

Keysight Technologies

Getting Better Measurements on the Go with a FieldFox Handheld Analyzer

Application Note





Introduction

Today's signal environment is crowded, complex, and dynamic. Wifi devices are clogging up the unlicensed portion of the frequency spectrum. Regulatory agencies have been reassigning FM stations, UHF and VHF television channels, and more, as digital transmissions supplant analog technologies. Cellular subscribers have an insatiable appetite for wireless data, and in some areas, the wireless bands overlap with military radar frequencies.

When you're working on deployed RF, microwave and millimeter-wave systems, every piece of gear in your field kit has to be ready for whichever task you're facing: routine maintenance, in-depth troubleshooting, or anything in between. The ideas and tips in this application note will help you get better measurements and accurate results with a handheld analyzer.

Getting Excellent Results in a Variety of Situations

On any given day, you may need to measure a wide variety of devices or signals: cables, antennas, filters, line-replaceable units (LRUs); carrier signals, interfering signals; and elusive or intermittent spurious signals. Keysight's FieldFox handheld analyzers are uniquely able to help you handle these measurements and more.

Measuring up and earning a spot in your kit is the driving idea behind FieldFox. With access to multiple instrument capabilities, and MIL-spec durability, these analyzers deliver precise microwave and millimeter-wave measurements wherever you need to go. We explain how and why on the next several pages, focusing on three broad applications: cable and antenna testing, vector network analysis, and spectrum analysis.

Testing cables and antennas – pinpointing fault location and type

A failure in a transmission line is a major issue in complex communication systems. In the field, these measurements are challenging because the lines can be hundreds of meters long. Because the ends of a transmission line are physically separated, it is impossible to make an end-to-end measurement. Useful alternatives include “distance to fault” (DTF) and time-domain reflectometry (TDR) measurements. One end of the transmission line is connected to FieldFox and the “distance-to-fault” (DTF) and “time-domain reflectometry” (TDR) signals are examined. These techniques can help you pinpoint the location and nature of the fault in the line. With its wide frequency range and high output power levels, FieldFox can make these measurements accurately, on both short and long cables.

The photo in Figure 1 provides an example. The coaxial cable is damaged in two ways: at point A, the bend radius is much sharper than the specified minimum (e.g., one inch); and at point B, the braided shield has been partially removed, exposing the inner dielectric.

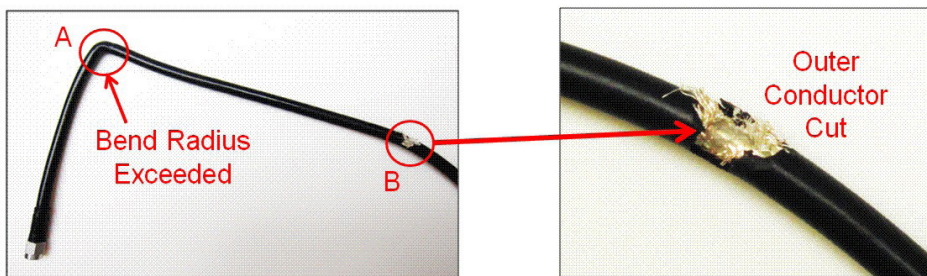


Figure 1. This coaxial cable has obvious damage, and single-ended measurements will help locate and diagnose the trouble.

A DTF measurement will report the location of each fault, and this is a good starting point. To get greater detail, you can use TDR to characterize the type of fault (Figure 2). Any discontinuities in the TDR trace will help you determine the nature of each fault (e.g., bend is capacitive, nick is inductive). To enhance diagnosis and troubleshooting, FieldFox can provide additional information such as insertion loss, return loss, and cable loss.

