A SMALL CHAMBER FOR WIRELESS OVER-THE-AIR MEASUREMENTS

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Abstract

Both mathematical simulations and experimental results have shown that it is possible to make accurate over-the-air measurements of wireless devices at much shorter range lengths than those indicated by the far-field criteria of $2D^2/\lambda$. This paper describes a small shielded anechoic chamber designed to minimize the cost and floor space requirements of over-the-air measurements while at the same time providing measurement uncertainties that are comparable to larger chambers whose design is based on the far-field criteria. The design trade-offs are presented and the construction of the chamber described. The chamber was evaluated at different wireless frequency bands using the ripple test procedure from the CTIA Test Plan for Mobile Station Over The Air Performance. Total Radiated Power measurements were also made on gain standard dipoles to determine the uncertainty in integrated measurements. These measurement results are presented.

Keywords: **OTA, TIS, TRP, wireless, CTIA**

1. Introduction

Engineers designing wireless devices need access to over-the-air test facilities in order to iterate and improve their designs. In many cases they do not need the full capability of certified chambers. They need to make measurements with reasonable accuracy and good repeatability in order to determine if a specific design change has made an improvement in the product performance. This paper describes the design and performance of a small wireless test chamber, the Howland Model 2100, oriented towards the needs of the design engineer.

2. Design Parameters

The design parameters for the Model 2100 had to be carefully selected. The goal was to design a chamber that would provide the capability needed by the design engineer to test most wireless devices. We were willing to accept some small increase in measurement uncertainty in order to meet the size objectives.

Access requirements: In order for the chamber to be useful in the lab, we had to first get it into the lab. The Model 2100 was designed to fit through a standard 6ft wide double door. For labs that have only a personnel door, the Model 2100 can be disassembled and the pieces carried through the personnel door and re-assembled in the lab.

Frequency range: The Model 2100 was designed to operate from 800MHz to 6GHz. The frequency range covers the vast majority of wireless applications. Although there are applications that use frequencies below 800MHz, going lower in frequency would have increased the size of the chamber. It was felt that focusing on the frequencies where most of the wireless development takes place was the most sensible approach.

Test zone diameter: The Model 2100 was designed around a 12in (30cm) test zone. This size test zone accommodates both free space and simulated use testing of handsets, tablets, and the majority of notebook computers.

Measurements: Our goal was to design a test chamber that would allow the engineer to make very good Total Radiated Power (TRP), Total Isotropic Sensitivity (TIS), and antenna efficiency measurements. We were willing to accept an increased measurement uncertainty in antenna pattern measurements.

3. Design Tradeoffs & Rationale

The challenge was not in designing a small chamber, but in designing a small chamber that would allow an engineer to make low uncertainty measurements. This meant that we had to carefully consider the tradeoffs between overall size, range length, absorber thickness, and the spacing of the test zone to the absorber.

Since one of the design constraints was that the assembled chamber had to fit through a standard 6ft wide double door, this essentially fixed the outside width and height of the chamber.

Positioner Configuration: There are two positioner configurations that are widely used for wireless device measurements. These are the combined axis configuration and the distributed axis configuration. The combined axis system is basically a roll over azimuth configuration. The distributed axis system uses an azimuth rotator for the phi axis and an elevation boom for the theta axis. The combined axis system was attractive because it minimizes the chamber height requirement, but ultimately we decided in favor of the distributed axis system. The distributed axis system has several significant advantages over the combined axis system:

1. Ease of mounting the DUT
2. Better electromagnetic performance
3. Can support heavier DUT's

One disadvantage of the distributed axis system is that we had to limit the theta axis travel to 150 degrees because of interference with the DUT support. This does induce an error into the integrated measurements because one must ignore the data from 150 degrees to 180 degrees, but the error in TRP is on the order of 0.15dB. We felt that this was a reasonable tradeoff in order to gain the advantages of the distributed axis system.

Range length: Both experimental results and numerical simulations have convinced us that it is not necessary to adhere to the typical far-field criteria of $R>2D^2/\lambda$ when performing TRP or TIS measurements on small to medium sized wireless devices. We found that using a range length of 24 inches caused only small changes in the measured values of TRP and TIS in both free space and simulated use measurements.

Absorber thickness: Absorber is available only in certain industry standard thicknesses. In our larger wireless test chambers we use an 18 inch thick pyramidal absorber. The nominal reflectivity specification at 1 GHz is -37dB. In contrast the next smaller size is a 12 inch thick absorber whose reflectivity specification is -35dB. The tradeoff of 12 inches of interior space for only 2 dB of reflectivity was compelling.

