# Automated Radiated EMI Measurements

WERNER SCHAEFER
Hewlett-Packard Company *

## INTRODUCTION

Conducting radiated EMI compliance measurements according to commercial regulations is a complex task involving much more than finding the worst-case amplitudes of the device under test (DUT). The individual parts of the test, including the definition of the measurement system being used and the limit lines being applied, affect the accuracy of the measurement data and the repeatability of the test. The maximization procedure used to find the highest field strength levels of the DUT is of fundamental importance because the sequence and mode of antenna tower and turntable movement determine the detection of emissions and their measured amplitude values. As mandated by many commercial EMI regulations, this process involves the variation of antenna height over a certain range (e.g., 1 m to 4 m), the change of antenna polarization (horizontal and vertical) and the rotation of the DUT. Therefore the definition of the maximization procedure must address the peculiarities of the DUT to ensure repeatable results.

The overall test strategy has to be tailored to the individual measurement situation, because tests on an Open Area Test Site (OATS) always require discrimination between ambient signals and DUT emissions, which is a time-consuming and complicated task. This step can be omitted in cases of testing in a semi-anechoic chamber, where no ambient signals are present. Furthermore, the test purpose is

***The definition and execution of commercial radiated EMI measurements require many different steps to be completed before a test can actually be run.***

reflected in the measurement procedure: for example, a pre-compliance test made during the EMI troubleshooting phase will be more interactive to verify applied modifications made to the DUT or to analyze the cause of DUT failure. A compliance test, on the other hand, will be automated to the highest degree possible to determine whether the DUT meets the requirements called for in the regulations.

The definition and administration of the components of the measurement system is an additional task which needs to be dealt with efficiently. A hierarchical structure and graphical interface provides the necessary ease of use, and avoids possible re-work of the definition of the measurement process and of the whole equipment specification in case a system component needs to be exchanged. In the case of an antenna needing calibration, and therefore temporary replacement, only the definition of the replaced component has to be updated; all the other elements of the test will remain unchanged. This approach also allows retrieval of a different measurement procedure. For example, an interactive test can replace a compliance measurement without the need to redefine the current equipment.

The specification and archiving of limit lines as a separate entity in the test definition process allows easy, one-time entering of data and automatic recall at the beginning of a measurement. The documentation of test results in tabular and/or graphical form has to meet different regulations or in-house standards. The exchange of data between the actual measurement program and other applications, such as word processors or spread sheet programs, is essential to allow fast and efficient completion of this task.

Many individual steps within a radiated EMI measurement can be automated, while others can be completed using software tools in an interactive test. This article describes one possible methodology along with required procedures and their implementation in the MS-Windows® environment, providing an interface and nomenclature which is familiar to most users of PCs today.

## DEFINITION OF A RADIATED EMI MEASUREMENT

All the information necessary to define a complete radiated EMI measurement can be organized into different categories, called test resources, which address specific development areas. This structured approach ensures ease of use because one part of the definition process, the specification of the measurement sys-


*See Advertisement on Page 6.

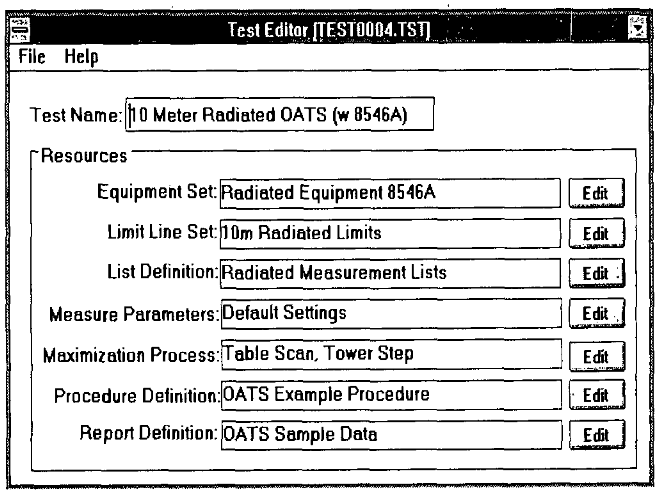


***Figure 1.*** *Test Editor.*

tem, can be completed without having to simultaneously interact with other areas like the maximization process. A dedicated test editor (Figure 1) provides the top level interface through which all the parts of the definition process are accessible. This interface should only be available to users with the appropriate security level, which can be assigned in an administrative part of the program. Users who don't have access to the definition area can only execute previously defined tests. The test resources which are necessary to provide a structured description of a complete radiated EMI measurement are:

