Application Note

Choose your Units!

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The Brüel & Kjær Signal Analyzer families Type 3550 and Type 2140 (with FFT options) allow you to choose the appropriate units to suit your measurement signal, be it deterministic, random or transient.

The frequency spectrum amplitude can be scaled in terms of:

- Root mean square (RMS) for deterministic signals
- Mean square, Power (PWR) for deterministic signals
- Power spectral density (PSD) for random signals
- Energy spectral density (ESD) for transients

The noise bandwidth ($B = \Delta f \times k$, where k depends of the choice of time window) and record length (T) selected for the measurement affect the amplitude scaling of the frequency spectra. The analyzers of the 3550 and 2140 families will automatically compensate for these factors if the correct scaling has been selected.

Deterministic signals

Stationary, deterministic signals are made up entirely of sine waves at discrete frequencies. The resolution of the frequency analysis is determined by the filter bandwidth used in the analysis. The filter bandwidth should enable the analyzer to distinguish between the two most closely spaced frequency components. This means that there should only be one sinusoid in each filter passband at any one time. If this is the case, then the power transmitted by the filter is independent of the bandwidth. Therefore, the averaged frequency spectrum of a deterministic signal should be scaled in terms of root mean square (RMS) or mean square, power (PWR).

Fig. 1 shows the time record and frequency spectrum for a deterministic signal. The "TOTAL" field (lower cursor setup) gives the total power or total RMS of the displayed function. Alternatively the delta cursor can be

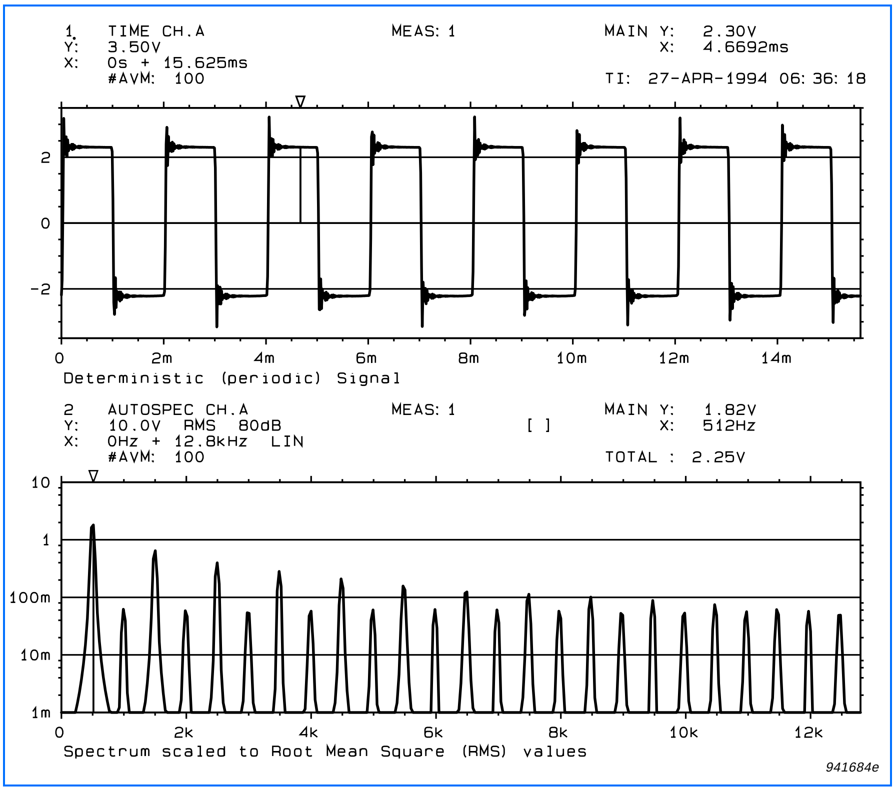

Fig. 1 Time record and frequency spectrum for a stationary, deterministic signal. The frequency spectrum is scaled as the root mean square of the signal

used, in which case the "TOTAL" field gives the total power within the band selected by the delta cursor, and the "/TOTAL" field gives the fraction of the total power within the band selected using the delta cursor.

Each type of time-weighting function produces a different number of frequency lines in the filter bandwidth. This affects the magnitude of the power transmitted through the filter. But the analyzers of 3550 and 2140 families automatically scale the power spectrum according to the type of time-weighting function used. This ensures that the value of the power spectrum found, using the main or delta cursor, is correct and independent of the time-weighting function.

Random signals

Random signals have a spectrum which is continuously distributed with frequency. Consequently, there is a continuous frequency distribution within the filter passband. Accordingly, the power transmitted by the filter is dependent on the filter bandwidth, i.e. the resolution of the analyzer ($B = \Delta f \times k$). For a relatively flat spectrum, it is possible to remove the influence of the filter bandwidth by dividing the transmitted power by the filter bandwidth. This normalises the result to a mean square spectral density, often called the power spectral density (PSD) which is a measure of the power per unit bandwidth.