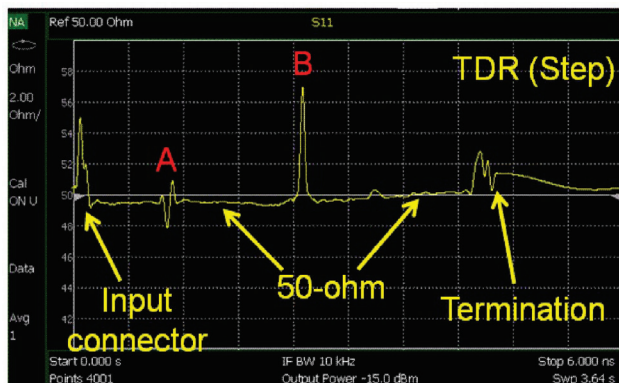


Figure 2. This TDR measurement shows that the cable impedance is generally 50 ohms unless a discontinuity is present: A indicates the sharp bend in the cable and B indicates the damage to the shield.

Utilizing remote operation

Remote control with an iOS device is available for FieldFox analyzers (Option 030). The companion FieldFox application emulates the instrument front panel and provides full control from a remote location. A tower climber can be overhead with a FieldFox analyzer while a coworker on the ground operates the instrument using an iPad or iPhone (through a network connection).

Characterizing system components with vector network analysis

In today's most demanding systems, carrier frequencies are rising, bandwidths are increasing, and dynamic range is expanding. As a result, high-performance filters are crucial to system operation. Depending on the application, the filter may be a band-reject or bandpass device with a narrow band and a relatively high Q factor. To ensure ongoing system performance, the ability to perform accurate and repeatable filter measurements in the field is essential.

There are many ways to implement such filters and one of the most common is a cavity device. In one form, a cavity, with only an input coupling loop, is hung off a transmission line using a matched tee. This provides a path that removes the blocked frequency from the system and allows all other frequencies to pass with minimum loss.

The left side of Figure 3 shows the frequency response of a typical notch cavity. When greater isolation is needed, two filters can be coupled in sequence. If both filters are tuned to the same frequency, then the resulting response will be a very deep notch, as shown on the right side of Figure 3.

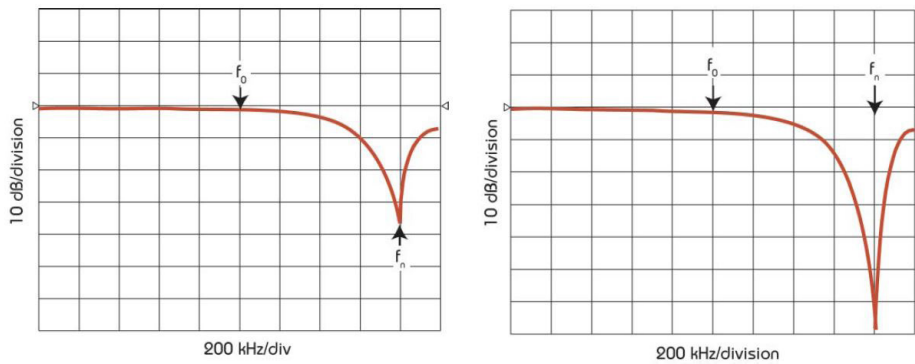


Figure 3. Measuring deep notch filters requires a high quality handheld network analyzer.¹

Understanding device performance with flexible displays

Figure 4 shows network measurements of a bandpass filter that must be tuned to a match a specific frequency in the amateur radio band. The overlay trace shows two S-parameters measured with FieldFox operating in VNA mode: S_{11} is the forward reflection coefficient or input match and S_{21} is the forward transmission loss. In VNA mode, FieldFox has full vector capability, meaning it can measure S-parameters, magnitude, and phase. It can also make time-domain and mixed-domain (i.e., time and frequency) measurements.

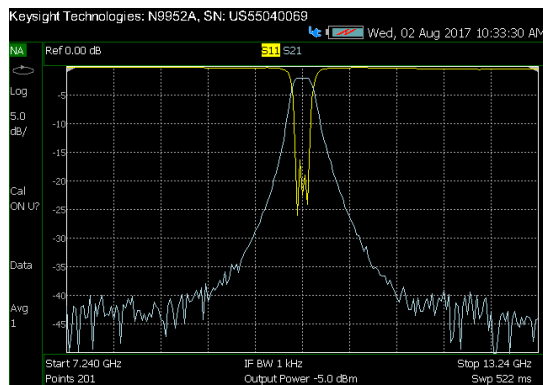


Figure 4. These S-parameter measurements show the characteristics of a narrow bandpass filter tuned to 10.24 GHz.

