WIRELESS TEST CELL DESIGN CONSIDERATIONS

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Abstract

This paper describes a family of new measurement systems, termed "test cells", designed to satisfy the certification requirements of the Cellular Telephone & Internet Association's (CTIA) *"Method of Measurement for Radiated RF Power and Receiver Performance"* test plan for wireless subscriber stations. These test cells employ simultaneous dual-axis mechanical scanning and operate in both far-field and near-field modes over the 750MHz to 6 GHz frequency range. Operation can be extended to higher frequencies through the use of suitable sampling antennas. Test cell facility configuration is detailed. Scanner layout and RF sampling antenna designs are discussed. Anechoic chamber characterization data is presented along with typical measured pattern and efficiency data for both broadbeam and directive AUT's. Measurement test times for various test scenarios are discussed.

Keywords: antenna and receiver performance measurements, omnidirectional antennas, dielectrics, scanner, CTIA, test cell, wireless measurements, fiber optic lighting.

1. Introduction

An often used rule-of-thumb for anechoic chamber design is "bigger is better". However, wireless subscriber station (handset) manufacturers often have limited space in which to install an antenna test chamber. Thus, a family of sequentially sized test cells utilizing common components and fixturing has been developed to allow the user to fit the facility into his/her available space and budget.

These test cells have been developed over a period of 5 years beginning with the largest cell [1,2]. A total of three chamber sizes have since been configured for various applications: 5m, 3m, and 3m plus. All chambers are configured to meet the requirements of CTIA document *"Method of Measurement for Radiated RF Power and Receiver Performance"* [3]. The 5m system (Figure 1) is the most versatile and can accomodate testing using human test subjects or artificial test bodies (phantoms) involving significant portions of the human body, but it requires significant floor space and ceiling height.

Figure 1. 5m Test Cell

The 3m system (Figure 2) was designed for applications where ceiling height and/or budget are very limited. It can be configured for head or torso phantom testing using low height probe antennas. The 3m plus system can accomodate a wider range of probe antennas but requires more ceiling height. All systems use the same scanner configuration and control system and will support various RF instrumentation configurations.

2. Scanner Configuration

Antennas used in wireless handsets typically have low to moderate gain and broad beamwidth and are best evaluated

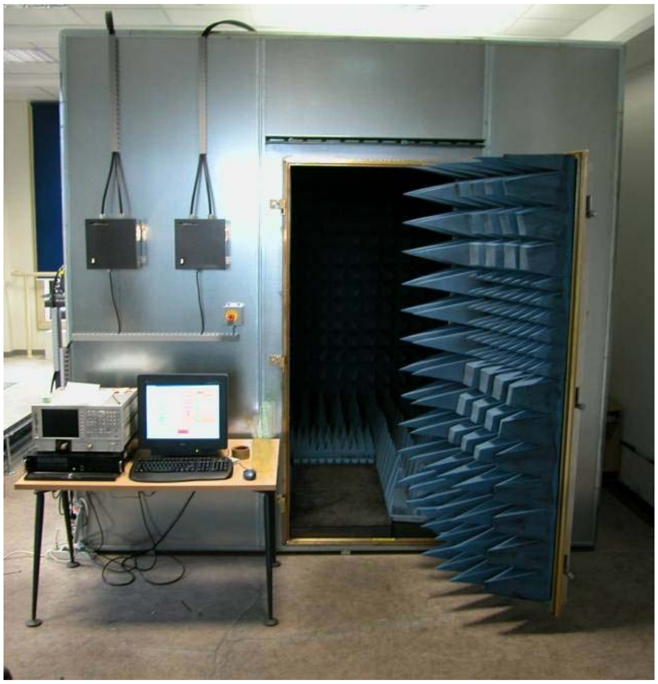

Figure 2. 3m Test Cell

in a spherical coordinate system. Two spherical scanner configurations are commonly employed for handset testing: roll-over-azimuth and elevation-over-azimuth. Roll-over-azimuth systems (Figure 3a) are generally somewhat simpler to implement but require that the DUT (Device Under Test) be mounted horizontally on the roll axis and move in both azimuth (theta) and roll (phi). This is satisfactory for small DUT's but generally not practical for measurements involving humans or large phantoms.

