Hunting for Sources of Interference in Mobile Networks

Recognizing Clues and Gathering Evidence with Measurement Tools

There are many possible offenders capable of creating signals that interfere with the wireless RF signals and plague cellular communications systems.

This application note will help you better recognize those interference sources and gather "evidence" to prove your findings to others.[1] Part 1 describes new measurement tools and techniques that will help you identify and locate many types of interfering signals. Part 2 is an illustrated reference with examples of measurement results from typical interference sources.

Part 1 – Test Tools and Techniques

Selecting, Connecting and Using Test Tools

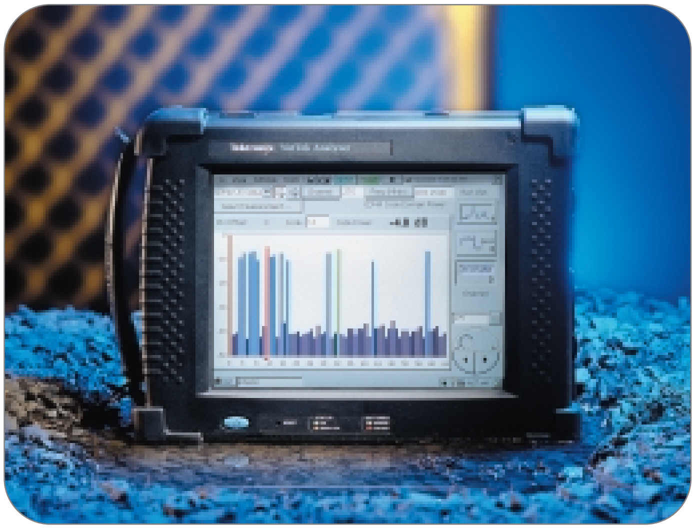
Today's technician is responsible for maintaining many more base stations than ever before. When a BTS is plagued with interference, you need a tool that helps you identify and find the source of the offending signal quickly. The Tektronix NetTek YBT250 field transmitter and interference tester, as shown in Figure 1, includes automated measurements specifically designed to speed the process of identifying the causes while greatly reducing the complexity of testing on site. Among the automated measurements are spectrum display, signal modulation identification, spectrogram displays, signal strength indication, and unattended signal logging. The NetTek YBT250 also features high sensitivity (with a built-in pre-amplifier), battery operation, accessory antennas and results storage – all in a compact, rugged, weather resistant package.

[1] For additional information, see *Fundamentals of Interference in Mobile Networks,* a companion application note from Tektronix.

Measurements at the Base Station Receiver

The best way to hunt for interference in the base station receiver is to disable traffic on the channel to be measured. This will assure that no calls are assigned to it and the only signals that you will see are the interfering ones. This is a routine matter when the interference is so severe that the channel or the entire face (sector) has already been completely shut down.

If you need to leave the channel active, you should disconnect one of the two diversity receivers. While you are looking at the signals from one receive antenna, the remaining receiver will handle legitimate call traffic. In this case, you must wait for a quiet time between active calls to get valid measurements of the interference. This procedure is more difficult and time-consuming, and should only be used if absolutely necessary.

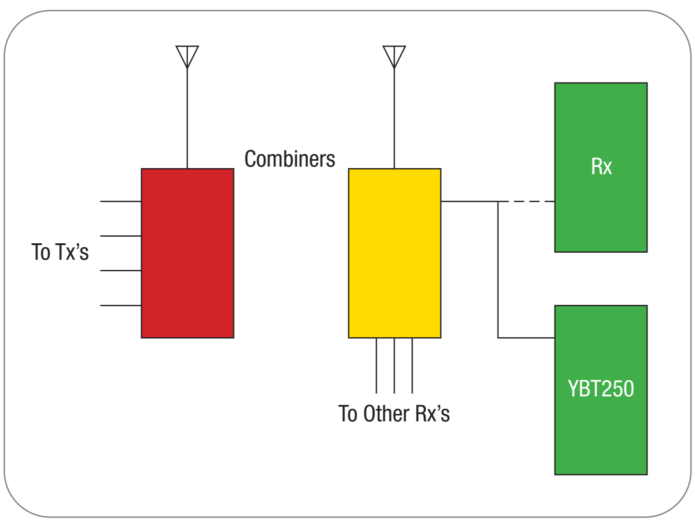


▶ ***Figure 1.*** *YBT250.*

Connecting the Test Equipment

Start your search at the receiver that has the problem. Disconnect the cable from the receiver input, and connect it to the YBT250; you should be looking at just what the receiver would see.

Figure 2 shows the connection being made after the receiver multicoupler (and TMA, if used). If you prefer to connect in front of the multicoupler, stay on the receiver side of any power insertion unit. The TMA may not be equipped with relays to pass signals without power being applied to a mast-mounted preamplifier.



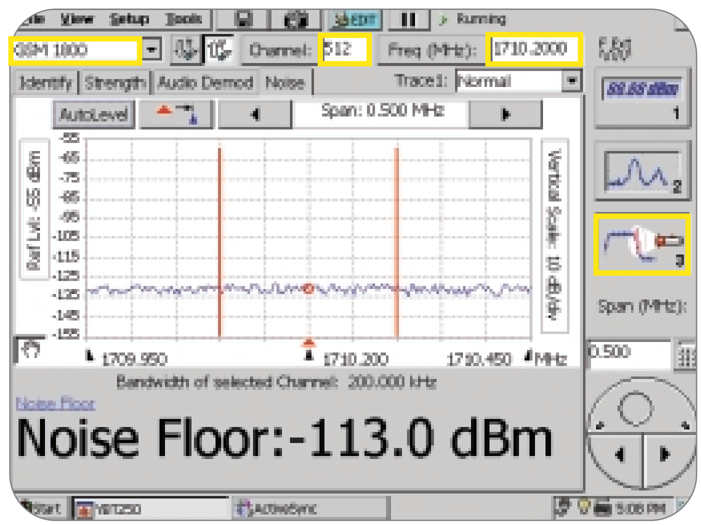
▶ ***Figure 2.*** *Connect the YBT250.*

Measuring the Noise Floor

Begin by examining the incoming signal, with and without interference (if possible). The YBT250 lets you measure the total RF power arriving at a receiver, including noise, undesired signals of all types and any desired signals that happen to be present at the time of measurement.

Select the signal standard on the YBT250 that matches the BTS being tested (GSM, CDMA, AMPS, etc.) and enter the measurement frequency (or channel number) of the channel that is experiencing the interference. Tap the *Noise* tab within the *Interference Main Button (3)* to make the Noise Floor Measurement and record the total power found in the receiver channel.

Figure 3a shows the result of a noise floor measurement on a channel with no interference. The number displayed is the total power of all signals found in this channel (between the red cursors.). Since there is no interference at this time, the noise floor readout is the sensitivity of the YBT250 itself.



▶ ***Figure 3a.*** *YBT250 noise floor.*

This same channel is shown in Figure 3b with an interfering signal adjacent to it. The interfering signal is affecting the channel of interest. Note that the total noise floor is now 2 dB higher than before.

This example shows a fairly mild case of interference. Interference that is 6 dB higher than a clear channel would reduce by a factor of 2 the maximum distance that this site could reach – shrinking the coverage to one fourth of its specified area.

