WAVECONTROL

Measurement of radar using field probes with diode technology

APPLICATION NOTE

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+34 93 320 80 55
www.wavecontrol.com
info@wavecontrol.com

Index

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1. INTRODUCTION

The use of portable radio frequency (RF) measurement devices with isotropic field probes represents, for many applications, a much simpler and more practical solution than the use of spectrum analysers and antennas.

One such application is the measurement of radiation levels in radar signals, with two basic aims:

1. **Functionality**: to determine the strength of the radar signal.
2. **Safety**: to assess the level of human exposure to electromagnetic fields.

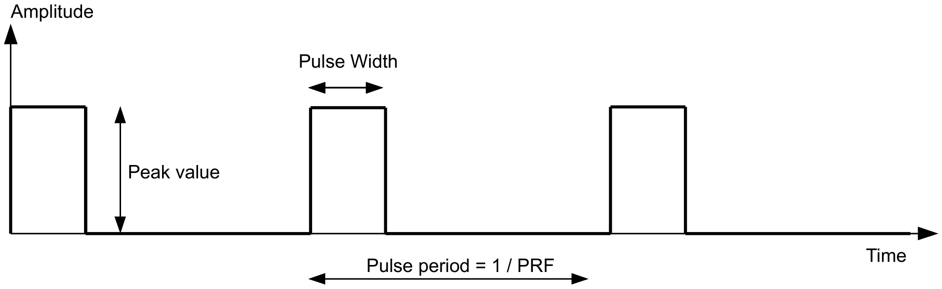
Using this technique, the electric or magnetic field can be measured independently of its polarity or direction of propagation, with practically no influence on or distortion of the result.

That ease of use, though, should not lead us to forget that, in the case of pulsed signals such as radar signals, it is important to examine the signal in advance to be able to determine the real RMS value.

This application note provides basic information for users of the Wavecontrol **SMP2** device **[1]** on how to calculate the RMS and peak values of pulsed signals using broadband probes, of the **WPF18 [2]** or **WPF40 [3]** type.

2. PULSED SIGNALS CHARACTERISTICS

The pulsed signals used for radar normally have a high crest factor, i.e. a large difference between the peak value and the RMS value. The following diagram illustrates the time variation of a typical signal.



The defining parameters are:

- **Pulse width**
- **Pulse period**
- **Peak value**

Those parameters are used to calculate:

- **The duty cycle (DC):** $DC = \frac{PulseWidth}{PulsePeriod} = Pulse\ Width\ .\ PRF$
- **The pulse repetition frequency**: $PRF = \frac{1}{PulsePeriod}$
- **The pulse duration:** $PD = PRF\ .\ DC$

If the purpose of the measurements is to assess human exposure to electromagnetic fields, we need, as specified in the ICNIRP guidelines [4], to assess the RMS and the peak value of the signal. The peak value may be calculated using the RMS and the duty cycle, as shown below:

$$E_{rms} = E_{peak} \cdot \sqrt{DC} \qquad E_{peak} = \frac{E_{rms}}{\sqrt{DC}}$$

3. PULSED SIGNALS AND DIODE-BASED DETECTORS

E-field probes using diode-based detection perform differently, depending upon the intensity of the field. They present a quadratic response at low field levels and a linear response at high field levels.

Radar signals have high crest factors, which means that they have very high peaks. Under such conditions, the diode-based detector of the probe will not be working in the quadratic range and this will give rise to an error in the reading of the RMS value.

Nevertheless, that disparity between the reading and the actual RMS value may be rectified by applying correction factors arrived at by means of laboratory tests.

Figures 1 and 2 give an example of correction factors based upon the duty cycle and the pulse repetition. Figure 1 shows correction factors for the **WPF18** probe [2], and Figure 2 shows correction factors for the **WPF40** probe [3].

- The graphs on the left show the factor to be applied, in dB, to the reading given by the device, to obtain the RMS value.
- The graphs on the right show the factor to be applied, in dB, to the RMS vale, to obtain the reading given by the device.

Tests were performed for different values:

- Duty cycles: 1/316, 1/1000 and 1/3162.
- Pulse repetitions 316 Hz, 1 kHz and 3.16 kHz.

The correction factors can be applied for the value ranges shown in the tables. For greater accuracy, figures for intermediate values may be interpolated. We can provide more detailed information to interested users and perform specific laboratory tests to obtain the correction factors needed for each application.