- Equipment Set: the components of the measurement system such as cables, antennas, switches, receiver, tower, turntable, DUT, etc.
- Limit Line Set: group of one or multiple limit lines, which might also have a margin associated with them. Arranging limit lines in sets allows fast retrieval of all the information in one step.
- List Definitions: When making radiated EMI measurements, it is advantageous to take trace data with a swept receiver and discern signals in these traces mathematically. This processing requires signal lists to store measurement results. The layout of individual lists can be specified by the user. The list name as well as the number and content of the visible columns (e.g., corrected and/or uncorrected peak, quasi-peak and average amplitudes, antenna height, antenna polarization, turntable angle, signal class, etc.) will be unique for each list. This flexibility is necessary to address different measurement needs and test goals.
- Measure Parameters: receiver settings used to measure signals in a list. Different detectors can be used for measurements at fixed frequencies and for scans over frequency ranges.
- Maximization Process: specification of the sequence of antenna tower and turntable movement, including the change of polarization and possibly the state of the DUT. The reference positions of the movements along with their mode, i.e., scan or step, are also included.
- Procedure Definition: specification of the actual measurement procedure, using the definition of up to four sub-procedures. The execution mode, automatic or interactive, is also included.
- Report Definition: Test results acquired during a measurement can be saved selectively in files in tabular and graphical form along with applied

correction factors and system information. These files can be imported into commercially available word processors for compilation of final test reports.

The test editor is used to completely define measurements, which can be saved in a special library for future use. When a measurement definition is retrieved from the test library, all the information of the seven resources is automatically loaded from their individual libraries and the test can be executed. A hierarchical library concept minimizes potential rework, which might be necessary if a different maximization routine has to be used due to different DUT characteristics, or if a measurement system component needs to be changed. Only the affected resources need to be modified to reflect the change; all other resources remain unchanged.

The "Edit" keys in the test editor (Figure 1) access the actual definition area of each resource. The general concept of completing necessary individual tasks in a radiated EMI measurement is shown using two important resources, the equipment set and procedure definition.

## EQUIPMENT SET DEFINITION

All software packages used to automate EMI measurements need to provide some means to specify the measurement system components such as the receiver, cables, antennas, etc. The definition of the equipment is a complex task which requires a structured approach. Ideally, a graphical interface is used to define the complete system. In the first step a generic description of the system is put together using icons, organized in a tool box, which represent individual system components (Figure 2). The connecting lines between these icons, e.g., from the antenna to the receiver, indicate the signal flow; the currently active signal path is shown in red. The categories of system components which are necessary to define a radiated EMI measurement setup are: antenna, cable, tower, amplifier, attenuator, signal source, DUT, receiver, turntable, switch, filter and a general (user definable) instrument. The generic description of the measurement system is accomplished by simple "click and drag" operations using the PC mouse.

The necessary information to completely describe an individual system component should be grouped into four different categories: general information, communication method, correction factors and control commands. Specifically designed interfaces are used to enter this information as necessary. De-

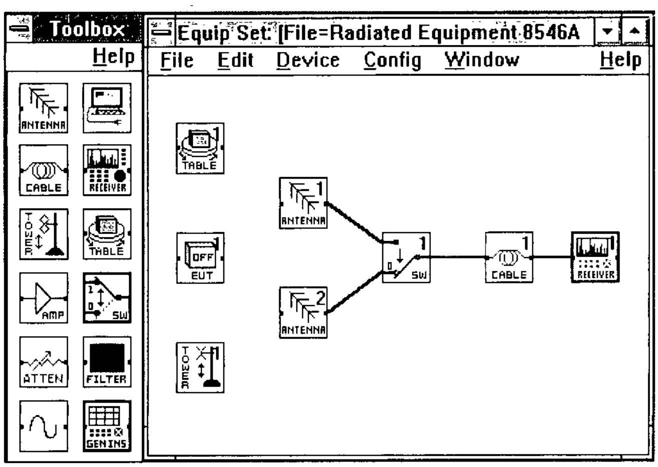


***Figure 2.*** *Equipment Set Resource and Tool Box.*

pending on the icon chosen, only the appropriate interfaces will be accessible in the component definition process. A completed component specification can be stored in a dedicated library for future use.

