Cost and Quality Improvement of Automating Radiated Emission Preliminary Scans

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***Abstract*— Automation of the radiated emissions preliminary scan saves time, money, and improves the quality of measurements. With self declaration in Europe and a growing part of the world, many small and medium sized companies are performing their own final regulatory testing. This paper focuses on the development of an automated radiated emissions preliminary scan test system and the benefits of doing so.**

Keywords-radiated emissions; radiated immunity; automation; European Union; Federal Communication Commision; shielded enclosure; semi-anechoic chamber

I. Introduction

In many countries digital devices must meet electromagnetic compatibility (EMC) requirements. The continued market growth in portable electronics, advanced control systems for transportation and computerized factories have flooded the radio frequency (RF) spectrum. The increase in RF noise makes EMC of digital devices essential to insure continued expected operation.

Radiated emissions is one of the most prominent forms of electromagnetic interference (EMI). This is the most regulated EMC requirement because excessive EMI generated by one product may affect the operation of another product. The European Union, United States, and numerous other countries enforce radiated emission limits on digital devices. In the United States, these emission requirements are set by the Federal Communication Commission (FCC) for Information Technology Equipment (ITE) as well as other types of digital devices.

FCC Class A verification of digital devices requires that radiated emission measurements be taken from Equipment Under Test (EUT) at a distance of 10 meters on an Open Area Test Site (OATS). The EUT is rotated from 0 to 360 degrees and the measuring antenna's height varied from 1 to 4 meters to maximize the emission measured. In order to effectively measure all of the EUT's emissions, it is recommended that a preliminary scan be performed. Although a preliminary scan is useful, it can not replace final measurements at an OATS or similar. This paper demonstrates the benefits of automating the preliminary scan.

II. Background

Prior to automating the preliminary scan, measurements were taken manually by an EMC technician. The total measurement time varied depending on the emission characteristics of the EUT and the technician's skill level. In addition to the time required to perform a preliminary scan, historical data from our laboratory shows that a full set of data, including maximized peaks, takes an average of 8 hours to complete at the OATS.

It is important to note some of the difficulties in taking measurements at an OATS. With the increase use of digital devices the RF spectrum below 1 GHz is nearly saturated. Cellular phones, high definition television broadcast, and digital devices in mobile and automotive applications are just a few examples of the devices that are saturating the RF spectrum. This increased RF noise makes it difficult to discern emissions of a EUT from these ambient signals. Personnel with little experience in performing RF test measurements could overlook an emission that is masked by this RF noise. Emissions from a EUT that get overlooked could be in violation of a regulatory limit. Products that are marketed with unknown non-conformances can be costly. Governing bodies may require you to resolve disturbances and could ultimately require you to withdraw the product from the market.

Commercial test laboratories and most company's EMC laboratories take preliminary measurements in a shielded enclosure or semi-anechoic chamber. To manually take measurements for one EUT from 30-1000 MHz at 4 turntable orientations and 2 antenna polarizations took a technician approximately 4 hours in our laboratory. This test assumed that the technician maximized the cable configuration for the highest emission and manually recorded emissions at each of the 8 positions (4 configurations for both the vertical and horizontal antenna polarization). The time spent for preliminary measurements combined with the time for final measurements at the OATS summed to a total of 12 hours.

By automating the preliminary scan the amount of work required by the technician decreased. The technician configured the EUT, located the maximized cable configuration, and then configured the test software. The configuration screen is shown in Fig. 1. Most fields would be populated by default and the technician would fill out the remaining fields within minutes.