Parameter	Value	Validity range
Duty cycle	1/316	1/562 to 1/177
	1/1000	1/7778 to 1/562
	1/3162	1/3162 to 1/1778
Pulse repetition frequency	316 Hz	177 to 562 Hz
	1 kHz	562 to 1.78 kHz
	3.16 kHz	1.77 to 5.62 kHz

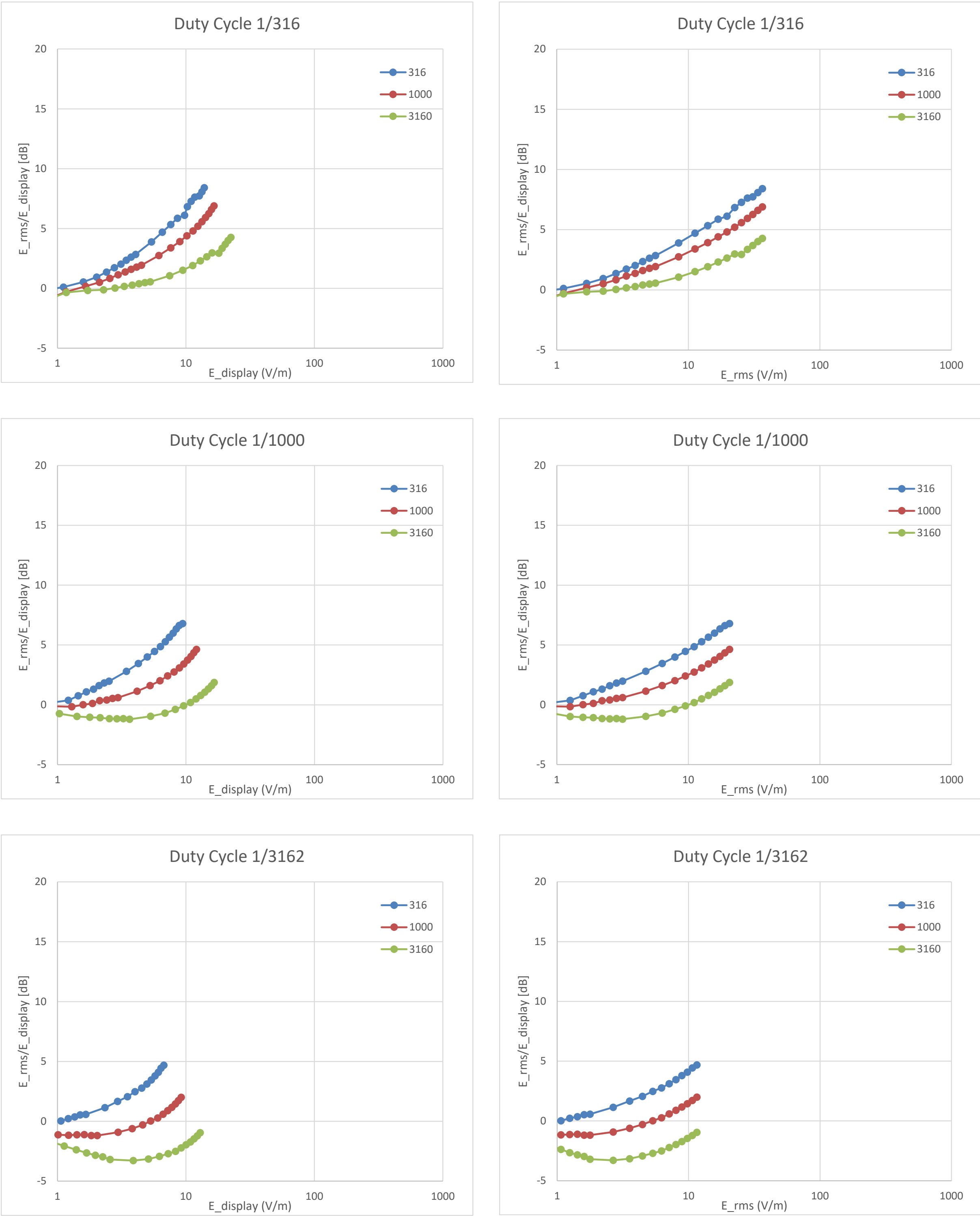


Figure 1: RMS deviation for different duty cycles and pulse repetitions for the WPF18 probe.

