Uncertainties in TRP Measurements Due to Finite Range Lengths

James D. Huff
Carl W. Sirles

The Howland Company, Inc.
4540 Atwater Court, Suite 107
Buford, Georgia 30518

Abstract

Total Radiated Power (TRP) and Total Isotropic Sensitivity (TIS) are the two metrics most commonly used to characterize the over the air (OTA) performance of a wireless device. The minimum range length for these measurements has usually been determined using the arbitrary far-field criteria of $R>2D^2/\lambda$. This paper quantifies the changes in measured TRP as the range length is increased from D^2/λ to infinity (or thereabouts). TRP measurements on a UMTS dipole combined with a phantom head have been made at different range lengths. Additionally, numerical simulations of TRP measurements on an array of point sources have been made at different range lengths. The result is a theoretical determination of TRP measurement errors versus range length supported by actual measurement results.

Keywords: **far-field, OTA, TIS, TRP, wireless**

1. Introduction

Total Radiated Power (TRP) is calculated from measurements of EiRP taken over the entire sphere surrounding the device under test (DUT). Historically it has been assumed that the diameter of the measurement sphere, or range length, needs to be greater than $2D^2/\lambda$, where D is the diameter of the DUT and λ is the wavelength at the measurement frequency. This paper investigates the validity of this assumption by comparing TRP measurements made at different range lengths. Measurement simulations have also been made using an array of point sources and the change in TRP calculated for different range lengths from D^2/λ to 1 million kilometers.

2. The TRP Measurement

One of the most common parameters measured on a wireless device is the total radiated power (TRP). The measurement is made by placing the device under test (DUT) in an anechoic chamber with a two axis positioning system and the DUT positioned to different coordinates in a spherical coordinate system. The transmitted power is then sampled at equally spaced increments in phi and theta over the entire sphere surrounding the DUT. These relative power measurements are then converted to Effective Isotropic Radiated Power (EiRP) using a range reference measurement. The EiRP values are then weighted by the sine of theta and summed to calculate the total radiated power.

3. The Basic Concept

TRP is measured by sampling the radiated power over a spherical surface surrounding the DUT. In Figure 1 we have two spheres surrounding a device transmitting power P_0. It is obvious that the same total power that radiates outward from the DUT passes through both the large sphere and the small sphere on its way to infinity. Therefore in concept it should be possible to make accurate TRP measurements regardless of the diameter of the sphere used to sample the transmitted power.

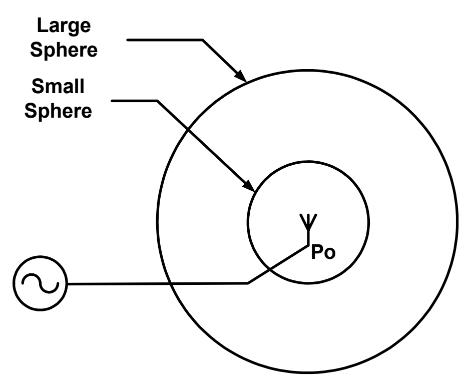

Figure 1 The Basic Concept

4. Experimental Measurements

In order to verify this concept, measurements were made at three different range lengths. The device under test (DUT) was a SAM phantom head with a UMTS dipole. The DUT is shown in figure 2. This DUT was chosen because it fills up a 30cm quiet zone and provides a realistic test scenario comparable to testing a cellular phone. The UMTS frequency band (2110 to 2170MHz) was used because effects due to range length should be more pronounced at higher frequencies, and the UMTS band is the highest frequency cellular phone band currently being utilized.

Figure 2 The Device Under Test

In order to change the range length spacers were used on the boom of a distributed axis positioning system. Three different spacers were used providing range lengths of 65cm, 119cm and 126cm. This setup is shown in Figure 3.

