5G Module Aids in Smart-City Buildouts p8

Fundamentals of Smith Charts p20

Open Standards Drive Defense Flexibility p24

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p12

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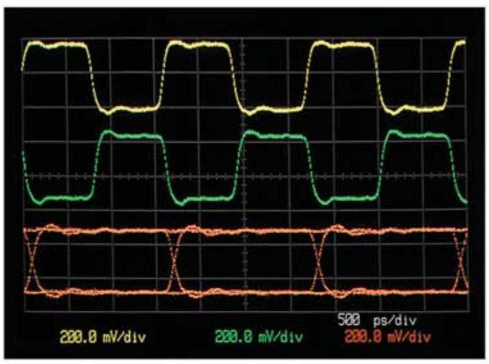

Plot shows complementary clocks and PRBS (opt. 01) outputs at 622.08 Mb/s with LVDS evels. Traces have transition times of 80 ps and jitter less than 1 ps rms.

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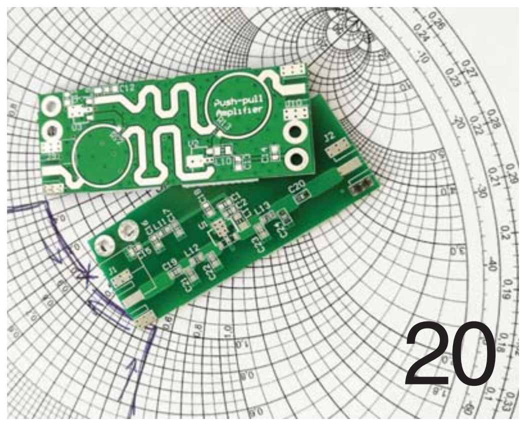

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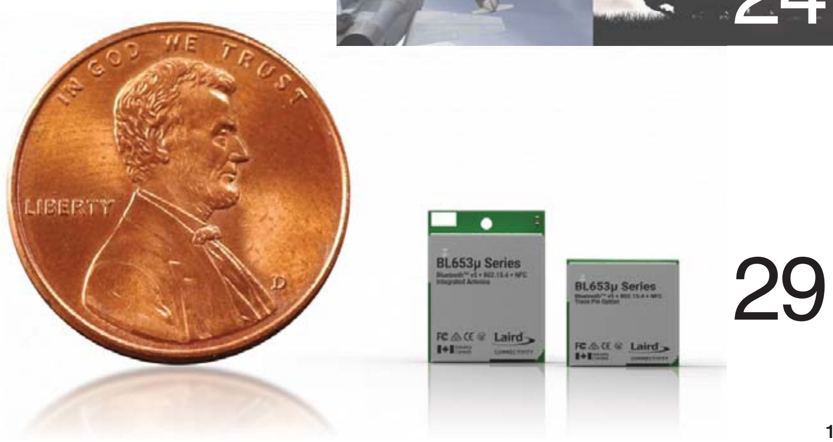

Editorial

DAVID MALINIAK | Editor
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5G Adoption Ramps Up Worldwide

What's the state of 5G as we enter the second half of 2021? According to one market report, adoption of 5G technology and systems, from 5G SA to XaaS, has begun to escalate.

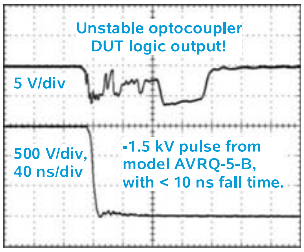
Periodically, I like to step back a little and look at how 5G adoption is progressing among service providers. A mid-year reassessment of the market by Spirent Communications provides one relevant data point. Spirent is a purveyor of automated test and assurance products and services, which brings a measure of objectivity to its data.

According to this update on the first half of 2021, 5G trends are accelerating rapidly. There's a significant surge in the number of 5G standalone (SA) core network evaluations, testing, and launches. And, more specifically, Spirent found great demand for managed solutions and Anything-as-a-Service (XaaS) offerings. Test automation, the company maintains, is a key enabling technology that smooths out the complexity of testing in multi-vendor environments.

Based on its work with service providers, network-equipment manufacturers, governments, and device makers, Spirent's update finds 5G adoption booming across both commercial and government segments and in all global regions. Here are some highlights from the report:

- **Geographic trends:** All major regions (North America, Europe, and Asia) are aggressively pursuing 5G SA core testing and deployments. North America is driving the demand for customer experience and service assurance solutions. Asia Pacific continues its focus on, and investment in, transport infrastructure, toward the goal of supporting industrial use cases. Europe is starting to accelerate activities after COVID and high-risk vendor delays.
- **5G standalone:** New services and differentiation drive 5G SA. 5G SA core evaluation, testing, and launch continue to grow significantly across all geographic regions. Large service providers look to use multiple vendors while smaller telcos gravitate to one key partner.
- **5G telco edge cloud**: Partnerships, early trials, and deployments between hyperscalers and service providers are expanding. Providers are still working to benchmark edge performance and integrate assurance for consistent, deterministic latency. Expect latency to become a key battleground for the hearts and minds of industry and enterprises.
- **Open RAN:** There are currently 45 ongoing Open RAN trials and early deployments across 27 countries (source: TeckNexus). Leading 5G service providers will target larger-scale Open RAN non-dense urban rollouts during 2022. Early deployments will focus on rural, indoor, and private coverage. Interoperability, performance, robustness, and system integrator overheads require that service providers continue to test and validate every deployment phase.
- **6G vision:** The industry is beginning to coalesce around some key themes, including terahertz frequencies, use of intelligent reconfigurable surfaces and metamaterials, open networking, and network of networks (terrestrial cellular, NTN, subsea, and Wi-Fi convergence). mw

Transient Immunity Testers



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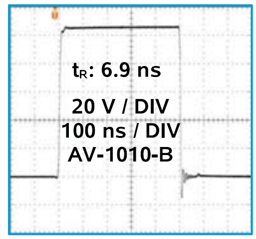

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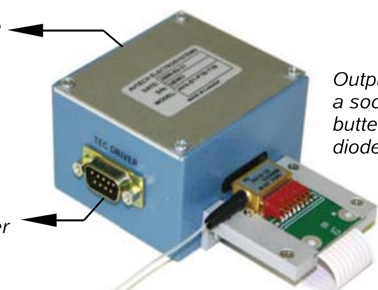
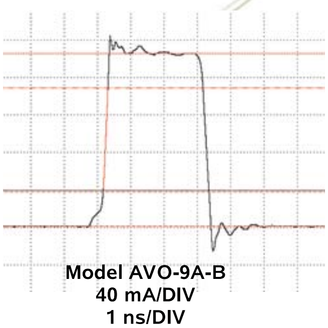
To Pulse Driver



To TEC Controller

Output module with a socket-mounted butterfly-packaged diode installed.



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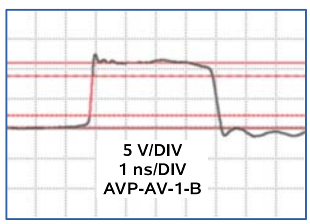

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20 V	120 ps	1 MHz	AVP-AV-HV2-B
20 V	200 ps	10 MHz	AVMR-2D-B
40 V	150 ps	1 MHz	AVP-AV-HV3-B
50 V	500 ps	1 MHz	AVR-E5-B
100 V	500 ps	100 kHz	AVR-E3-B
100 V	300 ps	20 kHz	AVI-V-HV2A-B
200 V	1 ns	50 kHz	AVIR-1-B
200 V	2 ns	20 kHz	AVIR-4D-B
400 V	2.5 ns	2 kHz	AVL-5-B-TR

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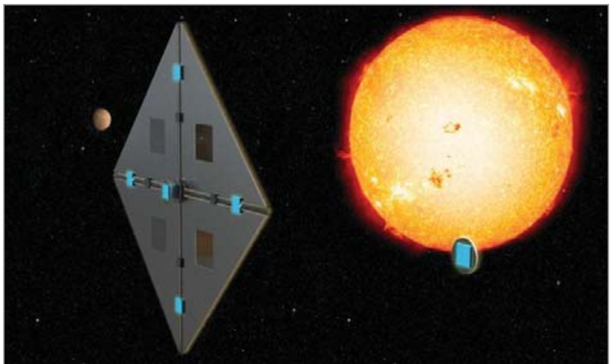

Solar Sails Propel Deep-Space Exploration

Solar sails provide a means of propulsion that could make interstellar space travel possible and practical.

https://www.mwrf.com/markets/defense/article/21171932/microwaves-rf-solar-sails-propel-deepspace-exploration

Atlas Robots Run Parkour Course

In this video, check out Boston Dynamics' Atlas robot, which is capable of navigating a parkour course.

https://www.mwrf.com/markets/defense/video/21172878/atlas-robots-run-parkour-course

Trends in 5G for 2021/2022

Houman Zarrinkoub, Senior Wireless Product Manager at MathWorks, discusses the trends in 5G for the balance of 2021 and into 2022.

https://www.mwrf.com/technologies/systems/video/21174009/trends-in-5g-for-20212022

The Importance of RF Filters in Advanced Wireless Systems

How can today's wireless systems best meet user expectations? Resonant's Mike Eddy weighs in on that question and provides insight into the company's new RF filter that leverages the firm's XBAR technology.

https://www.mwrf.com/technologies/components/article/21175392/evaluation-engineering-the-importance-of-rf-filters-in-advanced-wireless-systems

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News

5G WIRELESS MODULE SERVES Smart-City Buildouts

Advantech's versatile AIW-355 5G module is a step toward ubiquitous connectivity for edge computing, mobile gateways, and globally deployed mobile devices.

