A Basic Virtual Test System for EMI/RFI Problems

E. Lunca, C. Donciu, M. Cretu, A. Salceanu

Faculty of Electrical Engineering, Bd. Dimitrie Mangeron 53, 700050, Iasi, Romania,
+40.232.237.627, {elunca, cdonciu, mcretu, asalcean}@ee.tuiasi.ro

Abstract-The paper presents a virtual system for locating and measuring near-field electromagnetic emissions in the frequency bandwidth from 100 kHz to 500 MHz. The implemented software controls the test equipment and performs both E and H-field strength measurements. The virtual system is not intended to verify compliance with international emission regulations. However, it is helpful in characterizing the abnormal electromagnetic fields and in extracting frequency and time domain information.

I. Background

It is not easy to precisely identify the electromagnetic radiation from electronic circuitry. The E and H-field probes are useful tools to evaluate electric and magnetic field structure and to locate EMI sources. Accurate and repeatable results require a carefully established and calibrated test setup, usually an open area test site (OATS) or absorber lined chamber (ALC), but such tests are time consuming and quite expensive [1].

A probe set is designed to be used with a signal analyzing device such as an oscilloscope, EMI receiver or spectrum analyzer. The means for using near-field probes with the oscilloscope are: to gain information about the radiation source, to reduce the test expense by adding relatively inexpensive equipment and to reduce the test time by quickly pre-screening solutions.

Today, automated test and measurement instruments have become the norm, and nearly all modern spectrum analyzers come with a variety of standard interfaces. In recent years, many connectivity solutions providing high data transfer rates have increased in popularity, but the most common one remains GPIB [2].

A variety of commercial software products are available to remotely control the spectrum analyzers over a typical interface, but the users can develop their own software in several ways. It is possible to directly communicate with the instrument by sending commands and receiving measurement results or data relating to the instrument state. Other method is to use Plug&Play instrument drivers, providing a standard and simple programming model for all drivers and native source code for the programming environment (i.e. LabVIEW or LabWindows/CVI). Most recently, an exciting new technology has become available. Interchangeable virtual instruments (IVI) drivers are more sophisticated instrument drivers that feature increased performance and flexibility for more complex test applications that require interchangeability, state-caching or simulation of instruments [3].

These tools combined with the powerful features of LabVIEW and connectivity capabilities of popular desktop computers allows user to conduct automated measurements, providing low cost, flexible and more competitive solutions.

II. A common approach to deal with EMI

As shown in Figure 1, the test system consists of:

- Personal computer running the developed software application and remotely communicating through GPIB and RS-232 interfaces with the measurement instruments.
- IFR 2398 Spectrum Analyzer with 9 kHz to 2.7 GHz fully synthesized frequency range, five detection modes, AM/FM demodulation and wide input range (+26 to –105 dBm).
- Fluke 199 Dual Channel ScopeMeter with 200 MHz bandwidth and 2.5 GS/s real-time sampling.
- ETS-EMCO Model 7405 Near-Field Probe Set, designed as a diagnostic aid for locating and characterizing sources of E and H-Field emissions.

The set includes three loop probes, one stub and one ball probe. The loop probes are H-Field selective and directional. The ball and stub probes are E-Field selective and omni-directional. The probe set can be used with any of the two measuring instruments.

For locating the sources creating a propagating field, a simple and helpful technique is to demodulate the offending signal while it is being received in the far field [4]. The 2398 can operate as a selective level meter in which the horizontal axis is graduated as a time axis by setting the frequency span to 0 Hz [5]. By using the 2398's video output, the oscilloscope may be used to capture a time domain representation of the signal of interest.

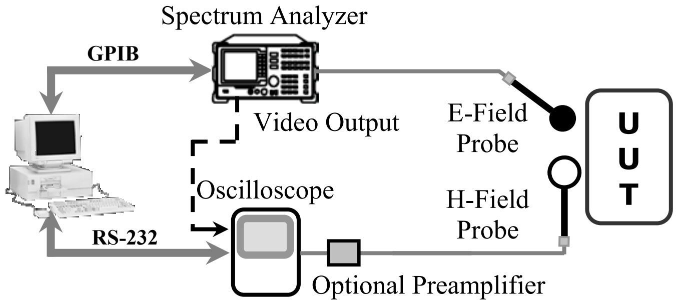


Figure 1. Test System

The oscilloscope ensures greater flexibility in adjusting the signal amplitude and in triggering on waveforms. The 199's Connect and View™ function provides reliable and repeatable displays of signals and all signal details are revealed. The complex signals are triggered automatically and flawlessly.

III. EMI Software considerations

The EMI software has been developed in LabVIEW graphical environment as a virtual instrument and performs both frequency and time domain measurements. The software controls the test equipment through GPIB and RS-232 interfaces, extracts the measurement data and directly computes the E-field strength and H-field strength.

