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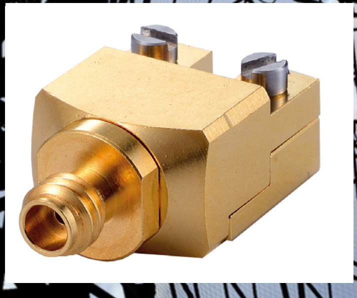
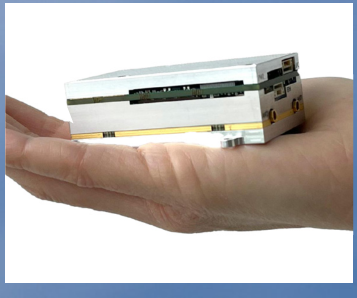
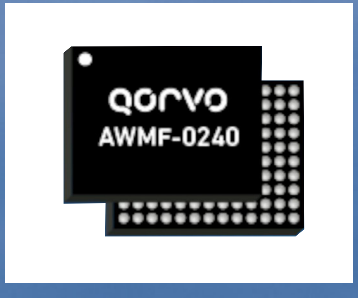
ANTENNA TEST FOR DEFENSE APPLICATIONS







The makeup of military and aerospace systems is constantly changing as the technologies behind the tools used continue to become more sophisticated. Not only is the pace of this change ramping up, the application spaces involved are also growing in complexity and competitive pressures. This puts the onus on developers of military antenna and RF systems to select and integrate the most cost-effective and functional solutions.

Alix Paultre
Editor-at-Large
Microwaves & RF

The importance of antennas and their related RF systems in a military or aerospace platform can't be understated—they often directly impact mission readiness and chances for success. The various roles they play and the applications they serve must be addressed by optimized solutions that minimize weight and bulk while maximizing precision and performance. Whether the role is electronic warfare, navigation, command and control, or data networking, the antennas and RF systems involved have to be among the best available.

This eBook collects together articles that focus on this ever-more-critical area of design.

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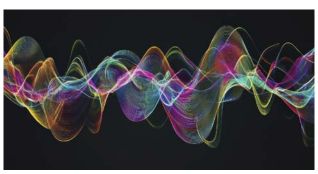

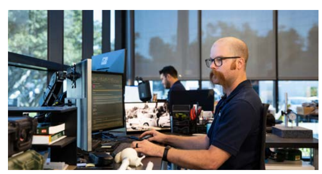

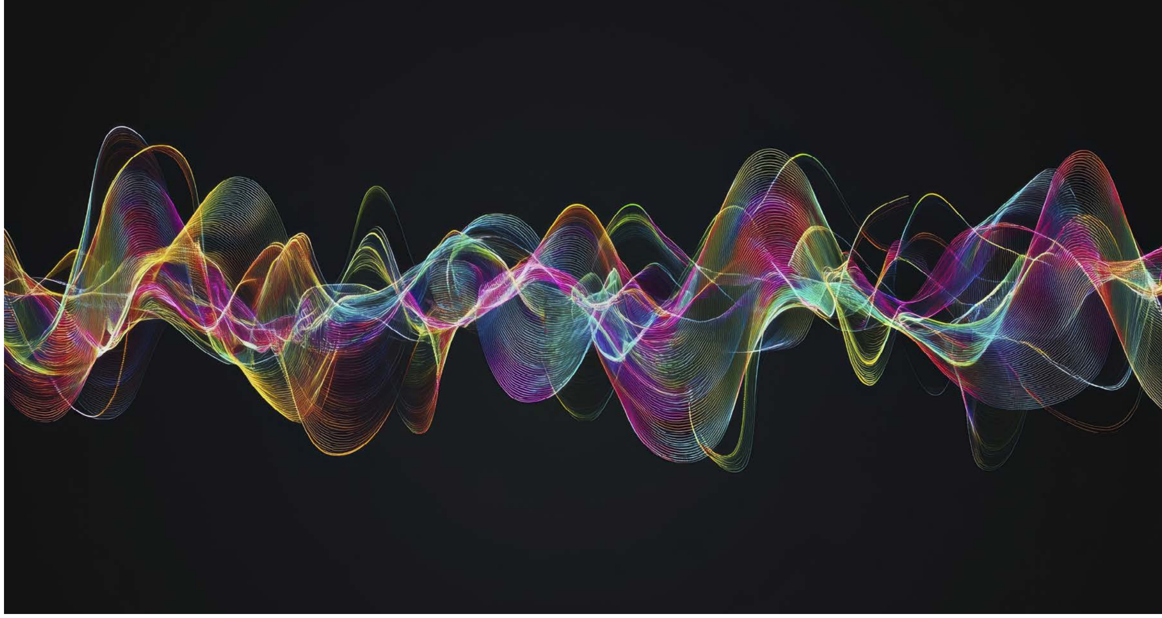

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CHAPTER 1:

Using a VNA to Design Antennas for GPS Interference Detection

LIZ LLOYD, Engineering Editor, *Pico Technology*

Engineers often turn to VNAs to measure the return-loss characteristics of an antenna, but they must be used carefully because there are numerous potential ways to trip up.

GPS interference can come in many forms. The most well-known is intentional jamming or spoofing, denying GPS for a variety of (typically nefarious) reasons. It's common knowledge that parts of the Middle East are denied GPS service, evidenced by cases of ships in the Black Sea suddenly reporting being located 25 nautical miles away, inland, at an airport.

There are also numerous recorded cases of unintentional interference from multiple sources. Real-life examples include a worn cable in a car shark-fin antenna causing the entire roof to radiate; a waterlogged antenna on a building re-radiating and jamming nearby GPS antennas; and even the output of a GNSS simulator accidentally left unterminated after an exhibition demonstration! Being able to quickly determine the presence of GPS interference, and its direction of arrival, is vital in both civilian and defense applications.

GPS signals are very weak—below the thermal noise floor. A GPS receiver needs to boost the signal-to-noise ratio (SNR) to acceptable levels using process gain—i.e., by knowing in advance the precise sequence it's looking for, a receiver can distinguish the signal from the noise.

The process gain is sufficient to identify a signal in a typical environment's noise level. However, if the noise level is higher than normal, then the process gain can be insufficient, at which point the receiver is jammed. Fortunately, the GPS L1 frequency (a 20-MHz band centered on 1575.42 MHz) is a protected frequency and radiation in this band is tightly controlled.

How to Detect GPS Interference

A typical GPS jammer works by increasing the interference, or noise, in the specific band of interest. The signal doesn't need to contain any information; it just needs to drown out the already quiet GPS signal. Unintentional radiators also jam in this way.

A single tone at the right frequency could jam GPS, but many jammers use a frequency sweep over a small band to relax manufacturing tolerance requirements. Because the GPS L1 frequency is protected and the GPS signal is below the noise floor, any detectable signal in the band of interest must be interference.

Spoofing is a much more complicated subject. However, evidence shows that the signal needs to be strong enough to overcome the true GPS signal and thus is likely to still be detectable using a received signal strength indicator (RSSI)-based method.

To make a GPS interference detector, then, a receiver needn't be any more complicated than an antenna and a power detector. A logarithmic amplifier, which returns a voltage proportional to the received power, plus an ADC, would suffice. The system should have a narrow bandwidth centered on the L1 band to avoid false positives. To detect just the presence of jamming (and not its source), the receive antenna should have a wide beamwidth.

Rather than add more components to create a bandpass filter, with care an antenna can function as a basic filter. This is easier when targeting a single narrow frequency such as the GPS band, rather than trying to capture a wide band or multiple bands.

A patch antenna is easy to fabricate. The simplest form is an area of copper on a piece of FR4 PCB material, which can be made at any PCB manufacturer or even on a prototyping router. A basic patch antenna meets both requirements of being narrow bandwidth and wide beamwidth. Basic patch antennas are typically fairly narrowband and single patch has a roughly hemispheric beam pattern.

The intricacies of designing a patch antenna are beyond the scope of this article. Simulation software ensures that a designer can have a good amount of confidence in their design without having to spend time waiting for hardware. However, a simulation can only take into account what's known and measured. Reality will always come with unmodeled factors, and hardware test is an inevitable step in design. A VNA is the ideal piece of equipment for validating an antenna design.

Validating the Patch Antenna

Testing an antenna with a VNA will result in the antenna radiating. GPS L1 is a protected frequency. EMC emissions standards imply that to avoid being considered to be jamming, the radiated power should be less than −70 dB(μV/m) at 3 m. When testing a passive device such as an antenna, the VNA usually would be set to its maximum power output to achieve the best SNR. A PicoVNA has a maximum output power of 10 dBm, or 0.01 W.

The EU harmonized standard for (industrial) EMC specifies a maximum emission level of 70 dB(μV/m), equivalent to 3.2 mV/m, at 3 m from the emitter. A 10-dBm signal into an antenna with a radiation efficiency of 0.5 would generate a 129-mV/m field, over 40X the limit. This assumes an isotropic antenna—including antenna directivity, the field strength would be even higher. To remain under the limit, the input power would have to be at most −74 dBm.

It's important to understand what different measurements can be made on a VNA and what information they can and cannot provide. The overall gain of an antenna (not including the radiation pattern) is determined by two, somewhat independent, factors.

The first is the match between the antenna and its feed network—the antenna input match. The quality of this match determines how much of the signal source's energy is successfully transmitted into the antenna. The second is the match between the antenna (perhaps its "output" impedance) and free space. The antenna radiation efficiency, which indicates how much of the RF energy successfully delivered to the antenna is radiated into free space. Both parameters combine to create the antenna gain.