1. FM Combining Systems, Shively Labs

Figure 5 shows the same measurement process displayed as a Smith chart. Impedance values in the hemisphere above the line are inductive and those in the lower hemisphere are capacitive. Every crossing of the horizontal centerline is a resonant frequency at a real-valued impedance. From this, a real-time Smith chart display is a useful, interactive way to manually tune filters or antennas.

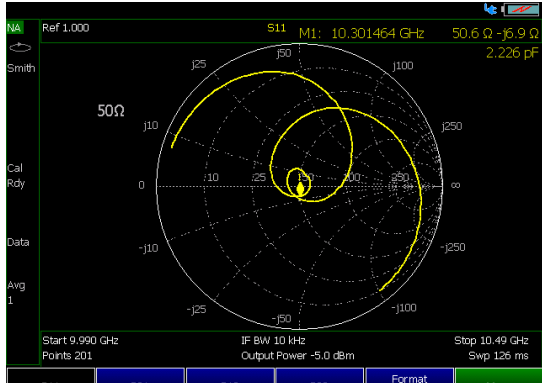


Figure 5. The upper-right corner of the Smith chart shows the actual impedance value at the marker location.

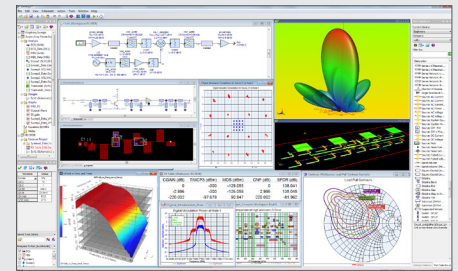
Enhancing measurement accuracy with calibration

When making network analyzer measurements in the field, it is common to perform calibration routines that account for the instrument and the cables connected to the device under test (DUT). This removes systematic errors and enables the instrument to apply error-correction techniques that enhance measurement accuracy.

FieldFox handheld analyzers can be calibrated using mechanical calibration standards or electronic calibration (ECal) modules. To simplify the process and save time, FieldFox includes a calibration wizard that guides you through each step.

Keysight's N755xA series is a value-priced line of ECal modules designed to work with FieldFox as a fully integrated solution. These modules cut calibration time in half, when compared to a traditional cal kit. Simply connect the ECal module to the instrument's measurement ports and USB port and the firmware does the rest.

FieldFox can also eliminate the need to carry calibration accessories into the field. Features such as Cal Ready and QuickCal save time and reduce complexity while still enhancing measurement accuracy.



Creating and verifying filter models

Keysight EEs of Genesys software is an affordable use tool for RF and microwave circuit synthesis and simulation. It accelerates the design process with automatic circuit synthesis of matching networks, filters, oscillators, mixers, transmission lines, PLLs and signal-routing structures.

A designer can use Genesys to create a cavity filter and render it, using a three-dimensional (3-D) printer. After installation, measurements made with FieldFox can be compared to the original design models to detect signs of aging, drift, damage or failure.

Genesys TestLink captures measured data directly into Genesys from FieldFox and more than 140 instruments from 15 manufacturers. For example, you can use this approach to create matching networks for measured antennas.

www.keysight.com/find/eesof-genesys

Characterizing wireless signals with spectrum analysis

Legal and illegal signals fill the airwaves in today's signal environment. Measurement needs range from basic spectrum monitoring to standards-compliant verification to complex interference investigations. FieldFox offers standard and optional spectrum analysis capabilities at a choice of maximum frequencies, ranging from 4 GHz to 50 GHz.¹

Capabilities like time gating and triggering are needed to capture and measure complex signals, such as those from heavily modulated cellular standards to pulse-modulated radar systems. As a result, the simple spectrum analyzers of yesterday may not be up to the task.

