SOLUTION BRIEF

Satellite Test Solution for Field and Lab Applications

FieldFox Microwave Analyzers

Satellite Technology Expands

Satellite communication systems play a central role in modern communication applications. Government and commercial entities expect to place nearly 60,000 satellites into the Earth's orbit by 2030. Increasingly, complex information and data throughput support advancements in radar, surveillance, and navigation systems, and play an important role in mission-critical military applications. In addition, access to low Earth orbit (LEO) satellites will make it more cost-effective to support commercial applications like 5G, on satellite networks.

Satellite test solution benefits include

- Wide frequency coverage to 54 GHz
- Supports Q/V band satellites
- Compact for field or R&D bench use
- Offers 25 + measurement types in one 7 lb.-box
- Tests satellite ground stations in all weather conditions

Modern satellite networks operate at higher frequencies and use active phased array antenna systems. Phased array antennas, or active electronically scanned arrays (AESAs), are now highly integrated. In fact, AESAs can support thousands of radiating elements to electronically steer beams quickly and independently and point them to precise locations. In addition, software-defined phased array antenna systems provide mission flexibility to the communication link by enabling a change of function on the fly. For example, you can switch rapidly from a defense radar to 5G antenna communications.

KEYSIGHT TECHNOLOGIES

FieldFox Provides Portable Precision

The number of satellite ground stations and end-user terminals needed to support the increased capacity of these satellite networks is expected to grow even more rapidly. Keysight's satellite test solution, based on the FieldFox microwave analyzer, is a completely portable toolkit for radio frequency (RF) engineers and technicians. FieldFox delivers precision measurements in R&D environments and is portable for field use to install, maintain and troubleshoot satellite ground station networks. The solution is capable of testing cable and antenna conditions, and verifying system hardware performance of amplifiers and frequency converters. FieldFox can also verify over-the-air (OTA) signal quality, transmit power, and coverage area path loss, as well as identify and troubleshoot interference issues.

Interference Detection

As broadband wireless services expand at scale, frequency regulators are reallocating spectrum for complex, spectrum-sharing situations between terrestrial and fixed satellite service (FSS) networks. Satellite communications in C-band normally receive signals in the range of 3.4 to 4.2 GHz and transmit signals in the range of 5.85 to 6.425 GHz to deliver broadcast television, internet, voice, and data communications. S-band radar systems, typically used for air traffic control, marine positioning, and weather surveillance, operate between 2-4 GHz and coexist with C-band satellite communications without causing serious interference issues. However, that could soon change as a significant amount of mid-band spectrum in C-band, in the range of 3.7 to 4 GHz, will transition to flexible use for 5G and other advanced wireless services. The flexible use spectrum between terrestrial and satellite networks is not limited to C-band; it also impacts other FSS networks in RF/microwave and millimeter-wave bands.

Satellite Interference on the Rise

Satellite downlink receivers are sensitive devices that are exceptionally prone to interference since they most often handle long-range communications, and have the ability to receive ultra-low-power signals. FSS networks have largely coexisted with radar systems without serious interference issues since these radar systems operate at fixed point locations with highly focused beams. However, in recent years, interference from 5G ground base station and user equipment (UE) emission sources began to impact satellite communication links, safety-critical systems, and low-range aircraft radar altimeter operations within the 4.2 to 4.4 GHz aeronautical band. 5G base stations and mobile devices emit signals in all directions and the UEs are constantly moving to new locations. If enough power from an interfering signal saturates a nearby receiver, it can take down the entire communications link. For this reason, 5G network interference has become a hot topic.

FieldFox handheld analyzers with real-time spectrum analysis (RTSA) up to 54 GHz can detect the most elusive signals causing interference in complex signal environments. FieldFox supports up to 120 MHz of real-time bandwidth and can detect pulses as narrow as 5.52 μs with a 100% probability of intercept (POI). Its data-rich and dynamic display updates about 50 times per second and offers adjustable persistence to fade the older data. With a fast Fourier transform (FFT) rate of almost 120,000 per second and FFT overlapping, each display update represents about 2,500 spectra of gap-free data capture that allows you to see subtle details in the spectrum. For example, you will see signals inside of other signals, and signals near the analyzer noise floor, even when they are small and infrequent.

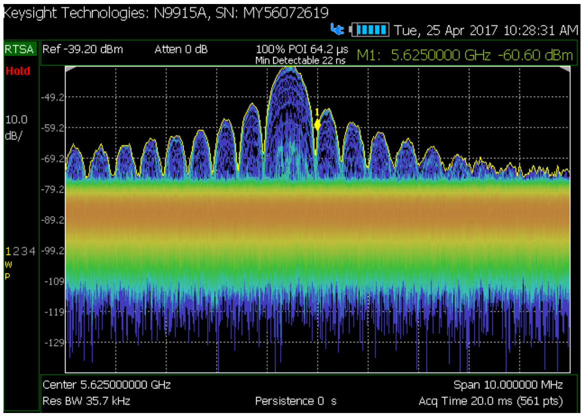

Figure 1. FieldFox easily detects weather radar pulses using real-time spectrum analysis mode

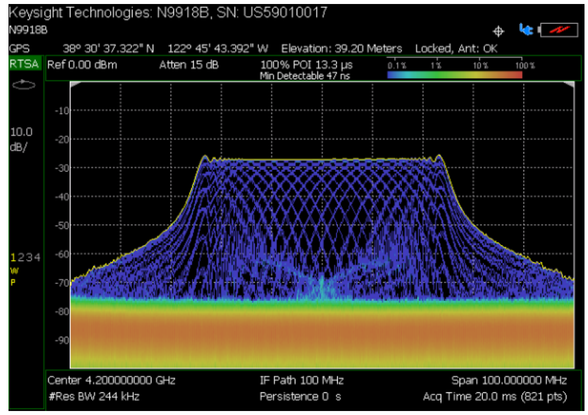

Figure 2. FieldFox detects frequency-modulated continuous-waveform (FMCW) radar from altimeter receivers on civilian aircraft and identifies any 5G interference emission issues

Millimeter-wave Channel Quality

Satellite communications operating at millimeter-wave frequencies offer many advantages, including higher data throughput capability with access to wider bandwidths on the millimeter-wave spectrum. Physical antenna sizes are also smaller since the size of the radiating elements is directly proportional to the wavelength. However, various circumstances affect millimeter-wave coverage — rain, foliage, free space, buildings, mountains, distance of propagation, and more. These conditions cause an electromagnetic wave to lose power density as it propagates through space. The loss in power density is called path loss.

