Application Note

RF Interference Hunting Techniques

Spot, Find, Fix

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Spotting Interference or What Am I looking for?

As wireless services grow, interference, once uncommon, becomes a fact of life for wireless and broadcast services. A metropolitan area of a million people may have 1000 licensed two way radios, 600 cell sites, and 100 broadcasters. To this mix, add military, aeronautical, and emergency services. And then there are all the lower powered unlicensed signals such as Wi-Fi, wireless microphones or video cameras. If you consider that many of these services are expanding, being modified, ageing, or failing, it becomes evident that interference will be an issue.

First Indicators

The first indicators of interference are noisy links, for analog systems. Legacy AM and FM systems indicate interference problems by various noises. Hiss, hum, or even voices from other transmissions can be heard. For digital transmissions, such as HDTV, cellular, or P25, interference shows up as limited range, blocked or dropped calls, or low data rate. That familiar waterfall sound on your cellular phone indicates poor reception and a high bit error rate, which might be caused by interference.

A second indicator of interference is a high noise floor, or a high bit error rate, in the receive channel. Interference naturally affects reception first, where the signal levels are normally small. Some radio systems, cellular systems in particular, monitor the receive noise floor level specifically to detect poor reception conditions. Broadcasters, who don't receive, rely on customer complaints and field measurements instead.

A high receive noise floor is the diagnostic for interference. This warrants an interference hunt and identifies the geographic starting point.

Spotting Interference in the Field

Once a high receive noise floor has been identified, it's time to get a spectrum analyzer out and take a look. The first and best place to start looking is at the input to the receiver. If the receiver has a pre-filter, it's best to measure the signal after the pre-filter. This will allow you to see what the receiver, and the receiver's antenna, sees. The idea is to 1) measure the receiver's noise floor, and 2) to look for any obvious interference that might be present at the input to the receiver. It's important to get a "visual ID" on the signal at this point so you can be sure you are on the same signal later.

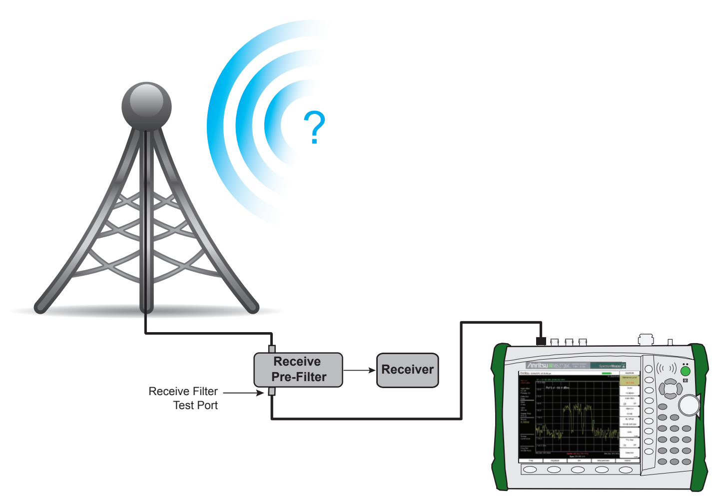

Figure 1. Spectrum analyzer hooked up to the test port of a receive pre-filter

What to look for?

Interference, as we have said before, is a receive issue. This means that you need to be looking for interference on receive frequencies. If you are working a cellular issue on a base station, and the base station has a high noise floor, you need to be looking on the uplink channels, not the downlink. Two Way Radio and other Push-to-Talk systems often use the same frequency for both the uplink and the downlink so this distinction becomes less important for them.

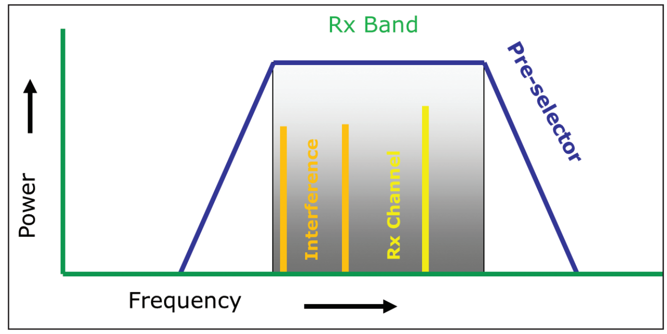

Figure 2. Interfering signals may be off-channel but inband.

A key point is that an interfering signal does not need to be on the receive channel to cause interference. It only needs to be within the receiver's bandwidth, which normally means that it only needs to get past the receive pre-filter. Once an interfering signal is present at 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 (noisy, waterfall effect, low data rate, dropped calls), except that the received signal strength measurements will be strong due to the high noise floor. It's as if you were at a noisy party, trying to hear a soft-spoken person while the band was playing. Plenty of information is getting to your ears, but much of it is preventing you from hearing the conversation.

This interference mechanism is called Receiver De-Sensitization, or Receiver Desense. In extreme cases, it can even result in Receiver Blocking where the interfering signal completely blocks receiver function. The key take-away is that interfering signals are 1) on your receive frequencies, and 2) need not be on your receive channel.

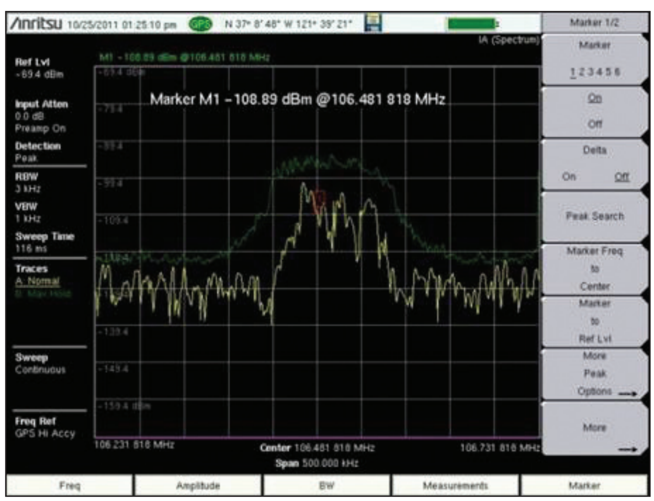

Figure 3. Using a Max-Hold and a Normal trace to characterize an intermittent signal.

