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How to Measure All Types of Antennas Using Very-Near-Field Measurement

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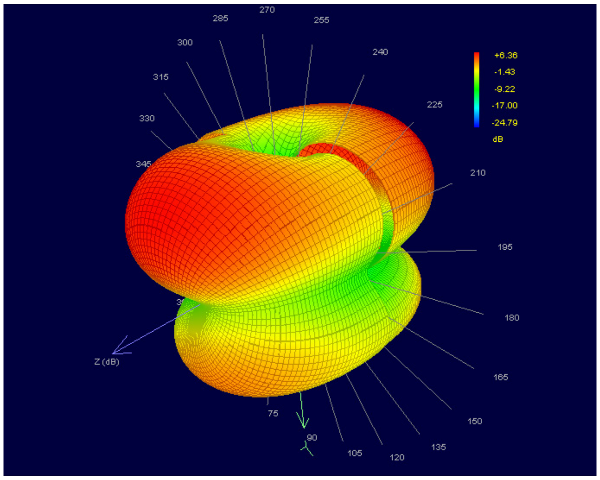
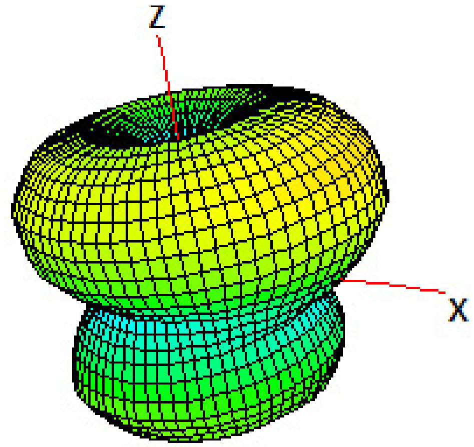
RFxpert test result



CTIA Chamber test result



RFxpert™

How to Measure All Types of Antennas Using Very-Near-Field Measurement

Introduction

Antennas that fail to meet specified design criteria, regulatory requirements or consumer satisfaction either rapidly find the scrap heap or cause costly delays. If the antenna in question actually makes it to market and consumers identify a problem, it can create a widespread public relations nightmare. Designers therefore need to characterize an antenna to meet performance criteria including desired frequency, gain, bandwidth, impedance, efficiency and polarization.

Traditional antenna characterization requires full-fledged far-field testing or gathering near-field data sets to project far-field patterns. Unfortunately, the planar sampling mode, the fastest and least costly traditional near- or far-field technique, only generates reliable results for directional antennas. Omnidirectional antennas must currently be sampled in spherical mode in a sufficiently large shielded test chamber to overcome potential sensor coupling.

For an omnidirectional antenna under test (AUT), such a system also requires a three-axis (X, Y, and Z) robot system and many sampling points. Every traditional antenna testing method thus requires a trained technician and a large shielded chamber. These requirements prove costly both as a capital outlay and an ongoing operations expense. To overcome these hurdles, a novel very-near-field technology based on a probe array samples the AUT on a plane surface at a distance of 2.5 cm. The AUT can be either directional or omnidirectional. In a two-step internal process, seamless to the user, the instrument first projects very-near-field results to far-field results using well-established algorithms. Then a second algorithm adjusts the projection to account for the predictable effects of the interference between the probe array and the AUT. To begin, we will review traditional antenna measurement systems.

Traditional Test Methods: What is the Near-Field?

Currently, different test methods correlate to two different regions used to measure antennas. The far-field region, also referred to as the Radiating Far-Field or the Fraunhofer Zone, is defined as the zone where the pattern does not change with distance. Although there is not a strict definition of the far-field, one common approximation for electrically large antennas mathematically represents this area as $d \geq 2D^2/\lambda$, where d is the distance from the antenna to the sensor, D the largest dimension of the antenna, and λ the wavelength. Another common approximation which makes no mention of the antenna size is that $d>10\lambda$. Antenna manufacturers only undertake the more costly and resource demanding far-field test infrequently.