Making Path Loss Measurements

Understanding the path loss of a communications system is critical to determining the link budget of that system. Since path loss plays a significant role in establishing a link budget, it is important to have test equipment capable of making path loss measurements in the field.

You can make path loss measurements over-the-air via a radio link using one FieldFox unit as a receiver to measure signal power level in spectrum analyzer or RTSA mode. A and a second FieldFox unit serves as the base station transmitter if there is no base station present. Each FieldFox has a built-in continuous waveform (CW) signal generator capable of generating frequencies and a DC variable voltage source to power an external amplifier.

Figure 3. A 54 GHz FieldFox with horn antenna acts as a receiver to measure satellite ground station path loss

Signal Quality and Spectrum Interference

The 5G NR FR2 millimeter-wave frequency ranges overlap with FSS uplinks (27.5 to 29.5 GHz) and FSS downlinks (37.5 to 40 GHz). Spectrum sharing occurs and, in many cases, the 5G base station may use the lower band frequency at 27.5 GHz to set up its communication link. The 5G base station needs to adjust to ensure it gets enough throughput to avoid causing interference to the satellite link because the orbiting satellite communication link frequencies cannot be changed.

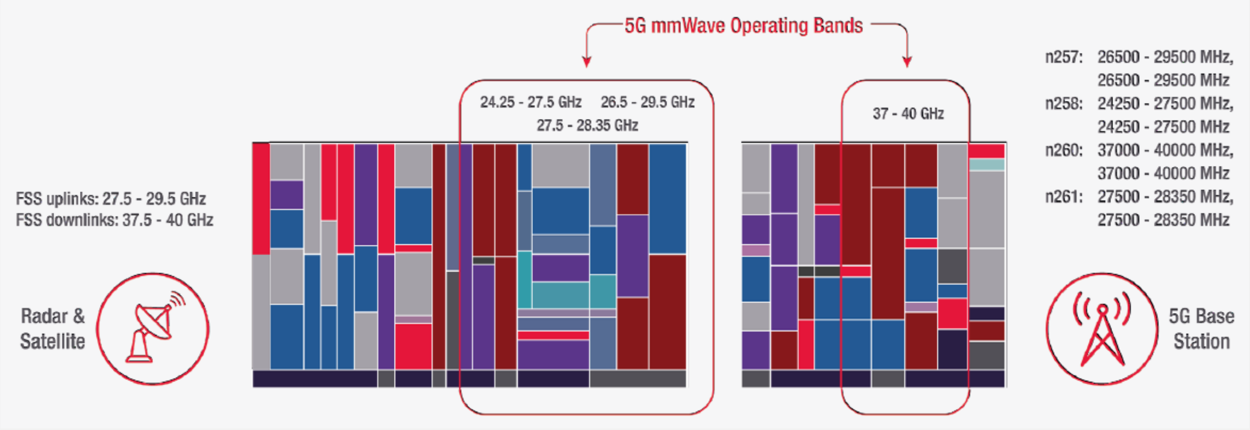

Figure 4. Satellite and 5G millimeter wave communications share portions of the same frequency spectrum and are prone to interfere with one another

When it connects to a FieldFox analyzer, Keysight's PathWave Vector Signal Analysis (VSA) software can analyze digitally modulated signals simultaneously in the modulation, time, and frequency domains. This software provides useful insights into modulation quality and interference between adjacent satellite and 5G signals. The spectrum display (Figure 5) provides a robust view of the guard band between two adjacent 5G and satellite signals that do not interfere with one another.

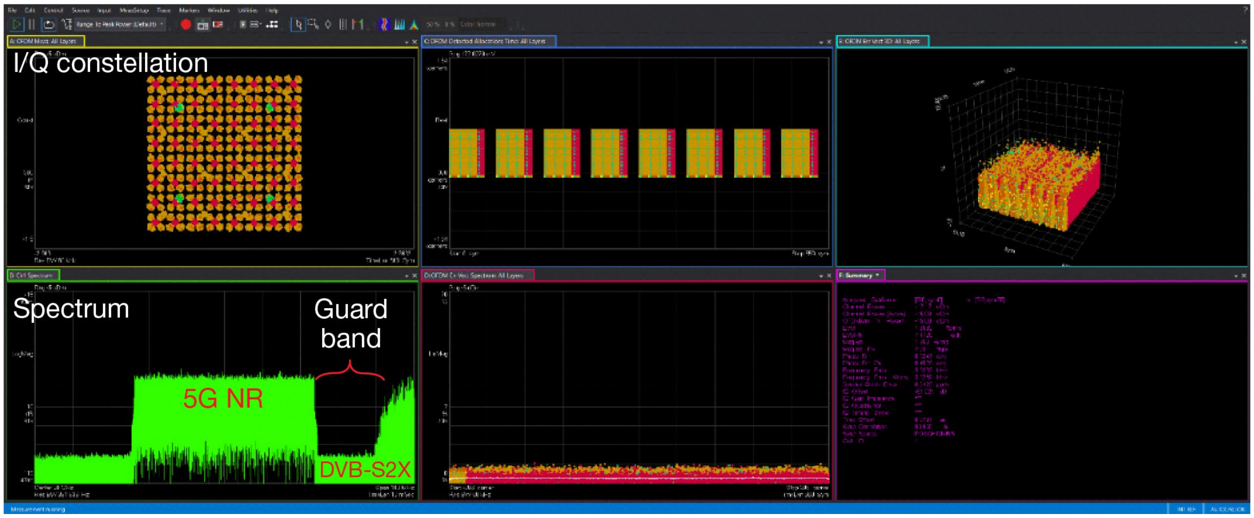

Figure 5. A 28 GHz modulation analysis of a 5G NR (New Radio) downlink with an adjacent satellite communications uplink DVB-S2X digital broadcast

