# Data Reduction Techniques in Automated EMI Emission Measurement Systems

MANFRED STECHER
Rohde & Schwarz, Munich, Germany

## INTRODUCTION

Data reduction is a process that becomes necessary when the amount of data produced by a system is too voluminous to provide an easy overview. Data reduction is vital for the man-machine interface to be effective. In EMI systems it is mainly the test report that provides essential information at a glance. Information is provided by graphic printouts of the emission spectrum. However, the test report should also contain essential information, such as numeric data, and include identification of emission peaks and printouts.

It is not only the task of presenting measurement results that calls for data reduction. The measurement procedure itself also requires data reduction to achieve acceptable measurement times. Data reduction techniques are available with EMI test receivers and EMI measurement software. However, instead of being a software description with many different aspects of human interface, measurement procedures and reporting of results, this article focuses on the important subject of data reduction.

> *Data reduction techniques are available with EMI test receivers and EMI measurement software.*

## PEAK AND QUASI-PEAK DETECTORS

The spectrum of an EUT may consist of various types of narrow and broadband signals. Continuous wave (cw) signals are one extreme. Since, by definition, they do not vary with time, their measurement can be accomplished using the peak detector with a settling time of 2/BW per bandwidth step. This results in sweep/scan times of 0.73 s for Band B (0.15 to 30 MHz; BW = 9 kHz) and 0.135 s for Bands C and D (30 to 1000 MHz; BW = 120 kHz). However, such a short scan time will be insufficient to capture both narrowband signals varying with time and broadband signals. Assume that the spectrum contains broadband components with a pulse repetition frequency of 60 Hz, the line frequency in the U.S. This means that the spectrum is only present approximately every 17 ms. Correct display of the pulsed spectrum is only achieved when the receiver dwells on each frequency long enough for at least one event to fall within the reception bandwidth. These considerations result in the minimum scan times with the peak detector shown in Table 1.

For the quasi-peak detector, the worst cases that must be considered are narrowband signals. In these cases, the quasi-peak detector requires a high settling time of approximately 1 s for each frequency step. When auto-ranging with the quasi-peak detector is required, this settling time may even be higher. In cases where pure broadband emissions are to be measured, the settling time will be low and the number of frequency steps required to scan the emission spectrum can be substantially lower, since the steps can be wider than the measurement bandwidth. Table 2 gives minimum scan times for narrowband emissions.

## AVERAGE DETECTORS

International and European standards call for the measurement of conducted emissions (RFI voltage or RFI power using an absorbing clamp) using quasi-peak and average detectors. Again, one may as-

| Frequency Range | Bandwidth | Step Size | Number of Steps | Minimum Sweep Time |
|---|---|---|---|---|
| 0.15 to 30 MHz | 9 kHz | 4.5 kHz | 6633 | 112.8 s ≈ 2 min. |
| 30 to 1000 MHz | 120 kHz | 60 kHz | 15500 | 264 s ≈ 4½ min. |

*Table 1. Minimum Scan Times for Correct Measurement of a 60-Hz Impulse Signal Using the Peak Dectector.*

*Continued on page 218*

sume that the characteristcs of the emission to be measured determine the measurement time of the average detector. This is true for a correct measurement of narrowband signals. A narrowband signal may vary with time and the result should be equal to the maximum output of a lowpass filter with a time constant equal to that of the CISPR meter time constant.[1] This is a practical requirement, though not explicitly cited in CISPR 16-1.

For the measurement of broadband signals, however, the average indication need only be correct to confirm that the limit for the average detector is not exceeded where the limit for the quasi-peak detector is not exceeded. (To fail the requirement, the violation of one limit — quasi-peak or average — is sufficient; to pass the requirement, both quasi-peak and average must be below the limit.) This can be seen from the weighting curves of the quasi-peak and average detectors on Figure 1, taking the differences between the limits for the quasi-peak and average detectors into account. The limits for the average detector are 10 dB lower for residential, commercial and light industry environments and 13 dB lower for industrial environments compared to the quasi-peak limits. It is therefore sufficient to choose the time constant of the average detector such that the indication of the impulsive signal with a pulse repetition frequency lower than approximately 1.8 kHz is more than 15 dB below the peak value. This is the case when the time constant is greater than 1 ms. These data may help later when measurement times for prescan and final tests are discussed.