While basic measurements of signal power are still essential, advanced measurements such as channel power, adjacent channel power and occupied bandwidth are needed to characterize and troubleshoot modern signals. When configured as spectrum analyzer or combination analyzer, FieldFox can be equipped with those capabilities and more: frequency counter, RF power meter, tracking generator, GPS receiver, analog demodulation, and the list goes on.

Verify coverage with channel scanning

Testing wireless network coverage and hunting for interference are prime applications for channel scanning. A FieldFox handheld microwave analyzer equipped with the channel-scanner mode can scan up to 20 channels at any given frequency and bandwidth. Each channel can be set with custom frequencies and channel bandwidths (5 GHz maximum bandwidth).

You can display power vs. frequency in multiple formats: bar charts (vertical or horizontal), strip charts, chart overlay, and channel power (Figure 6). There is also a scan-and-listen mode. When equipped with the built-in GPS receiver, data can also include time stamps.

Enhancing amplitude accuracy

Comparable benchtop instruments are specified to operate at a set temperature and often require lengthy warmup times. In contrast, FieldFox's SA mode features an automatic internal alignment function that compensates for temperature changes over a range of -10 to +55°C. With this InstAlign feature, the analyzer is ready to make highly accurate spectrum measurements at turn-on and through any temperature changes over the specified range.

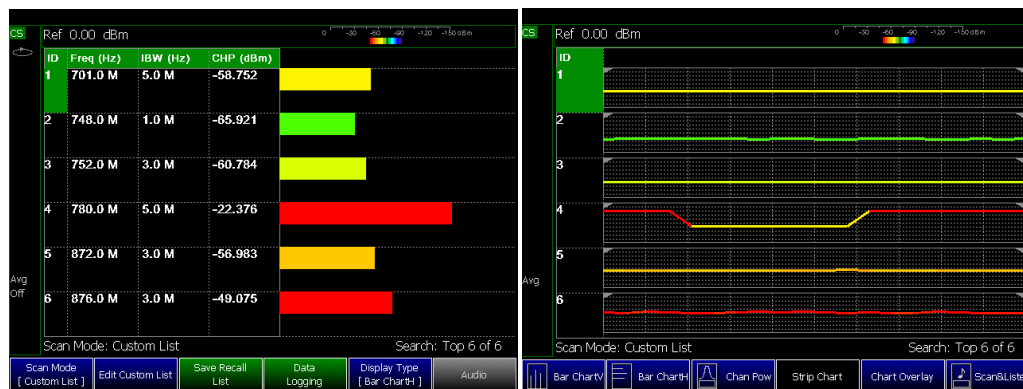


Figure 6. Monitor multiple wireless channels using FieldFox's Channel Scanner. The channel strip chart (over time) display can help pinpoint drop outs or changes

1. Maximum frequency range and many of the capabilities described in this section are optional. While some options are noted, please see the FieldFox configuration guide for complete details.

Hunting for interference

If a system is not operating as expected, some form of radio interference may be the root cause. FieldFox can help you confirm the presence of undesired signals near or within specific frequency channels. Your measurements may reveal constant, occasional or intermittent signals of unexpected frequency, bandwidth and duration. If the system uses full-duplex mode, it may be necessary to examine the uplink and downlink channels for signs of interference.

Because interfering signals are often much lower in level than the channel carrier, over-the-air (OTA) measurements require a spectrum analyzer that has a very low noise floor or displayed average noise level (DANL). The noise level is affected by the selected resolution bandwidth (RBW): narrower settings reduce the noise floor but at the expense of longer measurement times.

