

Interference Hunting with the Field Master™ and Site Master™ Series

Overview

Our lives are becoming increasingly dependent on wireless communications. Wireless technology connects our smartphones to the world using multiple cellular technologies, delivers internet connectivity through Wi-Fi connections, streams high fidelity audio to Bluetooth earbuds, connects our first responders with Land Mobile Radio handsets, and provides television and radio from terrestrial broadcast transmitters and satellites. There are applications in automotive collision avoidance radars, weather radars, defense systems and point-to-point radio links.

For all these systems to operate smoothly, the spectrum is regulated by national authorities to ensure each operator or technology has dedicated spectrum to prevent interference. There are a multitude of wireless communication systems operating in the same geographic space that interference does arise. Interference between networks degrades the performance of all systems and is observed by users in ways such as dropped voice calls, reduced data rates resulting in poor quality video or slow downloading of files, and reduced area coverage from a transmitter.

Legitimate owners of RF spectrum need to monitor this resource to ensure that network integrity is maintained. When interfering signals are detected, it is important to detect, locate, and identify the source as fast as possible.



Figure 1. Sources of Interference are Numerous and Disparate

Sources of Interference

Intentional Interferes

A special case of interference is known as intentionally generated interference. The most common examples are cell phone signal jammers and electronic warfare jammers. Cellular signal jammers are illegal in most countries. Despite their illegality, they are widely available from internet sites and often used to prevent the use of mobile phones in public or private spaces.

High power communication jammers are used by defense forces and use high power amplifiers to drown out the receiver of hostile radars and communications. These are most often used in frequency bands that are not part of the commercial communications bands.



Figure 2. Example of a Cell Phone Jammer that can be Purchased Readily over the Internet

Unintentional Interferes

There are many sources of unintentional RF interference. The most common include:

Spurious and harmonics from legitimate transmitters. All transmitters emit spurious and harmonic signals. VHF broadcast FM radio stations typically transmit at 1 to 10 kilowatts (+60 to +70 dBm). Regulatory requirements for these transmitters may require -100 dBc harmonic performance, which is still a level of -40 dBm to -30 dBm. Enough to cause interference with LMR networks that operate in the UHF frequency bands. At the time of installation, new transmitters are measured to ensure regulatory compliance. Many countries also require annual performance verification. Notch filters must be used to remove the carrier power to prevent saturation of the measuring analyzers front end.



Figure 3. Transmitter Towers with High Power VHF Broadcast Radio and UHF Terrestrial Digital Television Transmitters Require Regular Testing to Monitor for Harmonic and Spurious Emissions

Use of Unapproved Radio Devices. Consumers can purchase radio devices such as cordless digital phones, radio microphones and repeaters from web sites, or bring them into the country after international travel. The frequency plans from the country of origin may be different than the country to which they are being imported. Users are often unaware of the licensing requirements for imported radio devices and can inadvertently use them on unlicensed frequencies.

Radiation from Buried RF Cable Runs. Cable television is distributed by long coax cable runs in ducts around residential streets. Cable TV supporting over 100 channels can have up to 550 MHz bandwidth with amplifiers every 300 meters. The installations are expected to have a lifetime of many decades, and over time the insulation can degrade or the cable become damaged or subject to failing connector seals. These degraded cables are a common source of broadband interference in residential areas.

In the United States, the FCC issues maximum signal leakage levels for cable systems with specifically stringent levels at frequencies used for safety critical avionics systems. The regulations are in part 76 of the FCC rules, specifically in §76.605, which lays out the technical standards to which cable TV operators in the United States must comply.



Figure 4. The Insulation of Buried Cable TV Cables and Their Amplifiers can Degrade with Time, or be Gnawed by Rodents as Seen in the Right Hand Image. Breakdown of the Insulation Results in Radiating Interference in Residential Neighborhoods

Poorly Suppressed Consumer Products. Today, all new consumer electronics are required to meet national EMC regulations, for example from the FCC in the USA or regulators enforcing CE in Europe. Consumer goods that have switched-mode power supplies or electronic motors will radiate high levels of RF interference if their suppression hardware fails.

Repeaters. There are two common interference issues caused by repeaters. Insufficient isolation between the transmit and receive antenna can create a high-power oscillation. This is typically found with low cost, often illegally installed repeaters used in the home or small office. Another common repeater issue occurs when a network operator installs a wide area repeater that unintentionally amplifies another operator's signals. This can lead to unexpected excess coverage problems and frequency re-use issues.