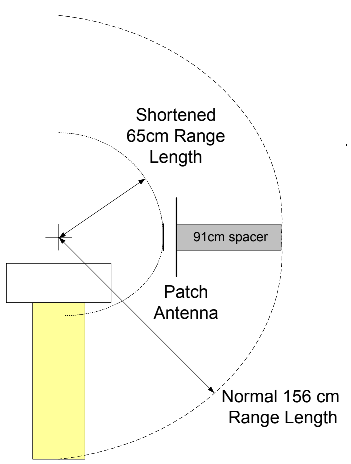

Figure 3 Measurement Setup

Measurements were made at five frequencies in the UMTS band at five degree steps of phi and theta. The only setup change between measurements at different range lengths was the spacer itself. The RF instruments and cables were kept unchanged. This meant that it was only necessary to calibrate the range at one range length. The cal factors for the other range lengths could be calculated from the change in range length using the following formula

$$\text{Change in Cal Factor} = 20\text{LOG}(R_1/R_2)$$

where R_1 and R_2 are the two range lengths. The reason for using this procedure was to remove as many uncertainties from the data as possible.

5. Measurement Results

The measurement results are summarized in Table 1 below. For a point of reference, 126 cm is approximately equal to $2D^2/\lambda$ while 65cm is approximately equal to D^2/λ. Referring to the table below, one will see that the largest change in TRP is approximately 0.1 dB and that there is no obvious trend as the range length is increased. The effect of the change in range length is probably being masked by the effect of extraneous signals in the range. As the range length is changed the relative phase of the direct signal to the extraneous signal is changing causing the received signal level to change.

Table 1 Measurement Results

Freq MHz	TRP Delta (dB)		NHRP ±45 (dB)		NHRP±30 (dB)	
	126 to 119 cm	126 to 65 cm	126 to 119 cm	126 to 65 cm	126 to 119 cm	126 to 65 cm
2110	-0.11	-0.02	-0.11	-0.01	-0.11	0.00
2125	-0.08	0.02	-0.09	0.03	-0.09	0.04
2140	-0.03	-0.02	-0.03	-0.02	-0.04	-0.01
2155	-0.02	-0.08	-0.03	-0.08	-0.03	-0.08
2170	0.01	-0.09	0.01	-0.09	0.01	-0.08

Values for the near horizon radiated power (NHRP) at ±45 degrees and ±30 degrees were also calculated. These results are similar to the results for TRP, with maximum changes on the order of 0.1 dB. Again there is no clear trend in NHRP versus range length.

6. Measurement Simulations

A numerical simulation was performed using seven point sources. One point source was placed at the center of the quiet zone and the other 6 were placed at ± 15cm along the X, Y and Z axes. This is shown schematically in Figure 4 below.

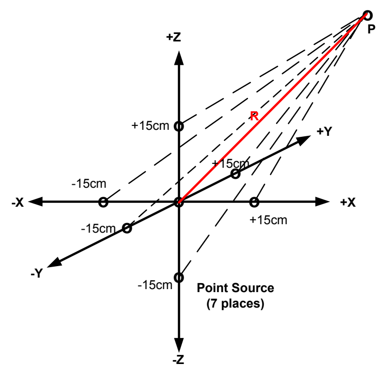

Figure 4 Point Source Array

The vector sum of the contribution of each source was calculated at every 5 degrees in phi and theta using ray optics. The resulting pattern was weighted and summed and corrected for free space dispersion. Simulations were made for range lengths of D^2/λ, $2D^2/\lambda$, $3D^2/\lambda$, $4D^2/\lambda$, $5D^2/\lambda$ and 1 million kilometers. For each range length simulation values for TRP, NHRP ±45 and NHRP ±30 were calculated. These calculated values were then normalized to the values calculated for a range length of 1 million km. The results are shown in Table 2.

Although the effect of range length can be seen in the results, the calculated changes in TRP, NHRP ±45 and NHRP ±30 versus range length are fairly small.