However, the quality of the communication path decreases when these two signals move closer together through power and frequency adjustments (Figure 6). The in-phase and quadrature (I/Q) constellation display and error vector magnitude (EVM) modulation metric help to determine the quality of a signal and how much power will start to corrupt the communications on the satellite receiver.

For orthogonal frequency-division multiplexing (OFDM) modulation, the entire transmission spectrum is the sum of individual contiguous sub-carriers. The OFDM error vector spectrum view (Figure 6), indicates that the upper carriers are seeing higher bit error rates, or EVM, as the adjacent 5G and satellite signals interfere with one another. The OFDM view allows you to see where the interference occurs on the spectrum. In this case, the interference on the upper end of the spectrum suggests that the 5G carrier needs to move to a lower frequency to avoid the interference.

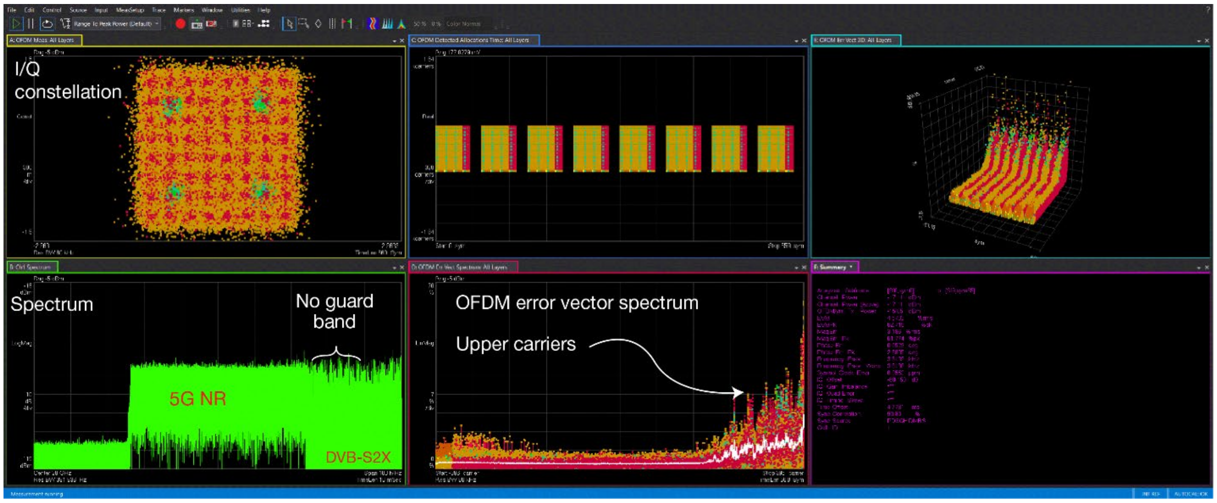

Figure 6. A 28 GHz 5G NR (New Radio) signal interferes with an adjacent satellite communications DVB-S2X digital broadcast and shows degraded modulation analysis metrics

Satellite and 5G Base Station Colocation Assessment

A critical requirement for 5G network installation is to determine the best colocation between the 5G base station and a neighboring satellite ground station. The colocation of satellite ground stations and 5G base stations must deliver the maximum coverage area for 5G services while also not interfering with any satellite communications links. Fortunately, 5G base stations use phased array antennas that can shape and steer the beams to avoid interference with a satellite ground station. You may find limited 5G coverage in geographic locations near a satellite ground station.

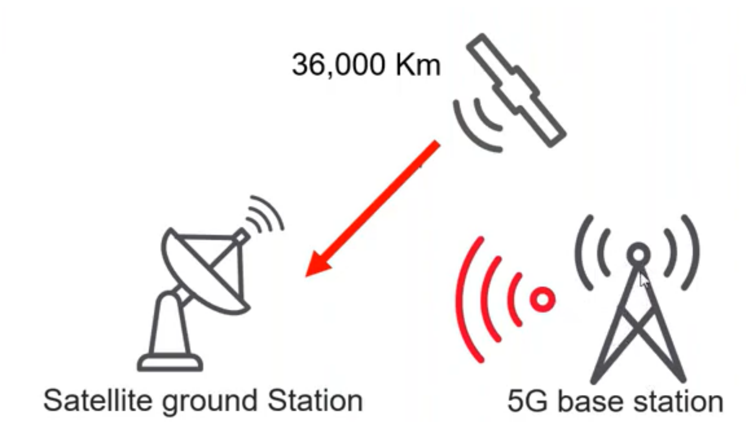

Figure 7. Neighboring satellite and 5G ground stations should be geographically located to avoid or minimize potential interference issues

Use field “drive” test verification to identify the best location for a 5G base station by creating concentric circles at various distances around a satellite ground station while measuring a 5G signal transmission. The FieldFox handheld analyzer with 5G NR over-the-air (OTA) measurements provides key performance indicators (KPIs) including physical cell ID and beam index, received power levels, and EVM. An analysis of the KPIs at various locations on the concentric circles will identify places that cause interference with the satellite link.