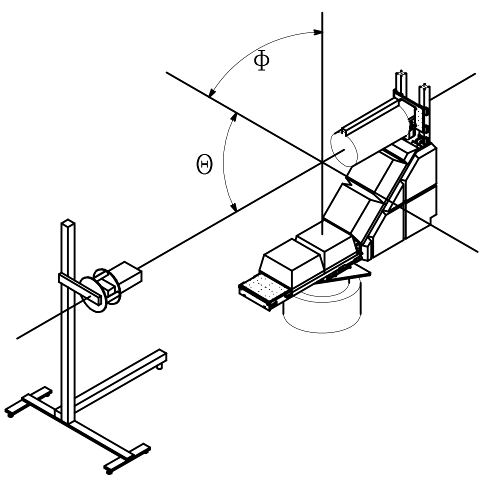

Figure 3a. Roll-Over-Azimuth Scanner Configuration

In elevation-over-azimuth systems (Figure 3b), the DUT is mounted vertically and moved only in azimuth (phi), more easily accomodating large DUT's. However, the scanner system is somewhat more complex, since the probe antenna must move with the elevation (theta) axis.

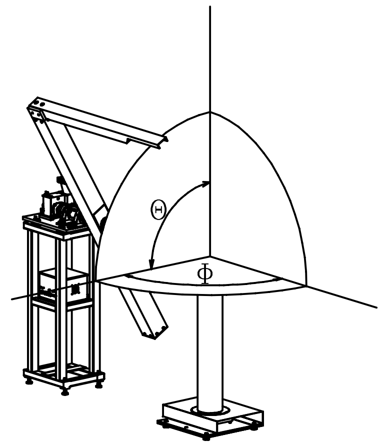

Figure 3b. Elevation-Over-Azimuth Scanner Configuration

An elevation-over-azimuth scanner configuration was selected for the test cells described here to minimize DUT mounting complexity and to permit measurement of torso or full body phantoms. Stepper motor-driven mechanical scanning was selected for both axes to minimize scanner complexity and to permit user-specified sample intervals in both axes. The scanner system is integrated into a shielded anechoic chamber to minimize measurement errors due to external interference.

The elevation positioning system is configured as a gantry system (Figure 4). The gantry cross-arm is the only exposed scanner component inside the chamber and is fabricated from dielectric materials.

The azimuth turntable is floor mounted and supports a low reflectivity pedestal which in turn supports the DUT. This configuration results in a truncation cone for $165 < \theta < 180$ degrees. This truncation can be avoided by using an elevated turntable [2], but it has been found experimentally that reflections from the turntable structure cause measurement errors of the same magnitude as truncation effects.

3. Anechoic Treatment

The reflectivity performance of an anechoic chamber is determined by the type and layout of the absorber materials used. The small size and low operating frequency of these test cells makes absorber selection even more critical.

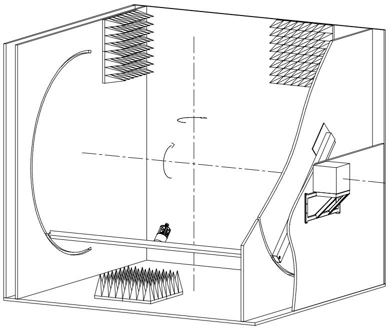

Figure 4. Gantry Style Elevation Positioner

Chamber reflectivity is only one parameter in the overall measurement system error budget. A reasonable magnitude for this error component is ±0.5 dB. To achieve this error level at 700 MHz and above, 18" pyramidal absorber is used on all chamber surfaces which present a direct reflection path between the DUT and probe antenna. Further, all metallic scanner components are shielded by absorber covering. The elevation positioner sidearms are completely hidden behind a stationary cantilevered false wall structure (Figure 5).

