A COMPARISON OF METHODS FOR EVALUATING THE TEST ZONE PERFORMANCE OF ANECHOIC CHAMBERS DESIGNED FOR TESTING WIRELESS DEVICES

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Abstract

The two most common test methods used to evaluate wireless test chambers are the Ripple Test Method standardized by CTIA - The Wireless Association and the Field Sensor Method standardized by the 3rd Generation Partnership Project (3GPP). Both methods sample the magnitude of the illuminating field at fixed spatial points in the Test Zone to determine the magnitude of the ripple in the test zone. This ripple data is then statistically processed to determine the expected measurement uncertainty attributable to chamber reflections at a given frequency. The strengths and weaknesses of each of these evaluation methods are discussed in detail. Test results using both methods to evaluate a single chamber are presented.

A third wireless test chamber evaluation method is also described. In this method a series of Total Radiated Power (TRP) measurements are made on an antenna with the antenna positioned at various spatial locations in the test zone. If measured with a perfect plane wave, each TRP measurement should produce the same result regardless of the spatial location of the antenna. Variations in measured TRP relate directly to measurement uncertainty caused by deviations of the incident wave from a perfect plane wave.

Keywords: CTIA, 3GPP, Ripple Test, Field Sensor, TRP, Wireless Test Chamber, Measurement Uncertainty

1. Introduction

An uncertainty budget for wireless measurements will contain many contributors. Typically, one of the larger contributors will be the measurement uncertainty due to extraneous signals that add in and out of phase with the direct signal. In order to have a meaningful understanding of the measurement uncertainty, it is necessary to accurately measure the level of extraneous signals in the test zone and convert that level to an uncertainty contribution.

Two methods for test zone characterization have been standardized for wireless test systems. The oldest and most accepted is the method defined by the CTIA <u>Test Plan for Mobile Station Over the Air Measurements</u>. More recently the 3rd Generation Partnership Project (3GPP) standardized a second method using a broad band field sensor. Each method has its advantages and disadvantages, but both methods require converting the measured signal levels into an uncertainty contribution.

It is also possible to measure the uncertainty contribution directly by making a series of TRP measurements with a probe antenna positioned at various points in the test zone.

In concept the three methods should provide the same uncertainty contribution. This paper presents experimental data collected in a typical wireless test chamber using all three methods and compares the calculated measurement uncertainty.

2. The CTIA Ripple Test

The method defined by the CTIA uses dipoles and loop antennas that have highly symmetrical patterns. The antennas are required to have an azimuth plane pattern symmetry of <+/-0.1 dB. The probe antennas are positioned at a series of defined locations within the test zone and the received signal is recorded as the phi or theta axis is rotated. The resulting patterns will show a ripple as the extraneous signals phase in and out with the direct signal. Because the antennas are highly symmetrical, any ripple in the pattern is assumed to have been caused by an extraneous signal.

Phi patterns are made with the theta axis at 90 degrees. The probe antenna is positioned at six different positions within the test zone. These positions are shown in figure 1. The probe is rotated about the phi axis and the field in the test zone is sampled at 2 degree increments. A typical phi axis measurement setup is shown in figure 2 below.

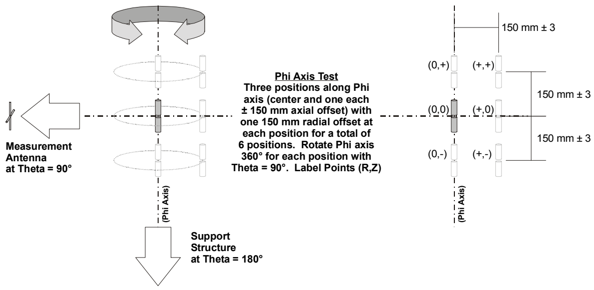

Figure 1
Phi Axis Test Positions

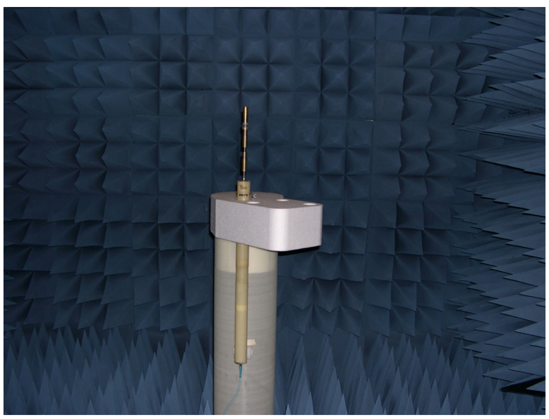

Figure 2
Typical Phi Axis Scan Configuration

Theta patterns are made with the phi axis at 0 degrees. The probe antenna is positioned at seven different positions within the test zone. These positions are shown in figure 3. The probe is rotated about the theta axis and the field in the test zone is sampled at 2 degree increments. A typical theta axis test setup is shown in figure 4 below.