The VI front panel allows user to change the most important settings of the spectrum analyzer for remote operation: the primary functions (frequency, span, amplitude) and control functions (resolution bandwidth, video bandwidth, sweep time, input attenuation). The amplitude scale is settled to logarithmic mode with 10 dB per division and the reference level unit is in dBm.

Initially, the 2398 spectrum analyzer provides a 500 points trace representing a power measurement in units of dBm. Depending on the selected probe, the EMI software converts the power into either E-field strength (dBµV/m and V/m) or H-field strength (dBµA/m and mA/m) by using the RF specific equations.

Since the probes are to be used in a 50 Ω system, the voltage developed by an electric or magnetic field probe will be computed with the following formula:

$$U[dB\mu V] = P[dBm] + 107 \qquad (1)$$

The E-field strength in dBµV/m is obtained by adding the performance factor (PF) of the selected probe to the measured voltage:

$$E[dB\mu V / m] = U[dB\mu V] + PF[dB] \qquad (2)$$

The H-field strength in dBµA/m is obtained with a similar equation, but 51.52 dB must be subtracted from the performance factor found on the calibration graph of the probe:

$$H[dB\mu A / m] = U[dB\mu V] + PF[dB] - 51.52dB \qquad (3)$$

Because the measured E and H-field strengths include the probe performance factor (PF), the software will automatically determine it in the frequency bandwidth from 0.1 MHz to 500 MHz. To achieve this target, as shown in Figure 2, a new LabVIEW library bas been implemented. According to the manufacturer's PF versus frequency plots, each VI in the library computes the PF values in units of dB for a particular probe corresponding to the input frequency values in units of MHz.

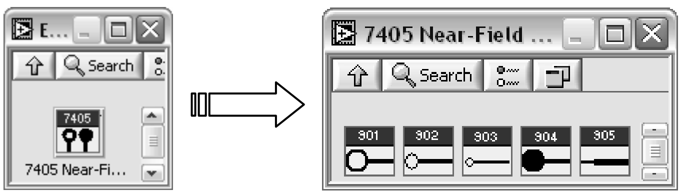


Figure 2. The LabVIEW library for PF determination

Knowing the values of E-field strength in dBμV/m or H-field strength in dBμA/m, the basic conversion to the units of V/m or mA/m is performed by using the following equations:

$$E[V/m] = 10^{\frac{E[dB\mu V/m]}{20}} \cdot 10^{-6} \qquad (4)$$

$$H[mA/m] = 10^{\frac{H[dB\mu A/m]}{20}} \cdot 10^{-3} \qquad (5)$$

The electromagnetic quantities above are 1D array. They are extracted or computed from received trace data (ASCII format) and plotted as a function of frequency on graphs. In essence, the software allows to display either E-field strength or H-field strength spectrums between the user-defined start and stop frequencies.

As shown in Figure 3, the VI performs peak search on E or H spectra and returns the amplitudes and frequencies of the peaks and the number of encountered peaks. The peak detection algorithm can be set to *single peak* mode or *multiple peaks* mode.

In the *single peak* mode, the VI returns the maximum power and maximum E or H-field amplitude and their corresponding frequency. In the *multiple peaks* mode, the VI returns the valid peaks exceeding the threshold level and ignores the others. For example, by setting a threshold level of 95 dBμV/m, in the frequency bandwidth from 190 MHz to 220 MHz two peaks were detected. In this case, the E-field strength measured values were 107.6 dBμV/m (0.24 V/m) and 101.42 dBμV/m (0,117 V/m) corresponding to the frequencies of 199.24 MHz and 205.69 MHz, respectively.

The peak detection is relatively accurate, ensuring repeatable results. However, the user can check to see if the reported frequencies and amplitudes are reasonable.

