What's Happening in Ultra-Wideband? p10

Is Wireless Power Transfer Safe? p18

How to Use VNAs Like a TDR p22


# Microwaves & RF®

RF, COMMUNICATIONS, AND MICROWAVE TECHNOLOGY AND NEW-PRODUCT COVERAGE—IN DEPTH AND IN CONTEXT

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## Ready for *Whole-Home, Multi-Gb Wi-Fi 7?*

p12




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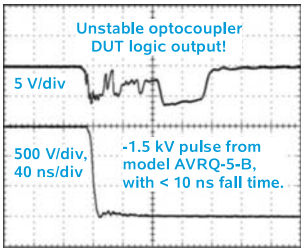


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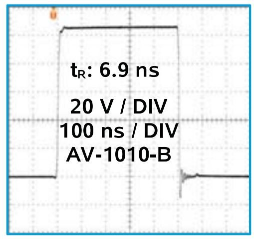


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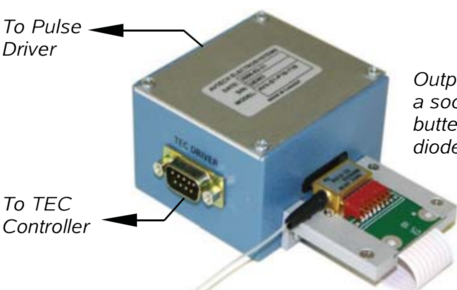
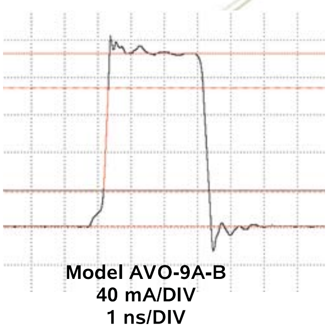



*Output module with a socket-mounted butterfly-packaged diode installed.*

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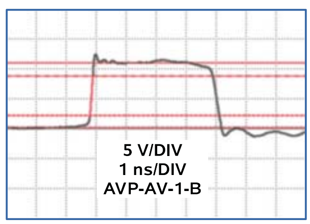


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| 100 V | 300 ps | 20 kHz | AVI-V-HV2A-B |
| 200 V | 1 ns | 50 kHz | AVIR-1-B |
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## FEATURES






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Editorial
DAVID MALINIAK | Editor
dmaliniak@endeavorb2b.com

# What's Driving the RF Components Market?

**Rapidly proliferating smart-home technology and the rise of wireless-equipped industrial robots will fuel steady growth in the RF components market.**

**AS WITH JUST ABOUT** every industry under the sun, the COVID-19 pandemic certainly took its toll on the RF/microwaves market. Looking back especially to 2020, national regulatory bodies around the globe went into lockdown mode in hopes of stemming the COVID tide. As a result, international trade barriers and supply-chain disruptions loomed large and severely impacted the global market for RF components. The recovery has proceeded in fits and starts ever since.

But fast-forward to today, and the outlook is significantly rosier. According to a report by Global Market Insights (GMI), the RF components market bounced back nicely in 2021, exceeding $15 billion with an anticipated compound annual growth rate (CAGR) of over 16% from 2022 to 2028, by which time we'll be looking at a $40 billion market. That's a rather healthy outlook.

When GMI says "RF components," they're talking about power amplifiers, antennas, switches, multiplexers, filters, modulator/demodulators, and transistors and diodes. But where is all that growth in demand for such components expected to come from?

A good portion of it will arise from the deepening penetration of industrial robotics and automation across the manufacturing and processing sectors. The International Federation of Robotics estimates that by the fourth quarter of 2021, there were around 3 million industrial robots at work in factories worldwide. The preponderance of those robots, and those to come in future smart factories, are outfitted with RF controllers, radar modules, IoT sensors, and RFID chipsets to facilitate remote monitoring and control.

But the biggest factor in the RF component market's projected upswing is consumer electronics, which accounted for about 40% of revenues in 2021 with a CAGR outlook of 17% through 2028. We can't seem to get enough of smartphones, tablets, laptops, and wearables, all of which require antennas, filters, multiplexers, and amplifiers to achieve high-quality wireless connectivity. Look for the proliferation of smart-home technology to push a lot of that growth, too.

Another factor in this expected surge, of course, is the ongoing buildout of 5G infrastructure. These days, the bulk of that buildout is happening in the Asia-Pacific region. The Chinese government's Ministry of Industry and Information Technology says that the country's telecom operators have already installed some 1.3 million 5G base stations to support about 497 million 5G users. Europe and North America will catch up before long.

Which RF components comprise most of the market progression? Well, in 2021, power amplifiers had a 25% share of the RF components market. PAs are seeing rapid technology advances in selectivity, sensitivity, and signal-to-noise ratio, which is spurring growth in segments such as electronic-warfare systems, public safety radio systems, and military radios.

The RF component market leaders—think vendors such as Analog Devices, Broadcom, Infineon, NXP, Qorvo, STMicroelectronics, TDK, and Texas Instruments—will remain in the vanguard, thanks to their robust R&D efforts. mw

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PMC-33D7-6D8-SFF


PMC-56-SFF

| PMI Model No. | Frequency Range (GHz) | Gain (dB) | Noise Temperature | Phase Balance | Size (Inches) Connectors |
|---|---|---|---|---|---|
| MPC-20R2G21R2G-CD-LNF | 20.2 - 21.2 | 0 to +10 | 100 K | ±3° | 6.25” x Ø4.8” x 2.0” SMA (F) |

| PMI Model No. | Frequency Range (GHz) | Insertion Loss (dB) | Isolation (dB) | Phase Balance | Amplitude Balance (dB) | Size (Inches) Connectors |
|---|---|---|---|---|---|---|
| PMC-24-7D5-SFF | 2 - 4 | 7.5 | 18 | ±10° | ±1.0 | 3.23” x 3.23” x 0.43” SMA (F) |
| PMC-2D22D4-6D8-SFF | 2.2 - 2.4 | 6.8 | 25 | ±5° | ±0.4 | 3.563” x 3.563” x 0.433” SMA (F) |
| PMC-3G3D5G-6D8-SFF | 3 - 3.5 | 6.8 | 23 | ±5° | ±0.4 | 3.23” x 3.23” x 0.43” SMA (F) |
| PMC-33D7-6D8-SFF | 3 - 3.7 | 6.8 | 24 | ±7° | ±0.5 | 3.23” x 3.23” x 0.43” SMA (F) |
| PMC-56-SFF | 5 - 6 | 1.0 | 20 | ±5° | ±0.5 | 2.60” x 2.60” x 0.43” SMA (F) |
| PMC-9G10G-7D9-SFF | 9 - 10 | 7.9 | 18 | ±6° | ±0.6 | 3.48” x 3.48” x 0.43” SMA (F) |
| PD-CD-001-1 | 9.3 - 9.9 | 8.0 | 30 | ±7° | ±0.5 | 2.35” x 1.7” x 0.5” SMA (F) |
| PMC-9D5G10D1G-7D6-SFF | 9.5 - 10.1 | 7.6 | 20 | ±5° | ±0.5 | 3.48” x 3.48” x 0.43” SMA (F) |
| PMC-9D5G10D5G-7D6-SFF | 9.5 - 10.5 | 7.6 | 20 | ±5° | ±0.5 | 3.48” x 3.48” x 0.43” SMA (F) |
| PMC-12G13G-1D6-SFF | 12 - 13 | 7.6 | 18 | ±5° | ±0.5 | 3.48” x 3.48” x 0.43” SMA (F) |
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PMC-9G10G-7D9-SFF


PD-CD-001-1


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PMC-16G17G-SMA

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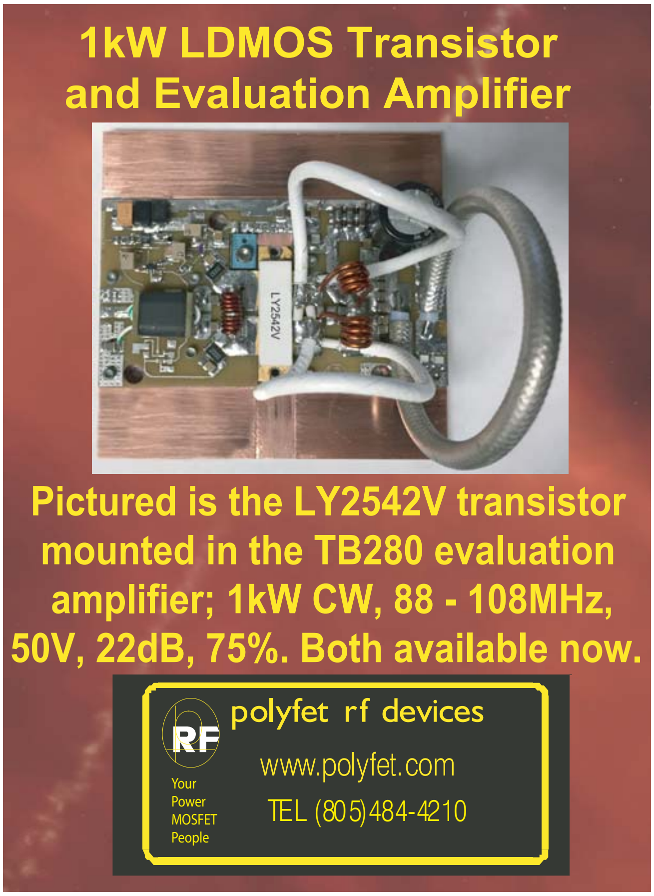
**West Coast Operation:**
4921 Robert J. Mathews Pkwy, Suite 1
El Dorado Hills, CA 95762 USA
Tel: 916-542-1401, Fax: 916-265-2597

**East Coast Operation:**
7311-F Grove Road
Frederick, MD 21704 USA
Tel: 301-662-5019, Fax: 301-662-1731

sales@pmi-rf.com • www.pmi-rf.com





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**EDITORIAL**
Senior Content Director: **Bill Wong**
*bwong@endeavorb2b.com*

Senior Editor: **David Maliniak**
*dmaliniak@endeavorb2b.com*

Managing Editor: **Roger Engelke**
*rengelke@endeavorb2b.com*

Senior Staff Writer: **James Morra**
*jmorra@endeavorb2b.com*

Technical Editor: **Jack Browne**
*jack.browne@citadeleng.com*

**ART DEPARTMENT**
Group Design Director:
**Anthony Vitolo**
*tvitolo@endeavorb2b.com*

Art Director: **Jocelyn Hartzog**
*jhartzog@endeavorb2b.com*

**PRODUCTION**
Production Manager:
**Brenda Wiley**
*bwiley@endeavorb2b.com*

Ad Services Manager:
**Deanna O'Byrne**
*dobyrne@endeavorb2b.com*

**AUDIENCE MARKETING**
User Marketing Manager:
**Debbie Brady**
*dmbrady@endeavorb2b.com*

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**SUBSCRIPTION SERVICES**
**OMEDA:**
847-559-7598 or 877-382-9187
*microwaves&rf@omeda.com*

**LIST RENTAL**
List Rentals/Smartreach Client Services Manager: **Mary Ralicki**
*mralicki@endeavorb2b.com*

**SALES & MARKETING**
**Gregory Montgomery**
*gmontgomery@endeavorb2b.com*
AZ, NM, TX

**Jamie Allen**
*jallen@endeavorb2b.com*
AL, AR, SOUTHERN CA, CO, FL, GA, HI, IA, ID, IL, IN, KS, KY, LA, MI, MN, MO, MS, MT, NC, ND, NE, OH, OK, SC, SD, TN, UT, VA, WI, WV, WY, CENTRAL CANADA

**Elizabeth Eldridge**
*eeldridge@endeavorb2b.com*
CT, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT, EASTERN CANADA

**Stuart Bowen**
*sbowen@endeavorb2b.com*
AK, NORTHERN CA, NV, OR, WA, WESTERN CANADA
AUSTRIA, BELGIUM, FRANCE, GERMANY, LUXEMBURG, NETHERLANDS, PORTUGAL, SCANDINAVIA, SPAIN, SWITZERLAND, UNITED KINGDOM

