Accuracy Considerations for Automated EMI Measurements

The accuracy of EMI measurements made with automated systems is dependent on the method and the precision of the technique.

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INTRODUCTION

One objective relative to all types of measurements is to improve the measurement accuracy by increasing the degree of precision. Accuracy is defined as conformity to true value. Precision is defined as the degree of care and refinement in making a measurement.[1] This article will describe a number of measurement procedures relating to EMI signal measurements using spectrum analyzers to help improve accuracy. Most of the procedures discussed can be applied manually with other measurement systems and will be of general interest to EMC engineers.

There is a general misconception that the use of automated measurement systems will result in a reduction in the accuracy of measured data. As in all types of measurements, the accuracy depends primarily on the measurement method and the precision of the measurement, and not on whether the measurement process is controlled manually or automatically.

Because of the requirements of ANSI C63.4-1991 to optimize certain parameters for each individual signal, a multi-step measurement process is required. Such a multi-step measurement process also provides an opportunity to utilize accuracy-enhancing procedures that ensure both frequency and amplitude accuracy. The use of these accuracy-enhancing procedures in the EMI Commercial Measurement Program, EMICMP, has demonstrated the validity of this assumption.[2,3,4] These accuracy-enhancing procedures can be used manually or incorporated into other measurement systems.

OVERLOAD CONDITIONS

The multi-step measurement process described here applies to measurements performed with a spectrum analyzer as the basic measurement instrument. Spectrum analyzers, because of a lack of preselection, may in some situations be subject to front end, mixer overload. This condition may, in turn, cause either excessive harmonic responses in the spectrum analyzer or amplitude errors or both.

Three signal types can cause input overload. The most obvious type is large, out-of-band signals that are outside the frequency span of the spectrum analyzer. The second type is impulsive, or signals with extremely fast rise times, which may be clipped by the spectrum analyzer mixer. The third type is broadband noise. The deleterious effects of these types of signals can be minimized to acceptable levels by use of a preselector. The typical preselector has a tunable bandwidth greater than the spectrum analyzer's bandwidth that tracks with the spectrum analyzer tuned frequency. Unfortunately, this type of preselector is often as expensive as the spectrum analyzer. Another option is to use bandpass filters for each measurement band. This approach is much less expensive and will also minimize the deleterious effects of these signals.

A procedure to check in-band overload within the frequency span is essential. This procedure is based on the concept that the signal being measured will have an amplitude error within the error limits of the RF attenuator when a specified amount of attenuation is removed. The RF attenuator must be changed by at least 10 dB. If the error is greater than the attenuator error, then it is reasonable to assume that any excessive error is caused by an overload condition. When this situation occurs, it may be possible to add fixed attenuation, in increments of 3 dB, external to the spectrum analyzer, and gain more sensitivity than would be possible by selecting the 10-dB incremental setting of the spectrum analyzer attenuator. Before any measurement is made, the input to the measurement receiver, be it a spectrum analyzer or EMI receiver, must be at an optimum level. There is no way to compensate for, or predict, the errors caused by the input overload.

*See Card on Page 82.

One type of error which has received little attention, except in articles written by this author, is that of omission. An error of omission is the inability of the measurement system to detect a signal. [2,4] The most relevant example is the measurement of radiated signals in which there are three random variables: signal waveform, signal cancellation due to a reflected wave, and the equipment under test (EUT) radiation pattern. For a signal to be detected under such conditions, the value of all three of the random variables must be coincident, and the measurement receiver must be tuned to the signal's frequency during the period of coincidence. Reference 2 provides a detailed discussion of this subject.

The preceding procedures ensure that the input signal is at an optimum level and that the measurement receiver has a high probability of signal detection. The next step is to assure the maximization of the measurement precision to improve accuracy.

FREQUENCY AND AMPLITUDE

The individual signals to be measured have two attributes: frequency and amplitude. The least critical attribute is frequency, mainly because it is rather difficult to define. Nearly all signals are modulated and thus have a spectrum; consequently, the carrier frequency concept has little relevance. The generally accepted definition is the frequency at the point of peak amplitude. When a spectrum analyzer is used, the frequency accuracy is dependent on the frequency span in which the signal is measured. When the peak value of the MAX HOLD trace of the signal's spectrum is measured in a very narrow frequency span, the optimum frequency accuracy is ensured.

