TRADITIONAL ANTENNA MEASUREMENTS AND CTIA OTA MEASUREMENTS – MERGING THE TECHNOLOGIES

Donald J. Gray
Nearfield Systems, Incorporated
19730 Magellan Dr
Torrance, CA 90503

Ike Lin
Wavepro Incorporated
296 Shry Yuan Rd.
DaShi, Tao-Yuan 335, Taiwan, R.O.C.

ABSTRACT

This paper describes traditional antenna measurements and the relationship to the Over-the-Air (OTA) measurements specified by the Cellular Telecommunications & Internet Association (CTIA). It discusses the differences, the likenesses, and the importance of providing a system that can provide both traditional antenna measurements and CTIA OTA measurements. It will address the processes of providing a complete turn-key system – including chamber – that will meet CTIA certifications. Further, this paper shows the unique flexibility and features that the 700S-90 provides for meeting the customer's needs, for a wide-variety of applications.

Keywords: CTIA; low-gain, omni-directional; OTA, TIS, TRP, NHRP, NHIS wireless, mobile station, BSS

1.0 INTRODUCTION

Applications for wireless technologies have been growing at an astonishing rate. Everywhere we look there are laptops, PDAs, cell phones, and more, and everything (and everyone) is "connected." Some of these applications, and the interfaces, can be seen in Figure 1.

Figure 1: Antenna Applications

The improvements in electronics, signal processing, and infrastructure have increased the applications for wireless networking technologies and for personal communications. These devices are small and mobile, and this requires smaller and smaller antennas. Therefore, the physical characteristics of the various antennas that are used in wireless devices become more important. Further, the way these antennas are affected by their environment and surroundings become more important. Thus, testing the antenna as part of the overall final package is important. The CTIA organization addresses these concerns with the OTA testing to analyze the effects on propagation and performance.

The 700S-90 is a system that is designed to address all of the concerns of testing the antennas designed for the wireless technologies. It builds on NSI's expertise in providing leading-edge antenna measurements. It has been installed as part of facilities designed as approved, turn-key CTIA Authorized Test Laboratories (CATL). Moreover, it provides the flexibility to successfully handle the technological advancements and higher frequencies that likely will occur in the future.

2.0 TESTING ANTENNAS FOR WIRELESS APPLICATIONS

In traditional antenna measurements, we are typically interested in the pattern, directivity, and gain of the antenna. Figure 2 shows the radiation pattern for a high gain antenna.

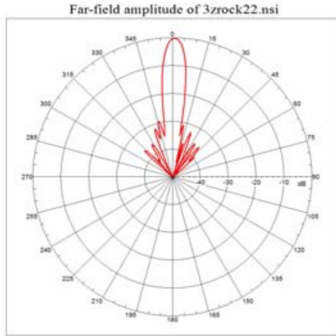

Figure 2: High Gain Antenna Pattern

Antenna engineers use this data to examine such parameters as the peak power being output in the main lobe, the pointing accuracy, 3-dB beamwidth, and sidelobe patterns. The pattern is similarly examined in wireless applications. However, the antennas used in wireless applications are mostly low-gain antennas with omni-directional (or nearly so) patterns. Figure 3 shows an example of a pattern from the wireless card of a laptop.

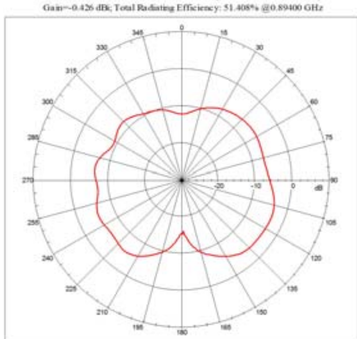

Figure 3: Laptop Wireless Pattern

As with most wireless applications, the directivity is very nearly 0 dBi. The nearly-circular shape of the pattern is important in obtaining the overall best performance. Parameters such pointing accuracy or absolute gain are not as important. Parameters such as average output power and efficiency; however, are paramount to achieve the omni-directional coverage.

Another important consideration is the size of the antennas used in wireless technologies. As the antenna size shrinks, the problems with impedances and mismatches grow. This is exacerbated at lower frequencies. Electrically small antennas interact with the environment to a much greater degree. Thus, although the pattern and gain of the antenna might be acceptable by itself, the poor impedance and limited bandwidth might make it ill-suited for use in the final package.

This phenomenon is of considerable concern for mobile handsets, in which the antennas are appreciably affected by the surrounding environment and material. The overall package, fingers, head, cables, etc., can adversely affect the end performance of a handset (not to mention, the possible ill-effects of other antennas intended for "secondary" applications, such as GPS).