Claiming it as a milestone in its own technology journey, Advantech's AIW-355 5G module is designed for AIoT solutions that require ubiquitous connectivity, dynamic mobility, and extreme security. AIW-355 is an excellent choice for use in edge-computing devices, mobile gateways, and diverse globally deployed mobile devices.

The AIW-355 uses 5G to provide capabilities and power previously unavailable with 4G. 5G delivers a 10-fold increase in speed (10 Gb/s compared to 1 Gb/s for 4G) and supports connection to up to a million devices per square kilometer. In addition, 5G enables a 100-fold increase in capacity, a 10-fold decrease in latency, and drops lag times to just 1 ms (vs. 10 to 20 ms for 4G).

In its AIW-355 module, Advantech deploys the Snapdragon X55 5G modem, which supports 5G NR sub-6-GHz frequencies in both 5G standalone (SA) and non-standalone (NSA) operations. It's compatible with LTE and WCDMA standards; and is backwards compatible with LTE-A and 3G networks. The module helps optimize customer investment at the initial stage of 5G construction and accommodates emerging market demands.

Advantech's AIW-355 5G wireless module features a M.2 3052 form-factor M.2 Key B USB interface. This M.2 module accommodates most mainstream carriers and eases 5G integration. The unit also integrates a multi-constellation GNSS receiver and USB 3.1 high-speed interfaces.

The Advantech AIW-355 5G module delivers high-speed capabilities to applications in industrial monitoring, remote medical treatment, transportation, and high-quality surveillance systems. It brings the 5G capabilities needed to support city-based video surveillance systems, which are vital to public safety and require high-speed transmission and low latency. 5G meets these needs while supporting innovative information technologies that improve government response times. In short, AIW-355 can augment the efficiency of public security infrastructure.

The scope of security monitoring applications has expanded to include the use of dimensional monitoring data and real-time vehicle monitoring. Advantech's AIW-355 also accommodates these applications while helping enterprises reduce costs by efficiently monitoring restricted, potentially dangerous areas.

Three versions of AIW-355 are available for applications in North America, Europe, and China. Every version supports both 5G SA and NSA network architectures and delivers faster transmission speeds, better carrying capacities, and lower network latency. Each model can operate in broad temperature ranges (–30 to 75°C/ –22 to 167°F) and is compatible with Windows and Linux. mw

thinkRF, TMYTEK TEAM on 5G and Advanced mmWave Applications

thinkRF, A PROVIDER OF software-defined spectrum analysis platforms, has entered a global strategic partnership with Taiwan-based TMY Technology (TMYTEK), a maker of mmWave RF front-end products, to collaborate on the development of industry-leading products for enabling the deployment of 5G, 6G, and advanced millimeter-wave (mmWave) applications. It's hoped that this global partnership will position thinkRF and TMYTEK among the leading providers for the 5G, 6G, and advanced mmWave applications.

"We are excited and very pleased to announce our strategic partnership with TMYTEK. This new partnership represents a unique opportunity for thinkRF and its customers." said Jim Nerschook, think RF's Chief Commercial Officer and VP of Global Sales and Marketing. "Our collaboration will provide industry-leading innovative products and enhanced offerings to our customers today and in the future."

Ethan Lin, VP of TMYTEK, indicates his strong faith in the synergy of the partnership between thinkRF and TMYTEK. "We are thrilled to have thinkRF as our global channel partner, accelerating the penetration of TMYTEK's innovative mmWave solutions into 5G FR2 market, satellite communications, radar sensing, and other industrial applications around the world," said Lin. ■

OTDOA POSITIONING TEST for 5G New Radio Verified

WITH THE EXPANDING ROLE of the cloud in an increasing number of markets, 5G New Radio (NR) is expanding functionality in application spaces such as industrial automation, automotive, and mil/aero, with additional positioning mechanisms added to the NR standards defined by 3GPP Release 16. OTDOA (observed time difference of arrival) is one such method, originally introduced for 4G LTE.

OTDOA relies on measuring the time difference of positioning reference signal (PRS) from multiple cells, using it to help compute its location. Recently, Anritsu Corp. and MediaTek revealed that an OTDOA Protocol Conformance Test (PCT) for 5G NR was verified using a MediaTek M70 5G modem and Anritsu's 5G NR Mobile Device Test Platform ME7834NR.

"MediaTek's collaboration with Anritsu continues to go from strength to strength, supporting us in this rapidly evolving industry with verification of these leading features in our 5G modems," said Mr. JS Pan, General Manager of Wireless Communication System and Partnership at MediaTek. Mr. Shinya Ajiro, General Manager of Mobile Solutions Division at Anritsu added, "We are proud to be able to support MediaTek with our test solutions, and together we look forward to introducing Advanced 5G features to market quickly."

The 5G NR Mobile Device Test Platform ME7834NR is registered with both the GCF and PTCRB as Test Platform 251. The ME7834NR is a test platform for 3GPP-based PCT and Carrier Acceptance Testing (CAT) of mobile devices incorporating multiple radio access technologies. It supports 5G NR in both standalone (SA) and non-standalone (NSA) mode in addition to LTE, LTE-Advanced, LTE-A Pro, and W-CDMA. When combined with Anritsu's OTA RF chamber MA8171A and RF converters, the ME7834NR covers the sub-6-GHz and mmWave 5G frequency bands. ■

STMICRO'S SPACE-QUALIFIED REGULATORS

Power Xilinx's Rad-Hard FPGAs

RADIATION-HARDENED FPGAs for satellite-communications applications need power from circuitry that's just as capable of withstanding the rigors of spaceflight. To that end, STMicroelectronics is collaborating with Xilinx to build a power solution for the latter's Kintex UltraScale XQRKU060 radiation-tolerant FPGAs, leveraging QML-V qualified voltage regulators from ST's space-products portfolio.

The programmability of the Xilinx XQRKU060 revolutionizes the economics of equipment like space-research instruments and commercial satellites. The device delivers a combination of high compute density and integration that historically required an application-specific IC (ASIC), which typically involves custom design with associated engineering expenses and turnaround time. Unlike an ASIC, the XQRKU060 FPGA can be reconfigured in orbit, allowing bug fixes and updates to be applied cost-effectively at any time to protect the mission.

ST worked closely with Xilinx to design a power source that ensures reliable operation of the XQRKU060 by providing high fixed-point voltage accuracy as well as stability in the event of transients due to normal FPGA operation and radiation events. The solution uses ST's RHRPMPOL01 rad-hard, point-of-load, 7-A monolithic synchronous step-down regulator and RHFL6000A linear voltage regulator, all single-event-latchup (SEL)-immune and QML-V qualified. These devices meet the requirement for an input voltage up to 12 V and output voltage down to 0.8 V. Both exhibit high fixed-point accuracy with radiation performance that ensures high resistance to total ionizing dose (TID), thereby minimizing any output-voltage drift.

With their fast-transient response, the RHRPMPOL01 and RHFL6000A maintain the regulated output in the event of large and rapid changes in current demand as the FPGA continuously activates and deactivates internal circuitry during normal operation. Their radiation hardness also resists disruption due to single-event transient (SET) radiation encountered in space.

This power solution helps simplify and shorten the development time for next-generation flexible, reprogrammable space systems that leverage the Xilinx XQRKU060 FPGA to benefit from faster project completion, lower mission costs, and greater reliability and fault resilience.

The RHRPMPOL01 (SMD 5962R20208) is a complete point-of-load (PoL) converter that contains an N-channel power MOSFET, bootstrap diode, and system protection. By supporting synchronization and current sharing, it can handle demanding loads such as FPGAs, as well as microprocessors and ASICs. The device is Radiation Hardness Assured (RHA) up to 100 krad(Si), and SEL- and Single-Event Snap-Back (SESB)-free up to 70 Mev.cm^2/mq. Single-event upset (SEU) and single-event functional interruption (SEFI) are characterized at 7-V operating voltage.

The RHFL6000A (SMD 5962F15216) is a low-dropout regulator with adjustable output voltage, built-in protection, and circuitry for remote sensing and external inhibit control. Dedicated internal circuitry for absorbing transients ensures SET below 3.3% of V_{OUT} at 120 MeV, and the device is SEL-free up to 120 Mev.cm^2/mq. ■

EVE DANEL | Senior Product Marketing Manager, LitePoint

How Bluetooth 5.1, UWB, and Wi-Fi 802.11az Empower the Next Frontier of Micro-Location

With the popularity of GPS, location is becoming an important feature for wireless devices. Now, consumers want micro-location, and, in turn, wireless technologies are adapting to it and accuracy levels are on the rise.