Measuring the S_{11} of an antenna only quantifies the input match and not the radiation efficiency, and therefore not the antenna gain as a whole. However, it's much simpler to conduct than a two-port S_{21} measurement. Consider a generic S_{11} measurement of a black box device under test (DUT); ignore that the DUT is an antenna. When measuring S_{11}, the smallest amount of reflection occurs when the input impedance of the DUT best matches the VNA. With a good match, most of the signal is successfully transmitted into the DUT. Mismatches increase the proportion of power reflected.

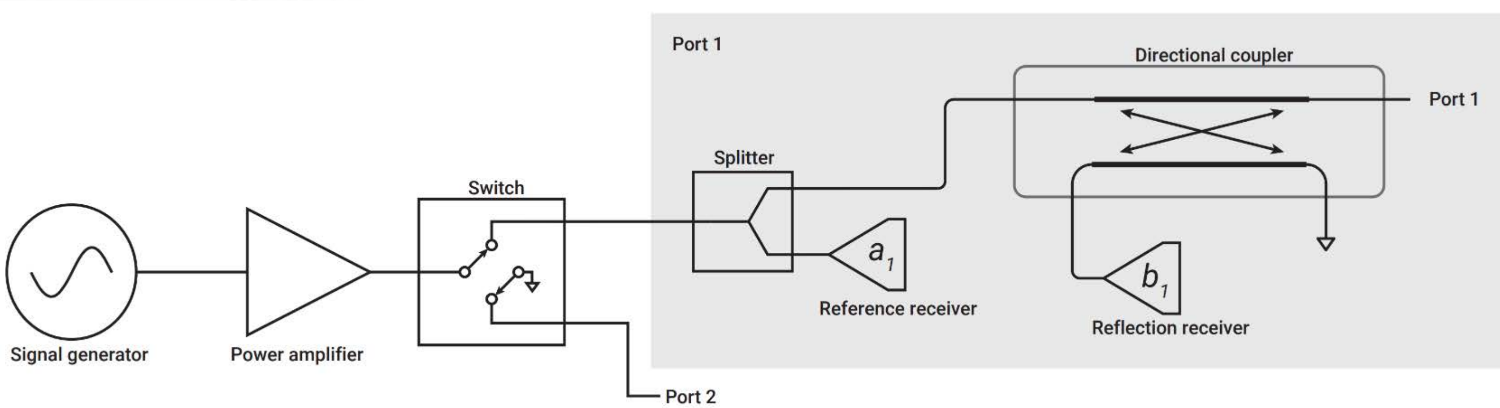
A mismatch could be at the DUT, but it could also be from the VNA. The purpose of a VNA calibration is to correct for any inherent errors in the VNA and test fixtures (the cables and connectors used between the VNA and DUT).

One source of VNA port mismatch is the port directivity. "Directivity" is a somewhat misleading term for an antenna engineer, but it refers to the directional coupler at the output of the VNA port; any non-ideal VNA port directivity is due to the leakage between two of the directional coupler's ports. The calibration process measures, among other things, the leakage between the directional coupler's ports, enabling a calibrated VNA to correct for it in measurements.

Most VNAs have a four-receiver architecture (**Fig. 1**). In this design, the VNA generates the source signal. After the signal generator, the signal is split: one portion is for the reference receiver, *a1*, which measures the signal level before it leaves the port. The other portion goes to the port via the directional coupler. The DUT is connected to the through port of the directional coupler. Signal that's reflected back couples across and is measured by the reflection receiver, b_1.

Calibration and Calibration Kits

During calibration, the VNA generates a frequency sweep. It then measures the signal at *a1* and at *b1*. A known DUT (the calibration standard) means that, from these measurements, the VNA can calculate the leakage through the directional coupler with frequency. Applying the calibration then corrects for the leakage. Any imperfection in the calibration, or rounding errors in calculation, will affect this correction and therefore the effective directivity after calibration. And any error in the effective directivity can add to or subtract from



1. Simplified view of a typical VNA front-end architecture. Ports 1 and 2 have the same hardware. (Credit: Pico Technology)

the measured return loss of the DUT; the exact effect will vary with frequency.

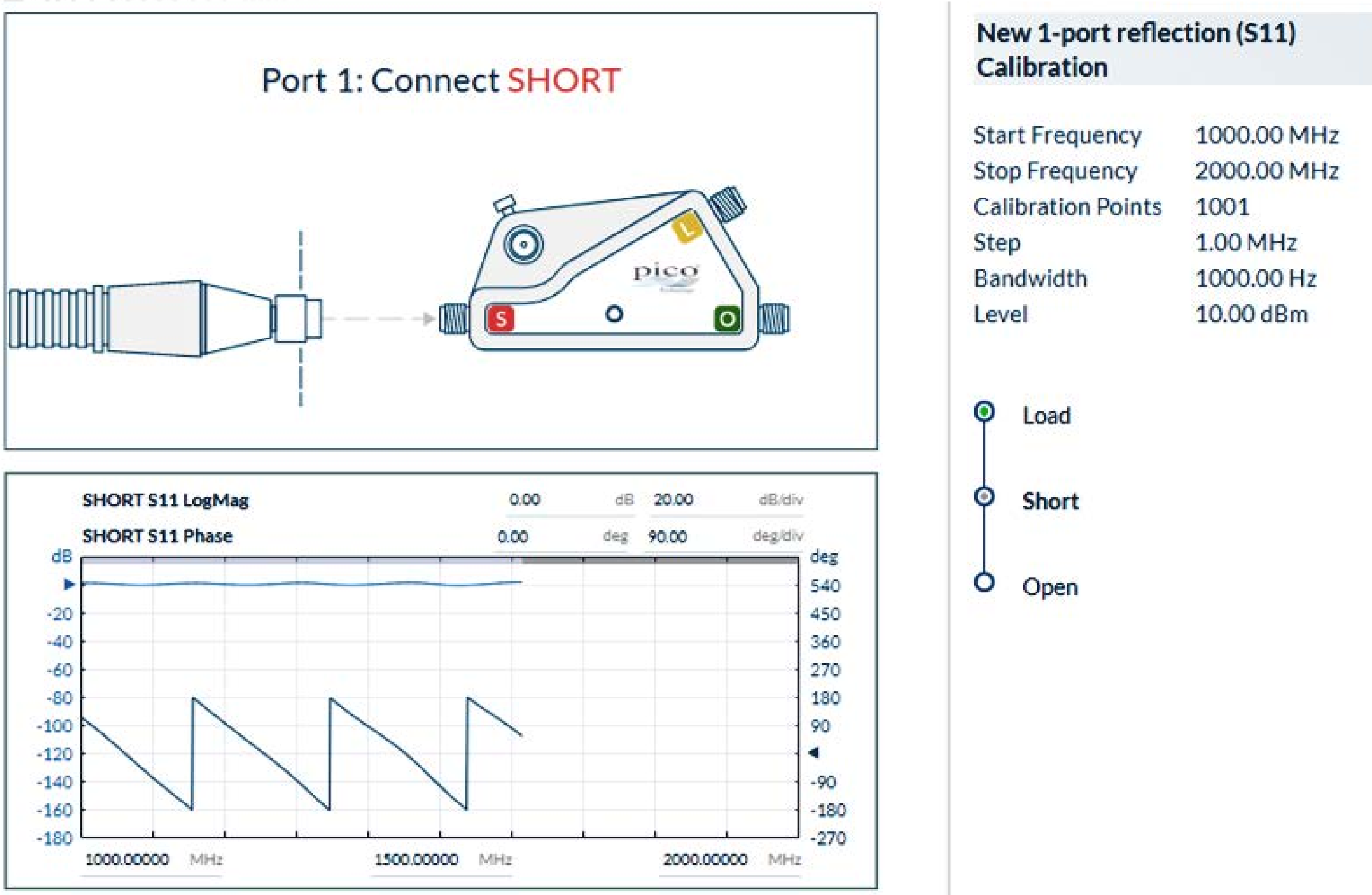
When it comes to calibration kits, there are two main approaches. The first approach has the various parts of the kit (load, short, open) precisely match a predefined set of polynomial coefficients. The second has the kit measured after manufacture, preferably with measurements traceable back to national standards. The precise measurements, in the form of a lookup table unique to a calibration kit serial number, are then used by the VNA during the calibration process. Both approaches can deliver the same level of accuracy.

When carrying out high precision measurements, it's important to have traceable standards; the calibration is only as good as the calibration kit. The kit's parameters will have been measured by another piece of equipment—and have its own errors. And that piece of equipment will have been measured by another, with its own errors…

A good quality calibration kit will have every error in its characterization process quantified and traced back to national standards. The directivity, for example, is affected by the load match. It's crucial to know the exact impedance across the frequency sweep to achieve a good calibration.

Errors during calibration have numerous potential sources. The most common are related to incorrectly tightening cables and connectors. Lower-quality cables have lower phase and gain stability; therefore, if the cables are moved between calibration and test, then the characteristics could change. Calibrations can be checked during the process if a graph is displayed (**Fig. 2**), or by using a check standard after calibration.

2. VNA calibrations can be validated in real-time with a readout of the measurements. (Credit: Pico Technology)



For antennas, the input efficiency of the antenna depends on the match between the feed (the VNA in this measurement) and the antenna input. The radiation efficiency is thus determined by how well the antenna matches free space. Because these are two separate ports, the frequency with the lowest S_{11} may not be the antenna's resonant frequency. The impedance of an antenna also varies hugely with frequency—this is what determines the bandwidth of an antenna.

