Application Note

Solving Your Radio Frequency Interference Problems

MS2721B, MS2723B, MS2724B

Spectrum Master™

RF interference takes many forms. In this application note we discuss how to detect and eliminate, or at least reduce, interference caused by discrete emitters. These emitters may be devices intended to be transmitters or they may be devices that due to design flaws or malfunctions are radiating signals where they shouldn't be. We will also discuss interference caused by intermodulation. We specifically do not discuss power line interference, which is too broad a topic to be given proper treatment here. Interference can occur at any frequency from below the AM broadcast band to microwave link frequencies and beyond.

The Problem

As more and more diverse uses for the radio spectrum emerge, the number of signals that may potentially cause interference inexorably increases. There are literally millions of radiators in operation at any one time in relatively small geographic areas. For example, in California there are more than 700 pages of commercial and government licensed emitters covering the state and the radio spectrum. In some cases a single license may covers dozens or hundreds of mobile users who could show up next to your site and unintentionally cause problems. That list doesn't include licensed private radio systems such as Amateur Radio, and GMRS. Of which there are over 100,000 in the state. As big as those numbers seem, they are tiny compared to the numbers of unlicensed emitters such as *Bluetooth*, Wi-Fi, wireless microphones, remote control cars, etc. And those numbers are small compared to the numbers of unintentional emitters such as TV and radio receivers, microwave ovens – basically any device that contains an oscillator or that, due to failure or poor design, oscillates and radiates signals.

Put a decent antenna on a spectrum analyzer, turn on the preamplifier if the signals aren't too big, set the input attenuation to zero dB and the frequency range from 500 kHz to about 1 GHz, and capture measurements for a while using max. hold to get an idea of the magnitude of the problem in your area. Here is a sample of a measurement taken in Santa Clara Valley. Several of the AM broadcast signals were so strong, that the preamplifier had to be turned off to make the measurement shown in figure 1. You may want to extend the top frequency to 2.5 GHz to include signals in the 2.4 GHz unlicensed spectrum where 802.11(b) and 802.11(g) reside.

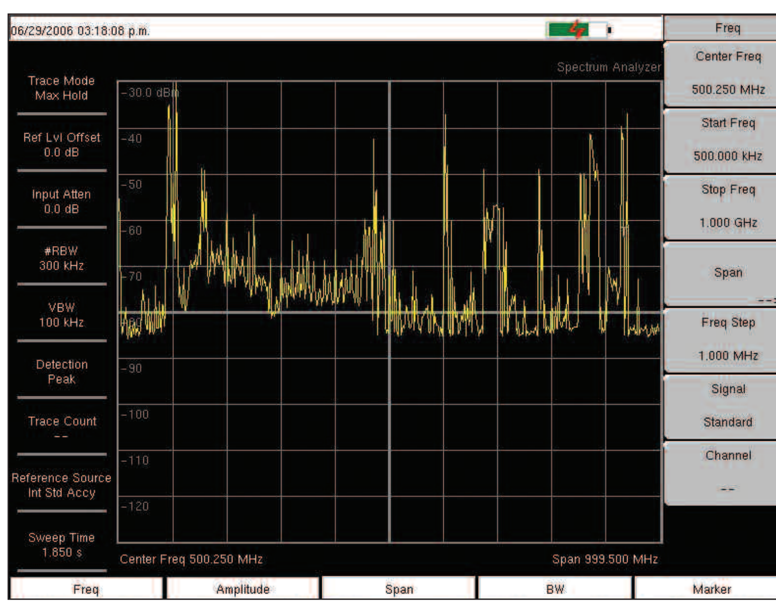

Figure 1. Crowded Radio Spectrum in Santa Clara Valley

Spectrum Competition

Some users of the radio spectrum have channel definitions that cause extensive overlapping of adjacent channels. Properly used, such overlap doesn't cause problems. This is generally the case for licensed services such as CDMA cellular services. However for unlicensed services such as 802.11, a user can install a wireless LAN with no regard or knowledge of other uses of the spectrum. For 802.11(b) and 802.11(g) there are only three channels that can be used near each other without causing extensive interference – channels 1, 6 and 13. In Japan an additional channel, number 14, was assigned with spectrum space that allows four channels to be used simultaneously. For 802.11(a) the channel assignments don't overlap so badly making 11 channels available. In the following graphs, non-overlapping channels are shown in blue.

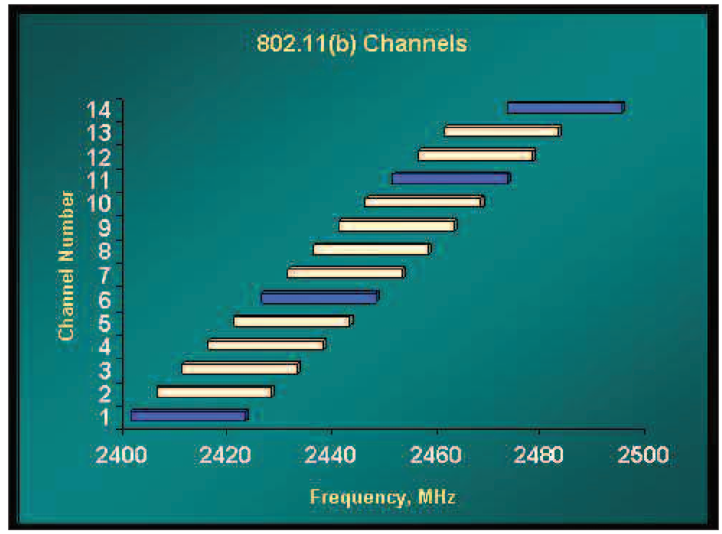

Figure 2. 802.11(b) and 802.11(g) Channels

Finding Interference

Here is where you need to get a good night's sleep so you can think clearly, put on your detective hat and think in ways outside of usual linear thinking patterns. Like any other kind of troubleshooting, there is no clue that should be discarded too quickly. There may be patterns to interference that can give clues as to the source of the problem. Pay attention to the time of day, day of the week, time of the month and time of the year as well as temperature, humidity, precipitation, etc. There have been instances when coverage problems for VHF and UHF radio systems occurred only in the spring and autumn and all attempts to find interfering signals proved to be fruitless. By patient record keeping of coverage degradation, the system operators eventually discovered that rising and falling sap caused deciduous trees in the intended coverage area to absorb more energy. It seems that they became decent dummy loads due to resonance effects at the operating frequencies of the radio systems.

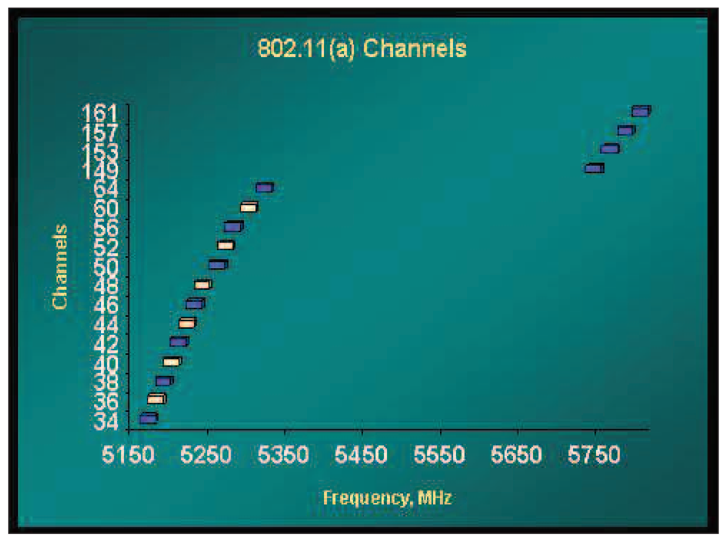

Figure 3. 802.11(a) Channels

Sometimes interference is caused by fundamental overload caused by a nearby large (perhaps mobile) signal. Such interference causes a reduction in the effective sensitivity of the receiver due to saturation of the front end mixer. This can be difficult to solve if the interfering emitter is on the air only sporadically. Clues such as occasional reduction in the coverage area, dropped calls for cellular systems and the inability of distant users of a land mobile system to communicate through a repeater in locations where they normally can do so can help you to troubleshoot this sort of problem. If you determine that you have fundamental overload interference, about the only way to solve the problem is by filtering to reduce the amplitude of the interfering signal enough that the sensitivity of your receiver isn't significantly degraded. The filter could be a bandpass filter that covers your intended receiving frequency range or a notch filter centered on the interfering signal, or both.