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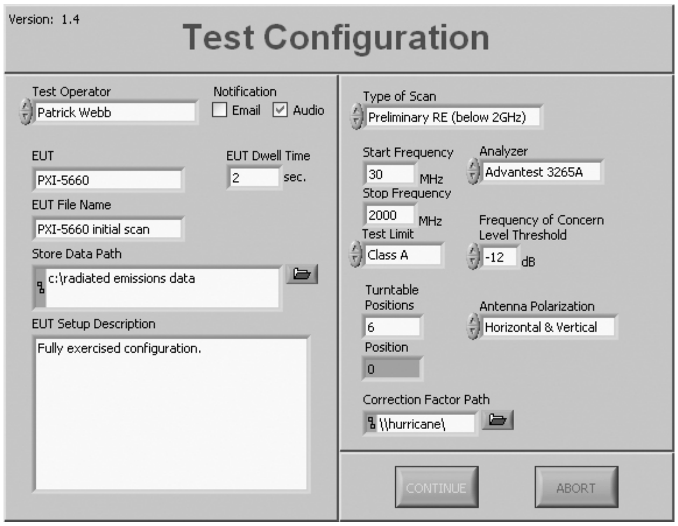


Figure 1. Configuration front panel

III. EXPECTED BENEFITS FROM AUTOMATION

Several expected benefits factored into our decision to automate this test. A reduction in test cost was most certainly the driving factor. Savings are seen in the reduction of man hours per test as well as equipment and facility usage.

In addition to the cost savings associated with reducing the required resources, releasing these resources was expected to provide a large benefit. The personnel in the laboratory are the most valuable resource. If they are not required to perform an automated test, they can use their time to work on other projects. Better usage of test equipment would allow for increased testing capacity. We can perform additional preliminary scans each day or use the equipment for other tests or debugging. Freeing up personnel and test facilities was expected to increase the productivity of the lab.

Most importantly there should be a great deal of quality improvement from automation. Having a computer perform the measurements, the test will be performed the same way each time. This repeatability is extremely valuable to R&D engineers. Automation increases their confidence in the data and provides test results in a timely manner. In addition, with automation, more data points will be recorded. This adds the ability to create a spectral plot of the EUT. The spectral plot included in a full report produces an accurate representation of how the test was performed and the results of the test.

IV. TEST SYSTEM OVERVIEW

The preliminary radiated emissions test system is primarily composed of the following hardware: A 3x3x8m ETS Lingren shielded enclosure, EMCO turntable, antenna mast, positioner controller, biconilog antenna, National Instruments PXI test system; embedded 1.26 GHz computer, 9 kHz – 2.7 GHz spectrum analyzer, and a Mini-Circuits RF pre-amplifier. This hardware was selected for its capability, cost, and flexibility of future test expansion. It was particularly beneficial to have the spectrum analyzer in the same physical piece of equipment as the host computer running the automated test.

The software packages used to develop this automated test are: National Instruments LabVIEW 7.0 Express, National Instruments Spectral Measurements Toolkit for Windows, and Microsoft Word. Utilizing LabVIEW, allowed our student intern to quickly develop the test application with little programming experience. LabVIEW enabled us to control test equipment, perform measurements, record data, and create a report in Microsoft Word with no user intervention.

The test software application that was developed has only 4 screens as the user interface. The first is a simple splash screen showing software version information. Immediately following is the configuration screen where all of the parameters of the scan are set. Inputs are grouped logically to make it as simple as possible to configure the test. The configuration screen is shown in Fig. 1.

Testing can begin once the configuration is complete. Error checking is also performed on all configuration data. A screen showing the current measurements and an indication of test completion time remains on screen until all the measurements are taken. This screen is shown in Fig. 2. During the test, live measurements are displayed. There is an indication of the current antenna position and at what angle the EUT is positioned. A simple indication of the remaining test time is displayed here also. The user has the ability to abort the test early if he so desires.

A summary screen is displayed when the test is completed. This is depicted in Fig. 3. Here a maximized spectrum of the EUT is displayed, along with a list of frequencies in a tabular format. The user has several options at test completion. By analyzing the data, the user may want to repeat the scan after making any necessary modifications to the EUT. Most of the time, the user will want to create a report of the test. There is code designed to protect the user from inadvertently exiting the software or repeating a scan before a report has been created.

