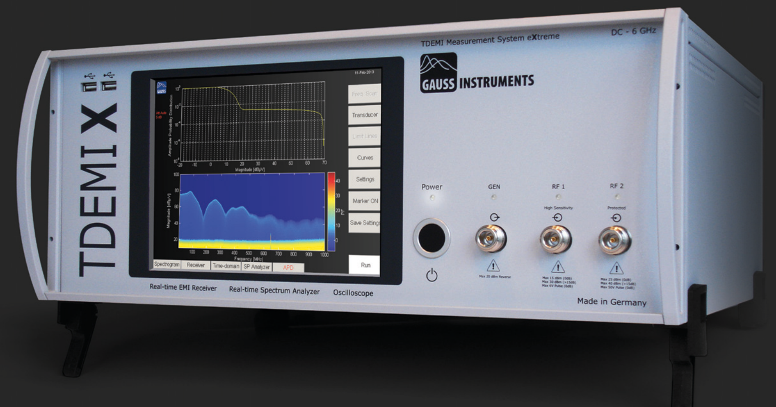
Emission Measurements for the 21st Century



Introduction

Since the 30s of the last century emission measurements have been performed in frequency domain using analog superheterodyne receivers. E.L. Bronaugh mentions in his article "An Advanced Electromagnetic Interference Meter for the Twenty-First Century" that, in the future, the conventional technology of super-heterodyne EMI receivers will be replaced by digital emission measurement systems [1].

Digital emission measurement systems have the advantage, like software defined radio receivers, that the frequency conversion as well as the IF filtering, demodulation and detectors are performed fully digitally. Using software defined radio design in combination with powerful digital signal processing FPGAs including several thousand embedded multipliers, a set of several thousand parallel digital EMI Receivers are integrated into one instrument. The benefit is that measurements can be performed in parallel up to 64000 points simultaneously rather than sequentially.

Such instruments fulfill the old CISPR 16-1-1 (2003 & 2007) standard for superheterodyne receivers, as well as the latest CISPR 16-1-1 Ed 3.2 including the FFT-based measuring instrument. In addition these instruments allow to speed up measurements according to MIL461 and DO160, as well as further national and international standards.

The combination of a full digital implementation of all IF bandwidths, detectors and parallel implementation into a single instrument provides many outstanding advantages including ultra-fast scanning, real-time visualization of angular scans and simplification of test procedures.

EMI Measurements – a challenging task

The measurement of electromagnetic interference (EMI) is a challenging task that may take a lot of time, especially when the device under test is a complex system. Such systems have many operation modes and the emissions are present at a lot of frequencies with different pulse repetition frequencies and different radiation directions.

In the past, such measurements were carried out with traditional superheterodyne receivers and a pre-scan, data reduction and a maximization at a list of frequencies were perfomed. Such a procedure required experience in EMI testing and knowledge about the device under test.

As the complexity of devices is increasing and the time-to-market is continuously reduced, it has become mandatory to have tools that are capable to quickly measure and analyze the behavior of EMI. For such complex devices, measurements have to be as simple as possible, but without loosing accuracy.

EMI Measurements with TDEMI X

During the development of the TDEMI X the simplicity of operation was always kept in mind. This simplicity of operation has been achieved with several revolutionary improvements in comparison to traditional receivers.

The Block Diagram of the TDEMI X is shown in Fig. 1

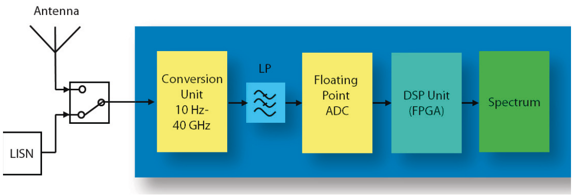


Fig. 1 – **Block Diagram of TDEMI X**

The TDEMI X samples the EMI Signal with a bandwidth up to 1 GHz. From 1 GHz – 40 GHz a frequency conversion unit with a real-time bandwidth of 325 MHz is available. This frequency conversion unit allows to speed up also measurements above 1 GHz dramatically. For all operation modes the conversion unit provides pre-selection for image rejection. Also in the range from 10 Hz – 1 GHz the TDEMI X provides a pre-selector.