FieldFox combines receiver measurements with global positioning system (GPS) location tags or uses indoor markers to verify network coverage and identify interference in a specific area. FieldFox can also import maps from OpenStreetMap (OSM) for data collection and mapping to the FieldFox instrument display. You can save the maps to the internal memory of FieldFox, a SD card, or USB drive via a direct wired local area network (LAN) connection. Alternatively, you may save OSM maps to your FieldFox using the FieldFox Map Support Tool.

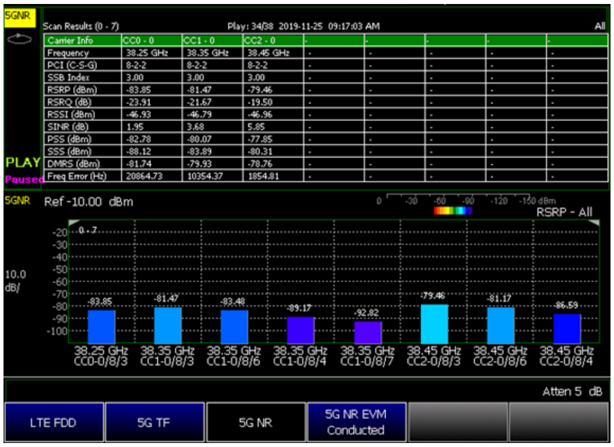

Figure 8. A 5G NR OTA FR2 measurement of eight physical cell identifiers, received power levels, and beam index information

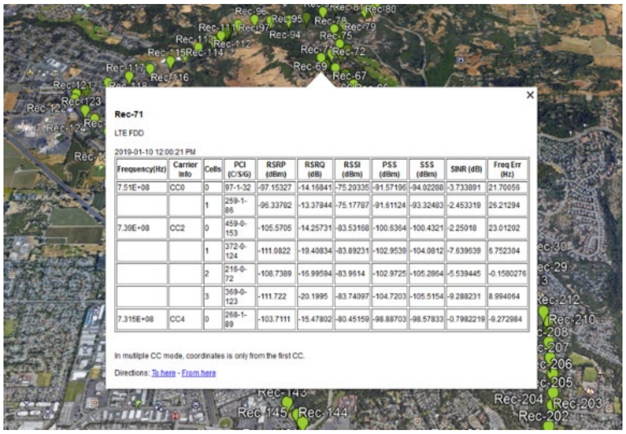

Figure 9. An outdoor map of LTE OTA syncs with GPS

Millimeter Wave Phased Array Coverage Tests

Satellite and 5G communications at millimeter wave frequencies may encounter severe path losses to the radio link from the atmosphere, weather changes like rain or snow, trees and buildings in the path, and more. You can overcome these challenges by using phased array antennas with beamforming and beam steering capabilities.

What is beamforming and how does it work?

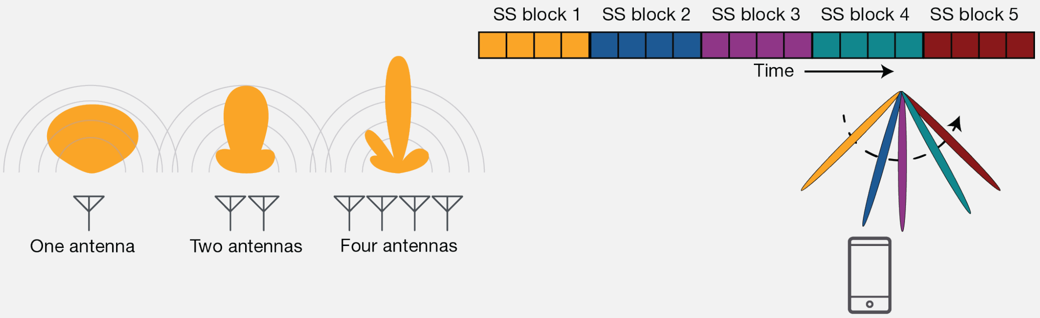

Figure 10. What are beamforming and beam steering and how do they work?

Understand 5G and Satellite Base Station Beam Characteristics

FieldFox integrated with a 64-element phased array antenna (Figure 11) performs over-the-air coverage testing of satellite and 5G millimeter wave base stations. The antenna serves as a RF probe, while FieldFox controls the measuring beam. Since 5G control channels are based on beamforming technology, and are not always on, it can be difficult to determine the location of the 5G signal. Switching into RTSA mode on FieldFox quickly detects 5G signals, control channels and provides insights to beamforming performance (Figure 12).

Beamforming adjusts signal amplitudes and phases of individual antenna array elements. It directs and shapes an antenna pattern to suit your coverage area.

Beam steering takes beamforming a step further by dynamically changing the antenna pattern in real-time to change the signal phase.

Figure 11. FieldFox performs millimeter wave 5G air interface characterization when integrated with a phased array antenna.

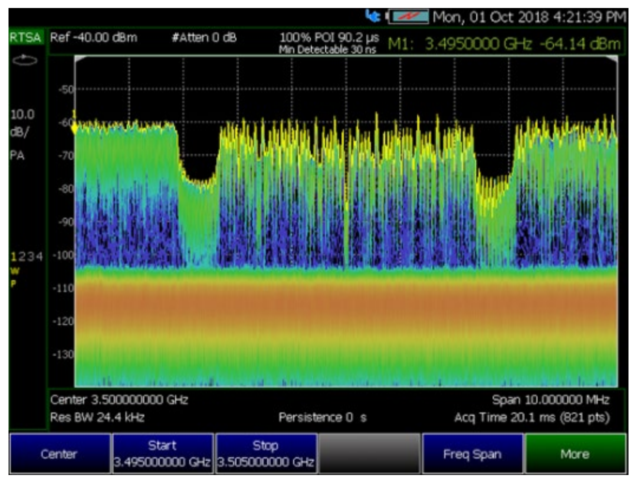

Figure 12. RTSA density display detects beam sweeping 5G synchronization signal blocks (SSBs) when they pair with a phased array antenna.