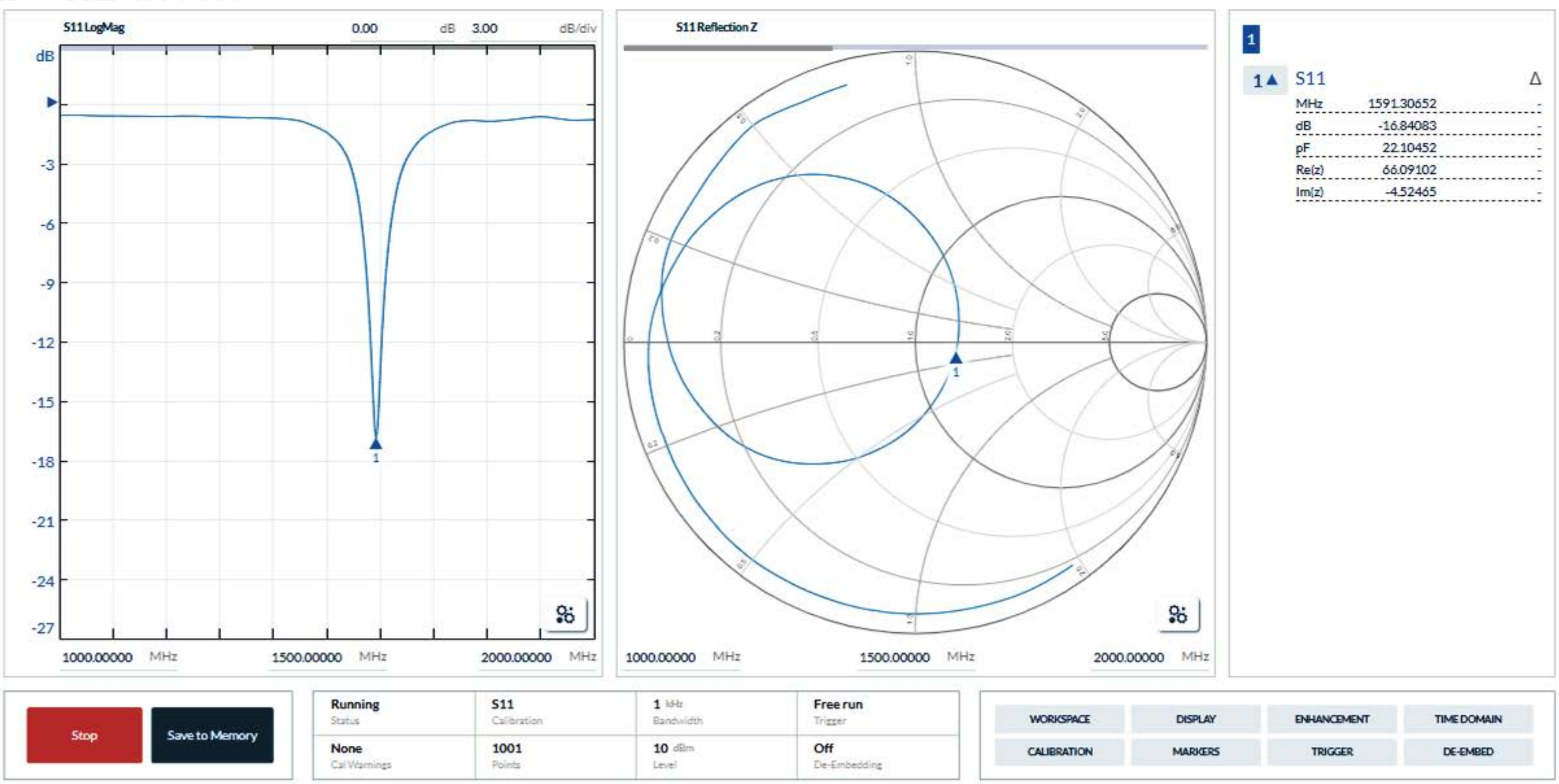
If the input impedance of an antenna doesn't determine all of the antenna gain, and the input impedance of the antenna changes with frequency, and changes in impedance affect the directivity of a VNA, it's clear to see how measuring the S_{11} of an antenna alone could give misleading results.

More Measurements

The best S_{11} result would be when the antenna input impedance best matches the VNA port impedance, but in a final design the VNA will not be the signal source nor receiver. The antenna design must be matched to the feed network. A VNA can measure the real and imaginary components of the input and aid with matching (**Fig. 3**).

An S_{21} measurement is the gold standard for characterizing an antenna. With port 1 connected to the antenna under test and a second antenna—well-characterized, with a known frequency response—on port 2, an S_{21} measurement will determine the total antenna gain with frequency. It can also be used to measure the beam pattern.

To gain an accurate picture, sufficient signal strength for the received signal would be



3. Determining the impedance when the S_{11} is at its lowest is done by pairing markers on log mag and Smith chart representations. (Credit: Pico Technology)

within the dynamic range of the VNA. This is unlikely to be possible while staying within the radiated emissions limits and, therefore, a proper test site is a must.

Detecting Jamming

With a narrowband patch antenna tuned to GPS L1, the receiver need only be an amplifier and a power detector. Designing a basic GPS jamming detection system is a simple task, assuming appropriate care is taken to attain accurate measurements. With this simple hardware (an antenna plus a power detector), it's quick to confirm the presence of jamming, saving time diagnosing equipment malfunctions.

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Handbook of Microwave Component Measurements with Advanced VNA Techniques, Joel P Dunsmore, 2nd ed.

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CHAPTER 2:

The Importance of RF Interconnects in Phased-Array Systems

BY KETAN THAKKAR, Product Manager, *Cinch Connectivity Solutions*

We explore key considerations for designing RF interconnects in next-generation phased-array radar and communication systems, with a focus on emerging trends and practical solutions.

The latest advances in phased-array radar and communication systems for applications like active electronically scanned arrays (AESAs), 5G, and tactical communications are pushing boundaries in frequency operation and physical densification. As these systems integrate increasing numbers of antenna elements, transmit/receive modules, and analog or digital beamforming components, the importance of optimized RF interconnects becomes evident. Engineers must address challenges of size, weight, cost, and installation complexity while ensuring system performance and reliability.

This article investigates key considerations for designing RF interconnects in next-generation phased-array radar and communication systems, focusing on emerging trends and practical solutions.

Trends in Phased-Array Radar

Phased-array radar systems leverage electromagnetic principles to enable higher-frequency operation with reduced antenna sizes. As operating frequencies increase, antenna elements can be smaller, yielding compact, efficient systems.

However, higher frequencies also introduce more significant losses, including RF attenuation and atmospheric absorption. These challenges necessitate additional antenna elements and advanced phase and amplitude control to maintain performance.

Actively controlled phased arrays, such as AESA radars, provide precise beamsteering, which is essential for jamming, low-probability-of-intercept (LPI) communications, and tactical operations. Narrower beam widths at millimeter-wave (mmWave) frequencies enhance directivity, making mmWave phased arrays attractive for radar, communications, and 5G applications. Such advances drive the need for high-density, high-performance RF interconnect solutions capable of withstanding the demands of these compact, complex systems.

RF Losses and Mitigation Strategies

Operating at higher frequencies introduces challenges, including increased RF losses and attenuation. Effective mitigation strategies involve:

- **High-quality interconnects**: Using low-loss coaxial cables and connectors minimizes insertion loss and maintains signal integrity.
- **Phase control:** Ensuring a stable and predictable phase across signal paths requires phase-stable and phase-matched coaxial cables.
- **Robust materials**: Advanced materials help manage environmental factors such as temperature changes, vibration, and mechanical stress.

These considerations are particularly critical in dense phased-array systems, where minor losses or inconsistencies can impact overall performance.

Millimeter-Wave Phased-Array Challenges

At mmWave frequencies, phased-array antennas benefit from reduced size and weight but also face challenges related to densification. Increasing the number of antenna elements demands tighter integration of transmit/receive modules, beamforming components, and signal processors. High-density RF interconnects must support this integration without compromising performance.

Emerging mmWave systems, including industrial 5G applications, often adopt ruggedized designs initially developed for military and aerospace use. These designs prioritize reliability and resistance to environmental stress, ensuring durability under challenging conditions. The same principles are expected to extend to automotive, infrastructure, and industrial applications, reinforcing the need for robust interconnect solutions.

The Phased-Array Signal Chain

Phased-array antenna systems rely on interconnected components, including amplifiers, phase shifters, and antenna elements. Advances in integration have led to the development of transmit/receive (TR) modules, which consolidate power amplifiers and low-noise amplifiers into compact units. These modules reduce overall system size and weight, but they require high-density RF interconnects to connect seamlessly with the rest of the system.

Hybrid and digital beamforming architectures further shrink phased-array designs by incorporating system-on-chip (SoC) and system-in-package (SiP) technologies. These systems reduce reliance on RF connections between components, instead utilizing high-speed digital links. However, they still require tight-pitch RF interconnects for critical signal paths, particularly in high-frequency and high-power applications like jamming and radar.

Key Design Considerations for RF Interconnect

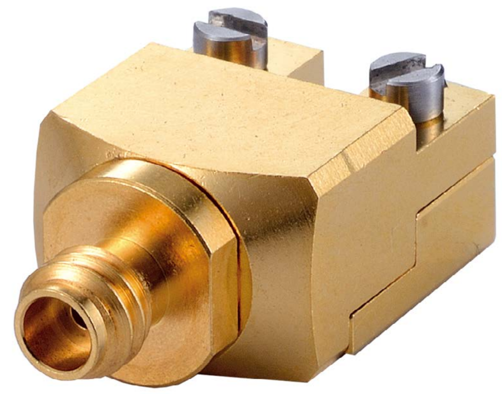
Phase Stability and Matching

The performance of phased arrays depends on precise phase control across signal paths. Two critical factors include:

- **Phase stability:** RF interconnects must resist environmental influences such as temperature fluctuations, shock, and vibration. Phase-stable cables are essential for maintaining consistent performance.
- **Phase matching:** Systematic phase errors can arise from inconsistencies in cable production. Phase-matched cables ensure uniform phase response, improving system predictability and performance.