For this reason, additional measurements (other than the traditional "passive" antenna measurements) are important. To address these issues, CTIA developed a new set of standards called OTA performance measurements, in which the overall radiation performance and sensitivity of a device is evaluated.

3.0 OTA TESTING

Over-the-Air performance testing basically is concerned with: 1) The amount of power radiated over an entire sphere, or a defined portion of the sphere and 2) the isotropic sensitivity of the device integrated over a sphere or a defined portion of the sphere.

The figures of merit for radiated power are Total Radiated Power (TRP) and Near-Horizon Radiated Power (NHRP). The TRP is basically ERIP integrated over the total sphere. The NHRP is EIRP integrated over a specific portion of the sphere, called the near-horizon. The near-horizon angles of interest are defined as ±45 degrees of the horizon (theta = 90 degrees) and ±30 degrees of the horizon.

The figures of merit of isotropic sensitivity are Total Isotropic Sensitivity (TIS) and Near-Horizon Isotropic Sensitivity (NHIS). The TIS refers to receiver sensitivity integrated over the sphere. TIS measures the minimum power required to achieve a specified Bit Error-Rate (BER) or Frame Erasure Rate (FER). The NHIS, like NHRP, is isotropic sensitivity integrated over a specific portion of the sphere called the near-horizon. Similar to the power measurements, the angles of interest for sensitivity measurements are ±45 degrees and ±30 degrees.

The purpose of OTA testing is to test the radiated performance of the final package. The overall effectiveness of the transmitter, receiver, and Antenna Under Test (AUT) – like the example shown in Figure 4 – is tested.

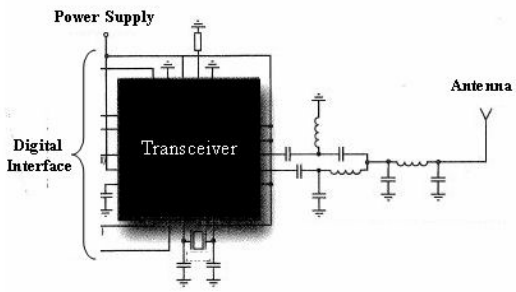

Figure 4: Transceiver and AUT

The OTA tests must be accomplished with a Base Station Simulator (BSS) using the appropriate connection protocols (for example, GSM, CDMA, TDMA). A typical system used for OTA measurements is shown in Figure 5.

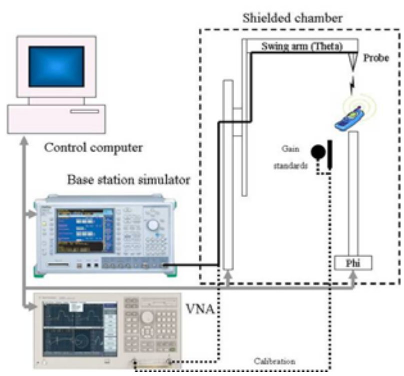

Figure 5: 700S-90 OTA Test Set Up

In the OTA measurements the phone is actively controlled (calls are made and power is controlled) by a BSS (therefore, it is often referred to as "active" antenna tests).
These tests must be executed in an environment that is free of reflections and interference.

To become a CATL, the antenna range must have less than 1.0 dB of combined error sources in the chamber. These include such errors as amplitude ripple of the quiet zone, noise and leakage of the Base Station Simulator, etc. Additionally, CTIA specifies standards for calibrating the entire system. The calibration is necessary to normalize the power and sensitivity measurements to account for path and space losses. This is done using a set of calibration antennas – a resonant loop antenna and a sleeve dipole. Figure 6 shows a picture of a resonant loop antenna on the left and a sleeve dipole on the right being tested on the NSI-700S-90 system.

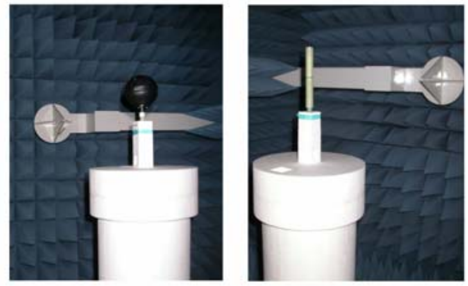

Figure 6: Calibration Standards

Many factors are at play in providing effective communications for mobile telephones. The number of base station towers as well as the location, power output, and pointing of the base station are important. Buildings, mountains, and other obstructions affect the ability to get a line-of-sight path. Also, of course, the performance of the phone itself is important. However, when there is a problem, typically only the provider (such as Verizon or Sprint) is blamed. For this reason CTIA OTA measurements are being more readily adopted to ensure that each phone meets some minimum standard for radiated power and receive sensitivity. When manufacturers sell a phone to US vendors, they must prove the phone meets these minimum standards.