Not all interferers are continuous emitters

Continuous interference is the easiest to resolve. Use a directional antenna to track down signals that are there all the time. Radio Direction Finding, often called DFing, is an art in itself. In some parts of the world it is a major sport with prizes for quickly finding a hidden transmitter. Here is basically what you do.

1. Center the signal you want to track down on the spectrum analyzer display.
2. Rotate the antenna to find the maximum signal strength. Rotate the antenna 180 degrees from what appears to be the strongest point to make sure that you are not receiving the signal off the back of the antenna. Most directional antennas have very sharp nulls off the side of the antenna. Use that fact to confirm your fix by rotating the antenna 90 degrees to make sure the weakest reception appears at the expected bearing. Sometimes it won't, which may indicate that you will need to deal with multi-path signals, which can significantly complicate directional finding.
3. From your position, draw a line on a map in the direction of arrival of the signal. Due to reflections and multipath this won't always be the direction to the emitter, but it gives a good starting point.
4. Go to another position not along the line you have drawn. I like to monitor the signal continuously using a non-directional antenna while going from one location to another since I might gain clues or drive through an area where the signal is particularly strong and worth investigation.
5. From the second position find the direction of arrival and draw another line on the map. Where the two lines cross, is probably close to the location of the emitter. If the lines don't cross, one or both of them may be reflected signals
6. If the lines didn't cross or if the position appears to be an unreasonable location for a transmitter, take more direction finding measurements until you get a pair that crosses.
7. Go to the location where the lines cross.
8. Measure the signal; it probably will be very strong. Look around for the source. It may be obvious or you may need to knock on doors.
9. If the signal isn't strong at the location where the lines crossed, you were unlucky with reflected signals or the source is mobile. One clue that may lead you to the conclusion that a source is mobile is rapid fluctuations in the signal strength as multipath signals add and subtract from the direct signal as their path lengths vary and the signals go in and out of phase.
10. If you believe that you were misled by reflected signals, a good approach to find the real source is to make direction-of-arrival measurements from several locations, plot all of them on the map and investigate the location or locations where lines cross. Another approach is to use a small directional antenna mounted on your vehicle and drive, as much as possible, in the direction that causes the signal to get stronger.

However most of the time you won't be so lucky, especially in cases involving unintentional emitters.

Tracking down intermittent emitters requires patience and dedication. Fortunately there are measurement tools now available that reduce the need to unblinkingly stare at a spectrum analyzer screen so you won't miss the intermittent signal when it does occur.

In the MS2721B, MS2723B and MS2724B, you can employ "save on event" to capture suspect signals. Here's how it works.

1. You define a spectrum mask that the suspect signal will exceed. Depending on what you want to catch, you can use an upper mask or a lower mask or both.
2. You set save on event to automatically save measurements that exceed the value set by the mask or masks. Traces that contain measurement points that are larger than the upper mask or smaller than the lower mask are saved into the instrument's internal memory.
3. Do a trial run to make sure that the mask is set properly so it doesn't save too many uninteresting traces.
4. Let the instrument run to capture enough instances of the suspect signal so that you may be able to detect a pattern to the occurrence of the interference, if there is one.
5. Connect the instrument to a computer upon which is installed Anritsu Master Software Tools (MST). The latest version of this free software may be downloaded from the Anritsu web site at www.us.anritsu.com. You may connect to the instrument either by using a LAN connection or by using the USB device port on the instrument.
6. Run MST and connect to the instrument.
7. Download the saved measurements into a separate directory on the computer. All measurements that were saved because they exceeded the limit lines are named "LIM" followed by the date and time, such as "LIM20060214152306" for a measurement that was saved on February 14, 2006 at 15:23:06, or 3:23:06 PM.
8. Use the folder spectrogram option to view all the saved measurements. This option is located under | File | New… | Folder Spectrogram |.
9. When folder spectrogram starts you will be asked to specify the directory that holds the measurements. Navigate to the directory, click on it to highlight the directory name. Click OK to start the process of generating the spectrogram and other related views of the data.

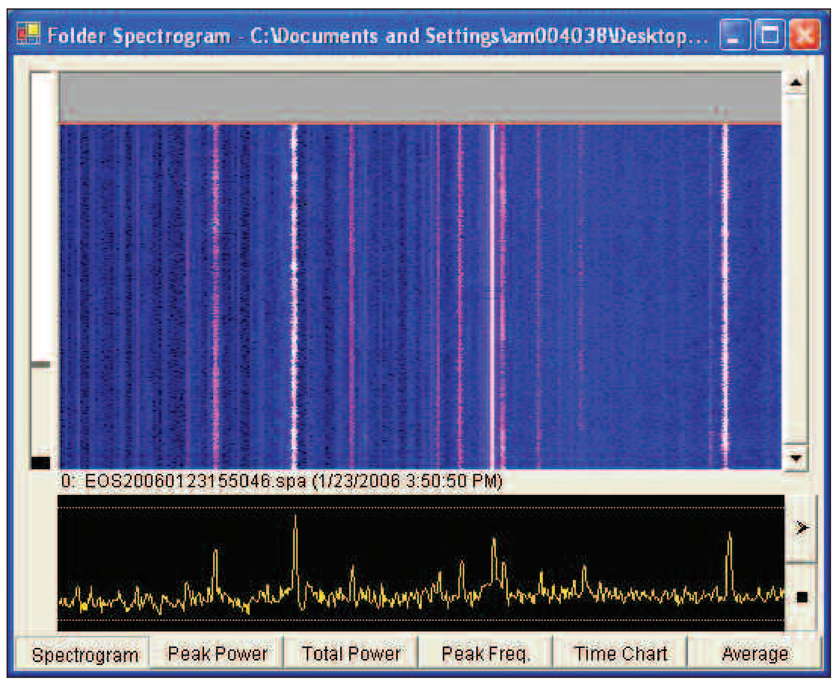

Figure 4. Folder Spectrogram

Once you have the folder spectrogram display you can switch views to see the information in different ways. For an intermittent emitter, the time chart sometimes can give you helpful insights as to when the emitter was on the air. You may also select a display of peak power over time, total power over time, the frequency containing the highest power level over time and the average power over time. Figure 5 shows the time chart of a folder spectrogram. It shows that there were between 7 and 9 sweeps captured in each time slot. The time slots are divided evenly between the start and end times of the files in the folder. Using this view, you can see if there is any insight to be gained by discovering if there is any timing pattern to the occurrence of the interfering signal.

