Test Speed Considerations in Automated EMI Measurements

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Throughput and efficiency, along with measurement accuracy and repeatability, are major concerns of EMI test facility operators today.

INTRODUCTION

Commercial EMI regulations specify the maximum amplitudes of equipment under test (EUT) emissions in specific frequency ranges. For radiated EMI compliance measurements this requires the rotation of the EUT relative to the receiving antenna (typically 0° to 360°), the variation of antenna height (e.g., 1 m to 4 m) and the use of both horizontal and vertical antenna polarizations. Furthermore, the EUT has to be in the operating mode causing the highest emission levels. The setup of the EUT, including cable orientation and use of peripherals, also has to reflect the worst-case condition leading to the highest signal amplitudes.

A maximization procedure defines the sequence of antenna tower and turntable movements as well as antenna polarization changes. The actual movement mode, a stepped or continuous movement of the positioners, is also part of the maximization procedure. Different sequences will lead to different final measurement results. This causes a repeatability problem, because the maximization procedure itself is not precisely defined in most EMI regulations.

One exception is the ANSI C63.4 (1992) document, which proposes a generic sequence of antenna tower and turntable movements that can be used in case a continuous azimuth search cannot be made. Since the execution of the maximization procedure requires many time-consuming positioner movements, careful specification of the maximization process is important to avoid excessively long measurement times.

This very complicated task is made even more difficult when the measurement is carried out on an open area test site (OATS), which still serves as the reference test environment today. High level ambient signals can mask EUT emissions completely, which makes emission detection impossible without prior knowledge of the EUT spectrum. Superposition of ambient and EUT signals causes erroneous measurement results or their incorrect interpretations. In any case, additional steps in the test procedure are necessary to discriminate between ambient and EUT signals.

The actual measurement strategy and the test system itself also impact the overall test time. For instance, a swept receiver can scan wide frequency ranges quickly and locate "quiet zones" in a frequency range of interest containing no or only very low signals.[1] These parts of the spectrum can be omitted in the final measurement involving signal maximization. Furthermore, a maximization procedure can take advantage of a swept receiver's speed to simultaneously maximize multiple signals in a certain frequency segment, which reduces the test time drastically.

This article discusses the different categories of factors impacting the overall measurement time and provides examples of how a dedicated application software can be used to ensure high throughput by reducing test time.

EUT RELATED FACTORS

According to commercial EMI regulations, EUTs must be tested in their worst-case configurations. This usually requires preliminary measurements before the actual compliance test to determine the operating mode leading to the highest emission levels. For instance, many electronic devices use different internal signal paths involving dedicated circuitry when the system input is switched. Frequency conversion circuits are only utilized when the system is tuned to a specific frequency range; otherwise, the signal is re-routed and these circuits are inactive. Obviously, the radiation pattern of the system can change, depending on its mode of operation.

Another factor to consider is the setup of the EUT for the actual measurement. The position of the cables attached to the EUT and other peripherals, such as printers, have to be varied in order to identify worst-case orientation causing maximum emission amplitudes. Cables function as antennas at higher frequencies and their positions relative to the receiving antenna determine the radiation pattern of the EUT and, therefore, the overall test result. Variation of cable orientation is usually done during another preliminary test and can be very time-consuming by itself. The use of a swept receiver is necessary in order to display rapid spectrum changes very quickly. A virtual receiver display implemented in a software product, can provide additional analysis capabilities like advanced marker analysis functions, limit line