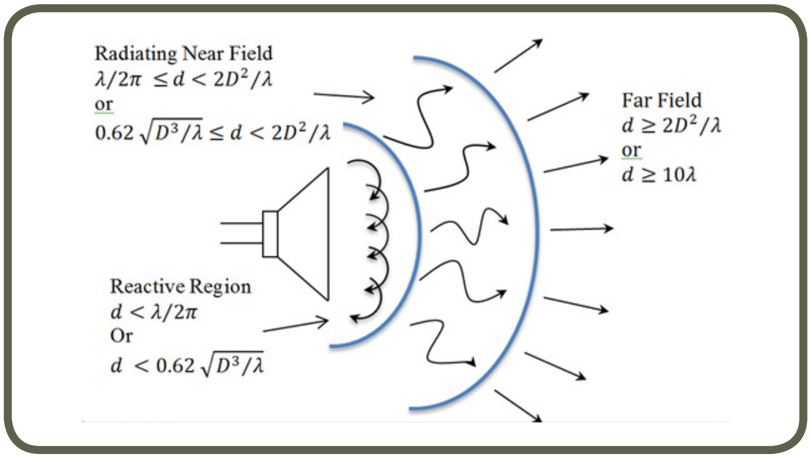


Fig. 1: Distinction in the various fields

By contrast, the near-field, formally called the Radiating Near-Field or the Fresnel Zone, represents the propagation region most frequently measured by antenna manufacturers. As one would expect from the name, near-field measurements literally shrink the area measured to a smaller field, thus requiring a smaller chamber. Once near-field results are obtained, a well-established transform algorithm projects the results to the far-field. Theoretically, despite projecting from the near-field, there is no loss of information in the projected far-field results. Since the objective is to obtain accurate far-field measurements, near-field chambers must provide a controlled and shielded environment. Otherwise, reflections and external noise can severely impact the accuracy.

Like the far-field, the near-field is also not formally defined, other than saying that the near-field is anything that is not the far-field. This means it can be mathematically represented as $d< 2D^2/\lambda$. Less formally, the near-field is said to be three to ten times the wavelength. By applying a Fourier transform to the near-field measurements, the desired far-field projection results. The particular Fourier transform is referred to as the “planar aperture distribution to angular spectrum transformation”. This method to project near-field results into the far-field is accepted as accurate by most regulatory bodies.

Introducing the Very-Near-Field

The very-near-field, a new term, measures the AUT near enough to the sensors that they influence the AUT’s performance. The very-near field can actually impinge into the reactive region, as versus the near-field which always avoids this region. Traditional measurement methods do not usually sample AUTs in the reactive region which can be mathematically defined as $d \le \lambda/2\pi$ for small antennas or as $d <0.62 \sqrt{(D^3/\lambda)}$ for large antennas. Measurements in the very-near-field are taken so close to the sensors that they cannot avoid coupling.

To successfully function as a very-near-field measurement tool, the instrument must minimize the coupling effect and make it predictable. To do so, a static array of probes, which covers the entire scan surface, first captures the data (See Figure 2). Since there is no mechanical movement of the probes during the measurement process, the instrument captures the very-near-field data incredibly quickly. A further advantage of having no motion is that the coupling between the AUT and the probe array is exactly the same throughout the measurement process. Even with this approach, no single methodology can completely resolve the coupling problem since the coupling is dependent on the form of the AUT. However, a reasonable approximation of the effect can be made even for unknown antennas.