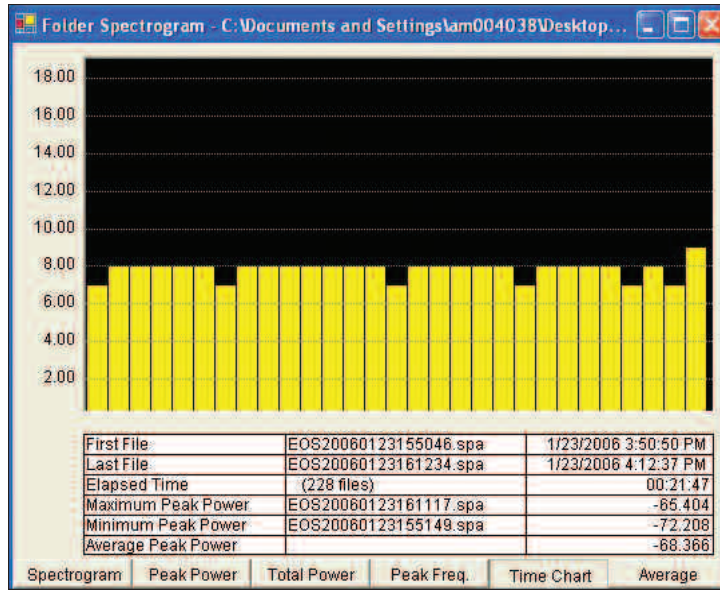

Figure 5. Folder Spectrogram Time Chart

There are options in the folder spectrogram section to filter the files contained in the folder to display only those files that exceed the level set by a user-defined limit line. Also there is an option to create a movie of the files in the directory. The user can select the frame rate from 1 frame to 10 frames per second. The video file can be viewed directly or imbedded into a presentation.

Frequency Hopping Emitters

Frequency hopping emitters can cause intermittent problems. Some slow hoppers may spend several seconds on a frequency before moving on because of that they can be among the most difficult to find. Assuming all the frequencies used by the emitter fall in a relatively small band, here is a way to find one.

1. Make an educated guess as to the probable frequency range of the emitter and set your spectrum analyzer to cover that range and a little more, just to be sure.
2. Set a limit line that will be exceeded by the interfering signal but is higher than known emitters in the range. The limit line may need to be relatively complex if there are several strong emitters in the frequency range.
3. Set the instrument to capture signals based on exceeding the limit line.
4. Let the measurements run for a long enough time to capture a representative sample of the problem.
5. Use Master Software Tools to move the measurements from the spectrum analyzer into a separate directory on the computer.
6. Create a folder spectrogram in MST using | file | new | folder spectrogram |
7. Look at the time view and the average power views to see what can be learned.

Once you have identified the frequencies used by the hopper, you may be able to use a directional antenna to triangulate on the source. We suggest creating a bumpy limit line to help you pay attention to frequencies used by the hopper. Simply sweep over the frequency range and use traditional DFing methods to find the emitter.

If your spectrum analyzer has a channel scanner option, you may be able to create a custom channel list that includes the hop frequencies that you have identified. This will make it easier to pay attention to only the identified hop frequencies.

Mobile users can cause temporary problems anywhere as they move around.

Imagine the intrepid policeman trying valiantly to communicate with the base station while pinned down near a cell site that is operating on a frequency near the policeman's frequency. Not only can the police transmitter interfere with the cell site, but the cell site's signal can interfere with the police's ability to receive a distant signal. Such interference can be caused by fundamental overload or broadband noise or both. In addition, intermodulation products can potentially place a hash of noise at inopportune frequencies.

For each licensed land-mobile system, there are multiple mobile transceivers. Such mobile users can show up anywhere, sometimes making life difficult for other systems that happen to be nearby. You may have designed a site that is properly filtered and shielded against nearby fixed transmitters. A mobile transmitter that happens to be nearby can potentially cause fundamental overload problems, or if you are unlucky, lead to the generation of harmful intermodulation products. These sorts of problems are extremely difficult to prevent completely.

Intermodulation Product Interference

Receiver Input Intermodulation
Receivers live under constant bombardment of signals which enter through the antenna port. Some of these signals are immediately attenuated due to front-end filtering, which often called pre-selection. When the remaining signals reach a non-linear element, such as a detector, mixer or amplifier, harmonics of the signals are generated. Most of the harmonics are well outside the pass band of RF and IF filters and cause no problems.

However there are some frequencies where the mixing products – intermodulation products – of the various signals fall on or near the desired receive frequency range. The intermodulation products that tend to cause the most problems are the so-called odd-order products. This is true because odd-order products of signals near your desired receive frequency also are near your receive frequency. Channelized communications systems tend to suffer more from these issues due to the uniform spacing of the channels.

Figure 6. Location that may have serious intermodulation issues

Intermodulation Example

Any communications system can suffer from intermodulation interference problems. Problems are exacerbated by having evenly spaced channels such as this VHF maritime communications example shown in figure 7 where 50 kHz channel spacing is used. In this example a user is attempting to use channel 3 at 156.15 MHz. There are nearby users operating on channel 4 at 156.2 MHz and channel 5 = 156.25 MHz.

The second harmonic of channel 4 is 312.4 MHz. A third order intermodulation product falls squarely on channel 3. This third order product could be generated in the receiver, in the output of a transmitter or be caused by environmental diodes caused by rusty and corroded metals on one or more of the vessels.

$$312.4 - 156.25 = 156.15 \text{ MHz}$$

These channel assignments are from the New Zealand maritime communications regulations.

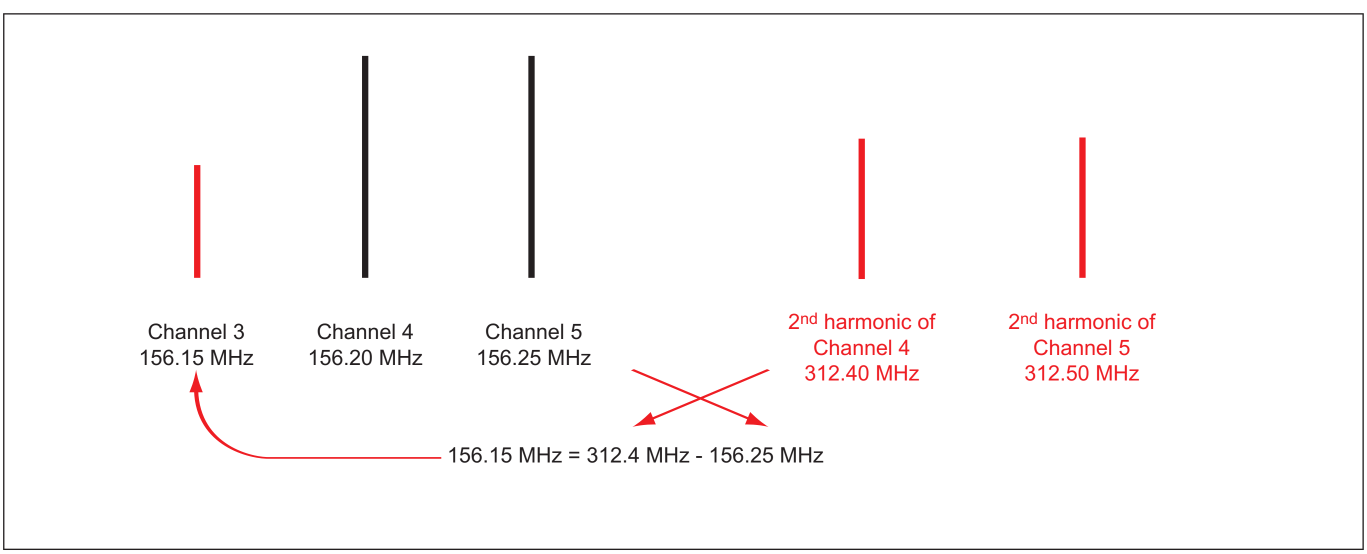

Figure 7. Intermodulation Example

Transmitter output intermodulation

With today's complex modulation formats, there is RF energy at many frequencies at the output of a transmitter. When non-linearity exists in the transmitter's circuits, intermodulation products are generated within the transmitter and transmitted along with the desired signal. These products may interfere with nearby channels and even distort the intended output of the transmitter. The measurement of adjacent channel power ratio of a CDMA signal demonstrates the issue. An ideal CDMA signal would have skirts that drop all the way to the noise floor.