Mechanical Robustness

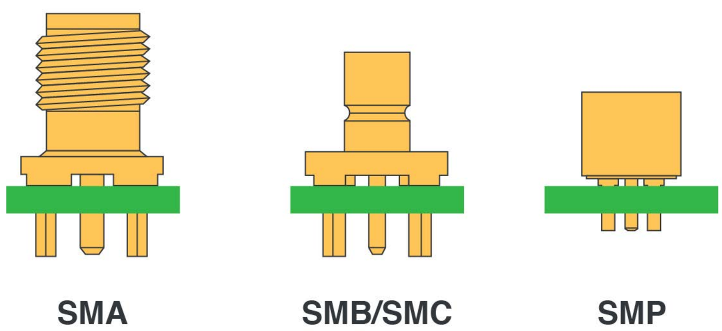
Military and aerospace applications demand mechanically robust interconnects that can withstand shock, vibration, and thermal cycling (**Fig. 1**). These requirements often extend to automotive and industrial applications, where reliability is critical. High-reliability (Hi-Rel) interconnects, certified to meet stringent standards, are essential for mission-critical systems.



1. Military and aerospace applications demand mechanically robust interconnects capable of withstanding shock, vibration, and thermal cycling.

Compact and High-Density Interconnects

Due to size and performance limitations, traditional RF connectors like N-type and SMA may no longer suffice at mmWave frequencies. More miniature connectors, such as 2.92 mm, 2.4 mm, and SMPM, offer higher-frequency operation and compact form factors (**Fig. 2**). Blind-mate and ganged connectors enable efficient assembly and disassembly, reducing pitch requirements and simplifying system integration.



2. Traditional RF connectors may no longer suffice at mmWave frequencies. Miniature connectors offer higher-frequency operation and compact form factors.

Board-to-Board and Component-to-Board Interconnects

Modern phased arrays increasingly use printed circuit boards (PCBs) with surface-mounted components. This trend necessitates:

- **Surface-mount connectors:** Compact, solderless connectors reduce RF path loss and support high-density layouts.
- **Stacking solutions:** Mezzanine-style connectors provide reliable interconnects for stacked PCB configurations, minimizing interference and enhancing system reliability.

Addressing Supply-Chain Challenges

Sourcing RF interconnects for phased-array systems can be complex, involving numerous vendors and stringent quality requirements. Military and aerospace applications often require MIL-SPEC compliance, necessitating careful material selection and manufacturing oversight. Partnering with experienced suppliers familiar with these standards simplifies procurement and ensures consistent quality, benefiting defense and commercial applications.

As phased-array systems evolve, so do the demands placed on RF interconnects. Upcoming technologies like mmWave AESA radar, 5G, and advanced tactical communications will rely on innovative solutions that balance performance, integration, and reliability. High-density interconnects, robust materials, and advanced manufacturing techniques will be critical to meeting these demands.

Moreover, as industries like automotive, industrial automation, and telecommunications adopt phased-array technologies, the importance of standardized, scalable interconnect solutions will grow. Engineers and designers must stay informed about emerging trends and technologies to ensure the success of next-generation systems. By addressing the challenges of RF interconnect design, engineers can unlock the full potential of phased-array antennas, paving the way for advances in radar, communications, and beyond.

Ketan Thakkar, product manager of Cinch Connectivity Solutions' Johnson RF & Microwave product line, has over two decades of experience in the electronics industry. He started his career as a hardware design engineer in the communications and consumer electronics industry and then moved on to sales and field applications engineering in the electronics and semiconductor industry. He holds a bachelor's degree in electrical engineering from the University of Illinois at Urbana-Champaign

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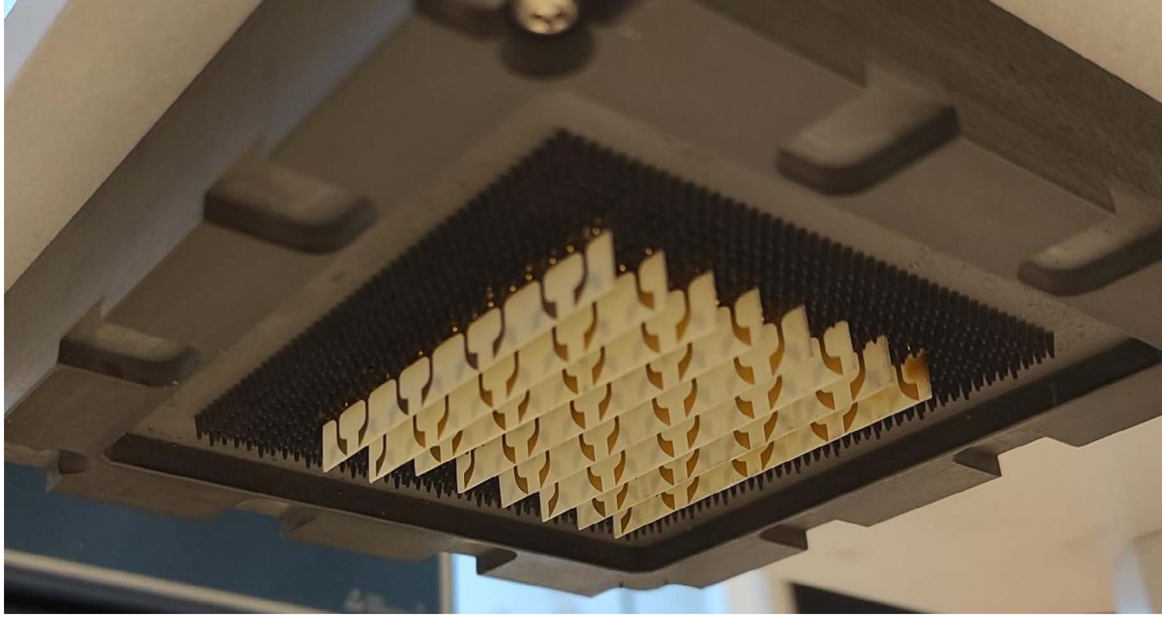


Emerson Test & Measurement

CHAPTER 3:

Future-Ready Near-Field Technique Will Transform Antenna Measurements

THOMAS DECKERT, Principal Software Engineer, and VINCENT KOTZSCH, Chief Engineer,
Emerson Test & Measurement

Measuring an antenna's radiation properties is important, especially when it comes to complying with regulations and system specifications, and verifying the system's mission-readiness.

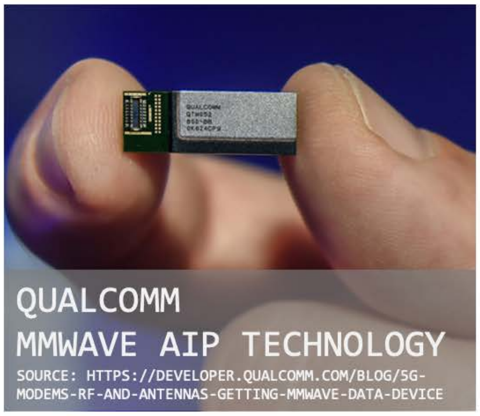
Antennas are a necessity in any wireless communications or sensing device. Modern antennas in radar, cellular, or satellite communications come integrated with circuitry to control transmission direction, interference, eavesdropping protection, etc. This enables a radar system to clearly determine the location of targets and improves the capacity of communication links and networks.

These antennas are also called electronically steered arrays (ESAs). They're arrays of passive antenna elements, e.g., patch antennas, combined with a feed network (or beamformer) that enables control of amplitude and phase per array element. Thus, RF transmissions can be steered into desired directions. Implementations vary significantly in frequency range, power characteristics, array design, etc. (**Fig. 1**).

Measuring an antenna's radiation properties is important; for example, to comply with regulations or system specifications, or to verify the system's mission-readiness. The measured signal propagates over the air. Compared to measuring conductively, i.e., tapping the signal using probe tips or connectors and cables or waveguides, radiated measurements are usually more complex and costly. That's because they need measurement antennas and anechoic chambers to reduce interference from other signals which also introduce more measurement uncertainty.

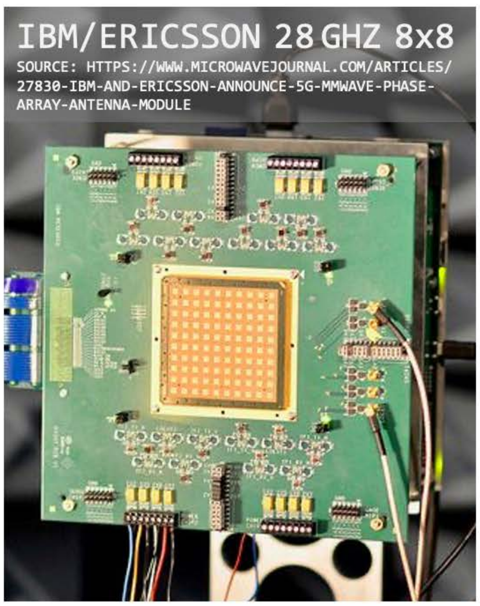
Measuring spatial characteristics requires rotating the antenna under test or the probing antenna, using positioners, turntables, or robots. Unfortunately, this comes with mechanical complexities, such as minimizing position uncertainty and phase variations when moving cables.