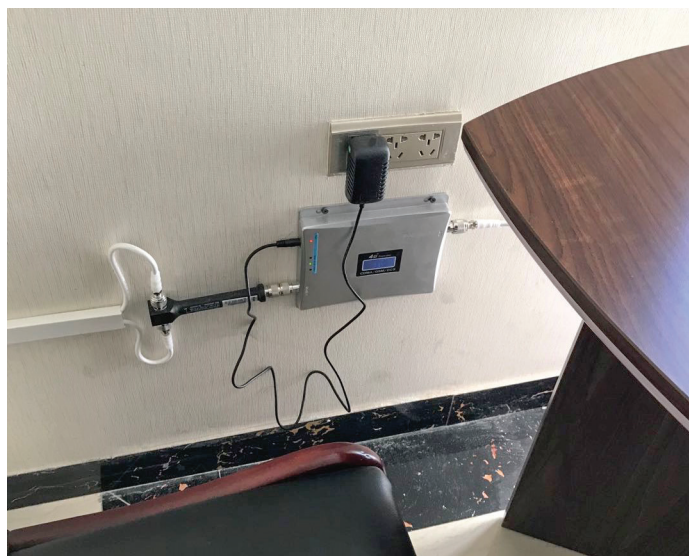


Figure 5. Example of an Illegally Installed Repeater in a Small Business that Generated Interference in the Center of a Local Cellular Band

Industrial Machinery. Many heavy engineering plants have industrial machinery that causes RF interference. Arc welders and industrial plants with high voltage switches are all common sources of RF interference.



Figure 6. Arc Welders and other Heavy Industrial Processors can Create High Levels of RF Interference

Intermodulation Interference. When multiple RF transmitters are collocated, the individual signals can mix with each other generating intermodulation products at the sum and difference of their individual frequencies. Intermodulation typically occurs at the antennas or input stages of a receiver on which the signals are incident.



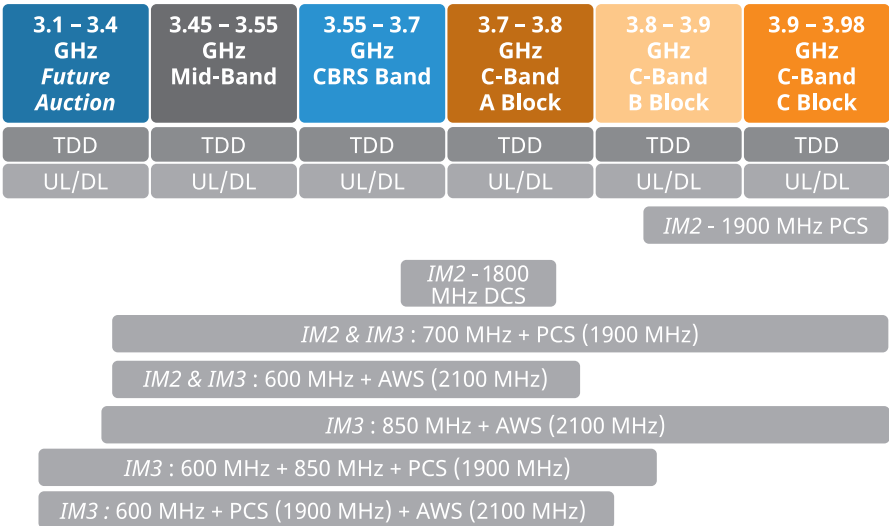
Figure 7. Multiple Co-Located Transmitter Towers often Result in Intermodulation between Signals

Passive Intermodulation. Passive intermodulation has often been considered to be exclusively a concern in RF cable feeds to an antenna. With the increased occupancy of the RF spectrum, passive intermodulation that occurs beyond the antenna has become a significant source of interference. Many metallic junctions act as a diode when RF energy is radiated at them. Examples include rusty metal joints on a rooftop in front of antennas, metal fences, and advertising billboards.



Figure 8. Rusty Bolts and Corroded Metallic Surfaces Generate PIM and Intermodulation Products When Located in Front of Transmitter Antennas

When high power transmitters are directed at metal joints they can act as diodes. The result is the generation of multiple high level intermodulation products.



PIM generated by lower band FDD systems (IM2 & IM3) is the most problematic and high in amplitude:
IM2 = F1 + F2
IM3 = {(2 x F1) + F2} or {2 x F2) + F1}

Figure 9. Graphic Illustrates How Passive Intermodulation from Legacy LTE Transmitters Incident on External PIM Sources can Result in Interference in the 5G 3.5 GHz and C-Band Frequencies

Interference Hunting

The list of example sources of interference highlights that interference can originate from many different sources. There is no single procedure to identify and track down the source of interference. Field engineers build up a set of skills from experience in tracking down many different causes of interference.

There are some basic principles that can be followed, but each interference hunt will require different tools to identify and locate the source. The four basic stages of an interference hunt are:

1. Discovering and validating there is an interference problem
2. Identifying the nature of the interference
3. Identifying the location of the interference
4. Mitigating the interference

The Anritsu Field Master and Site Master Series contain a number of features to help field engineers identify and locate RF interferers, including an RTSA with 40 MHz instantaneous bandwidth, AM/FM demodulation, geolocation with directional antennas and audio tones, and triangulation on a digital map.