Table 2 Simulation Results

Range Length	ΔTRP (dB)	ΔNHRP±45 (dB)	ΔNHRP±30 (dB)
D^2/λ	-0.054	-0.053	-0.090
$2D^2/\lambda$	-0.013	-0.015	-0.022
$3D^2/\lambda$	-0.006	-0.007	-0.010
$4D^2/\lambda$	-0.003	-0.004	-0.006
$5D^2/\lambda$	-0.002	-0.002	-0.004
1 M km	0.000	0.000	0.000

7. Summary

Both the measured data and the measurement simulations show only small changes in TRP as the range length is varied from D^2/λ to $2D^2/\lambda$ and beyond. High performance wireless test labs such as The Howland Company Model 5100 typically have an expanded TRP measurement uncertainty of approximately 1 dB. Including the additional uncertainty contribution for measurements at a range length of D^2/λ would have a very small impact on the overall measurement uncertainty.

The real importance of these results is that larger devices can be tested at higher frequencies on existing ranges. Wireless devices are being marketed that operate as high as 5.8GHz, and these devices will be installed in everything from automobiles to appliances.

8. References

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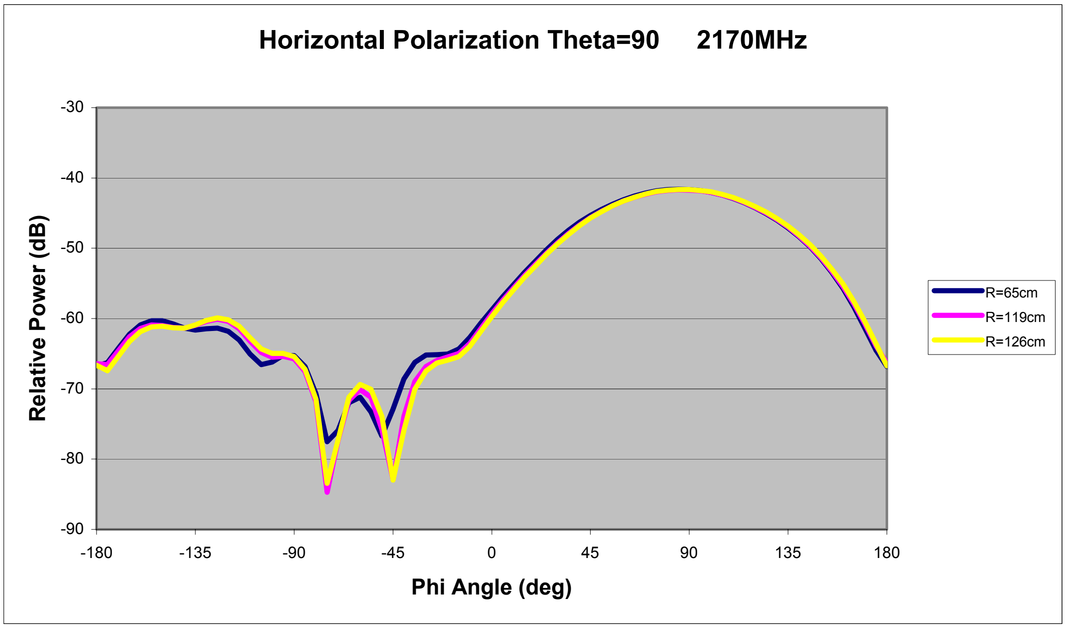
[3] Huff, J. D. and Sirles, C. W. “The Effect of Range Length on the Measurement of TRP”, 29th Proceedings of the Antenna Measurement Techniques Association (AMTA-2007), St. Louis, MO, pp 441-444