Phased Array Coverage Test Measurement Capabilities

Due to the nature of beamforming and beam steering, simply logging geolocation points is not enough. RF engineers must collect signal power data across azimuth and elevation in order to understand the antenna beam pattern and dynamic movement within a coverage area. FieldFox sweeps the beam from 0 to 120 degrees in azimuth and 0 to 90 degrees in elevation. It then captures and logs three data points: azimuth, elevation, and amplitude. The built-in GPS receiver also records geolocation information.

FieldFox can generate a heat map display to show two-dimensional coverage of azimuth versus elevation (Figure 13). It can also display the polar antenna pattern to understand the beam characteristics of the gNB phased array antennas (Figure 14), or perform a boresight scan to verify antenna performance (Figure 15).

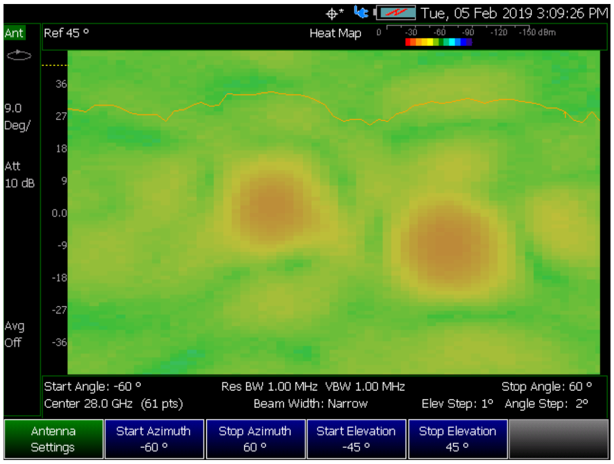

Figure 13. A 2D heat map (azimuth vs. elevation)

Figure 14. Polar antenna pattern

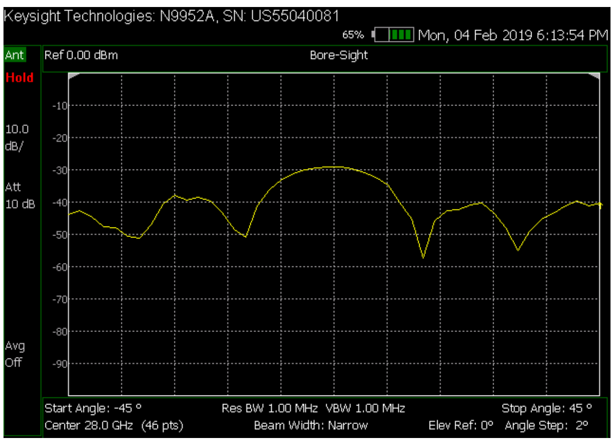

Figure 15. Boresight scan

Satellite Spectrum Monitoring

Increasingly, satellite spectrum delivers more platforms and services and is becoming more crowded. Therefore, satellite service providers need to keep an eye on downlinks and the quality of their services. Spectrum monitoring is the process by which a service provider or regulator evaluates allocated signals and frequencies that deliver a particular service.

Spectrum monitoring involves not only regularly detecting the spectral activity, but also extracting parameters from those signals. For example, the parameters might include signal operating frequency and bandwidth, power levels and modulation formats, and how often a specific frequency channel allocation is in use. In addition, 5G and satellite services are being dynamically shared on the same channels and also must accommodate for the insertion of aerospace and defense capabilities as well as time-critical public safety services.

Spectrum monitoring of a satellite transponder typically looks at a broad spectrum to determine band occupancy, aggregate power, and individual downlink performance. It is also helpful to understand whether there is a problem universally with the signals coming off the transponder, or if the problem is limited to just one signal.

More recently, there is growing concern over vulnerabilities in Global Navigation Satellite Systems (GNSS), as almost every technology is dependent in some way on precision time that is derived from GNSS. This concern extends to C-band mobile satellite operators (i.e., media, news, event coverage, etc.) that experience uplink interference from new 5G NR services operating in bands n77 and n88 (3.3 to 4.2 GHz and 3.3 to 3.8 GHz, respectively).

When FieldFox connects to Spectrum Monitoring Surveyor 4D software, it transforms into a versatile and truly portable monitoring system covering very low frequency (VLF) to 54 GHz, including satellite Q/V bands as well as 5G millimeter wave bands.