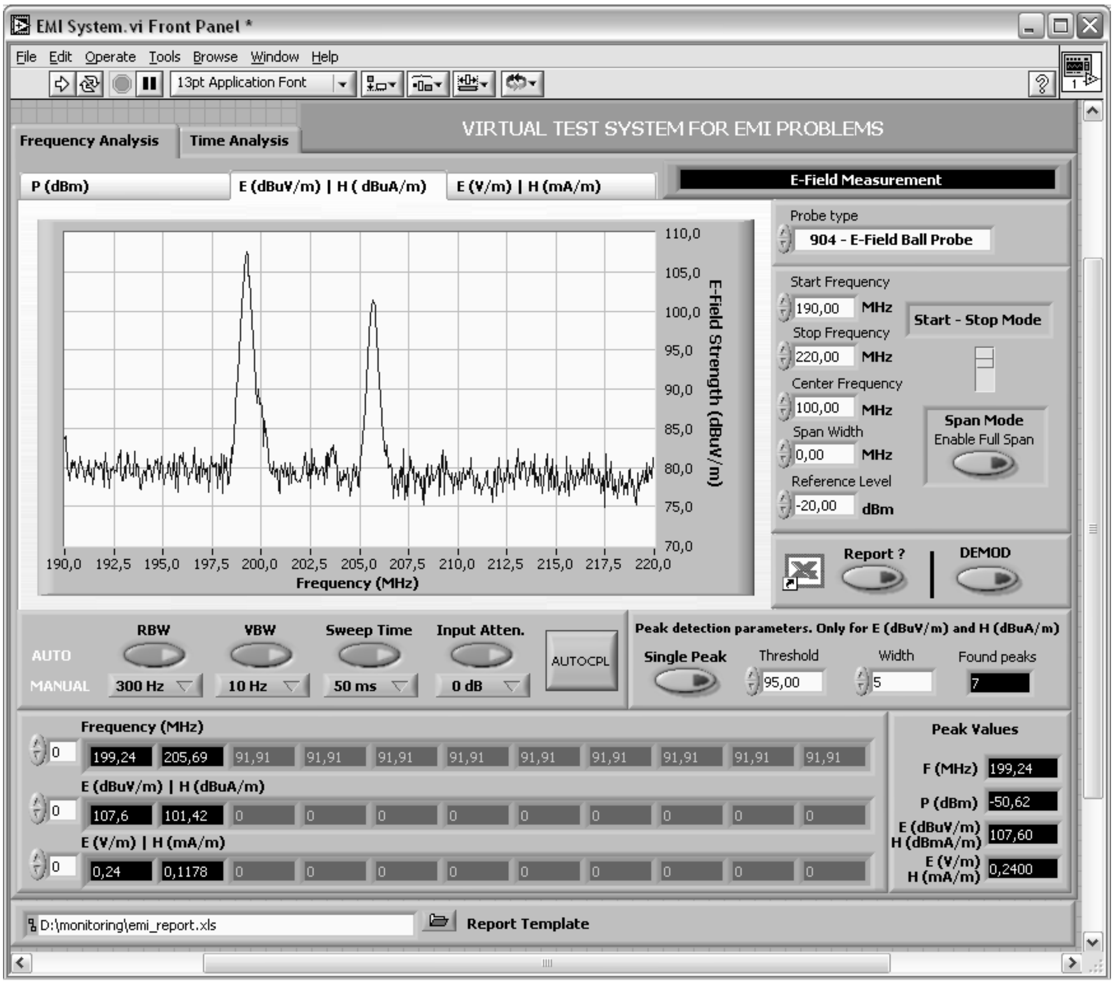
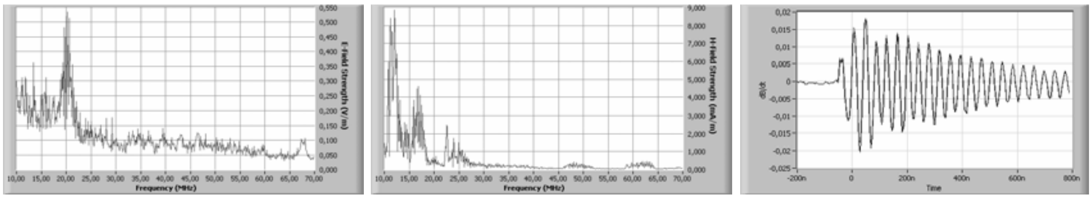


Figure 3. The front panel of virtual instrument – E-field strength measurement in the frequency bandwidth from 190 MHz to 220 MHz

Figure 4.a shows the E-field strength in V/m measured with 904 ball probe at distance of 10 cm from the aperture of an electronic device. Figure 4.b shows the H-field strength in mA/m measured with 901

loop probe at the same point. By using two probes, the field impedance at that point can be determined as the ratio of E-field to H-field. In order to indicate the predominant component, the calculated value is compared to the free space impedance of 377 ohms.

Capturing the scope trace via an RS-232 connection is usually useful when performing AM/FM demodulation. Alternatively, the time derivative of magnetic flux density may be recorded. When used in conjunction with a loop probe, the 199 oscilloscope offers a time domain representation of the magnetic field as a min/max trace (Figure 4.c). A min/max trace is a series of waveform samples consisting of minimum and maximum waveform points.



a b c

Figure 4. Frequency and time domain representations of the EM radiation from the aperture of an electronic device

Very often, it is necessary to record measurement data as a file on the computer. If desired, the software can transfer the instrument settings and trace data directly to a Microsoft Excel spreadsheet. The reports are generated by opening the report template and inserting data into it. Therefore, the VI works properly if the path control on the front panel contains the correct path to the report template on the system.

The developed software reduces significantly the overall test time and increases the automated measurement capabilities of electromagnetic field strength. The program code can be easily improved or adapted, allowing an extension of current features. For example, measuring high-frequency fields with an electrical antenna involves only the implementation of a VI that computes the antenna factor.

IV. Conclusions

The here presented paper describes a virtual test system which help us in dealing with electromagnetic radiation from electronic circuitry in the frequency bandwidth from 100 kHz to 500 MHz. It is a simple and budget solution to perform a fast characterization of E and H-field emission sources according to our needs. The software offers a user-friendly interface and can generate test reports including the measurement data and the associated set up configuration.

Acknowledgements

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