Discovering and Validating the Presence of RF Interference

Degradation of system performance is typically the trigger for an interference hunt. Degradation manifests itself as noise, reduced data throughput, reduced coverage from a cell site, dropped calls or in extreme circumstances no reception at all. Modern digital networks continually monitor essential KPIs and automatically report potential interference issues. On other networks, the presence of a potential interferer is often first reported by users experiencing poor performance from their radios.

Although interferers degrade the performance of radio receivers, interference is caused by radio transmitters. A key point is that an interfering signal does not need to be exactly on the receive channel to cause interference. It only needs to be within the receiver's input bandwidth, which means that it only needs to get through the receiver's input filter. Once an interfering signal is incident on the input of a receiver, it affects the receiver's front end, causing a reduction in sensitivity. This will cause the effective carrier-to-interference ratio (C/I) to be lower and result in all the symptoms of a weak signal. In this situation, the received signal strength measurements will be strong due to the high noise floor. This interference mechanism is called Receiver Desensitization. In extreme cases, it can result in receiver blocking. The requirement is to monitor the receiver frequency. In a frequency division duplex system (FDD), the transmitter and receiver operate at different frequencies. In a Time Division Duplex (TDD) system, the transmitter and receiver operate at the same frequency so the analyzer may need to use a gated sweep to view the receive spectrum.

The first task is to confirm that the degradation is a result of interference and not other network issues such as timing errors, damage to antenna RF cable feeds, or the antenna itself. Initial investigations typically center on monitoring the spectrum of the channel that is suspected of suffering from interference. If the degradation is being experienced continuously, the signal should show up on a standard spectrum analyzer trace. The Field Master and Site Master Series in Swept Tuned mode monitor up to 4 GHz with a sweep rate of up to 45 GHz/s. The fast sweep speed helps to view activity in the spectrum of interest in close to real-time. In the event of an unusual or hard to identify interferer, record spectrum activity over a period for deeper analysis at a later time or share the recorded file with colleagues. In Playback mode, a spectrogram highlights any periodicity or pattern to the interfering signal that may be hard to spot in standard trace view.

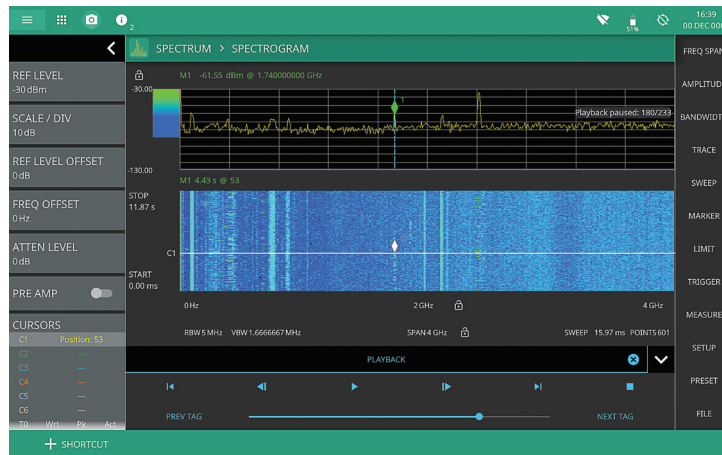


Figure 10. Screen Shot of Playback of Recorded Spectrum Traces

Trace detector selection is important. The standard detector for the Field Master and Site Master Series is the peak detector. This will always display the highest value sampled signal in every display point. Where interfering signals are close in amplitude to the background noise level, a peak detector will make them hard to see. Selecting the negative peak detector often results in a drop in the average noise floor which results in low level coherent signals becoming visible above the noise.

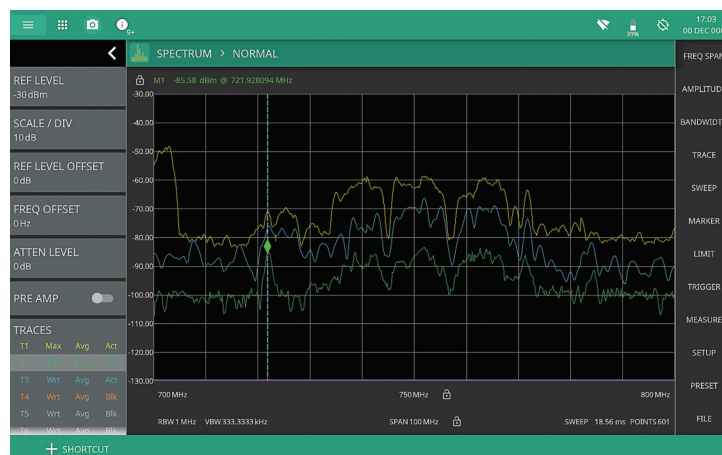


Figure 11. Marker Position Highlights Use of Negative Peak Detector on Green Trace to View Low Level Coherent Interferers Close to the Noise Floor

If the degradation is intermittent or from a TDD transmitter, it is beneficial to use a real-time spectrum analyzer (RTSA). RTSA captures all activity in the scanned spectrum in real time, so even short duration bursted interferers are captured. Including an RTSA spectrogram records an image of the spectrum over time, keeping a record of intermittent interferers.