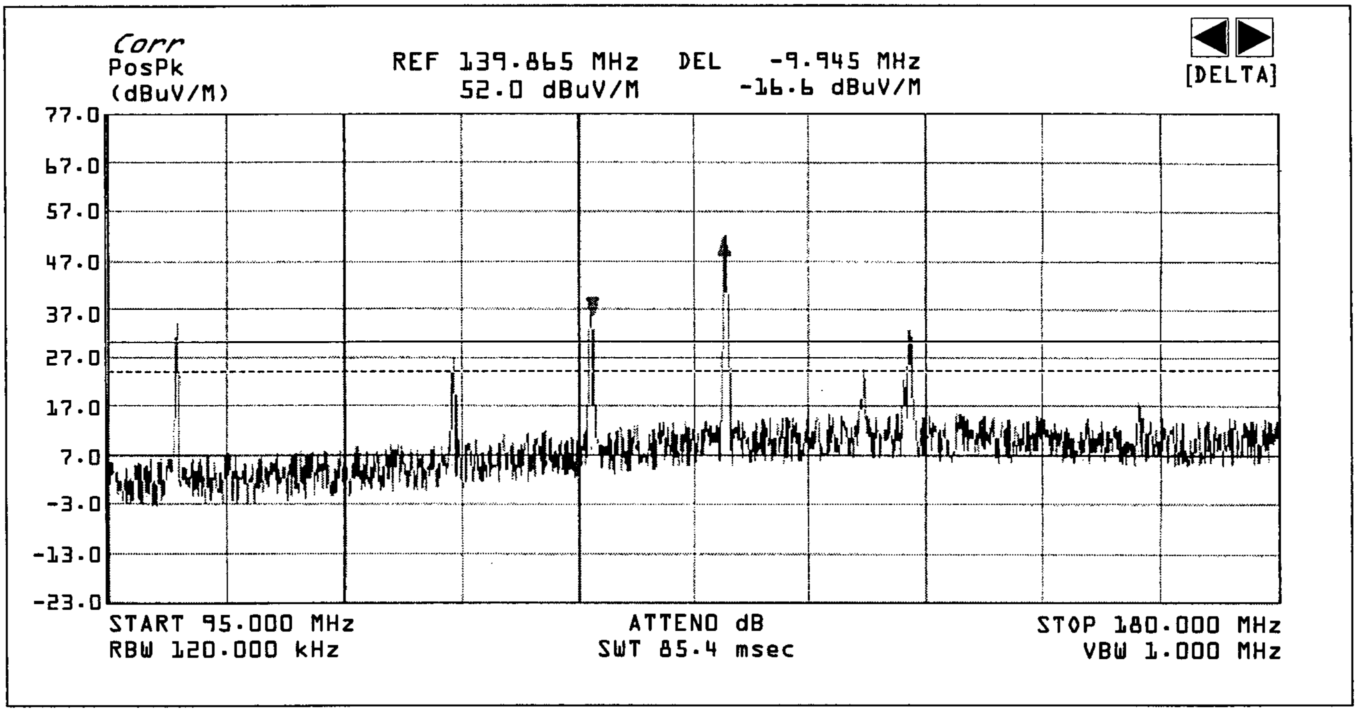

Figure 1. *Virtual Receiver Interface.*

checks and real time amplitude correction (Figure 1).

When the EUT is remotely controllable (e.g., via an IEEE 488.2 interface), the time for preliminary measurements can be reduced by switching the EUT into different modes under software control while taking data with a swept receiver and analyzing it using a virtual receiver display functionality. During the compliance measurement itself, the EUT can be switched into its worst-case operating mode and kept in this state for a certain dwell time, which is related to its functionality and/or design. Different frequency segments within the spectrum of interest might demand switching the EUT into several states to truly capture the worst-case amplitudes. The switching time involved also impacts the test time but might be negligible compared to other factors. Obviously, the EUT mode setup and switching is an integral part of the maximization procedure, which is an often overlooked fact.

MEASUREMENT SYSTEM CONSIDERATIONS

The speed of the motorized antenna tower and turntable as part of a radiated EMI compliance measurement system is one major factor determining the overall test time. These specifications, along with other features like the fast continuous rotation mode of turntables, determine the test strategy and the maximization procedure definition. Other characteristics of the motor bases, like their start time (time elapsed between standstill of the positioner and movement at specified speed) or the generation of excessive emission levels during startup by the motors, which might cause erroneous test results, contribute to the overall measurement time. In the latter case, the data acquisition process of the test procedure needs to be delayed by the start time of the motor bases to avoid recording signals which are not related to the EUT.

