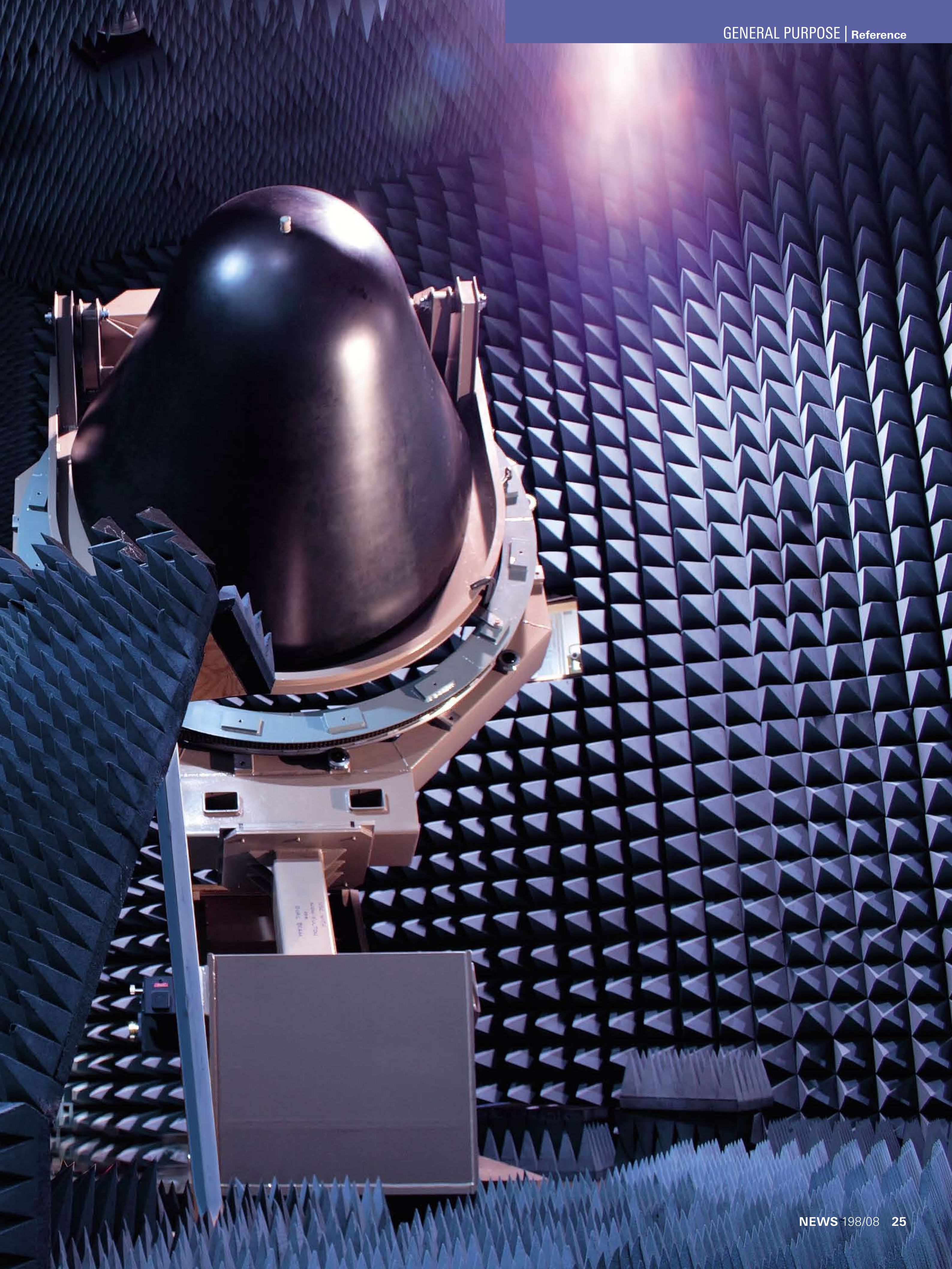
Vector network analyzers – key components of antenna measurement systems

MI Technologies, a leading manufacturer of antenna measurement systems, offers more than 50 years of experience in every aspect of this complex test and measurement field. The company supplies a variety of products, including all important components ranging from highly accurate positioning systems up to sophisticated control and analysis software. MI Technologies also designs and implements turnkey test and measurement systems that use vector network analyzers from Rohde & Schwarz. Derek Skousen from MI Technologies explains what types of measurements are carried out and the basic principles of how antenna measurement systems are set up.