1. Exemplary active antenna array: compact mmWave designs (a), large phased arrays (b), and beamforming (c).



(a)

(b)



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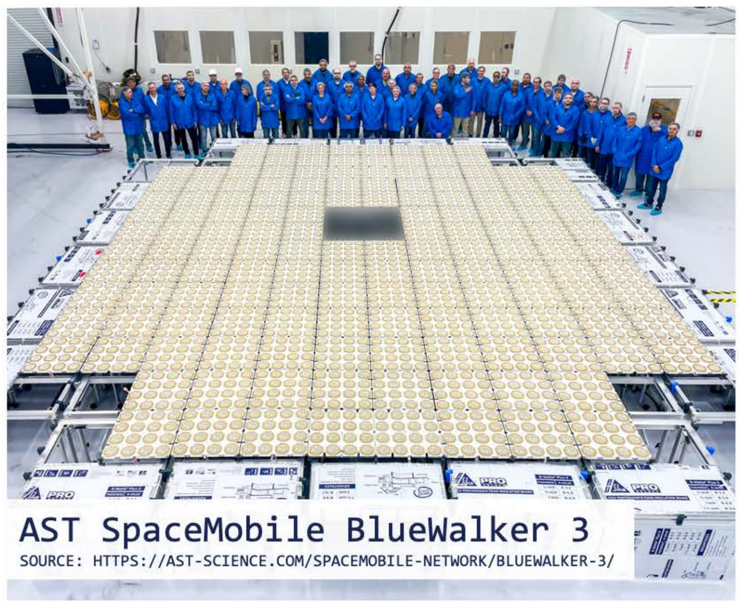


(c)

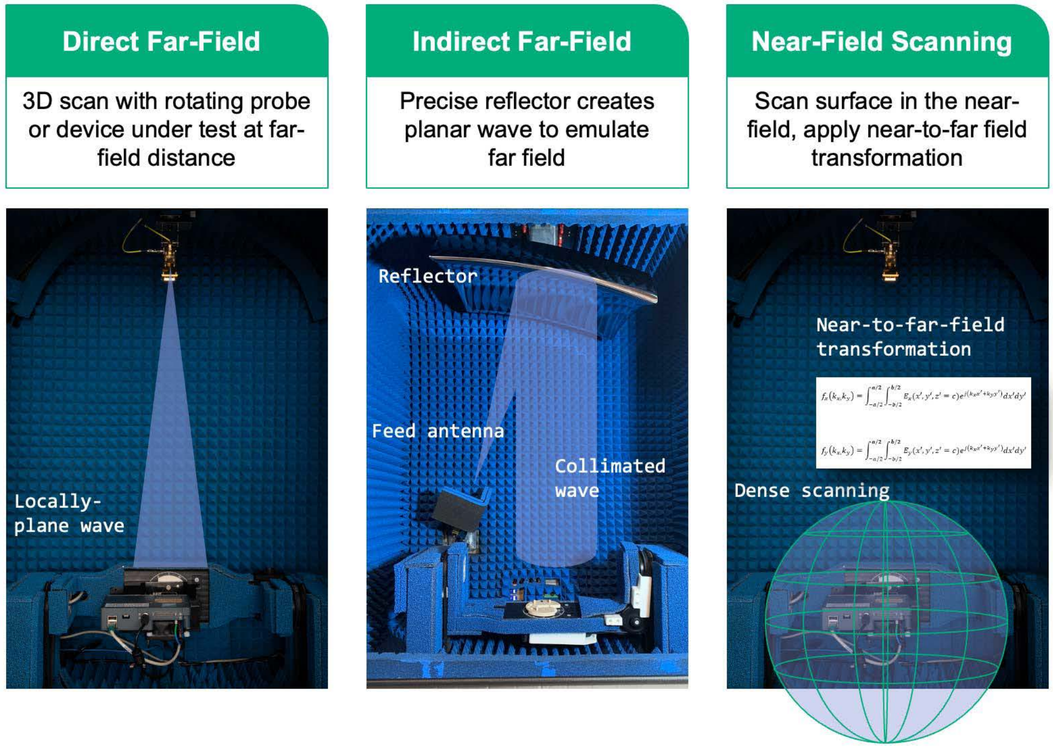
Most antennas are meant to overcome a significant distance between transmitter and receiver. As a result, there's interest in determining characteristics for such distances in what's known as the "far-field zone."

Figure 2 shows three common arrangements to obtain far-field characteristics: measuring with sufficient separation between the antenna and the probe; collimating the electromagnetic waves with a reflector to create far-field conditions at closer range; or scanning a surface close to the antenna, in its so-called "near field," and transforming the data to the far-field characteristics.

These arrangements have their individual tradeoff of size, complexity, speed, and cost.[1] Generally, however, their overall economics are challenging, especially for larger antennas, and may prevent more thorough testing.

Innovative Near-Field Measurement Technique to the Rescue

Researchers at NI and TU Dresden found a disruptive approach that enables the test engineer to measure an antenna's radiation with very compact equipment, at a fraction of

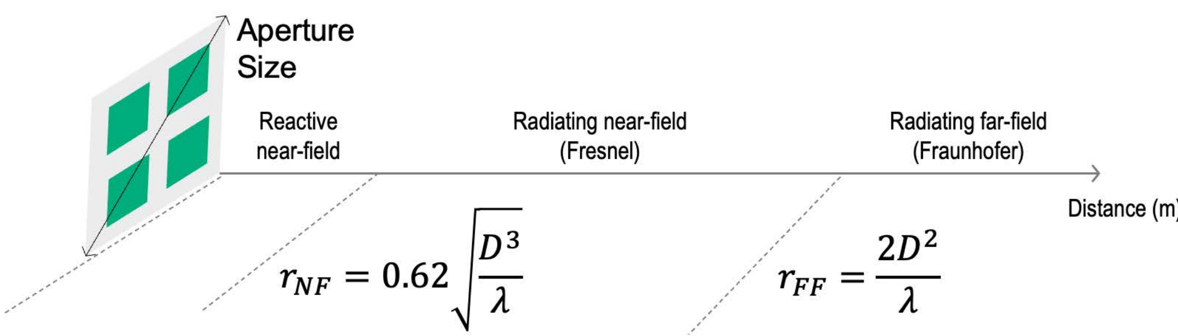


2. Conventional antenna radiated measurement methods.

the time required with conventional methods, and with the same accuracy that's achievable with these incumbent methods.[4,6] The setup's compactness would make it ideal for testing ESAs in the field. One could avoid putting large devices in larger chambers or taking the antennas out of these devices for measurements.

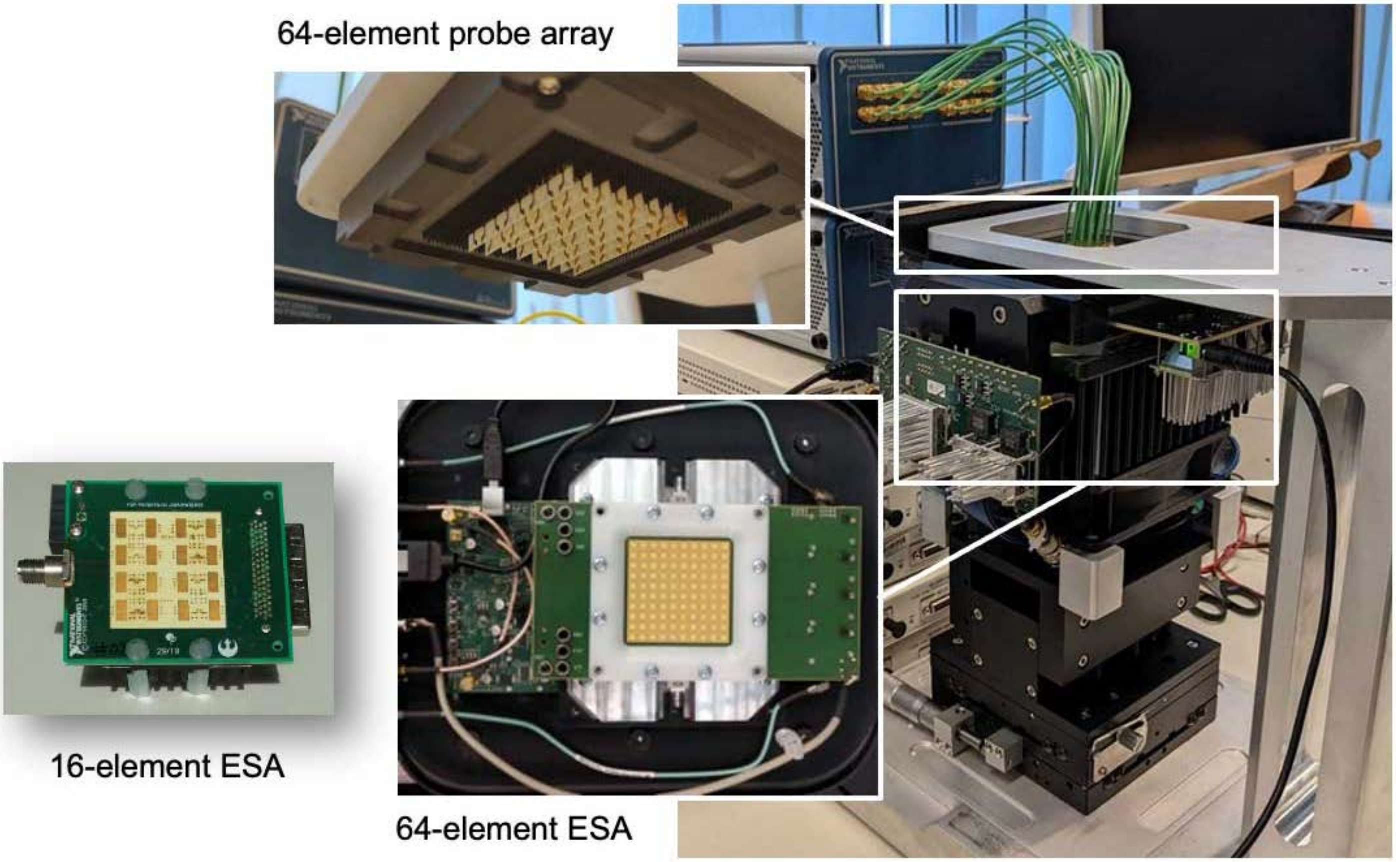
An array of probe antennas is placed very close to the antenna under test (**Fig. 3**). Bringing the antenna and probe close together makes the setup small. Again, "close" means "near field."