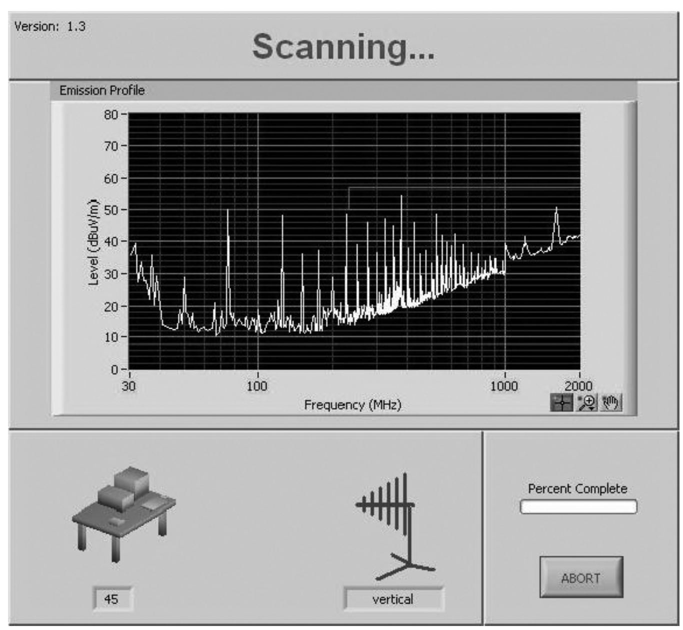


Figure 2. Scanning front panel

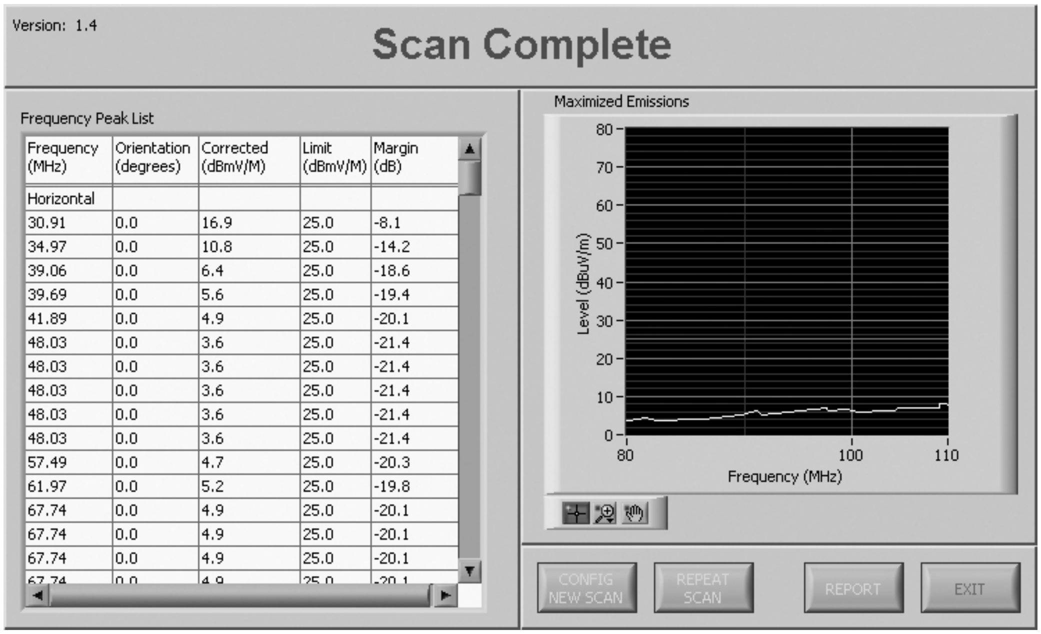


Figure 3. Summary front panel

If a report has not been created and the user selects the exit option the software will simply confirm the user's selection by reminding the user that a report has not been created. Software features such as these provide a great deal of added benefit that will make your test operators very satisfied with the application.

