HAZARDS TO AVOID WITH AUTOMATED EMI TESTING

Automated EMI testing has gained popularity in the last year, more than ever before. Reasons for this surge in popularity include the availability of EMI receivers with enhanced automation capabilities, an increase in the power and flexibility of microcomputers used as controllers in the automated system, and an increase in the number of vendors producing data processing equipments for sale to the government. The growing number of vendors has increased the demand for high quality EMI testing services, which in turn, has increased the demand for qualified EMI technicians and engineers.

Automation of EMI testing can offset to some degree, the shortage of qualified, experienced test personnel. However, without precautions, the application of automation can cause subtle problems. The results are not subtle however; they are often gross testing inaccuracies.

Measurement inaccuracies include signal strength measurement errors due to the EMI receiver's insufficient digital voltmeter (DVM) bandwidth, unpredictable receiver overload (amplifier saturation) response, and calibration errors. Operator error is also an important consideration, such as inappropriate DVM gate time selection. These problems and pitfalls have been demonstrated in the laboratory by the author. Testing of any automated test system (ATS) is essential for a thorough understanding of the ATS. A thorough understanding is essential to insure high quality, accurate EMI testing.

WHAT IS AN AUTOMATED TESTING SYSTEM?

An Automated Testing System (ATS) consists of a computer, a controllable receiver, a mass storage device (i.e., disk or tape), a hardcopy and/or display device, a calibration source, and the software to control the equipment. A variety of computers or microprocessors (8, 16, and 32 bit) have been applied to custom systems and off-the-shelf systems. Controllable receivers are available from a surprisingly large number of manufacturers. ATS software repeatedly increases the receiver's frequency step-by-step, measures the signal level at each step, then calibrates and corrects the measurement, resulting in a visual or hardcopy display. The composite of the multitude of measurements is a frequency domain display of the emanation from the equipment under test.

The major operational difference between a manual testing system and an ATS is the degree of operator involvement in the measurement process. An ATS simply measures the peak value of whatever signal exists at a particular tuned frequency and bandwidth. These measurements occur (point-by-point) much faster than a manual measurement, resulting in a time savings. Each ATS measurement typically takes between 1 millisecond and 100 milliseconds (depending on the DVM gate time — discussed in detail later). A very complete spectrum measurement can be made during an ATS sweep due to the rapidity of each measurement. When using very narrow bandwidths, the ATS scan may take longer than a manual scan (over the same frequency span) since not as many points are typically measured with a manual scan. Such automated scans of fine resolution and high precision are extremely helpful to engineers engaged in emanation suppression. The automated scan can quickly show if the suppression of a particular emanation has resulted in a new emanation of some other frequency, or whether the design correction was completely effective. The available ATS's offer little or no signal analysis for information of received emanations. Signal analysis is at the very heart of EMI measurement science. Such analysis is still the domain of the experienced EMI technologist, using either manual equipment, or ATS in a manual control mode.

Once an automated frequency sweep is completed, experienced test personnel can manually examine frequencies of interest based on the peak signal results. Therefore, it becomes critical that these automated peak measurements are accurate. The possible hidden errors to this automated peak measurement are discussed here. The value added by these basic sweeps are apparent enough. Additional added features are the ATS ability to adjust a measurement with antenna correction factors, coaxial cable loss factors, and any other appropriate correction factor. The final plotted value can be compared automatically to the appropriate limits.

DIGITAL VOLTMETER BANDWIDTH

The typical ATS receiver uses an internal digital voltmeter (DVM) for peak measurements of the signal at the output of the detector. Between the RF input, and the DVM are various RF, IF, and video stages, each with different bandwidths. The IF bandwidth and sometimes the video bandwidth are selectable, but the DVM bandwidth is usually fixed. The DVM bandwidth must equal or exceed the receiver's widest video bandwidth, or peak signal levels will be filtered and measurement errors will occur when broadband signals are measured.

It is important for test operators to realize the importance of high-pass filtering. The DVM may be AC coupled or DC coupled. A DC coupled DVM allows measurement of CW signals where an AC coupled DVM only measures the modulation on a carrier frequency. This difference is important and a receiver should be chosen considering this parameter, depending on the type of testing intended.

OVERLOAD RESPONSE

An operator must continuously adjust a manual receiver's RF and/or IF gain to avoid the gain compression occurring when the receiver is overloaded. The effect of gain compression due to overload is present also with automated testing, but the computer and receiver must sense the overload and make corrections to decrease the system gain.

Overload response can be characterized for both continuous and impulsive signals. A continuous overload occurs when a carrier with or without modulation is applied at a signal level much higher (50-60dB) than the receiver's noise floor. As the ATS tuned frequency is swept from below to above the carrier frequency the ATS must correct for the overload, measure the level accurately, and resume low level (noise floor) measurements.