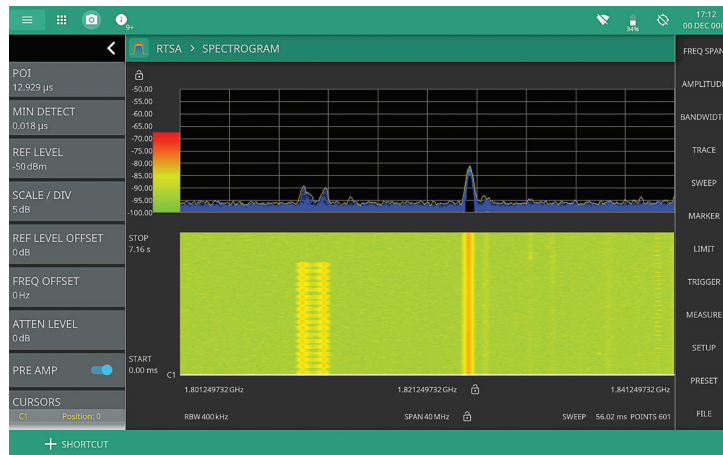


Figure 12. Screen Shot of RTSA with Spectrogram

Another advantage of an RTSA for interference hunting is that the spectral density display highlights the presence of in band interfering signals, even if their power level is lower than the main carrier. The RTSA spectral density displays a power against frequency plot where color is used to highlight signals at all power levels. For wideband systems such as 4G and 5G cellular and broadcast satellite downlinks, it is common for interfering signals to be in band but lower in power than the fundamental signal. These interferers can still degrade system performance but are hard to capture with a standard spectrum analyzer.

Identify the Nature of the Interferer

Having confirmed the presence of an interfering signal, the next step is to establish the nature of the signal.

Low Power Very Wide Noise Power. This is white noise that results in a wideband lift to the background noise level as seen on a spectrum analyzer. Such noise is often caused by consumer product displays, switched-mode power supplies, LED lights, or electric motors where noise suppression has failed.

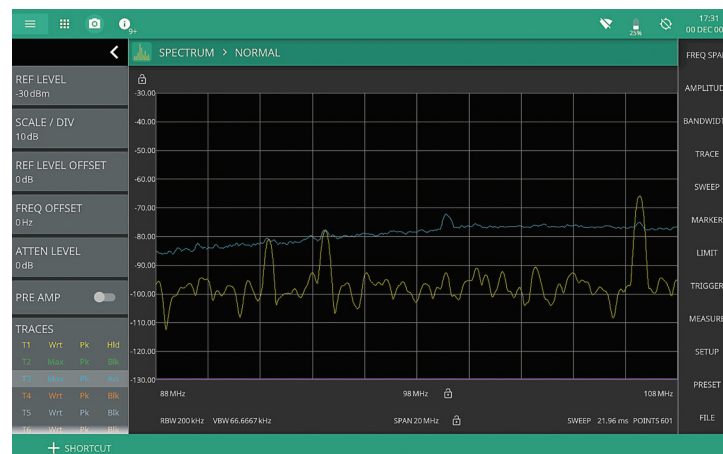


Figure 13. Yellow Trace Shows Clear FM Commercial Spectrum with Three Stations. Blue Trace Shows High Level Rise in Noise Floor when High Power LEDs are Active, which Interferes with the Full Commercial FM Broadcast Band

CW Unmodulated Interferes. This can be seen in local oscillators in communication systems becoming unlocked and drifting away from their design frequency. This is easily seen in swept analyzer mode. Typically, the signal has no modulation and drifts over time.

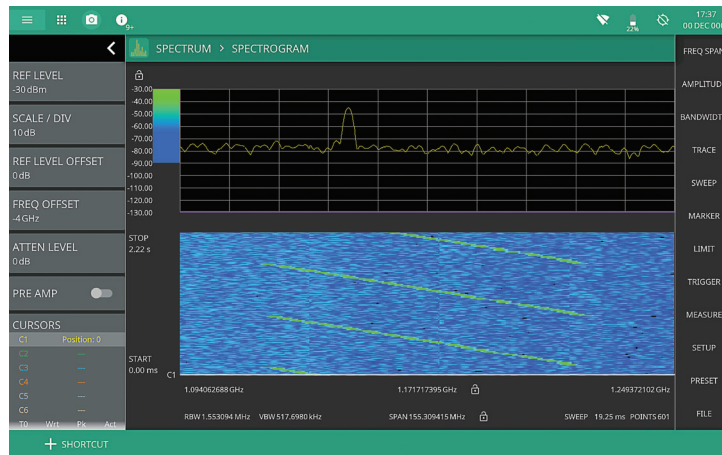


Figure 14. The Spectrogram Captures the Frequency Response of an Unlocked Oscillator Drifting Across the Spectrum Causing Interference

Illegal Broadcasts. Examples include Pirate Radio stations and pseudo (fake) GSM cellular base stations. For broadcast stations, use the spectrum analyzer's AM/FM demodulator to listen to the radio station and identify the user. Detection of pseudo GSM base stations used for illicit and malicious transmission of scams and text messages is complex as in the RF domain they appear as regular base stations.

