measurements is detectable. In the frequency range from 400 to 500 MHz a strong variation of the short-time EMI spectrum with time can be observed. For such non-stationary interferences the time domain measurement system is capable to give information about the non-stationary behaviour of the EUT, within a short measurement time.

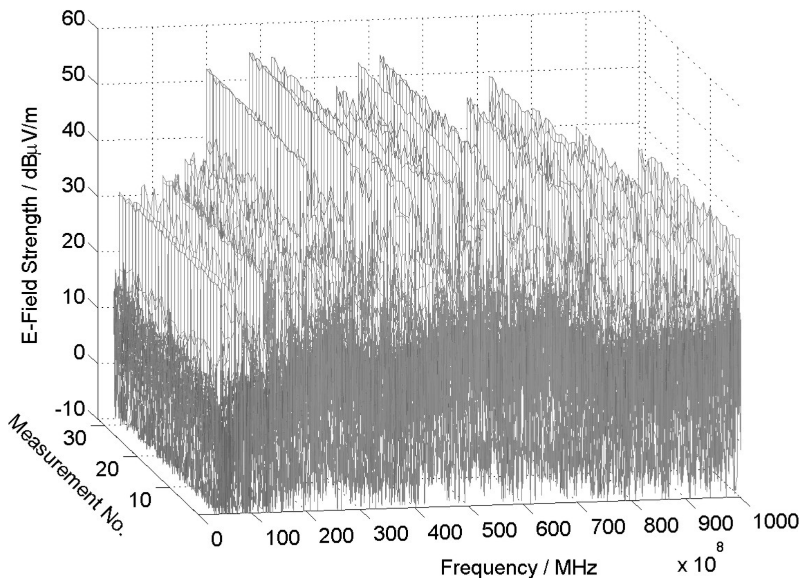

Fig. 6. Comparison between 30 FFT measurement

Table 1 a detailed itemization of the required measurement time for a frequency range of 30 up to 1000 MHz is shown.

Table 1. Measurement and processing time

	TDEMI system	EMI-receiver (peak detection, 100 msec./step)
Data length	64 kSample	19 kSample
Measurement time	100 msec.	40 min.
Computation time	2 min.	-
Total time (approx.)	2.1 min.	40min.

CONCLUSION

A time-domain electromagnetic interference (TDEMI) measurement system has been presented. The TDEMI measurement system allows to emulate the modes of operation of conventional analogous EMI measurement systems. In addition to this phase spectra and short-time spectra may be extracted from the measurements, statistical signal valuation and FFT-based time-frequency analysis is facilitated. System performance has been evaluated experimentally. Compared with conventional analog EMI measurement equipment the measurement time is reduced by one order of magnitude.

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