**Diego Casiraghi**
*diego@casiraghi-adv.com*
ITALY

**Helen Lai**
*helen@twoway-com.com*
PAN-ASIA

**Charles Liu**
*liu@twoway-com.com*
PAN-ASIA

**DIGITAL**
VP Digital Innovation Data:
**Ryan Malec**
*rmalec@endeavorb2b.com*

**DESIGN & ENGINEERING GROUP**
EVP, Design & Engineering Group:
**Tracy Smith**
*tsmith@endeavorb2b.com*

Group Content Director:
**Michelle Kopier**
*mkopier@endeavorb2b.com*

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### OCTAVE BAND LOW NOISE AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|---|---|---|---|---|---|---|
| CA01-2110 | 0.5-1.0 | 28 | 1.0 MAX, 0.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-2110 | 1.0-2.0 | 30 | 1.0 MAX, 0.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA24-2111 | 2.0-4.0 | 29 | 1.1 MAX, 0.95 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA48-2111 | 4.0-8.0 | 29 | 1.3 MAX, 1.0 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA812-3111 | 8.0-12.0 | 27 | 1.6 MAX, 1.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1218-4111 | 12.0-18.0 | 25 | 1.9 MAX, 1.7 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1826-2110 | 18.0-26.5 | 32 | 3.0 MAX, 2.5 TYP | +10 MIN | +20 dBm | 2.0:1 |

### NARROW BAND LOW NOISE AND MEDIUM POWER AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|---|---|---|---|---|---|---|
| CA01-2111 | 0.4 - 0.5 | 28 | 0.6 MAX, 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA01-2113 | 0.8 - 1.0 | 28 | 0.6 MAX, 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-3117 | 1.2 - 1.6 | 25 | 0.6 MAX, 0.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA23-3111 | 2.2 - 2.4 | 30 | 0.6 MAX, 0.45 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA23-3116 | 2.7 - 2.9 | 29 | 0.7 MAX, 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA34-2110 | 3.7 - 4.2 | 28 | 1.0 MAX, 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA56-3110 | 5.4 - 5.9 | 40 | 1.0 MAX, 0.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA78-4110 | 7.25 - 7.75 | 32 | 1.2 MAX, 1.0 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA910-3110 | 9.0 - 10.6 | 25 | 1.4 MAX, 1.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA1315-3110 | 13.75 - 15.4 | 25 | 1.6 MAX, 1.4 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA12-3114 | 1.35 - 1.85 | 30 | 4.0 MAX, 3.0 TYP | +33 MIN | +41 dBm | 2.0:1 |
| CA34-6116 | 3.1 - 3.5 | 40 | 4.5 MAX, 3.5 TYP | +35 MIN | +43 dBm | 2.0:1 |
| CA56-5114 | 5.9 - 6.4 | 30 | 5.0 MAX, 4.0 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA812-6115 | 8.0 - 12.0 | 30 | 4.5 MAX, 3.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA812-6116 | 8.0 - 12.0 | 30 | 5.0 MAX, 4.0 TYP | +33 MIN | +41 dBm | 2.0:1 |
| CA1213-7110 | 12.2 - 13.25 | 28 | 6.0 MAX, 5.5 TYP | +33 MIN | +42 dBm | 2.0:1 |
| CA1415-7110 | 14.0 - 15.0 | 30 | 5.0 MAX, 4.0 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA1722-4110 | 17.0 - 22.0 | 25 | 3.5 MAX, 2.8 TYP | +21 MIN | +31 dBm | 2.0:1 |

### ULTRA-BROADBAND & MULTI-OCTAVE BAND AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure (dB) | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|---|---|---|---|---|---|---|
| CA0102-3111 | 0.1-2.0 | 28 | 1.6 Max, 1.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0106-3111 | 0.1-6.0 | 28 | 1.9 Max, 1.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0108-3110 | 0.1-8.0 | 26 | 2.2 Max, 1.8 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA0108-4112 | 0.1-8.0 | 32 | 3.0 MAX, 1.8 TYP | +22 MIN | +32 dBm | 2.0:1 |
| CA02-3112 | 0.5-2.0 | 36 | 4.5 MAX, 2.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA26-3110 | 2.0-6.0 | 26 | 2.0 MAX, 1.5 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA26-4114 | 2.0-6.0 | 22 | 5.0 MAX, 3.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA618-4112 | 6.0-18.0 | 25 | 5.0 MAX, 3.5 TYP | +23 MIN | +33 dBm | 2.0:1 |
| CA618-6114 | 6.0-18.0 | 35 | 5.0 MAX, 3.5 TYP | +30 MIN | +40 dBm | 2.0:1 |
| CA218-4116 | 2.0-18.0 | 30 | 3.5 MAX, 2.8 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA218-4110 | 2.0-18.0 | 30 | 5.0 MAX, 3.5 TYP | +20 MIN | +30 dBm | 2.0:1 |
| CA218-4112 | 2.0-18.0 | 29 | 5.0 MAX, 3.5 TYP | +24 MIN | +34 dBm | 2.0:1 |

### LIMITING AMPLIFIERS

| Model No. | Freq (GHz) | Input Dynamic Range | Output Power Range Psat | Power Flatness dB | VSWR |
|---|---|---|---|---|---|
| CLA24-4001 | 2.0 - 4.0 | -28 to +10 dBm | +7 to +11 dBm | +/- 1.5 MAX | 2.0:1 |
| CLA26-8001 | 2.0 - 6.0 | -50 to +20 dBm | +14 to +18 dBm | +/- 1.5 MAX | 2.0:1 |
| CLA712-5001 | 7.0 - 12.4 | -21 to +10 dBm | +14 to +19 dBm | +/- 1.5 MAX | 2.0:1 |
| CLA618-1201 | 6.0 - 18.0 | -50 to +20 dBm | +14 to +19 dBm | +/- 1.5 MAX | 2.0:1 |

### AMPLIFIERS WITH INTEGRATED GAIN ATTENUATION

| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure (dB) | Power-out @ P1-dB | Gain Attenuation Range | VSWR |
|---|---|---|---|---|---|---|
| CA001-2511A | 0.025-0.150 | 21 | 5.0 MAX, 3.5 TYP | +12 MIN | 30 dB MIN | 2.0:1 |
| CA05-3110A | 0.5-5.5 | 23 | 2.5 MAX, 1.5 TYP | +18 MIN | 20 dB MIN | 2.0:1 |
| CA56-3110A | 5.85-6.425 | 28 | 2.5 MAX, 1.5 TYP | +16 MIN | 22 dB MIN | 1.8:1 |
| CA612-4110A | 6.0-12.0 | 24 | 2.5 MAX, 1.5 TYP | +12 MIN | 15 dB MIN | 1.9:1 |
| CA1315-4110A | 13.75-15.4 | 25 | 2.2 MAX, 1.6 TYP | +16 MIN | 20 dB MIN | 1.8:1 |
| CA1518-4110A | 15.0-18.0 | 30 | 3.0 MAX, 2.0 TYP | +18 MIN | 20 dB MIN | 1.85:1 |

### LOW FREQUENCY AMPLIFIERS

| Model No. | Freq (GHz) | Gain (dB) MIN | Noise Figure dB | Power-out @ P1-dB | 3rd Order ICP | VSWR |
|---|---|---|---|---|---|---|
| CA001-2110 | 0.01-0.10 | 18 | 4.0 MAX, 2.2 TYP | +10 MIN | +20 dBm | 2.0:1 |
| CA001-2211 | 0.04-0.15 | 24 | 3.5 MAX, 2.2 TYP | +13 MIN | +23 dBm | 2.0:1 |
| CA001-2215 | 0.04-0.15 | 23 | 4.0 MAX, 2.2 TYP | +23 MIN | +33 dBm | 2.0:1 |
| CA001-3113 | 0.01-1.0 | 28 | 4.0 MAX, 2.8 TYP | +17 MIN | +27 dBm | 2.0:1 |
| CA002-3114 | 0.01-2.0 | 27 | 4.0 MAX, 2.8 TYP | +20 MIN | +30 dBm | 2.0:1 |
| CA003-3116 | 0.01-3.0 | 18 | 4.0 MAX, 2.8 TYP | +25 MIN | +35 dBm | 2.0:1 |
| CA004-3112 | 0.01-4.0 | 32 | 4.0 MAX, 2.8 TYP | +15 MIN | +25 dBm | 2.0:1 |

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# News

## KEYSIGHT, NOKIA Demo First 800GE Readiness and Interoperability Public Test

**The test solution enables network operators to validate the reliability of high-bandwidth, large-scale 800-Gigabit Ethernet (GE) in service-provider and data-center environments.**

Keysight Technologies

Keysight Technologies collaborated with Nokia to successfully demonstrate the first public 800GE test, validating the readiness of next-generation optics for service providers and network operators.

With the move to the 800GE pluggable optics on front-panel ports, interconnect and link reliability requires a new round of validation cycles to support carrier-class environments. These high-speed interfaces create a unique challenge as new 800GE-capable silicon devices, optical transceivers, and high-bandwidth Ethernet speeds must be accurately tested.

The readiness testing, conducted at Nokia's private SReXperts customer event in Madrid in June 2022, included Keysight's AresONE 800GE Layer 1-3 800GE line-rate test platform and the Nokia 7750 Service Routing platform. The AresONE was used to test and qualify Nokia's FP5 network processor silicon along with 800GE pluggable optics. Specific Nokia platforms used in the validation were the FP5-based 7750 SR-1x-48D supporting 48 ports of 800GE and the 7750 SR-1se supporting 36 ports of 800GE.

Nokia's FP5 silicon delivers 112G SerDes, which enables 800GE support in hardware. FP5 enables networks to efficiently scale capacity and, concurrently, IP subscriber services while maintaining integrity. Thus, it provides advanced protection against escalating network security threats and lowers power consumption.

The company is the first vendor to ship high-density 800GE systems this year with platforms supporting a range of 36 × 800GE in compact fixed platforms to 432 ports of 800GE in the flagship 7750 SR-14s. mw

## DEV KIT ACCELERATES PROTOTYPING of Low-Power IoT Device Clusters

**WITH THE LAUNCH OF ITS** Sparrow development kit, Blues Wireless hopes to offer a solution for the last-mile problem of internet-connecting a group of low-cost, low-power device sensors for shared data backhaul to the cloud. The kit provides a complete solution, with reference hardware, example firmware, and an easy-to-deploy web application. The power-efficient Sparrow Gateway provides cellular or Wi-Fi backhaul and orchestrates LoRa-based communication with Sparrow sensors.

In the Sparrow schema, sensors are organized into clusters, and LoRa-based sensor data is routed through inexpensive Notecard-powered cellular gateways. The Notecard's developer experience is designed to simplify cellular, democratizing a capability formerly only available to large engineering firms. The full range of Notecard offerings simplify wireless across cellular, Wi-Fi, and LPWAN technologies. ■

# Matchmaker


*0402DC Series Designer's Kit (C472-2):*
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# Antenova's Small-Space Antenna Serves 5G and LTE Signals

**The company's smallest-ever 5G antenna will aid in the push to deploy millions of IIoT devices and help future-proof wireless designs as 3G fades and LTE and, ultimately, 5G dominate the landscape.**

### The Overview

In its Minima model SR4L075 antenna, Antenova now offers the smallest SMD antenna for 5G frequencies it's ever had. With volume of just 40 × 10 × 3.3 mm and weight of <3 grams, the Minima antenna suits small and lightweight designs for 4G and 5G frequencies, as well as designs that use both frequencies.

### Who Needs It & Why?

According to Bloomberg, there's burgeoning demand for high-bandwidth entertainment services, with services such as 4K video streaming and remote AR/VR gaming driving the growth. Meanwhile, oil, gas, mining, and energy utilities are investing in 5G networks to connect millions of industrial IoT (IIoT) devices. Emergency healthcare, transport, smart cities, V2X, and drones will also use 5G.

It's hoped by Antenova that Minima will help designers future-proof their designs as operators move away from 3G and roll out 5G services. The Global Mobile Suppliers Association (GMSA) reports an increase in super-fast 5G networks and 5G devices, identifying 493 operators in 150 countries that have invested in 5G, and 205 operators in in 80 countries that have launched 5G mobile services and 5G devices. The number of devices available for the 5G networks has grown by more than 60% in the last 12 months, according to the GMSA.

### Under the Hood

Minima is a multi-band cellular antenna covering the common 4G and 5G frequencies used globally, including the popular Band 71, 617 to 698 MHz, which is used by T-Mobile in the U.S. It can therefore be used in designs that will be marketed globally.