Bursted and Intermittent Interferers. An interferer that occurs at a consistent frequency but in apparently random time pattern is likely to be generated by a random event. Examples can be high current devices switching on or off or interference that results from wind causing RF cables to knock against a transmitter tower or each other.

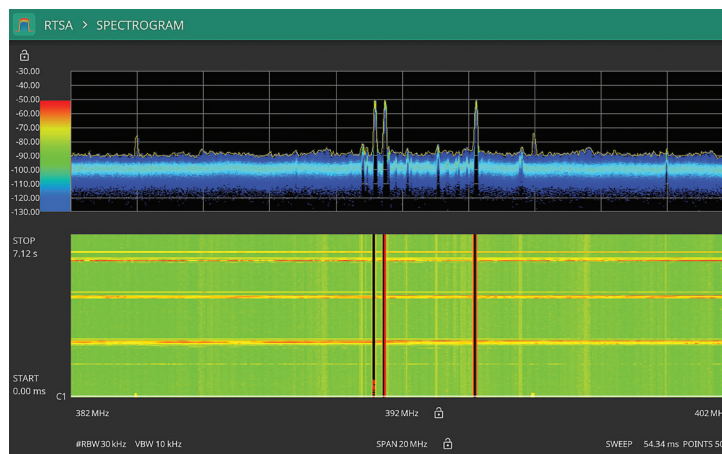


Figure 15. Spectrum Trace Identifies Three LMR Transmitters Around 390 MHz. On the Lower Spectrogram Plot, Transient Bursts of Wideband Interference are Highlighted that were Found to be Generated by High Power Industrial Machinery Activating Electrical Motors

Regular Periodic Interference. This is typical of interference from a rotating radar. Many radars, including maritime radars, defense radars, weather radars, and air traffic radars, transmit kilowatts of power. If the antenna is rotating to provide 360 degree coverage, the high power radar pulses can easily overload the input of other receivers, even if those receivers are functioning at a different frequency. The interference manifests at a regular period determined by the rotation rate of the antenna.

By performing an AM or FM demodulation on the interfering signal, it is possible to pick out characteristics of different sources. The Field Master and Site Master Series include an AM/FM demodulator with audio output from a speaker or headphone jack. If the output is speech or music, the source is clearly an analog radio station and the content should provide an indication of the specific user. Analog narrow band radio systems

around 400 MHz are still common globally for first responders and logistic companies and the second harmonic of these systems often falls in the cellular bands. If the audio output is white noise, it is likely to originate from poorly suppressed industrial products such as arc welders or lighting appliances. Cracks and pops are indicative of high voltage machinery switching on and off.

Identifying the Location of the Interferer

The Field Master and Site Master Series include a number of features to aid in the location of an interfering signal. A common starting technique is to connect a directional antenna to the RF input of the spectrum analyzer. If the signal hunt is taking place near high power transmitter towers, it is best practice to insert a band pass filter between the directional antenna and the RF port of the spectrum analyzer. The filter should be centered on the receiver frequency that is suffering from interference. The purpose of the filter is to remove high power signals that would otherwise be incident on the analyzer input circuits that could potentially result in desensitization of the input or internally generated intermodulation products.

Using a directional antenna such as a Yagi or log periodic antenna enables basic interference hunting without signal mapping. The process is simply to tune to the frequency of the interferer and sweep the antenna in an arch to identify the direction that gives the maximum signal strength. The technique is powerful, but does require an experienced user. To help identify the direction of the interferer, set one trace to clear/write mode, and a second trace to Max-Hold. This gives a visual indication when the antenna is pointing towards the strongest signal. When using this method, care must be taken if there are RF reflecting surfaces. Reflected signals are indistinguishable from direct path signals which can result in misleading outcomes. Option 24 in the Field Master and Site Master Series include a fast-responding audio tone that changes in pitch as the level of a detected signal changes, which helps identify the direction of the interfering signal without continuously watching the screen.