| Frequency Range | Bandwidth | Step Size | Number of Steps | Minimum Sweep Time |
|---|---|---|---|---|
| 0.15 to 30 MHz | 9 kHz | 4.5 kHz | 6633 | 6633 s ≈ 1 hr. 50 min. |
| 30 to 1000 MHz | 120 kHz | 60 kHz | 15500 | 15500 s ≈ 4 hrs. 18 min. |

***Table 2.*** *Minimum Scan Times for Correct Measurement of Narrowband Emissions Using the Quasi-Peak Dectector.*

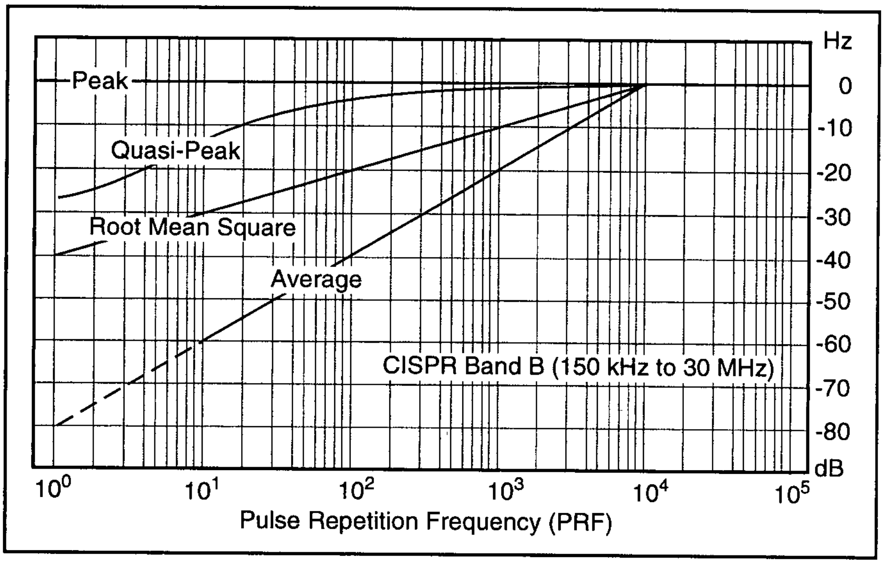


***Figure 1***. *Detector Responses of a Test Receiver for Impulse Disturbance.*

## PROCEDURES FOR AUTOMATED EMISSION MEASUREMENTS

When comparing the values for the minimum scan times of Table 2 with the values of Table 1, the idea of replacing quasi-peak measurements with peak measurements is reasonable. Figure 1 shows that the peak measurement result will be higher than or equal to both the quasi-peak and the average measurements. This means that if an emission stays below all limits in the peak mode, the EUT complies in any case. The only restriction is that the measurement time for the peak detector must be long enough to capture the maximum event. If, however, the peak indication exceeds the average or the quasi-peak limit, average or quasi-peak measurements have to be made for a final decision (Figure 2).

Table 2 is not complete: measurements of conducted emissions have to be made on several lines of the mains port, and measurements of radiated emissions have to be made using antenna height scanning at two antenna polarizations and at various EUT azimuths. The peak detector may be used for a pre-scan with an acceptable measurement time to extract the critical frequencies with the aid of an efficient data reduction procedure. The results of this pre-scan and data reduction can be used for a final test with the proper detector and the full measurement time on the order of 1 s.

The final result not only includes measurements with the detectors as prescribed in the standards, but may also include a maximization procedure using the peak detector again. The maximization technique involves searching for the mains line of maximum emission, varying an absorbing clamp, and varying the antenna height, polarization and EUT azimuth for cases of radiated emissions.