Characterizing Interference

Once the interfering signal is spotted, it's important to characterize the signal before disconnecting from the receiver's pre-filter or test port. To characterize the signal adjust the spectrum analyzer's pre-amp, reference level, span, and resolution bandwidth controls to get the best view of the signal you can. Observe the signals' shape, bandwidth, and behavior over time. Look for frequency drift, amplitude changes, and frequency hopping. If the signal is intermittent, or turns on and off, use the Max-Hold trace function to create an envelope. If you have spectrogram capability (see figure 5), this can be used to check for periodicity. For signals that are intermittent with a long time between appearances, it can be helpful to use a "Save on Event" capability. This capability uses a mask automatically generated from the "normal" signal and only saves a trace when something unusual appears. Once saved, the traces can be examined for time-of-apperance, and signal characteristics. It may be helpful to save the trace for later reference. Most of all, make sure you will recognize the signal if you see it in another context.

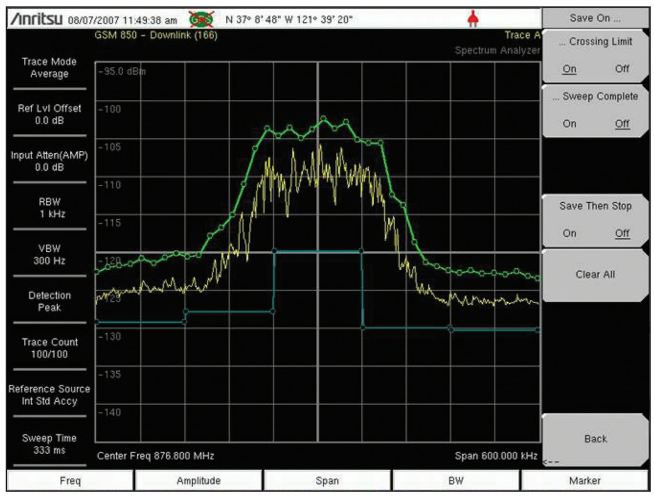

Figure 4. Save-on-Event masks.

Identifying Signals

One reason we mentioned using the test port on a receive filter is that this filter will prevent many signals from getting to the receiver. By using the receiver pre-filter test port, these eliminated signals are also not present at the spectrum analyzer input, saving you the time it would take to sort through signals that don't matter, and making your task simpler. If you don't have a filter on your receiver, and have an interference problem, it's likely time to get one!

While you are looking for signals that don't belong on the input to your receiver, it's important to know what signals are typically present in your bands. For instance, if you are chasing inference on a CDMA base station, it would be helpful to know what the signal from a CDMA cell phone looks like, which should be there, before you start chasing it as if it was interference! It's also important to know what other signals may be present, legitimately. This can save a lot of time when hunting signals. For instance, it's quite possible that a strong signal from a nearby transmitter in an adjacent band is getting through your pre-filter. This is common near band edges. It helps to know just who might be putting out interfering signals, and this knowledge can be an excellent short cut when hunting interference. If you can glance at the spectrum analyzer and confidently say "That's from company XYZ" the problem is much closer to being solved. Taking a survey of the spectrum ahead of time can help.

If this is not possible, and often, it is not, it may be possible to demodulate the signal and listen for the station ID call sign. Call signs are required to be transmitted at least every half hour. TV and Radio station call signs can be heard when using AM or FM demodulation techniques on the spectrum analyzer. Pagers typically transmit a Morse code station ID at the start of every page. This can be heard, using FM demod, or in Zero span, observed.

Sometimes, it is possible to identify a signal by its frequency and location using government data bases. For instance, in the United States, the Federal Communications Commission maintains a data base of signals and locations, linking them to owners, with contact information. Unfortunately, some of these data bases suffer from being out-of-date.

Some signals may be intermittent. Hopefully, they are periodic, or at least repeat with some discernible pattern. When they are short term intermittent, or bursty, signals, it can be helpful to use Max-Hold on Trace B, while keeping the Trace A in the normal view. This allows you to see the shape of a bursty signal and may help with visual identification.

Other signals may be intermittent over a longer period. Spectrum analyzers have two tools for these types of interfering signals. The first is called “Save-on-Event” and uses an automatically generated mask to spot unusual changes in the signal. Once spotted, the trace is saved for later analysis.

The Spectrogram shows how signals change over time. This colorful display has Frequency on the horizontal axis, Time on the vertical axis, and shows changing power levels as different colors. The time scale can be varied, depending on just how slow it needs to be to capture changes. The Spectrogram color axis can be changed to better show the signal of interest. In general, the Spectrogram is an excellent tool for spotting patterns. The signal in the adjacent figure is unstable in frequency. This clearly shows up in the spectrogram. This sort of oscillation in frequency is characteristic of a repeater with insufficient isolation between its input and output antennas.

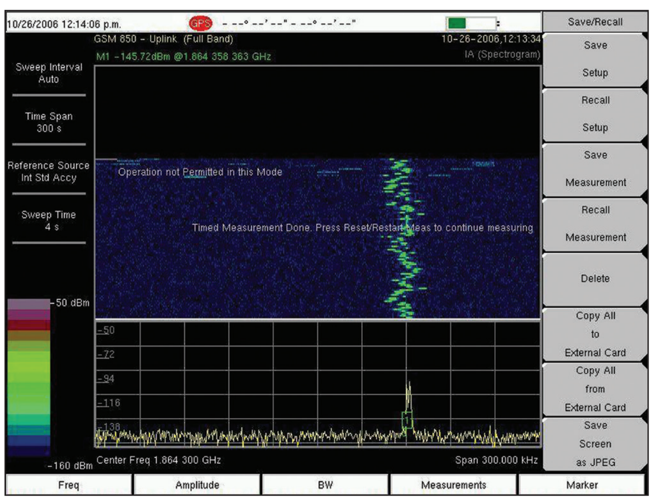

Figure 5. A Spectrogram display shows how signals change over time.

Many signals do not yield to the easy identification techniques and you need to find them by hunting. That’s what we will cover next.

Interference Mechanisms

When starting to hunt interference, there are a series of questions we need to ask:

- Is it On-Channel interference?
- Is it In-band interference?
- Is it Impulse Noise?
- Is it Harmonics?
- Is it Passive Intermodulation?
- Is it a Near Far problem?
- Is it intentional?

The answers to these questions will let us better identify the source. Let's look into these one at a time.

On-Channel Interference

This can happen to broadcasters due to channel assignments that are close in frequency while also being geographically close. It can also happen due to variations in the ionosphere, which will cause signals to travel further. The classic example of this is how distant AM radio stations can be received easily at night, but not during the day.