Figure 4 helps illustrate the benefit of being in the near field—e.g., for an antenna with a diameter of 1 m and a frequency of 1 GHz, the radiated near field, where conventional near-field scanners would operate, begins about 1.13 m away from the antenna, and the



Aperture Size D	Frequency	Near-Field r_{NF}	Far-Field r_{FF}
100 cm	1 GHz	113 cm	667 cm
10 cm	30 GHz	20 cm	200 cm

3. Experimental setup with antenna under test and probe array in a fixture in the center, and part of the mmWave instrumentation in the back.



4. Distances to near-field and far-field zones grow with antenna size and frequency.

far field at 6.7 m. What's more, in the experiments, very good results were obtained with the probe array positioned in the reactive near field, that is, with an even more compact setup.

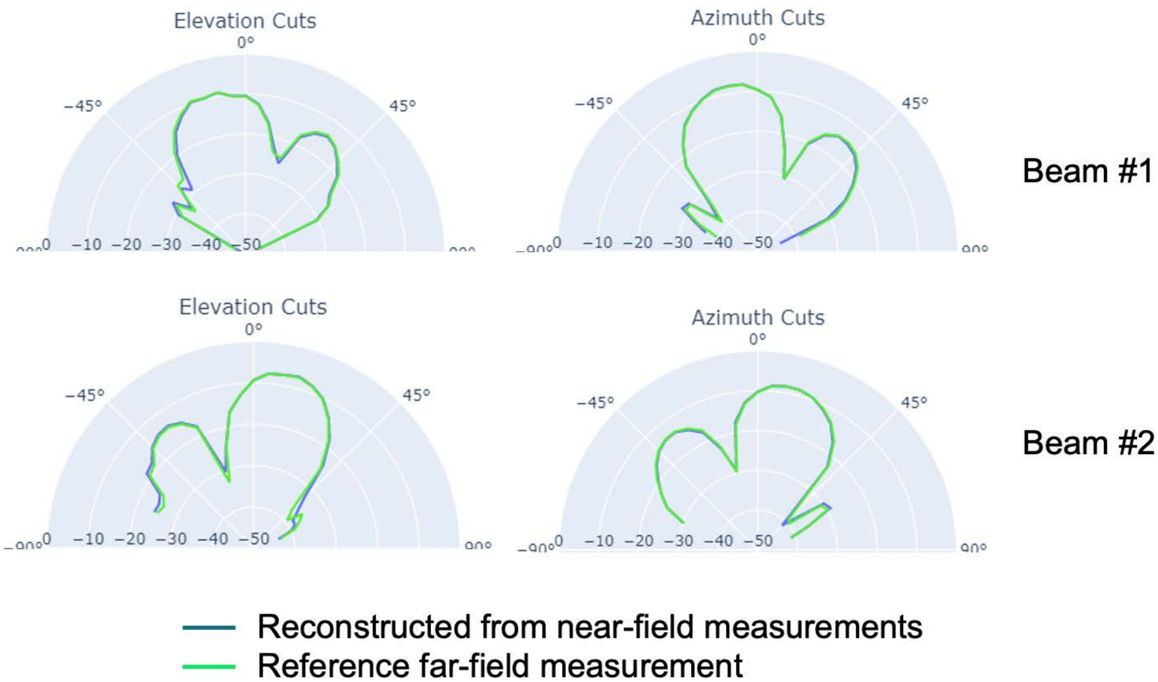
In contrast to near-field scanners, the novel technique requires no mechanical movement. This greatly simplifies the mechanics and avoids early wear-and-tear of cables, significantly improving operational stability and measurement repeatability. Also, avoiding movement leads to fast measurements, especially those of radiation patterns and the spatial distribution of other RF parameters.

A linear mapping transforms near-field data to far-field equivalents. To do that, one needs at least as many probes as there are array elements in the ESA. One may measure the field on all of these probes simultaneously using just as many instrumentation channels. This is the quickest route, but only practical for a small number of elements.

One may switch through the probes using a single instrument channel. This is easiest and enables accurate measurements of the antenna's transmission characteristics. To make a single-channel setup scale well to various array sizes would require combining the near-field probe array with a beamforming network. This gives best control of the fields generated by the probe array and, thus, also enables test engineers to measure an ESA's receive characteristics.

Proof-of-Concept

We demonstrated the measurement approach in a proof-of-concept based on commercial mmWave communications technology.[4] **Figure 3** shows the setup with a 64-ele-

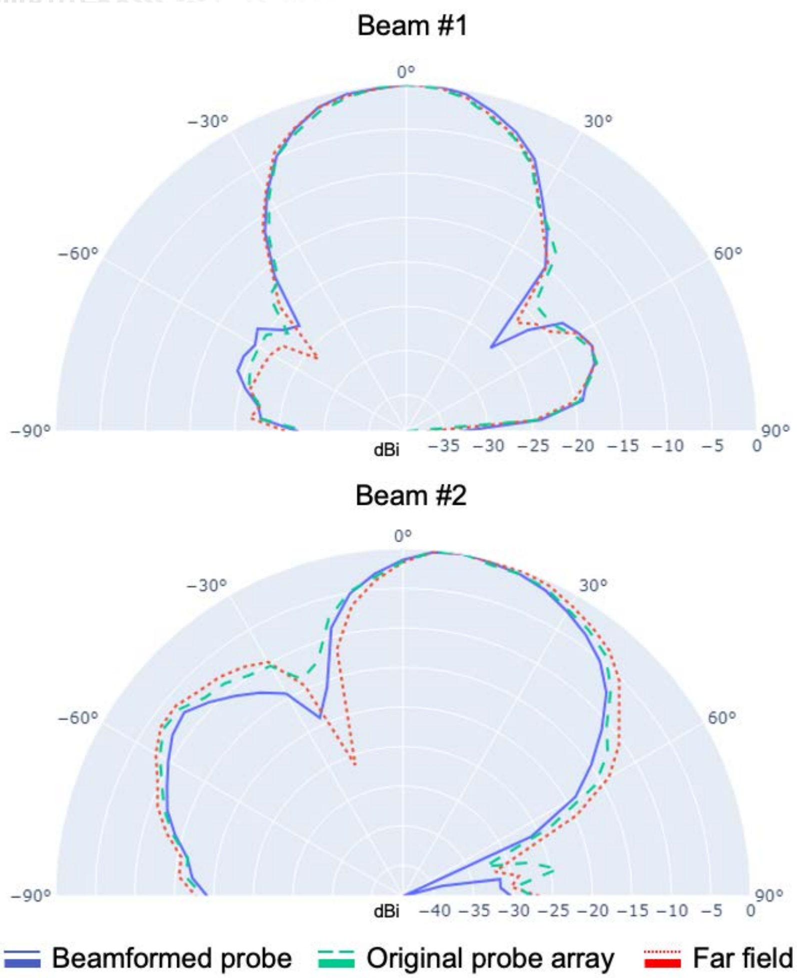


5. Novel near-field measurements of the ESA's transmit beam patterns correlate very well with direct far-field measurements made for reference.

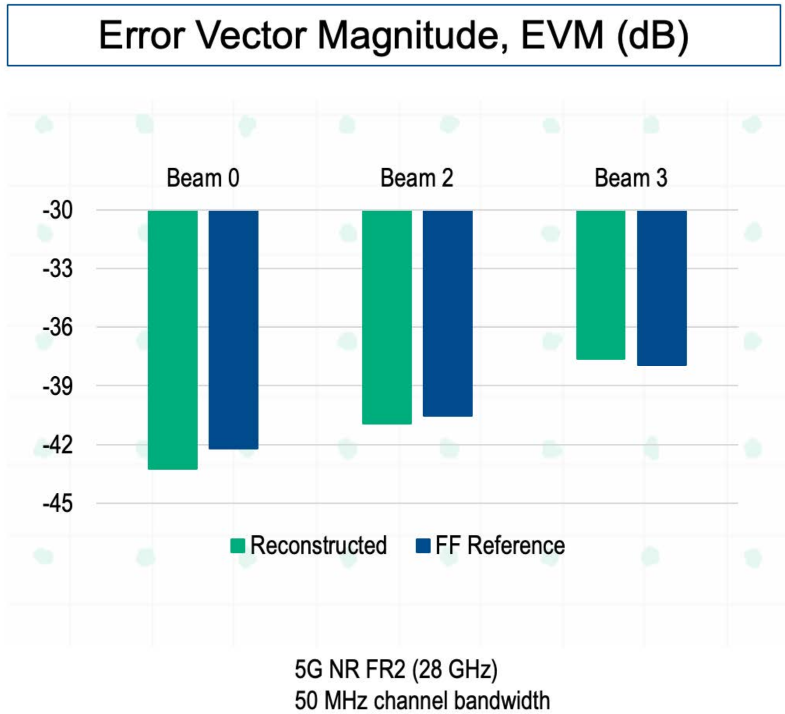
ment array of passive probes and a 64-element dual-polarized ESA featuring NXP MMW9014K beamformers. Another ESA that we measured had 16 single-polarized elements and used Anokiwave AWMF-0108 beamformers. The distance between the arrays was 5 mm.

For comparison, we made measurements directly in the far field in a Bojay anechoic chamber using NI RFmx and OTA measurement software.[2] In all measurements, we used an NI PXIe-5831 mmWave vector signal transceiver (VST) with 18 ports.