The sampled signal is digitally processed by an FPGA. In the EMI receiver mode and real-time spectrogram mode the TDEMI X provides up to 16000 parallel receivers and quasipeak detectors. In the real-time spectrum analyzer mode and spectrum analyzer mode there are up to 64000 parallel spectrum analyzers including RBW filter, video filter and detectors available. The number of points in this mode is by more than a factor of 50 higher than other available real-time spectrum analyzers. A simplified block diagram of the digital Implementation is shown in Fig. 2.

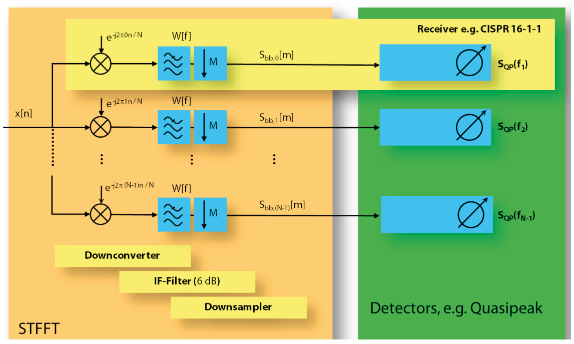


Fig. 2 – **Block Diagram of the digital Implementation of multiple receivers in parallel**

The time-domain signal is fed into several branches and each branch contains a full digital receiver. As the frequencies are linearly spaced, these calculation can be performed by using the short-term fast Fourier transform (STFFT). The STFFT with N Points is basically the synthesis of N downconverters and IF Filters [2].

Based on the mathematical property and the correct implementation, in 2010 the FFT-based measuring instrument was included into CISPR 16-1-1 and the mathematical explanations and our implementation regarding the system up to 1 GHz was provided to perform a maintenance cycle of CISPR 16-1-1.

It is important to mention that a FFT-based measuring instrument implemented according to CISPR 16-1-1 and CISPR 16-3 will always provide the same measurement results as a classical superheterodyne receiver, when the measurements is performed correct [3].

The TDEMI X provides various operating modes. All operating modes can be controlled via a gigabit Ethernet interface according to the SCPI standard.

Full Compliance Receiver Mode

For measurements according to CISPR the emission measurements are performed using the quasipeak detector mode. A comparison of the scan times between a traditional analog receiver and the TDEMI X are shown in Table 1:

Frequency range	Band	Scan time classical approx.	Scan time TDEMI X approx.
9 kHz - 150 kHz	A	24 minutes	1s
150 kHz - 30 MHz	B	1:40 hours	1s
30 MHz - 300 MHz	C	1:30 hours	2s
30 MHz - 1 GHz	C/D	5:25 hours	7s

Table 1 – **Typical scan times with quasi-peak detector - superheterodyne Receiver in comparison to TDEMI X**

By using extremely powerful FPGAs and ADCs the implementation of up to 16000 Receivers in quasipeak has been achieved. This results in extremely fast scan times, e.g. 2 seconds for a measurement from 30 MHz to 300 MHz in comparison to several hours.

Unlike other receivers full functionality is available via a touchscreen interface. This allows also to fully control the instrument via remote desktop. Limit lines, transducer and setup can be stored and recalled afterwards.

Full Compliance Real-time Spectrogram Mode

The TDEMI X provides a real-time spectrogram mode with the detector modes peak, quasipeak, average, CISPR-avg and CISPR-rms. Two traces can be activated in parallel, and compared to a limit line. The spectrogram mode using the function Maxhold allows to perform a weighted measurement, e.g. with quasipeak and CISPR-avg in parallel, while the turntable and antenna mast is positioned continuously.

In Fig. 3 the screenshot of the real-time spectrogram mode is shown. The traces peak and quasipeak are activated showing the result of a measurement using a signal generator that steps from 100 MHz - 300 MHz in 1 MHz steps. Both traces can be also visualized providing a time domain mode at each frequency comparable to a traditional receiver. It is shown that the Maxhold quasipeak result is 3 dB lower than the result of the quasipeak detector mode. The result of the time-domain mode of two parallel detectors is also visualized at 100 MHz. The charging and discharging of the quasipeak detector is visualized for this type of frequency hopping signal.