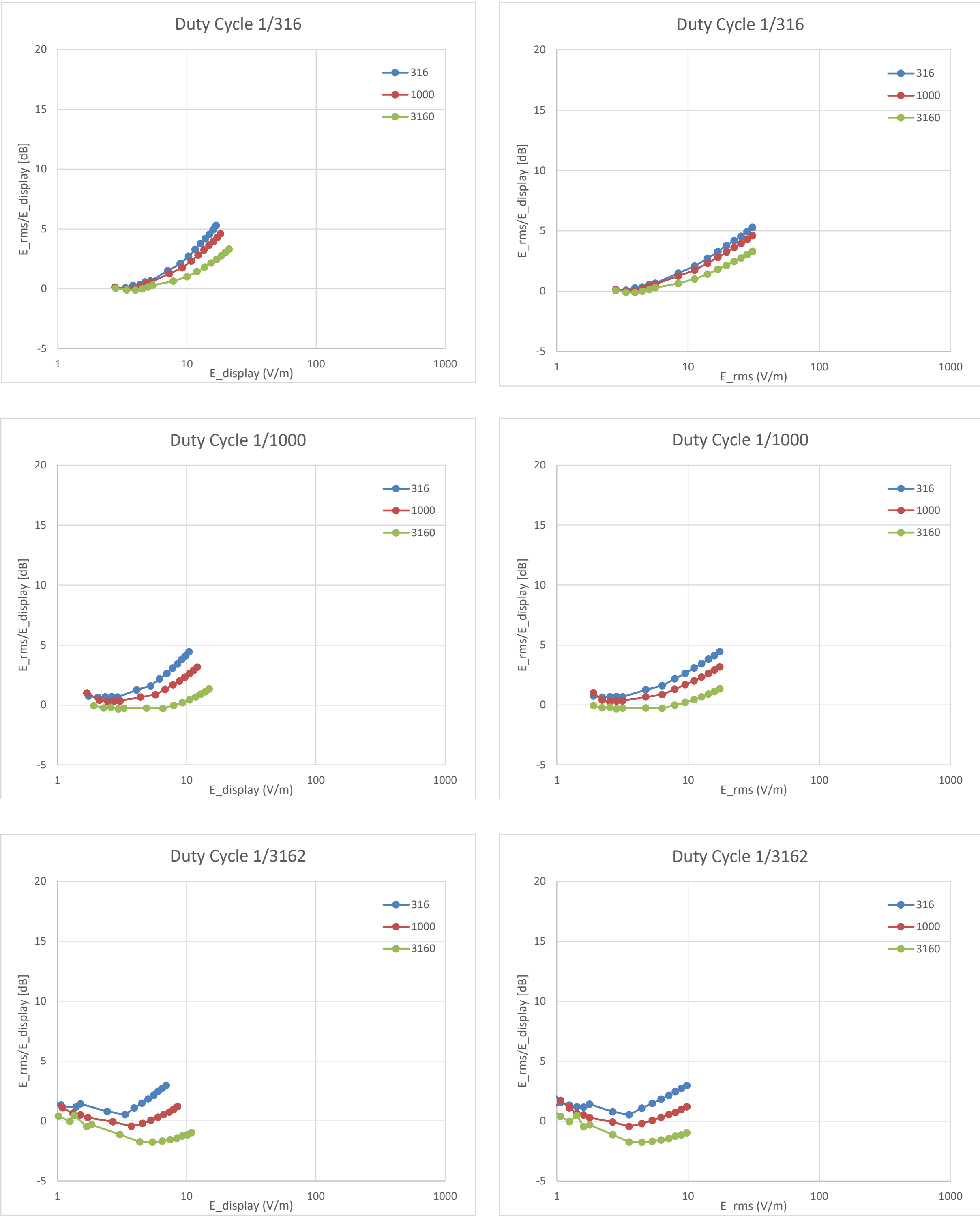


Figure 2: RMS deviation for different duty cycles and pulse repetitions for the WPF40 probe.

Example:

Suppose that we are using the WPF40 probe to measure a pulsed signal with a duty cycle of 1/1000 and a pulse repetition of 1 kHz. The value we see on the screen is 10 V/m.

Consulting the graph on the left in Figure 2, we see that for that value of 10 V/m the correction factor is approximately 2.4 dB.

Using the following formula:

$$E_{rms} = E_{display} \cdot 10^{\left(\frac{CF}{20}\right)}$$

we may conclude that the actual RMS result is 13.18 V/m.

4. SCANNING RADARS

The purpose of scanning radars is to detect objects in their vicinity. In order to do so, as the name suggests, they rotate on their axes to scan a full 360 degrees. In the interest of efficiency, they only illuminate a portion of space (a given number of degrees) at any time, and so they need to move (rotate) quickly in order to cover the 360 degrees as quickly as possible.

That behaviour has two important implications for our purposes:

A. We have very little time to measure the emission power of the radar.

B. The exposure of an object or person to the scanning radar signal occurs only during the fraction of time that the radar is illuminating that portion of space.

It is not usually possible to measure the emission level of radar (**A**) using broadband equipment because its integration time is too high (300-400 ms), much greater than the illumination time.