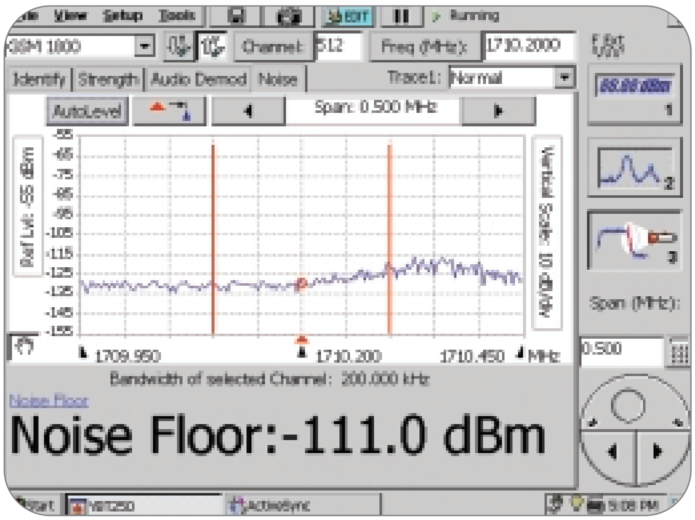


Figure 3b. *Higher noise floor due to interference.*

Automatically Identifying Communication Signal Sources

The YBT250 memory contains tables of characteristics for common communications signals. When you tap the *Measure* button, a series of tests are automatically performed to capture the characteristics of the interference. In many cases, the *Identify* function will automatically suggest the type(s) of signal that might be causing the interference. This can save you considerable time in your hunt.

Figure 4 illustrates the results of an automatic identification process for interference in an IS136 PCS channel. The left column at the bottom of the screen shows a list of the signals that might be authorized for this frequency. The right column lists suggestions of what is actually present – in this case, a CDMA signal.

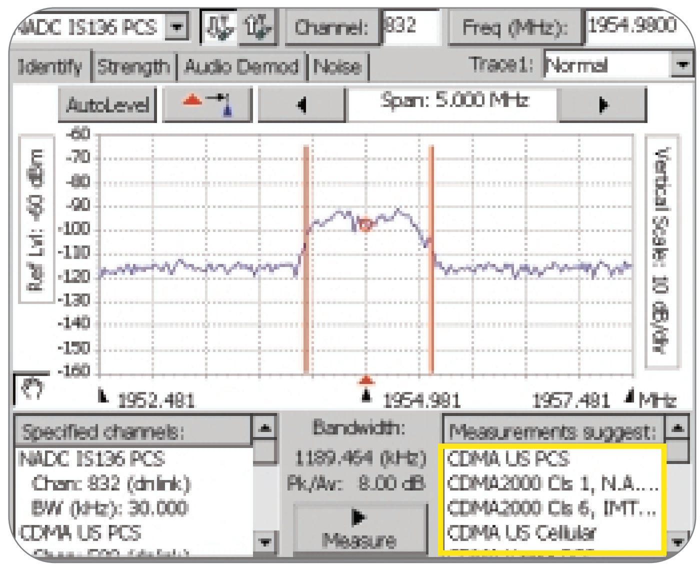
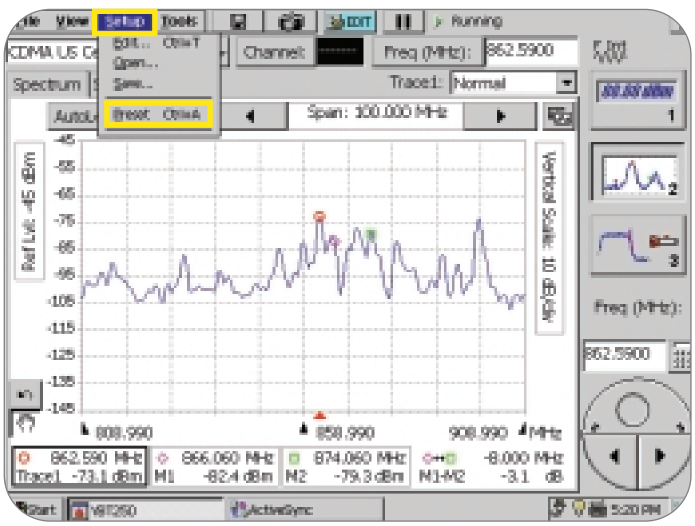


Figure 4. *Interference identity screen.*

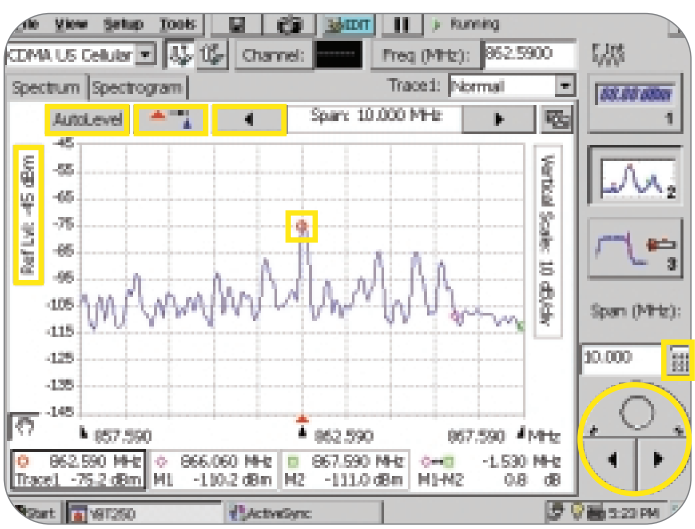
Using Automatic Spectrum Analysis to Learn More About the Signal

Many of the normally complex settings of a spectrum analyzer can be automatically set for you by the YBT250. There is no need to adjust controls such as resolution bandwidth or video bandwidth, they are automatically set internally.

To quickly view an entire wireless frequency band, you first select from the list the standard that matches the network you are testing. Next tap the *"Setup"* menu, and then *"Preset",* as shown in Figure 5a. After you confirm the preset operation, the measurement frequency and the frequency span will be set to automatically display the entire assigned range (including transmit and receive bands) plus a little extra on each end. Now tap *"AutoLevel",* as shown in Figure 5b, and the YBT250 will set its sensitivity (reference level) to maximize the viewing window of the signals being tested. *AutoLevel* also protects against distortions caused by an excessively large signal that is present outside of the viewing area.



▶ ***Figure 5a.*** *Preset for the cellular band.*



▶ ***Figure 5b.*** *Automatic spectrum features.*

If the signals are constantly changing amplitude (as with GSM, for example), you may not catch the signals at their maximum when you press *AutoLevel*. If the levels increase beyond range, a warning banner on the screen will ask you to decrease the reference level. Tap the *"Ref Lvl"* button and the *"increase"* arrow, or enter a reference level 10 or 20 dB higher using the numeric keypad. This will allow more headroom for those highly variable signals.

Tap on the trace of the suspect signal in the display to place the Measurement Marker (round red icon) on the trace. Tapping the button next to *"AutoLevel"* moves the measurement frequency to the center of the screen, and the *"Decrease Span"* button allows you to focus the screen on the suspect signal.

Getting Clues from the Spectrum Width

The *Spectrum* display of the YBT250 can give you valuable clues to the source of an interfering signal. The spectrum width of the signal is one of the most useful. Table 1 lists the spectrum widths for some common interference signals.