Another way to improve the signal-to-noise ratio (SNR) at the analyzer's input detector is to reduce the amount of input attenuation. With a lower setting (e.g., 0 dBm) it may be possible to use a wider RBW and thereby shorten measurement time. One note: lowering the input attenuation can cause distortion or even damage the analyzer when high-power signals are close to the interferers of interest.¹

A portable, lightweight test antenna that covers the frequency range of interest is another important part of your field kit. Keysight's N9311X RF and microwave accessory kit provides a complete solution that is compatible with the durable type-N female connector (50 ohm).

When the interfering signal is pulsed, hopped or otherwise intermittent, you can configure FieldFox for different display modes that aid detection and identification: zero span, MaxHold, waterfall (Figure 7) and spectrogram (Figure 8).

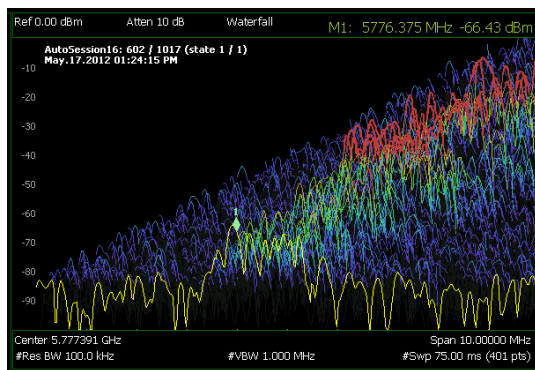


Figure 7. Waterfall displays, available with option 236, provide a visual history of frequency spectra versus time, and the traces move up and to the right with every update.

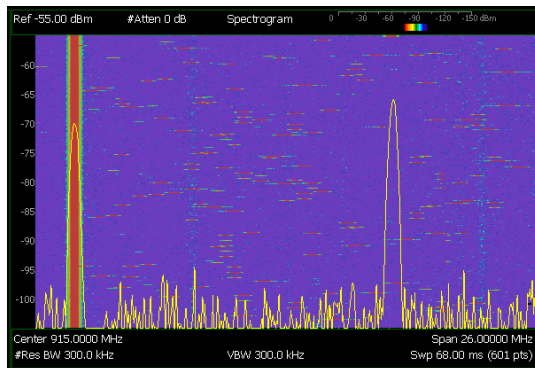


Figure 8. A spectrogram is a dynamic display of frequency (horizontal axis) versus time (vertical axis), with color indicating amplitude (blue is low, red is high). This display, available with option 236, shows the most recent spectrum (yellow) superimposed on the screen.



Verifying new 5G algorithms in the field

During the early stages of 5G product development, field tests can help ensure the viability of newly developed algorithms in real-world conditions. Because actual end-user devices are not yet available, one useful way to understand 5G beam characteristics is to measure signal power from a base station.

Keysight's Nemo Outdoor solution supports emerging wireless technologies such as three-carrier aggregation, LTE Cat 16, VoLTE/ViLTE, VoWiFi/ViWiFi, 4x4 MIMO, and eMBMS testing. FieldFox handheld analyzers can serve as the measurement front-end for the software.

The combination of Nemo Outdoor and FieldFox measures 5G radio propagation and coverage. Nemo analytics tools provide capabilities for visualizing and post-processing data, enabling developers to evaluate and verify base station propagation models and check coverage levels.

www.keysight.com/find/nemooutdoor

1. For more information about DANL and dynamic range, see <http://rfmw.em.keysight.com/spectrum-analyzer>

Capturing and understanding intermittent signals

In a highly dynamic environment, it can be difficult to see small signals with low duty cycles when the frequency content overlaps with signals that are wider. Real-time spectrum analysis (RTSA) reveals signals within signals and is especially effective for interference hunting and signal monitoring. RTSA, installed on a handheld analyzer, allows field personnel to see and focus on infrequent events or transients, then separate them from other behavior. Through the use of high-speed digital signal processing (DSP) technology, Keysight's RTSA capability provides gap-free measurements of elusive or intermittent signals (Option 350). FieldFox is the industry's first handheld analyzer to provide RTSA up to 50 GHz.