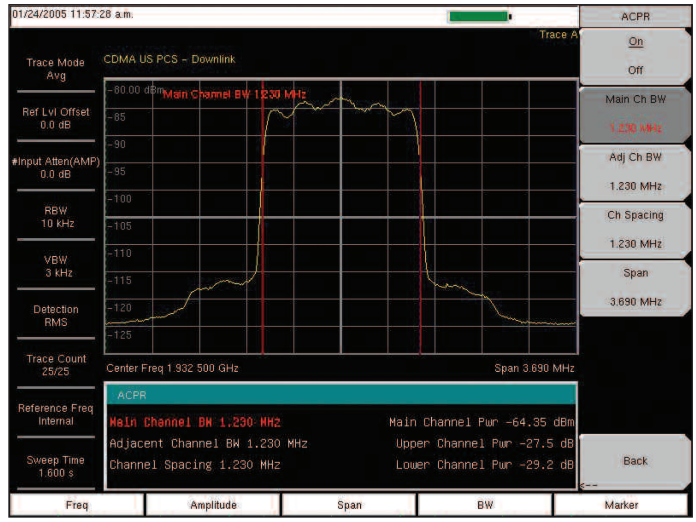

Figure 8. Adjacent Channel Power

Re-transmitted or Re-radiated intermodulation

When there is non-linearity in an output amplifier, any signal picked up by the transmit antenna and fed into the transmitter output has the potential of creating intermodulation products which are then transmitted. Also, a receiver input can create intermodulation products that can be sent back to the receive antenna and radiated.

Mitigating receiver and transmitter intermodulation

Filtering is the key to reducing receiver and transmitter intermodulation. The basic concept here is to keep undesired signals from entering a transmitter output circuit and from entering a receiver input, creating intermodulation products that can interfere with the signal you want to receive or be radiated from the receive antenna.

For a single-channel systems, use a band-pass filter to reduce the amplitude of out-of-channel signals. For wider-band systems, use an isolator and a filter if possible to absorb any re-radiated signals.

Transmit bandpass filters are appropriate for single channel systems. Isolators are also useful, although high powered isolators tend to be very expensive. If you use an isolator on a transmitter output, be sure to follow it with a bandpass filter as shown in figure 10 since isolators can generate harmonics and intermodulation products by itself because of the nonlinear characteristics of ferrite.

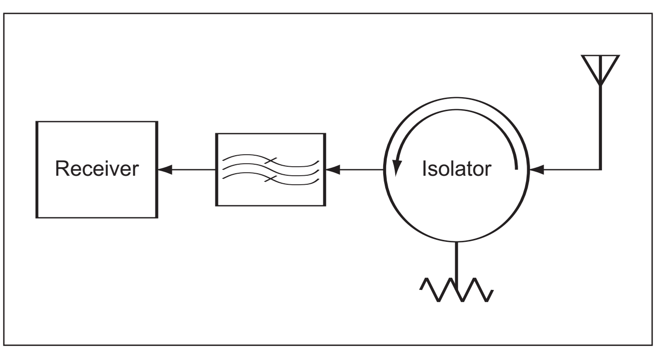

Figure 9. Filtering receiver input

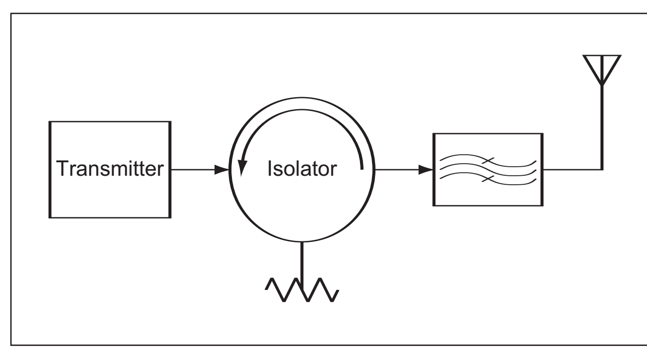

Figure 10. Filtering Intermodulation at Transmitter Output

Passive Intermodulation

Passive intermodulation is a term that is applied to situations where intermodulation exists and there don't appear to be any non-linear elements present to cause intermodulation. While to the casual observer, there doesn't appear to be anything non-linear in such a string of components, in fact there can be - you just may need a microscope to see the non-linear elements. Different metals when connected directly together may, under the right circumstances, create a non-linear element that can, when excited with enough power, create intermodulation products.

For passive intermodulation to occur there are two or more signals directly involved feeding substantial power into a series of passive components such as filters, sections of coaxial cable, diplexers and antennas. The most common way for this to occur is for multiple transmitters to be coupled into one feedline structure. It can also occur with a single carrier with complex modulation (such as CDMA and GSM) if the power levels are high enough.

Low Passive Intermodulation Products

Responding to market need, many passive component manufacturers have begun testing their products and specifying intermodulation performance. You can find passive intermodulation specifications on coax cable, connectors, filters and adapters and any other components and devices that are subject to the application of high power in base stations of all sorts.

Phase Noise Interference

What is phase noise?

The random variation of the phase of a signal with time is called phase noise. On a spectrum analyzer you see phase noise as "skirts" on a signal as shown in figure 11.

Whose phase noise is causing the problem?

If there is interference being caused by phase noise, almost universally the transmitter whose phase noise is causing trouble will be nearby since phase noise skirts are significantly lower in power than the main signal.

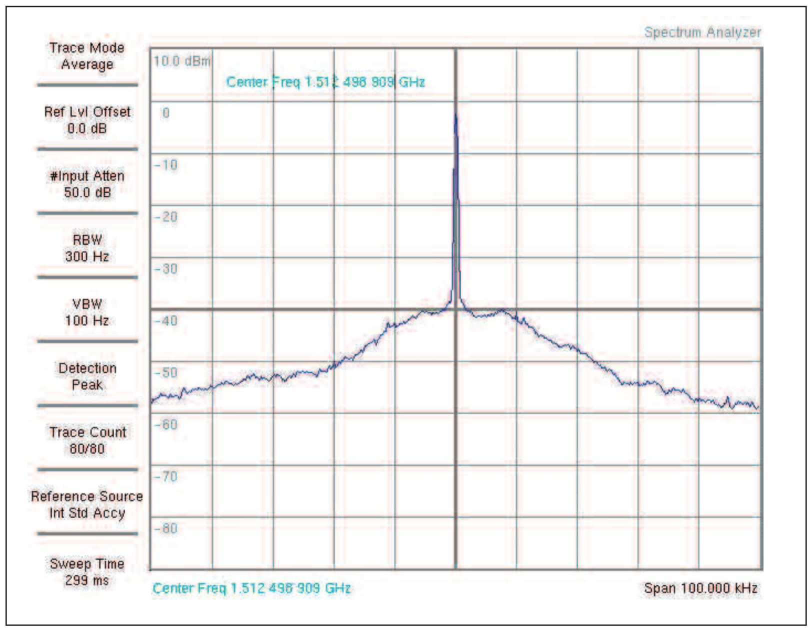

Figure 11. Phase noise skirts

Assuming that the carrier of the offending transmitter is off screen, you can use the phase noise measured on the spectrum analyzer to indicate if the carrier frequency is above or below the frequency to which the spectrum analyzer is tuned. If the noise floor is higher at the left side of the spectrum analyzer than the right, the offending signal is at a lower frequency. This makes it easy to tune to the center frequency of the offending transmitter.