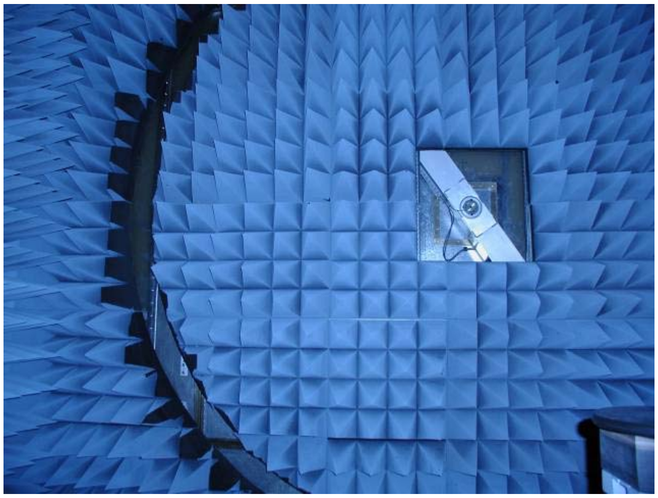

Figure 5. Cantilevered False Absorber Wall

Use of walkway absorber for DUT access is generally avoided. A retractable catwalk (Figure 6) is used for DUT access in the 5m chamber to avoid having to remove/replace floor absorber. Fiber-Optic "Lite Pipes" are used to provide chamber interior lighting, avoiding the need for metallic fixtures or high heat sources near the absorber material.

Figure 6. 5m Chamber DUT Access Catwalk

4. Probe Antennas

Several different styles of probe antennas have been developed to support handset testing in the test cells. Each was developed to provide low to moderate directivity in a lightweight, physically small form factor. A series of single-polarized rectangular OEWG (Open-Ended WaveGuide) probes (Figure 7) is available in standard waveguide bands from 700 MHz up. These probes offer cross-pol levels better than –40 dB and are well suited to spherical near-field measurements. The larger probes are fabricated from carbon composite materials to minimize probe mass.

Figure 7. Low Mass OEWG Probe Antennas

A dual-polarized ridged-horn antenna has been developed following the guidelines given in [4] to support high speed broadband measurements from 700 MHz to 6 GHz. Cross-pol isolation is typically 25 dB, adequate for many handset measurements.

Finally, a series of dual-polarized low profile patch antennas (Figure 8) have been developed to allow CTIA compliant "far-field" testing in even the smallest available test cell size, the 3m. Bandwidth of each probe is approximately 8%.

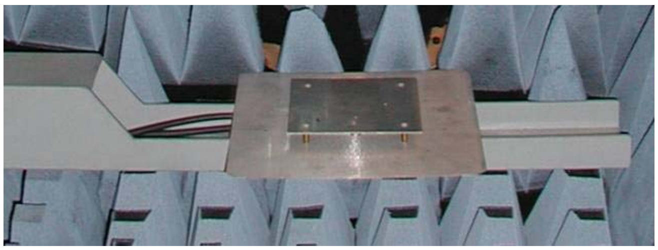

Figure 8. AMPS Band Patch Probe Antenna

5. DUT Support Fixtures

During testing, the DUT must be supported at or very near the coordinate origin of the spherical scanner system. For these test cells, this point in space is 40 – 90 inches above the azimuth turntable surface. If a full-size phantom is used for the test (Figure 9), much of the necessary support is provided by the phantom. For tests involving head or torso phantoms, or the handset alone, low reflection support systems are required. The design and fabrication of these structures has proven to be a major factor in achieving chamber performance goals.

In general, low density foam pylons (Figure 10), thin walled reinforced composites, or a combination of these materials are required to achieve satisfactory reflectivity levels from the support structure. Furthermore, RF cables connecting to the DUT must be "decoupled" to minimize field perturbations due to the presence of the cable. Lossy absorber material will shield the cable, but will itself perturb the surrounding field and produce measurement errors; ferrite-based chokes are not effective above about 1 GHz.

6. Chamber Characterization

The CTIA test plan requires that chamber reflectivity performance be evaluated periodically using reference antennas that place significant energy on all chamber surfaces. Sleeve dipole and loop antennas with highly symmetric radiation patterns are specified for these tests. The reference antenna is located in the DUT position and the chamber probe antenna is used to measure the composite field within the chamber as the antennas are moved (scanned) relative to each other in theta or phi. Sequential measurements are made with the reference antenna located at the coordinate origin and then offset from the origin by an electrical length sufficient to produce min/max reflection error conditions. Test data is corrected for space loss variation to yield the reflection error bounds for the chamber.