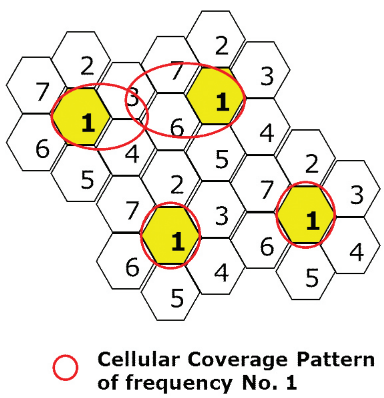

Figure 6. Cellular tiling patterns.

Cellular providers have a wider variety of issues. Sometimes, they use a tiling pattern for the cells, assigning frequency or codes in this pattern, which helps control cell overlaps. Factors that can cause excessive overlap, as shown between two cells near the top of the illustration include:

- Antenna tilt
- Valleys
- Antennas mounted on high buildings
- Better than expected signal propagation over water
- Errors in frequency settings
- And for CDMA systems, excessive multi-path.

Antenna tilt, valleys, and antennas mounted on high buildings all have a common cause. The antenna is transmitting further than intended because it is aimed too high. Water, oddly enough, allows radio waves to propagate better than over land. It is similar to how sound travels better over water than land. This can be a particular issue at national borders where a river or gulf forms part of the border.

Errors in frequency settings are more wide spread than one might think. A cellular operator in a medium size metro area might have 500 cell sites. If each cell has 9 radios (typical for a GSM site), there are 9 * 500, or 4,500 radios. All of these radios need to be set to the right frequency at all times. How often does a radio get swapped without being set to the right frequency?

Finally, CDMA systems are quite tolerant of multi-path. However, when the multi-paths exceed the capability of the phone's rake receiver to delay signals, the resulting "extra" paths are seen as interference. Typically, phones can handle 4 or 5 signal paths and still get signal gain. If there are more paths, they are seen as interference.

In-Band Interference

As we noted before, interference does not need to be on the receive channel. If the interfering signal is within the pass band of the receiver's receive filter, that is often sufficient to cause receiver desense. These signals can come from:

- Carriers from other services
- Intermodulation products
- Harmonics of other signals

The key point is that a signal does not need to be on the receive channel to cause interference. It only needs to make it through any receive filter to the front end of the radio receiver.

Impulse Noise

Impulse noise is created whenever a flow of electricity is abruptly started or stopped. A surprising variety of items can create impulse noise:

- Lighting suppression devices at a site

  These arc suppressors work by allowing excess voltage to arc to a ground. Over time, as they age, the breakdown voltage tends to lower, to the point where the higher power legitimate RF transmissions can cause arcing, which can create receive interference.

Figure 7. Lighting suppression device

- Electrical motors from elevators, floor buffers or even FAX machines
  - — Many types of electric motors have brushes, which can create quite a bit of arcing and sparking. Have you ever looked into the back end of an electric drill and seen the blue sparks around the brushes? That's a good example of impulse noise caused by an electric motor.
- Bakery ovens
  - — Bakery ovens have high wattage heating elements, over 2,000 watts. The ovens are typically regulated by turning the heating element on and off as needed to maintain the desired temperature. This switching action generates impulse noise.

Figure 8. Bakery Oven

- Welding
  - — This is a large electric arc that starts and stops every time the welder draws a bead. Need we say more?

Figure 9. Welder

- Electric fences
  - — Electric fences generate a short pulse of high voltage then turn it off for a second or two. This allows shocked animals time to move away from the fence before it shocks them again.
- Power lines, which may arc and spark
  - — Have you ever been near a high voltage transmission line on a damp or foggy day? Enough said.
- Light dimmers
  - — Light dimmers operate by suddenly turning the AC power off part way through the power cycle of the sine wave. This creates impulse noise. While these dimmers are filtered, filters may fail.
- Micro-arcing, or fritting
  - — Micro-arcing, or fritting, is created when RF connectors do not make firm contact. Fritting first shows up at peak RF power levels as wideband, intermittent, jumps in the noise floor. This can be a 5 dB to 20 dB jump.

Most of these impulse noise sources affect the lower frequencies. It's hard to give a specific number, but it's unlikely to see impulse noise above 500 MHz. Micro-arcing or fritting is the exception, since it is generated by the RF signal itself and can affect reception at any frequency. It is typically very broad-band, over a GHz wide. Micro-arcing or fritting can be caused by this sequence of cable mishandling:

1) Over torquing a 7/16 DIN connector
    a. This causes the center pins to move back into the cable a bit
2) Re-opening the connection, perhaps as part of a test
3) Re-connecting the cables at the right torque, but now with pair of center pins that do not make firm contact

There are many possible sources of impulse noise. This section is intended to give you an appreciation of possible sources. When looking for impulse noise, it is important to keep an open mind!

Harmonics

Harmonics are multiples of an RF carrier. For instance, if we had a transmitter at 100 MHz, it might have harmonics at 200 MHz, 300 MHz, 400 MHz, 500 MHz, and so on. Typically, the odd numbered harmonics (300 MHz, 500 MHz and so on) are stronger than the even harmonics. Governing bodies normally regulate the power level of harmonics. However equipment does fail or go out of specification. Many of those failure mechanisms create high harmonic levels. Also, if the original broadcast is at a high power level, even legal harmonics can be powerful enough to cause problems.

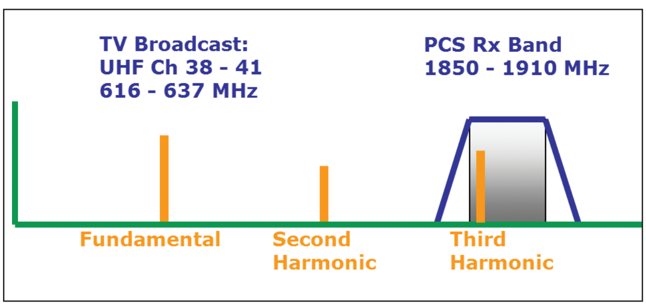

Figure 10. Harmonics can reach receive bands.

For instance, if you have a 1 mega-Watt transmitter in your area, it may be required to have a third harmonic 60 dB lower than its effective radiated power. However, 60 dB down from 1,000,000 watts is 1 Watt. Your receiver is looking for power levels in the neighborhood of 0.000,000,000,000,1 Watt. You can see how a 1 Watt harmonic could be a serious problem if its frequency is within the pass band of your receive filter. Here's an example: A third harmonic of the TV channels between 616 and 637 MHz lands in the PCS receive band, which goes from 1850 to 1910 MHz. If a Cellular PCS band tower is physically near a high channel TV transmitter, this can be a problem.