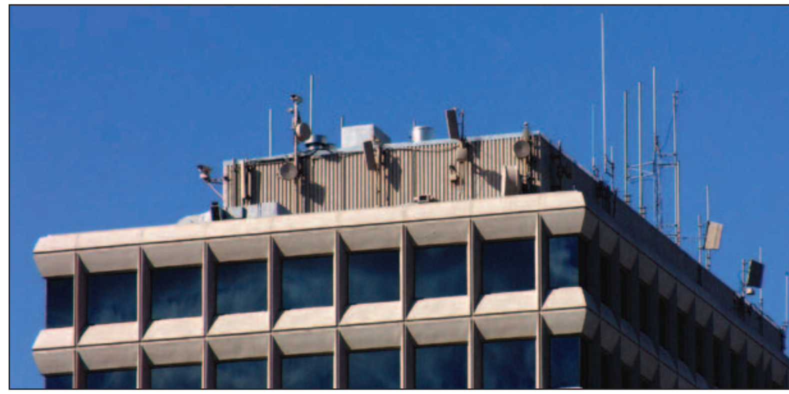

Figure 12. Phase Noise and Intermodulation Interference Location

You can use normal direction finding techniques to find the offending transmitter even if you aren't tuned to its center frequency – simply rotate your directional antenna to maximize the amplitude of the phase noise signal. However, direction finding is usually easier if you tune to the actual transmitter frequency since the signal will be much stronger than the phase noise sidebands and DFing will be simpler.

What do you DO about interfering phase noise?

There are several things that can be done to mitigate phase noise interference. This list is in no particular order since what needs to be done depends on the situation.

- Filter the offending transmitter with a bandpass filter to reduce the overall phase noise sidebands
- Use a notch filter on transmitter to reduce the sidebands at input frequency, such as shown in figure 13.
- Fix the offending transmitter so its local oscillators are cleaner.
- Reorienting antennas may help, but certainly isn't a real cure.

Primarily, the changes need to be done at the offending transmitter. Attempting to filter out phase noise interference at the receiver does no good since phase noise is broadband and impinges on the frequencies you intend to receive.

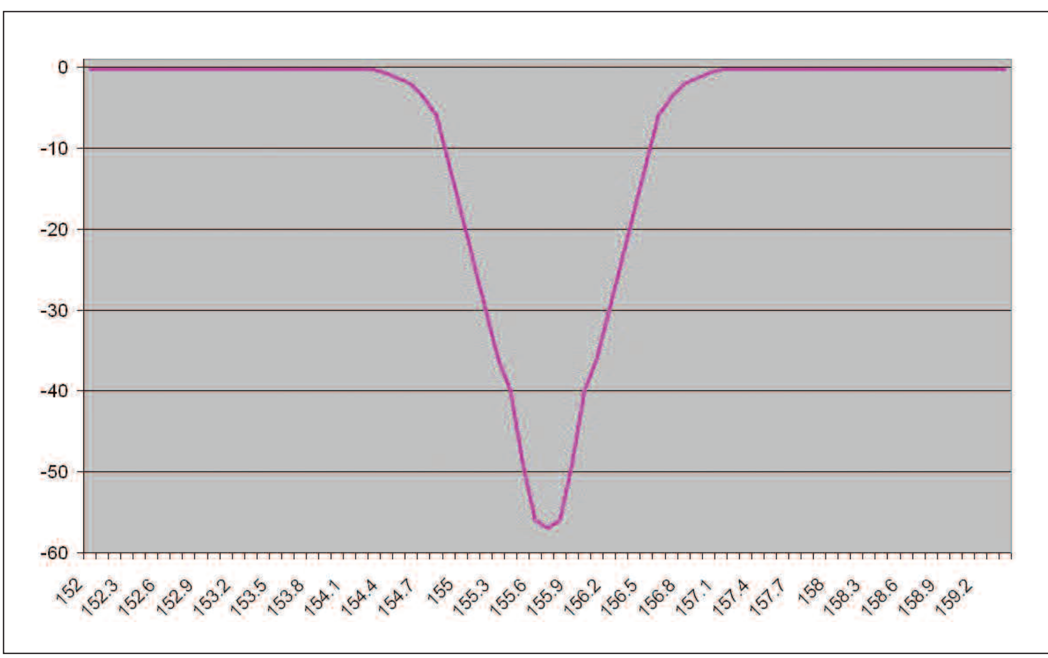

Figure 13. Transmitter Notch filter to help reduce interference

Unintentional Emitters

Whenever electricity flows through a circuit, there is the possibility of radiation due to poor connections that cause arcing or sparking. As you are tracking down unintentional emitters, be especially aware of motors in the area. They don't have to be large motors. Arcing and sparking in cheaply made motors in shredders, printers, copiers and other consumer devices have been known to cause serious interference due to the broadband nature of the signals they generate. In these cases paying attention to the time of day may give important clues.

Big motors can also cause problems as their brushes wear. Here again time-of-day interference patterns can yield helpful clues. For example, is there an increase in interference at the times of days when elevators get lots of use – morning when people are arriving at work, mid-day when they go to lunch and evening when they go home? Or, perhaps interference is low at those times, showing up during work time.

Problems that show up only at night may involve temperature changes or perhaps degraded or poor quality custodial equipment such as vacuum cleaners and floor polishers.

Almost any electrical device is potentially a source of interference. Just a few examples include old electric blankets or heating pads left plugged in and forgotten, a sparking electric fence, an oscillating public address amplifier, power line noise caused by sparking or arcing. The possibilities are virtually endless. Arc welding can be a source of broadband intermittent interference. The troubleshooting methods and direction finding techniques tend to be the same regardless of the source of the interference.Some people worry about interference caused by coronal discharge on high-tension power lines. Corona discharge is the partial breakdown of the air that surrounds an electrical element such as a conductor, hardware or insulator. While Corona makes considerable audible noise, radio signals emitted by coronal discharge don't tend to create much radio frequency interference since the signals are radiated from the corona ball and not in the power line conductor itself. RF interference caused by coronal discharge therefore occurs in the immediate vicinity of the discharge. The amplitude of the interference decreases as the square of the distance from the discharge. However arcing and sparking on a power line can generate interference that can travel for many kilometers down the power line.

How do you find the emission source?

This can be tricky as you need to think very creatively. It is easiest to use a directional antenna to find the direction of arrival of the signal. You will want to get multiple bearings on the signal to triangulate the approximate geographic location, as shown in figure 14.

After you have an idea of the location of the offending source, go to the location and look around.

- If the signal is noise-like, look for things that may be arcing or sparking.
- If the signal is discrete, look for electronic devices that may be oscillating at radio frequencies.
- You may need to knock on doors and ask questions of residents. There are some good interference locating tips at www.rfiservices.com

Mitigating unintended emitters

Each unintended emitter case will be different. You will need good direction finding skills since the emitters generally won't announce themselves with external antennas, towers, and obvious signs. A pleasant personality and the ability to knock on doors and gain cooperation is also important. Many times the person you are talking to won't know that there is a problem and developing a cooperative approach. You may need to turn off circuit breakers to nail down the source of the emission.