FIG 1 Measurement of the influence of a radome on an antenna in a shielded chamber. This compact-range system makes measurements under far-field conditions possible. The measurements are taken once with and once without the radome. The difference between the two results indicates the influence of the radome on the system. (Photo: MI Technologies)



Antenna measurement systems: as diverse as antennas themselves

The large variety of today's wireless applications is also matched by the demands placed on the transmitting and receiving antennas they require. Therefore, antennas are probably the most highly varied of components in wireless communications systems, with virtually no restrictions in size, shape and structure. Yet, all of these antennas serve basically the same purpose: As transmitting antennas, they must convert conducted electromagnetic waves to free-space waves, and as receiving antennas they must convert these free-space waves back to conducted waves. To determine if the antenna properties are optimally suited for the application at hand, they are precisely analyzed using antenna measurement systems. To accomplish this, several basic parameters must be determined:

The radiation pattern is a graphical representation of the radiated energy versus the radiation angle (FIG 2).
Directivity describes the distribution of the radiated antenna power. It is defined as the ratio of maximum radiation density of the antenna in the direction of the strongest radiation to the radiation density of an isotropic antenna.
The antenna gain is the product of the antenna's efficiency and directivity.
To avoid reflections, the antenna's input impedance must match the impedance of the line connected to it. This measurement can be performed as an s_{11} measurement using a vector network analyzer.
Additional measurements: In many cases, several of the above-mentioned measurements are combined. For example, radiation efficiency can be determined by calculating the ratio of antenna gain to directivity.

FIG 2 Antenna radiation pattern with high gain over an azimuth range of –180° to +180°.

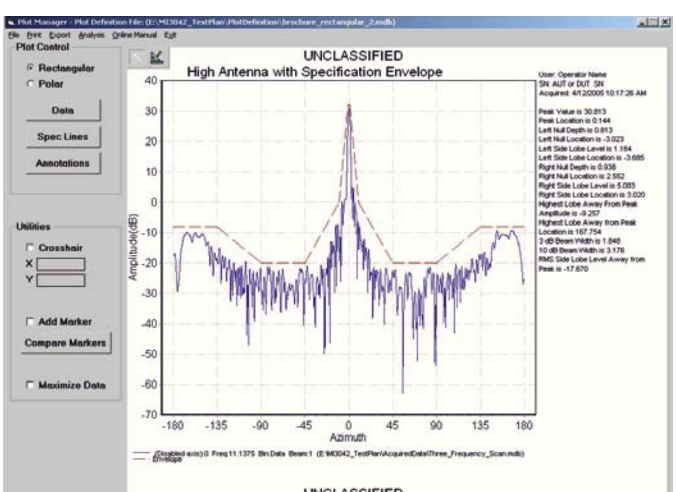


Figure: MI Technologies

Antenna measurements have a variety of applications beyond antenna characterization such as radar cross section (RCS) measurements for determining the reflection by a device under test as well as material measurements in the microwave frequency range.

Near-field and far-field measurements

When measuring antennas, the far-field characteristics of the antenna under test (AUT) are usually of primary interest. The basic parameters of an AUT are defined using the assumption that the wavefronts run parallel. The selection and configuration of an antenna measurement system therefore usually starts by choosing one of several methods for determining these parallel wavefront or far-field characteristics. A distinction is drawn between two different configurations for far-field measurements and one for the near-field.

Far-field measurements

If the distance between the transmitting and receiving antennas is large enough that parallel wavefronts arrive at the receiving antenna, the measurement is considered to be in the far field. This distance occurs when the following condition is met:

$$2D^2/\lambda_0 \leq d$$

where D = antenna diameter
λ_0 = free-space wavelength
d = distance

In many applications, particularly those with large antenna structures and small wavelengths, this condition is achieved only after a long distance is reached. This is why far-field measurement systems can sometimes extend over great distances.