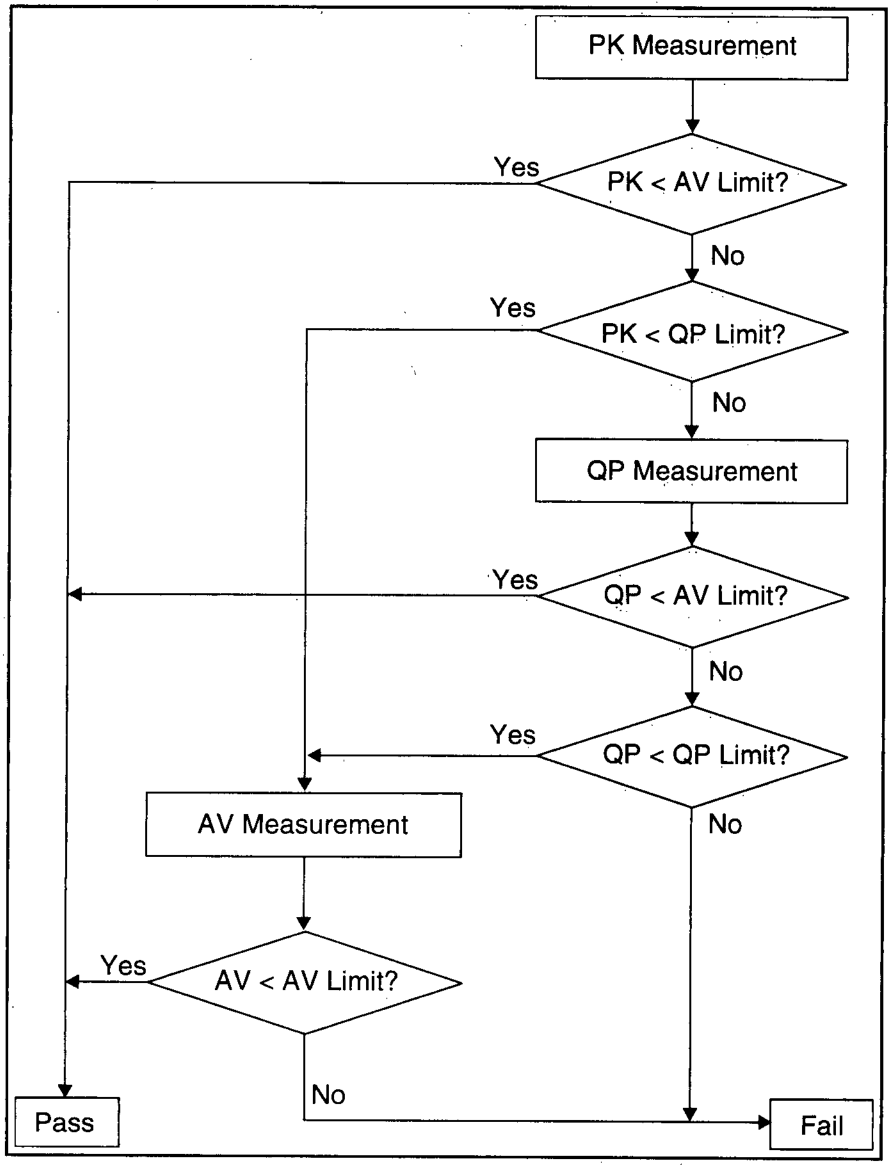


***Figure 2**. Decision Tree in Accordance with CISPR/A (Secretariat) 149.*

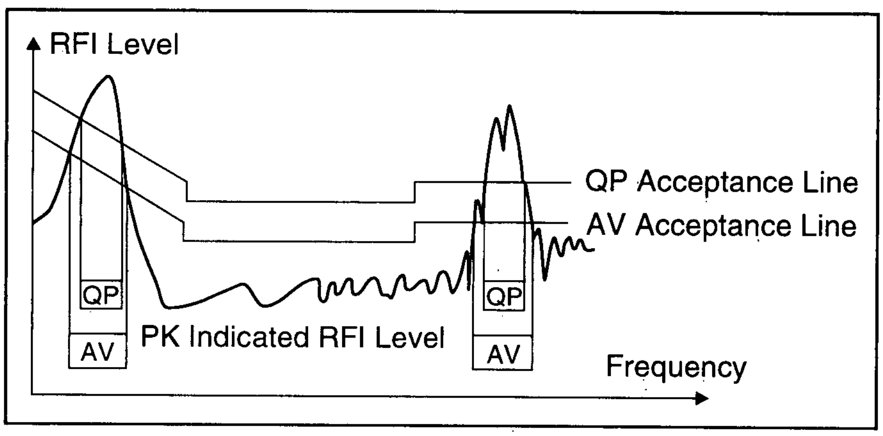


***Figure 3**. Data Reduction Technique Using the Acceptance Line Method. Note: Final quasi-peak and average detection show the peak level above the quasi-peak and average acceptance lines. The acceptance lines selected should be below the quasi-peak and average limits by a safety margin of several dBs.*

## CISPR METHOD INCLUDING ACCEPTANCE LINE PRINCIPLE

CISPR/A (Secretariat) 149[2] gives a decision tree for measurements at every frequency, which is the first step to data reduction (Figure 2). This method has been used for many years and has been extended by using an acceptance margin below the quasi-peak and average limits. This provides a safety margin against measurement uncertainty and EUT sample variations.[3] As can be seen from Figure 3, the disadvantage of the method is that it does not prevent the measurement system from executing thousands of quasi-peak measurements where the quasi-peak acceptance line is exceeded by a broadband spectrum. Therefore, another procedure is recommended.