Figures 5 through 7 show how well our measurements correlate with conventional methods. **Figure 5** shows this for the 64-element ESA's transmit patterns for two different beam configurations at 25.875 GHz.4 **Figure 6** illustrates measurement of receive patterns of the 16-element ESA at 28 GHz. Here, we also compare implementations with four signal generators and one that uses a single gen-



6. ESA receiver sensitivity patterns for two 2x2 beam configurations: good correlation of measurements with a beamformed probe array and single generator, a probe array with four signal generators, and directly in the far field.



7. Highly repeatable wideband modulated measurements with EVM accuracy better than 1 dB.

erator plus beamformer on the probes' side.[7,8]

Figure 7 shows wideband modulated measurements of the error vector magnitude (EVM) for the same 16-element array at 28 GHz, based on a 3GPP 5G NR frequency range 2 signal.[5] Results for three different beam directions are in good agreement with those from conventional methods.

For these results, the near-to-far-field mapping parameters need to be calibrated before any measurements can be transformed into far-field characteristics. Once known and stored, the parameters are valid for processing measurements over a long period. This is because the mapping depends on those "passive" properties of the antenna design that shape the electromagnetic field over the air (i.e., mechanical layout and choice of material of the parts facing the radiated scenery). Thus, the mapping parameters are independent of the effects of any active circuitry in the antenna under test.

Calibration of the mapping is described in detail in References 4 and 6. It requires measuring a reference ESA one time. Unlike a "golden unit"-type approach, by design of the process, we don't need to worry about longer-term drift or it failing over time. Still, the mapping parameters depend on the ESA design.

Consequently, this near-field probe array method is great if measurements for a particular ESA design need to be made repeatedly. Such situations arise, for example, in automated validation during development, in production testing, and to verify mission-readiness over the lifetime of the system.

A New Antenna Measurement Technique

Antenna arrays are an important part of modern communication and radar systems. For applications at higher frequencies, they're indispensable.

In this article, we described a novel near-field antenna measurement approach that leverages NI's PXI platform and VST instrumentation. The new approach promises test engineers can use compact measurement setups that avoid moving parts for ease of operation. This suits it particularly to perform measurements repeatedly for extensive test coverage in validation, production, or in the field.

By avoiding movement during measurements, the technique is very fast. Of course, the method works for CW-based radiation pattern measurements as well as under modulation conditions.

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Taoglas

CHAPTER 4:

Simplify Antenna Selection, Optimization, and Integration with Online Tools

BAHA BADRAN, Global Head of Engineering, *Taoglas*

Online tools are streamlining all processes involved with RF antennas, helping developers accelerate design, reduce complexity, and improve performance in modern wireless devices.

Since its inception in the late 19th century, RF antenna development has been driven by events such as the Second World War and the space race, and its ongoing evolution has leveraged advances in materials such as metamaterials, nanotechnology, dielectrics, and advanced composites. The defense industry continues to benefit from innovation in antenna design, but as other sectors increasingly adopt wireless communications, the RF antenna has become a fundamental enabler of modern life.

Antenna design is a complex task, but one that must be addressed up-front in any project to avoid expensive and time-consuming rework later in the development cycle. This can present a formidable challenge to the developer who is under pressure to reduce development cycles and get to market quickly.

Fortunately, a growing range of off-the-shelf (OTS) antennae are being produced by specialist antenna manufacturers. These devices come in a variety of form factors, supporting different protocols, and are available in military-grade options complying with standards such as MIL-STD-810.

Although OTS antennae significantly simplify the developer's life, care and knowledge are still required to deploy them into any solution. On this front, a range of powerful online tools can help guide the designer through antenna selection and integration. In this article, we look at some of the trends driving innovation in antenna development and discuss the challenges facing developers when optimizing antenna design, along with the online tools and support available.

The Ubiquitous RF Antenna

Wireless applications are incredibly diverse, ranging from smart-home devices to secure entry and surveillance systems and industrial control applications, and RF antennae are appearing in a wide range of these devices. In the defense sector, high-performance and versatile multiband antennae support applications such as military communications (MILCOM), radar, and surveillance, and they're integrated into equipment such as handheld radios, manpack communication systems, and vehicles.

Most wireless applications leverage multiple wireless protocols. Thus, devices contain multiple antennae—for example, smartphones can have up to six, supporting 5G, LTE, Wi-Fi, Bluetooth, GNSS, and NFC protocols.

The growing demand for broadband connectivity is driving the use of more cellular, Wi-Fi, and Bluetooth antennas in wearable electronics and a vast array of embedded IoT and M2M devices. And positioning technology is a rapidly growing field, with wireless devices leveraging protocols such as Wi-Fi, Bluetooth Low Energy, and GNSS to offer a seamless transition between indoor and outdoor environments.

The use of GNSS technology is expanding across multiple sectors and military use cases, including navigation, search and rescue, reconnaissance, unmanned vehicles, and munitions guidance. The list goes on, and the market for wireless devices is projected to grow from USD 1811.24 billion in 2025 to USD 2569.50 billion by 2034, representing a CAGR of 3.96% over the forecast period.[1] Significant opportunities, therefore, exist for innovative developers, with short development cycles, cost-effectiveness, and speed-to-market key to success.

Developing any wireless device requires taking on the challenging task of designing the RF front end, which will include at least one, and more often multiple, antennae. Designers beginning a project will invariably always start with OTS antennae. That's because antenna design is a complex endeavor requiring specialist skills and expensive test and development tools, and it can easily add months to development cycles.

When a custom antenna is needed, though, the design and testing resources of an experienced antenna supplier are vital in creating a solution that works effectively for today's complex, often small wireless devices.

Today, most antennae aren't visible externally, either mounted on the PCB or internally cabled. A range of online tools are available to help in the selection, configuration, and placement of the antennae on the PCB or within the device enclosure.

Overview of Online Design Tools

Several important decisions must be made up-front when selecting and integrating an antenna, and a growing selection of cloud-based online tools is available to guide the designer through this process. These tools, developed by specialist antenna manufacturers, range in sophistication and capabilities, from relatively simple configuration tools to more complex simulation and modeling tools.

Common functionalities include support for optimizing and expediting antenna selection, best practices for antenna placement, and PCB optimization for best RF performance, with recommendations for component layout, ground-plane space, vias, enclosure materials, and gaps. Online tools can also provide support for antenna tuning and matching.

For example, for NFC applications, they offer recommended starting values for filter components based on PCB and antenna data provided by the user. Antenna design is iterative, and most tools let the designer specify starting parameters and then run simulations to converge on the optimal design, without the cost of developing prototypes.

As cloud-based resources, these tools enhance the workflow of development teams, enabling online access, facilitating remote working, and enhancing productivity by supporting real-time collaboration across different geographical locations. Many tools also offer features such as version control, which can be particularly valuable for complex projects like MIMO antenna array development, where comparing different iterations and their performance metrics is essential.

AI and Advanced Features in Online Antenna Design

Artificial Intelligence (AI) continues to play an increasingly significant role in antenna design. Modern AI-powered tools can suggest design optimizations, predict potential interference issues, and even generate initial antenna concepts based on specified parameters. In particular, generative design algorithms are pushing the boundaries of antenna design by exploring solution spaces that human engineers might not consider, potentially leading to innovative and highly optimized designs.

These cloud-based tools can be said to “democratize” access to the types of powerful design and simulation tools that were once the preserve of specialist RF design engineers. It’s important, however, to ensure that the selected tools align with the existing capabilities and systems of the organization. In general, more sophisticated toolsets require higher levels of RF skills to operate them, whereas, for many developers, the value of a toolset can lie in the simplicity of its user interface.

Antenna Integrator presents the user with a simple graphical interface, enabling the user to specify PCB dimensions and supporting the ideal placement of the chosen antennae on the board. Taoglas

For example, the AntennaXpert tool set from Taoglas offers three main tools to the wireless system developer—Antenna Builder, Cable Builder, and Antenna Integrator. The first two tools save the developer time and effort by simplifying the often-tedious process of gathering information, consulting with various experts and selecting components. These rule-based tools guide the selection of antenna and cable components, connectors, etc., while bringing all relevant information, such as specifications and datasheets, into a single, easily accessible space.

Antenna Integrator, on the other hand, presents the user with a simple graphical interface, enabling the user to specify PCB dimensions and supporting the ideal placement of the chosen antennae on the board (**see figure**). The tool fully automates the process of antennae placement and produces a report predicting system performance based on the input design.

The user interface of these tools is relatively simple, but having the developer make the necessary decisions without access to specialist RF knowledge can be tricky, since the underlying enabling technology is much more complex. Online tools such as AntennaXpert make it possible for users to leverage the experience and resources of the antenna manufacturers without investing in specialist skills, RF test equipment, or computing infrastructure.

For applications that require custom-designed, as opposed to OTS, antennae, the developer has the option of working closely with the antenna manufacturer to leverage their resources and capabilities or acquiring them in-house. The decision will ultimately be based on a range of factors, including existing capabilities, production volumes, and the strategic aims of the organization.

Choose the Right Toolset for the Application

Online tools combined with OTS devices are transforming antenna design, offering the designer a palette of functionality and complexity. At one end of the scale, the developer can leverage tools that enable selection, configuration, and optimization of OTS antennae, reducing development cycles and accelerating time-to-market while avoiding the need to consult or employ expensive RF design resources.

At the other end of the spectrum, sophisticated AI-enabled tools support advanced simulations and RF design iterations, leading to new and custom antennae design. Security is a key concern, particularly for developers of military systems. Many providers of antennae and online toolsets provide manufacturing, design, and support environments that comply fully with relevant military standards. Developers must carefully assess the needs of their specific project and the capabilities of their organization when choosing the right tool for their requirements.