Figure 2 shows a user interface for the specification of antenna mast attributes. Another factor is the "stop delay," which specifies the time between sending the stop command to the moving device and the actual standstill. This factor also impacts the positioning accuracy of the device because the value chosen is dependent on its physical mass and its related inertia, which, in turn, is dependent on the speed at which the device is moving before a stop command is issued. The software uses this parameter during tower and/or turntable movement, along with the device's speed information, to determine the point in time to send the stop command over the bus before the desired location is reached. Using the device's inertia assures proper positioning in a location with reasonable accuracy (e.g., 2° for the turntable, 2 cm for the antenna tower).

The required change of antenna polarization also contributes to the measurement time because a delay time is usually desirable, during which the actual polarization change occurs while the mast is not moving and no data is taken. This avoids ambiguous polarization information and thus, erroneous test results. Depending on the

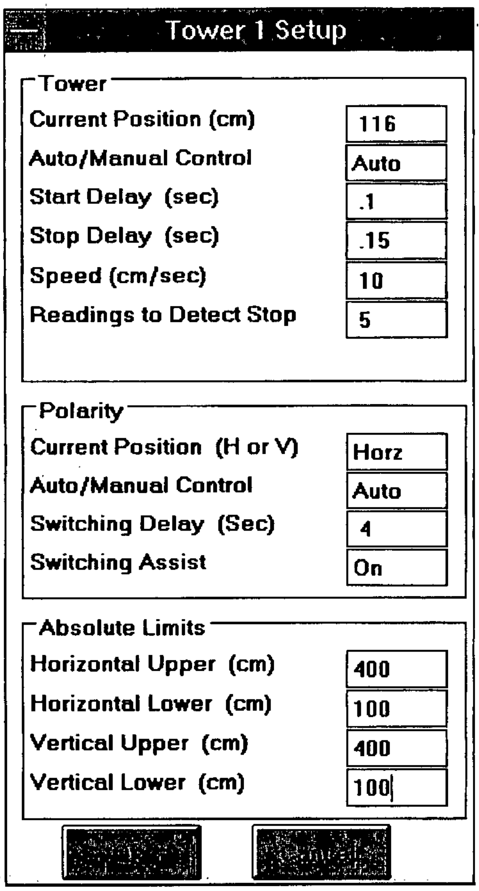

Figure 2. *Antenna Tower Definition.*

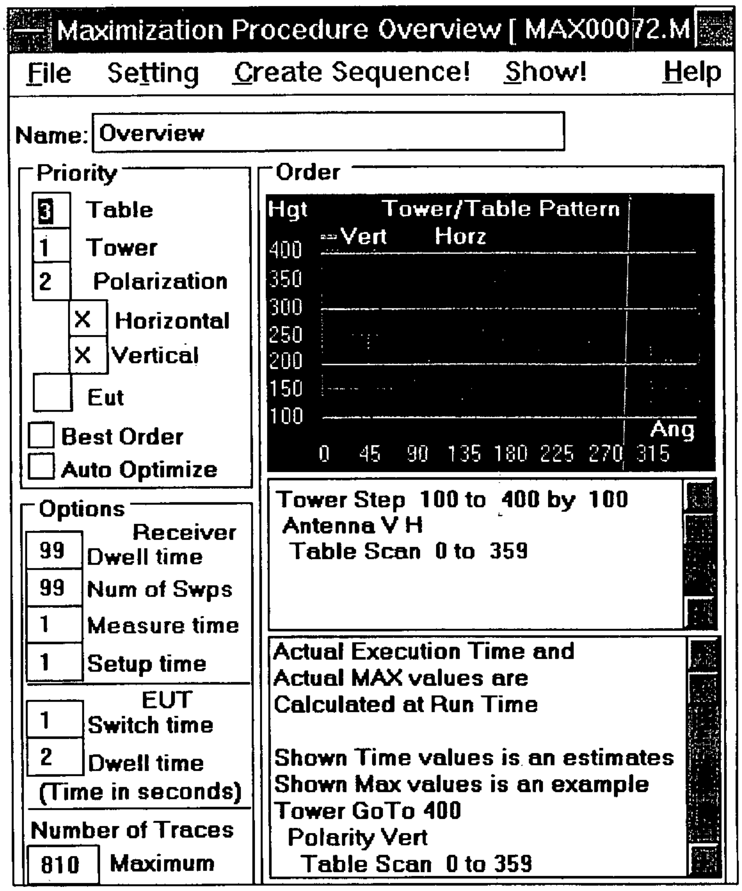

Figure 3. *Maximization Procedure Definition.*

measurement environment, additional movement of the tower might be required when changing antenna polarization. For instance, if the polarization is changed from horizontal to vertical, there might not be sufficient clearance between the antenna and the ceiling absorbers or ground plane. In this case, the antenna has to be moved to a lower location (away from the upper positioning limit) or higher position (away from the lower limit) respectively to prevent both absorber and antenna damage. These time-consuming movements can be minimized by optimizing the overall maximization procedure.

MAXIMIZATION PROCEDURES

The maximization procedure is a key element of the overall radiated EMI compliance measurement process. Commercial EMI regulations specify the highest amplitudes for all EUT emissions. To achieve this goal, a determination of the antenna height and polarization as well as the turntable angle leading to the worst-case level is necessary. However, in most regulations the actual movement sequence is not called out, which causes ambiguous results because very often different movement sequences and modes will show the maximum amplitude in different locations. Only the antenna height scan range, polarization change and the change of EUT position relative to the antenna are specified.