V. MEASURED BENEFITS

By automating the preliminary radiated emission scan the technician's time decreased significantly from 6 to 2 hours. The technician simply configures the EUT, finds the maximized cable configuration, and then configures the test software for the computer to take the measurements. As mentioned previously, most fields are populated by default for the typical test and the technician fills out the remaining fields within minutes. The time savings are depicted in Table I.

TABLE I Time savings analysis

0.5 hours - setup EUT and test equipment	
Manually	Automated
1.0 hours - Take initial measurements across spectrum	0.25 hours – Take initial measurements across spectrum
1.5 hours – Maximize EUT orientation and retake peak measurements	0.5 hours – Maximize EUT orientation and retake peak measurements
2.0 hours – Maximize all peak measurements for maximum orientation and antenna polarization	1.5 hours – Make a complete scan of the maximized EUT configuration
0.5 hours – Complete documentation	1 minute – Complete documentation
0.5 hours - Tear down	
6.0 hours total test time	**3.26 hours total test time**

As expected, in addition to the reduction in test time there was significant cost savings. This is depicted in Table II. The figures in this table are conservative. The table illustrates the cost savings associated with the labor for the test. It does not account for the savings associated with getting the product to market faster, the reduction in product development time, or the overhead cost savings of running the test such as the use of equipment and facilities. Even though the equipment and facilities are owned, there is a cost associated with using the equipment and facilities for any length of time. The application's development costs are due to the development time and the cost of the programming tools to develop it. Weighing the added benefit with respect to cost, breakeven is at 102 completed tests. That is, the development costs are received back as savings after just 102 tests! For a company that produces 300 products a year, the benefit would be realized in just 4 months.

TABLE II Cost savings analysis

Benefits	
Manually	Automated
6.0 hours technician time x $40/hour = $240	2.0 hours technician time x $40/hour = $80
Savings per product = $160	
Costs	
480 hours student intern development time x $20/hour = $9,600	
80 hours engineer development time x $60/hour = $4,800	
LabVIEW = $2,000	
Total costs = $16,400	

The most significant benefit of automating this test was the reporting capability of the application. After test completion, a

frequency spectral plot of the EUT is delivered with a table of emissions. All of the relevant test settings are also delivered in a Microsoft Word formatted report. This report is shown in Fig. 4. This replaces the manual report of the past which did not have the detail that the automated report possesses. The report is delivered to the customer as a finished product of the test. It serves as valuable data for future debug and evaluation. In depth scans can be performed repeatedly with minor modifications made to the EUT delivering complete reports for useful engineering evaluation. The engineer can perform evaluations with out the assistance of valuable lab personnel. Hence the lab personnel can perform their other duties with out having the engineering debug and evaluations impact their schedule.