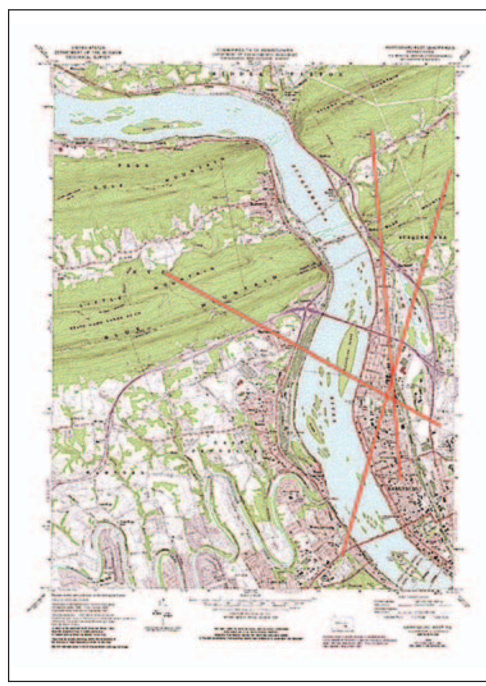

Figure 14. Direction Finding to locate an emission source

Applicable FCC Rules

Violation of FCC rules can subject violators to significant fines.
However, usually it is better to gain corporation without threatening to get the FCC involved.

There are many different parts to the FCC rules.
Here are a few that may be of particular interest to people involved in RFI work.

– Some unintended emitters fall under FCC part 15
– Industrial Scientific & Medical equipment – part 18
– Broadcasting is regulated by part 73
– Private land mobile – part 90
– Amateur radio – part 97
– Microwave – part 101

What is an environmental diode?

Any joint of dissimilar materials can form a diode. Soldiers have been known to make a simple radio detector from a pin and a rusty razor. A diode can be formed by a rusty fence with galvanized or aluminum fence posts. In fact, there can be thousands of dissimilar joints, such as the one shown in figure 15, any one of which could cause trouble given the right conditions and the right signals.

If plumbing is done with a combination of copper and galvanized pipes, (for example in a plumbing retrofit in an older house) there can be severe corrosion even if the dissimilar pipes are separated by a dielectric union – which is a joint separated by an insulating dielectric. A dielectric joint is great in theory and works for the intended purpose until the pipe is filled with water, at which time corrosion begins.

Figure 15. Potential environmental diodes

How do environmental diodes cause problems?

Any non-linear element can generate harmonics of the signals applied to it and environmental diodes are no exception. Frequently environmental diodes are associated with large expanses of metal, such as fences, railroad tracks, plumbing and rain gutters which act as antennas. If the environmental diode is near high power transmitters, the re-radiated intermodulation products can cause severe interference.

Finding environmental intermodulation sources

A good directional antenna is essential for this sleuthing. When you get very close to the source, using small receiving loops such as those shown in figure 16 gives you the flexibility to home in on the exact source of the re-radiated signal.

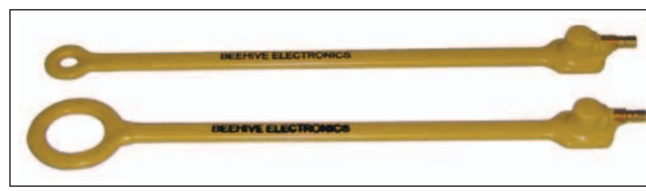

Figure 16. Small receiving probes.

Patience is essential

- If either signal goes off the air, the intermodulation product will disappear
- Work quickly to get a bearing when the signal appears.

Carry a spray bottle containing water.

- Squirt water on the suspected environmental diode to change the conditions. If the intermodulation changes, you've found your culprit.
- What you do next depends completely on what you find.

Removing environmental diodes

What needs to be done to remove an environmental diode depends on what is causing it.
Basically the joint needs to be made so it won't act like a diode.

- Clean the joint to remove oxides – this will be a temporary fix
- Insulate the joint with paint, plastic insulation, etc. Some creativity may be required here to insulate the joint sufficiently that it won't be able to become a diode anytime soon.
- If possible remove the joint entirely. Obviously this isn't always possible, but it is by far the best solution if it can be done.

Mitigating environmental re-radiation

Change the resonant frequency of the metal attached to the joint.
For a wire fence this may involve wires connected vertically between the horizontal wires of the fence.

- Just make sure you aren't introducing more joints that will cause problems in the future – if possible use the same kind of wire as the fence.
- The vertical wires should be spaced unevenly to avoid a bunch of elements that are resonant in the same frequency range.

How to track down environmental diodes

1. Determine the direction to the source of the intermodulation signal.
2. Use usual direction finding techniques to get an idea of the location of the radiator.
3. Go to the area and look for corroded metal items – fences, rain gutters, poorly maintained towers, power lines, and so forth.
4. Use a directional antenna to aim at suspected items.
5. Once you think you have found the item that is generating the source, use a small loop probe attached to the spectrum analyzer to track down the exact location that is radiating.
6. What you do next depends on what you find. You often will need to gain the cooperation of a property owner to try to cure the problem.

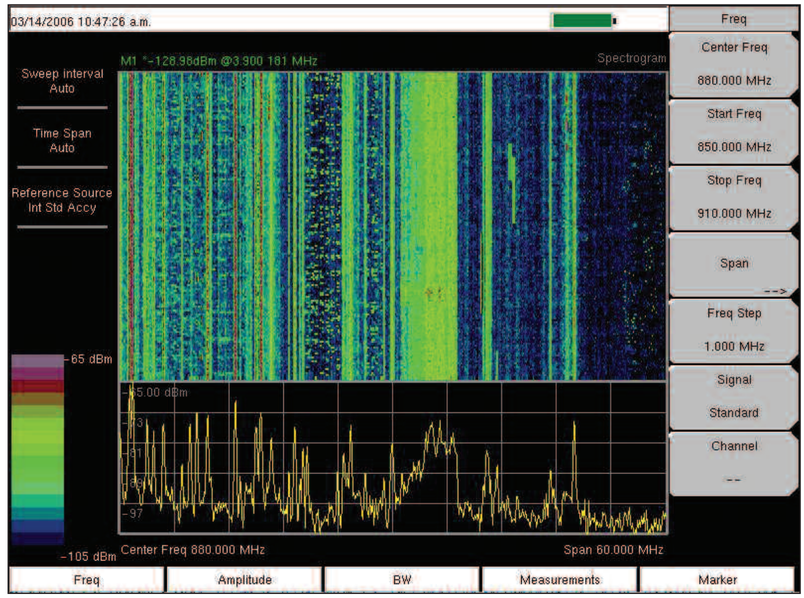

Figure 17. Spectrum Master Spectrogram Display

Monitoring Over Time Can Help Identify Problem Transmitters

When an interfering transmitter isn't causing problems all the time, there are tools that are helpful to track down the problem transmitter. There is an option for the Spectrum Master that provides a spectrogram display such as shown in figure 17. This display shows multiple spectrum analyzer sweeps over time. Intermittent or drifting signals can be easily seen. Another good tool for this job is Oasis spectrum monitoring software. This software can be ordered from Anritsu Company, as part number 2300-507. A sample display from Oasis is shown in figure 18.