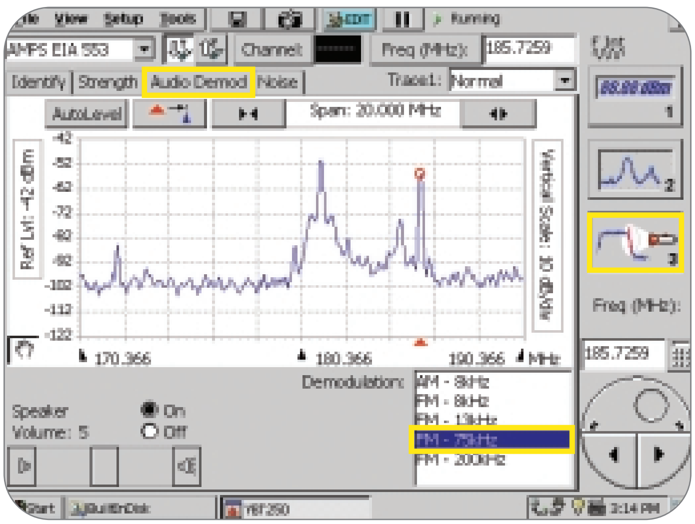
Table 1. Spectrum Width Characteristics

Signal Class	Signal Type	Width
Wide Digital	CDMA (IS-95)	1.23 MHz
	W-CDMA	~4 MHz
	TV Digital Broadcast	5 to 7 MHz
	TV Digital STL	7 MHz
FM	2-Way FM	15 kHz
	Analog Cellular	7 – 30 kHz
	Paging FM	15 kHz
	FM Broadcast	250 kHz
	TV Sound	70 kHz
	Broadcast Audio STL	250 kHz
	Broadcast Video STL	15 or 30 MHz
Narrow Digital	Paging FSK	10 kHz
	US-TDMA	30 kHz
	GSM	200 kHz
	SMR	20 kHz
Other	AM Voice	6 kHz
	SSB Voice	3 kHz

Demodulating and Listening to the Interference

There are many interference sources besides communications signals. Power-line related sources, or other unique sounding signals may be easier to identify when they are demodulated and can be heard through the speaker or headphones.

Tap the *"Audio Demod"* button to have the YBT250 demodulate the signal. You can also select from both AM and FM demodulation to monitor analog communication and broadcast signals for station identification. The demodulation operation is limited to short time periods to conserve battery power.



▶ ***Figure 6.*** *Demodulating an incoming signal and listening to it.*

Tracking Interference over Periods of Time Using the Spectrogram

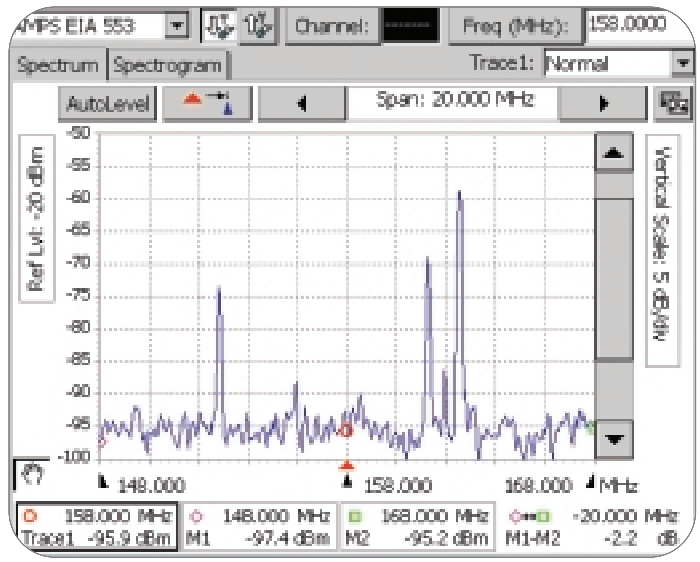
Sometimes the interference is not present when you are looking for it. Some forms of interference only appear for short periods of time during long periods of inactivity. The spectrogram is a valuable tool for the detection and tracking of time-variant interference.

Start with a spectrum measurement and adjust the display to the area where the interference is occurring. Select the *"Spectrogram"* button. The spectrum display acquires a third dimension – time. The signal amplitude (which was displayed as the vertical axis of the spectrum view) is now displayed as color, the horizontal axis is still frequency and the vertical axis is time.

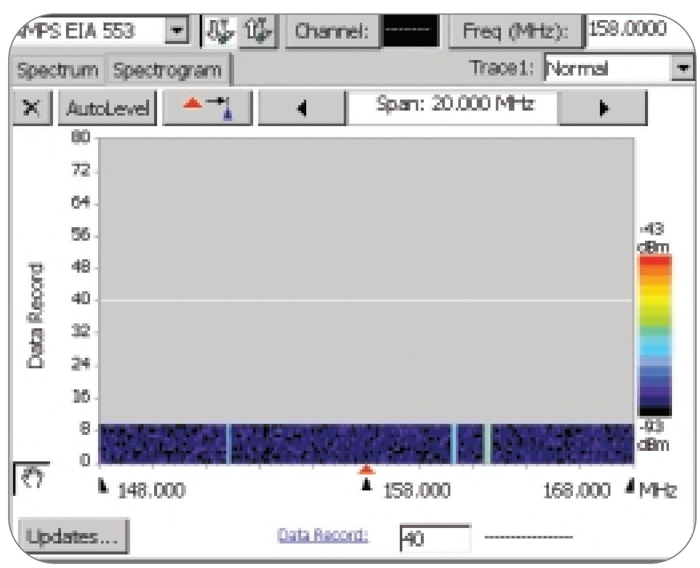
Note that the amplitude scale can be set for less than 10 dB per division. This stretches the signals over the entire axis to make best use of all of the available colors in the spectrogram and makes it easy to see each of the different signal strengths.

The history builds up with earlier time shown at the top of the display. As each new acquisition is processed into a frequency spectrum, its trace is placed on the bottom of the spectrogram, pushing the older spectrum traces up. This creates a display where a continuous signal produces a solid vertical line (no change in frequency over time), while intermittent signals appear as broken lines at each of their separate frequencies. Colors indicate signal strength at each frequency and time.

Figure 8 shows the beginning of a spectrogram with the first ten spectrum traces at the bottom of the display. The lines at approximately 153, 161 and 162.5 MHz correspond to the signals seen in the spectrum display of Figure 7.

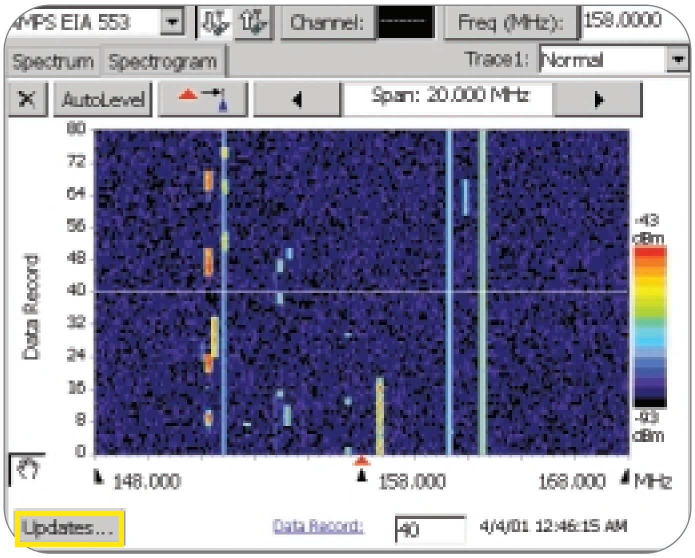


▶ ***Figure 7.*** *A snapshot of some communication signals.*



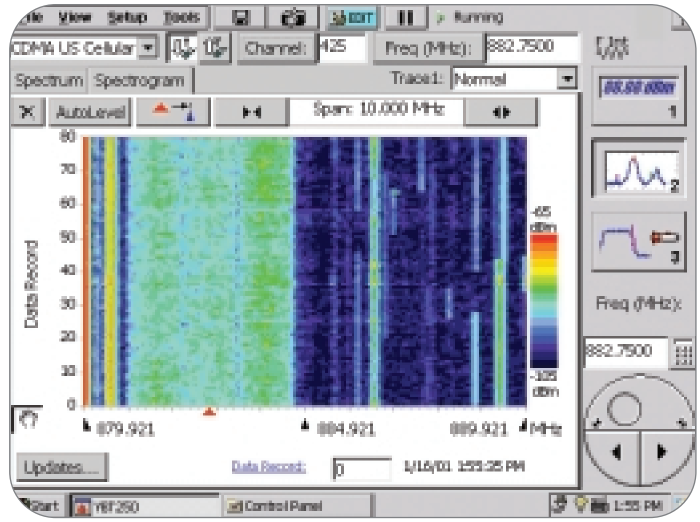
▶ ***Figure 8.*** *The beginning of a spectrogram.*

A little over a minute later the full spectrogram is completed, as shown in Figure 9. You can see that at least nine other signals have come and gone during the time span of the spectrogram.