Ideally, the EUT's radiation pattern dictates the positioner's movement sequence and mode but usually the radiation pattern is not well-known. Furthermore, the maximization process is the key contributing factor to the overall test time for a radiated EMI measurement and its definition will determine if the throughput and efficiency goal can be achieved. A conflict of interest exists between the reduction of test times and the precise determination of worst-case amplitudes based on tower and turntable positions. A software tool can assist in determining and understanding different maximization procedures in order to minimize this conflict (Figure 3).

The order in which the setup and/or change of all components occur can be specified by assigning priorities. The priority of the individual components of the maximization procedure, i.e., table, tower, polarization and EUT, indicates the sequence. In this example the EUT is set up first, the antenna tower is positioned to its first predefined position (step movement mode), the antenna polarization is set next and the turntable rotated within the defined scanning limits (scan movement mode). While the turntable is moving, data will be taken with the receiver and continuously stored in computer memory along with the related positioner information. The "Best Order" option can be used to reduce the movement time of the positioners by automatically identifying the movement limit that is closest to the current position and starting the movement for maximization from there (e.g., if the actual table position is 320° and a search needs to be performed from 0° to 359°, this option moves the table to 359° and searches backwards). The tool also indicates the search pattern both graphically and verbally. The lower text field contains the exact sequence of movements and setup as currently defined. This along with the graphical representation is of tremendous help to define, verify and understand maximization procedures.

The movement mode, i.e., step or scan for both tower and turntable as well as the reference position for each movement, also needs to be specified. In a stepped mode of the tower and/or turntable, data will only be taken after the devices reach one of the defined positions. While the devices are moving from one to the next position, e.g., 100 cm to 250 cm, no measurement is made.

In the scan mode, data will be taken during positioner movement (table movement in Figure 3) and recorded along with positioning information. If both tower and turntable are in a stepped movement mode, the overall time required tends to be longer compared to a maximization procedure, where one positioner is scanned and the other one stepped, assuming comparable positioning resolution of the stepped approach. However, if the most precise positioning information is required, the stepped method is preferable over a scanned movement. Simultaneous scans of both tower and turntable tend to minimize the maximization process time but usually cause fairly significant inaccuracies in the determination of the worst-case positions and repeatability problems.

