Measure the real impulse bandwidth

With the help of a pulse generator, designers can characterize receiver pulse response more accurately.

EMI characterization requires the exact analysis of pulsed signals. Government and international standards committees recognize this and are making changes to their specifications regarding EMI. But manufacturers of spectrum analyzers and receivers have not necessarily followed suit. In most cases, these manufacturers use the traditional but inadequate 3-dB and 6-dB bandwidth specifications. It behooves the design engineer, therefore, to understand how to determine the correct impulse bandwidth required for EMI pulsed-signal analysis.

A clear definition of impulse bandwidth will provide the necessary characterization of analyzer or receiver filters. Understanding new regulations that require the use of receivers with specific impulse bandwidths for MIL-STD EMI measurements will also help to clarify the characterization of filters vis-a-vis the impulse bandwidths. Additionally, a straightforward technique for measuring the impulse bandwidth will allow engineers to characterize their own equipment.

In order to establish the clear definition, the operation of a filter must be thoroughly understood. If a filter's bandwidth were to be made wider, more spectral components would be passed by the filter and the output amplitude would increase. The filter's bandwidth may be increased until it passes the entire signal spectrum (Fig. 1), at which point the amplitude increases no further. If a rectangular pulse is put through a bandlimiting filter the resulting output is lower in amplitude and longer in time.

The impulse bandwidth of the filter is defined (Fig. 2) as

$$BW_{imp} = V_{out} / (2 * V_{in} * \tau * G)$$

where

V_{out} = the output voltage,
V_{in} = the input voltage,
τ = the width of the input pulse, and
G = the gain of the filter.

The impulse bandwidth of a filter depends on the 3-dB or 6-dB bandwidth, the shape factor, and the phase

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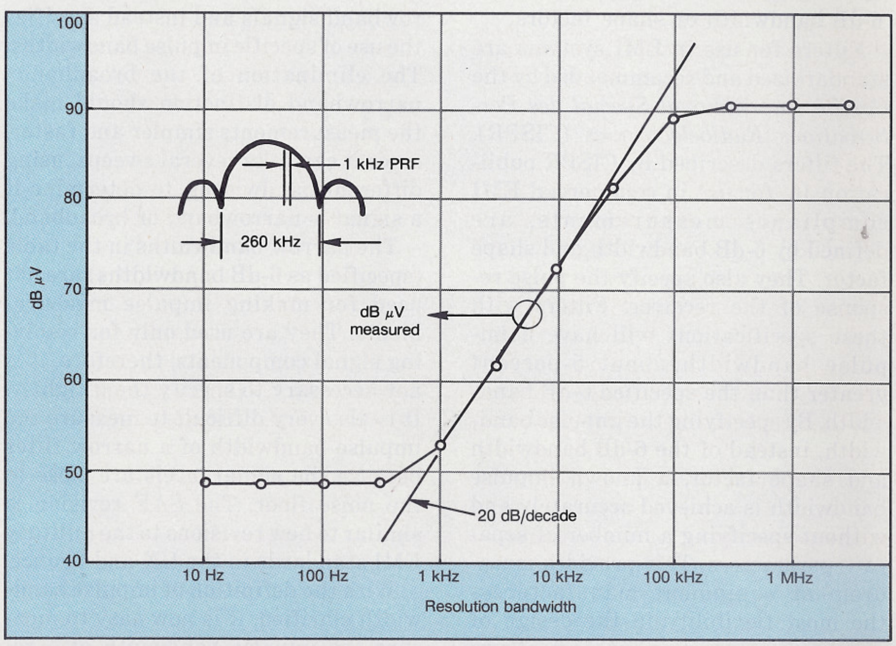

1. A signal of repetitive RF impulses *will give greatly different amplitude readings depending on the receiver resolution bandwidth used.*