Transmitters do break. If one transistor of a class B transmitter goes out, the transmitter will produce only half of the sine wave it should be transmitting. This will create high power harmonics across much of the RF spectrum. This sort of harmonic display is called a comb or a "picket fence" signal.

Passive Intermodulation (PIM)

This is also called the Rusty Bolt Effect. It is caused when two or more strong RF signals combine in some sort of non-linear device, such as a transistor, diode, or even the crystals found in corrosion or rust. This corrosion may even be outside the radio system. It can be caused by a rusty fence, rusty bolts, corroded rooftop air conditioners, or even a rusty barn roof. Of course, it's also possible that loose or dirty connectors in an antenna feed line or poorly configured transmitters can be the cause.

Figure 11. Rusty Bolts can cause PIM.

PIM requires at least two strong signals and a non-linear device of some sort. Once generated, PIM frequencies are very predictable. If you have two original frequencies, F1 and F2, the third, fifth, and seventh order intermodulation products will be found equally spaced above and below the two original signals. For instance, if the two original signals are at 900 and 910 MHz, other PIM products will be found at 920, 930, and 940 MHz. They also will be found at 890, 880, and 870 MHz. There are many cases were legitimate transmitters can produce PIM that falls into another radio's receive band. There are calculators available on-line that help predict where PIM might fall, given two or more source signals.

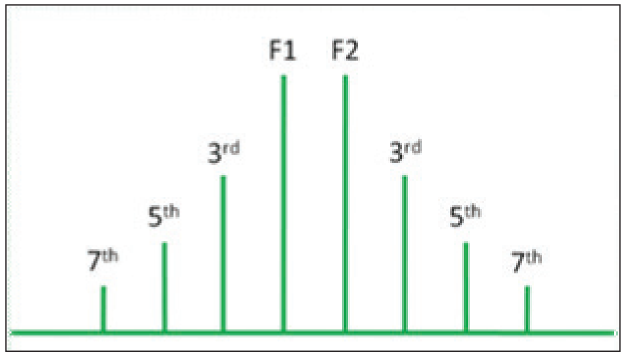

Figure 12. PIM occurs in predictable patterns.

For more detail, Anritsu has an application note available called "Understanding PIM" that covers concepts, causes, and testing for PIM in detail.

Near-Far Problem

The Near-Far problem is the RF equivalent of two people trying to talk across the room at a loud party. The surrounding noise tends to make conversation difficult or impossible. In the case where a wide area RF coverage is overlaid with a smaller area coverage, and the two operating frequencies are close enough to give receivers a problem, the nearby, in-band-but-off-frequency signal can overload a receiver trying to listen to the weaker signal.

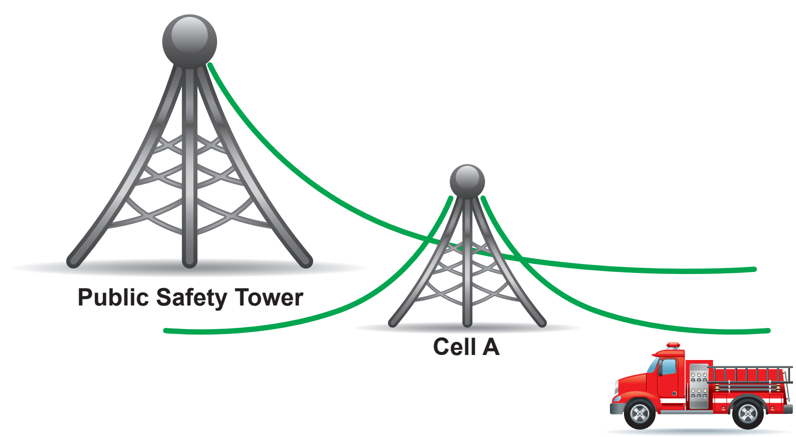

Figure 13. Near-Far problems with cellular and point-to-multi-point transmissions.

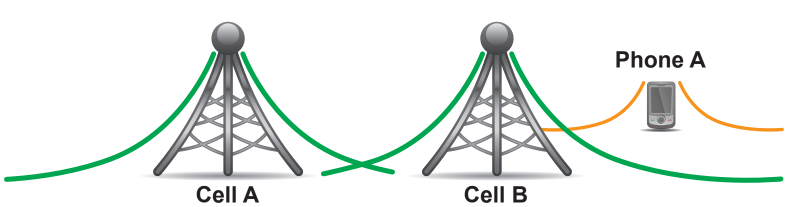

Figure 13. Near-Far problems with cellular and point-to-multi-point transmissions.

In the figure to the left, the green lines represent field strength of the respective transmitters. In this case, the fire truck is trying to listen to the public safety signal but has a radio receiver that is overwhelmed by the nearby cell tower signal. Two conditions must be present for this to happen. 1) The interfering carrier must have a frequency that is passed by the receiver's pre-filter, 2) The interfering carrier must be strong enough to desense the receiver. Solutions might include adjusting transmitter frequencies or improved filtering on the fire truck's radio receiver.

The near-far problem can also happen between cell towers, as long as the cell phone cannot make a handover. This may be the case near the edge of a metropolitan market where a cell phone of carrier "A" is broadcasting a strong signal to reach the distant cell tower of carrier "A." If there is then a cell tower operated by carrier "B" near that phone, the "B" carrier receiver may be temporary de-sensed by the loud Phone "A."

Intentional Interference

Some sources of interference are intentional. A quick search of the internet using terms like "Cell Phone Jammer" will find dozens of companies specializing in jamming. Regulators take a dim view of this practice, as you would expect. Jammers can be found in shopping malls, where employers want to ensure employee productivity, in cars, restaurants, churches, schools or even in military bases. Generally, civilian use of jammers is illegal.

In the United States, the Federal Communications Commission has concentrated legal action on companies selling cell phone jammers, citing potential harm from interfering with emergency communications.

Figure 15. Intentional Interferers

Interference Source Summary

There are a wide variety of scenarios that can cause interference. Interference can be directly on a receive channel, in a receive band, impulse noise, originate as a harmonic, or come from passive intermodulation, Cable TV Leakage, Oscillating TV PReamps, IM from co-located transmitters, wireless microphones, Cordless phones, DECT phones on European frequencies, and other unlicensed transmitters.. In addition, it can be a Near-Far problem or even be intentional. Knowing specific mechanisms that cause interference will help you spot interference in the field.