Clearance test zone to absorber: The chamber design must allow a reasonable gap between the test zone and the wall/ceiling/floor absorber. This is to keep energy in the reactive near-field from being absorbed in the chamber absorber and hence causing measurement errors in the radiated field. Near-field measurement systems generally keep the probe antenna 2-3 wavelengths from the device under test. At 800MHz the wavelength is just under 15 inches, and even two wavelengths or 30 inches becomes a large portion of our 72 inch wide chamber. Ultimately we decided on a 24 inch spacing from the absorber to the center of the quiet zone which meant that the spacing from the edge of the test zone to the absorber tips was 18 inches. At 800MHz this corresponds to 1.2 wavelengths. This becomes 2 wavelengths at 1.3GHz.

4. The Final Design

The final design is shown in Figure 1. The outside dimensions are 69in wide by 88in long by 74in high. It has a 26 in range length measured from the center of the quiet zone to the measurement antenna mounting surface of the theta axis. The spacing from the center of the quiet zone to the absorber is a minimum of 24 inches, and the absorber is 12 inches thick.

Figure 1

The Model 2100 Wireless Test Lab

In order to preserve the range length, the Model 2100 uses dual band patch antennas for the measurement antennas. These antennas are only 2 inches deep and keep the range length at a minimum of 24 inches. The Models PA-1 and PA-2 Patch Antennas are shown in Figure 2 below.

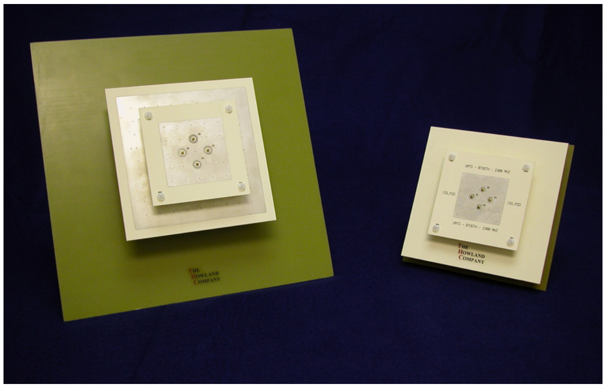

Figure 2

Models PA-1 & PA-2 Dual Band Patch Antennas

One of the many challenges in this design was how to mount the device under test (DUT). In larger chambers the operator simply enters the chamber and places the DUT on the phi axis DUT support. The Model 2100 is too small to enter, so the operator has to reach into the chamber and place the DUT on the DUT support. With 12 inch absorber and 24 inch spacing from the absorber to the center of the test zone, this becomes a 36 inch reach. To accommodate operators with normal arm lengths, the DUT support is mounted on a slide so that it can be moved towards the access door. This reduces the reach required to a more manageable 12 inches.

Figure 3

Phantom Head mounted on the DUT Support

5. Ripple Tests

The most universally accepted method of evaluating wireless chambers is the ripple test method defined in the CTIA Test Plan for Mobile Station Over-the-Air Performance. This test method uses narrow bandwidth dipoles and loops having highly symmetrical patterns as probe antennas. Patterns are made with the probe antenna in different positions and orientations within the test zone. This method is essentially a pattern comparison using a low gain, highly symmetrical antenna. With the probe positioned off of the center of rotation, the reflected signals add in and out of phase with the direct signal producing a ripple in the measured pattern. The magnitude of this ripple indicates the level of the extraneous signals present in the chamber.