## SUBRANGE MAXIMA TECHNIQUE OF DATA REDUCTION

To overcome the problem with the acceptance line technique that is described above, a subrange maxima technique has been developed.[4] This method divides the whole frequency range into a user-selectable number of subranges. During a pre-scan with a peak detector, the maximum level in each subrange is determined.

When the subrange maxima technique is compared with the acceptance line method, the user may be concerned that essential components of the emission spectrum have been overlooked. The following points address these concerns.

- There may be narrowband components within the emission spectrum, where the quasi-peak is higher than a (broadband) subrange maximum. For this case, narrowband emissions will be detected using the average detector.
- There could be a superimposition of a high repetition rate impulse signal of lower amplitude and of a low repetition rate impulse signal of higher amplitude. In this case, the quasi-peak of the high

repetition rate signal may be higher than that of the low repetition rate. The probability of such an event is negligible.

When the peak detector is used for an overview, narrowband signals above the limit for the average detector may indeed be masked by broadband signals below the quasi-peak limit. It is insufficient to measure the average value just at the subrange maximum found with the peak detector.

CISPR officials intended to avoid this kind of masking when standards using limits for different detectors were introduced. Therefore, it is vital to use the average detector during the pre-scan, at least where the peak detector exceeds the limit for the average detector, and to determine the subrange maxima with the peak and average detectors. When the measurement time of the peak detector is greater than or equal to the minimum measurement time for the average detector to prevent masking of narrowband signals, the use of the average detector in parallel with the peak detector does not substantially extend the measurement time for the peak detector.