Spotting the Signal at Ground Level

Once an interfering signal has been spotted and characterized using the Tower's antenna, the next task is to find the same signal using a ground level antenna. This will allow you to search for the signal, either by direction finding (covered later) or seeking areas of higher signal strength.

The issue is that signals that may be strong at the altitude of the tower's antenna may be weak at ground level. There may be hills or buildings between your ground level location and the source of the signal.

The first thing to try is to see if the signal is visible near the base of the tower. If it is, the signal has been spotted at ground level and it's time to move to the next task, locating the source. If not, there are several things to try:

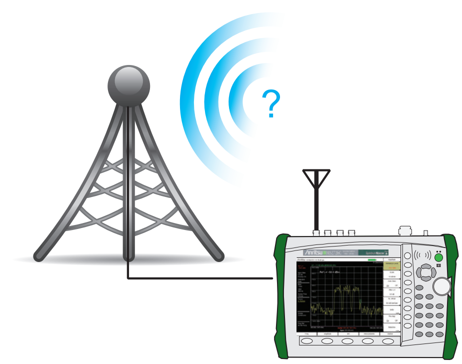

Figure 16. Spotting an interfering signal from the ground.

1. Check other sectors for the interfering signal. This will give you an idea of the signal direction.
2. Try looking for the interfering signal from a nearby rooftop or top floor. In an urban area, this may be the best way to direction find. You are up above all the buildings that cause RF reflections with, hopefully, a clear line of sight to the source.
3. Try moving to a hill of some sort. This can also give you a clear (or clearer) line of sight to the RF source.
4. Investigate nearby valleys, swales, or other low spots. If a RF interference source is in a valley, the radiation pattern will be only visible when you have a direct line-of-sight inside the low spot.
5. Use in-instrument mapping techniques to plot signal strength versus location. This can be a "brute force" but effective way to find the interfering signal, eventually. A magnetic mount Omni-directional antenna placed on your car's rooftop is useful for this sort of search.

Locating the Source

Once the signal has been spotted at ground level, it's time to move to the next step, locating the RF source. The method goes like this:

1. Get a geo-referenced map onto your spectrum analyzer
2. Select an antenna
3. Setup the spectrum analyzer to display the signal to best advantage.
4. Go to mapping mode
5. Find the direction to the signal.
6. Repeat the direction finding process from several locations.

Geo-Referenced Map

A Geo-referenced map has GPS latitude and longitude information embedded in the map. This allows a GPS-enabled spectrum analyzer to locate your current position when plotting signals on the map. To prepare a map, Anritsu provides a PC based software tool called Map Master, as a free download. This simple-to-operate utility allows you to quickly capture a map and reformat it into something that the spectrum analyzers can use.

Select an Antenna

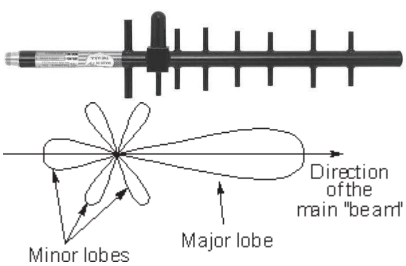

Figure 17. A Yagi antenna and its pattern.

Traditionally, a Yagi antenna is used for direction finding. They have:

- Good directivity, which means that it is easy to figure out when the antenna is pointing at the signal
- Good front-to-back ratio, which means that you will not likely be misled by signals coming from exactly behind the antenna.
- Generally low side lobes, which means that it's not too likely you will be misled by signals received from a minor lobe, which would throw off the direction finding.

The biggest disadvantage with a Yagi is that they tend to have a fairly narrow frequency band. You might need one Yagi for signals between 800 MHz and 900 MHz and a different one for signals between 900 MHz and 1000 MHz. If you work with a fixed set of receive frequencies, this becomes a minor issue.


Figure 18. A Log-Periodic antenna

A Log Periodic antenna has the broadest frequency range. A few antennas can cover most frequencies below 6 GHz. The trade-off is that they have less directivity. It is normally harder to establish a direction with a Log-Periodic as the minor lobes of the antenna are strong enough to be potentially confused with the main beam. One technique to deal with this is to set up the spectrum analyzer with a normal and a Max-Hold trace, which allows you to see small differences in amplitude easier. Another way is to hold the Log-Perodic antenna so that it's active elements are vertical. On some antennas, this helps the directivity.


Figure 19. A Panel antenna

A panel antenna can also be useful when hunting signals. While panels are not that directional, they generally have a very good front-to-back ratio. This allows quick elimination of reflections. The broad beam width can be dealt with by moving the antenna from side to side and seeing where the signal dips a given amount, say, 6 dB, on each side of the swing. Halfway between these two points is where the signal source is.


Figure 20. An Omnidirectional Antenna

Omni-directional antennas often are set up to be mounted on a car roof by a magnetic disk. These antennas can be used when seeking the strongest signal. Traditionally, signal strength is plotted as part of coverage mapping. However, the technique can also be used for signal hunting, and is particularly useful when dealing with multi-path. This technique eventually will lead you to the area of strongest signal, although it is normally be slower than direction finding.

Once the antenna is selected it's time to set up the spectrum analyzer.

Setup the Spectrum Analyzer

When setting up the spectrum analyzer, you may want to consider these items:

- Center the signal-of-interest on the screen.
- Span down to remove other signals from the screen
- Turn the preamp on. Generally, the preamp is useful when viewing signals originating from an antenna.
- Set the reference level so that the signal is 20 or 30 dB below the top of the screen for headroom. This allows you some margin when moving around mapping the signal.
- Set the span so that the interfering signal takes up about half of the display width. This allows you to view the true shape of the signal and gives you another check that you really are viewing the same signal you started chasing.
- Set the sweep mode to “Fast.” Some Anritsu handheld spectrum analyzers allow you to select a fast sweep mode, with slightly less amplitude accuracy. This will speed up the sweep time by as much as 100 times, depending on your span. This is very useful when moving the antenna around or looking for a signal that is intermittent.
- Some signals will benefit by lowering the Resolution Bandwidth (RBW). If the signal is not noise-like, lowering the RBW will lower the spectrum analyzer’s noise floor without lowering the signal, making it easier to spot. While lowering the RBW generally lowers the sweep speed, the “Fast” sweep mode mentioned above tends to more than make up for it.
- Set Trace B to Max-Hold, while leaving Trace A on Normal. The Max-Hold trace records your maximum signal strength while the normal trace shows the current signal level. This makes it really clear when your antenna is pointing at the maximum signal. Max-Hold traces need to be reset when you travel to a new location.