Figure 7, shows an example of OTA radiated power data obtained on a 700S-90 system for a PDA phone.

Device Mfr/Model/Serial number/IMSI	px2 gsm 900-0511///Connecti
Hardware version/Software version	
TX Frequency:	CH*-TX (38, 897.60 MHz)
RX Frequency	CH*-RX (38, 942.60 MHz)
Antenna [Retracted, Extended, Integrated]	Internal
Test condition [Free space, Sim head left ear, Sim head right ear]	Free space
Date of Measurement	11-May-2006, 16:14:22
BSS Output power as mobile station	-80.00 dBm
Mobile station output power setting (PCL setting)	5
Summary Max power (dBm)	29.95 dBm
Summary Min power (dBm)	-15.70 dBm
Summary TRP (dBm)	27.24dBm
Summary NHPRP+/- 45 deg (dBm)	26.52dBm
Summary NHPRP+/- 30 deg (dBm)	25.32dBm
TRP Hpath loss Cal adjustment: (included in measureme	-31.36 dBm

Figure 7: Radiated Power Report Data

The CTIA OTA test plan specifies that these tests be executed with the mobile unit in free space and also with the unit on a model human head (phantom head). Overall field performance is best characterized from the average EIRP (that is, EIRP, integrated over the entire sphere) with the phone on a phantom head.

Similarly, the TIS gives a good indication of overall receiver sensitivity. Figure 8 shows an example of OTA sensitivity data obtained on a 700S-90 system for the same PDA phone.

Date of Measurement	11-May-2006, 18:05:41
BSS Output power as mobile station	-70.00 dBm
Mobile station output power setting (PCL setting)	5
Summary Max power (dBm)	0.00 dBm
Summary Min power (dBm)	-103.53 dBm
Summary TIS (dBm)	-100.86dBm
Summary NHPIS +/-30 (dBm)	-98.80dBm
TIS Hpath loss Cal adjustment: (included in measurement	-32.04 dBm

Figure 8: Sensitivity Report Data

4.0 COMPARISON OF DATA

The OTA performance standards give a good indication of overall performance for mobile handsets. Still, there is a need to test the antenna apart from the overall package. One reason is in the case of poor OTA performance. In this instance, one will not readily know if the loss in efficiency is because of a defect in the antenna itself, or merely a flaw caused by the interaction of the antenna and the overall package and environment. The engineer must be able to isolate the source of the problem.

Figure 9 shows a comparison of phi radiation patterns (at theta = 90 degrees) for a BenQ mobile phone, tested on a 700S-90. In that plot, the phone's antenna is coming out of the page (from the origin) and the keypad is facing phi = 270 degrees. In the measurement with the phantom head, we'd be looking at the top of the head with the face looking at phi = 0 degrees.

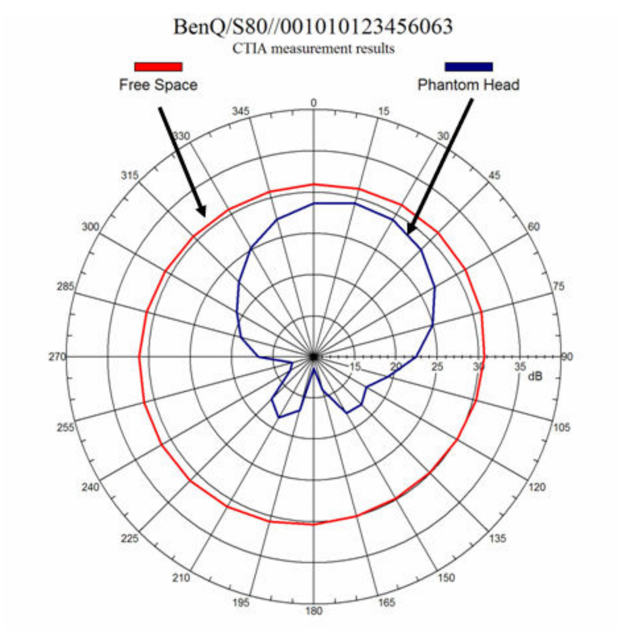

Figure 9: Mobile Phone Radiation Patterns

The red pattern (indicated by the "free space" arrow) is from testing the mobile unit in free space and the blue pattern (indicated by the "phantom head" arrow) is from testing of the phone on the right ear of a phantom hand. The plot from the free-space testing shows a much more circular pattern and the plot from testing with a phantom head shows the adverse effects of the head.