(Continues on page 16)

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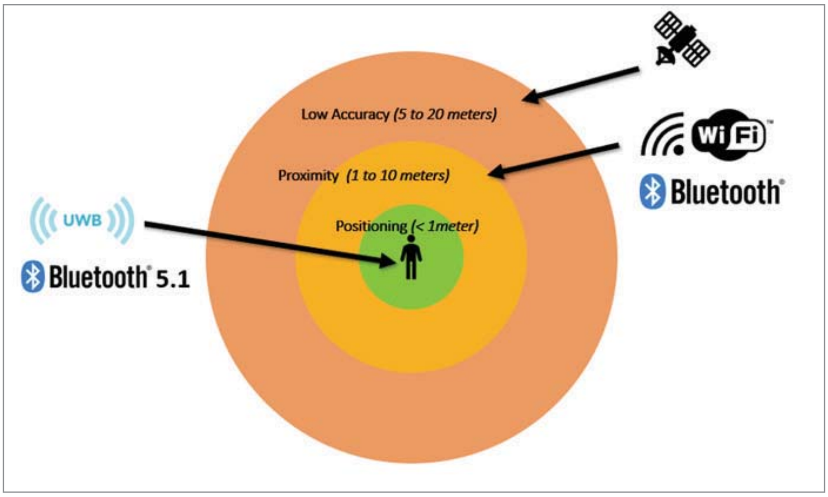
(Continued from page 12)

Using wireless technologies for positioning isn't new. However, the level of accuracy required has evolved over the years upon identification of new location-based use cases.

A GPS system, for example, can achieve roughly between a 5- to 20-meter level of accuracy, depending on signal conditions. This is sufficient when driving around to locate a particular building, but a GPS level of accuracy can't meet the needs of finding, say, a specific shelf in a store or point to the right painting in a museum tour.

Today's Bluetooth and Wi-Fi positioning systems based on received signal strength can deliver indoor positioning at a level sufficient for applications like detecting the proximity of an object or person within a few meters. The next generation of technologies, though, aims to unlock an even higher level of accuracy, reaching a sub-one-meter level of accuracy down to a few centimeters—otherwise known as micro-location positioning. It unlocks a new generation of use cases that allow users to interact very precisely with various actors in the environment, from hands-free access control to asset tracking and much more.

Systems based on Bluetooth 5.1 core specifications, ultra-wideband based on IEEE 802.15.4z, and Wi-Fi Next Generation Positioning based on IEEE 802.11az offer the potential to unlock these next-generation positioning applications *(Fig. 1)*.

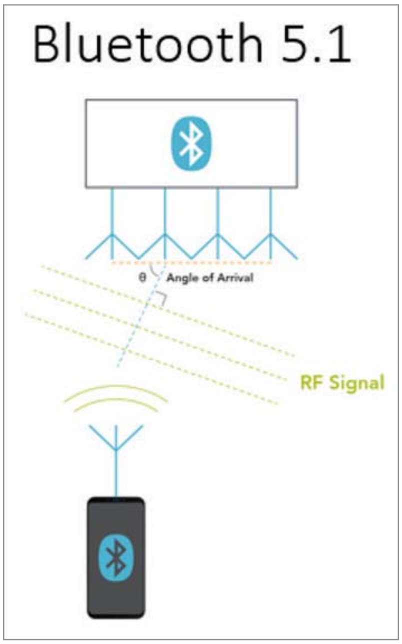


1. Bluetooth has progressed from low positioning accuracy to under-one-meter precision via ultra-wideband support.

How Does Bluetooth 5.1 Provide Micro-Location?

Released in 2019, Bluetooth SIG updated the Bluetooth core specs for Bluetooth 5.1, including enhancements for direction finding. Prior to the 5.1 release, Bluetooth was already used extensively in deployments for indoor location tracking, using a technique called received signal strength indicator (RSSI) to estimate the distance between a transmitter and a receiver based on how much path loss is measured.

However, the receiver can only detect that the transmitter is in a circular zone and doesn't have information about the direction of the incoming signal. Bluetooth 5.1 specifications add directionality to an incoming signal by providing angle information. Systems for asset tracking or wayfinding applications can be implemented using angle of arrival (AoA) or angle of departure (AoD) Bluetooth 5.1 methods *(Fig. 2)*.



2. Bluetooth direction finding is done by detecting the angle of arrival from a Bluetooth device.

The direction is based on the angle of the incoming signal. For direction finding, the Bluetooth 5.1 devices transmit packets appended with a constant tone extension (CTE) field. The CTE field is a bit sequence of unmodulated 1s with variable duration that simplify the phase computation on the receiver. Bluetooth 5.1 receivers use an antenna array with at least two antennas and compute the angle of incidence based on the phase difference between the antennas, the signal's wavelength, and the distance between the antennas.

Combined with the RSSI measurement, the angle information allows devices to pinpoint their location with better accuracy than the RSSI method alone.

The accuracy of Bluetooth 5.1-based systems depends on multiple factors including the number of antennas in the array and the antenna pattern, as well as the post-processing algorithm to determine the angle from phase I/Q information. The topology of the site also is important as both RSSI and phase accuracy are degraded by obstacles. However, the measurements can be greatly improved with the deployment of multiple locators for trilateration.

Depending on the implementation, Bluetooth 5.1-based systems should be able to achieve a sub-meter level of

The accuracy of Bluetooth 5.1-based systems depends on multiple factors including the number of antennas in the array and the antenna pattern, as well as the post-processing algorithm to determine the angle from phase I/Q information.

accuracy down to tens of centimeters. At the time of this writing, support for Bluetooth 5.1 has been added by all major chipset manufacturers.

How Does Ultra-Wideband (UWB) Enable Micro-Location?

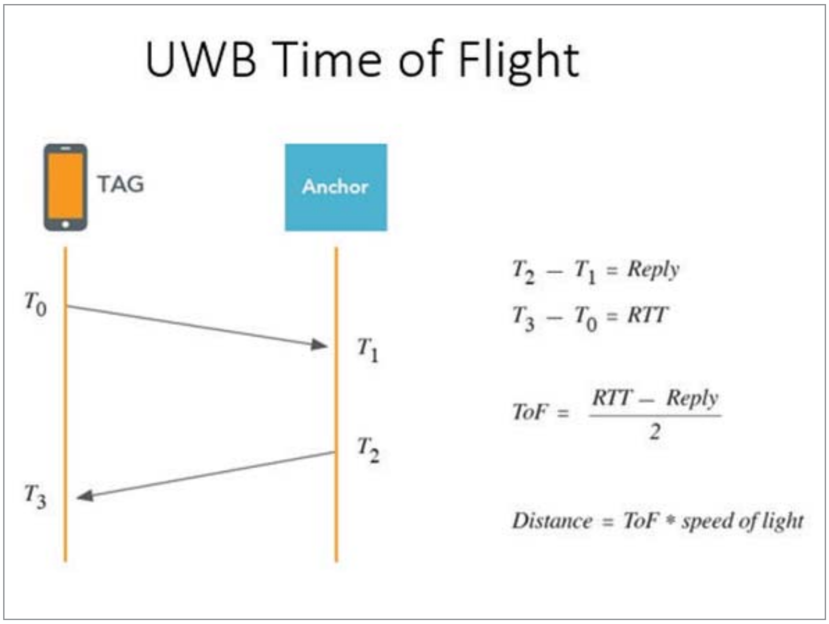
UWB isn't a new technology. As defined in the IEEE standard 802.15.4, it was first deployed in the early 2000s. At the time, it was geared toward high-speed transmission USB replacement, but it never quite achieved wide commercial adoption. In recent years, the MAC and PHY layers were improved in the IEEE 802.15.4z amendment for ranging purposes.

Unlike Bluetooth, UWB doesn't use signal strength to evaluate distance; instead, it uses time of flight (ToF). ToF measures the signal's propagation time from the transmitter to the receiver. Since RF signals travel at the speed of light regardless of the environment, distance estimation based on ToF is more robust to the environment than the RSSI method used in Bluetooth *(Fig. 3)*.

UWB differs from Bluetooth and Wi-Fi. It doesn't use modulated sine waves to transmit information; rather, it utilizes modulated pulse trains. UWB pulses have very short duration, on the order of a nanosecond. The signal's properties make this technology more resilient to multi-path environments typical in indoor areas because UWB's short pulses are more immune to impairments from reflected signals than Bluetooth or Wi-Fi.

UWB's ToF measurement can be supplemented with angle information to provide even more precise location. Similar to what was described earlier for Bluetooth 5.1 AoA, the UWB anchor receiver employs an antenna array of two or more antennas. The calculation uses the arrival times on each antenna and the antenna spacing information to determine the angle of incoming signal.

Systems based on UWB technology can achieve an accuracy in the range of 10 cm depending on the environment. At the time of this writing, several major chipset manufacturers offer UWB solutions, and the adoption of this technology by some smartphone manufacturers is proof of the growing momentum.