The general information portion of a device definition contains the component's manufacturer, serial number, date of last calibration, date of next calibration and maximum input power. The correction factors, e.g., insertion loss of switches, antenna factors or frequency responses of cables, are entered into a table and are displayed graphically at the same time. The necessary interpolation is done either linearly or logarithmically, according to the user's specification. The graphical display provides a complete representation of the component's correction factors by showing both the defined and calculated values in the whole frequency range over which the device is usable. With the mouse pointing at any frequency on the graph, the appropriate correction factor can be determined.

Remotely controllable system components like receivers, towers, turntables or DUTs require specification of the communication method, i.e., the type of interface and device address. A device can also be defined as a manual system component (e.g., tower). It will be included in the automatic measurement process, but messages will be displayed for user interaction instead of controlling the component remotely via an interface. The specification of the receiver and tower/turntable controller only requires the selection of a supported model number; the appropriate driver will automatically be used during the measurement. The drivers for these devices should be included with the software at all times, which simplifies an exchange of these devices, if necessary, by selecting a different model number from the list.

Commands for remotely controllable and manual devices can also be specified. Antenna tower and turntable controllers are usually supported with dedicated software drivers. However, a set of generic control commands which allow the incorporation of a custom component in the measurement process must be supplied for these devices and for the signal source. In case of manual custom devices, these control commands are displayed as messages demanding user interaction.

## MEASUREMENT PROCEDURE

The definition of the actual measurement procedure is a fundamental part of the test definition process. The procedure editor (Figure 3) simplifies this task by organizing the complete test process in four subprocedures: prescan, data reduction, maximize/measure and post processing. Each can be executed automatically by selecting it with the mouse, or can be executed manually using the tools like the virtual receiver interface, list operations or control panels of the tower and turntable. If desired, the execution of multiple subprocedures can be concatenated to create a fully automated test. Furthermore, the frequency range for the test is specified; the actual frequency range used during test execution can be narrower.

## PRESCAN

Prescan measurement data is acquired in the frequency range of interest using a scanning receiver. An algorithm is applied to discern signals in these traces and thus separate emissions from system noise. The signals found are stored in specified lists for further processing (Figure 4). The spectrum envelope captured during the execution of this subprocedure can also be viewed in a trace graph, where the maximum amplitude at each frequency is presented. Segments of this graph can be marked with the mouse for a more detailed display in a second graph. Data from this "segment trace" is avail-