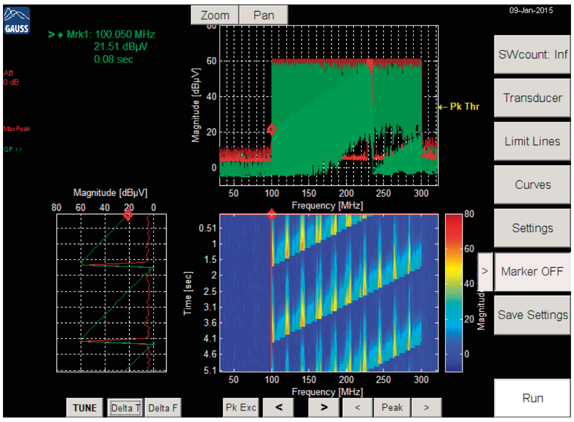


Fig. 3 – **Real-time spectrogram mode over 325 MHz for peak and quasi-peak detector.**

In addition a frequency mask trigger is available that compares the result with a limit line. Post and pre-trigger function allow to trigger precisely. In addition the results can be stored, evaluated and post-processed further by software tools.

AM/FM Demodulation

AM/FM Demodulation is available as an option DM-UG. Operation is easy such as putting the marker to a specific frequency by the touchscreen interface or remote via remote destop and pressing tune. As the demodulator is fully digital, it is also possible to store and stream the audio over Ethernet.

APD and Persistence Mode

In order to perform measurements of industrial, scientific and medical (ISM) devices according to CISPR 14 the amplitude probability distribution (APD) measuring function is available at up to 1024 points in parallel. In Fig 4 the result of such a measurement is shown. The measured signal was FM modulated and also alternates between two frequencies.

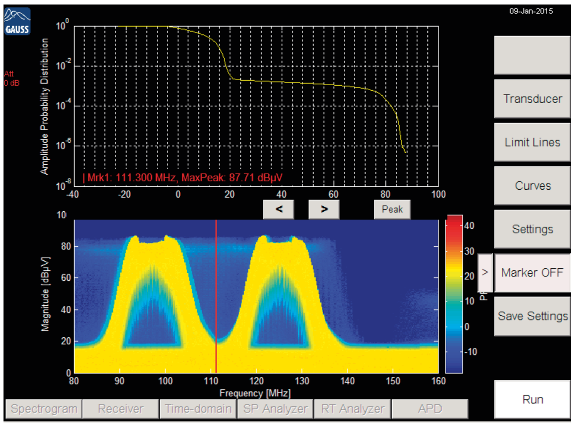


Fig. 4 – **APD mode**

In addition to the change in frequency, by the persistence mode the operation of the PLL of the source can be observed and investigated in detail.

Real-time Spectrum Analyzer

The analysis of signal is supported also by the real-time spectrum analyzer. The real-time spectrum analyzer provides an analysis bandwidth up to 325 MHz. In this mode up to 64000 frequencies are displayed in parallel. The real-time spectrum analyzer provides an unparalleled dynamic range.

In Fig. 5 it is shown that the dynamic range between the carrier and the Noisefloor is more than 120 dB. All modes that are available in a classical spectrum analyzer are also available in this mode, such as sweep time, video filters, IF bandwidths and detector functions. There is not anymore

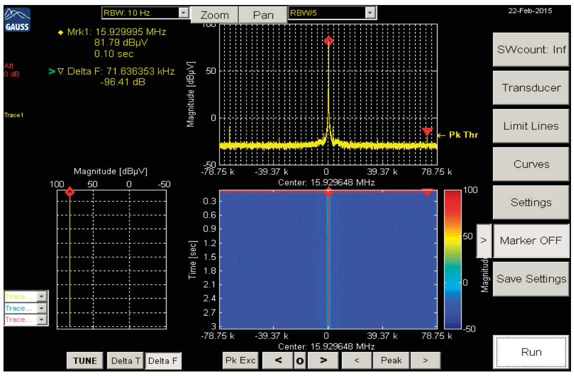


Fig. 5 – **Real-time analyzer mode**

the problem to setup the real-time spectrum analyzer in a way that it shows same results as a superheterodyne spectrum analyzer.