***The subrange maxima technique divides the whole frequency range into a user-selectable number of subranges.***

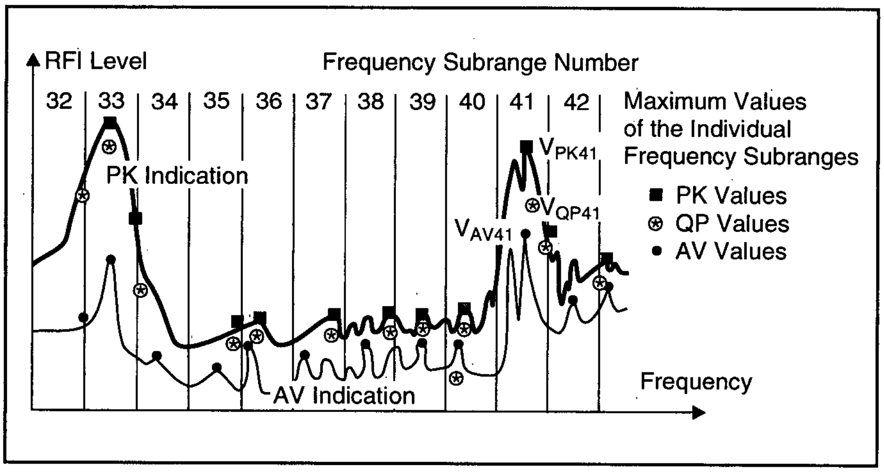


***Figure 4**. Data Reduction Using the Subrange Maxima Technique.*

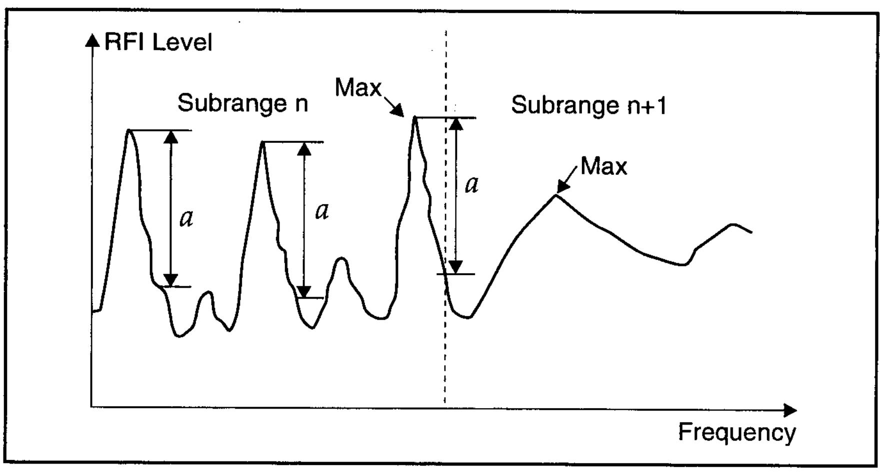


***Figure 5**. Data Reduction by Selecting Emission Peaks Using a Selection Criterion* a.

This method was introduced in 1991 and has been well accepted by many EMC test labs. In test receivers, selection is possible between 8 and 400 subranges. Experience has shown that for conducted emission measurements, 8 subranges are sufficient; 16 or 25 subranges may be used. This method has been intensively tested for conducted emission measurements and provides a total measurement, including pre-scan, data reduction and final test, in minutes.[4] For radiated emission measurements, the reduction in measurement time compared to the times shown in Table 2 is dramatic.

## DATA REDUCTION BY SELECTING EMISSION PEAKS

Some users of the subrange maxima technique may have reservations about using just one subrange maximum, which could be close in amplitude and frequency to other emission peaks. For these cases, an additional technique has been developed.

A quantity $a$ can be defined that sets the criterion for an emission peak, which should be high enough above the emission in the immediate vicinity (Figure 5). The criterion has been defined so that in subrange n, two additional peaks are found. In subrange n+1 only the subrange maximum is identified as the peak for final measurement. By selecting a very high $a$ (e.g., 100 dB), the result will be identical with the subrange maxima technique described above. When the parameter $a$ is reasonably chosen (which is always left to the user), this method will provide a useful addition to the subrange maxima technique.

## AMBIENT EXCLUSION

Ambient exclusion is another procedure involved during data reduction. Ambients cause severe problems, especially to radiated emission tests. It is therefore necessary to avoid measurements at frequencies where ambients are close to or above the emission limits. This is usually accomplished by a list of ambients where the system avoids making final measurements. It is normally not possible to measure emissions automatically when they are masked by ambients. Explanations for techniques for manual measurements are available.[5] They can be applied to computer-controlled measurements when manual interaction is possible.

## CONCLUSION

Data reduction in EMI emission measurements is a practical requirement both for providing useful test reports and for reducing the measurement time. The subrange maxima technique represents an important step forward. Further refinement is provided by the peak reduction method. These techniques can be applied in most testing situations. Exceptions are when electronic emissions are unstable and short measurement times for the peak detector cannot be used. In these cases, manual interaction is recommended and flexible measurement systems can be used to find critical frequencies within acceptable times.

## REFERENCES

1. CISPR 16-1993: CISPR Specification for Radio Disturbance and Immunity Measurement Apparatus and Measurement Methods.

2. CISPR/A (Secretariat) 149/8.94 Draft proposed amendment to CISPR 16-2 (Methods of Disturbance and Immunity Measurements), to be published.

3. Stecher, M., "Accelerated and Easier EMI Tests," Proceedings of the International Symposium on EMC, Zurich, Switzerland, March 1989.

4. Mueller, K. O., "Speeding up Quasi-Peak Weighting EMI Tests," Proceedings of the IEEE Symposium on EMC, Cherry Hill, NJ, August 1991.

5. Stecher, M., "Field-strength Measurements in the Presence of Ambients," presented at the 3rd EMC Seminar, June 1-2, 1995, Lisbon, Portugal.

***MANFRED STECHER** received the Dipl.Ing. degree in electrical engineering in 1967 from the Technical University of Munich. In 1967 he joined Rohde & Schwarz, Munich. At that time, he was engaged in the development of EMI and signal monitoring test receivers and field strength meters. In 1980, he became the group leader responsible for the development of test receivers and accessories, including hardware and software. Since 1985 he has worked with various German national standardizing committees on EMI instrumentation and control. He has been a member of CISPR Subcommittee A and a contributor to ITU-R study groups on radio monitoring since 1990. Fax 49-89-4129-3055.*