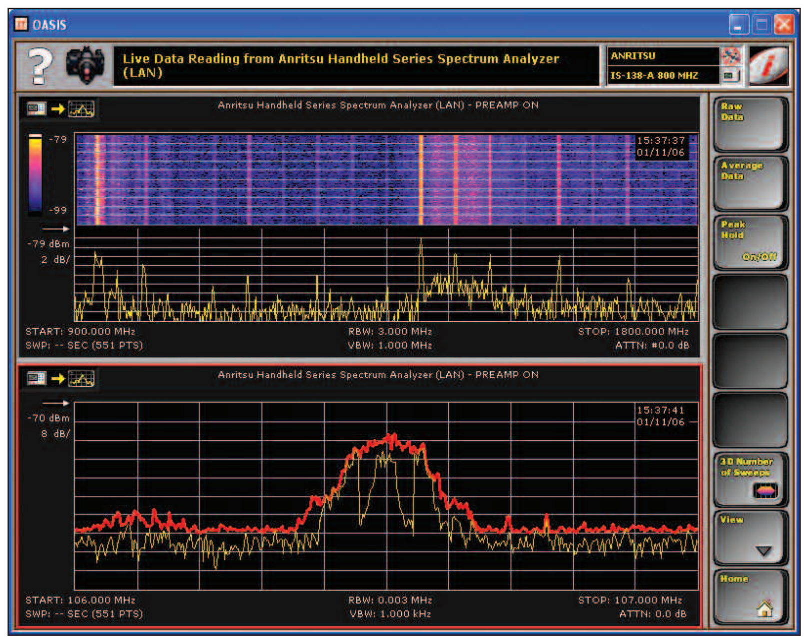

Figure 18. Oasis Display Example

Measurement Examples

Using Spectrogram to track down Interference.

The spectrogram display is used to see patterns in the signals being monitored. This is especially useful for signals that appear intermittently. Notice in figure 17 there are some signals near the top end of the frequency range that were there for only a small portion of the time. If those had fallen on a frequency of interest, there could have been significant interference.

Using Signal Strength to Find Interferers or other rogue transmitters

Once an interfering signal has been discovered, the next task is to find its source. The signal strength meter, shown in figure 19, which is part of the Interference Analysis option for Spectrum Master includes an audio tone output that the you may turn on to alert you to changes in signal strength. Attach a directional antenna to the Spectrum Master and rotate the antenna to get the highest audio frequency beep. The higher the audio frequency output, the higher the power level being received.

Move in the direction that causes the audio tone frequency to increase. The search may not be a straight line to the emitter due to reflections and multipath signals. If the direction of arrival of the strongest signal suddenly is very different than what it had been, don't be fooled as you likely are experiencing the cancellation of two signals arriving out of phase. What can be left to receive in that case is a third (probably weaker) multipath signal. Move a little bit in your original line of travel, if possible, to see if the signal returns to the previous arrival direction.

By using a cellular headset, the instrument doesn't have to be visible if surreptitious monitoring is needed; the instrument could be hidden away in a back pack, in an attaché case or under a large coat.

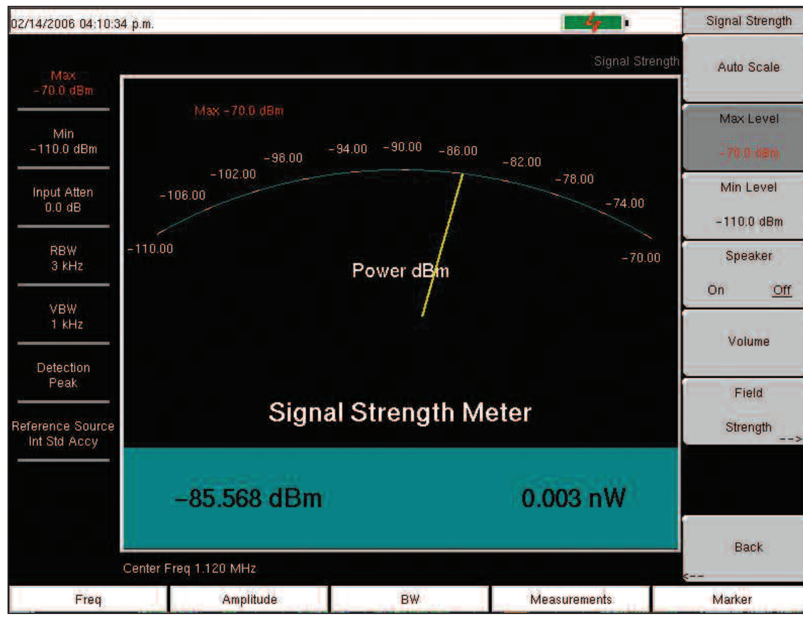

Figure 19. Signal Strength Measurement

Measuring Carrier to Interference Ratio

The throughput performance of Wi-Fi systems is determined primarily by the carrier to interference (C to I) ratio. When the C to I ratio gets low enough that the bit error rate becomes excessive, the transmitter-receiver pair negotiate a change to a simpler modulation format that can tolerate a lower C to I ratio. Measurement of this ratio is a two-step process. First the carrier level is measured then, with the carrier turned off, and the remaining interfering signals and noise are measured. Once the power values have been measured, the ratio can be calculated. The algorithm for doing this measurement in Anritsu handheld products is based on work done at Proxim. A fundamental facet of the algorithm is the realization that different types of transmitted signals degrade the carrier to interference ratio in different ways. Broadband signals, for example, cause less degradation to a Wi-Fi signal than does a frequency hopping signal.

Interference Analysis Measurement Tools

Anritsu makes many different instruments that are useful for RFI work. Which ones you may choose depends partially on the frequency range you need to cover. Some the instruments have additional capability either built-in or as orderable options that may make one the ideal choice to do the combination of measurements you want.

Spectrum Master – handheld spectrum analyzers
– MS2721B 9 kHz to 7.1 GHz
– MS2723B 9 kHz to 13 GHz
– MS2724B 9 kHz to 20 GHz
– MS2711D 100 kHz to 3 GHz

Cell Master – cell site test and maintenance tool
– MT8212B 100 kHz to 3 GHz

Site Master – cable and antenna analyzer
– S332D 100 kHz to 3 GHz

Options to add interference analysis and channel scanner are available for all these products.

Direction Finding Tools

There are a wide array of direction finding tools that can be deployed to track down signals.

Directional Antennas

Anritsu sells some small Yagi antennas that are very handy for direction finding. These are very sturdy antennas that will survive the typical abuse a portable antenna suffers bouncing about in the bed of a truck, or buried in tools and cables. If you can't find a commercial antenna that exactly meets your needs, there are several books and web sites at which you can find information on how to design and build your own antenna.