Another reason to test the antenna separately is in doing relative comparisons between antennas or products; it is much faster to do the passive antenna measurement than it is to do the active OTA measurements. Therefore, passive antenna measurements are extremely beneficial in the design phase.

A third reason for passive antenna measurements is the ability to test antennas for a wider variety of applications, such as wireless LAN cards for laptops, or Radio Frequency Identification (RFID) tags (an example of which is shown in Figure 10.

The pictures in Figure 10 show an extreme example of the effects the surrounding environment has on these antennas. In this case, an RFID tag was energized and measured in three different conditions on the 700S-90 system. The first case shows the RFID tag in free space. The second case shows the RFID tag placed on an empty box and the third case shows it on a box full of contents.

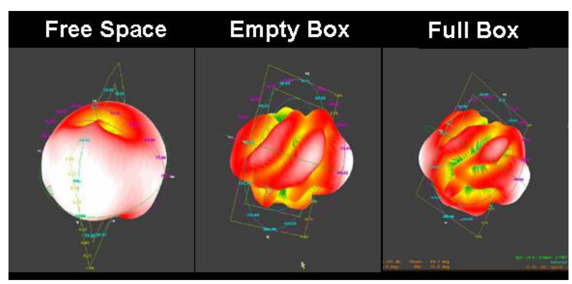

Figure 10: RFID Tag 3D Radiation Patterns

If the tag had been measured only in free-space, then the effects of the environment would not be obvious.

5.0 APPLICATIONS AND FREQUENCIES

For the most part, the frequency range for wireless applications has been concentrated in the 0.8 GHz to 6 GHz range. But as wireless technology advances and wireless networks become more pervasive, the number of standards to address the demands will proliferate. These new standards will expand the frequency over which these devices operate. As shown by Figure 11, current technologies expand to 10 GHz and higher. Thus, the system must be able to accommodate testing at higher frequencies.

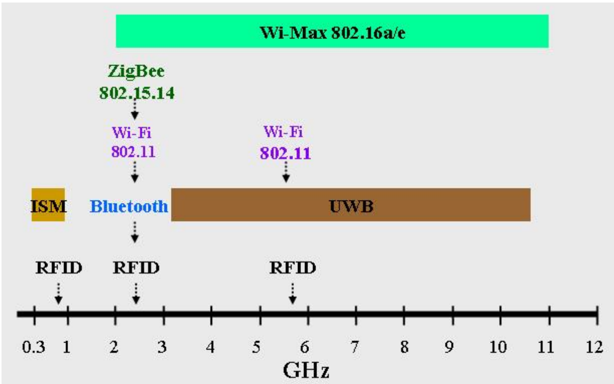

Figure 11: Frequency Ranges of Wireless Apps

The advancements in technology will also increase the complexity of many devices. One example is the emerging technology of RFID, which creates some challenges in testing. Because many RFID applications are designed to operate in the near-field region (or Fresnel Zone), testing in the traditional far-field is not applicable. Engineers are interested in determining the relative power density at different distances and angles from the RFID tags.

Spherical near-field measurement capability is becoming a necessary component to handle the new applications and standards. First, near-field measurements seamlessly provide for holographic analysis capability, which is useful for such measurements as RFID testing, for example. Second, because of the higher frequencies (over which future wireless applications will operate) the far-field distances will be too long to realistically test in the direct far-field mode. Third, spherical near-field techniques gives the capability to test larger or higher gain antennas (which also will have long far-field distances) that may be used in other technologies other than in the wireless industry. This gives the flexibility to adapt the range to cover different industries.

6.0 IDEAL SYSTEM

As stated earlier in this paper, the NSI-700S-90 system (reference Figure 12) is designed for testing antennas in the wireless industry. Additionally, it is designed for use in a CATL facility. Figure 13 shows a mobile unit being tested on a phantom head on a 700S-90.

This system uses an overhead dielectric swing-arm for probe motion in the theta axis, and an AUT support stage for motion in the phi axis. The swing arm and AUT support are constructed of dielectric material to minimize reflections. The overall system is specifically designed to eliminate the adverse effects from interactions between the AUT and the surrounding environment.