The device, which occupies minimum space in a design, operates with a small clearance beneath, making it a great candidate for 4G and 5G cellular designs in which space is tight on the PCB. In tests, Antenova claims, Minima achieved efficiencies up to 60%, which will help designers achieve certification for their 5G designs. The antenna operates on the most common 4G and 5G bands: LTE 700, GSM850, GSM900, DCS1800, PCS1900, WCDMA2100, LTE B7 (2500-2690 MHz), LTE B40 (2300-2400 MHz) and 5G B78 (3300-3800 MHz), B71 (617-698 MHz). mw



DR. NICK WOOD | Sales & Marketing, Insight SiP

# New Developments in Ultra-Wideband

**Significant barriers have impeded UWB from being widely adopted in the past, but now—one by one—they're getting knocked down.**

**Although they've been available in the market for some time, automotive wireless key solutions have proven to be insecure.** *Credit: Chris-kursikowski-wRpxzcowfKk-unsplash*

Ultra-wideband (UWB) has been a kind of "Cinderella" technology for some time—attractive in many ways, but not fully invited to the technological party. Or, perhaps it's thought of in some circles as the classic "solution in search of a problem." This article will look at UWB technology, what it's been used for, why it hasn't really become mainstream yet, and why this might change soon.

### UWB Technology

As the name suggests, ultra-wideband is a transmission method that involves transmitting over a rather large bandwidth. In quantitative terms, the currently accepted definition by the FCC and ITU is a bandwidth of 500 MHz or at least 20% of the center carrier frequency, whichever of these is smaller.

If one compares UWB with Bluetooth, where applying the above 20% rule would give you around 500 MHz anyway, each channel is in fact only 1 or 2 MHz wide. Wi-Fi channels, operating at a similar frequency, are 20 or 40 MHz wide. Thus, there's a difference of at least an order of magnitude in the channel widths.

This leads to important differences between UWB and more conventional radio transmission methods. The first is that UWB systems can transmit at a lower power level (as defined by spectral density, which is to say the power transmitted in each MHz of bandwidth) than narrowband radio. Indeed, they're transmitting at levels close to the noise floor.

The second is that it's possible to use different types of data encoding. Narrowband systems typically use frequency keying, varying frequency around a central value, amplitude modification, or orthogonal frequency-division multiplexing (OFDM).

The wideband nature of UWB allows for very short pulses (nanoseconds), which enables pulse position or time modulation—essentially, the presence (or not) of a pulse defines a bit of information. More complex OFDM schemes also are possible. This in turn enables a potentially very high data-rate transmission.

The final point is that the sharp pulses, as defined above, transmitted by UWB make it possible to accurately measure the time of a pulse's arrival, and with more precision than most competing technologies. One can say that the pulse width (duration) of a pulse is approximately 1/bandwidth, which works out to 2000 ps. If the time of departure and arrival are fixed, then the distance traveled can be determined.

To quantify, using the speed of light at 3 × 108 m/s, one can simply calculate that 1 meter of travel of a pulse takes 3.3 ns, or alternatively, achieving 1-cm accuracy requires a timing accuracy of 33 ps. Thus, the accuracy of any such distance measurement depends on how well the pulse edge can be consistently determined.

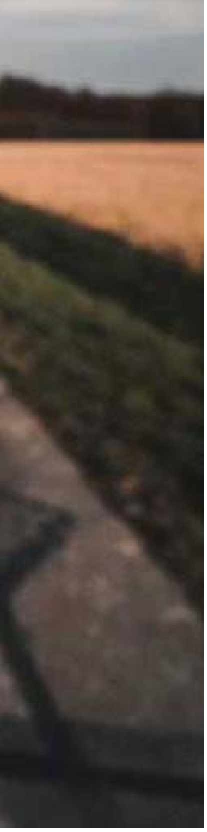
In practice, one makes time measurements using specific pulse trains with an achieved accuracy of typically around 200 ps or 5 cm. The limiting factors are the accuracy with which these pulse trains can be determined and the clocking inside the device.

Real-world distance or position measurements are typically made using one of two main approaches: two-way ranging or time-difference of arrival (TDoA). Two-way ranging simply measures the "round-trip" time between two devices to get a linear distance. TDoA measures the difference in arrival time of a pulse from the tag (device to be located) and multiple anchors (receivers at a known location), from which it infers a 3D position. This is like an indoor GPS, only with the signal going in the opposite direction.

Excluding optical methods, UWB offers the best radio-based positioning technology.

### Factors Restraining UWB Adoption

So, given all of these possibilities, why isn't UWB technology already ubiquitous? The answer to this lies in the practical issues in implementing solutions.



Although high data-transmission rates are possible, the signal is sensitive to obstructions, which means that in practice one must have a line-of-sight connection. This is a major disadvantage compared to, say, Wi-Fi. At one time, UWB was proposed as a high-speed data-transmission technology, but this drawback was a major issue, shifting the weight of investment to Wi-Fi.

A wideband transmitter/receiver tends to consume significant power. That's not an issue for mains-powered systems, but it becomes problematic for battery-powered devices. Thus, if battery-powered devices are envisaged as part of the ecosystem, UWB may not be the best solution.

For positioning technologies, UWB does have standout characteristics, as mentioned above, where there are few obvious competitors. The main barrier to adoption here has been practicality. Putting a positioning system in place is not straightforward, as it requires a custom infrastructure.

A TDoA system requires multiple anchors with highly synchronized clocks. Then it's necessary to gather data from all of the anchors and sort and combine it in a central system. Installing a UWB system over a large area such as a warehouse is a complex undertaking. Two-way ranging is simpler, but it increases the power consumption by an order of magnitude and can cause other issues in a large system.

A further barrier has been the lack of standards across the industry and the presence of well-known suppliers. Up until recently, the market has been served only by startup companies offering proprietary solutions and little interoperability.

This clearly made all but the most technologically adventurous hesitant to make major investments, as it would be easy to end up with a "stranded" asset due to having chosen the wrong standard and/or the wrong supplier. Relatively low volumes also led to the technology being relatively expensive.

### Shifts in the Market

Recently, the market has seen significant changes in several areas, including application demand, market players, standardization, and technical progress. In turn, one major driver of interest to deal with these changes is keyless entry systems.

Keyless entry solutions, or more correctly, wireless key solutions, have been a feature for some time in the automotive market *(see figure)*. Unfortunately, these have proven to be highly insecure. By ensuring the electronic key is truly close to the vehicle, UWB is resilient against the most common hacks (relay attacks) and requires much more sophisticated approaches to break the security.

Driven in part by its resilience to hacks, UWB capability has started to appear on phones. Many in the industry believe physical keys will ultimately become redundant or simply backup devices, and phones will become the dominant device to act as a key. This applies not only to cars, but potentially also for domestic use.

High-end devices from Apple (iPhone 11 and above), Samsung (S21+/Ultra and above), and others from Google and Xiaomi already have UWB capability. Apple's next-generation Air Tags use UWB for positioning.

This would not get us far if we still had a cluster of incompatible standards. Fortunately, the FiRa (Fine Ranging) Consortium is now driving standards, with involvement by all of the previously mentioned phone manufacturers and key chipmakers including NXP, Qorvo, Qualcomm, and others.

The presence of large semiconductor players in the market is another crucial development. Decawave, the most established chip startup company, was bought by Qorvo, and NXP has launched its own device. Apple designed its own chip, and all of these conform to FiRa standards. The risk associated with proprietary technology has therefore largely disappeared.

Semiconductors are largely a volume business—large development overheads see to that—so increased demand and interest drives technological development. The latest generation of devices has much improved performance, particularly in respect to power consumption, making battery-powered devices realistic. Miniature combined UWB/BLE modules such as those from Insight SIP allow for further power savings by the intelligent use of the two radios.

Real-time positioning solutions using TDoA will remain the most challenging application for the reasons mentioned in this article, and it will take longer to become mainstream. Nevertheless, all of the aforementioned factors will combine to lower resistance to investing in such technology. We have seen with other emerging standards such as BLE that initial projects are simple but become increasingly complex over time.

### Conclusion

UWB has long been an interesting technology with some unique characteristics. Major barriers have impeded it from being widely adopted in the past. However, one by one, these barriers are being knocked down. Secure entry offers a relatively simple application in which UWB adds significant value. The presence of UWB chips on phones offers a potential market for device makers (recall how BLE capability on phones arriving from 2011 onwards drove development of that market).

Increased demand for devices will inevitably boost performance and drive costs downward. As the technology becomes established and more widely known, implementing complex solutions such as real-time positioning will be more straightforward.

Technological predictions are never certain. What one can say is the most obvious constraints on UWB adoption are fading. The outlook has never been better. mw

# Wi-Fi 7: *Wi-Fi Reimagined for the Connected World*

**Emerging wireless applications demand increased throughput and low latency from Wi-Fi. Here's how next-generation Wi-Fi 7 is delivering on those requirements.**

GABRIEL DESJARDINS | Director of Product Marketing, Wireless Communications and Connectivity Division, Broadcom

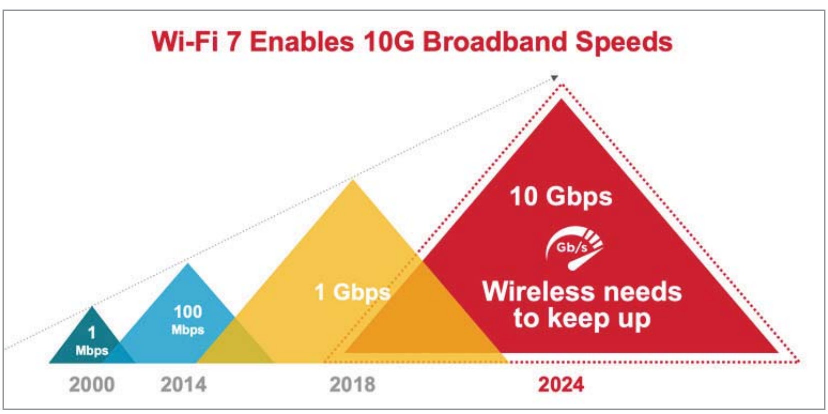
As Wi-Fi nears its 25th anniversary, the technology is so widespread that it's effectively become a utility for many people. While Wi-Fi speeds have increased at a rate that mirrors Moore's Law, the underlying technology was largely the same for the first 20 years of its life. It wasn't until Wi-Fi 6 was launched in late 2018 that Wi-Fi operations could, for the first time, be scheduled, which led to a major increase in Wi-Fi efficiency.

Key Wi-Fi applications have embodied both the growth in speeds and the innovations that started with Wi-Fi 6. Fifteen years ago, 802.11n (a.k.a. Wi-Fi 4) was a great mechanism for delivery of connectivity to a handful of devices in a home or office. When 802.11ac (Wi-Fi 5) was introduced, its higher speeds quickly made it the primary delivery mechanism for mobile video and over-the-top streaming.

In turn, Wi-Fi 6 and 6E used scheduling to vastly improve the performance of real-time video conferencing and mobile uploading, and quickly became the dominant technology in the market. Since 2019, Broadcom has shipped more than 1 billion Wi-Fi 6/6E devices.[1]

Going forward, several usage trends are driving the next generation of Wi-Fi. With the increase in remote work and virtual provision of services, 2021 saw major increases in spending on mobile gaming and virtual-reality products, leading to increased focus on reducing latency in these applications.

In parallel, operators worldwide are preparing for the introduction of 10-Gb/s cable-modem and fiber-optic broadband connections to homes and businesses. In addition, the 6-GHz band is now available for Wi-Fi usage in nearly 50 countries, with more than 75 additional




**1. A key feature of Wi-Fi 7 is its enablement of 10-Gb/s broadband speeds.** *Credit: Broadcom* countries contemplating opening the 6-GHz band.

This is where Wi-Fi 7 comes in: Combining 6-GHz spectrum, scheduling enhancements, and high-speed broadband *(Fig. 1)*, it provides the wireless backbone for whole home multi-gigabit service. Wi-Fi 7 also delivers high reliability for key future services like virtual and augmented reality (VR/AR) and next-generation mobile gaming.

### What's New in Wi-Fi 7?

Wi-Fi 7 has several major new features *(Fig. 2)*. For the all-important "number on the box," it introduces 320-MHz-wide channels, double the bandwidth supported by Wi-Fi 6/6E, and 4096-QAM modulation. Together, these features deliver 2.5X higher top-line throughput for all devices.