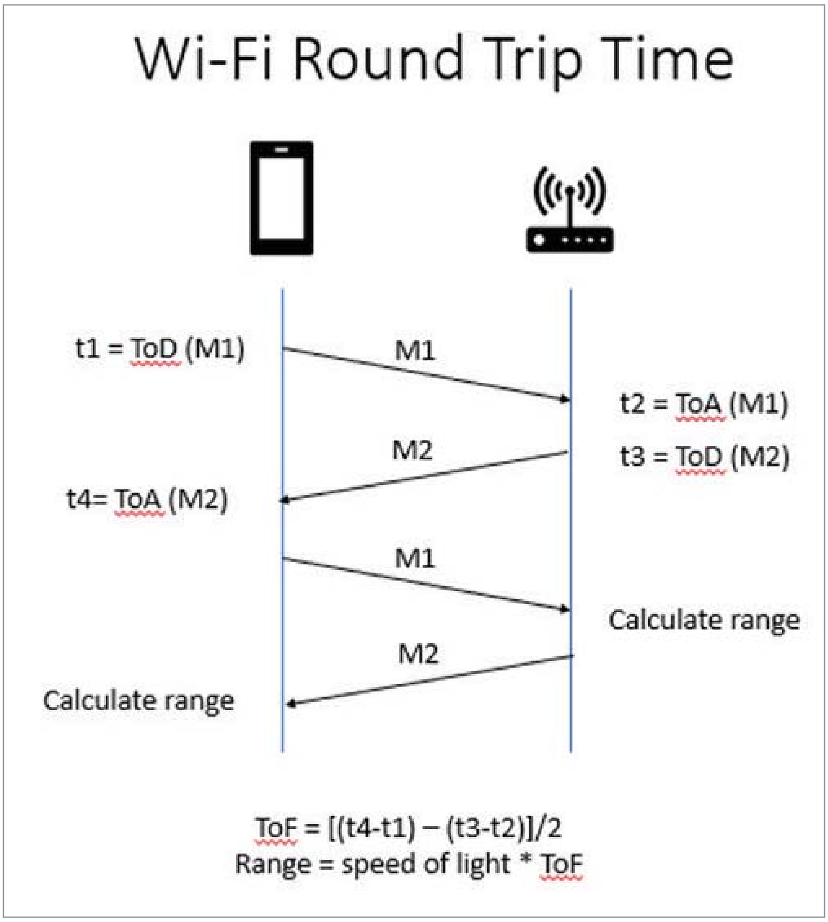
3. Time of flight provides distance information.

Micro-Location via Wi-Fi 802.11az

The newest and least notorious of the technologies discussed, the Wi-Fi 802.11az Next Generation Positioning (NGP) standard is nearing completion (targeted in 2022). Like Bluetooth, Wi-Fi technology has been used for some time with the RSSI-based method to provide positioning. But the NGP standard builds on a Wi-Fi feature called Fine Timing Measurement (FTM),

FTM uses round trip time (RTT) information to estimate distance between Wi-Fi-enabled stations and access points. The RTT mechanism employs time of departure (ToD) and time of arrival (ToA) timestamps. The 802.11az standard is designed to improve upon the legacy FTM by leveraging the latest features in the 802.11ax (Wi-Fi 6) standard *(Fig. 4)*.

For greater accuracy, 802.11az's enhancements take advantage of the wider channel bandwidth available in the newer generations since Wi-Fi 6 signals support up to 160-MHz channel bandwidth and Wi-Fi 7 up to 320 MHz. Wider bandwidth delivers higher resolution, while MIMO operation provides better resilience to multi-path effects.



4. Wi-Fi fine timing measures round trip time.

For improved protocol efficiency, NGP uses the null data packet (NDP) frames that are already defined in the 802.11ax standard for beamforming sounding. The new standard also utilizes the multi-user capabilities of Wi-Fi 6. When using trigger-based ranging with uplink and downlink OFDMA, the access point can effectively get ranging information from multiple stations in a single transmit opportunity. This significantly reduces the overhead needed to exchange ranging information and improve the scalability to more stations.

For improved protocol efficiency, NGP uses the null data packet (NDP) frames that are already defined in the 802.11ax standard for beamforming sounding. The new standard also utilizes the multi-user capabilities of Wi-Fi 6.

At the time of this writing, there's limited data available for commercial positioning solutions using 802.11az NGP technology. However, test data published on Wi-Fi Ranging shows promising performance for line-of-sight and non-line-of-sight environments where decimeter level of accuracy can be reached.

Comparing the Technologies for Next-Generation Micro-Location

When comparing the positioning accuracy among the three technologies, UWB can reach the highest level of accuracy with centimeter-level positioning. Bluetooth 5.1-based systems should be capable of reaching sub-meter accuracy, while Wi-Fi deployments based on 802.11az should be able to reach decimeter-level accuracy. Keep in mind that many factors must be considered when discussing the positioning accuracy. The environment, system design, antenna path delay, and other parameters can degrade the nominal accuracy.

Beyond positioning accuracy, numerous factors affect the decision to invest in a new positioning technology, and these criteria are application-dependent. For example, security, power consumption, cost, existing infrastructure, transmission reach, and interoperability may factor in the decision.

Regardless of the technology selected, careful design validation testing is required to ensure the best possible performance, and ultimately lead to successful deployment. mw

LOU FRENZEL | Technical Contributing Editor

Impedance Matching Basics: SMITH CHARTS

This article offers an introduction to the Smith chart and how it's used to make transmission-line calculations and fundamental impedance-matching circuits.

Most of you have probably heard of the Smith chart. The intimidating graph, developed by Philip Smith in 1939, is just about as bad as it looks. How he came up with this is an untold story, but he provided a solution to the complex calculations on transmission lines. And as you will find out, it's useful for working out transmission-line problems and in designing impedance-matching circuits. If you have avoided the Smith chart in the past, here's a primer on how to take advantage of it.

Getting Familiar with the Chart

The Smith chart is made up of multiple circles, and segments of circles arranged in a way to plot impedance values in the form of R ± jX *(Fig. 1)*. A horizontal line through the center of the main circle represents the resistance with R = 0 at the far left of the line and infinite resistance at the far right. Resistance values are plotted on the resistance circles, all of which are tangent to one another at the far right of the resistance line. The R = 1 circle passes through the center of the R line.

The remaining curves are parts of circles representing reactance. These curves all come together at the R = infinity point at the far right. The curves above the horizontal line represent inductive-reactance values and the curves below the line represent capacitive reactance. The Smith chart, as shown, is normalized, thereby permitting you to customize it to your application.

Plotting Values on the Chart

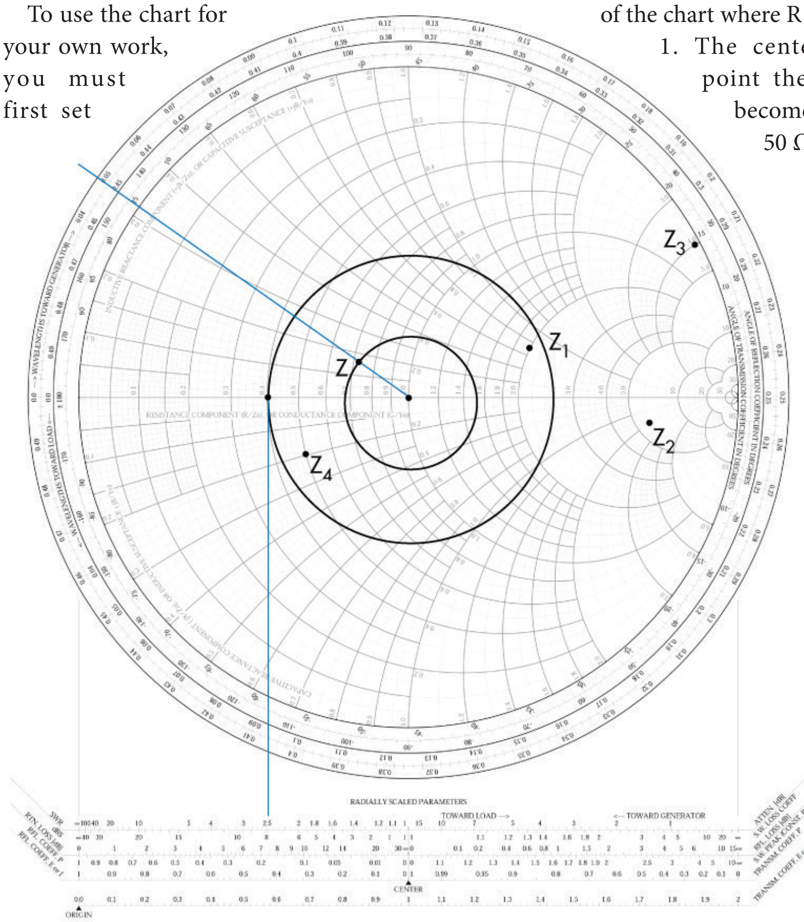
Figure 1 shows four examples of impedance plots:

- $Z_1 = 2 + j0.7$
- $Z_2 = 6 - j2.5$
- $Z_3 = 0.3 + j4$
- $Z_4 = 0.5 - j0.2$

Examine these examples to be sure you understand them.

To use the chart for your own work, you must first set the chart to represent values associated with a specific impedance related to your application. That impedance is usually the characteristic impedance of a transmission line you're using or the input and output impedance of a filter or impedance-matching circuit to be created. Most RF impedances are typically 50 Ω.

This value is assigned to the center of the chart where R = 1. The center point then becomes 50 Ω.



1. Four examples of plotting normalized impedances on a Smith chart.

To plot a specific impedance, you must adjust it to the main impedance. To do this, you just divide the R and X values by the assigned impedance of 50 Ω, and then plot the normalized value. For example, the value of Z_1 is the normalized value of 100 + j35. And Z_4 is the normalized value of 25 – j10.

Additional Chart Features

Referring again to *Figure 1*, you will see some scales around the perimeter of the chart. These represent wavelength. The outer scale is a measure of wavelength toward the generator, the next is wavelength toward the load, and the inner scale is the reflection coefficient that's the ratio of the reflected voltage to the incident voltage. At the bottom of the chart are scales for determining the standing wave ratio (SWR), dB loss, and reflection coefficient—all common characteristics of a transmission line.