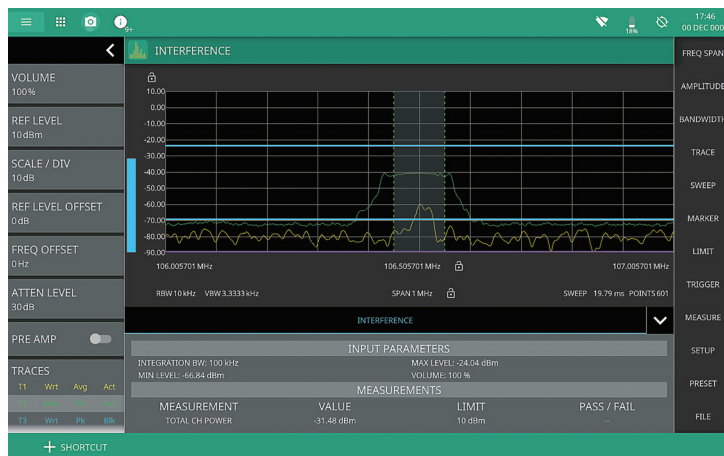


Figure 16. Green Trace is Max Hold Response of Illegal FM Station. Use a Directional Antenna to Determine the Direction of the Transmitter with an Audio Tone Response that Changes in Pitch with Channel Power Level

Antenna Selection

There are three fundamental types of directional antenna that are commonly used for interference hunting: Yagi, Loop, and Log Periodic.

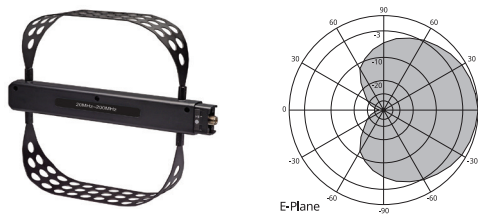
Yagi: Traditionally the most common directional antenna for interference hunting. Yagi antennas offer good directivity but their narrow band performance makes them most suitable for operators who only need to hunt in a fixed frequency band.

- Low cost
- Very good directivity
- Handheld, selective frequency bands in the range of 400 MHz to 3 GHz
- Narrow frequency bandwidth



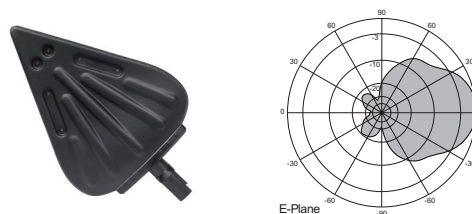
Small Loop Antenna: The most practical directional antenna for signals below 400 MHz due to their size. Yagi and log periodic antennas at these frequencies become too large for handheld interference hunting applications.

- Medium cost
- Handheld selective frequency bands in the range of 1 MHz to 500 MHz
- Small size for low frequency applications



Log Periodic: Log periodic antennas offer very broadband frequency coverage, potentially with less directivity than Yagi or loop antennas. The convenience of using a common antenna for interference hunts at many frequencies makes them increasingly popular.

- Higher cost
- Handheld from 300 MHz to 8 GHz from one antenna
- Very wide band frequency coverage
- Best for users that need to hunt interfering signals across a wide spectrum



The basic process described is most successful when within 100 or 200 meters of the interfering signal. For example, when finding an illegal repeater inside a building. To find interferers that are potentially hundreds of meters away, geolocation using triangulation on a digital map is the most efficient process. The handheld InterferenceHunter™ MA2700A includes an electronic compass that is monitored over a USB connection by the Field Master and Site Master Series. Connecting a directional antenna with a bandpass filter to the InterferenceHunter MA2700A activates a bearing line superimposed on a digital map on the Field Master and Site Master Series display. Sweep the antenna across the expected direction of the interfering signal and monitor for peak signal level, then pull the trigger on the handle when the antenna is pointed in the peak signal level direction. This drops a line on the map along which the interfering signal should lie. By changing location and repeating this process two or three times, the dropped bearing lines should intersect at a common point that is the expected location of the originating interfering signal.



Figure 17. Using InterferenceHunter MA2700A to Direction Find an Interfering Source