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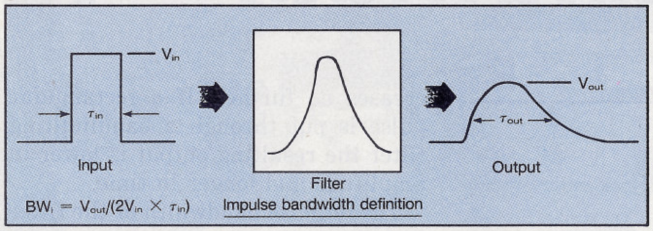
The SAE's proposed bandwidth classifications

Bandwidth	Tuned frequency
1 MHz ± 10-percent impulse bandwidth	1 GHz - 18 GHz
100 kHz ± 10-percent impulse bandwidth	30 MHz - 1 GHz
10 kHz ± 10-percent impulse bandwidth	1 MHz - 30 MHz
1 ± 10-percent impulse bandwidth	10 kHz - 1 MHz
200 Hz or less 6-dB bandwidth	500 Hz - 10 kHz
20 Hz or less 6-dB bandwidth	100 Hz - 500 Hz



2. Definition of the impulse bandwidth *is based on the amplitude and width of the input pulse, and the amplitude of the output pulse. Although a square pulse is used as an example, any shaped input pulse may exist. In the case of nonsquare-wave pulses, the area under the pulse curve is significant.*

response of the filter. Two filters with the same 6-dB bandwidth and different shape factors will have different impulse bandwidths and different responses to a broadband signal. Two filters with the same impulse bandwidth will have the same response to any coherent signal, broadband or narrowband, regardless of differences in 6-dB bandwidth or shape factors.

Filters for use in EMI systems are standardized and recommended by the *Comité International Special des Perturbations Radioelectriques* (CISPR). The filters described by CISPR publication 16, for use in commercial EMI compliance measurements, are defined by 6-dB bandwidth and shape factor. They also specify the pulse response of the receiver. Filters with these specifications will have a impulse bandwidth about 5-percent greater than the specified 6-dB bandwidth. By specifying the impulse bandwidth, instead of the 6-dB bandwidth and shape factor, a known impulse bandwidth is achieved accurately and without specifying a number of separate parameters. This provides measurement equipment manufacturers the most flexibility in the design of measurement equipment and allows the most accurate comparison of measurements made with different measurement equipment.

Concern for standard comparison of different measurement equipment is evinced also by the Society of Automotive Engineers' (SAE) proposed revision to US MIL STD 462. The proposed revision (see table) eliminates all references to broadband and narrowband signals and instead specifies the use of specific impulse bandwidths. The elimination of the broadband/narrowband distinction should make the measurements simpler and faster, since it can take several sweeps, using different bandwidths, to determine if a signal is narrowband or broadband.

The narrow bandwidths in the table (specified as 6-dB bandwidths) are not used for making impulse measurements. They are used only for resolving signal components; therefore, it is not necessary to specify them tightly. It is also very difficult to measure the impulse bandwidth of a narrow filter because the signal levels are close to the noise floor. The SAE revision is similar to new revisions to the military EMI standards in the UK and France.

With the definition of impulse bandwidth clarified, it is now easy to measure the impulse bandwidth of a receiver or spectrum analyzer. The only equipment required is a pulse generator. The pulse generator must have an accurately known and settable repetition frequency, and the pulse shape must remain constant as the repetition frequency is changed. It is not necessary to know the actual shape of the pulse.

Once the generator is available and before the actual procedure is implemented, several precautions must be taken. First, the analyzer must be in the same display mode (linear or log) as when used to make measurements. When using the log display mode, the user should realize that the log mode distorts the filter pulse response and changes the impulse bandwidth. MIL-STD EMI testing is usually done in log 10 dB/division, so the filter bandwidth should be measured in log 10 dB/division.

Secondly, the analyzer must have enough input attenuation to prevent overloading from the pulse generator. The adequacy of the input attenuation can be tested by changing the input attenuation level and making sure the displayed signal level changes by the same amount. Finally, the video bandwidth must be at least 10 times as wide as the resolution bandwidth to ensure that it does not introduce any averaging.