Amplitude, the more important attribute, is considerably more complex, particularly for radiated measurements. It is always necessary to make a complete error analysis, especially in the case of radiated measurements.[5,6] This error analysis should include site errors, antenna calibration, cable voltage standing wave ratio (VSWR) errors and measurement receiver errors. The root mean square (rms) value of all three errors should then be used as a guard band below the limit. The allowable limits of many of these types of errors are defined by the regulations, but the total of several of these types of errors soon becomes excessive, even when the individual errors are within the allowable range specified by the regulations. For example, site errors of ±4 dB, antenna factor errors of ±1 dB and receiver errors of ±2 dB are allowable, but could result in a total error of more than 6 dB. When the manufacturer is legally responsible to ensure compliance, this subject cannot be viewed lightly. Furthermore, this example assumes that everything is in perfect order. If a single connector is found to be partially unsecured, the value of an entire test is nullified. If the situation is not detected, the results could be catastrophic.

Because reducing measurement error may be impossible, extremely expensive, or very time-consuming, it is necessary to find error types that can be reduced in a practical manner. The receiver error is one such type. Manufacturers of measurement receivers specify an overall amplitude error of ±1 or ±2 dB. A detailed investigation of the components of the overall receiver error reveals the larger contributing components. Each error-contributing component is then studied to determine methods to improve measurement accuracy.

Every spectrum analyzer has some type of calibration procedure. The spectrum analyzer used for this analysis was chosen for a number of reasons, one of which was the four-level calibration scheme and the fact that the calibration can be initiated via the program control without having to connect any cables to make any adjustments. These features provide the opportunity to include an automatic calibration procedure into the measurement cycles as part of the program. A choice of four levels of calibration or the choice of not calibrating is provided. The use of this procedure ensures a current state of calibration.

MEASUREMENT PROCESS

As previously mentioned, changing the RF attenuation can change the spectrum analyzer performance due to overload conditions, and the exactness of each 10-dB step of attenuation will contribute slightly to the overall amplitude error. To reduce these errors, the RF attenuation is set to a manual mode, which will not change after the initial level has been set to optimize the input signal level. Thus during the measurement process the RF attenuator will not change. Moreover, for each RF attenuation setting, a measurement amplitude range is assigned by the program. The amplitude range data is taken from the spectrum analyzer manual and specifies both upper and lower amplitude limits that ensure minimum amplitude error. When the RF attenuator is set, the reference level will always remain in this optimum amplitude range.

The largest source of amplitude error is the spectrum analyzer's log amplifier. The reference level, which is the top of the display, corresponds to both the log and the linear value. The amplitude measurement error for the log amplifier increases with the dB distance below the reference level. In the second part of the measurement process, where each signal is measured individually using both a peak and an average detector, there is an amplitude criterion to identify the signal. When this amplitude criterion is satisfied, the log scale is changed from 10 dB per division to 5 dB per division, and the reference level is adjusted so that the signal is within 3 dB of the reference level. This change in log scale reduces the log error by half in terms of dB, and placing the signal within 3 dB of the reference level at the time of the actual measurement further improves the measurement accuracy.

Quasi-peak (QP) measurements are required by most commercial EMC regulations, and this type of measurement can be performed in the third part of the measurement process. In the multi-step measurement process, the peak amplitude of the signal is known prior to the measurement of the signal's QP value. This information is extremely valuable since the spectrum analyzer measurement range can now be set prior to the actual signal measurement, and measurement error due to the limited dynamic range of the linear amplifier required for QP measurements will not cause any problem. The required measurement range is, in fact, defined by the peak-to-QP ratio of the signal being measured. Since signals seldom have peak-to-QP ratios greater than 20 dB, the spectrum analyzer's 40 dB measurement range is more than adequate when the reference level is set to the value of the signal's peak. The measurement error will increase, as previously mentioned, as a function of the measured value below the reference level, but the probability of the signal's QP value exceeding the limit will decrease as a function of the level below the reference level, thus reducing the significance of any error.

Since the signal's frequency is also known prior to the QP measurement, the spectrum analyzer can be set to the zero span mode and the center frequency can be set to that of the signal being measured during the QP measurement.

In most cases, the methods described above to improve measurement accuracy could be performed manually, but the effort required would make a manual implementation unrealistic. These accuracy-enhancing methods are an integral part of the EMICMP and are thus performed automatically and in a manner transparent to the operator.

CONCLUSION

Tests of the effectiveness of these amplitude enhancing procedures have shown an increase in accuracy from the selected spectrum analyzer amplitude error of ±1 dB to approximately ±0.5 dB. This is a significant error reduction and it is gained with no additional operator effort and without posing any disadvantages.

These types of accuracy-enhancing methods are ideally suited for automated EMI measurements and will, when so implemented, result in significantly improved measurement accuracy over conventional methods.

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