▶ ***Figure 9.*** *Completed spectrogram.*

The spectrogram gives you a wealth of information in a single, compact easy to read format. Figure 10 is the spectrogram of measurements taken at a location in between several cellular sites. The left half of the display shows three CDMA channels next to each other. They have slightly changing amplitude as the number of users changes from time to time. The right half of the screen shows a dozen or so narrow-band cellular signals (both AMPS and IS-136). You can easily see how these traffic channels turn on and off as phone calls start and end.



▶ ***Figure 10.*** *Spectrogram of live cellular signals.*

Catching Sporadic Signals with Unattended Timed Spectrogram

In some cases the interference may appear only occasionally over long periods of time. The YBT250 can be left on site (using external power) to provide unattended monitoring of interference problems. You can get records of dropped calls from the mobile switching center and compare them to the timed spectrogram to see if an intruding RF signal is a likely cause.

The spectrogram can be programmed to update a new line only at timed intervals. In this mode, any arbitrary time span can be observed, and the YBT250 can be set so that the highest peak value of the signals seen during measurement time period is displayed on its own line. Any interference will leave its footprints in the spectrogram. The marker can be used to read out the time of the intrusion.

To set up a timed spectrogram, tap the *"Updates"* button in the lower left of the spectrogram screen, as shown in Figure 12a. You can select the time span of a spectrogram in minutes, hours, or days and set how many of those time units will be shown on a full spectrogram screen. The resulting time for each update will be displayed above the sliding entry bar. For the example in Figure 11, each update will take three minutes, and the full screen will show the signal activities over a four-hour period. When updates are scheduled for a delayed time, you will want to select the *Trace 1 type* to be *"Max Hold."* This will record the maximum of any of the signals that show up during the three-minute delay time (instead of just saving those that were present at the end of delay time.) When you have finished selecting the setup, tap the "OK" button to return to the spectrogram mode.

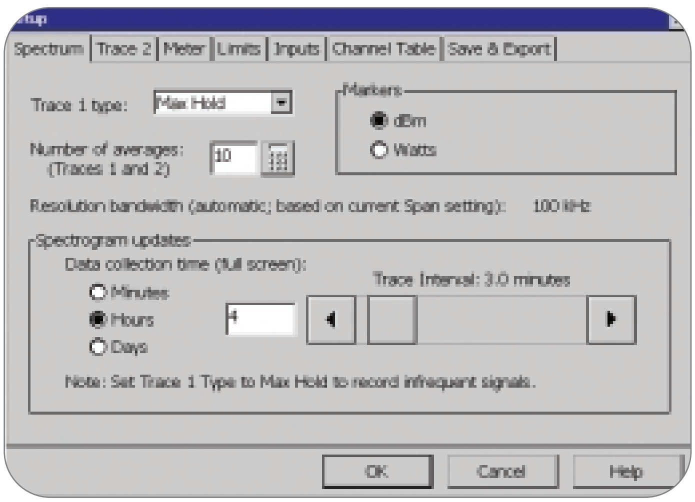


Figure 11. *The spectrogram Setup screen.*

Figure 12a shows the result of a timed spectrogram measurement. The spectrogram contains a four hour span of capture time, and you can see many signals that were only present for a short time. In particular, there is a signal that was only present during one update time during the entire four-hour period.

In Figure 12b, the cursor has been placed on the signal that was present during only one update time, and displays the number of the data record and its date and time.

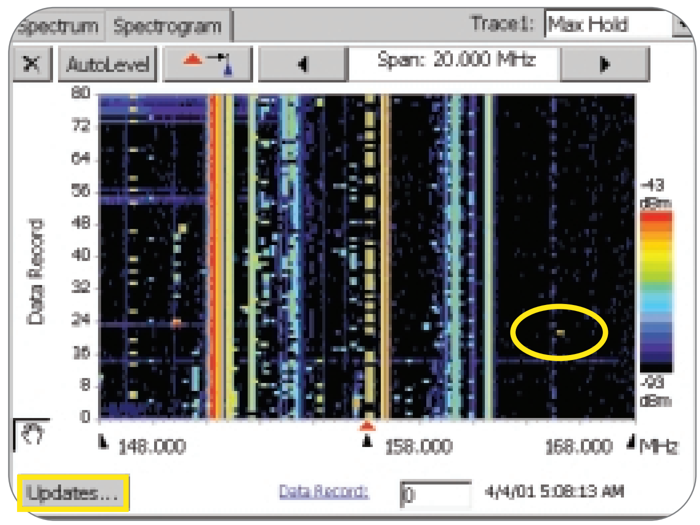


Figure 12a. *Timed spectrogram (four hours).*

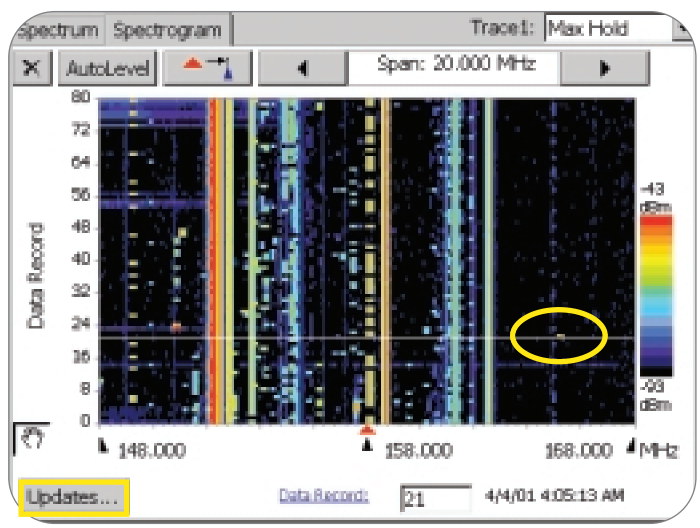


Figure 12b. *Timed spectrogram with cursor.*

Accessories for Mobile Applications

Several accessories for the YBT250 help you track interference in mobile equipment

- Directional antenna 824 – 896 MHz
- Directional antenna 896 – 960 MHz
- Directional antenna 1710 – 1880 MHz
- Directional antenna 1850 – 1990 MHz
- Non-directional sniffer antenna
- BNC to Type "N" adapter for sniffer antenna
- General Purpose RF cable (with type "N" connectors)

The non-directional sniffer is a small, flexible, general-purpose antenna. It allows you to detect increased signal strength as you move closer to the source of a signal. The unit is particularly suited to hand-held portable operation and can also be used inside a vehicle.

The handy sniffer antenna covers a wide range of frequencies, but does not have directional characteristics. To determine the direction of RF signals, we use multi-element beam antennas with approximately 30 to 40 degrees beam-width and 10 to 11 dB gain over a dipole. They are less than one meter long, which allows easy pointing by hand.

Special Considerations for Tracking Interference in Mobiles.

Interference in mobile equipment poses some different problems than we find in base station testing. While most of the same techniques used at the BTS can be used in the field, we need to work around some limitations. In a mobile environment, it is not as easy to disable a channel to clear out intended signals, so testing time may be lengthened while waiting for channel traffic. Most interference is relatively localized, so the mobiles will have acceptable call quality everywhere except in the trouble area, where they experience a high rate of dropped calls. That can force us to move around in the call area before we can even pick up the interference.

When trying to locate the source of interference from ground level, it is often difficult to see past local obstructions. To find the true direction of an offending signal, sightings may be needed from several locations due to the many reflections from local obstructions.