When all of the precautions have been taken, the procedure for measuring the impulse bandwidth of a filter is easily accomplished in two steps:

Step 1: The pulse generator is set to a pulse repetition rate (PRF) much higher than the analyzer resolution bandwidth. The amplitude of the signal is measured (V_1) with the analyzer center frequency tuned to the pulse repetition frequency or a multiple thereof. Only one spectral line will be contained by the resolution bandwidth filter and the amplitude $V_1 = 2 \times A \times PRF$ (from the Fourier analysis of a pulse), where A is the area of the pulse.

Step 2: The pulse repetition rate is changed to a rate much less than the analyzer resolution bandwidth. The pulse shape must remain constant. The amplitude of the signal is measured again (V_2), at the same tuned frequency. Several spectral lines will be contained by the filter and $V_2 = 2 \times$

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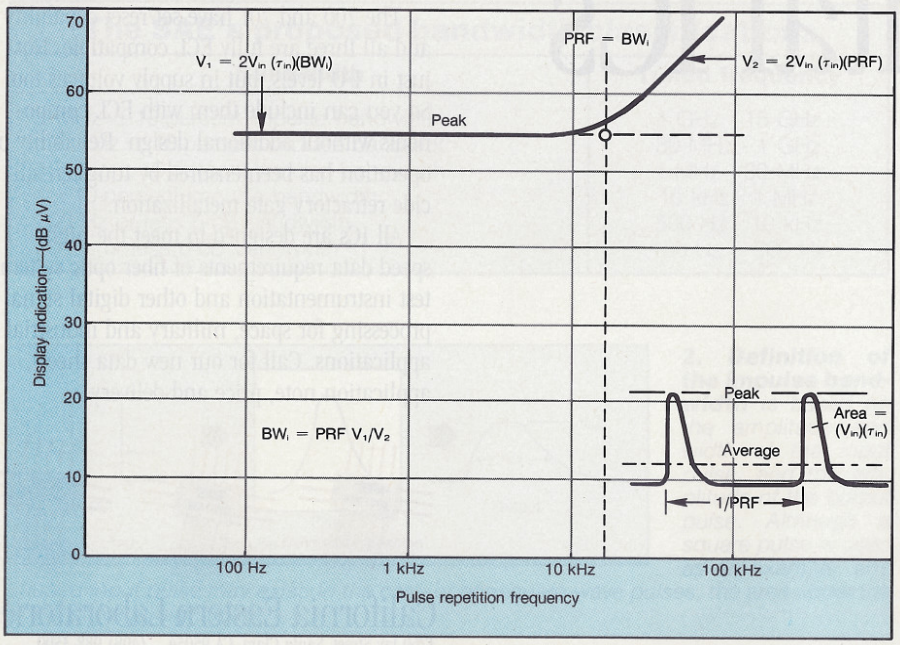
Impulse bandwidth *(continued from p. 94)*



3. By knowing the approximate impulse bandwidth *and the pulse repetition frequency of the pulse generator, the test engineer can make voltage measurements on either side of the bandwidth and can calculate the exact impuse bandwidth.*

$A \times BW_i$. The equations for V_1 and V_2 are combined to solve for the impulse bandwidth, and the term specifying the area of the input pulse (difficult to know accurately) drops out, leaving $BW_i = PRF \times (V_1/V_2)$ (Fig. 3).

The pulse width must be set narrow enough to give a flat frequency spectrum within the resolution bandwidth filter in Step 2 of the measurement. The pulse width must also be wide enough that the signal will be sufficiently above of the noise floor. If the spectrum analyzer or receiver cannot tune low enough in frequency to make the measurement directly, then a mixer can be used to move the pulse spectrum up to any convenient center frequency. ●●

References

1. Siegfried Linkwitz, "Discriminating between narrowband and broadband EMI using a spectrum analyzer," Sixth Symposium and Technical Exhibition on Electromagnetic Compatibility, Zurich, Mar. 5-7, 1985.
2. IEEE Standard for the Measurement of Impulse Strength and Impulse Bandwidth, ANSI/IEEE Std 376-1975
3. "Recommended Measurement Practices and Procedures for EMC Testing," Society of Automotive Engineers' draft, Nov. 20, 1985