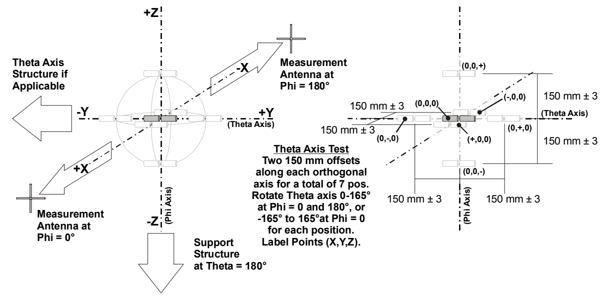

Figure 3
Theta Axis Test Positions

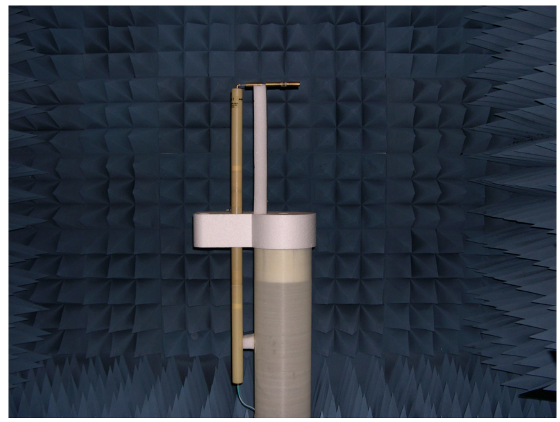

Figure 4
Typical Theta Axis Scan Setup

The CTIA method is essentially a variation of the classical pattern comparison method. Because the probe antenna patterns are highly symmetrical, the variations in the patterns are easy to interpret.

3. The 3GPP Ripple Test

The test method defined by 3GPP uses a broadband field sensor. The field sensor is positioned at seven different positions in the test zone as shown in figure 5 and the received signal level is recorded at the frequencies of interest. The field sensor measures the received signal in three orthogonal components which are then summed internally to provide a single composite output. The radiation pattern of the field sensor is assumed to be omni-directional so that variations in the signal received at the different positions can be interpreted as variations in the field of the test zone. A typical field probe measurement setup is shown in figure 6.

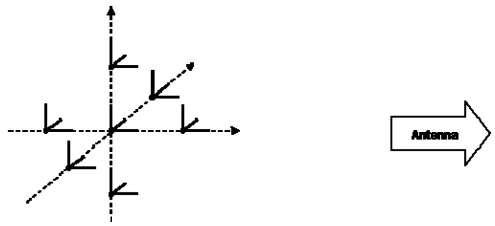

Figure 5

3GPP Field Probe Positions

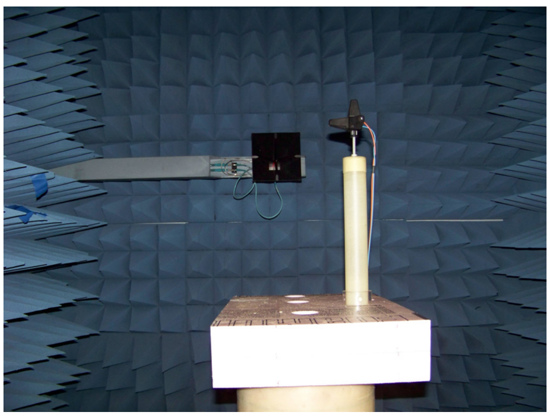

Figure 6
Field Probe Setup for 3GPP Measurement

4. Deriving the Uncertainty Contribution from Ripple Test Results

Having measured the amplitude variation (ripple) in the test zone, the next step is to calculate the measurement uncertainty that this ripple generates in a TRP or TIS measurement. For a single point measurement, it is fairly straightforward to calculate the measurement bounds when an extraneous signal interferes with the desired signal.

$$L_{MAX} = 20\log(e_D + e_X)\ \text{dB}$$

$$L_{MIN} = 20\log(e_D - e_X)\ \text{dB}$$

Where

$L_{MAX,MIN}$ are the max and min signal levels

e_D is the level of the direct signal

e_X is the level of the extraneous signal

A typical TRP measurement would consist of data points taken every 15 degrees in phi and theta for a total of 264 data points. The extraneous signal will contribute an error to each data point, but the magnitude of the error will depend upon the relative phase of the direct signal to the extraneous signal. The TRP is calculated by converting the measured values into values of EiRP, weighting them by the sine of the theta angle, and averaging them. There is a tendency for the individual errors to average out, resulting in a TRP measurement that has a lower uncertainty than the individual data points. However, determining a valid measurement uncertainty for the overall TRP measurement is somewhat complicated.