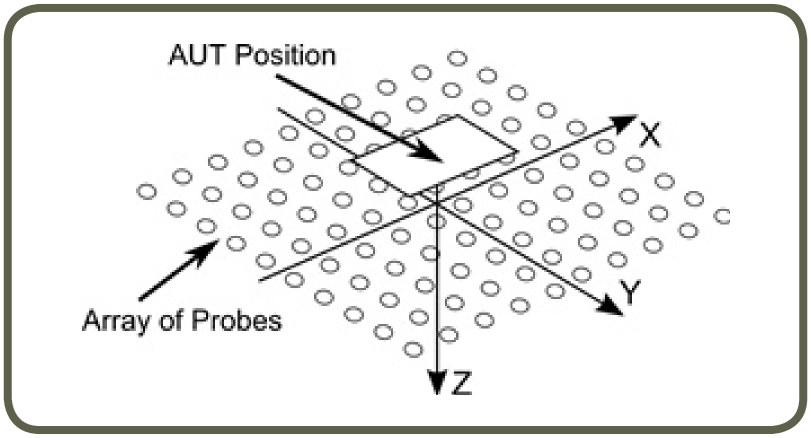


Fig. 2: Static Array of Probes and AUT

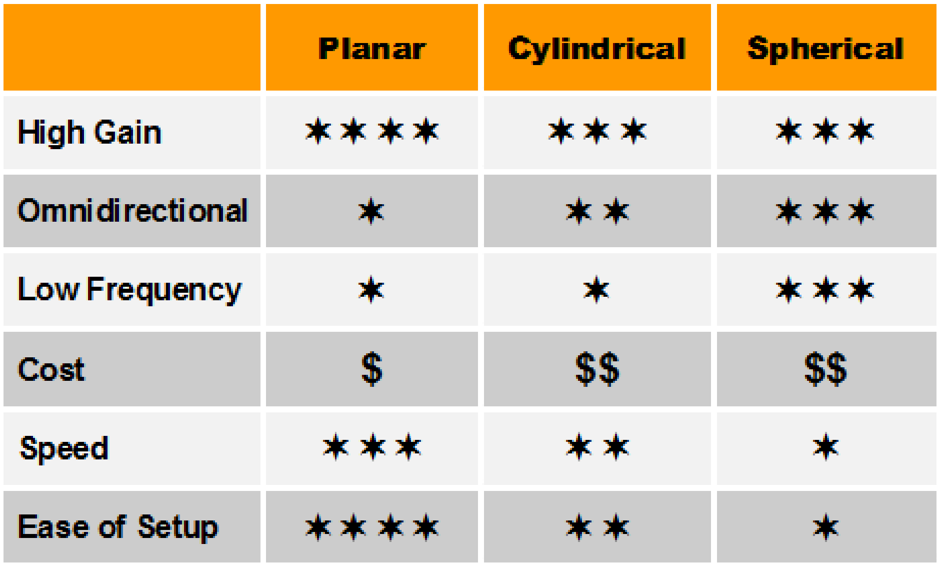
The implementation of this approach has an array of small loops which measures the magnetic field (H-Field) with the probe coupling effects included and projects this data to the far-field using the planar aperture distribution to angular spectrum transformation or plane wave spectrum (PWS) transformation. A second custom algorithm then adjusts the far-field projection to eliminate the predictable coupling effects of the measurement array. This prediction of the coupling effect will have some error since it is dependent on the form of the AUT. This error is typically very small but since it is fixed for a specific form the repeatability and ability to produce differential results for a given antenna model is extremely good.

Antenna Measurement Parameters

The primary goal of measuring any antenna is to identify performance that closely correlates to far-field results. Although many different types of projection are available, we will focus this discussion on Plane Wave/Modal Expansion. The basic measurements required include the radiation pattern, gain, efficiency, beamwidth, and polarization. More complex applications, such as 4G LTE, implement multiple antennas to improve speed and quality of transmissions. These applications may also require advanced measurements such as envelope correlation.

The axial ratio characterizes circularly polarized antennas such as those used for GPS, satellite, and some terrestrial antennas. Beam forming measurements, used for array antennas and common in radar applications, are also finding their way into commercial applications. Beam forming measurements can also be used to debug near-field issues such as the following; identify one or more faulty elements in a large antenna array, identify unintended resonances in a device, and identify energy leakage from non-antenna areas of the device.

Traditional Test Methods



	Planar	Cylindrical	Spherical
High Gain	✶✶✶✶	✶✶✶	✶✶✶
Omnidirectional	✶	✶✶	✶✶✶
Low Frequency	✶	✶	✶✶✶
Cost	$	$$	$$
Speed	✶✶✶	✶✶	✶
Ease of Setup	✶✶✶✶	✶✶	✶

Fig. 3: Generalized Comparison of Antenna Test Methods

The two traditional antenna test methods sample data in three modes; planar, cylindrical, and spherical. The chart above, Figure 2, compares the various measurement parameters of each mode in a general way. Briefly, planar near-field systems are ideal for measuring directional antennas, such as satellite transmitters.

Although traditional planar near-field implementations ignore coupling, in practice, coupling is always present but is minimized to a sufficient degree that it has only a small effect on the calculated results. That said, reducing the scan area for traditional near-field measurements does result in truncated near-field measurements that induce far-field pattern inaccuracy. To obtain good near-field results, the test methodology must maintain an internal sampling standard of λ/2 and sufficient scan area.

The near-field cylindrical test method is used for antennas intended to operate in a plane such as base station antennas. The near-field spherical test method is most suitable for measuring omnidirectional antennas used for mobile communications, Wi-Fi, Bluetooth, and similar antennas.