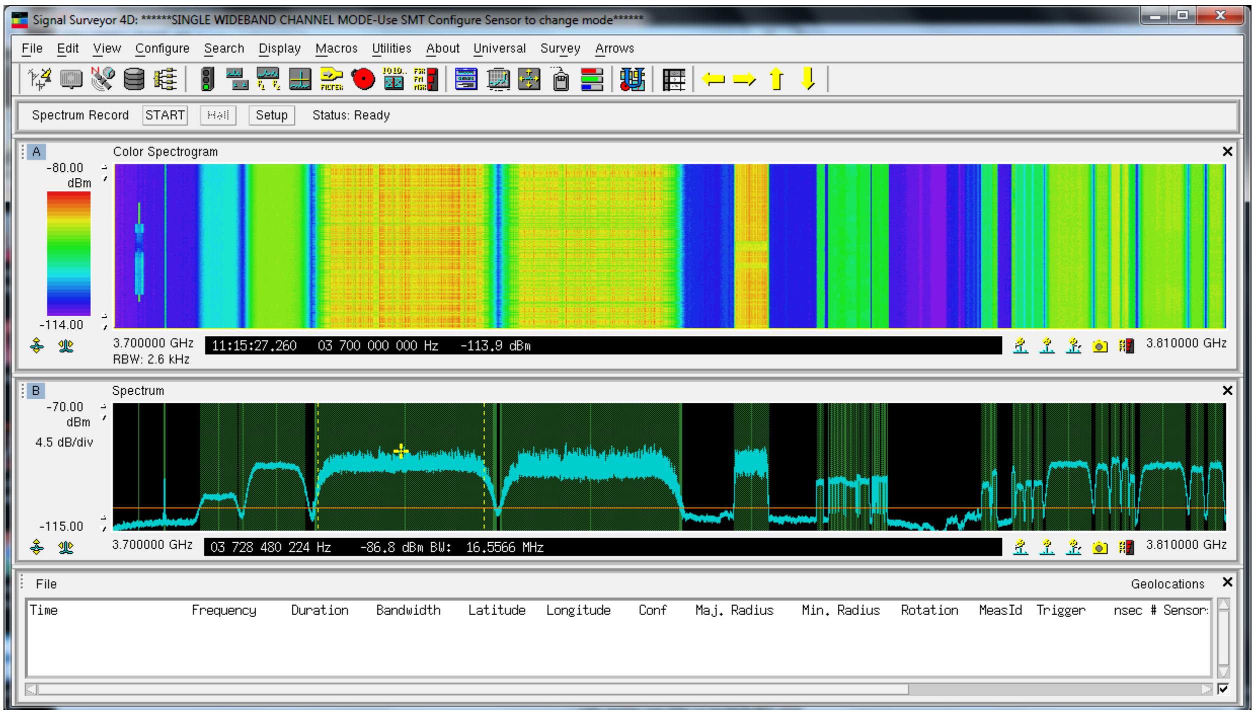

Figure 16. N6820ES Spectrum Monitoring Surveyor 4D software connects to FieldFox microwave analyzer sweeping C-band transponders covering 3.7 to 4.2 GHz

Component Verification in the Field

FieldFox is well-suited for cable and component testing RF and microwave (uW) frequency in the field. For example, you can configure FieldFox as a vector network analyzer (VNA) with a full 2-port capability to measure all four S-parameters. With a full 2-port VNA, you can measure the forward and reverse characteristics of your component without having to disconnect, turn it around, and reconnect it to the analyzer. Additionally, the full 2-port calibration offers you the best possible measurement accuracy. FieldFox's four independent, sensitive receivers provide 117 dB of dynamic range for measurement of high rejection, narrowband devices such as cavity filters.

Making Measurements in the Field

Distance to fault (DTF) and time domain reflectometry (TDR) measurements provide fault characteristic insights. DTF helps you determine the location of discontinuities in feeder lines. TDR helps you determine the nature of the discontinuities — for example, short, open, or water ingress. With FieldFox, you can make return loss (RL) and DTF measurements at the same time which will help you correlate overall system degradation with specific faults in the cable and antenna system. The built-in cable editor allows you to edit existing cable types onsite and save them as new cable types with user-defined names.

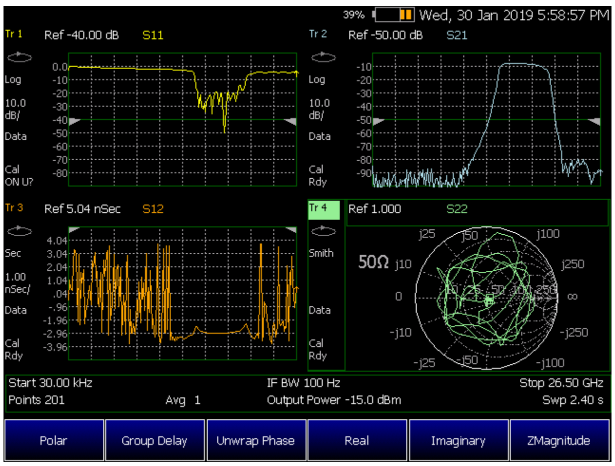

Figure 17. Full 2-port S-parameter filter measurement showing all four S-parameters

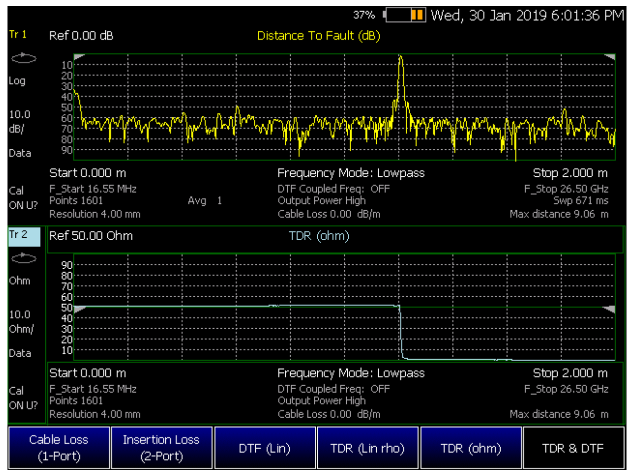

Figure 18. Cable fault measurement using DTF and TDR

Making cable measurements in the field can pose challenges. For example, the ports you need to measure might be hundreds of feet apart from where you need to make insertion gain or loss measurements on cables or systems. Or the two ends of long, high loss cables cannot be easily accessed such as those bolted in on ships or aircraft, or at satellite ground stations. Many of these types of cables are part of a larger system that requires tuning. In those cases, real-time speed is important and also potentially cumbersome if you are using a power-sensor based system.

Solve for Tight Tolerances

In addition, there is potential for significant loss if, for example, you are measuring a 200-ft. long RF cable which requires a solution with high dynamic range to characterize the loss. Customers using scalar systems often must use external amplifiers to increase the dynamic range. And measurements on mission-critical systems with tight tolerances require a high degree of accuracy; they also must be repeatable in the harsh environments where you perform them.