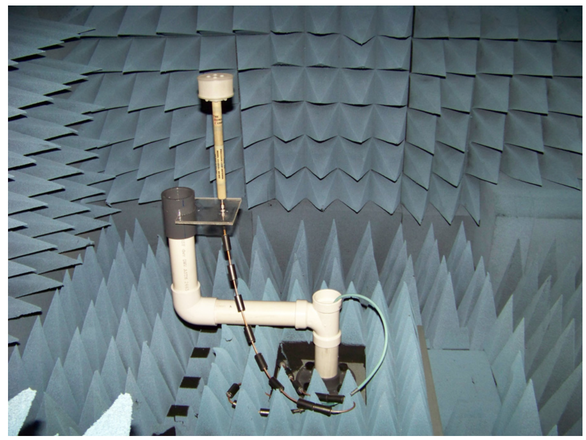

Figure 4

Phi Axis Ripple Test Setup

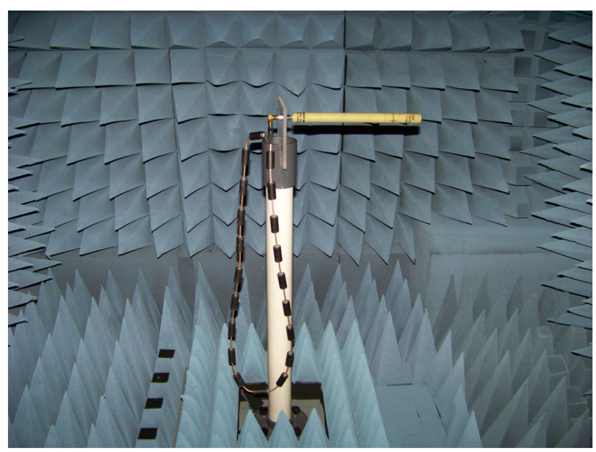

Figure 5

Theta Axis Ripple Test Setup

The CTIA test plan also provides a formula for calculating the measurement uncertainty contribution of the extraneous signals that caused the ripple in the probe pattern.

Measurements were made at four frequencies. The worst case peak-to-peak ripple and the calculated measurement uncertainty contribution are shown in Table 1 below.

Frequency (MHz)	30cm Quiet Zone	
	P-P Ripple (dB)	Uncertainty Contribution (dB)
836	2.80	0.38
1575	2.82	0.44
1880	2.43	0.42
2132	3.58	0.46

Table 1
Ripple Test Result Summary

These results are surprisingly good for a chamber of this size and are comparable to results achieved on much larger chambers. From these measurements one would expect the overall uncertainty of TRP and TIS measurements to be less than the 2 dB required by the CTIA for certified measurements. This is substantiated by TRP measurements of dipoles as detailed in the next section.

6. Dipole Measurements

In order to determine the uncertainty of TRP measurements in the Model 2100, a series of TRP measurements were made using dipoles of known gain and efficiency. The dipoles used were Howland Model VA100 dipoles. The gain of these dipoles is measured using the three antenna method. The directivity of the dipoles is also measured and the efficiency calculated from the ratio of the gain to the directivity.

These measurements are based on the following concept.

A. Measure the power into the dipole
B. Use the efficiency of the dipole to calculate how much of the power input to the dipole is actually radiated
C. Measure the Total Radiated Power (TRP). The TRP measurement will include errors from all of the over-the-air error sources. This will include errors due to extraneous signals (ripple), calibration, range length, sampling increment, etc.
D. Calculate the difference between the calculated radiated power and the measured radiated power.

Measurements were made at three frequencies in three different bands for a total of nine measurements. Data was taken at 15 degree increments from theta =15 to theta =150 and from phi=0 to phi=345.

The results are shown in Table 2 below. The worst case difference between the calculated radiated power and the measured radiated power was 0.16dB.

7. Summary & Conclusions

Both the ripple test results and the dipole TRP measurement results are very encouraging. The performance of the Model 2100 is comparable to that of a much larger chamber and certainly meets the objective of providing a compact test chamber that can be used in the lab by design engineers to iterate and improve their designs. Its performance is also good enough to provide accurate pre-compliance measurements.

8. References

[1] Test Plan for Mobile Station Over The Air Performance, Revision 2.2, CTIA Certification Program, November 2006
[2] Microwave Antenna Measurements, Second Edition; Lyon, Hollis, Clayton; Scientific-Atlanta, Inc.; 1970

[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

Band Designato r	Dipole Model Number	Dipole Serial #	Frequency (MHz)	Dipole Measured Efficiency (%)	Dipole Input Power (dBm)	Calculated TRP (dBm)	Measured TRP (dBm)	Delta (dB)
CELL Tx	VA100-1	012	820	94.9%	17.14	16.91	16.93	-0.02
CELL Tx	VA100-1	012	835	94.0%	17.10	16.83	16.94	-0.10
CELL Tx	VA100-1	012	850	93.6%	16.98	16.69	16.84	-0.15
GPS	VA100-5	008	1559	92.6%	16.14	15.80	15.79	0.01
GPS	VA100-5	008	1585	90.8%	16.46	16.04	15.97	0.07
GPS	VA100-5	008	1610	92.7%	16.37	16.04	15.91	0.13
BT/802.11	VA100-11	008	2400	91.4%	15.12	14.73	14.80	-0.07
BT/802.11	VA100-11	008	2442	90.6%	14.99	14.56	14.72	-0.16
BT/802.11	VA100-11	008	2484	91.4%	14.93	14.54	14.61	-0.07

Table 2
Dipole TRP Measurement Results