Impulsive signal overload can occur when a low duty-cycle impulse train is applied to the receiver's RF input port at levels significantly above the noise floor. The impulsive signal should be measured accurately for all bandwidths. The output display or plot should be a flat line for each bandwidth. The receiver must reliably indicate overload to the computer control system when gain compression occurs. A simple test can be performed by placing an ATS into a fixed-frequency mode. An increase in the input signal level into the overload area should be indicated by the receiver's overload indicator at a level corresponding to a compression of the IF output as monitored with an oscilloscope. When a 6dB, increase in input signal strength increases the IF output by less than 6dB, then an overload condition exists and should be announced to the computer. Some small amount of overload must exist before the receiver can detect it. Although the degree of overload in a properly designed receiver is small, it still must be considered as part of the overall system error budget.

CALIBRATION ACCURACY

Probably the most important source of error in any ATS is the DVM calibration error. This source of error does not exist with manual test systems, because signal substitution methods are used to measure signals. The DVM accuracy is affected by receiver warm-up time, stability, and by the DVM model used by the computer program. An ATS shares all of the conventional sources of error with manual systems, such as calibration generator errors, attenuator errors, and cable losses. A control program with some additional complexity can offset these errors to a first approximation, however.

The receiver warm-up time is an important parameter. If an automated calibration is performed at system turn-on time, the calibration will have significant error a short time later. Receiver warm-up time varies with manufacturers but may be in excess of an hour. ATS users should combine manufacturer's data with their own experiments to determine the necessary warm-up time.

The receiver stability (after warm-up) determines the length of time between system recalibration. Periodic checks of system accuracy are the only way to determine the calibration interval. The ATS must perform its self-recalibration often enough to meet the system accuracy requirement. If an overall system accuracy of ±2dB is required, then more frequent self-recalibration is required than if ±4dB system accuracy is required. Gradual receiver degeneration can be discovered by storing and reviewing error tables. A large difference in calibration factors between consecutive calibrations indicates such a problem and should be announced to the operator.

The model of the DVM must accurately represent the effect of an increase in voltage input to the DVM (detector output) versus the DVM output. Typically, DVM's are linear in the middle of their operating range but become non-linear at the low end of their operating range (due to receiver and DVM noise) and at the high end (due to amplifier saturation). Figure 1 shows a typical "S" curve DVM model. The high-end effects can be avoided by properly controlling attenuator or gain controls. This is a minor problem given proper overload sensing by the receiver.

At very low level signals, where most EMI measurements are performed the attenuator settings will be zero and the gain typically set to maximum in order to maximize system sensitivity. The DVM operating range will then lie along the lower portion of the "S" curve. Large errors (on the order of 15dB) can occur at low input levels if this significant non-linearity is not accounted for. A linear DVM model typically causes the ATS errors in the direction of higher measurements. Higher order models (multiple lines or polynomial expressions) plus multiple measurement averaging will reduce this error, but the averaging reduces effective measurement speed. The low-end portion of this "S" curve changes as a function of receiver bandwidth and frequency. Care must therefore be taken to insure a valid DVM model for all bandwidths and frequencies, not at just one bandwidth/frequency combination. The insertion of a logarithmic amplifier before the DVM will reduce the error of using a linear DVM model. Unfortunately, not all receivers are available with this feature.

DVM GATE TIME

The DVM gate time (sometimes called the "DVM time constant") is the time during which the DVM peak detector measures the signal. Many automated receivers allow the gate time to be varied by the operator. Gate time is an important and difficult parameter to control. The gate time must be longer than the period of the signal to be measured; but too long a gate time will cause higher noise floor levels and longer sweeps. The shortest gate time possible should be selected, dependent on the signal repetition rate (period), to insure the shortest overall sweep time. Too short a gate time will result in incorrect measurements and possibly missed emanations. The DVM gate time must remain selectable by the operator, but care must be taken when selecting the gate time.

Other DVM gate parameters may result in unexpected measurements. Some current receivers require up to 20 signal periods within a gate time for proper measurement, rather than the one signal period per gate time as would be expected. The "effective" gate time should therefore be understood by the operator.

TUNED FREQUENCY STEP SIZE

An EMI test operator must ensure a receiver's frequency is not varied too rapidly, as this would result in skipped frequencies. This is true for both manual and ATS. The computer software must ensure the frequency of the receiver is stepped at less than the selected bandwidth (typically .7 to .8 times the bandwidth) to insure complete frequency spectrum coverage.