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CHAPTER 5:

Mil/Aero Antenna and RF Systems: Product Roundup

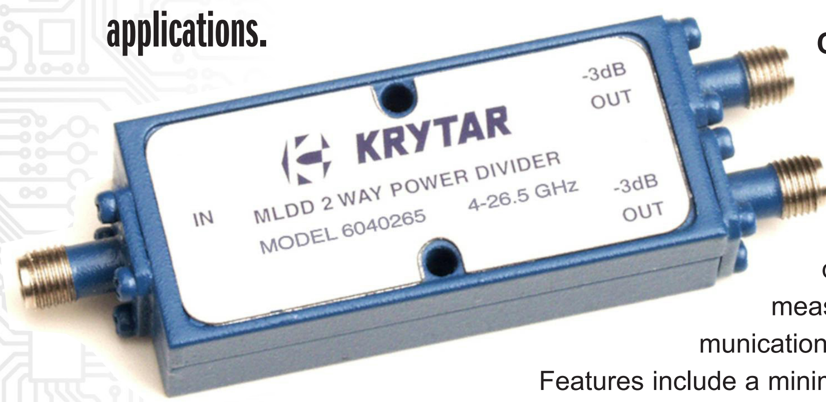
By ALIX PAULTRE, Editor-at-Large, *Electronic Design*

This is a collection of recently introduced antenna and RF system solutions targeting military and aerospace applications.

The significance of antennas and their related RF systems in military and aerospace systems cannot be understated, as connectivity is now a critical force-multiplier both on and off the battlefield. Not only must an RF solution for a military or aerospace platform operate in an optimal fashion, it must often do so under the most egregious of environmental conditions and situations.

Such demand for performance is constant, as the competetive nature and high stakes of warfare mean that everything involved must offer the highest levels of functionality.

This product gallery highlights some recent new products and solutions for military, aerospace, and satcom applications.



KRYTAR's extended family of 2-Way Power Dividers offer solutions for many ultra-broadband applications.

Krytar

Compact MLDD Power Divider Spans 4.0 to 26.5 GHz

KRYTAR released a high-performance Model 6040265 two-way power divider that operates in the C- through K-band frequency range from 4.0 to 26.5 GHz. The compact device serves emerging designs and test and measurement applications such as wireless communications, radar, electronic warfare, satcom, and more.

Features include a minimum isolation of 19.0 dB from 4 to 18 GHz and 18 dB from 18 to 26.5 GHz, a maximum amplitude tracking of ±0.3 dB from 4 to 18 GHz and ±0.5 dB from 18 to 26.5 GHz, and a maximum phase tracking of ±6 degrees from 4 to 18 GHz and ±10 degrees from 18 to 26.5 GHz. Insertion loss is less than 1.1 dB from 4-18 GHz and less than 1.4 dB from 18-26.5 GHz. Maximum VSWR is 1.45 from 4 to 18 GHz and 1.60 from 18 to 26.5 GHz. Units with tighter amplitude and phase-tracking specifications are available.

KRYTAR offers an assortment of matched-line directional dividers (MLDDs) offering high performance over a broadband frequency range, with the widest frequency coverage in a single package. The 2.25- (L) × 1.00- (W) × 0.52-in. (H) device weighs two ounces, and comes with standard 3.5-mm coaxial female connectors.

DF Antenna Targets Spectrum-Monitoring Applications

Offering the widest frequency range currently available in a compact design, Rohde & Schwarz's R&S ADD507 compact DF antenna is designed to meet the evolving needs of spectrum regulators and military spectrum managers. Providing a high level of performance and versatility, the DF antenna is a vital part of the company's compact spectrum-monitoring systems, Serving mobile, transportable, and portable stations, it provides direction finding over a frequency range from 9 MHz to 8 GHz in a single compact DF antenna.

Rohde & Schwarz recently launched the R&S ADD507 compact DF antenna. Rohde & Schwarz

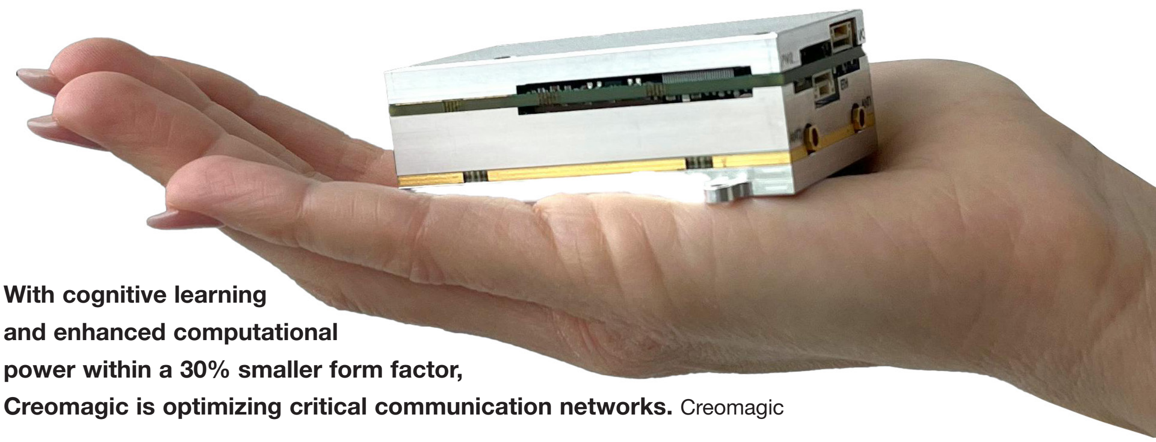
The R&S ADD507 makes it possible to significantly reduce complexity in spectrum-monitoring systems, while providing enhanced capabilities and performance specifications. Features of the compact and lightweight DF antenna enables easy installation and transportation, while its operation from 9 MHz to 8 GHz reduces the need for multiple DF antennas.

The antenna's innovative design provides increased coverage in the VHF range, enabling the detection of even weak signals. Meanwhile, an active-passive-switch offers high immunity to strong unwanted signals, and it can be adapted to the signal environment via a mouse click.

Wireless Module Optimizes Critical Communication Networks

Providing cognitive learning and enhanced computational power in a small form factor, Creomagic's latest generation of ultra-compact, high-performance wireless solutions are designed for the demanding requirements of aerial operations, The company's CreoAir advanced software-defined-radio (SDR) technology offers security and connectivity performance in challenging environments, like UAVs and aerial systems on the modern battlefield, The solution addresses demands for robust, long-range control and seamless interoperability with other units.

The CreoAir Pro is the company's latest generation of tactical transceivers, meeting the need for compact communication solutions adapted to smaller platforms. Its enhanced performance with regard to range, power, and security boosts computational power and advanced algorithmic processing. Fully optimized for future AI-driven operations, it enables dynamic spectrum allocation, real-time decision-making, and cognitive networking.



With cognitive learning and enhanced computational power within a 30% smaller form factor, Creomagic is optimizing critical communication networks. Creomagic

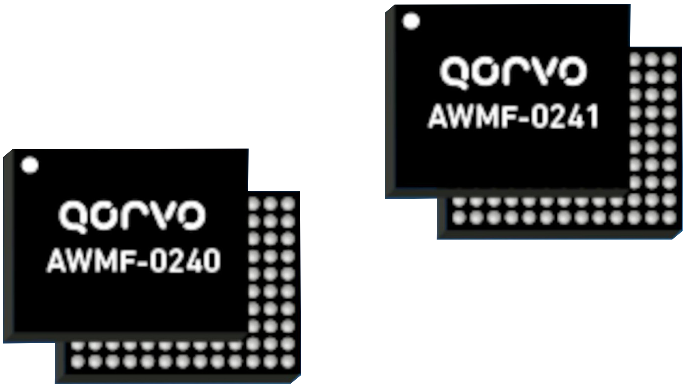
Reliable, low-latency, and secure communications are critical to tactical decision-making, and Creomagic's communication solutions are tailored to meet these needs with robust and resilient communication solutions for aerial operations. The CreoAir product line includes high-performance data links with data rates supporting aerial applications from lightweight, short-range operations to full, military-standard, long-range missions. Leveraging SDRs and mobile ad-hoc network (MANET) technologies, the solutions offer data rates of up to 40 Mb/s, adaptive video encoding, and simultaneous support for multiple data sources and control of multiple platforms.

Features include advanced COMSEC and TRANSEC features to ensure resilient, uninterrupted communication, with continuous spectrum scanning and analysis, AES-256 encryption, frequency hopping, and automatic interference avoidance. It's powered by cognitive SDR and advanced waveforms to reduce potential interception and detection with robust protection against EW threats. The CreoAir Pro's open architecture shortens development cycles, eases integration with third-party systems, and improves customization options.

Ku-Band Beamformers Serve High-Performance Satcom Terminals

Qorvo unveiled its latest silicon Ku-band satcom beamformer IC family for phased-array-based user terminals. The AWMF-0240 receive (Rx) and AWMF-0241 transmit (Tx) beamformer ICs reduce DC power consumption by up to 25% for transmit arrays and 14%

for receive arrays without compromising EIRP or noise sensitivity.



Qorvo launched next-gen Ku-band beamformers for high-performance satcom terminals. Qorvo

Created to address the increasing demand for high-speed, reliable satellite communications, the AWMF-0240 Rx and AWMF-0241 Tx ICs operate at Ku-band frequencies, with features that include full polarization flexibility, precise beam-steering, and built-in temperature stability. The compact, stable devices don't require external low-noise amplifiers (LNAs) or complex calibration.

Addressing the critical needs of both commercial and defense applications, they provide next-generation connectivity for compact, power-efficient, and highly reliable phased-array systems.

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