Figure 9. DUT Fixtured on Full Size Human Phantom

Scanning in theta is generally the most stringent test for chamber performance, since the probe antenna and DUT support structure are in relative motion with respect to each other.

Figure 11 shows a typical phi plane pattern taken in a 3m test cell with the reference antenna offset from the origin by 6 inches at 836 MHz. Ripple is less than ±0.3 dB (reference antenna asymmetry was <0.1 dB). Figure 12 shows a typical theta plane pattern for a 3m test cell with the same reference antenna offset as noted above. Pattern ripple is less than ±0.5 dB for angles up to 160 degrees. Probe-pylon interaction causes greater variations above 160 degrees.

Figure 10. DUT Fixtured on Foam Pylon

7. Measurement Capabilities

The test cells described above were designed to satisfy CTIA requirements for radiated testing of wireless handsets. The CTIA test plan stipulates that the distance from the coordinate origin to the nearest point on the probe antenna must be greater than 1.2m and that the maximum physical extent of the DUT must be less than 300mm. Under these conditions, measured data can be treated as far-field data.

The 5m test cell described above meets this requirement using any of the probe antennas described in paragraph 4. To meet this requirement in the 3m chamber, patch antennas must be used for the probe antenna. The 3m plus chamber satisfies the far-field requirement using either patch antennas or the broadband horn as the probe.

The CTIA test plan directly addresses handset testing. For these tests, the DUT is an active self-powered handset, and a base station simulator is used to communicate with the DUT via the test cell probe antenna. A primary parameter of interest is the Total Isotropic Sensitivity (TIS) of the handset. Basically a weighted spatial average of handset sensitivity, it must be measured at multiple frequencies and on multiple channels. This can be a very time consuming test. To minimize test time, the test cell control system supports dual-axis scanning wherein both the theta and phi axes are moved simultaneously during data acquisition. This can reduce hours of test time to minutes.

In addition to CTIA required tests, the test cells can be easily configured for generalized antenna testing to determine directivity, pattern distribution, polarization characteristics, gain and efficiency. Although the CTIA test plan does not address near-field measurements, the test cells will support spherical near-field data acquisition and processing and directly interface to Nearfield Systems, Inc. (NSI) control systems and software. This capability allows accurate measurements to be made with large DUT's or when probe spacing is less than 1.2m. A typical test data output file taken on a discone antenna in a 5m test cell at 1.85 GHz is shown in Figure 13. This data was acquired and processed using NSI-2000 system software.

Although primarily intended for wireless applications up to 6 GHz, the test cells can be used at higher frequencies with suitably selected probe antennas.

8. Conclusions

A family of antenna measurement "Test Cells" has been described which were designed specifically to satisfy CTIA test requirements for wireless subscriber stations (handsets). These test cells also support generalized far- and near-field antenna testing and were designed for limited-space installations. Reflectivity performance of the test cells satisfies CTIA guidelines for measurement errors attributable to the test chamber environment.

9. References

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4. Walton, K. L., and Sundberg, V. C. "Broadband Ridged Horn Design." The Microwave Journal, March, 1964, pp. 96-101.

10. Acknowledgements

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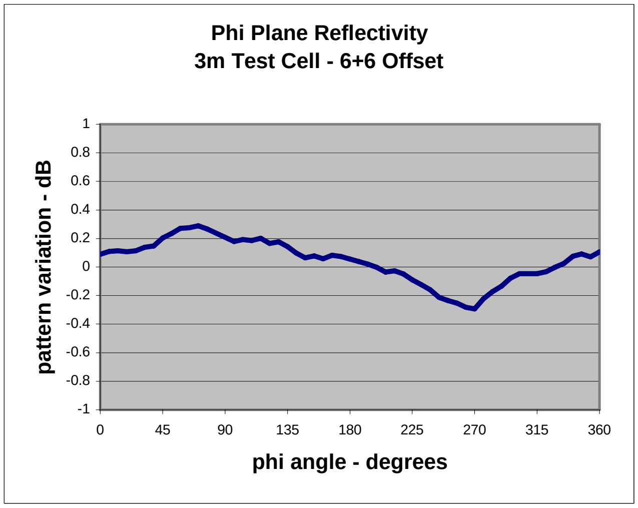