In RTSA mode, the spectrum density view is an excellent way to understand and visualize intermittent spectral content. It displays 3-D data on a 2-D display, using color to show the number of times a specific point (e.g., frequency and amplitude) is detected during a capture interval (Figure 9). Because interferers differ from carriers in terms of signal-level distribution, the density display makes it easier to detect multiple signals in the same channel, including low-level signals operating close to high-power transmitter frequencies.

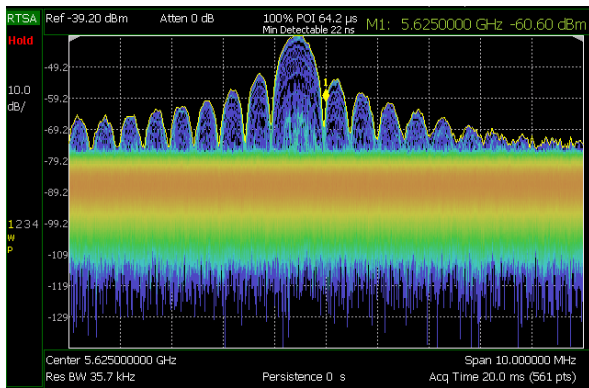


Figure 9. This weather radar pulse density display uses color to show the rate of occurrence, from “often” (red) to “less often” (blue).

With its fast-overlap FFT processing, FieldFox can capture signals as narrow as 12 μ s with 100 percent probability of intercept (POI) and with full amplitude accuracy. When detection of fleeting signals is the critical factor, independent of amplitude accuracy, the analyzer's 10 MHz real-time bandwidth (RTBW) can reveal pulses as narrow as 22 ns on the display. For troubleshooting, a 10 MHz RTBW is often sufficient for most of today's OTA applications.

During interference hunting, the use of RTSA with channel scanning and the dedicated interference analyzer mode (Option 236) can help save time by quickly identifying potentially offending spurs and other infrequent or transient unlicensed activity. Spectrogram displays and spectrogram recording enhance your ability to identify, isolate and measure intermittent signals.

Seeing through complexity with vector signal analysis

Keysight's 89600 VSA Software is the industry's leading toolset for signal demodulation and vector signal analysis. The FieldFox to 89600 VSA link enables analysis and troubleshooting of devices that use a variety of formats:

- APCO-25 and TETRA for public-safety radio
- IEEE 802.11p for wireless vehicular communication
- Cellular communication standards such as LTE, W-CDMA and GSM
- Low-power wide area networks (WANs) and other emerging signal formats for IoT

Installing the software on a compatible laptop or tablet creates a portable solution that combines signal acquisition up to 50 GHz with vector signal analysis of digitally modulated signals in the modulation, time and frequency domains. Display views such as spectrum, I/Q constellation, and error vector magnitude (EVM) enable greater insight into modulation quality in the field (Figure 10).



Figure 10. Through a LAN connection, an APCO-25 two-way radio signal is fed into the 89600 VSA Software for detailed analysis.

Documenting, Sharing and Planning for the Future

After your onsite work, a few follow-on tasks may be required: writing reports, offloading data for analysis by other members of your team, or planning ahead for equipment upgrades that keep pace with new technologies as they are rolled out.

Documenting your work

In the field, it may be necessary to save measurement traces and the associated analyzer settings. FieldFox can save results as screen captures (.PNG) and data files (.CSV), and you can store these to internal memory, an external flash drive or an SD flash card for easy retrieval. The PC-based FieldFox Data Link software lets you pull in screen files to illustrate a report or import data for further analysis in a spreadsheet.

Comparing results to detect potential problems

Before installation of a component or subsystem, many organizations make benchmark measurements and save them for future reference. Later, field measurements are used to look for signs of aging, wear, drift or failure. However, comparisons can be difficult because measurements made with high quality benchtop instruments are often much more accurate than those made with typical portable analyzers.