Far-field measurements using compact range systems

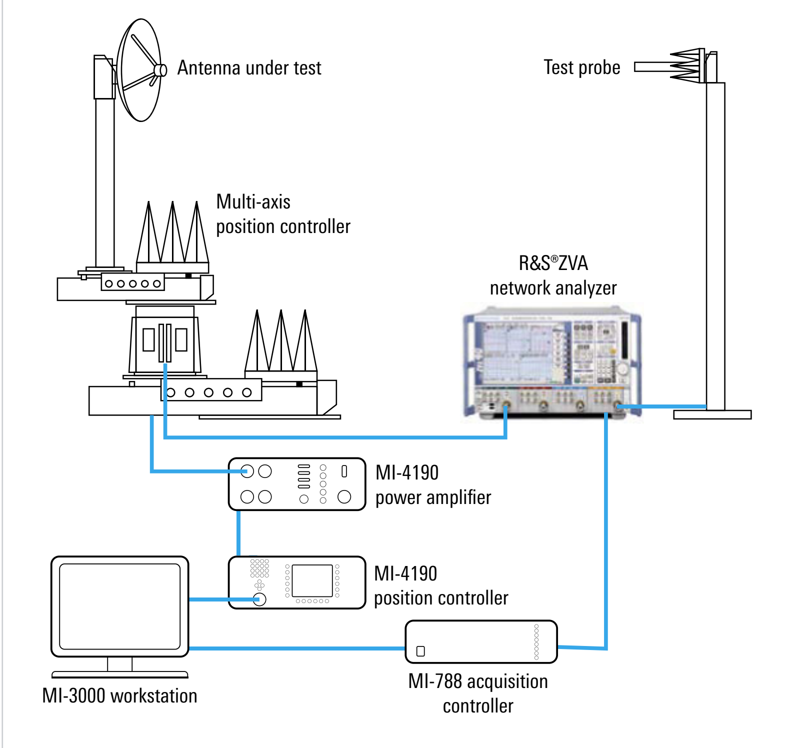
Systems for performing far-field measurements are also available in compact form. MI Technologies produces reflectors that are radiated by specially designed feeds. By using a reflector, the long signal path necessary in order to meet the far-field condition is folded in a small amount of space, thus allowing these systems to be housed indoors (FIG 1).

Near-field measurements

Near-field measurements are performed in close proximity to the AUT. To derive the far-field characteristics from the near-field characteristics, various algorithms for planary, cylindrical or spherical scanning geometries are used. Geometries are chosen based on the AUT characteristics.

FIG 3 Basic setup of an antenna measurement system for performing far-field or spherical near-field measurements.

Basic setup of an antenna measurement system



The basic components of antenna measurement systems

One engineering challenge encountered when designing an antenna measurement system is to properly select and integrate all electronic and mechanical components, the T&M equipment and the shielded chamber. Component selection largely depends on the type of AUT, and particularly on its dimensions, weight, frequency range and antenna gain. Any limitations of the measurement system must also be taken into consideration. FIG 3 shows an example of an antenna measurement system. The system consists of the following key components:

Shielded chamber with positioning system

A positioning system is used to define the positions at which the electromagnetic field must be measured in each case. The keys to obtaining conclusive measurement data are the accuracy of the position and the reproducibility of the measurements. Measurements are therefore performed in a shielded chamber lined with electromagnetic absorber material to suppress external interference signals and reduce internal reflections.

Position controller

The position controller is the interface between the mechanical positioning system (FIG 5) and the measurement system. It controls the various motion axes and provides information about the position and the required control signals.

Signal source

The signal source is the transmitting side of the antenna measurement system. Many systems use a continuous wave (CW) non-modulated signal, except for radar applications, which require pulsed signals. In many cases, additional mixers, multipliers and power amplifiers are used to produce signals with the desired frequency and power. Fast switching of the frequency is essential so as to cover as many frequencies as possible while the position of the AUT moves within a defined space.

Receiver

The receiving side of the system also uses external components such as mixers, amplifiers and multipliers to optimize the incoming signal level. Placing a mixer near the receiving antenna enables the low-loss transmission of power over long distances, for example. This is accomplished by mixing down to a lower frequency range. An antenna measurement receiving system must have a high dynamic range and short measurement cycles. This is the only way to determine the high peaks (positions with a high RX/TX ratio) and deep nulls (positions with a low RX/TX ratio) of the AUT at a variety of positions and frequencies.

Software

The heart of any state-of-the-art antenna measurement system is a complex software program that controls and coordinates all components in the test setup. An antenna measurement system scan can produce large volumes of data that

Vector network analyzers from Rohde&Schwarz offer optimum performance and functionality for use in antenna measurement systems.

The vector network analyzers of the R&S®ZVA family (FIG 4) are ideal for use in antenna measurement systems. They offer coupled generators and multichannel receivers, integrated mixer control, synchronized sweep functions and much more. They are available in the 0.01 GHz to 8 GHz, 24 GHz, 40 GHz and 50 GHz frequency ranges.

A key feature of the R&S®ZVA when used for antenna measurements, where large volumes of measurement data must be obtained, is its high measurement speed. Offering a speed of 3.5 µs per measurement point, the R&S®ZVA can perform measurements extremely fast. Therefore, it can quickly record the data at multiple frequencies for each position point.