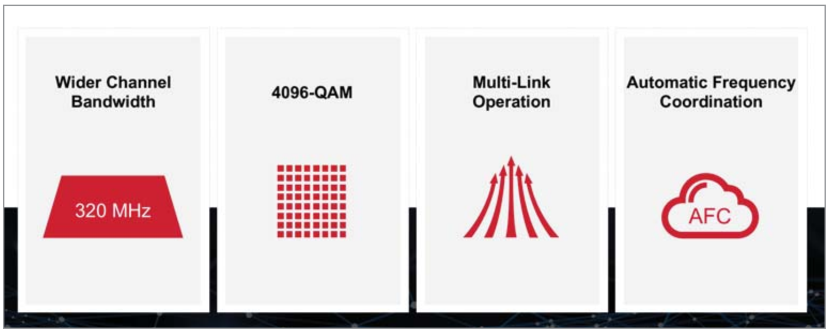
Wi-Fi 7 also introduces Multi-Link Operation (MLO), which, like cellular carrier aggregation, allows a device to connect to two independent channels simultaneously and route data in real-time (with switching times on the order of a few tens of microseconds) to whichever channel is optimal for latency and throughput. This is a critical new feature because quality of service and latency have become important metrics for wireless devices.

While higher top speeds improve those metrics by increasing available airtime, prior generations of Wi-Fi could see significantly degraded latency, particularly in congested environments.

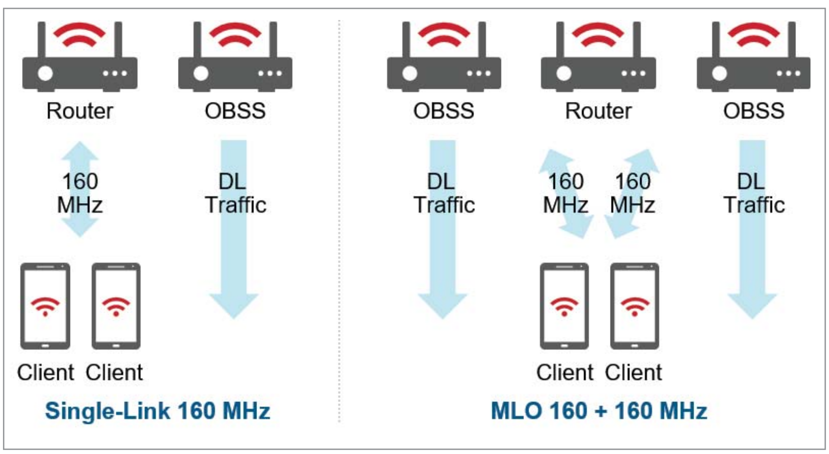
MLO greatly improves both latency and throughput even in simple scenarios. For example, take the case of a Wi-Fi 6 access point, which allows a device to connect on a single 160-MHz channel, and a Wi-Fi 7 access point that supports MLO on two 160-MHz channels simultaneously *(Fig. 3)*.

With no other traffic on the channel, both configurations achieve the same performance. But interference from an overlapping access point (referred to as OBSS) causes the single link's performance to degrade. It occurs because the OBSS attempts to transmit at the same time as the main access point. This blocks the single-link Wi-Fi 6 device from transmitting and receiving data, which degrades both its throughput and latency.

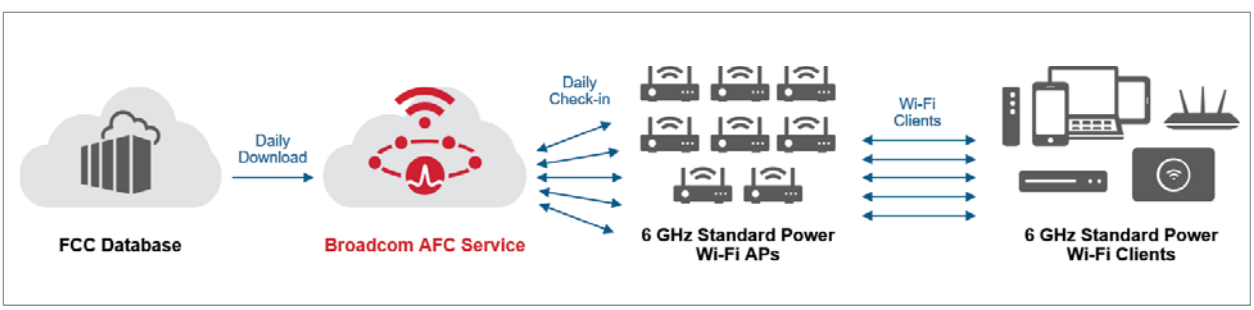
The Wi-Fi 7 MLO client device, on the other hand, monitors two channels simultaneously. Even though the OBSS interference increases the likelihood that each of the two channels are unavailable, the client has two opportunities in real-time to find an open channel.




**2. Wi-Fi 7 includes several important new features.**




**3. Multi-Link Operation significantly improves congested network performance.**




**4. The AFC service process flow uses regulatory data to enable higher power operation.**

The Wi-Fi 7 client sees a throughput boost of up to 50% depending on the OBSS loading, and a 60% reduction in 99$^{th}$-percentile latency, which is critical for virtual reality and gaming.[2]

To protect incumbent operations in the 6-GHz band, Wi-Fi 6E was constrained to operate indoors and at low power. which limits the performance of Wi-Fi 6E as well as the applications that it can serve. The good news is that Wi-Fi 7 can overcome these limitations using Automated Frequency Coordination (AFC), which permits devices to operate outdoors and at higher power levels based on geolocation.

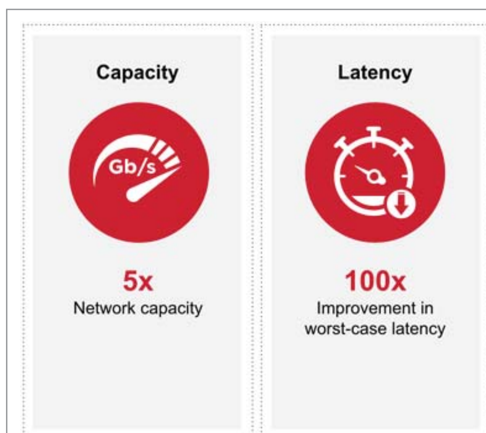
It can be difficult to extract gains from shared spectrum, but the AFC process for 6 GHz is relatively lightweight *(Fig. 4)*. To use the AFC service, an access point must know its location, and look up allowable channels and power levels in a cloud-based database.

Those channels and power levels are determined by interference calculations that avoid potential interference with other users of the 6-GHz band. Approval to use a channel is valid for a 24-hour period, resulting in a very simple process to achieve significantly longer range and access more spectrum than is possible today.

### Putting it All Together

Altogether, these features deliver a significant improvement in user experience. Wi-Fi 7 can deliver 5 Gb/s to smartphones, compared to 2 Gb/s today. Wi-Fi 7 also brings major improvements to congested network performance *(Fig. 5)*: a 5X boost in capacity, 100X reduction in latency, 15X improvement in determinism, and a 63X range increase.[3]

With increased speed and range, and major improvements in latency and determinism, Wi-Fi 7 will deliver wireless services for the next decade, whether for gaming and critical low-latency technologies like AR and VR, or for improved user experience in venues, offices, educational institutions, and telemedicine.




**5. Wi-Fi enhances congested network performance.**

**With increased speed and range, and major improvements in latency and determinism, Wi-Fi 7 will deliver wireless services for the next decade, whether for gaming and critical low-latency technologies like AR and VR, or for improved user experience in venues, offices, educational institutions, and telemedicine.**

Wi-Fi 7 also brings major improvements to home Wi-Fi experience, with improved mesh networking, multi-gigabit whole-home throughput, optimal video streaming and AR/VR performance, multi-link redundancy, and significantly increased range.

### Wi-Fi 7 is Here

Earlier this year, Broadcom was the first to announce a full ecosystem of Wi-Fi access-point and client devices, and the company is working with several other suppliers to make sure everyone's devices are interoperable. Its customers are already designing new products with device samples, and pre-certified Wi-Fi 7 devices are expected to be in mass production by mid-2023, with full certification expected by mid-2024. mw

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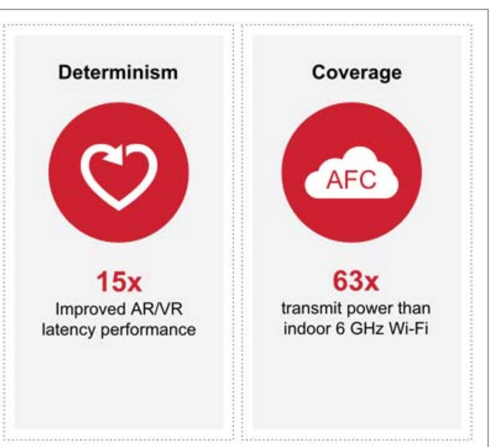

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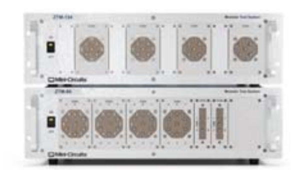

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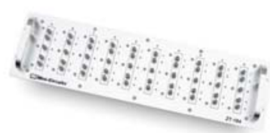

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# Is Wireless Power as Safe as Other Consumer Technology?

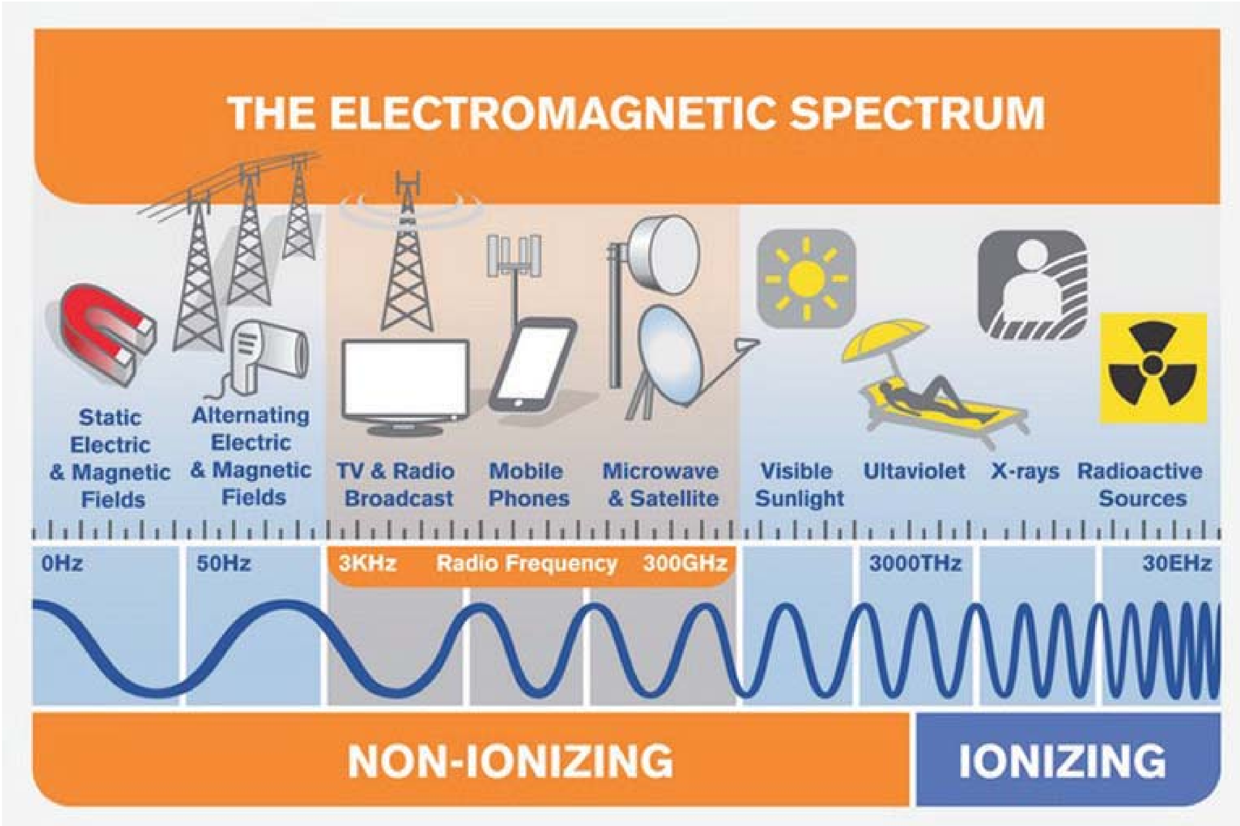
**Far-field wireless-power transmission is often believed to impose safety issues. People wrongly assume any tech development is dangerous without realizing that every device around them emits radiation already tested and approved by authoritative bodies.**

In today's digital world, we constantly rely on various power sources for consumer technology. Our mobile services, Bluetooth technologies, and internet connections all need power to function, whether it comes through solar, batteries, or what-have-you. More and more, we're using battery-powered devices that we carry for hours on end.