FieldFox handheld analyzers produce bench-caliber results that enable meaningful comparison and correlation with archived measurements made in the lab or during installation. This has been well documented in a Keysight application note: network measurements are often within a few hundredths of a decibel and spectrum measurements are within a few tenths of a decibel.¹

Future proofing with flexible upgradeability

For maximum functionality, a handheld analyzer should integrate the measurement capabilities you need in a single, compact instrument. They should also give you (and your budget) more flexibility.

FieldFox lets you create the right mix of features for your application: frequency range, analyzer functionality, and a wide range of timesaving optional capabilities. Your initial configuration can address your current requirements, and the instrument architecture lets you add functionality in the future as needs change. Several post-purchase options are field-upgradeable and can be added to a FieldFox combination analyzer through software license keys. Here are some examples:

- USB power sensor measurements versus frequency
- VNA full two-port S-parameters
- Spectrum analyzer
- Pre-amplifier
- Interference analyzer and spectrogram
- USB power sensor support
- GPS receiver
- DC bias variable-voltage source function
- Channel scanner
- Real-time spectrum analyzer
- And more

Keysight Trade-In is another way to keep pace with changing technology. From time to time, the Trade-In program offers substantial savings on new FieldFox analyzers. Because the details vary with each promotional program, please check the website at www.keysight.com/find/trade-in and search on “FieldFox” to see the latest offers.

1. Application Note: *Correlating Microwave Measurements between Handheld and Benchtop Analyzers*, publication 5991-0422EN

Conclusion

A durable, multi-purpose handheld analyzer gives you convenience, flexibility and accurate measurements on the go. It also saves time and effort by letting you learn a single user interface that gives you access to the full range of capabilities inside the instrument.

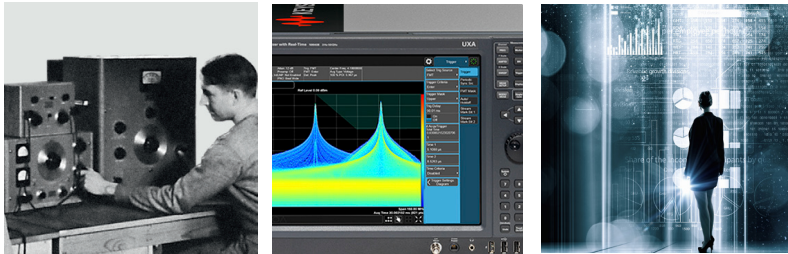
Because every piece of gear in your field kit has to prove its worth, we developed the FieldFox handheld analyzers to handle routine maintenance, in-depth troubleshooting and anything in between. Better yet, FieldFox delivers precise microwave and millimeter-wave measurements wherever you need to go. Add FieldFox to your kit and carry precision with you.

Related Information

- Technical Overview: *FieldFox Handheld Analyzers*, publication 5992-0772EN
- Data Sheet: *FieldFox Handheld Analyzers*, publication 5990-9783EN
- Configuration Guide: *FieldFox Handheld Analyzers*, publication 5990-9836EN
- Article Reprint: *Using Real-time Spectrum Analysis to Efficiently Troubleshoot Interference Issues*, publication 5992-2080EN
- Application Note: *5G Over-the-Air Performance Measurement and Evaluation Using FieldFox Handheld Analyzers*, publication 5992-2429EN
- Application Note: *Techniques for Precise Cable and Antenna Measurements in the Field*, publication 5991-0419EN
- Application Note: *Techniques for Advanced Cable Testing*, publication 5992-0604EN
- Application Note: *Techniques for Precise Power Measurements in the Field*, publication 5991-0423EN
- Application Note: *Techniques for Precise Measurement Calibrations in the Field*, publication 5991-0421EN
- Application Note: *Using FieldFox RF and Microwave Analyzers with Mass Storage Devices*, publication 5992-2408EN
- Application Note: *Correlating Microwave Measurements between Handheld and Benchtop Analyzers*, publication 5991-0422EN
- Brochure: *Genesys: An integrated simulation and synthesis design tool*, publication 5989-7014EN
- Brochure: *Nemo Outdoor*, publication 5992-2057EN

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