When working with transmission lines, a main concern is the SWR. If the load is matched to the line and generator impedance, the load will absorb all of the power; there will be no reflections back to the generator. The SWR is determined with the expression:

SWR = Z_L/Z_O or Z_O/Z_L

Z_L is the load impedance and Z_O is the characteristic impedance of the transmission line. If $Z_L = Z_O$, then SWR = 1. This is the ideal condition so that all of the generator power gets to the load and any reflections will not interfere with the generator. The center point on the R line represents an SWR of 1. If you trace a line from that center point down so that it intersects with the SWR scale, you see that the value is 1.

If the load doesn't match the line and the driving generator, there will be reflections back along the line. As a result, the load doesn't receive all of the power. The SWR will be greater than 1. Assume an SWR of 2.5 is determined, which is shown as a circle on the chart *(Fig. 1, again)*.

Around the perimeter of the chart are additional scales that represent wavelengths. One complete rotation (360 degrees) represents 0.5 wavelength at the operating frequency. One scale is called TOWARD GENERATOR and the other TOWARD LOAD.

At the bottom of the chart, the scales are SWR, reflection coefficient, and return loss.

Another Chart Version

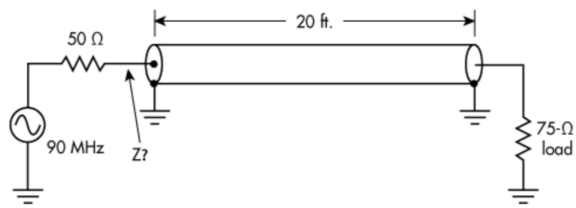
The Smith chart also can be used with admittance (Y), susceptance (B), and conductance (G), with units in siemens (S):

- G = 1/R
- B = 1/X
- Y = 1/Z

Such a chart is a mirror image of the standard chart shown here. For some problems, the admittance version may be easier to use than the standard chart. However, Y values can be read from the standard chart, as you will see later. The best way to learn the Smith chart is to follow some examples.

Example 1

Figure 2 shows a 50-Ω generator connected to a 20-ft. piece of RG-8/U foam coax cable. The characteristic impedance of this cable is 50 Ω and its velocity factor (vf) is 0.80. Remember, the speed of a signal in a cable is slower than it is in free space. The velocity factor indicates this condition as a percentage of the speed in space. That must be considered in determining any impedance-matching solutions.



2. The 75-Ω load doesn't match the cable impedance of 50 Ω, which will cause reflections. The SWR is 1.5.

The line is terminated in a resistive load of 75 Ω. The frequency of operation is 90 MHz. With this combination, what's the impedance that the generator sees at the cable input and what's the SWR?

First calculate the SWR:

SWR = Z_L/Z_O = 75/50 = 1.5

Mark that point on the horizontal resistance line to the right of the center point. Then draw a circle around the center point through the 1.5 mark. This is the SWR circle. You can also draw a vertical line from that point down and it should intersect the SWR scale at the bottom of the chart at the 1.5 mark.

The first step is to calculate the length of the line in wavelength:

λ = 984/f

where f is in MHz:

λ = 984/90 = 10.933 ft.

We can round this to 11.

With a velocity factor of 0.8, the wavelength is:

λ = 11(0.8) = 8.8

The 20-ft. line represents:

20/8.8 = 2.27 λ

Round to 2.3 λ. Next, determine the impedance at the generator end of the line.

Starting at the 1.5 mark on the horizontal resistance line, move back toward the generator 2.3 wavelengths. Two wavelengths require four clockwise rotations. Continue to rotate another 0.3 wavelength. That's one more half rotation (one half rotation is 0.25 wavelength) and an additional 0.3 – 0.25 = 0.05 wavelength. After that, draw a line from the 0.5 mark on the outer scale to the chart center. The point on the on the SWR circle where the line crosses is the impedance that the generator sees *(Fig. 1, again)*:

Z = 0.67 + j0.108

Multiplying this normalized value by 50 Ω gives the actual impedance:

33.5 – j5.4

which is an inductive load.

Example 2

Assume a load impedance of 60 + j40 is connected to the 20-ft. transmission line discussed earlier. What actual impedance will the 50-Ω generator see?

Plot the load impedance on the Smith chart using the normalized value. Then divide the resistance and reactive values by 50 Ω:

1.2 + j0.8

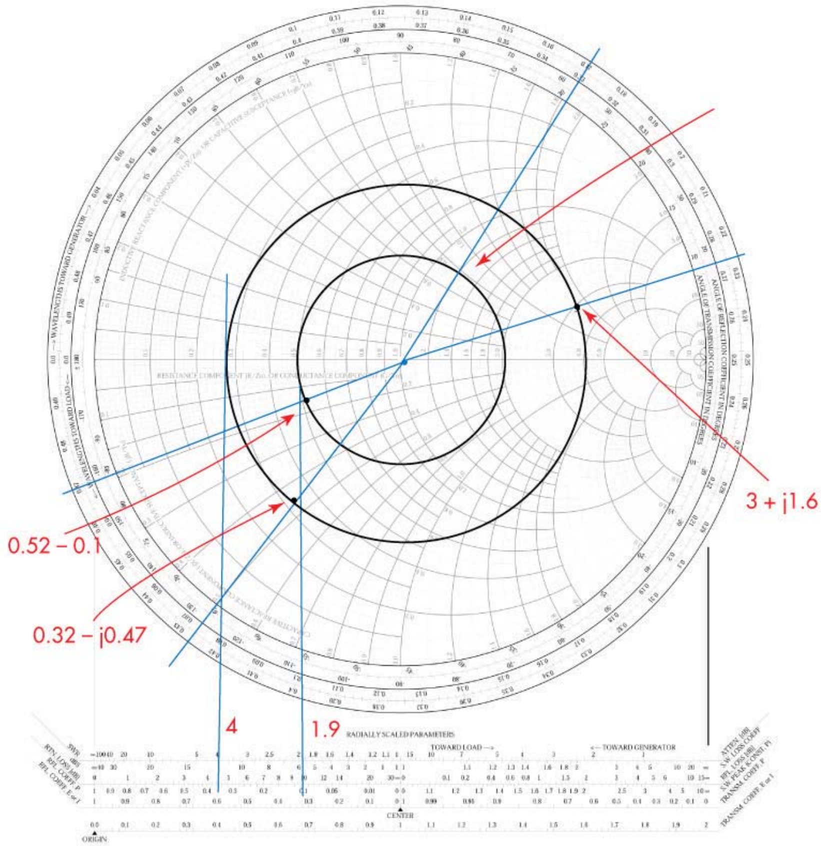
Once you plot that value, draw the SWR circle through the impedance point. Then extend a line down vertically to the SWR scale at the bottom of the chart. The SWR is about 1.9. Now draw a line through the center point and plotted impedance so that it extends to the TOWARD GENERATOR scale on the outer perimeter.

This line intersects with the scale at 0.17. Since the generator is 2.3 wavelengths away as determined in the earlier example, you move around the circle 2.3 wavelengths. You only need to use the 0.3 value, thus you add it to the 0.17 value to get 0.47. Find that value on the TOWARD GENERATOR scale. Draw a line from the center point to the 0.47 point. The load that the generator sees is at the intersection of this line and the SWR circle. Reading from the chart you should get:

0.52 – j0.1

Multiply the normalized value by 50 to get the actual value *(Fig. 3)*:

Z = 26 – j5



3. This chart depicts solutions to Examples 1 and 2.

Example 3

Suppose that you can measure the overall impedance of the transmission line connected to the antenna. Using an impedance bridge, SWR meter, or similar instrument, you measure a total impedance of the combined transmission line and antenna impedance that would be seen by a generator if connected. Let's say that it is 150 + j80. We can use the same transmission line and frequency of 50 Ω and 90 MHz. The line is 2.3 wavelengths long.

Normalizing the impedance, we get:

3 + j1.6

Plot the point and draw the SWR circle. Then extend a line down to the SWR scale and read the value of 4. Next, draw a line from the center point through the plotted normalized value to the TOWARD LOAD scale on the chart perimeter. You should read about 0.273.

Now rotate in the counterclockwise direction toward the load for 2.3 wavelengths or just 0.3 as before. The intersection will be at the 0.3 + 0.273 = 0.573 or at the 0.073 mark on the TOWARD GENERATOR scale. Draw a line from the center point to that mark on the outer scale. The antenna impedance will be at the intersection of this line and the SWR circle, which is:

0.32 – j0.47

The actual value is:

Z = 16 – j23.5

If you followed this procedure, you noticed that the values are approximate since you must interpolate between the lines. It's like reading from a slide rule, if you're old enough to know what that is.

An Impedance-Matching Example

A well-known and useful impedance-matching technique is to use a quarter-wave matching transformer. This is a one-quarter wavelength section of transmission line whose characteristic impedance (Z_O) is determined by the expression:

$Z_O = \sqrt{(Z_S Z_L)}$

Z_S is the source or generator impedance and Z_L is the load impedance *(Fig. 4)*.

(Continues on page 31)

JASON DeCHIARO | System Architect, Curtiss-Wright Defense Solutions

Open Standards Drive Flexibility in DEFENSE SYSTEM DESIGNS

Backed by broad support from government and industry, the release of SOSA Technical Standard 1.0 promises a new era of open standards-based system integration with flexibility and interoperability as its hallmarks.