For instance, you're probably reading this with a battery-powered laptop or your ever-present smartphone. All of these devices and technologies give off low-level, non-ionizing (less potentially harmful than ionizing) radiation in the form of an electromagnetic field (EMF). But you're likely not too concerned about it, because you trust that these devices are safe.

After all, these technologies are approved for use and cleared by the Federal Communications Commission (FCC). So, for the most part, you don't hesitate to trust your health and safety to the experts when it comes to these tried-and-true devices.

Credit: Dreamstime | Arenacreative_12249129




**Most of the infrastructure around us, and the devices we operate, transmit non-ionizing radiation to some degree. Some might be higher than others, but everything we use is first reviewed and approved by the FCC.** *Credit: WiGL*

On the other hand, you might be somewhat nervous when it comes to new technologies. For example, there are now ways to deliver power wirelessly through the air via a network of small wireless-power transmitters, called wireless-power-transfer (WPT) networks.

But while it might be nice to forego wires that tether you to the wall whenever you need to charge your device, it's understandable you might be leery of the safety levels for this new technology. Fortunately for you, the safety of WPT has already been confirmed by the FCC, so it's likely that you can lose the wires without compromising your health. Let's look at what that confirmation means for you.

### How Safe is Wireless Tech?

When you're at your desk, at the gym, on a hike, or simply relaxing, how often do you use your wireless headphones or earbuds? You might even be using them now. You probably have a certain amount of confidence in your purchase of that technology. And you can usually trust that gear as widely used as earbuds or wireless headphones is safe to use.

The headphones and all of the technology that supports it are regulated, and the manufacturers need to build and sell products that meet those safety specifications. If they weren't, we'd have likely heard about it in the news by now.

In truth, wireless earbuds produce 10X the EMF of what you'd experience from your mobile phone's speakers. And while that's about the same EMF as your Wi-Fi router emits, your router sits in a designated area of your house or office. Your earbuds stay with you for long periods of time. Are they safe?

The short answer is "likely yes." If the FCC approves the level of EMF transmissions, the earbuds and VR tech are considered safe.

But what about walking into electronics stores? A trip to the Apple Store, Best Buy, or Walmart probably doesn't promote a sense of impending EMF doom for you. Even with all of those televisions lining the walls, the cellphones, the computer screens blaring energy, not to mention various other electrically powered devices emitting EMF, you still feel safe. And you should.

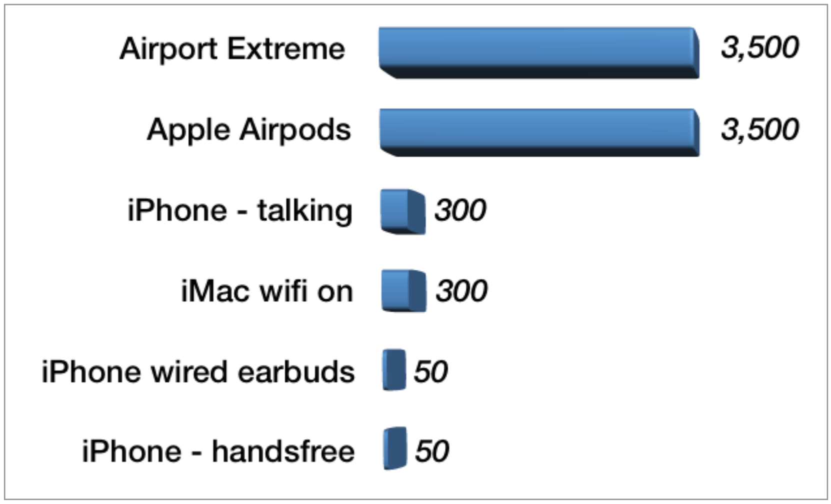
Yes, there's a ton of energy being blasted at you—all the time—but you don't feel the need to run for cover because you know the devices are generally considered safe.

The same goes for your home. If you look around, you'll likely see any number of EMF sources like electrical devices, light bulbs, appliances, TVs, and Wi-Fi, all of which are, according to the FCC, generally considered to be safe.

What does "safe" mean to the FCC? The EMF radiated by these devices is in the form of RF energy. RF is low-level, non-ionizing radiation, which means it doesn't damage DNA or cause cancer, as shown in numerous studies. Yet, if the RF is strong enough, it can overheat parts of your body and cause serious burns. Thus, a safe level of EMF means the RF isn't strong enough to overheat and destroy your cells.

The FCC measures how much RF your body absorbs in terms of a specific absorption rate (SAR). And according to the FCC, the SAR for mobile devices in a worst-case scenario—meaning the device is outputting RF is at its highest power and/or closest to your body—needs to be no more than 1.6 W per kilogram of human tissue.

A WPT network creates an environment with EMF levels like those of the devices in your home, your workplace, or your typical electronics retailer. The WPT is working in the background, recharging any of your devices within range of the transmitters.




**The chart shows EMF levels for various devices and environments. Devices we enjoy every day might emit an electromagnetic field we're not aware of yet feel very safe about.** *Credit: WiGL*

The future vision of WPT allows for a whole network of environments that can safely and smartly manage EMF levels within the bounds of what we already experience while providing wireless power through the air every day. In other words, you'll no longer need charging cords cluttering your home or office.

But the future of WPT goes beyond your home or personal office. Power transmitters in streetlamps or even satellites could recharge a passing drone, the handheld device in your pocket, or even your smart car while you're driving to work. There's no end to the potential applications of this technology.

### Wireless Power Safety

Because they know the risks of high-level EMF, wireless power providers know that they must adhere to FCC rules and other safety regulations. So, just as you know that you can safely have a battery housed inside your ear, or a phalanx of TVs and other EMF-radiating devices sur-

**Because they know the risks of high-level EMF, wireless power providers know that they must adhere to FCC rules and other safety regulations.**

rounding you at the electronics store, you can know that WPT networks are held to the same standards.

In 2021, experts arranged a study to test the safety and effectiveness of WPT. Representatives from WiGL, along with the Department of Electrical and Computer Engineering at Florida International University, demonstrated the safety levels of WPT with small, scalable applications, such as charging a single smartphone within an 8- × 10-ft. area using power transmitters. The goal was to adhere to the RF limits in accordance with FDA and FCC guidelines while providing power to the device within that area.

We were able to charge the device wirelessly through the transmitters while measuring the levels of radiation in the zones nearest to the transmitters (the near zone) and further away (the far zone). Transmitters at a power level of 1 W were able to deliver a significant charge to the smartphone within that area, and the RF levels were well within the FCC-allowed margin.

We foresee two potential benefits of the WPT technology soon. First, powering devices wirelessly even while they're moving and in use means device users will no longer have to be tethered to a wall while their phone charges. Second, mobile device and wearable technology manufacturing costs could tumble down considerably because devices will require smaller batteries, or perhaps even no battery at all.

#### WPT's Bottom Line

As technology leaders explore this new horizon of WPT technology, it's understandable and important for people to be concerned about safety. And we should never become complacent about the safety of EMF.

But it's also important to know that strict rules and regulations are in place to protect consumers, just as there are for any other consumer technology, and that WPT doesn't have to affect us any more than the devices already surrounding us. The world seems to be ready for full-scale wireless charging. mw

ROGER DENKER | Managing Director, MegiQ

# Using a VNA Like a Time-Domain Reflectometer

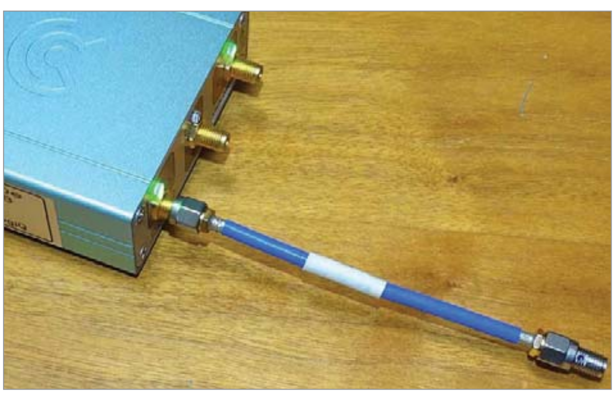
**While VNA network measurements in the frequency domain help optimize or verify implementation of devices and components, time-domain measurements are effective for analyzing network geometry and specific sections of a network.**

Time-domain reflectometry (TDR) is a technique that measures and displays the impedance of a network (cable, filter, and so on) over time. Traditionally, this is done with a device that generates very fast pulses, injects them on the network, and measures the time and amplitude of reflected pulses.

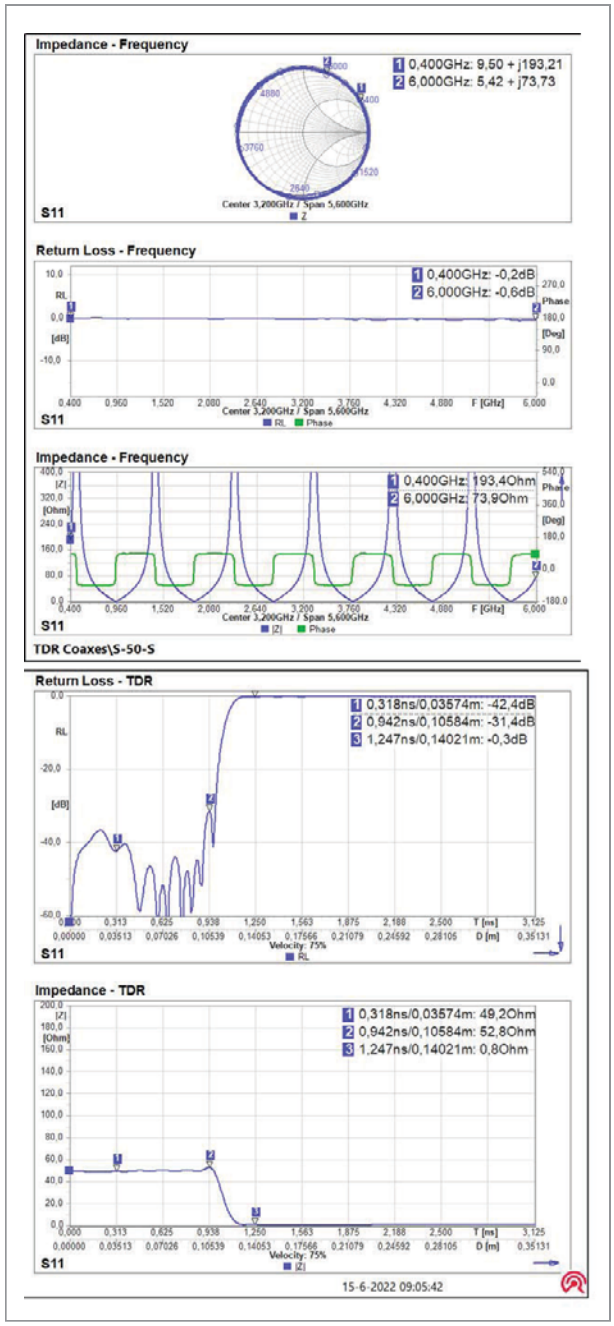
TDR yields information about the impedance as a function of the time it takes for a pulse to reflect or travel through the medium. And, because the signals travel with (nearly) the speed of light, the time can be translated to a distance through a cable or network.

The same kind of measurement can be taken using a vector network analyzer (VNA), but in a roundabout way. A VNA measures the (reflected) impedance over frequency. We can use a Fourier transform to convert this into a series of impedances over time, just as that produced by a TDR instrument.

This article describes frequency and TDR measurements of coax networks and the analysis of PCB trace impedances on a test PCB, which are some of the applications of TDR analysis.



1. **Here's the setup of a simple network measurement of a length of 50-Ω coax terminated with a short. Measurement results are provided in *Figure 2*.** *Photo credits: MegiQ*




2. **These graphs show the frequency and TDR measurement of the simple coax-cable network of *Figure 1.***

The measurements were done with a MegiQ VNA-0460e 6-GHz vector network analyzer.

## A Simple TDR Measurement

The following graphs illustrate a measurement of a piece of 50-Ω coax terminated with a short. *Figure 1* shows the setup of this measurement.