The spurious emissions of a signal generator that are more than 90 dB below the carrier can be investigated for example.

Simplifying your EMI Measurements

The TDEMI X allows to simplify test procedures dramatically in comparison to traditional receivers. For all modes transducer and limitlines are available to support automated emission measurements.

Conductive Emission Measurements

Conductive emission measurements are usually carried out in the receiver mode. The measurements are performed in the final detector mode e.g. quasipeak and CISPR-avg in parallel. The measurement for a single phase takes about 2 seconds for Band A & B with quasipeak.

The line impedance stabilization network (LISN) can be controlled by the TDEMI X and thus all phase can be measured automatically. A report is generated automatically. Measurement of discontinuous disturbance can be performed using the TDEMIClick that supports now up to 8 hours recording and evaluation time.

Measurements of Disturbance Power

Measurements of disturbance power are performed with an absorbing clamp that is moved over a slideway up to 6 m. This measurement can be performed very easy with the TDEMI X. The TDEMI X is put to full compliance spectrogram mode. MaxHold is activated and quasipeak as well as CISPR-avg is selected. After pressing the button RUN, the absorbing clamp is moved over the slideway in about 10 s. The result of all positions in quasipeak and CISPR-avg detector mode is stored and a test report is automatically created.

Measurements of radiated Emission using a GTEM Cell

The measurement in a GTEM cell is performed at 3 positions. The measurement is here also extremely fast as the final detector modes (e.g. quasipeak) are selected. For measurements up to 1 GHz each scan takes about 7 s. Afterwards the 3 scans are superposed as described in the standard and the final result is created and the test report is created.

Measurements of radiated Emissions in an Anechoic Chamber

There are several possibilities to perform measurements in an anechoic chamber. The TDEMI X provides a real-time spectrogram mode with two traces that can be set up in the final detector mode. A real-time analysis bandwidth of 325 MHz can be used to speed up measurements dramatically. The turntable is continuously turned while the real-time spectrogram is running. A time corresponds to an angular position. For measurements up to 1 GHz this procedure has to be repeated 3 times and a full angular characteristic, including a height scan of the device under test is achieved. The maximum is compared with the limit lines and a report is automatically generated. This procedure is also excellent for emission measurement of devices above 1 GHz. The stored radiation patterns are also useful to detect EMI and to solve EMI problems. Such tasks can be carried out be the EMI 64k Software.

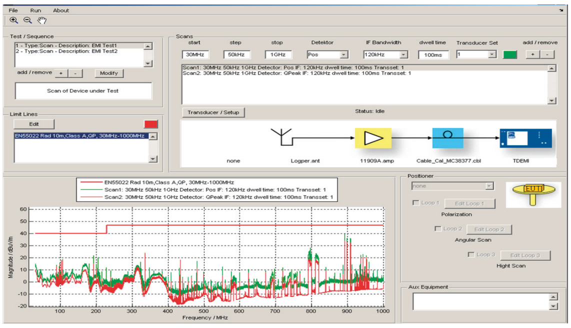


Fig. 6 – **EMI 64k Software**

List of literature:
[1] E. L. Bronaugh, "An Advanced Electromagnetic Interference Meter for the Twenty-First Century," in 8th International Zurich Symposium On Electromagnetic Compatibility, Zurich, Switzerland, 1989, pp. 215–219, no. 42H5, 1989.
[2] J. Allen and L. Rabiner, "A unified approach to short-time Fourier analysis and synthesis," in Proceedings of the IEEE, vol. 65, pp. 1558–1564, 1977.
[3] S. Braun and A. Frech, Requirements of CISPR 16-1-1 Test Receivers, Spectrum Analyzers and FFT-Based Measuring Instruments. In EMC Europe Guide 2013, Interference Technology - The International Journal of Electromagnetic Compatibility, Dec., 2012, pages 66-73

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