The open-standards approach to defense electronics has made great strides in recent years. Helping to drive the accelerated adoption of open architectures, such as the OpenVPX module and backplane architecture overseen by the VITA trade association, is the Modular Open System Approach (MOSA) memo issued by the U.S. Department of Defense (DoD) in January 2019. The memo, supported by the U.S. Army, Navy, and Air Force, mandates that all new systems "shall be designed and developed, to the maximum extent practicable, with a modular open-system approach to enable incremental development and enhance competition, innovation, and interoperability."

Specific mandates for MOSA now reach down to the Program Executive Office (PEO) and Program Manager (PM) level, and requirements for and interest in MOSA solutions continues to grow rapidly. This mandate was also codified into law (Title 10 U.S.C. 2446a.(b), Sec 805), requiring all new defense acquisition programs to be designed and developed using MOSA.

MOSA Expectations and Compliant Standards

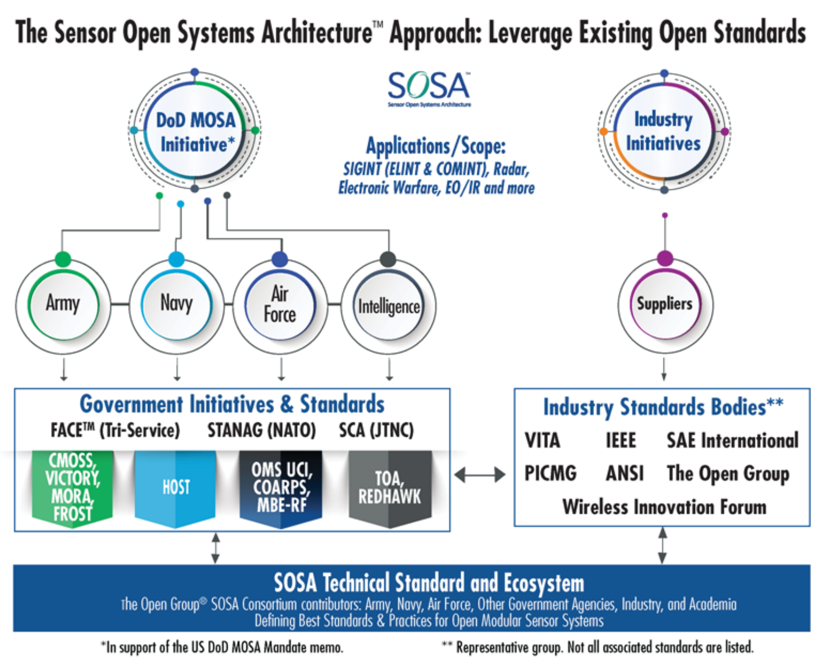
For designers of military sensor systems, the MOSA-aligned standard leverages modular design and widely supported, consensus-based, non-proprietary standards for key interfaces that are expected to:

- Accelerate fielding of new capabilities
- Reduce integration cost and risk
- Streamline development
- Simplify modernization and sustainment
- Mitigate obsolescence challenges
- Facilitate interoperability and reuse
- Enable rapid composition of capabilities from conformant elements

Examples of open standards that satisfy the MOSA mandate and the services for which they're most relevant include:

- *CMOSS:* C5ISR/EW Modular Open Suite of Standards
- *SOSA:* The Open Group Sensor Open Systems Architecture *(Fig. 1)*
- *FACE:* Future Airborne Capability Environment
- *HOST:* Hardware Open Systems Technologies
- *MORA:* Modular Open Radio Frequency Architecture
- *OMS/UCI:* Open Mission Systems/ Universal Command and Control Interface
- *VICTORY:* Vehicular Integration for C4ISR/EW Interoperability

The CMOSS architecture, which enables hardware commonality across ground vehicles, focuses on a network-centric approach to communications. It enables a transition from dedicated boxes for specific functionalities, referred to



1. Here's an overview of the SOSA Technical Standard and Ecosystem.

as line-replaceable units (LRUs), to the more flexible and cost-effective line-replaceable module (LRM) approach in which a rugged chassis hosted in the vehicle can be integrated with a mix of different boards to provide and introduce needed functionalities and technologies *(Fig. 2)*.

The LRU approach to CMOSS delivers significant size, weight, power, and cost (SWaP-C) benefits, such as simplified integration with less cabling and fewer peripherals. The use of open systems also eases technology refresh and insertion, plus it helps deliver common hardware across echelons and platforms to reduce the logistics burden.

2. In this example of an open systems platform architecture, a single, unmodified eight-slot chassis design provides all required functionality of the platform with different plug-in module payloads.

SOSA Standard

The SOSA Technical Standard is based on the hardware foundation of CMOSS. The definition of the standard is overseen by The Open Group SOSA Consortium, which empowers government and industry to collaboratively develop open standards and best practices. While the U.S. Army maintains control of CMOSS, it and SOSA are highly complementary.

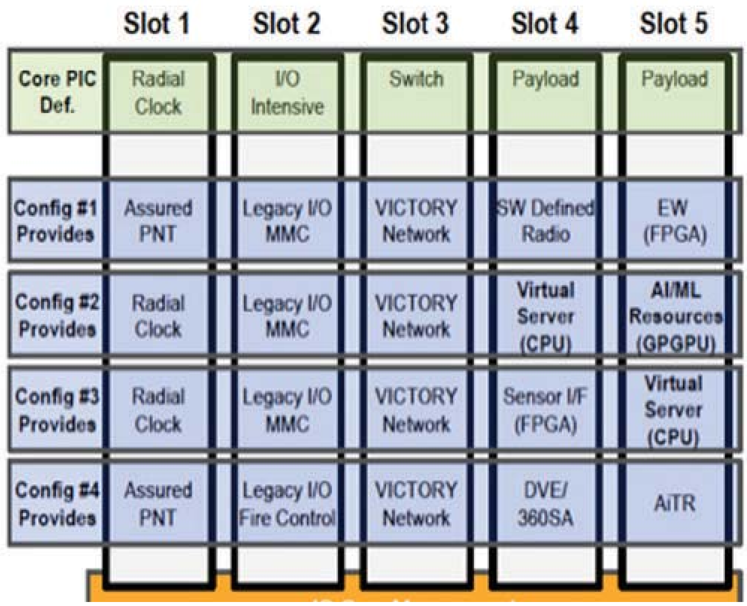
With its emphasis on interoperability, the SOSA Technical Standard will provide system designers the flexibility to choose best-of-breed solutions. The soon-to-be-released SOSA Technical Standard 1.0 will include third-party conformance validation to ensure compliance to the open standard. Because SOSA isn't subject to International Traffic in Arms (ITAR) regulations and not restricted to the U.S., its benefits can be realized worldwide.

The SOSA Technical Standard leverages and complements open standards in government and industry. It defines architectural modules (containing functions and behaviors) with defined open interfaces, enabling the development of capabilities made up of common components. The standard incorporates specifications for hardware elements including electrical and mechanical interfaces composing the SOSA sensor element.

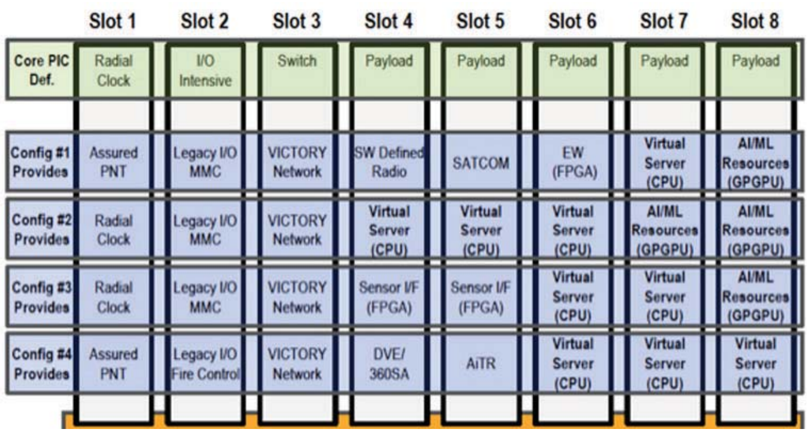
With its foundation in CMOSS, SOSA defines VPX slot profiles. The resulting LRMs are connected via Ethernet, so that slots can be placed in the most convenient locations in the platform, eliminating the need to collocate chassis.

Today, required combat platform functions and sensors are integrated as discrete boxes, such as positioning, navigation, and timing (PNT); Mission Command (JBC-P); SINCGARS Radio; Jammer (EW); IP Radio; and Intel Data Processing systems. With SOSA, these functions can be integrated onto single or multifunction VPX modules and housed in a rugged VPX chassis with either five or eight slots *(Figs. 3 and 4, respectively)*. Data flows are defined by system software and the use of network-centric architecture principles.

While SOSA defines both 3U and 6U plug-in cards (PICs) as system building blocks, most industry activity and interest have been for the smaller module size. Both sizes of LRM require +12-V power. While leveraging VITA's OpenVPX architecture, SOSA aims to foster interoperability by defining every signal pin on the standard PICs, thus eliminating the "user-defined" pins that have driven proprietary system designs. Platform-specific interfaces are confined to special user-defined modules, allowing for easy future upgrades to the processing and networking infrastructure.



3. Shown are some examples of five-slot SOSA system architectures.



4. SOSA system architectures of eight slots are illustrated in these examples.

The standard also calls out VITA 48.2 2-Level Maintenance (2LM) and VITA 47 environmental reliability. PIC profiles are provided for I/O-intensive single-board computers (SBCs), payload modules for processing (with 40-GbE and PCIe connectivity) and switch profiles that enable modules to communicate to each other via Ethernet, PCIe, and RF/optical switching. Radial clock modules also are defined to time-align processing elements and support positioning, navigation, and timing (PNT).