The Benefits of Extended Range Transmission Analysis (ERTA)

Extended range transmission analysis (ERTA) uses a pair of synchronized FieldFox analyzers to perform very high dynamic range scalar-transmission network measurements. One FieldFox unit serves as the ‘source’, and a second FieldFox unit is the ‘receiver’. Hardware triggering synchronizes the two analyzers over a LAN connection to transfer data between the two instruments and incorporate them into a single measurement system.

One advantage of using ERTA is that it can measure very long and lossy cables since the spectrum analyzer with high dynamic range serves as the receiver. However, if you have a short run of a cable, perhaps 10 feet, dynamic range is not as critical of an issue as when you have only 5-7 dB loss. But when you have long lengths of cable runs — 200 feet, for example — then your loss at microwave frequencies can easily run into the 50+ dB range, or even 70 to 80 dB. In that case, you need test equipment that has an even greater dynamic range. For a 50 GHz system, ERTA can measure up to 88 dB of loss, which is quite impressive dynamic range for a portable solution.

ERTA capabilities are also useful for measuring the insertion loss of waveguide systems or using the frequency-offset feature to measure devices such as mixers and converters.

Figure 19. A portable solution that measures scalar insertion loss of in-situ microwave cables with long distance between test ports

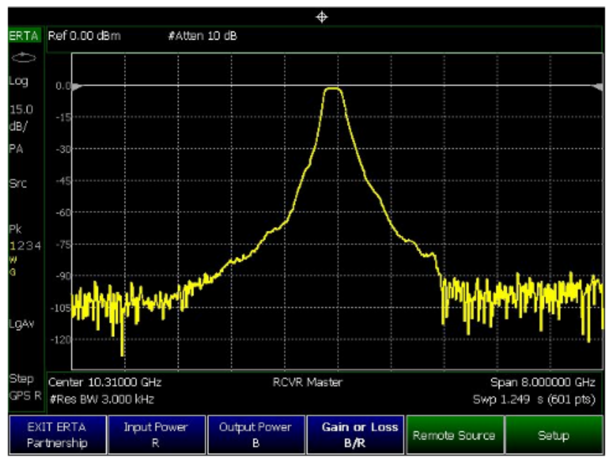

Figure 20. Using a spectrum analyzer as the receiver results in very high dynamic range measurements

Making Frequency Offset Measurements

FieldFox supports frequency offset measurements with a power sensor (FOPS) for downconverter conversion loss test. FOPS works well on converters with integrated amplifiers and filters, and supports offset frequency of negative, zero, or positive. Since FieldFox has a source that comes from Port 1, it stimulates the device under test (DUT), while the power sensor acts as the receiver. Additionally, you can sweep the output frequency in a reverse direction versus the source frequency.

But FOPS does have limits; it makes much slower measurements than the ERTA system (Figure 19). Additionally, the power sensor is a broadband device, and it will pick up any source harmonics and subharmonics along with the signal of interest. Only the signal of interest should be present for an accurate measurement, therefore, all harmonics and subharmonics must be filtered out. On the positive side, the FOPS solution is more cost-effective than the ERTA solution since it requires only one FieldFox and a power sensor.