Finding Overlap in Your Mobile Network

One of the more difficult problems to resolve is overlapping coverage from your own system. If a BTS is located on high ground, its coverage may unintentionally exceed the engineering plan. If the coverage is so great that it overlaps a cell that has the same control channel (BCCH for GSM), then the mobile can no longer distinguish between the two and is put out of service in the area of overlap.

For this problem, set the YBT250 to measure the strength of the control channel. A directional antenna will let you determine the source of each of the overlapping signals. Moving in those directions will confirm which of the base stations is causing the extended overlap.

Tracking Down the Culprit

Once the type of signal has been discovered, as well as the frequency of the offender, the next step is to find the location. This can be done using both directional and non-directional antennas. A magnetic-mount attaches a non-directional antenna to a vehicle, and the direction of the source can be found by moving to locations where the signal is stronger, as shown in Figure 13. A directional-antenna can also be used to determine the bearing to the source of the signal.

Use the Signal Strength Indicator in the YBT250 to monitor the signals. Connect the appropriate directional antenna to the YBT250 (operating on the internal battery) and enter the frequency of the identified interference. Tap the *Strength* button in the Interference window of the YBT250. See Figure 14.

Figure 13. *Taking the hunt mobile using a magnetically-mounted antenna.*

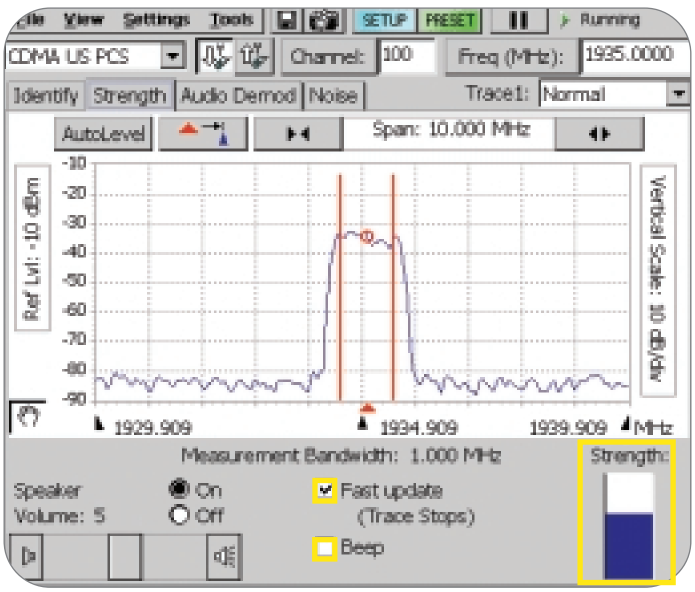


Figure 14. *Measuring interference strength.*

Use the *"Span"* to position the interference signal between the two vertical marker lines. If the signal spills out of the marker area, it will not affect the measurement. However, only the interference signal should be inside the lines. If other signals are present the strength may not correctly indicate the direction of the signal you are tracking.

The *"Strength"* indicator bar will show changes visually and a tone (selectable as either beeping or continuous) can be enabled to let you track the signal source without having to watch the display. As you slowly turn, the *"Strength"* indicator should reach the maximum when the antenna is pointing in the most likely direction of the source.

For the best results, check the box next to the *"Fast Update"* label. In this mode, the LCD screen will only occasionally update the spectrum trace, but both the beep and the strength bar will be much more responsive to changes in the signal strength. In normal mode, the update of the spectrum plot takes time away from the signal measurement and slows down the response to changing signal strength.

If the initial search with the directional antenna and the YBT250 points to a visible source, then your search may be done. If not, additional sightings may need to be taken from other locations. Use a compass to identify the heading where the signal is strongest and record the heading lines on a map – they should intersect at the approximate location of the interference source.

Once the culprit is found, you will need either to add filtering to your receiver, or to negotiate the resolution with the operator of the source. The companion Tektronix Application note titled "Fundamentals of Interference In Mobile Networks" includes suggestions for several different types of interference.

Figure 15. *Using the directional beam antenna and the signal strength measurement.*

Part 2 – Field Guide to Mobile Wireless Interference Testing

Now that we have become familiar with the tools and techniques, let's look at some examples of typical signal types with descriptions of some of the possible sources. Any of these signals, or related ones, may show up as interference to your system. These descriptions may also be generally useful in simply identifying your RF neighbors.

Analog Signals

Broadcast signals have some telltale characteristics. FM signals for voice or music vary in width. During quiet times, FM appears as a CW carrier without modulation. At other times it will vary in width up to the approximate maximum shown in Table 2.

This changing width is its most distinguishing feature. While AM also varies, it is narrower than FM. The best way to confirm this type of interference is to demodulate it and listen to it – you might also pick up the station identification.

Table 2. Spectrum Width Characteristics of Selected Analog Signals

Signal Type	Width
2-Way FM	15 kHz
Analog Cellular	7 – 30 kHz
Paging FM	15 kHz
FM Broadcast	250 kHz
TV Sound	70 kHz
Broadcast Audio STL	250 kHz
Broadcast Video STL	15 or 30 MHz
AM Voice	6 kHz
SSB Voice	3 kHz

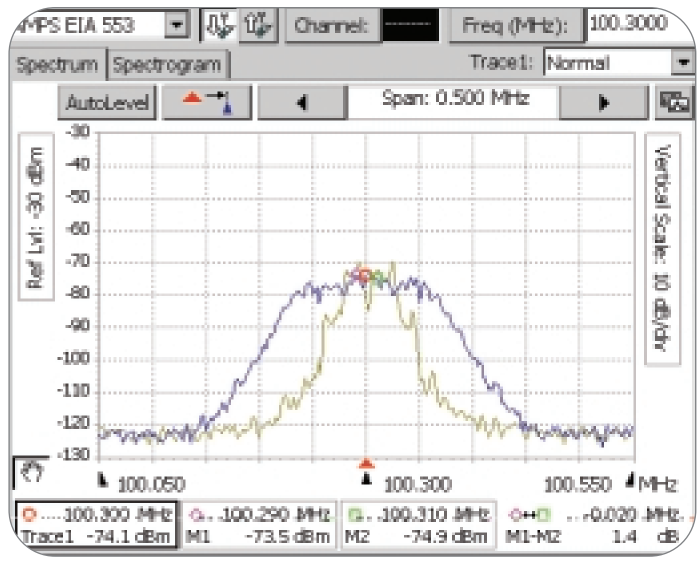
FM Broadcast

Figure 16 shows signals from an FM broadcast station that is playing rock-and-roll music. The signal varies rapidly from full-width to a much narrower one and sometimes to a signal with very apparent sidebands. The orange trace shows a more quiet time and the blue trace was taken during a louder passage.

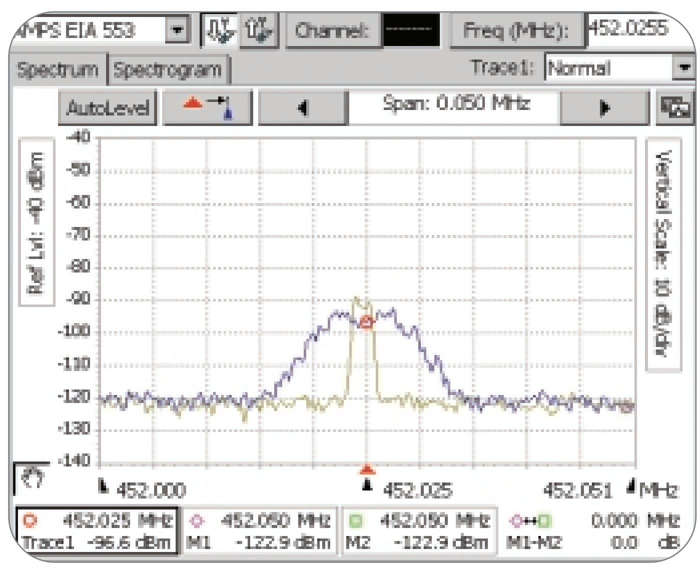
FM Two-Way Radio

The signal from an FM two-way radio is shown in Figure 17. The signal width varies with the loudness of the voice of the radio user. The orange trace was saved while the user was not talking at all (and there was no background noise). Only occasionally did the signal collapse into a completely quiet carrier. Many two-way radios have either a continuous low-frequency tone squelch such as shown in the orange trace, or they have a digital squelch modulation, which has a similar appearance.