Leading COTS suppliers currently offer modules that were developed in alignment with the SOSA Technical Standard. For Curtiss-Wright, CMOSS and SOSA provide an opportunity to minimize program risk with field-proven hardware. Single point-of-contact integration services and expertise enable customers to reduce the complexity of developing CMOSS/SOSA solutions while fully leveraging the many benefits of these open standards.

SOSA Modules

In addition to the MPMC-933x three-slot SOSA-aligned chassis, Curtiss-Wright has produced a range of SOSA-aligned and field-proven modules, with many

more in development. Examples of currently available CMOSS/SOSA 3U OpenVPX building blocks include:

- *VPX3-1260:* An Intel-based processor card for advanced processing and various C5ISR applications that offers variants aligned to both I/O-intensive and payload profiles.
- *VPX3-1707:* An Arm-based processor card that offers high performance per watt in systems optimized for SWaP, and is aligned to the I/O-intensive profile.
- *CHAMP-XD1S:* A digital signal processor (DSP) featuring high performance and hardened security for compute-intensive applications, and is aligned to the I/O-intensive profile *(Fig. 5)*.
- *VPX3-4935:* An NVIDIA Quadro Turing-based GPGPU board for intense processing and artificial intelligence (AI) in high-performance embedded-computing (HPEC) systems. The board, which is aligned to the 3U VPX A-PNT Timing Card designed to enable assured positioning, navigation, and timing (A-PNT), simplifies the integration of complementary PNT sources and is aligned to the radial clock profile.
- *VPX3-663:* A hybrid switch module that combines PCIe Gen 3.1 and 10G Ethernet switching in a single 3U VPX module and is aligned to the expansion/control plane switch profile.
- *VPX3-687:* A fully managed and versatile Ethernet switch optimized for both low-latency control-plane and high-throughput data-plane applications, aligned with the data/control plane switch profile.

5. Curtiss-Wright's CHAMP-XDS1, which features an Intel Xeon D processor and Xilinx MPSoC FPGA, is a digital-signal-processor OpenVPX module designed to align with the SOSA Technical Standard.

The defense electronics industry looks forward to the release of SOSA Technical Standard 1.0. It promises a new era of open standards-based system integration with flexibility and interoperability as its hallmarks. With broad support across the government and industry, the availability of numerous offerings from multiple vendors will help deliver today's most advanced sensor-processing system technologies more rapidly and cost-effectively to our warfighters. mw

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PS Form 3526-R, July 2014

Tiny LTCC Filters Isolate 5G Passbands

Mini-Circuits' BFCQ series of low-temperature-cofired-ceramic (LTCC) bandpass filters includes four models for isolating fifth-generation (5G) cellular wireless passbands n257, n258, and n260. The RoHS-compliant, 50-Ω filters measure only 2.5 × 2.0 mm and are surface-mountable but handle as much as 1-W input power. For example, model BFCQ-2552+ has a passband of 25.2 to 26.6 GHz for isolating 5G signals in the n258 band. It features low passband loss of 2.5 dB across that frequency range. It provides lower stopband signal suppression of 55 dB from 0.1 to 18.0 GHz and 35 dB from 18.0 to 22.2 GHz with upper stopband signal suppression of 35 dB from 29.5 to 32.0 GHz and 40 dB or more from 32.0 to 50.0 GHz. The compact filters handle operating temperatures from -55 to +125°C.

MINI-CIRCUITS, http://www.minicircuits.com/WebStore/dashboard.html?model=BFCQ-2552%2B

Microwave Assemblies Lend Flexibility to RF Board Interconnects

Times Microwave Systems recently launched its new InstaBend high-performance microwave assemblies, which offer a preassembled design for interconnects between RF circuit cards, modules, and enclosure panels. The assemblies are ideal for applications with space constraints, including space flight, thermal vacuum, microwave test, and many other commercial and military applications. The cable can be bent very closely behind the connector without damaging the assembly, thus minimizing the footprint and simplifying cable routing. What's more, the InstaBend assemblies provide engineers with significantly reduced lead time compared to competing solutions, with drastically reduced lead times. They come in standard configurations or can be customized to meet user's requirements.

TIMES MICROWAVE SYSTEMS, www.timesmicrowave.com/DataSheets/Literature/InstaBend%20086.pdf

Modules Provide Longer Range for the Industrial IoT

Laird Connectivity has launched its BL653µ Bluetooth 5.1 module series, which provides longer-range Bluetooth Low Energy (BLE) connectivity in harsh industrial environments. The series is powered by Nordic's nRF52833 WLCSP outfitted with a Cortex-M4F processor and Bluetooth 5.1 on the same chip. It also features USB access and provides up to +8-dBm transmit power and up to 5.5 V of power. Expanding on the connectivity options, the BL653µ series also has hardware support for NFC and 802.15.4 (Thread and Zigbee) if the application is warranted. What's more, the module supports Bluetooth mesh capabilities, extending communication range in environments that have limited access and temperature ranges of -40 to +105°C.

LAIRD CONNECTIVITY, www.lairdconnect.com/wireless-modules/bluetooth-modules

RFID Reader Chips Allow Engineers to Design IoT Devices to Meet Connectivity Demand

Impinj recently introduced three next-gen RAIN RFID reader chips that enable IoT device makers to meet the increasing demand for IoT connectivity in retail, supply chain and logistics, consumer electronics, and many others.The E710, E510, and E310 RAIN RFID reader SoCs deliver increased performance, integration, and ease of use with 2X better receive capabilities, 80% smaller RAIN RFID designs, 50% lower power consumption, and ease of use with software and pin updates. The RAIN RFID SoCs are ideal for mobile devices, robotics, inventory management, PoS devices, smart appliances, gaming devices, and more.

IMPINJ, www.impinj.com/products/reader-chips

Switch Matrix Goes Eight Ways to 18 GHz

Mini-Circuits' model ZTRC-8SPDT-A18 is a single-pole, double-throw (SPDT) switch matrix for testing and other switching applications from dc to 18 GHz. It consists of eight remotely controllable absorptive electromechanical switches housed in a 2U-high, 19-in.-wide rack-mount enclosure with female SMA connectors. The 50-Ω switches have a fail-safe, break-before-make configuration and are rated for 10 million switching cycles. They achieve 60 dB or more typical isolation with 0.30 dB or less typical insertion loss from dc to 18 GHz. Remote control is via USB or Ethernet connection, using the included software and user-friendly graphical user interface (GUI). The switches handle as much as 20-W cold switching power from -15 to +85°C with typical switching speed of 20 ms.

MINI-CIRCUITS, http://www.minicircuits.com/WebStore/dashboard.html?model=ZTRC-8SPDT-A18

EMC Filters Target SiC/GaN-Based Power Systems

SMP GmbH has designed all-mode EMC filters with high-frequency stability using high-frequency composite materials (HFCM) developed and manufactured by SMP, effective for frequencies up to the gigahertz range. The all-mode design combats both differential- and common-mode noise and satisfies all of the requirements for modern SiC and GaN applications. A combination of HFCM and all-mode technology makes it possible to reduce the number of filter components needed in the system by about 50%. It also means that common-mode chokes or filters are no longer needed. Because the materials are magnetostriction-free, the filters are noiseless. They also require fewer filter components, so volume is reduced, while the cost-effectiveness of the power-electronics system as a whole increases significantly.

SMP GmbH, www.smp.de/products/inductive_components

Industrial Network Device Serves Next-Gen Ethernet TSN Technology

Renesas announced its R-IN32M4-CL3 IC for industrial Ethernet (IE) communication and offers support for CC-Link IE Time-Sensitive Networking (TSN), a communication standard for next-generation Ethernet TSN technology. The IC provides time-synchronization accuracy of less than one-millionth of a second between applications, driving TSN support for applications that include ac servos, actuators, and remote I/O for network communications. The R-IN32M4-CL3 IC features an Arm Cortex-M4 core with a floating-point unit (FPU), real-time OS accelerator, Gigabit Ethernet PHY, and 1.3 MB of on-chip RAM. The IC also supports the existing CC-Link IE Field network protocol, providing flexibility for existing and next-generation systems.

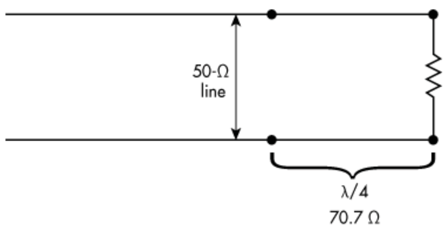
RENESAS, www.renesas.com/us/en/products/interface-connectivity/ethernet-ics-phys/industrial-ethernet-communication/r-in32m4-cl3-ics-industrial-ethernet-communication

Computing Module Uses AI to Process Sound for the Hearing Impaired

Lantronix announced that its Open-Q 820 µSOM was tasked with the development of the Whisper Hearing System. Created by San Francisco-based Whisper, the Whisper Hearing System is an AI-powered hearing aid and sound processor that improves over time. The Open-Q 820 µSOM is a computing module designed around Qualcomm's Snapdragon 820 processor and packs 3 Gb of LPDDR4 RAM, 32 Gb of flash, and built-in Wi-Fi and Bluetooth 4.2 and BLE. The module provides 3x I2S, PCM, 6x analog in/out, and 3x digital mics for audio. The Open-Q 820 µSOM takes advantage of neural networks for processing sound, along with the low latencies required for speech intelligibility.