Figure 5 Measured Radiation Patterns



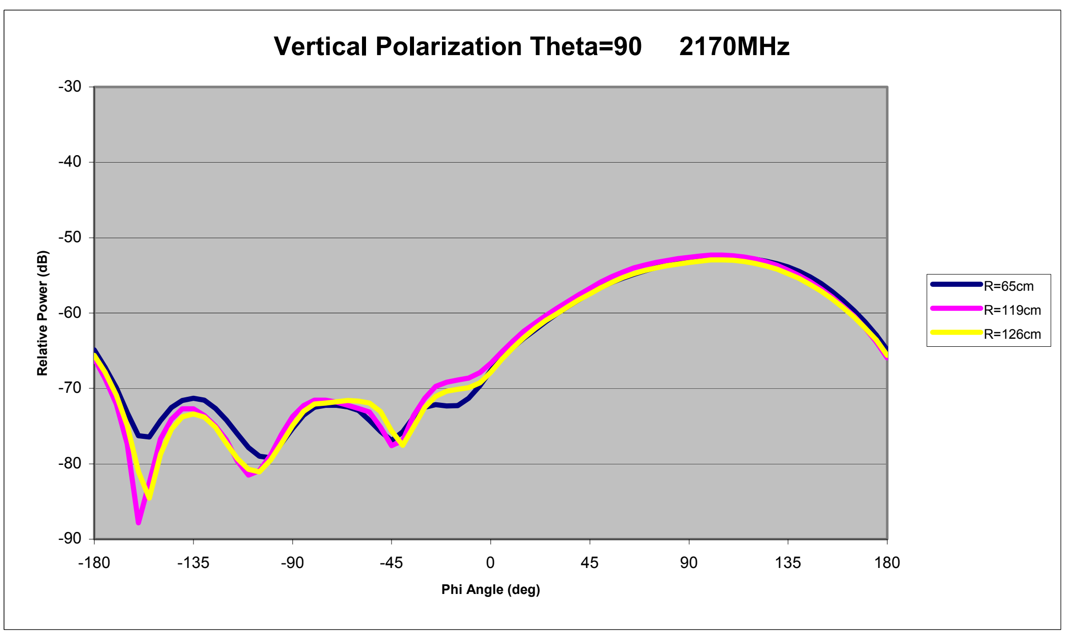
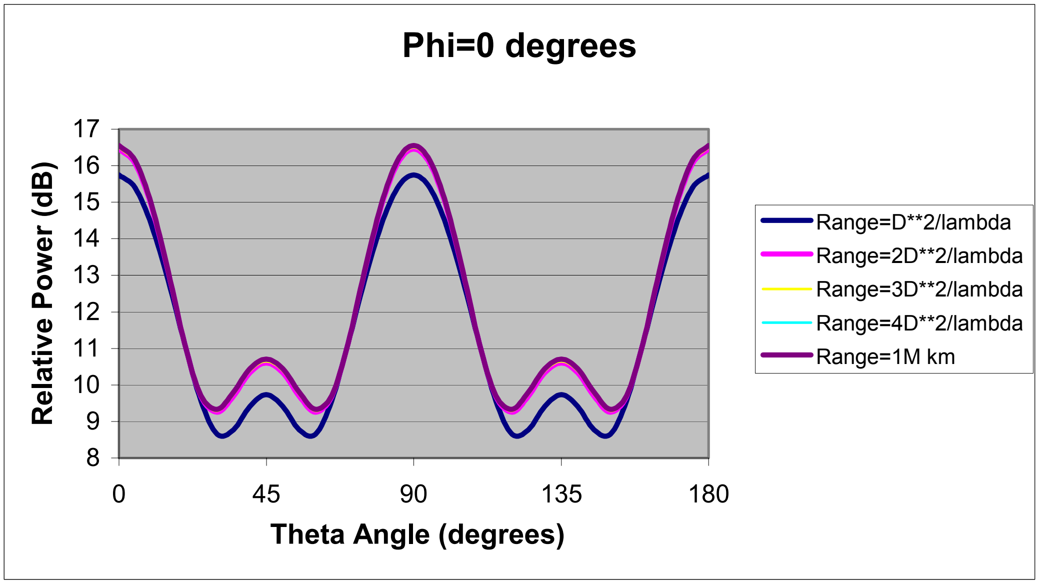