The Wavecontrol SMP2 device, used in combination with the WPF18 or WPF40, has a function called "***Max Fast RMS***" that activates a very fast integration time of just 4 ms, along with a ***Max Hold* time**, which allows measurement of the radar emission during the illumination time.

This allows fast and easy checking of the proper functioning of the radar, with no need to stop the rotation or use expensive and largely unpractical equipment.

If the aim is to assess human exposure (**B**) in accordance with ICNIRP criteria, we need to measure the RMS value and the peak value of the exposure.

The RMS must be averaged over 6 minutes, i.e. the device will be receiving the signal during the fraction of time that the radar illuminates it and will measure the ambient value the rest of the time, up until the following illumination. The resulting value must be compared with the ICNIRP reference value [4].

Nevertheless, it must also be checked that the peak level during the pulse width does not exceed 1000 times the reference level mentioned above. This means that the peak value is relevant in this case, including for duty cycles of less than 1:1000.

We can obtain the peak value using the "***Max Fast RMS***" mentioned above. Since it allows us to obtain the RMS value for the pulse, we can obtain the peak value using the formula given below, as explained in section 2:

$$E_{peak} = \frac{E_{rms}}{\sqrt{DC}}$$

If the illumination time of the radar is greater than the integration time of the probe, the reading will be correct with no need for any further calculation.

If, on the other hand, the radar is as fast as or slightly faster than our probe, we will still have to compensate for the attenuation so produced by applying a correction factor, as explained below.

The attenuation that occurs and that must be corrected for is the following:

$$A = 5 \cdot \log_{10}\left(1 + \left(\frac{t_{int}}{t_{exp}}\right)^2\right) \quad (1)$$

where

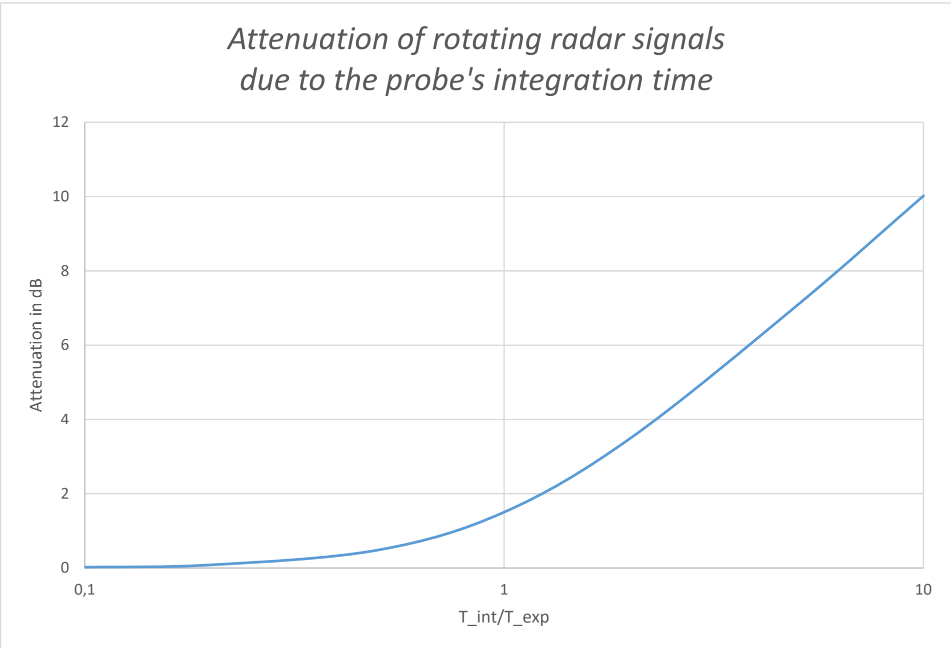
$t_{exp} = \frac{\mathrm{BW}}{360º} \cdot t_{rot}$ (under far field conditions).

BW = beam width (3 dB).

t_{rot} = revolution time in seconds

t_{int} = probe integration time (4 ms in the case of WPF18 and WPF40).

The following diagram shows the attenuation according to the formula (1)



References:

[1] SMP2 – Portable Electromagnetic Field Measurement System
http://www.wavecontrol.com/rfsafety/en/products/smp2

[2] WPF18 – Broadband field probe (300 kHz – 18 GHz)
http://www.wavecontrol.com/rfsafety/en/products/probes#WPF18

[3] WPF40 – Broadband field probe (20 MHz – 40 GHz)
http://www.wavecontrol.com/rfsafety/en/products/probes#WPF40

[4] ICNIRP (International Commission on Non-Ionizing Radiation Protection), "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz)," Health Physics, vol. 74, pp. 494–522, 1998.

WAVECONTROL
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+34 93 320 80 55
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info@wavecontrol.com