The graphs in *Figure 2* are all different representations of the same S11 measurement on this network.

At the top of *Figure 2* are three graphs of the impedance over frequency:

- In the Smith chart, the impedance is running circles around the perimeter. It's an open impedance with increasing phase over frequency.
- The return loss is almost 0 dB because all energy is reflected by the short at the end.
- In the impedance graph, the impedance varies wildly because the signal reflected by the short termination adds or subtracts at different frequencies.

It's difficult to discern very much about the geometry of the network from those frequency graphs.

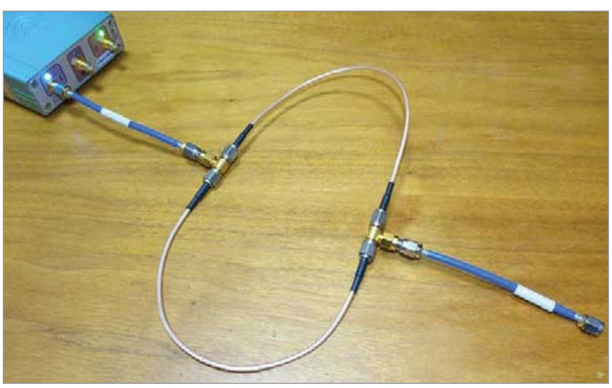
On the bottom of *Figure 2* are two TDR graphs that show the return loss and impedance over time:

- The return-loss TDR graph at the top illustrates the return loss at different times.
- The impedance graph below that shows how the impedance itself develops over time.

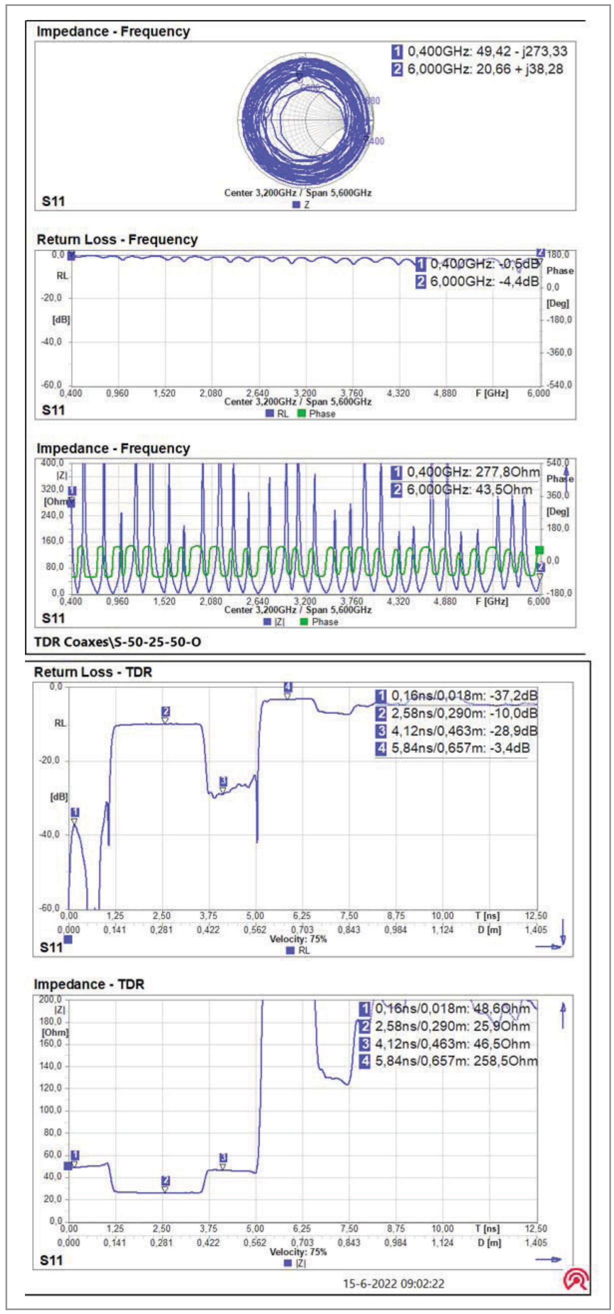
At T = 0, the signal leaves the VNA port. At T = 1 ns (marker 2), the signal that's reflected by the short returns to the VNA port. The signal first travels through the 50-Ω cable and the impedance then drops to (almost) zero at the short. In a coax cable, time is distance given that the signal travels at nearly the speed of light.

The second horizontal axis (at the bottom) of the TDR graphs converts the time to the distance in the cable. The signal travels through the cable with the speed of light, multiplied by a "velocity factor" that depends on the type of cable. The velocity factor is normally on the order of 60% to 90% of the speed of light; this setting can be changed for the cable in use.

For return measurements, the distance scale accounts for the round trip of the signal from port to end and back to the port again. So, the distance scale is the actual distance from the port to the impedance drop. Of course, the VNA can't look beyond



3. **A bit of coaxial creativity yields a network with impedance jumps.**




4. **These measurements of the network shown in *Figure 3* don't reveal much about its structure.**

the end of the cable. Generally, though, the graph slopes to the termination impedance.

The TDR transformation shows the real impedance at different positions in the network. A TDR signal doesn't have phase information. This resembles the characteristic impedance of a coax cable, which also is a real number. For this reason, there's no Smith-chart representation of a TDR signal.

### Multiple Impedance Jumps

With some coax creativity, we can make a more interesting network *(Fig. 3)*. The signal travels through a length of 50-Ω cable, then through two parallel 50-Ω cables (forming a 25-Ω line) and back again to a single cable, "terminated" with an open.

*Figure 4* shows the measurements of this network. Again, the frequency graphs look spectacular, but they don't tell us much about the structure of the network. In the TDR graphs on the bottom, the impedances and jumps are clearly visible. It transitions from 50 Ω to the 25 Ω of the two parallel cables, back to 50 Ω, and then to a high impedance at the end.

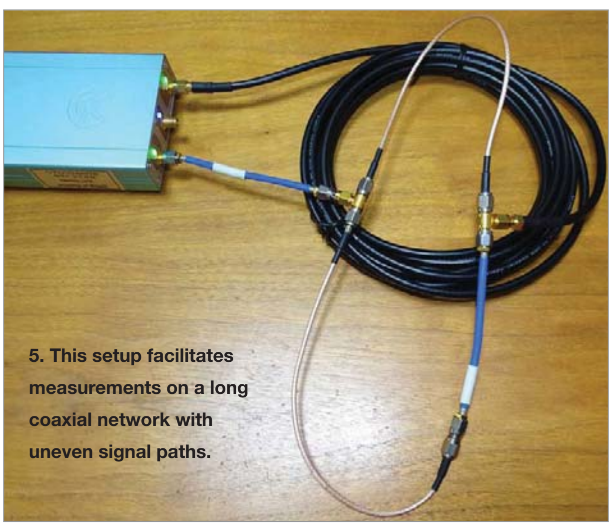
### Two-Port Measurements on a Long Cable

Next, let's connect a long 50-Ω coax to the jumping network from earlier and do a two-port measurement. The jumping network is made even more interesting with an additional length of coax in one arm of the split network *(Fig. 5)*. There are now two unequal signal paths. The "far end" of the network is connected to Port 2 of the VNA; therefore, it's terminated with 50 Ω. For Port 2, this is the "near end."

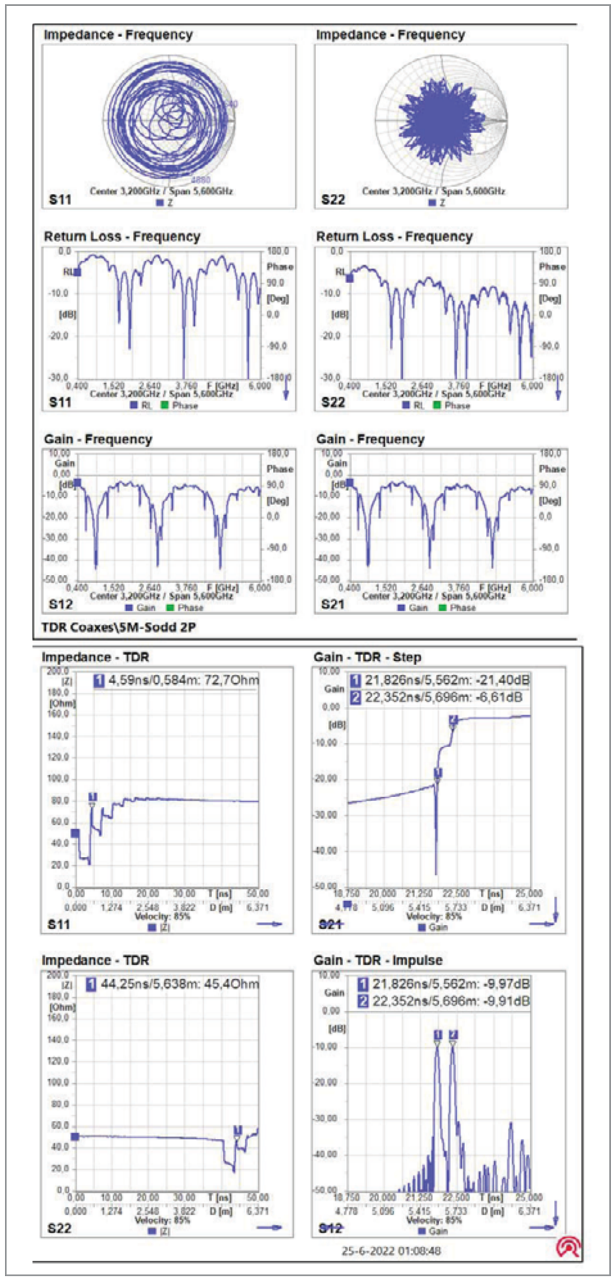
The measurement of this network is shown in *Figure 6*. On the top are the frequency graphs and on the bottom are the TDR graphs. The S11 Smith chart in the top portion of the figure looks like before. The S22 Smith chart seems to have a better impedance because the mismatch is located at the end of the long coax, which attenuates the reflections. The gains (S12 and S21) also vary wildly due to all of the impedance jumps in the network. Note that the forward and reverse gain (loss) are identical, as there's no directivity in the network.

In the TDR graphs of the impedances S11 and S22, we see that the jumps are near Port 1 and far from Port 2. The addition of an extra delay in one arm of the split part gives short extra jumps in the TDR impedance (marker 1).

The TDR graphs of the gain show that the signal arrives at the other port after the delay of the network. The "Gain-TDR-Step"



5. This setup facilitates measurements on a long coaxial network with uneven signal paths.




6. Shown are the measurements of the network with uneven signal paths. Note the two-step arrival, which is clearer with the impulse mode of the TDR transform.

graph reveals that the signal arrives in two steps. This two-step arrival is clearer with the impulse mode of the TDR transform. There are clearly two peaks in the arrival of the signal at the other end. The dual peaks are caused by the uneven length of the two arms of the split network part.

### Distance-to-Fault Detection

As shown by the previous examples, the impedance over a length of cable is clearly visible. This is the basis for distance-to-fault (DTF) detection, which aids in locating damage in a (long) coax cable.

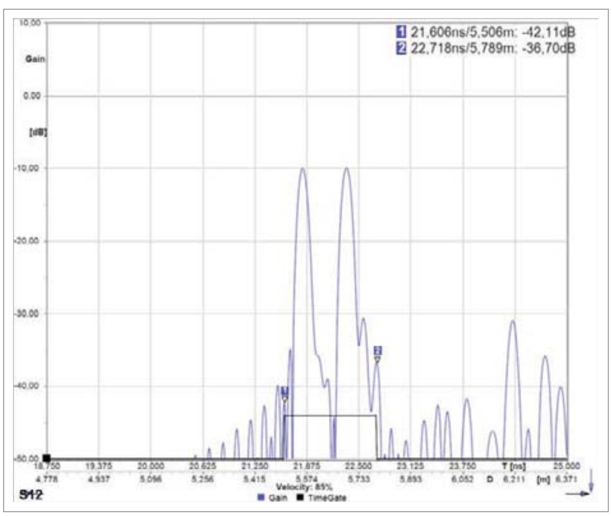
In the TDR graph, it's easy to see if there are impedance jumps, like a short or open in the cable, and how far they are from the VNA. When a coax has minor damage (crushed or bent), it can show a slight or large impedance variation along its length. The advantage of TDR for fault detection is that the cable needn't be terminated with a specific impedance, so it can be applied on long cables with no immediate control of the end point.