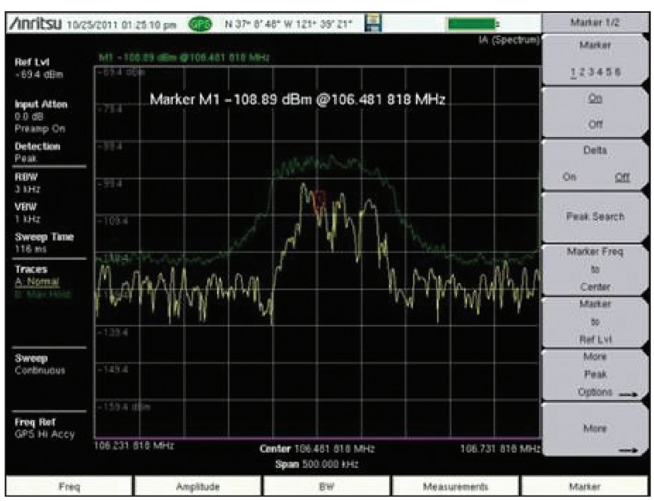

Figure 21. Signal centered on screen with Max-Hold enabled.

Go to Mapping Mode

At this point, it’s time to load the map and enter mapping mode. On an Anritsu handheld spectrum analyzer, this means entering Interference Analysis mode and starting the Interference Mapping measurement mode. It’s also time to install the GPS antenna on the spectrum analyzer and enable it. The GPS antenna should be mounted on a metal, perhaps your car roof, with a clear sky view. Now, the spectrum analyzer will show your current location on the map. If for some reason, the signal hunt leads you off the map, it’s still possible to gather data points and view them without a map. It is also possible to load another map to display the points.. Finally, they can be displayed by the Google Earth application.

Map the Signal

Once setup with a Yagi, or other directional antenna of your choice, and with the signal centered in the display, it's time to go to into the Interference Hunting Mapping mode. In this mode, the signal strength is displayed as a yellow bar with max hold and min hold lines. This takes its measurements from the center frequency of the spectrum display, so it's important that the signal be centered in the display before going to the signal strength mode, as mentioned above.

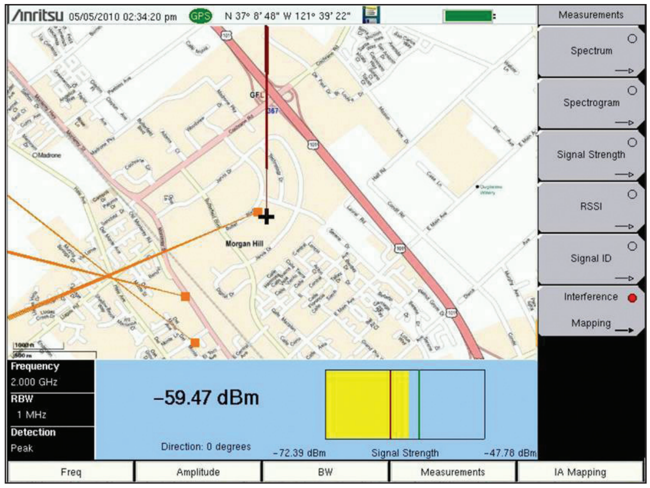

Figure 22. Plotting directions to an interference source on a map.

Once setup, with the GPS enabled, rotate the Yagi around to find the direction of the strongest signal. Bear in mind that hills and buildings look like a mirror to many RF signals, and can produce strong reflections. Once the direction of the strongest signal is located, turn the knob on the spectrum analyzer to move the on-screen "beam" or line, to a similar direction and press "Enter." This will place a record of the direction on the map. Now, move to a new location a few blocks, at right angles to the probable direction to the source, away and repeat the direction finding process. After three or more lines have been plotted, if any lines are wildly different than the majority of the results, feel free to ignore them, as they are likely the results of reflections.

The next step is to go to the location where the lines converge. If the uncertainty is large, it might be good to go through another direction finding exercise at closer range. If the area is small, it might work well to go to an Omni-directional antenna and seek the strongest signal while driving or walking around. Don't forget that the source of the signal may not be at ground level. In either case, you can expect to get quite close to the source of the signal using these techniques.

Direction Finding Tips and Tricks

One technique that works well at close range for screening out reflections is to step behind something that will shield you from the supposed source. If the signal is really coming from the direction you assume it is coming from, stepping behind a wall, building, shipping container, or van should shield your antenna from the signal and the signal strength should drop. If the signal is really coming from a radically different angle, the signal strength will not drop and you will know you have been chasing a reflection.

In heavily built-up urban areas, try to take your direction finding bearings from the tops of buildings. This will tend to eliminate many reflections that you would otherwise need to chase down to eliminate.

Another technique that works in urban areas is to drive to an intersection and take four signal strength measurements, one in each direction. Travel towards the strongest reading and take another set of readings at the next intersection. This tends to deal with multi-path issues.

You can also use the antenna's front-to-back ratio to your advantage. When you think you have a valid direction to the RF source, flip the antenna so it points in the opposite direction. The signal strength should go down by 20 dB or whatever the front-to-back ratio is for your antenna. If not, start thinking about reflections.

Mapping Signal Strength

Signal strength can be mapped for the more complicated interference hunts. This is a brute force technique. It can be slow, but it's hard to fool. Ideally, signal strength mapping is used over small areas.

In the illustration, a floor plan of a building was collected from the web, processed through Map Master, and loaded onto the spectrum analyzer.

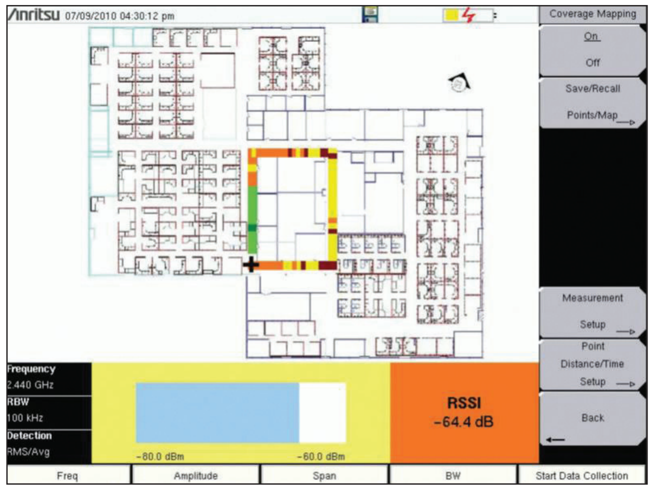

Figure 23. Plotting signal strength to find an interference source.