The blue trace is the spectrum of the signal when the user was talking loudly and with lots of high frequency energy (such as the spoken "S" sound.) This type of FM communications signal will be continuously varying between the two widths shown and will have no steady state.



▶ ***Figure 16.*** *Broadcast FM.*



▶ ***Figure 17*** *Two-way radio (FM).*

Tone-Burst Modulated Two-Way Radio

Figure 18 illustrates a tone-burst modulated two-way radio, where the modulating tone is about 800 Hz. A higher modulating frequency would produce more widely spaced sidebands. Most tone-bursts have clearly visible sidebands in this span.

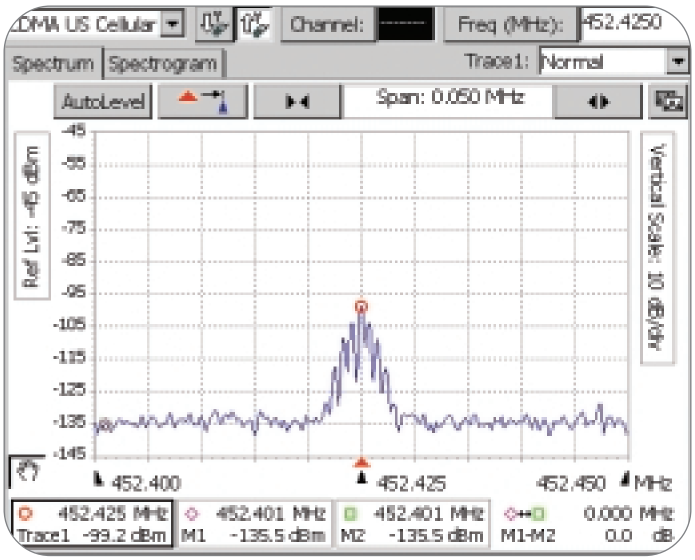


Figure 18. Two-way radio with tone burst.

AM Aircraft Voice Radio

Figure 19 shows an AM aircraft voice communications radio. Like FM voice, this signal is constantly changing with the voice sounds. But unlike the FM signal, it tends to have its wide part move up and down in strength rather than change in width; although it will change width somewhat with the modulating frequency. Again, the two traces shown were stored during the quietest and loudest times of this particular transmission.

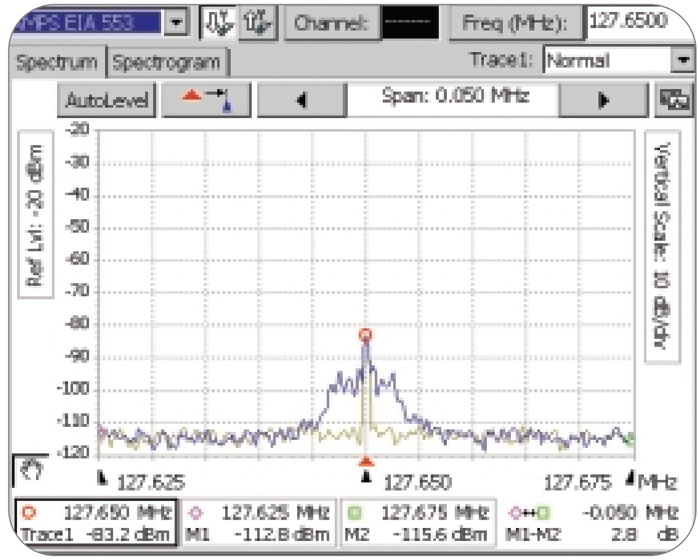


Figure 19. An AM transmission.

Analog Television Broadcast

This signal is quite distinctive. Although there are some differences from one country to another, TV broadcasts usually have both the main video signal (AM) and a separate sound signal at a fixed frequency spacing from the Video. In the United States, the spacing is 4.5 MHz; in much of Europe it is 6 to 7 MHz. The sound is usually FM and can be demodulated to listen for the identification of the station to validate its source. In Figure 20, the video carrier is near the center of the screen and the marker has been placed on the sound carrier about 4.5 MHz higher in frequency.

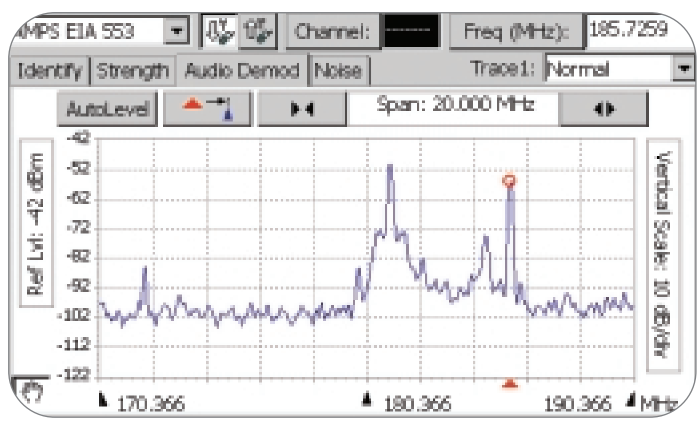


Figure 20. Analog TV (U.S.A. type).

Digital Communication Signals

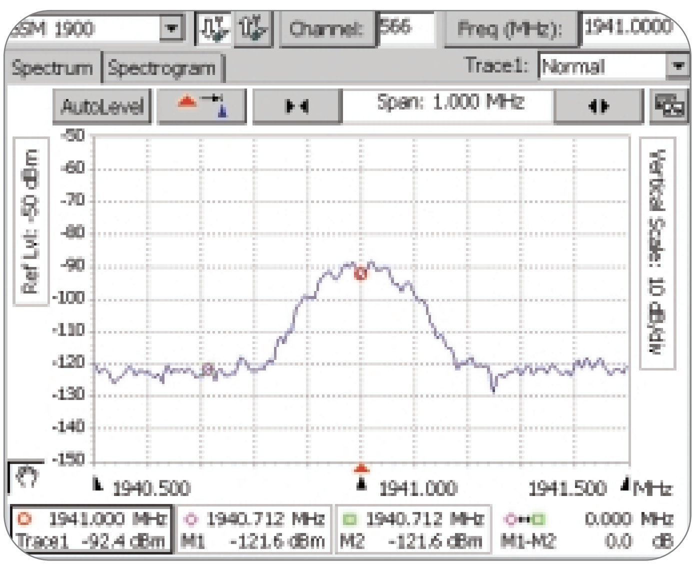
Digital signals also have some generally identifying characteristics. They often have a more constant envelope than the analog ones. This is due to the fact that digital bits are usually being transmitted whether the voice is loud or low.