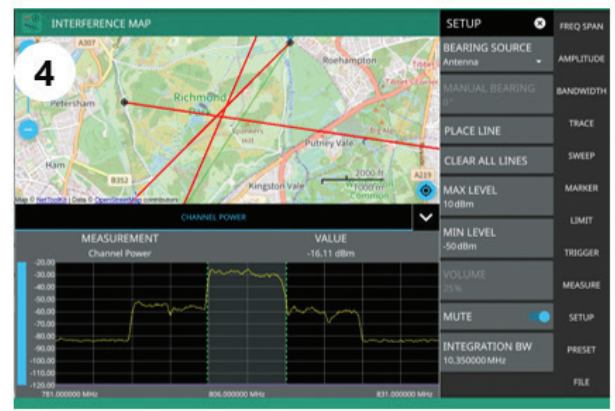
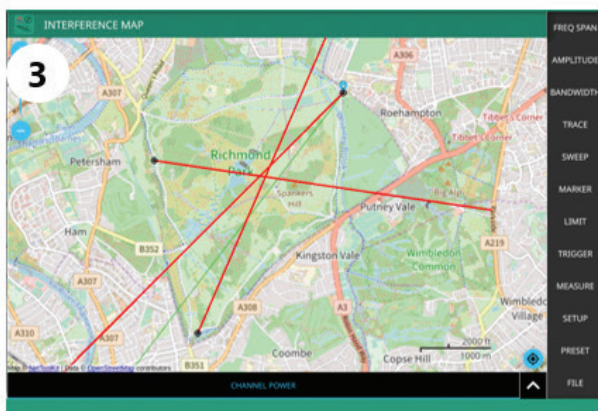
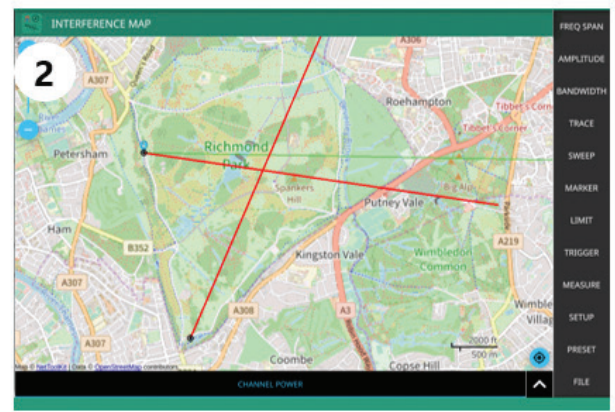
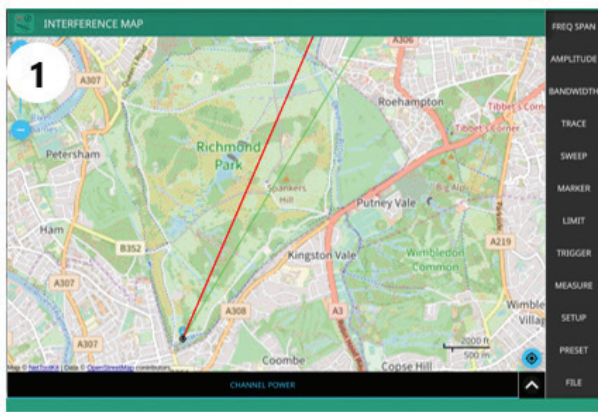


Figure 18. Geolocation the Interfering Signal Source by Triangulating on the Peak Signal Strength as Measured with a Directional Antenna from Three Locations

If the bearing lines do not intersect at a singular point, there may be multipath or fading issues influencing the result. A polar plot of signal strength can help indicate the presence of multipath signals at the point of measurement. Using the InterferenceHunter MA2700A to provide bearing information, by pointing the directional antenna away from your body while slowly rotating through 360 degrees, a polar diagram is created. A polar plot shows the relative signal strength of signals arriving from a full 360 degree rotation. If the signal is reflected off buildings and geographic features, then multiple peaks of power are seen on the plot. Some care and intuition is required to recognize if multiple peaks are caused by reflections or multiple base stations with a common transmit frequency. If multipath signals are suspected, it is best to move location and take a new triangulation bearing.

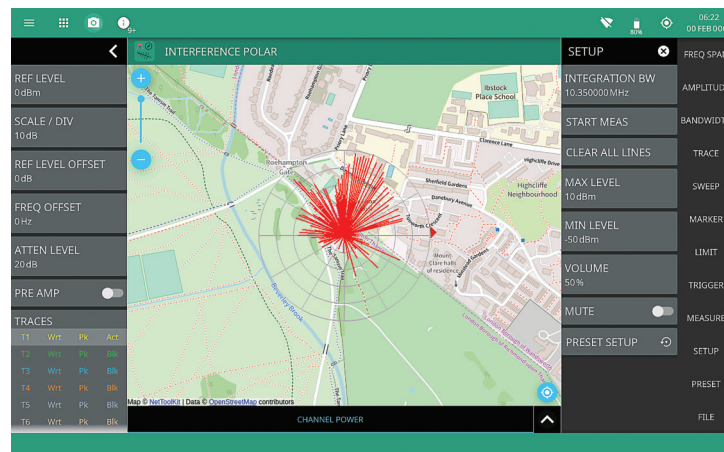


Figure 19. A Polar Plot Highlights the Direction from which an Illegal or Interfering Transmission is Originating

An additional tool available to find interfering signals when confronted with a large search area is the Mobile Interference Hunter (MIH) system MX280007A. MIH is a Microsoft Windows application that runs on a laptop or tablet computer and connects to the Field Master and Site Master Series through an Ethernet or a Wi-Fi interface. An MIH interference hunt automates the interference hunting process by capturing multiple channel power measurements over a wide geographic area. This is achieved using an omni-directional antenna mounted on the roof of a vehicle connected to the Field Master and Site Master Series input. These “power of arrival” measurements are plotted on a digital map and proprietary signal processing algorithms estimate the location of the signal of interest.