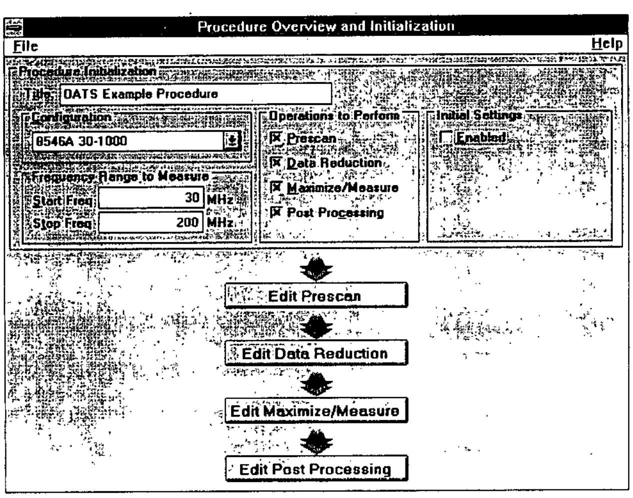


***Figure 3.** Procedure Editor.*

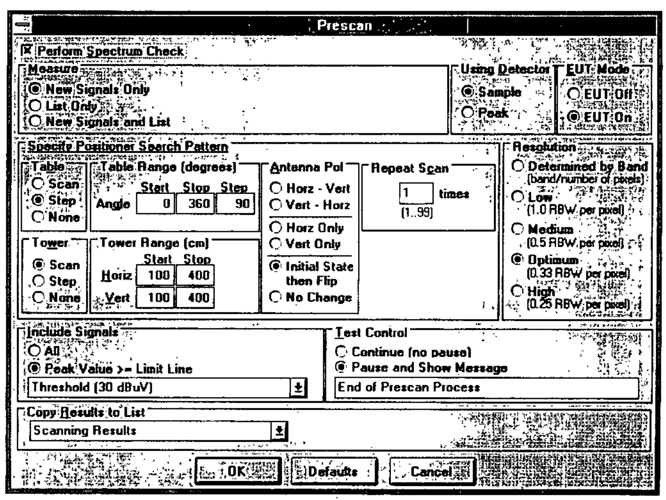


***Figure 4.** Prescan Subprocedure Interface.*

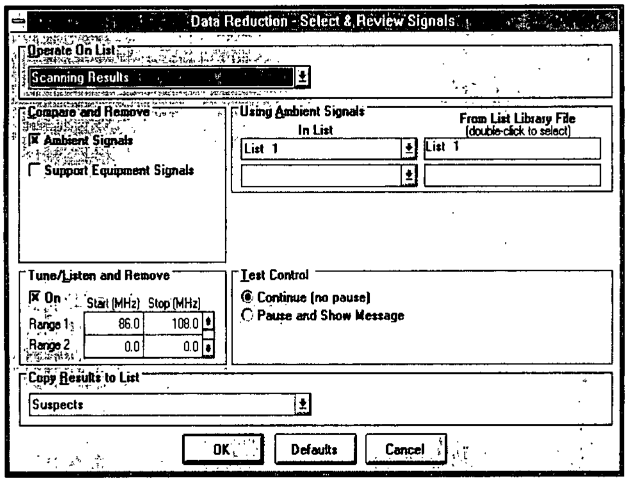


*Figure 5. Data Reduction Subprocedure.*

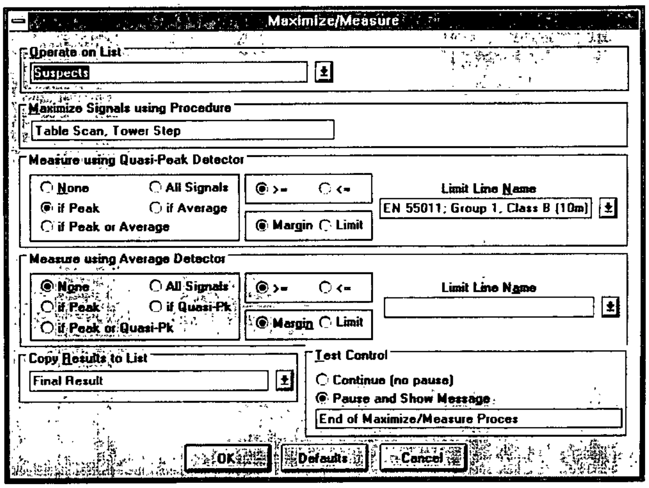


*Figure 6. Maximize/Measure Subprocedure.*

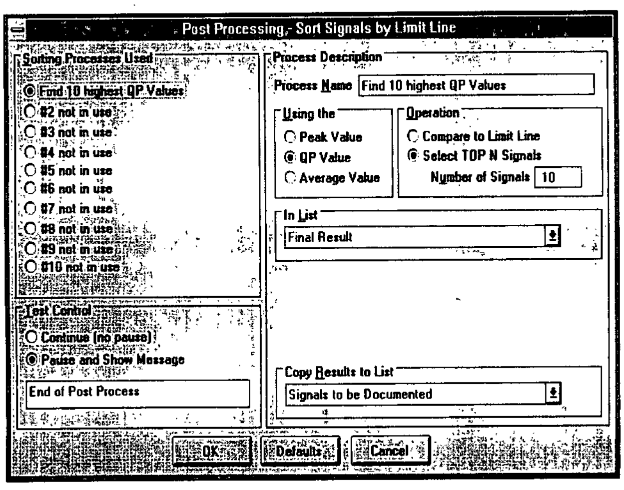


*Figure 7. Post Processing Subprocedure.*

able instantly without resweeping the receiver while improving the frequency resolution.