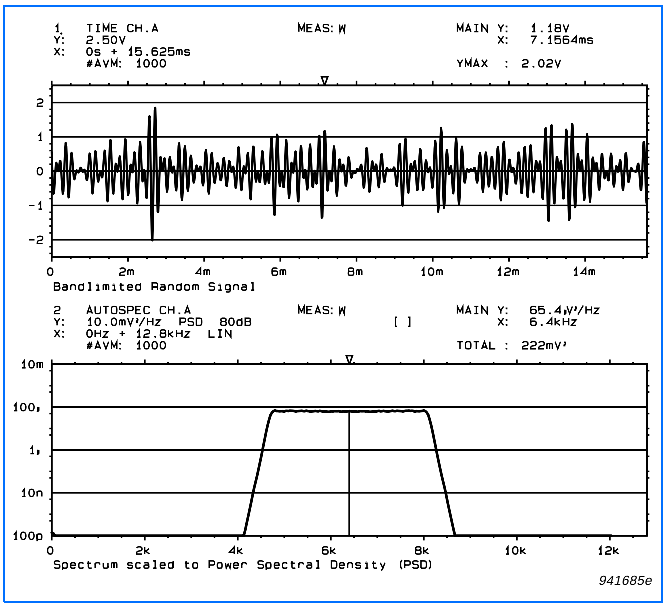

Fig. 2 Time record and frequency spectrum for a stationary, random process. The frequency spectrum is scaled as the power spectral density

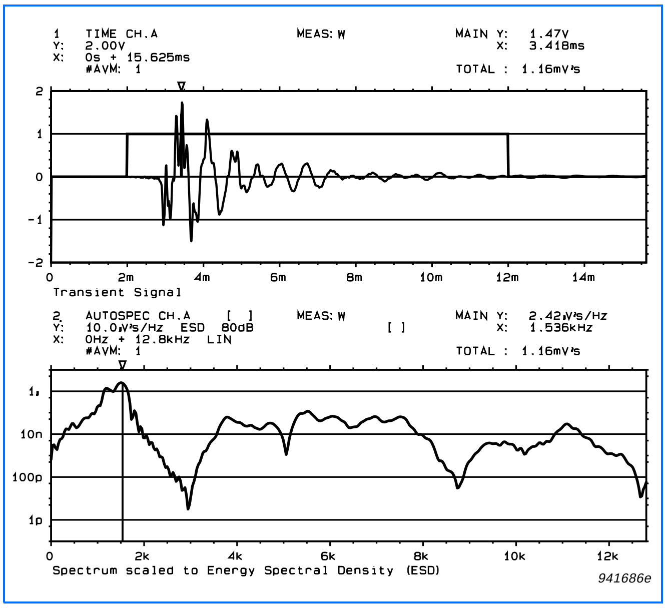

Fig. 3 Time record and frequency spectrum for a transient signal. A transient time-weighting function is used in the analysis of the time record, and the frequency spectrum is scaled as the energy spectral density

Fig. 2 shows the time record and power density spectrum for a random signal. The effective noise bandwidth is determined by the type of time-weighting function used in the analysis, and affects the magnitude of the power spectrum. The analyzers of the 3550 and 2140 families automatically compensate for the noise bandwidth according to time-weighting function used. This ensures that the cursors read out correctly.

Transient signals

A transient is a signal which starts and finishes at zero, as shown in Fig. 3. This signal contains a finite amount of energy and so cannot be characterised in terms of power, since the power is dependent on the record length: the longer the time window, the lower the average power. Transient signals also have a spectrum continuously distributed with frequency. Consequently, the transmitted power must be normalised with respect to the filter bandwidth and rescaled according to the record length. This results in an energy per unit bandwidth, often termed energy spectral density (ESD).

Fig. 3 shows the time record and energy density spectrum for a transient signal. Transients must be analysed using an equal time-weighting function across the signal. To achieve this, a rectangular weighting (no weighting) or a transient weighting function should be used, depending on the length of the transient. An exponential window can be used for transients which do not decay within the record length.

Summary

An analysis of a signal using a Brüel & Kjær analyzer of either the 3550 or 2140 families, results in a frequency spectrum which is scaled correctly irrespective of the frequency resolution and measurement time of the analysis. The appropriate spectrum scaling units are summarised in Table 1 for the different types of signals.

References

[1] S. Gade & H. Herlufsen, “Signals and Units”, Technical Review No. 3 1987, Brüel & Kjær, BU 0031

[2] Multichannel Analysis System, Type 3550, Technical Documentation, Vol.1: Guided Tours, Guided Tour 1. BE 1078

Type of Signal	Spectrum Unit (Scaling)	Units	
		Absolute	Relative
Deterministic	RMS (Root Mean Square)	u	e.g. dB re 1 u
	PWR (Power)	u^2	e.g. dB re 1 u^2
Random	PSD (Power Spectral Density)	u^2/Hz	e.g. dB re 1 u^2/Hz
Transient	ESD (Energy Spectral Density)	u^2s/Hz	e.g. dB re 1 u^2s/Hz

Table 1 A summary of the scaling units used for different signal types

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