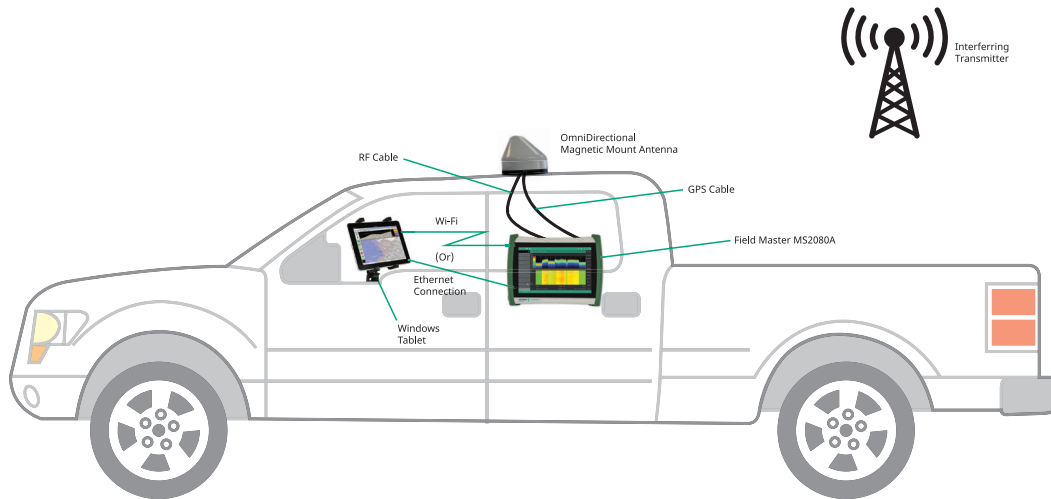


Figure 20. Spectrum Clearance and Interference Hunting Components



Figure 21. On Location with Mobile Interference Hunting MX280007A
Mobile Interference Hunter Software

Based on the power of arrival measurements captured during the drive, MIH plots colored breadcrumbs on a digital map that indicate relative signal power. The estimated position of the signal of interest is identified using a heat map superimposed on the street map.

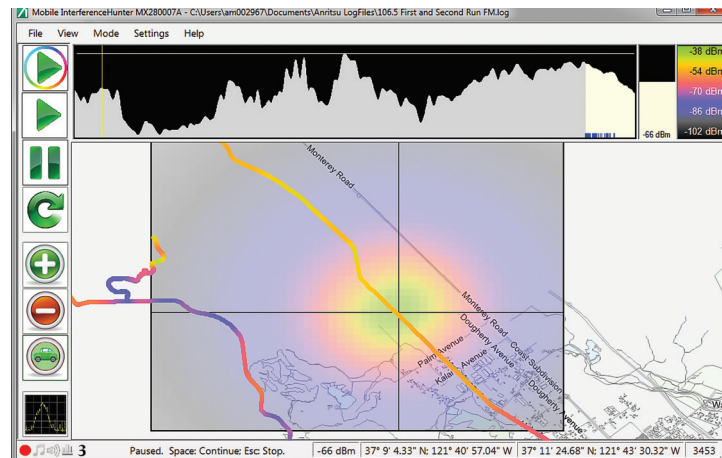


Figure 22. Heat Map Picture Screen from MIH

The MIH application is ideal for tracking down an interferer to within 100 to 200 meters, but the final identification of the signal typically requires a search on foot using a directional antenna.

Mitigation Options for Interfering Signals

Once the source of interference has been identified, the mitigation plan will depend on the nature of the interference source.

Where interference is a result of PIM or intermodulation products generated by environmental conditions in front of transmitter antennas, the simplest solution is to remove the offending item. This can be as easy as removing rusty objects from a roof top or hiding them behind RF absorbent material. This may not be practical if the offending object is a solid and permanent structure such as an advertising billboard or fence. In this situation, changing the direction of the antenna so that the offending object is no longer in the signal path may be the best solution.

When the interference is resulting from a consumer product used in a domestic setting, the fastest and easiest solution may be to offer a free exchange to the individual of a replacement product that complies with local and national regulations. This approach has been adopted by many network operators and national telecom companies who authorize their field technicians to purchase replacement items to an agreed maximum value to replace those that are causing interference issues.

Interference from industrial processes, such as arc welders or switching of machinery is harder to mitigate. Modern machinery should comply with national emissions regulations and ultimately these may need to be enforced.

Enforcement of the closure of illegal transmitters is typically the role of the national regulator. Strategies of national regulators vary. Some regulators actively monitor use of the RF spectrum and enforce licenses, searching out and closing down illegal transmitters. Others work on a complaints driven system requiring evidence of suspected illegal signals before they act.

Discover, Identify, Mitigate

The three stages of interference hunting, summarized as Discover, Identify, and Mitigate require experienced RF field technicians with the right instruments. Every interference hunt has unique origins and outcomes. Field Master and Site Master Series provide a comprehensive tool set to support the detection and location of interferers and, where necessary, the documented evidence expected from regulators for them to support mitigation.

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