INSTANTANEOUS DYNAMIC RANGE

Instantaneous dynamic range is the linear operating range of an ATS with fixed gains and attenuator setting values. Although instantaneous dynamic range does not affect system accuracy, it does affect the number of times

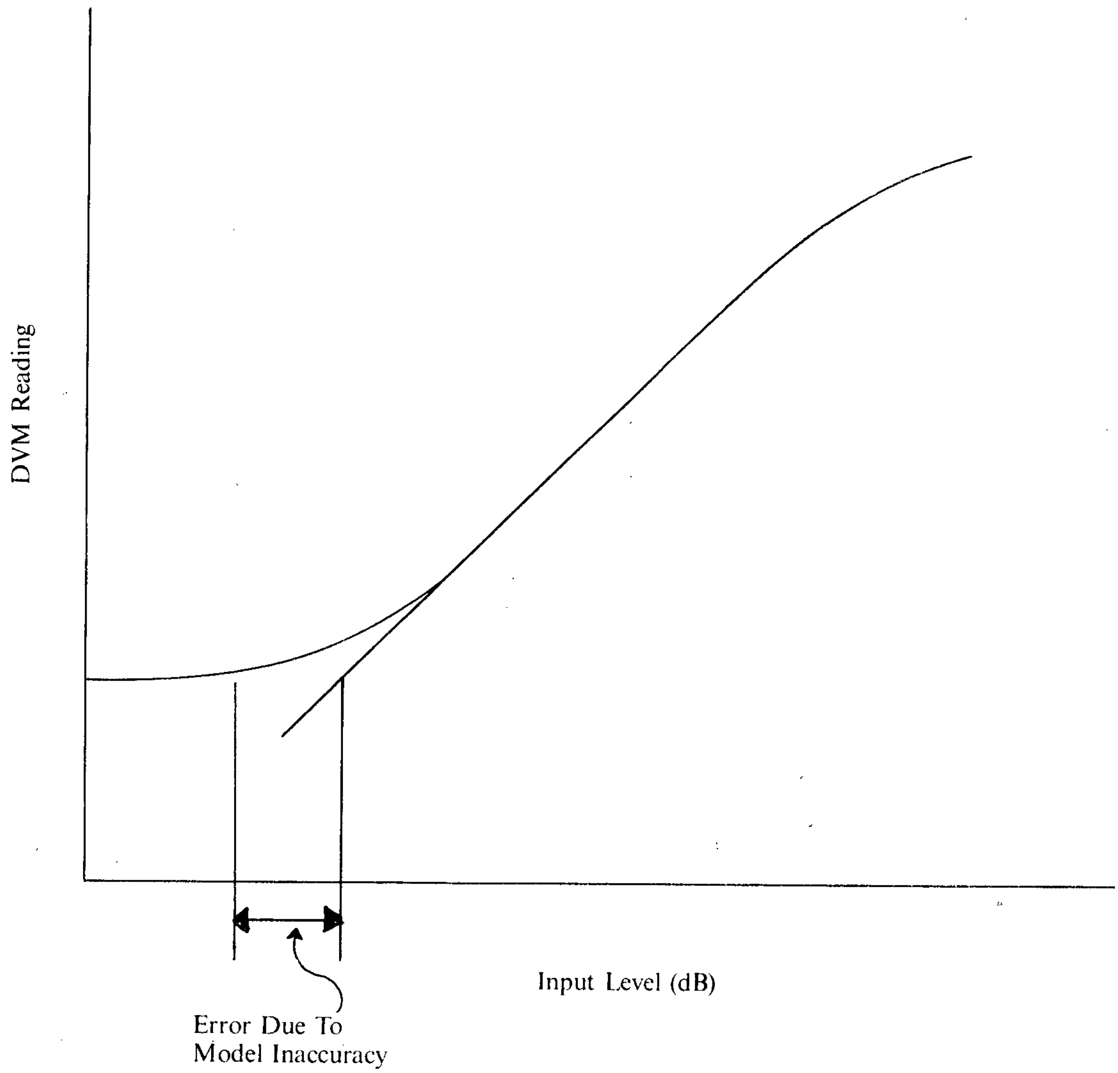

Figure 1. Generic DVM Input/Output Response.

it is necessary to change an attenuator value (or gain value). Each change requires extra time and affects the overall sweep time. In general, the larger the instantaneous dynamic range, the faster a sweep will be performed.

LIMITS

An automated system's usefulness is increased if the test limits are displayed on the scan plots. Since these limits may be classified, the disk used for data storage and any hardcopy plots may need to be stored in accordance with specific Government regulations. The computer system manager, when processing classified information, has an EMI requirement to consider. Managers and system managers should consult with the local security officer to identify the appropriate requirements.

SUMMARY

There are many inherent pitfalls to consider and avoid when changing from manual testing to automated testing. The DVM bandwidth, gate time, software model, the receiver's overload response, the system's calibration accuracy, and the incremental frequency step size must all be considered, evaluated, and understood. However, these pitfalls do not overshadow the benefits of automated testing. The user should be aware of these potential pitfalls before purchasing an ATS, or before developing an ATS for his own use. Manufacturers should perform and document tests which identify their system's behavior in the described critical areas.

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