The R&S®ZVA has a wide dynamic range of 110 dB at 10 kHz IF bandwidth, which permits the detection of even extremely weak signals. Its output power of +13 dBm and higher allows the instrument to easily handle high signal attenuation on the transmission path.

The analyzer's fast data transmission time of <0.7 ms helps ensure the rapid transfer of measurement data to the control software even as the measurement is taking place. The sweep function of the R&S®ZVA can collect measurement data in equidistant cycles without interruption by the operating system. This allows the instrument to optimally adapt to the movements of the positioning system.

FIG 4 The R&S®ZVA50 shown here is a member of the high-end series of vector network analyzers from Rohde&Schwarz. These analyzers, which are the fastest network analyzers worldwide, are available as two- and four-port versions and in various frequency ranges.

must be collected, processed, analyzed and – when required – combined. Additionally, switch control, triggering and data buffering may be needed to couple the asynchronous operating system software on the PC with the coordinated and chronologically synchronous measurement system.

Vector network analyzers – key components in antenna measurement systems

Because they contain one or more signal generators – as well as multiple receivers matched to each other – in a single instrument, vector network analyzers are a popular measurement tool in antenna measurement systems. They must exhibit outstanding characteristics in a variety of disciplines in order to accurately perform the complex measurements associated with antenna systems. The most important characteristics include:

Measurement speed Is the vector network analyzer fast enough to measure the data on the various frequencies without significantly compromising the measurement dynamic range?

Measurement dynamic range Can the vector network analyzer measure the strongest and weakest signals despite the overall loss in the system? In other words, is the range of the receivable signal level sufficient?

Output power Is the link budget being met, i.e. the sum of the gains and losses caused by all communications and measurement system components?

Data processing and control Can the vector network analyzer process the necessary trigger and control signals and provide the data in a reasonable period of time?

Depending on how complex the user's test and measurement requirements are, MI Technologies integrates spectrum and vector network analyzers from a variety of manufacturers into its antenna measurement systems. This also includes vector network analyzers from Rohde&Schwarz, because their outstanding performance is ideal for such complex test and measurement tasks (see box on opposite page).

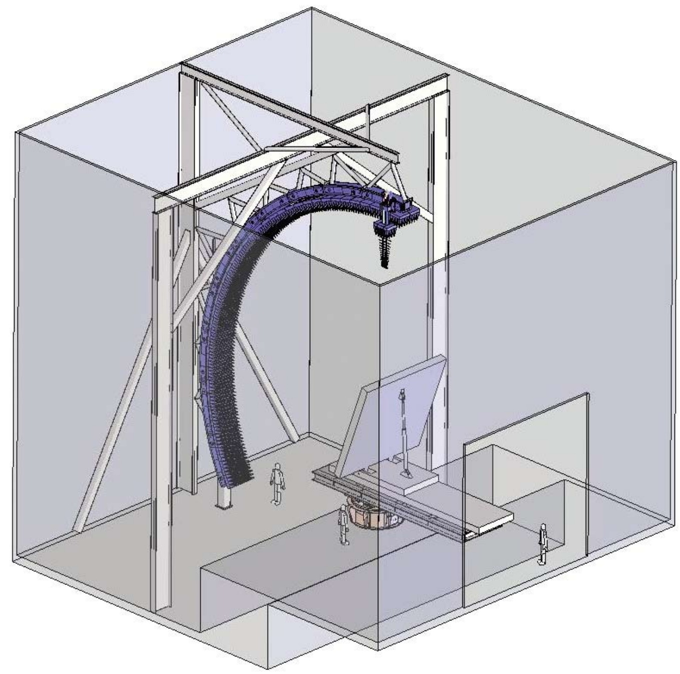


Figure: MI Technologies

FIG 5 Design of an arc-shaped positioning system for performing near-field measurements.

Summary

With more than 50 years of experience in all facets of antenna measurement systems, MI Technologies has the expertise to design and implement superior turnkey systems from highly accurate positioning systems to matching control and analysis software.

Rohde&Schwarz works hand-in-hand with leading manufacturers of antenna measurement systems. In addition to MI Technologies, this includes EADS, March Microwave, NSI and ORBIT/FR. The control of the R&S®ZVA vector network analyzers from Rohde&Schwarz is integrated into the software packages of these manufacturers. With outstanding features that make them the instruments of choice around the world, vector network analyzers from Rohde&Schwarz are ideally suited to meet these challenges.

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