LANTRONIX, www.lantronix.com/products/open-q-820-usom/

(Continued from page 22)



4. A quarter-wave section of transmission line can provide impedance matching. This technique is useful at high frequencies, where stripline can be used.

To match a 50-Ω source (Z_S) to a 100-Ω load (Z_L), a quarter-wave section of transmission line is needed with an impedance of:

$Z_O = \sqrt{(Z_S Z_L)} = \sqrt{(50)(100)} = \sqrt{5000} = 70.7\ \Omega$

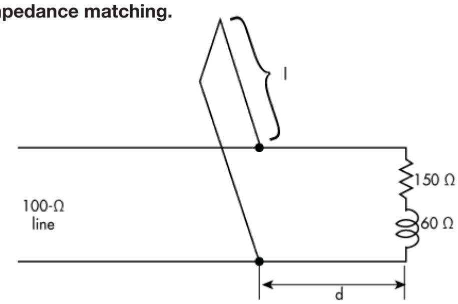
This is a workable approach, but it has problems. First, where do you get a 70.7-Ω line? Second, if the operating frequency is in the low RF range, the line could be many feet long. Third, the impedances are purely resistive, which isn't always the case in most applications.

However, if you are working at the higher frequencies of hundreds of megahertz or in the gigahertz range, the quarter-wave line will be short. In addition, you can create that line using microstrip or stripline on a PCB with any impedance you want by just adjusting the line widths, line spacing, dielectric material, and other factors involved in designing with microstrip lines. But other factors must be considered, such as when the source and load impedances are complex. This is where the Smith chart can be useful.

One approach to impedance matching is to use shorted transmission-line stubs in parallel with the transmission line. *Figure 5* shows an example. The stub acts as a reactance to cancel out the opposite reactance at a specific point on the line as determined by the load. The objective is to find the length of the stub (l) and the distance from the load (d) where it's to be connected.

Another example will illustrate this scenario. A load impedance of $Z_L = 150 + j60$ must be matched to a 100-Ω transmission line *(Fig. 5, again)* using these steps:

5. A shorted stub is placed at a specific distance from the load and provides impedance matching.



1. Normalize the load impedance. $150/100 + j60/100 = Z_L = 1.5 + j0.6$. Plot that on the Smith chart at point A *(Fig. 6)*.
2. Draw the SWR circle. Then draw a line down from the center of the chart to the SWR scale. It indicates an SWR of 2 to 1.
3. Draw a line from the center point through point A to the perimeter of the chart and read the wavelength on the TOWARD GENERATOR scale. It is 0.052.
4. Convert Z_L to its equivalent admittance. This is done by noting the intersection of the line you just made from Z_L through the center point to the perimeter. The point where the line crosses the SWR circle is Y_L. Its normalized value is $Y_L = 0.53 - j0.23$. Note the change in sign of the susceptance. This is point B in the figure.
5. Move from point B clockwise around the SWR circle until it reaches the R = 1 circle on the chart. That is point C in *Figure 6*. This value is the normalized susceptance. B = 1 + j0.62. Draw a line from the center point through C to the perimeter. It should read 0.15 λ.
6. Find the wavelength distance between the lines intersecting B and C. It is 0.15 + 0.052 = 0.202 λ. This is the distance (d) from the load to the point where the shorted line will be placed.
7. The shorted stub should have the opposite susceptance of the load or –j0.62. Connecting susceptances in parallel causes them to add directly and cancel one another.
8. To cancel 1 + j0.62, we need a stub that will produce 0 – j0.62. Extend the line from the 1 + j0.62 point through the center point to the R = 0 circle. Read this value on the R = 0 circle that's the outer perimeter of the chart. Note the wavelength reading of 0.42 λ.
9. Now, move from that value one quarter wavelength (0.25λ). The one quarter wavelength point gives the stub length: l = 0.42 – 0.25 = 0.17 λ.
10. Now knowing the stub length and distance from the load in wavelengths, you can calculate the actual lengths at the desired operating frequency.

It's important to point out that these values are frequency-dependent. The calculations are for a single frequency. If the line is operated over a wider range of frequencies, there will be some reflections on the line and a higher SWR.

There are other ways to perform impedance matching on a Smith chart. These procedures require the use of the chart's admittance version as well as the standard chart used here.

Conclusion

The Smith chart is a daunting tool. If you followed the examples here, you get the picture. The chart does help to avoid some calculations, but it takes time to master it. If you work enough problems, you will become more adept at using it. Multiple online tutorials and articles can provide additional examples that will show you other ways to use the chart. To find blank Smith charts, search for downloadable charts online; there's a variety of sources.

In addition, you should get yourself a good magnifying glass as the labels and numerical values are tiny and hard to read. A drafting compass also is needed to draw those perfect SWR circles. That will improve the accuracy in reading values from the chart.

Finally, keep in mind that there are multiple sources of Smith chart calculators and software. Most RF CAD software packages include them. Today, though, you may want to just plug in the numbers and let the computer do the work. mw

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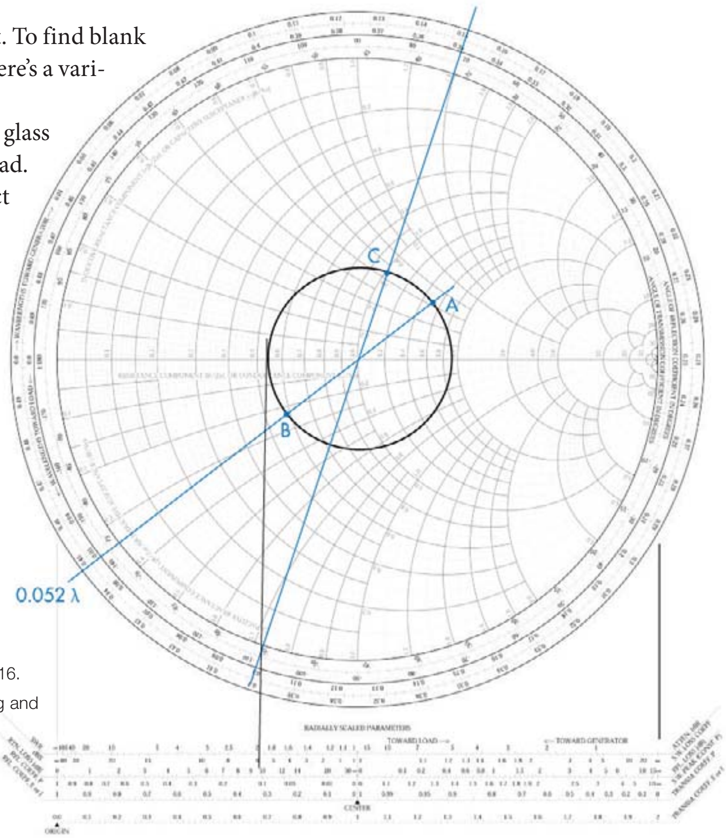

6. **The chart illustrates the solution to the shorted-stub matching technique.**

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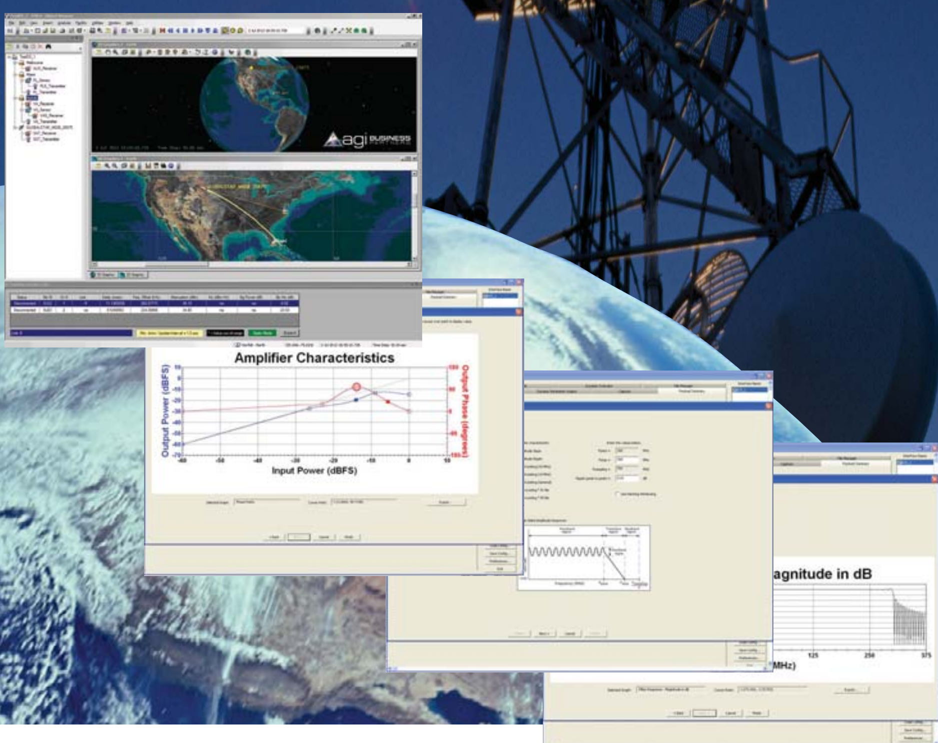

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