Figure 11. 3m Test Cell Phi-Plane Reflectivity

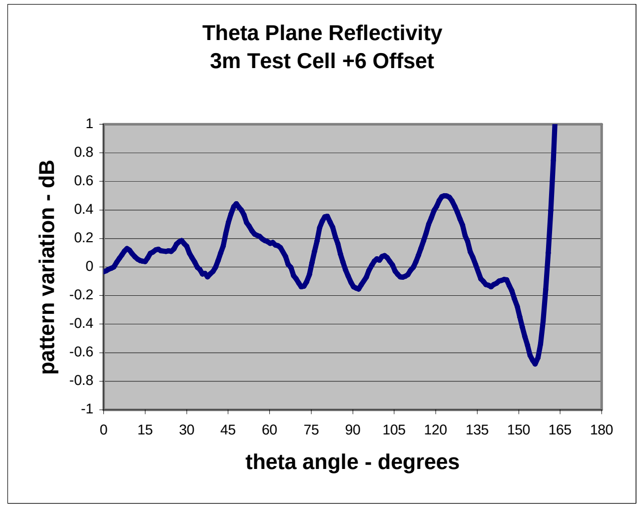
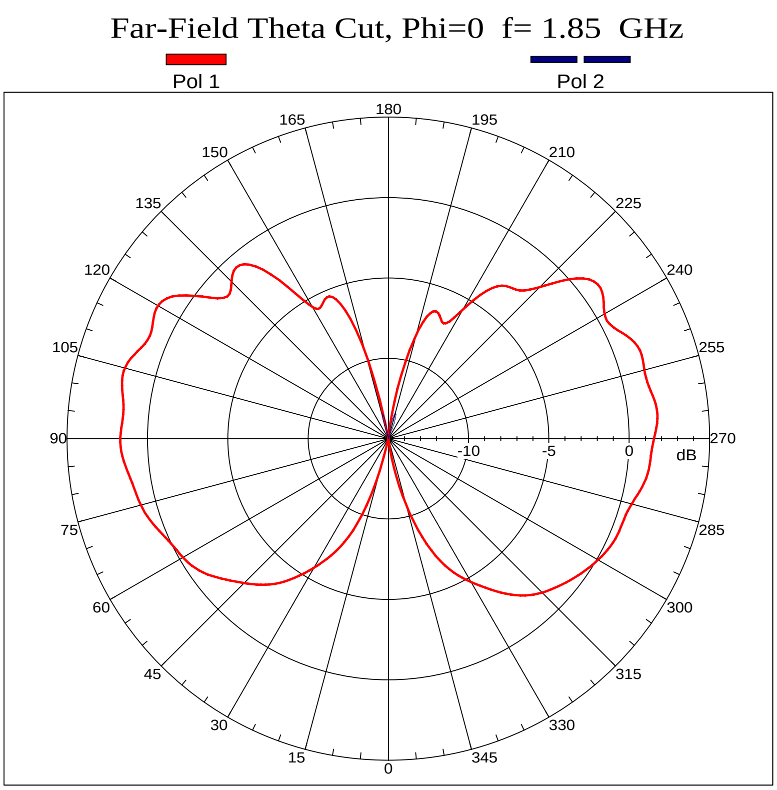


Figure 12. 3m Test Cell Theta-Plane Reflectivity



Far-Field Theta Cut, Phi=0 f= 1.85 GHz

PCS Band validation for after repair 2003-3-10
Filename: C:\NSI2000\Data\Validation\PCS\2003-3-10\I_PCS band validation after repair 2003-3-10.nsi
10/03/03 13:54:58
Computed values are terminal gains - AUT S11 not backed out

Max Pol 1 = 1.997dBi at 104 degrees
Ave Pol 1 = -1.441dBi
Max Pol 2 = -13.347dBi at 195 degrees
Ave Pol 2 = -21.472dBi
3dB Beam Width Pol 1= 77 degrees
3dB Beam Width Pol 2=20 degrees

Figure 13. Test Data for Discone Antenna Taken in 5m Test Cell