### Time Gating

With the TDR functionality, it's possible to "filter" the gain-frequency graph with a filter in time. Effectively, the VNA software can do a TDR transformation of the frequency measurement, remove signal components outside (or inside) a certain time range, and then transform the signal back to a frequency graph. This is known as time gating.

*Figure 7* shows the definition of such a time gate on the TDR-transformed signal. Markers 1 and 2 define a time range and the filter is shown in black.

*Figure 8* depicts the result of several time gates. At the top is the original gain graph, and below that is the gain with a time gate around both peaks. It shows the gain with the spurious



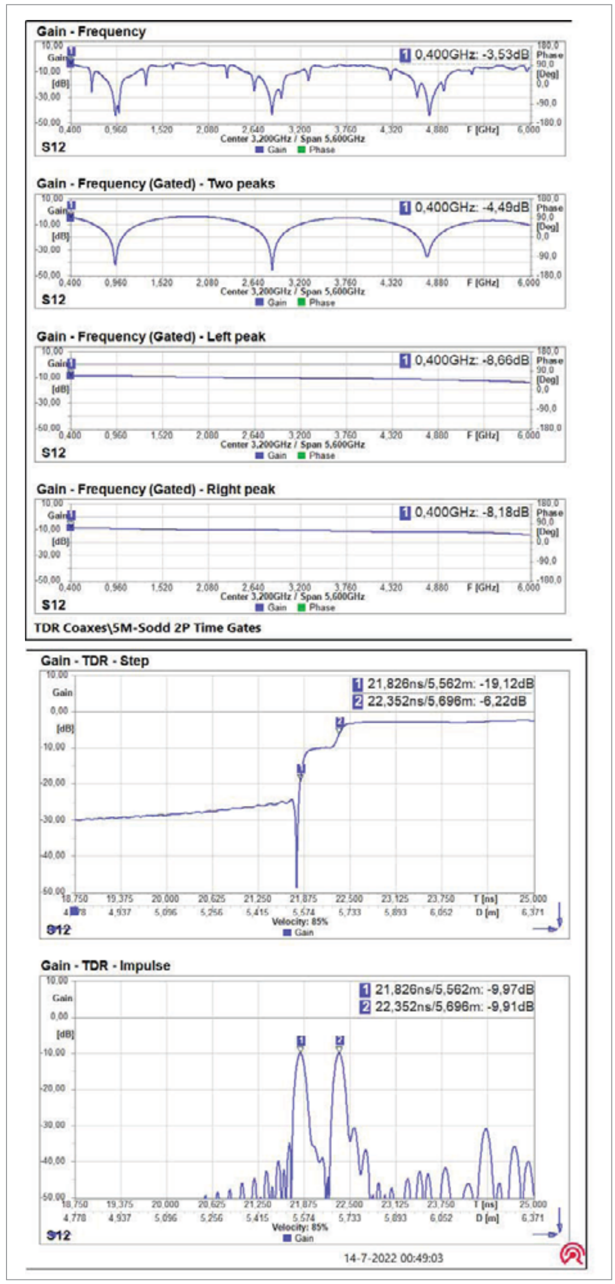

**7. This image shows the definition of a time gate on the TDR-transformed signal. Markers 1 and 2 define a time range and the filter is shown in black.**

(reflection) peaks removed. Third from top shows the gain with a time gate around the first peak, while the fourth graph is the gain with a time gate around the second peak.

### Analyzing PCB Traces

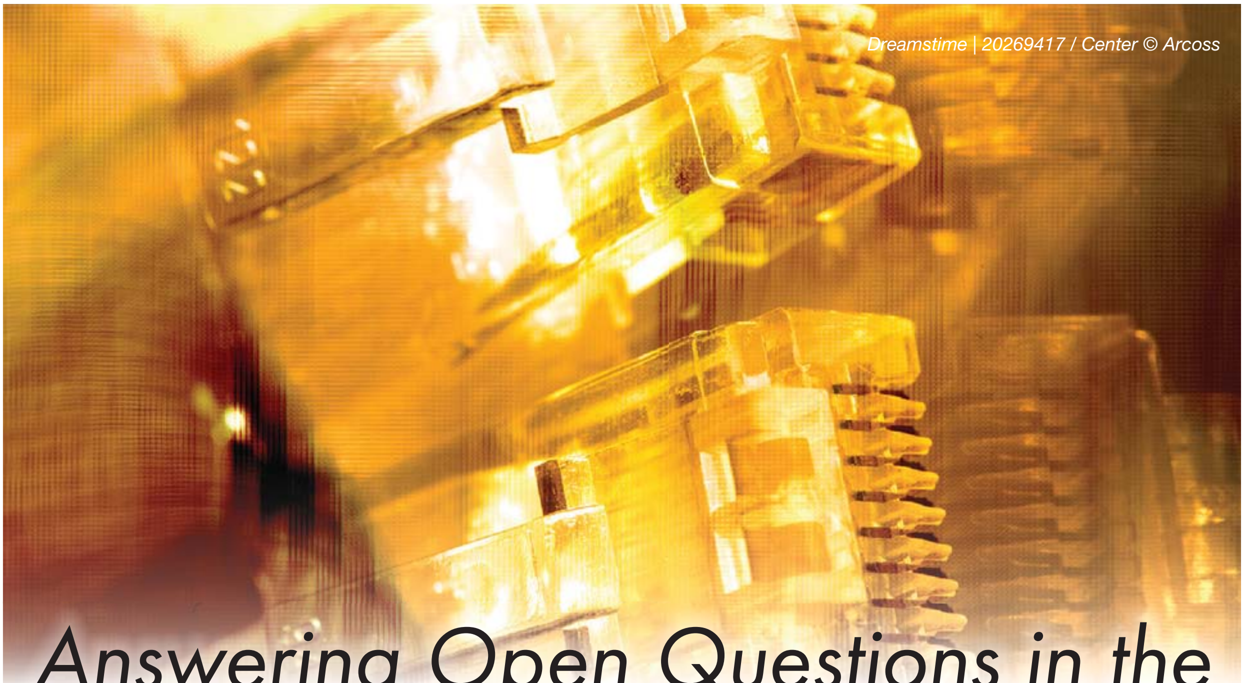
TDR measurements also can be used to analyze the impedances of PCB traces and connector launch footprints. To measure these small features, the VNA has an enhanced TDR mode that uses oversampling and extrapolation of the measurement data.

*(Continued on page 32)*




**8. Here are examples of time-gated gain graphs.**

ANIKET KHOSLA | Vice President of Product Management, Spirent Communications


Dreamstime | 20269417 / Center © Arcoss

# Answering Open Questions in the Race to 800G

**Operators of large-scale data centers are clamoring for 800G optics, but is the technology ready for prime time? Learn how vendors are navigating uncertainty in the drive to meet market demand.**

When building a house, any of a thousand decisions could lead to budget overruns, blown timelines, and big problems down the road. Fortunately, it's easy to get answers to most questions that arise: check the blueprints. But what if the blueprints are still being drafted even as construction gets underway?

Thankfully, no one builds houses that way. But such a scenario isn't far off from what vendors must contend with right now in the race to deliver 800-Gigabit Ethernet (800G).

The last big shift in data-center optics, moving from 100G to 400G, progressed over many years, leaving plenty of time for standards bodies to formalize the technology and for vendors to implement it.

This time around, we don't have that luxury. With exploding demand for cloud services, operators of the world's biggest data centers need higher-speed transmission technologies now, not in two or three years.

Vendors in this space—chipset makers, network equipment manufacturers (NEMs), and cable and transceiver vendors—are racing to meet the need as quickly as possible. But with standards still incomplete and open to interpretation, delivering production-ready 800G solutions is far from simple.

Let's review the biggest outstanding questions facing vendors bringing new 800G components to market and the steps they're taking to find answers.

## The Growing Data-Center Challenge

If it seems like you're having déjà vu, don't worry. Yes, the industry did just work through similar questions in the development of 400G optics, and many large-scale networks and data centers only recently adopted them. In the world's biggest hyperscale data centers, though, skyrocketing bandwidth and performance demands have already exceeded what 400G can deliver.

Having millions of enterprise workers suddenly switch to full-time, work-from-home status was among the biggest drivers of exploding cloud demand, but not the only one. The growing dominance of cloud applications in the enterprise, millions of Internet of Things (IoT) devices coming online, and sharp upticks in artificial-intelligence and machine-learning (AI/ML) workloads have also played a role.

These trends present a double-edged sword for vendors of data-center network and transmission technologies. On one hand, they find a market positively clamoring for 800G components for lower layers of the protocol stack, even in their earliest incarnations. On the other, big questions remain unanswered about the technology. These gray areas have the potential to create significant problems for customers in interoperability, performance, and even the in the ability to reliably establish links.

The good news is that 800G is based on well-understood 400G technology. Vendors can apply familiar techniques like analyzing forward-error-correction (FEC) statistics to accurately assess physical-layer health. At the same time, jumping from 400G to 800G isn't as simple as just tweaking some configurations.

Shifting to 112G electrical lanes alone—double the spectral content per lane of 400G technology—represents a huge challenge for the entire industry. Manufacturers in every part of the ecosystem, from circuit boards to connectors to cables to testing equipment, need electrical channel technology that operates well out to twice the symbol rate.

The physics involved in achieving that goal are enormously complex and interdependent, requiring players from across the industry to move forward on this journey together. It also means that vendors need earlier and more thorough testing and validation than any previous Ethernet evolution.

## Answering Outstanding Questions

As vendors push forward with 800G solutions, they're working through such open questions as:

***Where are 800G standards going, and what will they ultimately look like?***

The most immediate issue facing vendors today is the lack of a mature standard—and, in fact, they're staring at a scenario with two competing standards in different stages of development. In past technology evolutions, IEEE has served as a kind of lodestar for the industry.

However, while IEEE specifies the 112G electrical lanes referenced above in 802.3CK, they haven't yet completed their 800G standard. In the meantime, vendors seeking to deliver early solutions are using the only 800G standard that exists today, the Ethernet Technology Consortium's (ETC) 800GBASE-R.

How will these competing standards resolve? Should vendors expect a repeat of the Betamax/VHS wars of the 1980s, where one standard ultimately dominated the market? Should they invest in supporting both? What kind of market momentum will they lose if they wait for clear answers? Whichever way vendors go represents a significant bet, with major long-term implications.

***How will different vendor devices interact?***

Working with multiple standards in different stages of development also means that early components may not necessarily support the same electrical transmission capabilities, even for core functions like establishing a link. For example, some 800GBASE-R ASICs that support both Auto-Negotiation (AN) and Link Training (LT) are currently incompatible with ASICs that support only LT.

Therefore, even when all components comply with the ETC standard, customers can't assume that links will automatically be established when using different devices and cables. They may need to manually tune transmit settings. This increases the potential for link flaps, a condition where links alternate between up and down states, which can dramatically affect throughput.

***Which issues that had negligible impact in 400G will now become big problems?***

Jumping from 400G to 800G optics means more than a massive speed increase. We're also doubling the spectrum to use higher frequencies, as well as doubling the sample speed and symbol rate. Suddenly, issues and inefficiencies we didn't have to worry about in 400G can seriously diminish electrical performance.

One big problem we already know we need to solve: the huge amount of heat generated by 800G optics. Navigating this issue affects everything from the materials used for ASICs to pin spacing, and vendors are still working through all of the implications.

## Unleashing Tomorrow's High-Performance Ethernet

Those are just some of the questions vendors have to wrestle with as they race to get 800G components into the hands of customers. The only way to obtain answers is to perform exhaustive testing at all layers of the protocol stack.

Right now, vendors and their cloud-provider customers are hard at work testing and validating emerging 800G technologies. Given the unsettled standards space and the many aspects of the technology still in flux, these efforts run the gamut—even when focusing exclusively on products using the ETC standard.

Network equipment manufacturers (NEMs) are working to assure link and application performance under demanding live network conditions. Chipset makers are employing the latest techniques—Layer-1 silicon emulation, software-based traffic emulation, and automated testing workflows—for pre-silicon validation and post-silicon testing. Cable and transceiver vendors are performing exhaustive interoperability testing to validate link establishment and line-rate transmission in multivendor environments. And, as quickly as they can get 800G components, hyperscalers are launching their own extensive testing efforts to baseline network and application performance.