Even though the actual measurement time needed for the receiver to scan over a frequency range might be very short, its setup time and the number of sweeps necessary to intercept signals contribute to the overall test time.

Another factor to consider during the maximization procedure definition is the EUT's emission characteristics. When slowly varying signals are anticipated, a stepped movement might be more appropriate to determine the worst-case positions, although this method will lengthen the overall test time.

TEST STRATEGY IMPACT

The test strategy is usually tailored to the individual measurement environment and also reflects the test goals. When a semi-anechoic chamber is available for preliminary tests, the emission frequencies of an EUT can be determined. Furthermore, some tower and turntable movement can be included in these prescans to assess the precursory worst-case positions leading to the highest amplitudes.

The actual size of the chamber and its physical characteristics (reflections, resonances, etc.) limit the pre-determination of amplitudes and related positioner locations. However, these intermediate results might serve as an input to the actual compliance measurement on an OATS. The advantage of this approach is the reduction of necessary ambient discrimination. The actual time spent to search for the worst-case amplitudes might also be reduced by defining a maximization procedure involving relative searches around a predetermined positioner location. For example, if a maximum amplitude at a frequency was found during a prescan to be close to a 2-m antenna height, on the OATS a search of ±50 cm around the 2-m height might be sufficient to capture the highest emission level.

The frequency accuracy used during the prescan measurement also impacts the total test time. Usually, prescan measurements are made with a swept EMI receiver. This way information on EUT emissions can be gathered quickly and problems identified right away. However, test data resulting from swept scans over wide frequency ranges exhibit low frequency accuracy, which makes the identification of the EUT emissions in a crowded ambient spectrum on the OATS more difficult and requires extra steps to discriminate between ambient and EUT signals.

Higher frequency accuracy demands longer test times, because swept receivers need to be tuned over narrower frequency spans. This means that the spectrum of interest has to be broken up into narrower frequency segments which are measured individually with a swept receiver. Even though the actual measurement time needed for the receiver to scan over a frequency range might be very short, its setup time and the number of sweeps necessary to intercept signals contribute to the overall test time.

If compliance measurements are solely made on an OATS without preceding prescans in a chamber, a much more elaborate ambient discrimination process is required. The operator's level of knowledge of the ambient spectrum present on the OATS determines the time necessary to accomplish this part of the test. The ambient spectrum can be monitored during separate measurements and signals stored in dedicated lists. These lists can be used as an input for a sophisticated numerical signal discrimination algorithm, which is based on list comparison.[2] This approach minimizes the number of signals needing special attention from the operator to make the final decision on its category, i.e., ambient or EUT emission, using dedicated tools.

A swept receiver allows the simultaneous maximization of multiple EUT signals present in a certain frequency span. While one positioner is scanning, all amplitudes of the emissions are measured and stored in computer memory along with the position information. At the end of the search procedure, the stored data is processed and the maximum amplitude for each emission is determined. Since all amplitude information is related to position information, the tower and turntable can be moved to the worst-case locations for a final signal measurement using a detector called out in the regulation (i.e., quasi-peak or average). This approach results in tremendous time savings, because the tower and turntable movement is drastically reduced without sacrificing measurement accuracy or integrity.

SUMMARY

Many different factors determine the overall test time of radiated EMI compliance measurements. Some of them are related to the EUT itself, others to the test strategy chosen. The maximization procedure used for determining worst-case amplitudes is the major contributor to the measurement time, because it defines the movement sequence and mode of the positioners. The specifications of the antenna tower and turntable also impact the test time. Some of the factors mentioned are different in each test situation, and therefore a universally applicable number for the total measurement time cannot be determined. However, application software can be used to assist in choosing the right test strategy. Software can also reduce test time by providing algorithms like list comparisons or multiple-signal maximizations, which allow both efficiency and throughput goals to be achieved.

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