For this example, the spectrum analyzer has been setup to view the signal-of-interest much like it was above for direction finding. The instrument itself is in a coverage mapping mode and the thresholds for the colors have been set by the operator. Now, you can tap the touch screen at your current location to start taking measurements. The spectrum analyzer will record measurements at a constant rate while you walk down an aisle. Once you reach a corner, tap the screen again at your now-current location. The instrument will place the measurements equal distances apart along the line you just walked. In this case, you can see that the signal of interest is most likely in the green area. Further investigation proved this correct.

Locating the Source without a Map

Sometimes a map is not required for signal hunting. In the simplest cases, it can be faster to take direction finding readings with a signal strength meter, use the tried-and-true Max-Hold method, or simply travel until the signal strength readings increase.

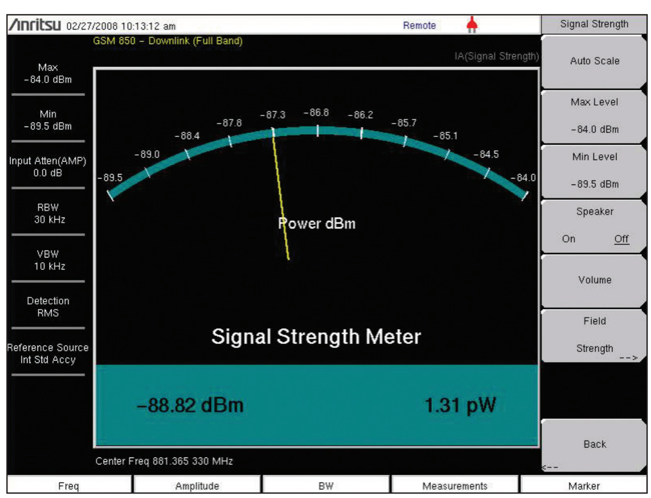

Figure 24. A Signal Strength Meter

The signal strength meter is available on many spectrum analyzers. It sometimes takes the form of an audible tone that changes pitch with signal strength. In other cases, it can look like a meter or a bar graph. The idea is to move a directional antenna around until you get the highest reading, move in the direction the antenna is pointing, and repeat the process. This can continue until the antenna is literally touching the source of the signal.

The advantage of a tone based system is that it allows the user to sight along the directional antenna while swinging it in a circle. This helps you spot likely objects that might be the signal source. The advantage of a meter based system is that it is easier to get exact highest readings, which help make sure that the antenna is pointing in the right direction. You can also use a two trace setup, with a normal and Max-Hold trace, as mentioned earlier, to do much the same task. This has the advantage that the peak signal value is always marked, and that any change in the signal is immediately apparent. After all, some of these interfering signals come from broken equipment and are inherently unstable.

If you use any of these non-mapped signal strength systems with an omnidirectional antenna, you will need to move around, seeking the strongest signal level. In small areas, this technique can be surprisingly fast.

Locating the Source

Once you are close to the RF interference source, you can use some of the non-mapped techniques listed above to find the source. As mentioned above, it is possible to even end up with your antenna touching the source, if it is accessible from ground level.

It's helpful to look around for possible sources of the interference. If you are chasing an intermodulation signal, look for rust or poor metallic connections. If in a residential neighborhood, look for consumer grade RF devices, like the TV remote pictured here. Intentional jammers are also a possibility.

Figure 25. A RF TV remote can cause interference.

Nearby radio transmitters are always a possible source of RF interference. They have the signal strength, and only need the right (or wrong) frequency, to become a problem. Antennas that are shared by multiple RF carriers are a great place for passive intermodulation. Finally, leaky cable TV lines or security cameras with an RF link can be an issue. The RF linked video cameras seem to be a particular problem as they seem to be freely exported/imported without regard to local RF spectrum assignments.

What to Look for in a Signal Hunting Spectrum Analyzer

Some spectrum analyzers are more capable than others when looking for interference. Handheld spectrum analyzers clearly have an edge over bench instruments, since they can easily go to where the signal is.

Long battery life is important. If you are going to be spending hours away from power sources, good battery life is critical. Voltage adapters for use in a car help, but in the end, you are likely to end up with the instrument in your hand, walking towards the interference source.

The ability to see small signals in the presence of large signals that may be nearby in the RF spectrum is important. This is specified as dynamic range. There are several different meanings to this term, depending on whose specification sheet you are looking at. However, for our purposes, we are talking about a spectrum analyzer that can see a small signal 90 dB or 100 dB below a strong signal, while both signals are present.

Another key capability is a fast sweep speed with a low resolution bandwidth. This allows the spectrum analyzer to sweep fast while still seeing a lot of detail. This also allows the analyzer to see non-modulated signals in the presence of noise, or modulated signals. It's hard to pin down a set of numbers here, because there are so many combinations of sweep speed and resolution bandwidth possible. However, a 1 MHz span is useful for many types of interference hunts. A good spectrum analyzer can use a 1 kHz resolution bandwidth to create a noise floor at -126 dBm, with a update rate of greater than 10 sweeps per second.

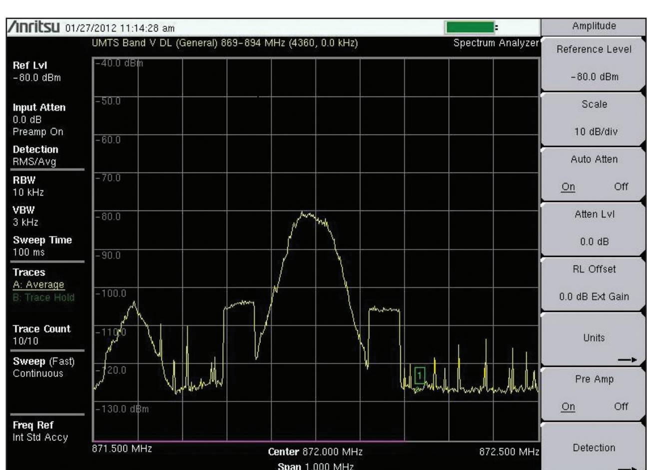

Figure 26. A fast sweep speed with good resolution.