This sub-procedure is well suited to scan the measurement environment, especially the OATS, to log ambient signals and compile ambient lists. These lists are used to discriminate DUT emissions from ambient signals. Another application for this sub-procedure is to acquire fast preliminary measurements on an OATS to find DUT emissions, which need to be maximized and measured with the appropriate receiver detector in a second step. Using a scanning instead of a stepped receiver is essential for this task to avoid long measurement times and ensure proper signal interception. Furthermore, preliminary lists of DUT emission frequencies can be compiled in a semi-anechoic chamber, and can serve as a basis for the actual compliance measurement on an OATS.

## DATA REDUCTION

Data reduction allows automatic reduction of list data by using other signal lists and complex data comparison techniques. DUT signals found during the prescan can be separated from ambient signals, which are kept in a dedicated ambient list. Since DUTs need to be exercised during an actual compliance test, many devices need to be controlled by other devices or systems to perform their normal operation (e.g., a printer controlled by a PC). The PC itself also emits unwanted signals, which are present in the measured spectrum. These support equipment signals can be stored in a separate list as well and used in an automatic signal comparison process to find the actual DUT emissions (Figure 5). List comparisons utilize different parameters like signal frequency, frequency accuracy and amplitude variation to determine if two or more signals are identical.

## MAXIMIZE/MEASURE

The maximum amplitudes of signals stored in lists are found during the execution of maximize/measure. Maximization includes the height variation of the antenna, change of antenna polarization, turning of the DUT and change of DUT states. The sequence of movements and the movement mode, i.e., continuous or stepped, can be specified in the maximization process resource of the test editor. After the worst-case positions of the peripherals yielding the maximum emission amplitude are found, the signals are remeasured using the appropriate detector called for in the applied regulation (Figure 6). The receiver state used during the measurement of the maximized signals is defined in the measure parameters resource of the test editor.

## POST PROCESSING

Signal lists can be processed by applying sort and selection algorithms. Up to 10 different processes can be used consecutively and results can be kept in different lists or stored in one list (Figure 7). Specific documentation purposes as well as data evaluation needs can be met by executing this sub-procedure.

## SUMMARY

The definition and execution of commercial radiated EMI measurements require many steps to be completed before a test can actually be run. A dedicated software package which is easy to use can assist in accomplishing repetitive tasks and also minimize re-work if modifications of test procedure, measurement equipment definition or report data specifications are necessary. Furthermore, the software has to be flexible enough to accommodate specific demands of different measurement environments and test purposes without sacrificing ease of use. This can be accomplished by presenting options for all relevant decisions to be made during each individual measurement step without inflicting actual code changes or macro programming on the user.

A hierarchical and modular structure throughout the program minimizes re-work and assures efficiency of maintenance of the test system, report generation and data archiving. The test procedure itself must offer functions to reduce the test time and therefore improve the throughput. Automatic amplitude comparisons are necessary to filter out certain signals according to user specifications. Dedicated graphical interfaces for the definition and execution of tests and logical grouping of individual procedural steps ensure ease of use, even for an occasional user.

***WERNER SCHAEFER** received the degree of Dipl.-Ing. from the Technische Hochschule of Darmstadt in 1982 and an MBA from Rendsburg University in 1991. His professional experience has been in the areas of microwave measurements, application software development and EMC measurements. Mr. Schaefer, a NARTE-certified EMC engineer, is an active member of both VDE and ANSI committees involved in the development of EMI standards. He published numerous papers on EMC and microwave topics in Europe and the U.S., and co-authored a book on microwave measurement techniques. (707) 577-2817.*