Challenges Posed by Traditional Antenna Measurement Technologies

Far Field: The biggest challenge to conducting far-field measurements is implied in the very name “far-field.” Far-field measurements require a large physical space. If measured outdoors, the unshielded measurement might be contaminated by ambient transmissions. If conducted indoors, far-field measurements require huge rooms with full shielding and costly radio wave foam.

Further, far-field technologies require a great deal of time because the solitary probe needs to be very accurately positioned in three axes (x, y, and z). By comparison, the planar method only requires accurate measurement in two axes (x and y). As a result, far-field measurements may take several hours or more, require a trained technician, and may involve time delays to schedule the measurement. To perform spherical or cylindrical testing, far-field measurements need an expensive, precision three-axis robot. In summary, far-field measurements prove costly from both a capital and operating expense viewpoint.

Near-field: Near-field measurement technologies pose almost all the same challenges as their far-field cousins with the possible exception that the chamber can be smaller. Although faster than far-field, even the fastest solutions still take several minutes. In addition, failure to account for coupling can lead to measurement and projection errors. And also like far-field technologies, near-field measurement technology is still costly to own and operate.

Reverberation Chambers: Although they address some of the challenges posed by near- and far-field technologies, reverberation chambers do have significant limitations. They cannot provide information about directivity or far field polarization. They do deliver results for a few measurements very quickly although balancing accuracy of measurement and test speed is difficult; diversity gain, Multiple Input Multiple Output (MIMO) capacity for multiple antennas, total radiated power, and receiver sensitivity at a certain bit error rate (BER) are some of the parameters well suited to reverberation chambers testing. Reverberation chambers are also smaller and lower cost than the anechoic chambers used for near-field and far-field measurements, but still require a significant capital investment in dedicated floor space.

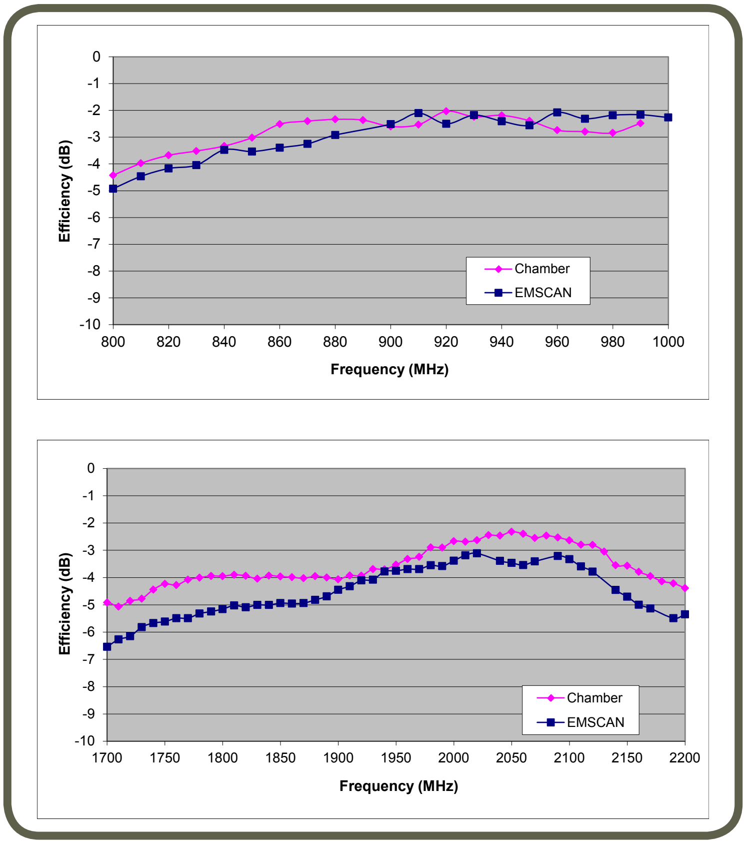
Correlating Very-Near-Field Data Projections with Actual Far-Field Results

Very-near-field instruments such as the RFxpert must provide meaningful projections that correlate closely to measured far-field results. Although many different antenna designs benefit from using very-near-field measurements, antennas with a planar structure like patch antennas and planar apertures like horn antennas will provide the most accurate results. A good example of this is the antennas in mobile devices. The companies making mobile devices measure a number of antenna parameters to meet regulatory requirements and verify performance specifications including directionality and antenna efficiency. Antenna efficiency is particularly crucial since the higher the efficiency of the antenna, the lower the power usage, which in turn extends battery life.