Table 3. Spectrum Width Characteristics of Selected Digital Signals

Signal Type	Width
CDMA (IS-95)	1.23 MHz
W-CDMA	~4 MHz
TV Digital Broadcast	5 to 7 MHz
TV Digital STL	7 MHz
Paging FSK	10 kHz
US-TDMA	30 kHz
GSM	200kHz
SMR	20 kHz

GSM Cellular

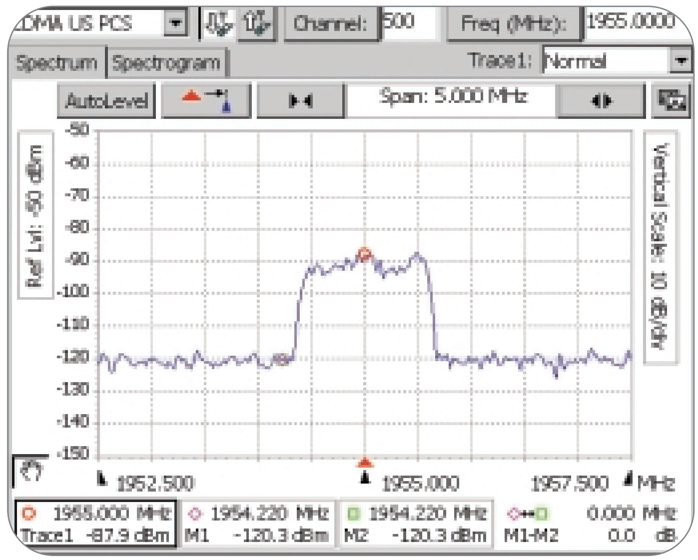
GSM has a distinctive rounded look due to its GMSK modulation, as shown in Figure 21. Since it is a TDMA signal, it may appear and disappear intermittently, depending on how many timeslots are active. Voice channels usually come and go quite rapidly as the individual timeslots are transmitted. The BCCH channel (like the paging channel in AMPS) is usually continuous.



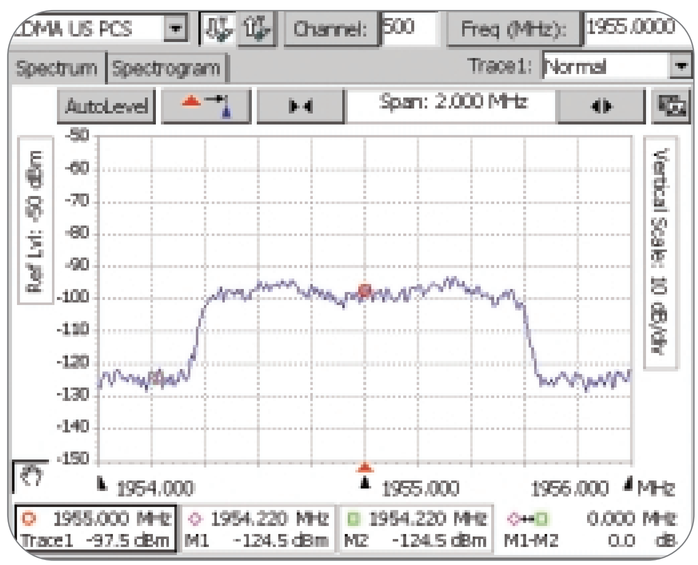
▶ ***Figure 21.*** *A GSM cellular signal.*

CDMAOne Cellular

The CDMA signal in Figure 22 has the familiar "Bart's Head" appearance. It is spread evenly across the entire 1.2288 MHz bandwidth. As more phone calls are added to this signal, it will simply increase slightly in amplitude, it will not have any noticeable change in its shape in a spectrum view. In Figure 23, the CDMA signal is displayed using a 2 MHz span.



▶ ***Figure 22.*** *CDMAOne (using 5 MHz span).*



▶ ***Figure 23.*** *CDMAOne (using 2 MHz span).*

4FSK

4FSK is another digital transmission type used for paging and public-safety transmissions. This signal has four distinct frequencies that will tend to merge and fill in the gaps between the frequencies as the data rate increases, as shown in Figure 24.

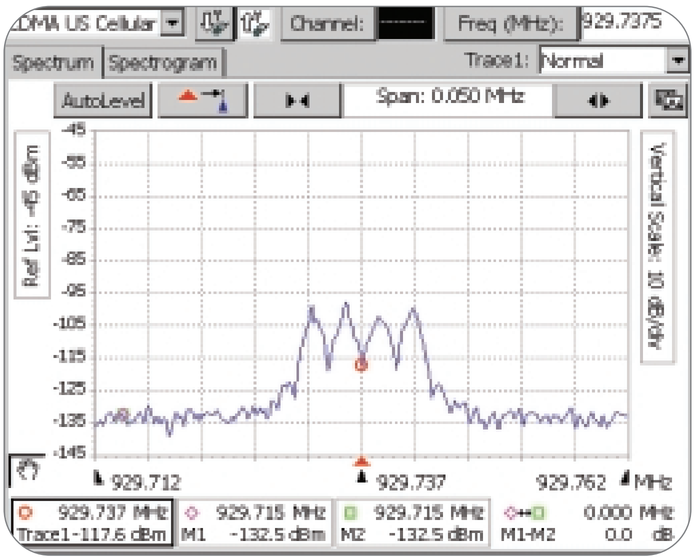


Figure 24. 4FSK paging.

IS-136

Originally known as NADC (North American Digital Cellular), this signal is about 30 kHz wide, as shown in Figure 25. It was designed to fit into one AMPS FM cellular channel. It has a much flatter top than GSM, but not quite as flat as CDMA.

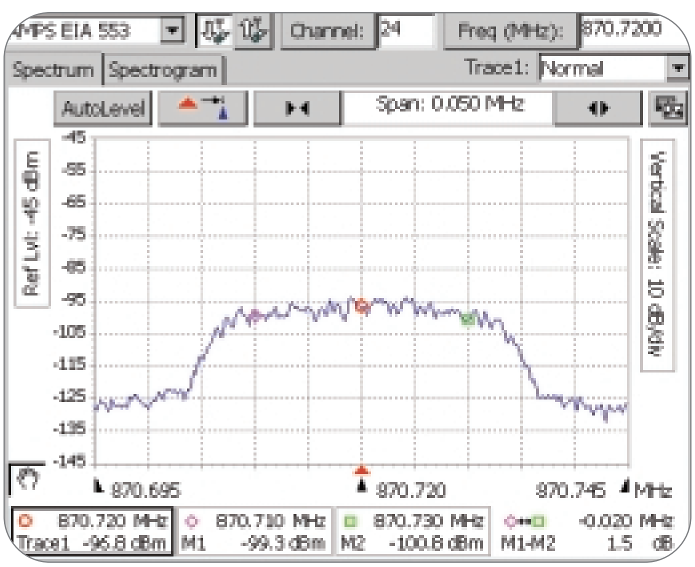


Figure 25. IS-I36.

Specialized Mobile Radio (SMR)

Figure 26 shows a signal from SMR, which is marketed as a cellular service in the U.S.A. Its assigned transmission frequencies lie directly between U.S.A. cellular receive and transmit bands. The signal is usually a bit narrower than IS-136, and has a much flatter top. This example is from a system marketed under the Motorola trademarked proprietary name of IDEN.

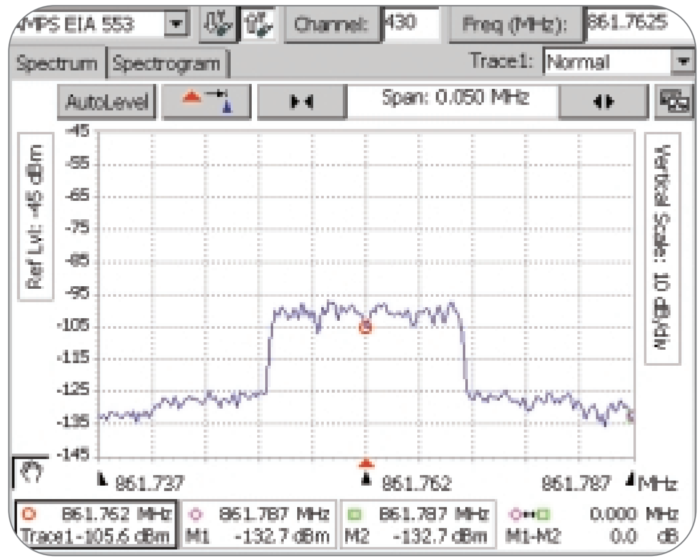


Figure 26. SMR (specialize mobile radio) signal.