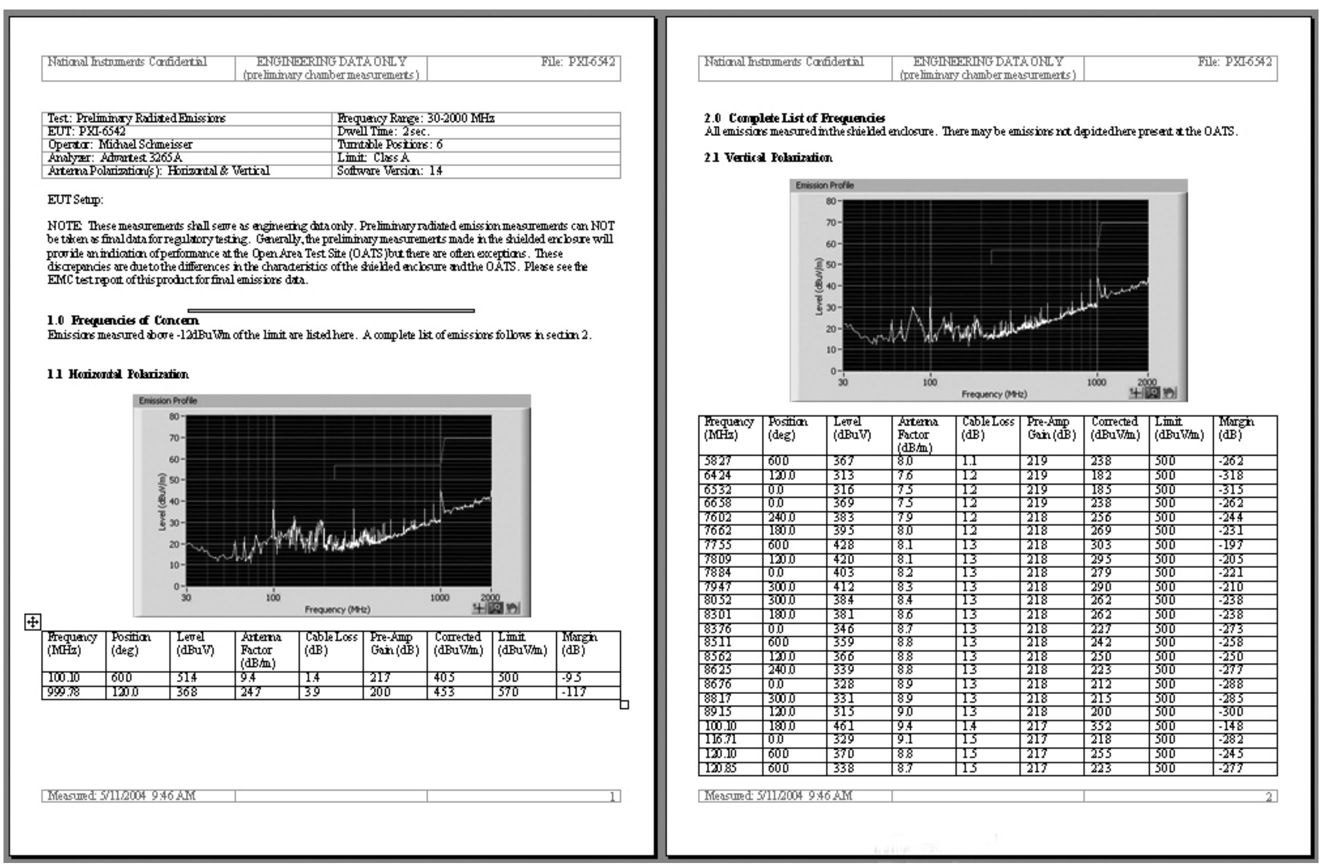
Before the automated preliminary scan, all debug of emissions was performed at the OATS. Now emissions that need resolution can be resolved in the preliminary scan chamber 90% of the time. It is much more convenient to perform the debug in the preliminary scan chamber. The chamber is located on the first floor of the research and development building, rather than the OATS, located outside and away from the building. Weather conditions do not inhibit debug either. Besides the convenience, this releases an additional resource, the OATS. This has proven to be much appreciated by our customers in R&D.

Having the ability to complete a preliminary scan in just a few hours, encourages engineering scans to be performed early in the product development cycle. R&D engineers have the flexibility to perform scans when selecting components etc. This improves the quality of the product and gives the engineer confidence that the product will perform well when they are ready to qualify their product.

Since the preliminary scan is automated, it can be run at anytime, day or night. This adds hours of additional available test time. Implementing audits of products coming off the manufacturing line will not impact new product development. This can only improve the quality of the products.