Flat panel antennas are very handy because of their small sizes and lack of protrusions. They are available for many of the popular

Anritsu Part #	Frequency Range (MHz)	Gain (dBi)	VSWR (max)	Length cm (in)	Width cm (in)	Weight kg (lb)	# of elements
2000-1411	822 – 900	12.1	1.5:1	61 (24)	28 (11)	1.4 (3.1)	7
2000-1412	885 – 975	12.3	1.5:1	71 (28)	19 (7.5)	1.4 (3.1)	7
2000-1413	1710 – 1880	12.3	1.5:1	48 (18.9)	7.6 (2.4)	2.3 (5.1)	8
2000-1414	1850 – 1990	11.4	1.3:1	25 (9.4)	7.6 (2.4)	0.45 (1.0)	6
2000-1415	2400 – 2500	14.1	1.5:1	41 (16.1)	6.4 (2.5)	0.57 (1.3)	10
2000-1416	1920 – 2230	14.1	1.5:1	59 (23.2)	9.3 (3.9)	0.53 (1.2)	12

Yagi Antennas

Directional antennas available from Anritsu

Spectrogram Display

This measurement is part of Interference Analysis, option 25. The display shows signals over time with color corresponding to the signal strength. Dark Blue shows the

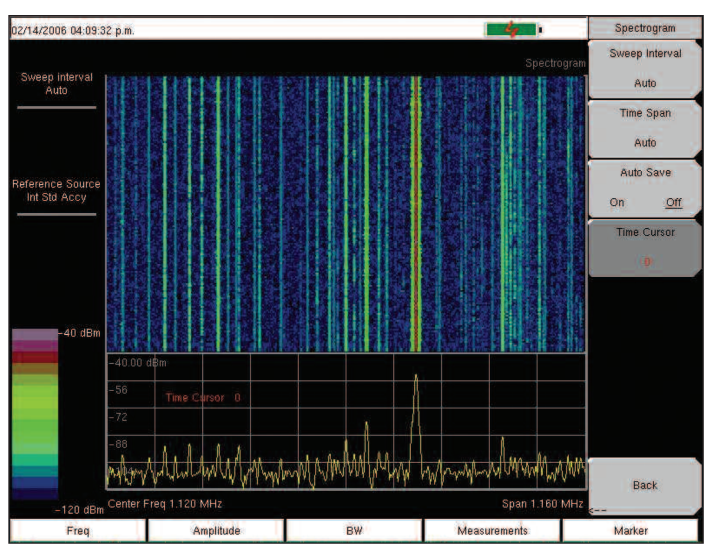

Figure 20. Spectrogram Display

weakest signals and violet shows the strongest signals. With this display, intermittent and drifting signals can easily be seen.

Signal Strength Measurement

Signal Strength measurement is included with of Interference Analysis, option 25. This is a single frequency measurement intended as a tool for finding the source of signals. Signal Strength may also be used as field strength measurement tool by including antenna factors in the measurement.

You adjust the resolution bandwidth to include the entire signal. An optional audio beep changes in frequency as the signal strength changes. Adjust the minimum and maximum levels to tune the sensitivity of the audio beep frequency to power changes.

Channel Scanner Option 27

You can view up to 20 channels with the channel bandwidth and spacing either defined by selecting a signal standard

– Defined by entering values for bandwidth and channel spacing

With the channel scanner option for the MS2721B. MS2723B, MS2724B, MT8220A, and MT8222A you can also create a custom channel list to look at up to 20 different independent signals.

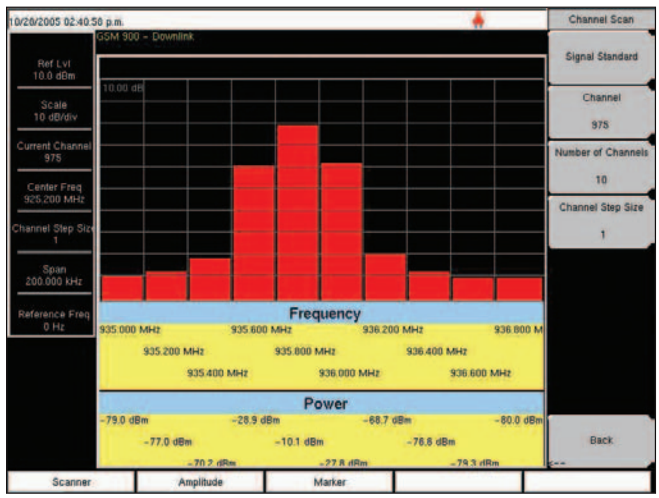

Figure 21. Option 27 Channel Scanner Display

Oasis Spectrum Monitoring Software

The Oasis spectrum monitoring software can control up to four different instruments simultaneously. Also, if the user wishes, multiple windows into the same instrument with different settings can be easily configured. The basic version of this software is Anritsu, part number 2300-507.

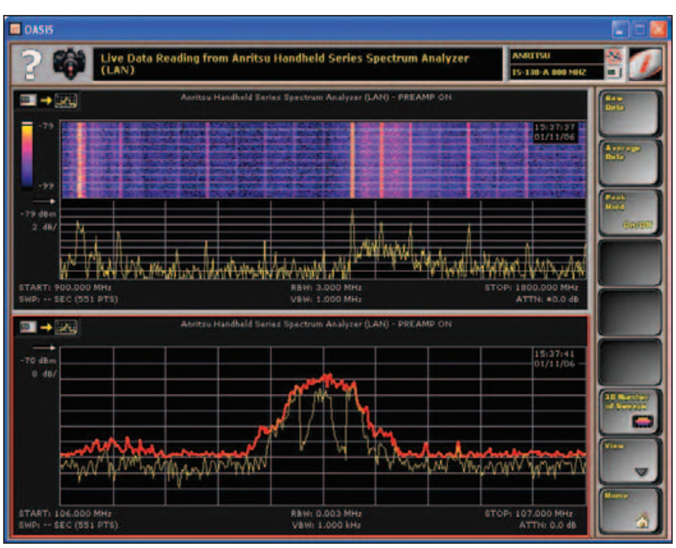

Figure 22. Oasis display

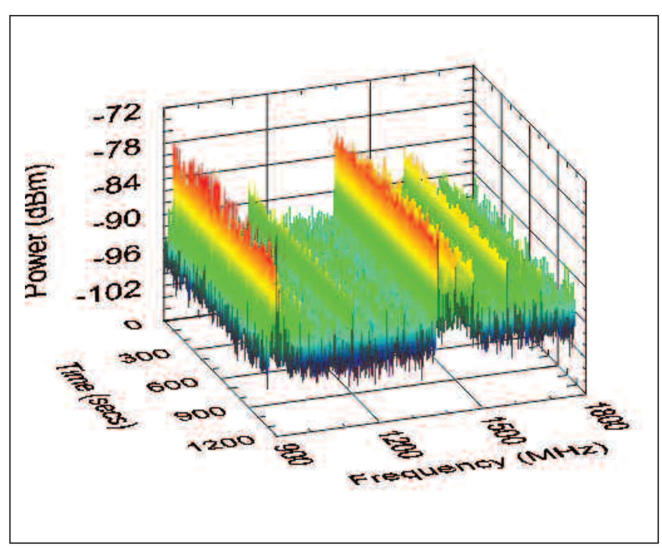

Figure 23. Oasis 3D Report

Master Software Tools combined with Microsoft Map Point

A measurement that is tagged with GPS location information can be shown in a Map Point window within Master Software Tools, as shown in figure 24. Map Point isn't included with MST. If you wish to use Map Point, purchase it on the open market and install in on your computer. Map Point, a Microsoft product, is currently available in North American and European versions.

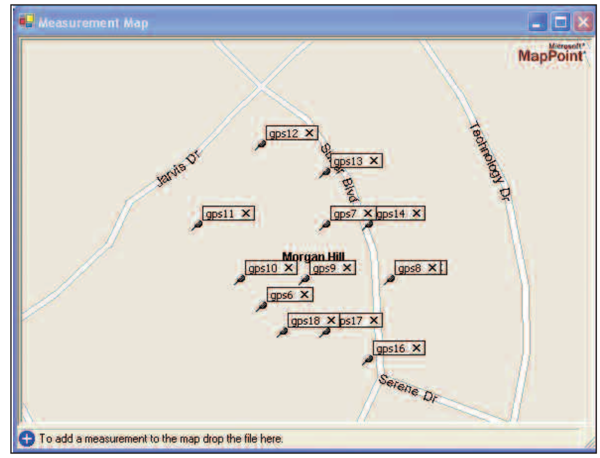

Figure 24. MapPoint display of GPS marked measurements

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