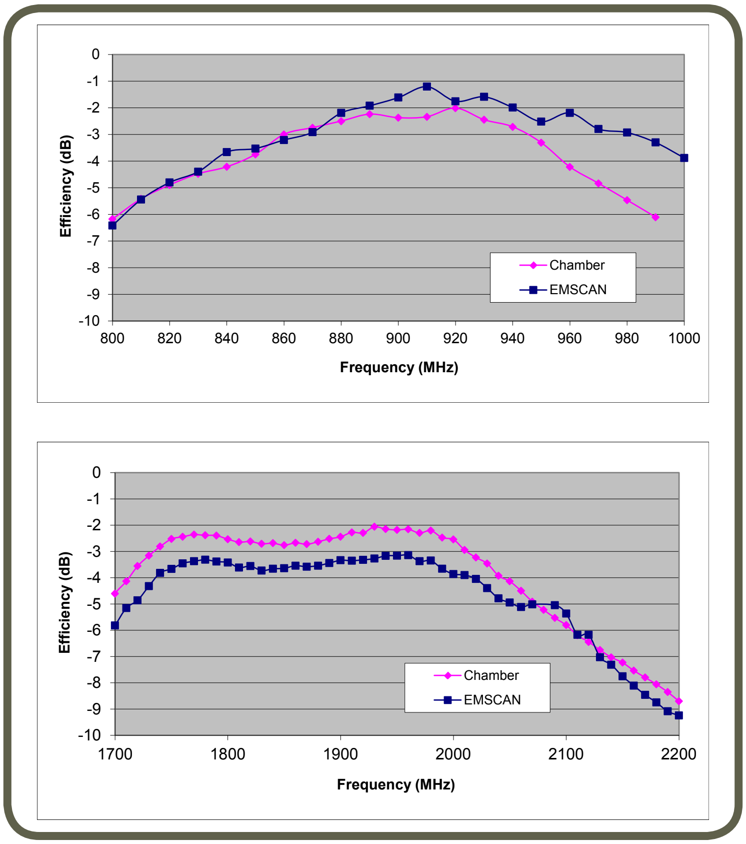
The following test results verify that very-near-field projections can compare favorably with actual far-field results. Variations between the two demonstrate a consistent range of ± 1.5 dB.

Test Results #1-3: Compares very-near-field projections to actual far-field results for three different cell phones in the typical mobile phone frequency range.

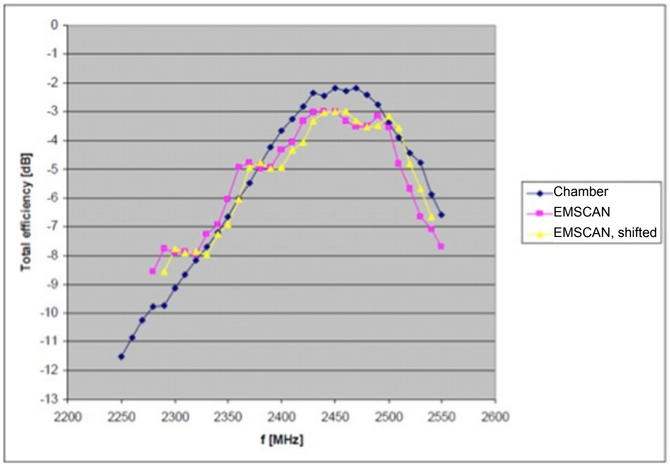
Test Result #1:



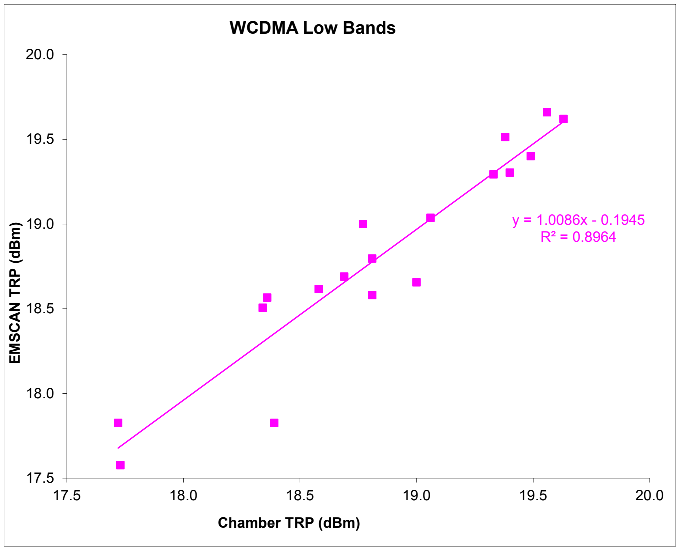
Test Result #2:

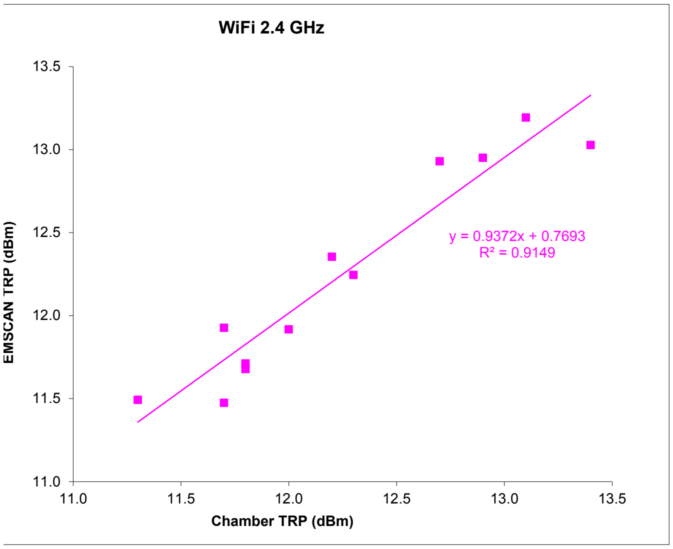


Test Result #3:

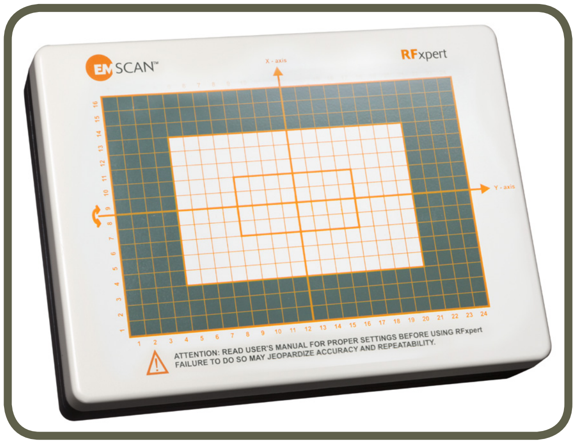


Test Result #4: The y-axis reports RFxpert very-near-field data projected to far-field results versus the x-axis which reports traditional near-field results projected to far-field. These results confirm that very-near-field WDCMA Low Bands and WiFi measurements at 2.4 GHz correlate with far-field measurements to within ± 1.5 dB.





Conclusion: Advantages of Very-Near-Field Antenna Measurement



Traditional near- and far-field measurement systems require ongoing maintenance and calibration, but none is needed with very-near-field measurements systems like the RFxpert. Likewise, many chambers require a reference antenna, but none is needed for very-near-field measurements. Perhaps most importantly for design workflows and accelerating time-to-market, the RFxpert delivers results right in the design area in less than a second.

The compact size of the system means that it can be used almost anywhere. It is literally a bench top antenna measurement system. Despite its small size, the system maintains excellent accuracy for both patterns and absolute far field parameters.

The system overcomes the traditional limitations of the planar scanner for non-directional antennas in the hemisphere by using the close proximity of the AUT to the scan surface to create a large angular coverage. By conducting a second back-side measurement, a design team can obtain complete spherical results.

The far-field results produced from very-near-field measurements offer a variety of user-selectable metrics including gain, radiated power, efficiency, directivity, and axial ratio.

Prepared with the assistance of Lee Stein, Stein Writes, Inc.

About EMSCAN

EMSCAN is the world leading developer of FAST magnetic very-near-field measurement technologies and applications since 1989, providing real-time test solutions to antenna and PCB designers and verification engineers, without the need for a chamber. The EMxpert, a compact EMC and EMI diagnostic tool, and the RFxpert, an antenna measurement tool, enable engineers to quickly optimize their designs. EMSCAN solutions dramatically increase designer productivity and substantially reduce time-to-market and project development costs.

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