VI. FUTURE DEVELOPMENT

Future plans for this test system specifically include incorporating the radiated immunity test with the preliminary scan. The radiated immunity test is performed in the same test chamber currently. It is an automated test that takes approximately four hours to complete. One application could control the chamber to perform a radiated emissions preliminary scan and then continue and perform the radiated immunity test. The two tests combined take nearly six hours to complete. When both tests can be run sequentially with one initial setup, the test can be executed overnight without any personnel support. The expected benefit from this will be the released resource of the chamber during the day. This provides more time during the day for engineering debug and evaluation, while the automated tests are still performed in the evening.



National Instruments Confidential	ENGINEERING DATA ONLY (preliminary chamber measurements)	File: PXI-6542

Test: Preliminary Radiated Emissions	Frequency Range: 30-2000 MHz
EUT: PXI-6542	Dwell Time: 2 sec.
Operator: Michael Schmeisser	Turntable Positions: 6
Analyzer: Advantest 3265A	Limit: Class A
Antenna Polarization(s): Horizontal & Vertical	Software Version: 14

EUT Setup:

NOTE: These measurements shall serve as engineering data only. Preliminary radiated emission measurements can NOT be taken as final data for regulatory testing. Generally, the preliminary measurements made in the shielded enclosure will provide an indication of performance at the Open Area Test Site (OATS) but there are often exceptions. These discrepancies are due to the differences in the characteristics of the shielded enclosure and the OATS. Please see the EMC test report of this product for final emissions data.

1.0 Frequencies of Concern

Emissions measured above -12dBuV/m of the limit are listed here. A complete list of emissions follows in section 2.

1.1 Horizontal Polarization

Frequency (MHz)	Position (deg)	Level (dBuV)	Antenna Factor (dB/m)	Cable Loss (dB)	Pre-Amp Gain (dB)	Corrected (dBuV/m)	Limit (dBuV/m)	Margin (dB)
100.10	600	514	9.4	1.4	217	405	500	-9.5
999.78	120.0	368	247	3.9	200	453	570	-117

Measured: 5/11/2004 9:46 AM		1

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2.0 Complete List of Frequencies

All emissions measured in the shielded enclosure. There may be emissions not depicted here present at the OATS.

2.1 Vertical Polarization

Frequency (MHz)	Position (deg)	Level (dBuV)	Antenna Factor (dB/m)	Cable Loss (dB)	Pre-Amp Gain (dB)	Corrected (dBuV/m)	Limit (dBuV/m)	Margin (dB)
5827	600	367	8.0	1.1	219	238	500	-262
6424	120.0	313	7.6	1.2	219	182	500	-318
6532	0.0	316	7.5	1.2	219	185	500	-315
6658	0.0	369	7.5	1.2	219	238	500	-262
7602	240.0	383	7.9	1.2	218	256	500	-244
7662	180.0	395	8.0	1.2	218	269	500	-231
7755	600	428	8.1	1.3	218	303	500	-197
7809	120.0	420	8.1	1.3	218	295	500	-205
7884	0.0	403	8.2	1.3	218	279	500	-221
7947	300.0	412	8.3	1.3	218	290	500	-210
8052	300.0	384	8.4	1.3	218	262	500	-238
8301	180.0	381	8.6	1.3	218	262	500	-238
8376	0.0	346	8.7	1.3	218	227	500	-273
8511	600	359	8.8	1.3	218	242	500	-258
8562	120.0	366	8.8	1.3	218	250	500	-250
8625	240.0	339	8.8	1.3	218	223	500	-277
8676	0.0	328	8.9	1.3	218	212	500	-288
8817	300.0	331	8.9	1.3	218	215	500	-285
8915	120.0	315	9.0	1.3	218	200	500	-300
100.10	180.0	461	9.4	1.4	217	352	500	-148
116.71	0.0	329	9.1	1.5	217	218	500	-282
120.10	600	370	8.8	1.5	217	255	500	-245
120.85	600	338	8.7	1.5	217	223	500	-277

Measured: 5/11/2004 9:46 AM		2

Figure 4. Computer generated report