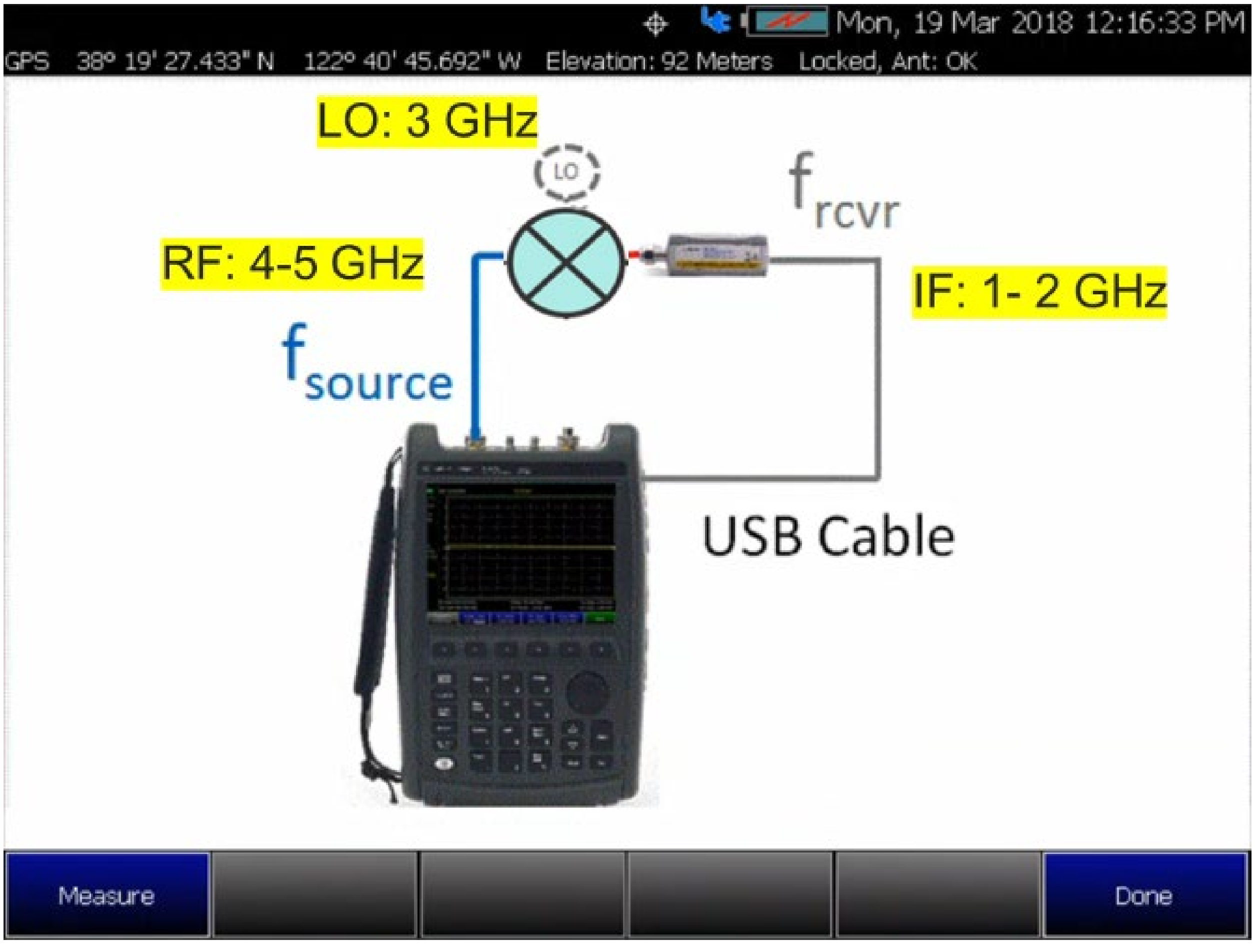

Figure 21. A FOPS scenario on the FieldFox measurement display

FieldFox Satellite Test Solution Configuration in Brief

The table below provides the FieldFox options (shown in red) that appear in this Solution Brief. See the FieldFox B-Series configuration guide for complete information on all FieldFox products and accessories.

Checkmark (✓) = Option available

Line (—) = Option not available

Options	Description	Combination analyzers N9913/4/5/6/7/8B N9950/51/52/53B	Spectrum analyzers N9933/4/5/6/7/8B N9960/61/62/63B
CAT / vector network analysis			
010	Vector network analyzer (VNA) time domain	✓	—
210	VNA transmission/reflection	✓	—

Options	Description	Combination analyzers N9913/4/5/6/7/8B N9950/51/52/53B	Spectrum analyzers N9933/4/5/6/7/8B N9960/61/62/63B
211	VNA full 2-port S-parameters	✓	—
212	1-port mixed-mode S-parameters	✓	—
215	TDR cable measurements	✓	—
305	Cable and antenna analyzer	Base model	—
308	Vector voltmeter	✓	—
320	Reflection measurement, return loss (RL), voltage standing wave ratio (VSWR), and scalar	—	✓
Spectrum analysis			
209	Extended range transmission analysis (ERTA)	✓	✓
220	Tracking generator	—	✓
233	Spectrum analyzer	✓	Base model
235	Preamplifier	✓	✓
236	Interference analyzer and spectrogram	✓	✓
238	Spectrum analyzer time gating	✓	✓
312	Channel scanner	✓	✓
350	Real-time spectrum analyzer (RTSA)	✓	✓
351	I/Q analyzer	✓	✓
352	Indoor and outdoor mapping	✓	✓
355	Analog demodulation	✓	✓
356	Noise figure (NF)	✓	✓
358	EMF measurements	✓	✓
360	Phased array antenna support	✓	✓
370	OTA (over-the-air) LTE FDD	✓	✓

Options	Description	Combination analyzers N9913/4/5/6/7/8B N9950/51/52/53B	Spectrum analyzers N9933/4/5/6/7/8B N9960/61/62/63B
371	OTA (over-the-air) LTE TDD	✓	✓
377	OTA 5GTF	✓	✓
378	OTA 5G NR	✓	✓
B04	Analysis bandwidth, 40 MHz	✓	✓
B10	Analysis bandwidth, 120 MHz	✓	✓
Power measurements			
208	USB power sensor measurement versus frequency	✓	✓
302	USB power sensor support	✓	✓
310	Built-in power meter	✓	✓
330	Pulse measurement with USB peak power sensor	✓	✓
System features			
030	Remote control capability	✓	✓
307	GNSS/GPS receiver	✓	✓
309	DC bias variable voltage source	✓	✓
Windows-based software			
89601B	PathWave vector signal analysis software	✓	✓
N6820ES	Spectrum monitoring surveyor 4D	✓	✓

Checkmark (✓) = Option available

Line (—) = Option not available

Carry Precision With You

Every piece of gear in your field kit has to prove its worth. Measuring up and earning a spot is the driver behind the development of Keysight's FieldFox analyzers. They can handle routine maintenance, in-depth troubleshooting, and everything in between. Better yet, FieldFox delivers precise microwave and millimeter wave measurements — wherever you need to go. Add FieldFox to your kit to carry precision with you.

Related literature	Number
FieldFox Handheld Analyzers N991x/3xB/5xB/6xB, data sheet	5992-3702EN
FieldFox Handheld Analyzers N991x/3xB/5xB/6xB, configuration guide	5992-3701EN
FieldFox Handheld Analyzers N991x/3xB/5xB/6xB, technical overview	5992-3703EN

Download application notes, watch videos, and learn more at www.keysight.com/find/fieldfox.

Contact Keysight Premier Rental Partners to get a quote now!

Premier Rental Partners

Americas

- Electro Rent: https://www.electrorent.com/us/manufacturers/keysight-technologies
- TRS-RenTelco: https://www.trsrentelco.com/keysight

Europe, Middle East, India and Africa

- Electro Rent: https://www.electrorent.com/eu/manufacturers/keysight-technologies
- TRS-RenTelco: https://www.trsrentelco.com/keysight

Asia Pacific

- Orix Rentec: http://www.orixrentec.jp/index.html
- SMFL Rental Company Limited: http://www.smfl-r.co.jp/english
- Yokogawa Rental & Lease: http://www.yrl.com/index.html
- Lotte Rental: http://www.lotterental.com

Find a Premier or Authorized Rental Partner nearest you:
www.keysight.com/find/rentalpartners

Keysight & Our Rental Network
RIGHT Instrument. FLEXIBLE Terms.
FAST Delivery.

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

KEYSIGHT TECHNOLOGIES