FSK Paging

This signal has two distinct frequencies for the digital “ones and zeros” when it is idling. As the data rate and random transmission data increase, the frequencies will become less distinct and the trough in the middle will fill in. In Figure 27, the orange trace is the typical idling spectrum – much of the time this signal will be more filled-in, as with the blue trace. The amount of fill usually changes continuously with the various data payloads being transmitted.

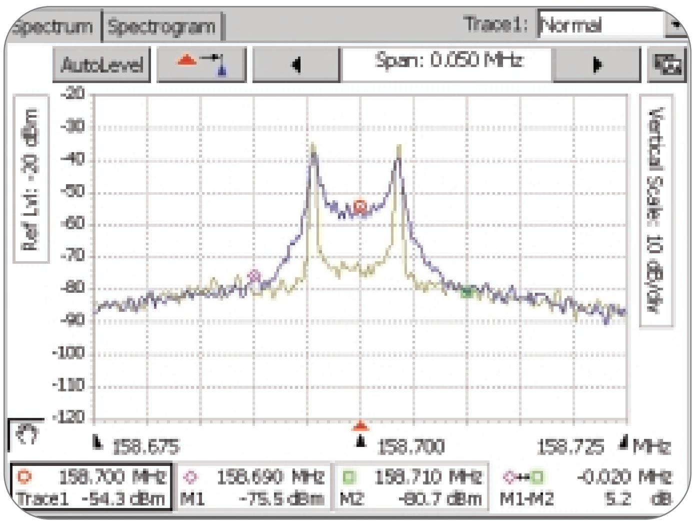


Figure 27. *FSK paging.*

Narrow-PCS

This digital signal is from a Narrow PCS cellular system in the U.S.A. In a wide span it wiggles slightly, as shown in Figure 28a.

However, in a slightly narrower span, as shown in Figure 28b, it has a unique manner of alternating between the orange trace of distinct frequency sidebands, and the blue trace showing broad filled-in side-bands. Even more unusual is the fact that the upper and lower side-bands may change independently at times, as shown in Figure 28c.

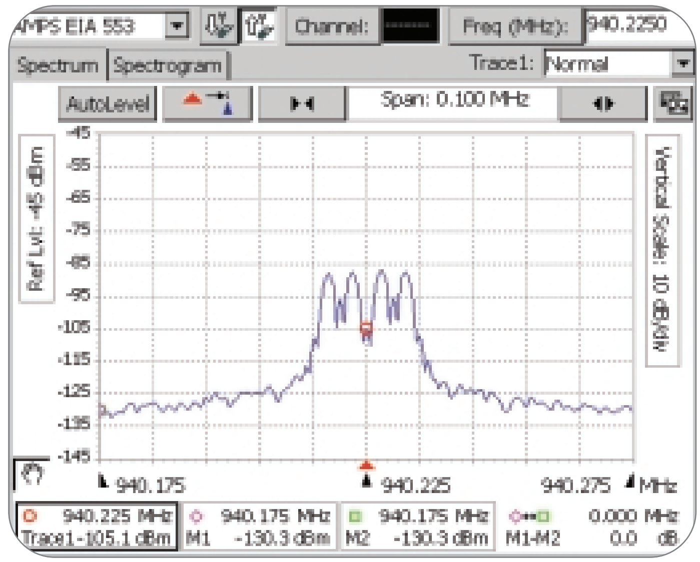


Figure 28a. *N-PCS transmission.*

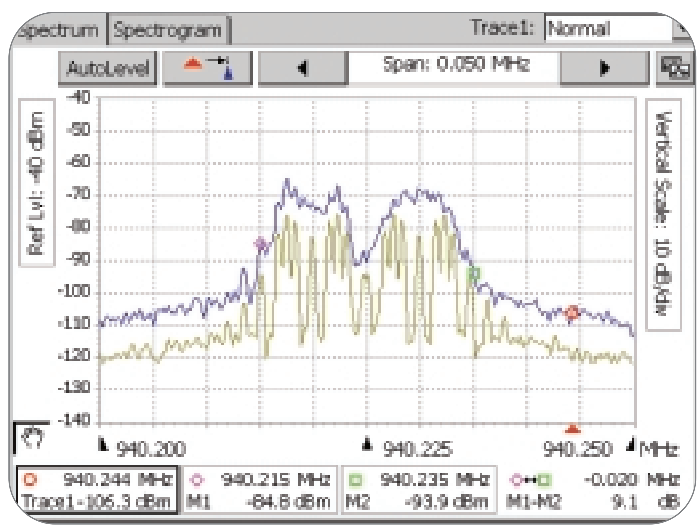


Figure 28b. *N-PCS seen in a narrower span.*

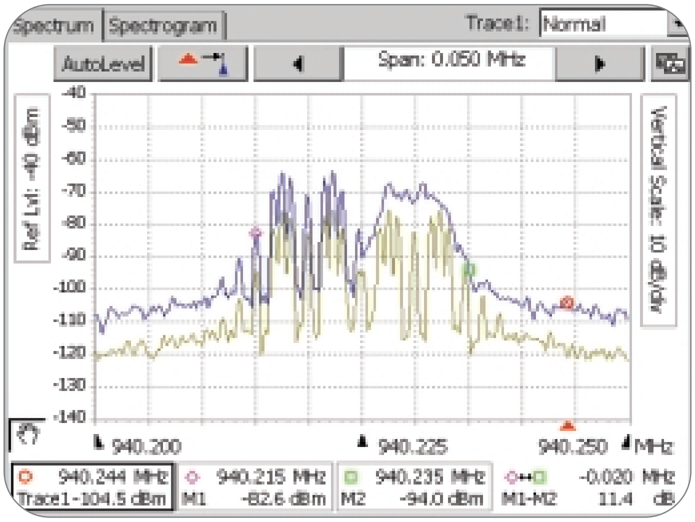


Figure 28c. N-PCS spectrum varies continuously.

STL Systems

Digital STL (Studio-to-Transmitter Link) systems are operated in the 2 GHz band. These are usually QAM modulated with approximately 7 MHz of bandwidth. Their spectrum looks similar to IS-136, except for the much wider frequency span. Analog STL for audio may be at 900 MHz or 2 GHz. Analog STL for TV video signals are 15 or 30 MHz wide FM. The spectra of both are similar to broadcast FM, as shown in Figure 29.

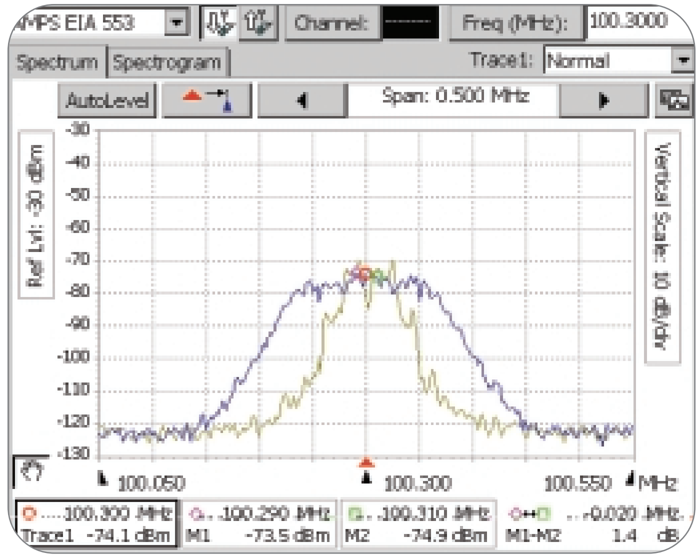


Figure 29. Broadcast FM.

Summary

These have been some selected example signals that you may see in everyday use while you look at all of the RF signals that surround your wireless system. These examples can help you identify what is and what is not a problem for you.

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