Figure 6 - Calculated Patterns for Point Source Array



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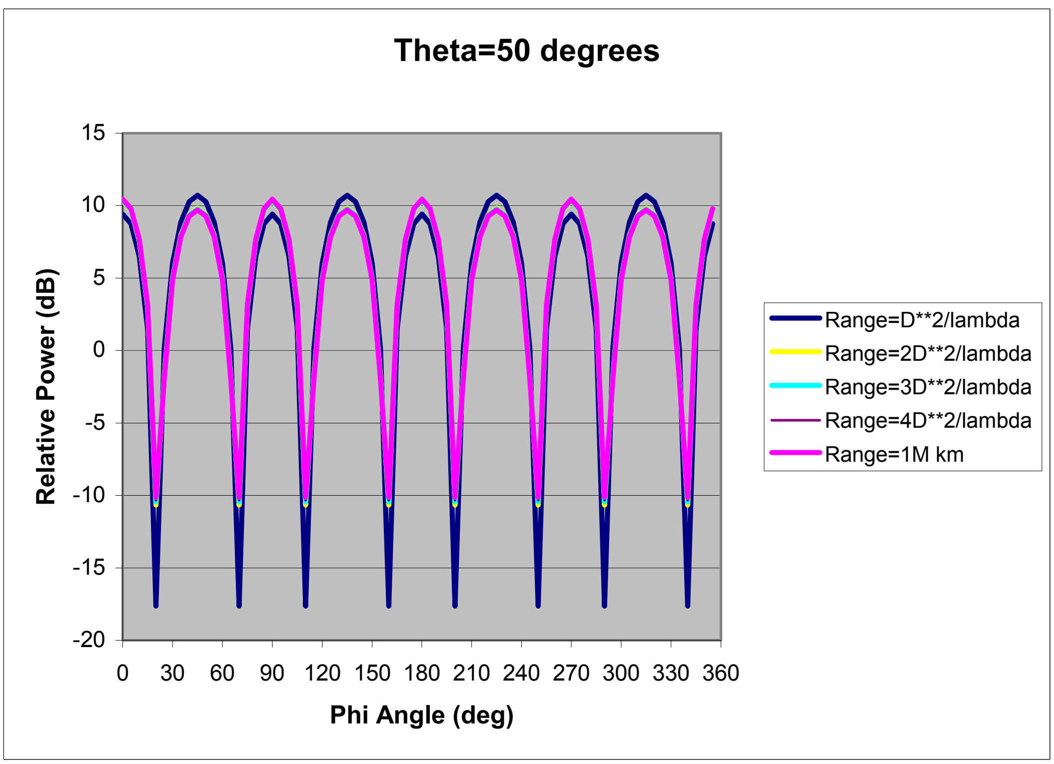

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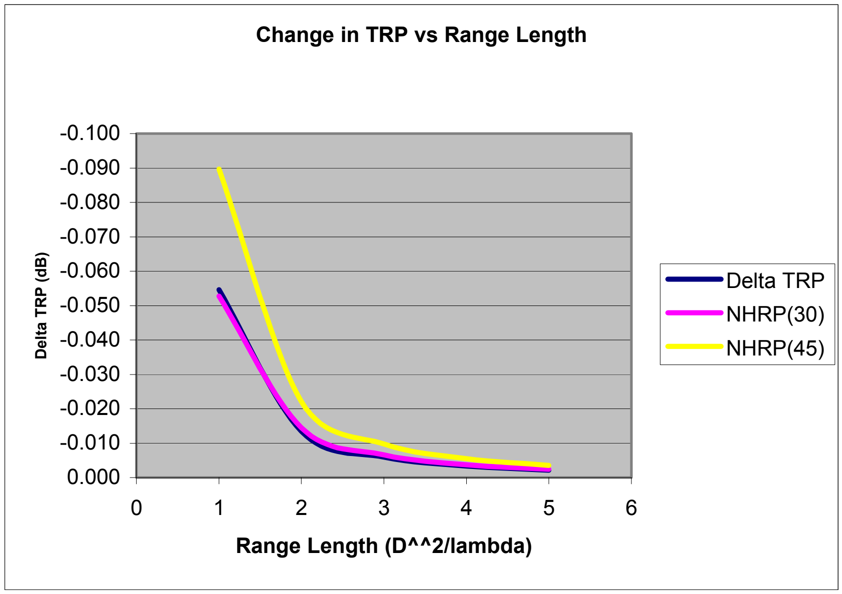
Figure 7 – Change in TRP vs Range Length



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