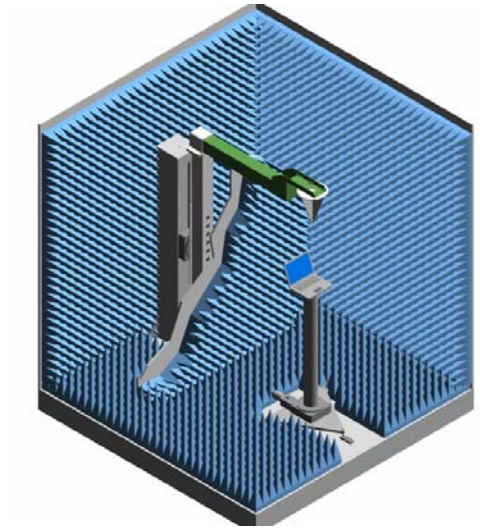

Figure 12: Cut-Away View of the NSI-700S-90

Figure 13: Test with Phantom Head

The AUT support provides “table-top” mounting. This is ideal for phantom heads to keep the fluids static during the duration of the test. Additionally, this eliminates the need for complicated mounting mechanisms and unwanted orientations for devices such as laptops. Lastly, it allows the ability to mount full size phantoms and larger antennas.

The system comes equipped with a wideband, dual-polarized probe. The polarizations are electronically switched so that both polarizations can be obtained on the fly. The system is designed for testing from 800 MHz to 6 GHz, but it can be easily extended from 500 MHz to 18 GH to accommodate emerging technologies.

Additionally, NSI can enhance performance in the chamber by using an optional feature of the NSI2000 software that eliminates measurement errors caused by reflections. The Mathematical Absorber Reflection Suppression (MARS) is the software component that suppresses unwanted signals using analysis and filtering techniques to post-process the data. This can help reduce risks when operating at lower frequencies or if using a less than ideal chamber.

The system includes the NSI far-field and spherical near-field antenna measurement software and CTIA OTA measurement capability. Thus, the system provides passive and active antenna measurements.

The spherical near-field capability allows the 700S-90 to be expanded to other applications and emerging technologies. The holographic analysis feature is one example of the capabilities that is facilitated by near-field measurements. Additionally, the near-field software gives the capability to perform testing on larger or higher frequency antennas

This system includes the NSI automated scripting capability and virtual reality 3D graphics. The automated scripting capabilities help the user develop automated routines for acquisition or processing of the data. This system includes the NSI automated scripting capability and virtual reality 3D graphics. The automated scripting capabilities help the user develop automated routines for acquisition or processing of the data. The NSI 3D viewer provides dynamic, three-dimensional representations of near- and far-field data. With the dynamic mode (which allows real-time rotation and manipulation by the user) of the 3D viewer, the user is optimally supported during the analysis of the characteristics of an antenna, which is very instrumental for the analysis of omni-directional antennas. Figs. 9, 11, & 13 give examples of the NSI 3D graphics and the benefits. Figure 14 shows two 3D images of a phone which was tested on a phantom head. The images have been rotated to different orientations.

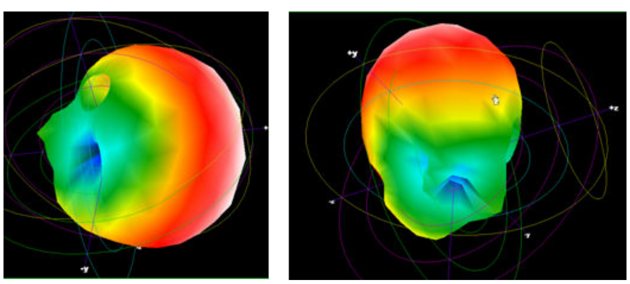

Figure 14: 3D Radiation Patterns of Phone on Phantom Head

7.0 CONCLUSION

As this paper has described, there are many unique concerns in testing antennas in the wireless industry. These antennas are electrical small and easily affected by the interactions as a result of the end product or by other factors in the surrounding environment. For this reason, these antennas must be characterized in the end state, and in a facility which simulates the intended operational environment. A system designed to provide this capability, along with "passive" measurements of the antenna itself. For mobile handsets, CTIA OTA testing is required.

The 700S-90 system gives customers the ability to execute all of the tests required in one system. It can easily expand the frequency coverage and provides flexibility to handle a variety of current and emerging technologies. The mechanical design and software help reduce reflections and interactions with the small antennas to more closely model the operational environment and to provide more accurate assessments of the antenna and overall device. Additionally, this system does not require complicated and expensive maintenance or calibration routines. It is an optimum system for handling the challenges of accurately collecting – and ultimately, analyzing – energy around low gain antennas and devices.

The NSI-700S-90 provides customers the ability to test antennas in the wireless industry. It is an optimum system for handling the challenges of accurately collecting – and ultimately analyzing – the performance low gain antennas and devices.

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