Mapping is very useful when interference hunting. A key question during this process is “Where?” This is reflected in the common questions of “Where am I?”, “What direction is the signal coming from?” or “Where is the interfering signal strongest?” Mapping provides the “Where.”

Fixing Interference – Reporting and Resolving Problems

Once interference problems are identified, the next task is to deal with the issues. The mapping capabilities of many handheld spectrum analyzers can be used as evidence. In addition, screen shots with a GPS location tag are useful for the same reason. These screen shots can be embedded in reports and in addition to the GPS information, include time, date, and signal strength information. This can clearly show the effects of the interference.

Figure 27. Filtering can solve many interference problems.

Many times interference issues can be solved without recourse to legal action. Often, a calm and clear explanation of the issues is enough to convince everyone involved to move towards a resolution. During this explanation, a handheld spectrum analyzer can be convincing. In some cases, this may be enough to resolve the issue at the time of discovery. If the interfering signal affects emergency services, or emergency cell phone locating services, the potential for harm can be very persuasive.

Resolving the Problem

Filtering is often a solution. Earlier, we mentioned that interference needs to make it past the receiver’s pre-filter. Changing or enhancing the pre-filter often eliminates the problem.

Another solution, if the problem is related to passive intermodulation, is to clean up environmental diodes. This can range from tightening a rusty bolt or replacing a connector to replacing a fence, air conditioner, or even a barn roof.

When the interference is from a co-located transmitter, the co-location contract often specifies remedial action in the event of interference. This can include filtering, turning off a transmitter, or even relocating.

Getting illegal or poorly preforming transmitters turned off is another solution. In the case where the signal is clearly illegal, the solutions are simpler.

Band reject filters, or notch filters, on the receive input are quite useful. These can be used to reject or reduce the amplitude of a specific signal. A tighter band pass filter can be used to reduce the overall frequency range that reaches the receiver. After all, the receiver only really needs to have access to its receive channel frequency or frequencies. These additional filters can reduce the amplitude of out-of-channel signals and may even reduce or eliminate the effects of passive intermodulation interference.

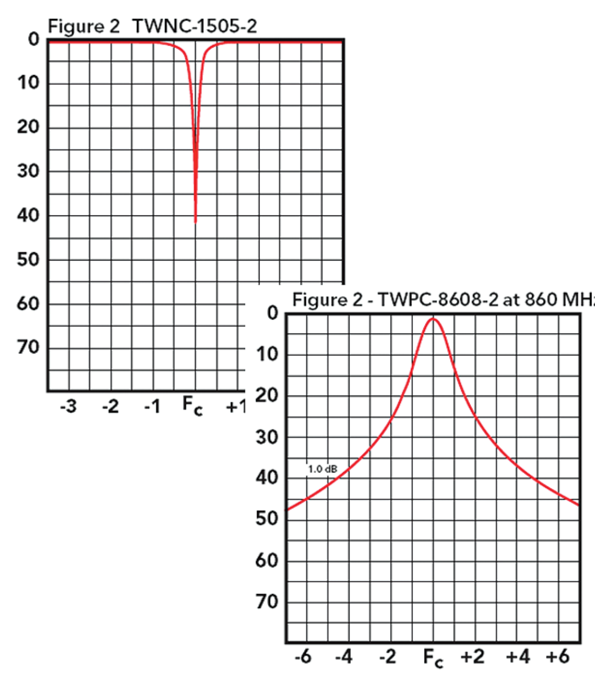

Figure 28. Notch filters or bandpass filters can cure interference problems.

Figure 29. Cleaning up sources of PIM can cure interference problems.

Cleaning up sources of passive intermodulation can go a long ways towards restoring full service at a radio site. For a roof mounted site, cleaning up old pipes or air conditioning units can often solve the problem. In other cases, rusty fences, barn roofs, or even electrical armored sheathing will need to be removed or replaced. In some cases, making a good electrical connection between the two pieces is enough to eliminate the problem. With a good, low resistance, connection, the environmental diodes are bypassed and no longer carry current.

Figure 30. Replacing old gas filled lighting arresstors can cure some impulse noise problems.

Gas filled lighting arrestors can age and create wide band noise, as mentioned earlier. Changing the lighting arrestors will cure this issue.

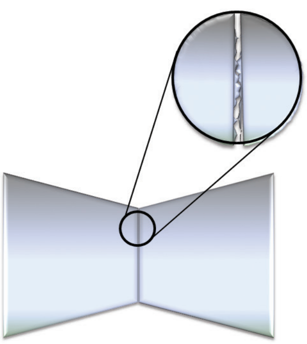

Figure 31. Connectors can cause fritting, or micro-arcing.

Micro-arcing or fritting is another source of impulse noise. The fix is to replace the connectors and use a torque wrench every time the new connector is tightened.

Summary

In this paper, we covered how to Spot, Find, and Fix interference.

Spot

Interference can be spotted by a raised receive noise floor. The extra power on the receiver input, which is not desirable signal, will lower the receiver's sensitivity, or De-Sense the receiver.

A good way to speed up the interference hunting process is to be able to recognize common signal types normally present in your bands. Sometimes, this will allow you to shortcut the interference hunting process and move directly to solving the problem.

If the signal is intermittent, a spectrogram display will help. This display type shows signal changes over frequency, power, and time. It is particularly useful when characterizing a signal that changes over time.

Find

The first place to look for interference is on a test port, or similar tap, on a radio's receive antenna. This gives the spectrum analyzer the same signal as the radio is seeing.

The second step in finding an emitter is to be able to see the signal with a portable antenna. Preferably, this is done at ground level, although in some cases, the search will need to start somewhere higher, perhaps on the roof of a tall building. In other cases, the search for a ground level signal will need to be done in a car, simply because of the pattern of the emitter.

Locating the source is best done with a mapping spectrum analyzer. This helps resolve the most complex cases in the quickest possible manner. Once close to the signal, or in simpler cases, you can hunt for the highest signal strength with the aid of tones that vary with signal strength, frequency selective power meters, or the traditional Normal and Max-Hold trace combination.

Fix

Once found, the measurements you gathered during the search can be used to document the interference. Documentation alone is often enough to resolve the issue. However in some cases, other action may need to be taken. This includes lowering signal strength, adding receive or transmit filters, adjusting antenna down-tilt, fixing passive intermodulation sources, or removing defective or illegal transmitters from service.

Notes

Notes

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