INTERPRETATION OF AVERAGE AND PEAK POWER

The average and peak power interpretations proposed in Draft KDB 653005 76-81 GHz Radars DR02-43130 are inconsistent. The text of §95.3367 (a) and §95.3367 (b) are identical except for paragraph (a) referring to average power and paragraph (b) referring to peak power. However the proposed interpretation is that peak means peak power density but average means average power.

Please advise the rationale for such a difference of interpretation (average power density, as contrasted with peak power) considering that the text of the average and peak rules are identical save the words “average” and “peak”.

TEST PROCEDURE CONSIDERATIONS FOR FMCW RADARS

We note that for devices utilizing FMCW modulation the maximum peak power density is equal to the maximum peak power, thus from this perspective

- the text of §95.3367 can be consistently interpreted to mean peak power and average power
- the procedures as documented are consistent with this interpretation

Nevertheless we caution that the proposed procedures can underestimate the emissions levels unless the readings are corrected for FM Sweep Rate.

The proposed procedures are only accurate when the response time of the RBW filter within the spectrum analyzer is fast enough relative to the FM Sweep Rate of the device (where FM Sweep Rate = Sweep Width / Sweep Time).

Appendix B of Keysight Application Note 5952-1039” (historically derived from Application Note 150-2) provides specific equations to calculate the decreased sensitivity that results when a CW signal is swept by the IF amplifier at a high rate compared to the bandwidth squared; these equations apply to Gaussian RBW filters.

The response time of the RBW filter is independent of the detection mode, therefore this correction for FM Sweep Rate relative to $(1\ \text{MHz RBW})^2$ is applied to both average and peak measurements.

TEST PROCEDURE CONSIDERATIONS FOR PULSED RADARS

With regard to measurements of pulsed radars, for swept spectrum analyzers there are three primary modes of operation: line spectrum, pulse spectrum, and zero span. Correction factors for pulsed radar measurements depend on the mode of operation, which is determined by various ratios of EUT parameters to spectrum analyzer settings.

The Part 95M Rules requirement that RBW = 1 MHz will limit the range of EUT parameters that can fall within (or outside of) any of these modes or regions.

We refer to Keysight Application Note 5952-1039 “Spectrum and Signal Analysis Pulsed RF” and Keysight Application Note 5989-7575 “Radar Measurements”.

The pulse desensitization factor is clearly applicable to peak measurements. Generally, average power can be determined from the peak power and the duty cycle of the radar signal. It is not known whether the pulse desensitization factor and/or other corrections would be needed when utilizing an average detector. Experimental validation of any proposed average-detection measurement procedures and related correction factors will be needed prior to finalizing such procedures.

Definitions

- PRF = Pulse Repetition Frequency of EUT signal
- T = 1/PRF = Period of EUT signal
- τ = Pulse Width of EUT signal
- RBW = Resolution Bandwidth of spectrum analyzer (specified as 1 MHz by §95.3367)
- B_{imp} = Impulse Bandwidth of spectrum analyzer
    - Depends on RBW filter implementation, typically B_{imp} is on the order of 1.5 RBW
- The pulse desensitization factor is the measured amplitude of the pulse compared to the actual amplitude of the pulse (which is equal to the amplitude of the unmodulated CW carrier)

Desensitization factors

- For the Line Spectrum mode $\alpha_L = 20 * \log(\tau / T)$
- For the Pulse Spectrum mode $\alpha_P = 20 * \log(\tau * B_{imp})$
- For the Zero Span mode there is no desensitization factor (thus α = 1, or 0 dB)

Line Spectrum Mode

From Application Note 5989-7575 page 30

To accurately measure and view each spectral component, the resolution bandwidth filter chosen for the spectrum analyzer must have enough resolution to resolve each spectral component.

The peak power of the displayed spectrum is related to the peak power of the signal, assuming a near ideal pulse, by a factor of 20 * log(duty cycle).

The peak power can be determined by placing a marker on the central or highest power line in the measured spectrum and then adding, in dB, 20 * log(duty cycle). The average power can then be determined from the peak power by subtracting the duty cycle, in log form, 10 * log(duty cycle).

- The most general requirement for the line spectrum mode is RBW < 0.3*PRF.

Application Note 5952-1039 Chapter 2 provides more detailed information about the line spectrum mode, instrument settings and specific conditions for the validity of the desensitization factor.

Pulse spectrum mode

From Application Note 5989-7575 page 31

The pulse spectrum mode applies specifically to signal/spectrum analyzers that employ swept architectures. It is what occurs when the RBW setting on the spectrum analyzer is too wide to resolve the individual spectral components of a pulsed RF signal but not wide enough to contain the majority of the spectral power. Under this condition, the spectral components within the RBW filter at any one instance are added and displayed. If the sweep time is similar to (or somewhat longer than) the pulse period, these lines, known as a PRF lines, will be displayed across the screen and have a sinc function shape similar to that of the line-spectrum view. Note, however, that these are not spectral lines.

- The most general requirements for the pulse spectrum mode are RBW > PRF and RBW < 0.2 / τ

Application Note 5952-1039 Chapter 3 provides more detailed information about the pulse spectrum mode, instrument settings and specific conditions for the validity of the desensitization factor.

Determining Line or Pulse mode

Two methods can be used to determine the operating mode of the analyzer: pulse-spectrum or line-spectrum. First, change the RBW. The amplitude of the displayed signal will not change if the analyzer is operating in the line-spectrum mode. If the analyzer is operating in the pulse-spectrum mode, the displayed amplitude will change because it is a function of RBW. Second, change the sweep time. The lines representing spectral components of the signal will not change with sweep time in the line-spectrum mode. In pulse-spectrum mode, the spacing between PRF lines will change as a function of sweep time.

Zero-span mode

From Application Note 5989-7575 page 33

In addition to making frequency-domain measurements, the signal analyzer provides a zero-span mode for time-domain measurements. In the zero-span mode, the signal analyzer becomes a fixed-tuned receiver with a time-domain display similar to that of an oscilloscope, but it instead displays the pulse envelope.

Pulse width > settling time of analyzer ≅ 2/RBW

(settling time = 2.56/RBW for the PXA and MXA signal analyzers)

- The most general requirement for the zero span spectrum mode is RBW > ~2.56 / τ

Regions to avoid

From page 12 of Application Note 5952-1039, the range between RBW < 0.3 PRF (line spectrum) and RBW > PRF (pulse spectrum) shows properties of both response types and should be avoided.

The 1 MHz RBW that is specified by §95.3367 may make it impossible to avoid this region, depending on the parameters of the EUT.

Perhaps such systems ought to be considered on a case-by-case basis.

While not mentioned by either of the referenced application notes there is a gap between RBW < 0.2 / τ (pulse spectrum) and RBW > ~2.56 / τ (Zero Span mode). For this region it appears likely that the pulse mode desensitization factor α_P will continue to be valid, however we have not studied this theory in sufficient detail to reach a conclusion.

ALTERNATIVE AVERAGE POWER CONSIDERATIONS

The average power can be calculated from the peak power by multiplying the peak power by the duty cycle of the signal, where

Duty cycle = (FM Sweep Time) / [(FM Sweep Time) + (OFF Time between successive FM sweeps)]

for devices utilizing FMCW modulation

Duty cycle = (Pulse Width) / Period

for devices utilizing pulse modulation

For devices that operate in a burst mode, the burst duty cycle factor would also be applied to either of the above modulation types.

As the RBW is specified as 1 MHz for both Peak and Average measurements we believe this alternative would be consistent with the Part 95M Rules.