The CTIA starts by defining a statistical uncertainty value referred to as the surface standard deviation (SSD). The SSD uses the measured ripple test results to determine a Type A uncertainty value for a theoretical isotropic radiator placed anywhere within the quiet zone.

The SSD is defined as

$$s(p_k) = \sqrt{\frac{1}{(N-1)} \sum_{k=0}^{N-1} \left[\left(\left(\frac{p_k}{\overline{p}} - 1 \right) \sin(\theta_k) \right)^2 \right]}$$

where p_k is an individual amplitude measurement point, converted to linear units, and $\overline{p}$ is the average of the amplitude measurements associated with a single measurement scan. The standard uncertainty contribution, u(x), due to the amplitude ripple is then given by the maximum of all the $s(p_k)$ values of the 26 phi and theta axis scans.

$$u(x) = 10\log(1 + \max(s_j(p_k)))\ \text{dB}$$

The 3GPP procedure is slightly different from the procedure used by the CTIA. The 3GPP calculates the uncertainty directly from the seven readings taken from the broadband field probe.

$$s = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} \left(P_i - \overline{P}\right)^2}$$

Where

S is the standard deviation

N is number of measurement positions

$\overline{P}$ is dB average of all P_n

P_i is P_n or P_{meas_n}

The 3GPP test plan also provides a means of obtaining a more accurate uncertainty calculation by sampling the field amplitude while scanning the probe in phi and theta. The average sample standard deviation is then calculated as follows:

$$\overline{S_{freq}} = \frac{\frac{\pi}{2IJ}\sum_{i=1}^{I}\sum_{j=1}^{J} s_{i,j,hor}\sin(\Theta_i) + \frac{\pi}{2IJ}\sum_{i=1}^{I}\sum_{j=1}^{J} s_{i,j,ver}\sin(\Theta_i)}{2}$$

Where

I is the number of angular intervals in elevation,
J is the number of angular intervals in azimuth and
Θ_i is the theta angle of measurement $s_{i,j,pol}$.

There are obviously significant differences between the approach of the CTIA and 3GPP.

5. Using TRP Measurements to Determine Measurement Uncertainty

A more straightforward approach to determine the measurement uncertainty due to extraneous signals is to simply make TRP measurements at selected locations in the test zone with near omni-directional antennas. For instance if measurements are made at six positions in the test zone using both loops and dipoles, one would end up with 24 different values of TRP. The effect of the extraneous signals in the chamber will show up as variances in the measured value of TRP.

A typical wireless OTA TRP measurement consists of measurements made at 15 degree steps in phi and theta. Measurements are made with both horizontal and vertical polarization. To calculate TRP, the raw data is converted to values of EiRP, weighted by the sine of theta, and averaged. Included in the measured TRP is the integrated effect of the extraneous signals.

There are several approaches one could take to define the measurement uncertainty from the results of the TRP measurements. The most straightforward would be to define the measurement uncertainty as the standard deviation of the 24 TRP measurements.

6. Comparison of Test Results

Single frequency data was taken in the same chamber using the three different test procedures described above. The frequency selected was 2140MHz.

The standard CTIA measurement procedure was used to generate ripple test data. Both phi axis and theta axis scans were made with the probe antenna in the prescribed positions. The measured data was processed per the procedure in the CTIA test plan and the worst case data selected as the measurement uncertainty contribution. The results are shown in Tables 1 & 2 below.

Phi Axis Scans 2140MHz				
Probe Position (x,y,z) in	P-P Ripple (dB)		u(x) (dB)	
	HP	VP	HP	VP
0,0,0	0.13	0.06	0.03	0.01
0,0,+6	0.22	0.12	0.07	0.04
0,0,-6	0.24	0.15	0.08	0.05
0,+6,0	0.75	0.75	0.16	0.20
0,+6,-6	0.97	0.86	0.21	0.20
0,+6,+6	0.66	0.89	0.15	0.21
Max	0.97	0.89	0.21	0.21

Table 1
CTIA Phi Axis Ripple Test Results

Theta Axis Scans 2140MHz				
Probe Position (x,y,z) in	P-P Ripple (dB)		u(x) (dB)	
	HP	VP	HP	VP
0,0,0	0.88	1.38	0.09	0.16
0,0,-6	1.15	1.78	0.11	0.14
0,0,+6	0.91	1.33	0.09	0.13
0,+6,0	1.42	1.30	0.11	0.15
0,-6,0	1.19	1.55	0.11	0.12
+6,0,0	1.75	2.27	0.10	0.15
-6,0,0	1.82	1.92	0.13	0.14
Max	1.82	2.27	0.13	0.16

Table 2
CTIA Theta Axis Ripple Test Results

The field probe used in the 3GPP measurement procedure was the Model HI-6005 from ETS Lindgren. Its calibration was current and it is specified to have an isotropic deviation of less than +/-0.5 dB. The measurements were made at seven different probe positions per the 3GPP test plan. The results are shown in Table 3 below.