It's a huge effort—and a testament to the industry's ability to push new technologies forward, even in the absence of settled standards. We may not have the comprehensive blueprints we'd prefer, but with state-of-the-art testing and validation, we can build an 800G future we'll all be happy to live in. mw

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Acceleration, fine leak, gross leak, HAST, HTOL, mechanical shock, thermal shock, and vibration. Additional screening available on request.

JACK BROWNE | Technical Editor


Credit: Persistent Systems

# TACTICAL RADIO
## Turns into Network Rig

**By joining design teams, Persistent Systems LLC and Thales were able to merge the capabilities of tactical and MANET radios into a combined, cable-connected unit.**

**BY COMBINING THEIR TALENTS,** Persistent Systems LLC and Thales created a rugged tactical radio that also can provide secure networked communications on the battlefield. The radio joins a reliable Persistent MPU5 networking radio with an AN/PRC-148E Spear tactical radio from Thales *(see image above)*.

As Shane Flint, vice president of business development at Persistent Systems explains, "Imagine a helicopter transmitting on an AM frequency to a dismounted ground team. With traditional tactical radios, some users might receive the helicopter's transmission and other users might not."

He points out the benefits of the combined radio architecture: "With a Spear/MPU5-equipped team, if any single Spear radio receives the helicopter's transmission, the entire team will receive it."

The radio uses the MANET radio-over-Internet-protocol (IP) capability to provide dependable in-field network communications. The tactical portion, the AN/PRC-148E Spear radio, weighs only 1.24 lbs. and incorporates programmable cryptography supporting the requirements of the National Security Agency's (NSA) crypto modernization program.

The Spear radio connects to the MPU5 MANET portion by means of a special cable that allows the networking radio to remotely configure settings and channel presets automatically on the tactical radio. Flint noted, "This capability was designed for combat operations, based on real-world feedback. The goal was to deliver a simple, no-fail solution that empowers the warfighter." mw

# DoD Focused on Defending Against HYPERSONIC MISSILES

**Funding to advance defense against hypersonic cruise missiles is being sought by several branches of the armed forces as part of the 2023 defense budget.**

JACK BROWNE | Technical Editor

*Credit: U.S. Department of Defense*

**HYPERSONIC CRUISE MISSILES** are viewed by the U.S. Department of Defense (DoD) as threats of growing significance, especially weapons launched by Russia and China.

During testimony at a recent House Armed Services Committee Strategic Forces Subcommittee hearing on the fiscal year 2023 strategic forces missile defense and missile defeat programs, U.S. Navy Vice Admiral Jon A. Hill, director of the Missile Defense Agency (MDA), addressed the importance of developing a stout defense against hypersonic cruise missiles. He also explained how a layered missile defense system will be needed to guard against the unpredictable paths of hypersonic missiles.

Part of the challenge in guarding against hypersonic cruise missiles is the unpredictability of the source, since they can be readily launched from several types of naval vehicles, including submarines and aircraft carriers. According to Hill, in March 2023, the MDA, together with the U.S. Space Force and Space Development Agency, plan a launch of two interoperable prototype satellites. By collecting sensor tracking data, the satellites will provide the capability to pinpoint hypersonic cruise missiles from space.

The satellites would serve as components within multifunction terrestrial- and space-based measurement capability for long-range detection and warning of cruise missiles, including hypersonic weapons. The admiral also mentioned development of glide phase intercept capability that would add to layered defense.

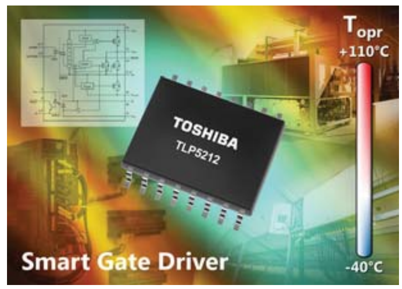
Joining Hill in the Armed Forces testimony regarding the need for advanced defense-technology development against hypersonic cruise missiles was John F. Plumb, the assistant secretary of defense for space policy; Air Force Lieutenant-General John E. Shaw, deputy commander of the U.S. Space Command; and Army Lieutenant-General Daniel L. Karbler, the U.S. Army Space and Missile Defense Command commander. mw

## Smart Sensor Reads Power from 500 MHz to 40 GHz

Mini-Circuits' model PWR-40PW-RC smart power sensor measures peak and average power from –20 to +20 dBm from 500 MHz to 40 GHz. It features a modulation bandwidth of 10 MHz and sampling rate of 20 Msamples/s to measure power of CW, pulsed, and complex modulation signal formats. It also includes full software support for operation from a personal computer with an Ethernet or USB interface. The device's 30-MHz video bandwidth permits power measurements of automatic-level-control (ALC) circuits.

**MINI-CIRCUITS,** www.minicircuits.com/WebStore/dashboard.html?model=PWR-40PW-RC

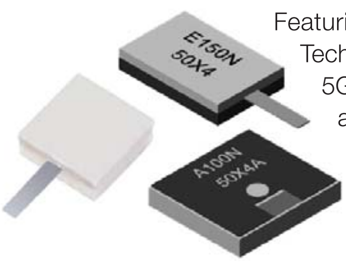
## Smart Gate-Driver Photocoupler Addresses Control and Power Protection




Toshiba Electronics Europe launched a ±2.5-A-output, smart gate-driver photocoupler for IGBTs and MOSFETs, protecting power devices from overcurrent. The TLP5212 features a new totem-pole output with two N-channel MOSFETs and incorporates protection functions such as desaturation detection, active Miller clamp, UVLO, and FAULT output, eliminating the need for several external circuits. Able to operate in severe thermal environments, the 10.3- × 10.0- × 2.3-mm TLP5212 can sink or source up to ±2.5 A via its totem-pole output. With its propagation delay of just 250 ns (max.) and propagation delay skew of ±150 ns, the device is suited for high-speed applications. The operating temperature range is –40 to +110°C. Minimum creepage distance is 8 mm, suiting the device for applications requiring high levels of safety isolation and insulation.

**TOSHIBA ELECTRONICS EUROPE,** toshiba.semicon-storage.com/eu/semiconductor/product/isolators-solid-state-relays/detail.TLP5212.html

## Termination Resistors Optimized for 5G Wireless Infrastructure




Featuring power handling from 100 to 150 W, three new termination resistors from TTM Technologies' Radio Frequency & Specialty Components business unit are optimized for 5G wireless infrastructure applications, as well as GPS/GNSS, Wi-Fi (including Wi-Fi 6), and legacy 4G/LTE. These new terminations include the A100N50X4A (100-W, 50-Ω chip termination), the E125N50X4 (125-W flangeless termination), and the E150N50X4 (150-W, 50-Ω flangeless mount termination).

**RICHARDSON RFPD,** www.richardsonrfpd.com/rfdesign/ttm-xinger-couplers-sub-6ghz/

## Optical Spectrum Analyzers Cover Wide Wavelength Range

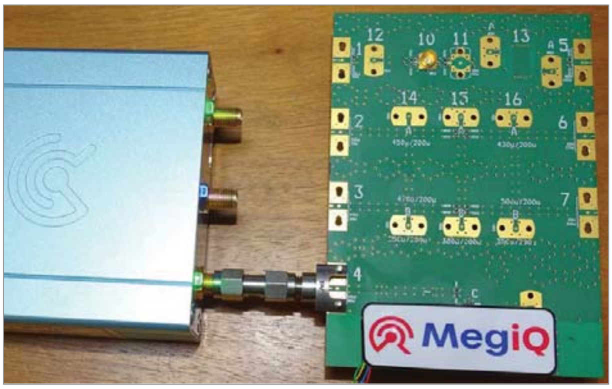
Yokogawa launched two optical spectrum analyzers (OSAs) able to measure a wide range of wavelengths. The Yokogawa AQ6375E and AQ6376E are presented as the only grating-based OSAs covering short-wavelength infrared over 2 µm and mid-wavelength infrared over 3 µm. The OSAs come in four versions: The AQ6375E Standard has a wavelength range of 1200 to 2400 nm; the AQ6375E Extended Wavelength version has a wavelength range of 1000 to 2500 nm; the AQ6375E Limited version has a wavelength range of 1200 to 2400 nm (with reduced wavelength resolution); and the AQ6376E Standard has a wavelength range of 1500 to 3400 nm.

**YOKOGAWA,** tmi.yokogawa.com/eu/solutions/products/optical-measuring-instruments/optical-spectrum-analyzer/aq6376e-optical-spectrum-analyzer/

*(Continued from page 25)*

We designed a PCB with different coplanar-waveguide-with-ground (CPWG) traces and SMA-connector launches to investigate the impedances of these geometries. The PCB *(Fig. 9)* is a four-layer PCB with a top and bottom core of 254-µm Isola I-Tera material.

Circuits 2, 3, 6, and 7 are traces with different widths and a ground clearance of 200 µm. They're terminated with 50 Ω (2 × 100 Ω) near the center of the PCB. The SMA connector is a solderless type that we moved to different positions. The connector was de-embedded from the measurements to view only the impedances of the traces.




**9. This PCB contains different coplanar-waveguide-with-ground (CPWG) traces and SMA launches to investigate the impedances of these geometries.**

The graphs in *Figure 10 (see link below)* show the impedance of traces with widths of 430, 450, 470, and 500 µm, respectively. The impedance decreases with wider track widths. The track of 450 µm shows the best 50-Ω match. The impedance dip at the end of the trace is due to the layout of the termination network with a wider footprint that accommodates two resistors.

### The Effect of Vias

We intended Circuit 4 (with the connector) for investigating the effect of vias. It has a trace width of 470 µm with two vias to jump to the bottom layer and back up again. The graphs in *Figure 11 (see link below)* show the impedance of the normal 470-µm trace (left) next to the impedance of the same trace with two vias. The impedance is very similar to the regular, with a slight drop because of the vias. This suggests that the vias have an impedance like that of the 470-µm trace.

### Conclusions

Where regular VNA graphs of network measurements can be confusing or complicated, TDR analysis of these measurements can provide better insight into the physical geometry of a network. Time-domain reflectometry also is useful to gain better insight into local impedance effects of networks. Furthermore, time gating can be utilized to isolate certain areas in a network for frequency representation. mw

*To view Figures 10 and 11, please visit the online version of the article at https://mwrf.com/21247456.*





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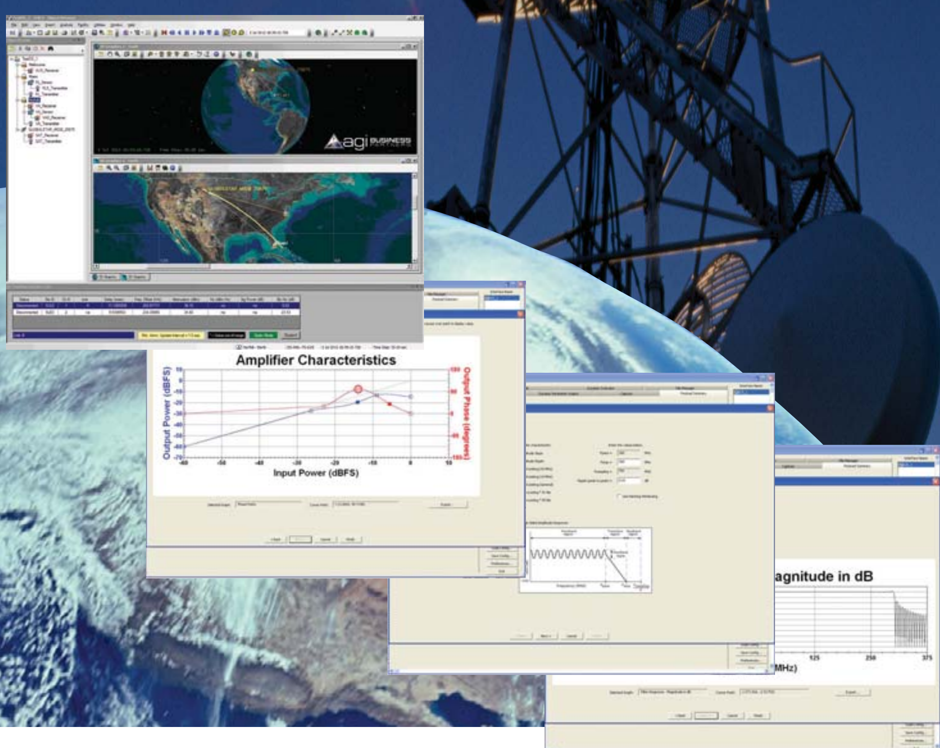


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