Probe Position (x,y,z) in	Probe Data (Normalized dB)	
	HP	VP
0,0,0	0.16	0.11
0,0,+6	-0.31	0.24
0,0,-6	-0.05	-0.46
0,+6,0	0.19	-0.30
0,-6,0	-0.52	-0.07
+6,0,0	0.06	0.04
-6,0,0	0.46	0.84
Standard Deviation	**0.33**	**0.43**

Table 3
3GPP Field Probe Data

A total of 24 TRP measurements were made using both a Howland VA100 loop and a Howland VA100 dipole positioned at different locations in the test zone. Data was taken at 15 degree increments in phi and theta. All 24 measurements were made at 2140MHz. The computed TRP values are shown in Table 4 below.

Probe Antenna	Pol	Probe Position (x,y,z) in	TRP (dB)	Delta
Dipole	VP	0,0,0	-21.87	0.00
Dipole	VP	0,0,-6	-21.81	0.06
Dipole	VP	0,0,+6	-21.92	-0.05
Dipole	VP	0,+6,0	-21.81	0.05
Dipole	VP	0,+6,-6	-21.82	0.05
Dipole	VP	0,+6,+6	-22.08	-0.21
Dipole	HP	0,0,0	-21.83	0.04
Dipole	HP	0,0,-6	-21.96	-0.09
Dipole	HP	0,0,+6	-21.94	-0.07
Dipole	HP	0,+6,0	-22.07	-0.20
Dipole	HP	0,+6,-6	-22.09	-0.22
Dipole	HP	0,+6,+6	-22.17	-0.30
Loop	VP	0,0,0	-22.54	0.08
Loop	VP	0,0,-6	-22.66	-0.04
Loop	VP	0,0,+6	-22.78	-0.16
Loop	VP	0,+6,0	-22.74	-0.11
Loop	VP	0,+6,-6	-22.85	-0.22
Loop	VP	0,+6,+6	-22.88	-0.26
Loop	HP	0,0,0	-22.62	0.00
Loop	HP	0,0,-6	-22.69	-0.07
Loop	HP	0,0,+6	-22.81	-0.19
Loop	HP	0,+6,0	-22.76	-0.14
Loop	HP	0,+6,-6	-22.89	-0.26
Loop	HP	0,+6,+6	-22.96	-0.34
Standard Deviation			**0.43**	

Table 4
TRP Measurement Results

7. Summary & Conclusions

In a perfect world one would expect all three test procedures and the appropriate uncertainty calculations to give the same result. However, apparently this is not a perfect world. The results are summarized in Table 5. The 3GPP and the TRP measurements resulted in essentially the same measurement uncertainty estimate. However, the CTIA ripple tests predict a significantly smaller measurement uncertainty.

	CTIA Test Plan	**3GPP Test Plan**	**TRP Measurements**
Maximum Amplitude Variation	2.27dB	1.3dB	N/A
u(x)	0.21dB	0.43dB	0.43dB

Table 5
Predicted Uncertainty Contribution

All three methods have their advantages and limitations.

The CTIA procedure requires tuned loops and dipoles making the measurement process fairly time consuming if multiple bands must be measured. On the other hand the 3GPP procedure uses a broadband field probe which makes taking data at many frequencies over a wide range of wireless bands fairly easy.

The dipoles and loops used in the CTIA procedure have a symmetry requirement of +/-0.1 dB. Thus even a perfect chamber can show a 0.2 dB ripple. The field probe used in the 3GPP procedure has a specified Isotropic Deviation of +/-0.5 dB. Hence the 3GPP procedure could show a variation of 1 dB even in a perfect chamber.

The CTIA test procedure requires a minimum of 3,300 data points to characterize the ripple in the chamber. In comparison the 3GPP test procedure only requires 14 data points (7 positions at 2 polarizations) at any given frequency.

Neither the CTIA nor the 3GPP test plan give a very detailed or convincing discussion of how the amplitude variations measured in the test zone are converted to measurement uncertainty.

The TRP measurement technique is attractive from its simplicity. It does not require any specific characteristics of the probe antenna other than near-omni performance. Measurements can be made at multiple frequencies over broad bandwidths. This procedure captures all of the effects of measuring a DUT with a less than perfect plane wave. This would include the effects of mutual coupling, phase taper, amplitude taper, polarization variations and extraneous signals.

8. References

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