Speaker:

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Abstract:

The rapid increase in the number of wireless services has increased the amount of interference possible in the RF spectrum. Even though some interference is to be expected, it can be difficult find and determine the best solution. The ability to be on-site quickly to examine the problem is not always possible. Remote observation of the RF spectrum can aid in solving problems, especially those that are intermittent.

This paper discusses requirements for local or remote observation of the RF spectrum surrounding transmitters or receivers with interference problems. Typical problems and how they have been discovered and identified will be reviewed. Averting future problems by taking preventive measures will also be covered.

Finding Interference Problems at Remote Radio Sites

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The rapid increase in the number of wireless services has increased the amount of interference possible in the RF spectrum. Even though some interference is to be expected, it can be difficult to find. The ability to be on site and quickly examine the problem is not always an option. Remote observation of the RF spectrum can aid in solving problems, especially those that are intermittent. The ability to see the frequency, level and spectral shape of the modulated carrier on a spectrum analyzer display will provide assistance determining its source.

1 INSTRUMENTATION AND RELATED EQUIPMENT

1.1 A spectrum analyzer is the first line of defense against interference. It will give a visual display of the frequency and level of various signals in the RF spectrum of interest. The spectrum traces displayed are from the 2398 and 2399 series Spectrum Analyzers from IFR, Wichita, KS using IFR's EasySpan Waveform Transfer Software.

1.2 A remote control capability will add versatility. RS-232 or IEEE-488 protocol are best, since they are well known and more programs will be available. RS-232 will provide a more simple operation, while the IEEE-488 may provide more complex testing capabilities requiring more than one instrument.

1.3 Multiple markers, with a table providing information about frequency and level, help to discern various frequencies on the trace without having to move one marker to all the points to identify them.

1.4 Peak hold or max hold builds up and retains the maximum level attained in every trace over a period of time. It will give a good history of everything that happened while the spectrum analyzer was in operation.

1.5 Semi-automatic test will speed up and give repeatable results of a particular test.

1.6 Limit lines will give an indication when the limit is exceeded by a trace. The alarm may be audible and/or visual and may include an event count feature.

1.7 AM/FM demodulation may give you an insight of the type of interference. Pagers and voice are easily detectable and will help to identify the problem.

1.8 Zero span can be used to look at pulsed RF or data in an analog radio system. Anything to help identify the interference will help find the source.

1.9 Counter functions help define the actual frequency or the signal of interest. All transmitters above 100 mWatts have to be registered with the FCC (Federal Communications Commission). Find the frequency and it is almost like looking in the phone book to find its owner.

1.10

The portability specifications of lightweight, small and battery powered are assets. Even though battery operation is sometimes preferred, the life of a battery is usually given in minutes. A DC to AC inverter providing AC power in a vehicle is a common way of powering instrumentation for field operations.

1.11 Memory provides the ability to save traces of concern for evaluation later by others or for archiving. Traces should be saved with a date and time stamp for verification. Saving setups will increase the speed required to reset the instrument for a required test requiring repeatable results.

1.12 Fig. 1 is a screen dump of a typical spectrum analyzer display. The trace displays the FM broadcast band with markers on the nine top peaks and their frequency on a table. Both the span and resolution bandwidth (RBW) are wide to enable a fast sweep speed. The markers and table quickly show points of interest with their frequency and level in a table format. All other information about the spectrum analyzer settings is visible on the picture.

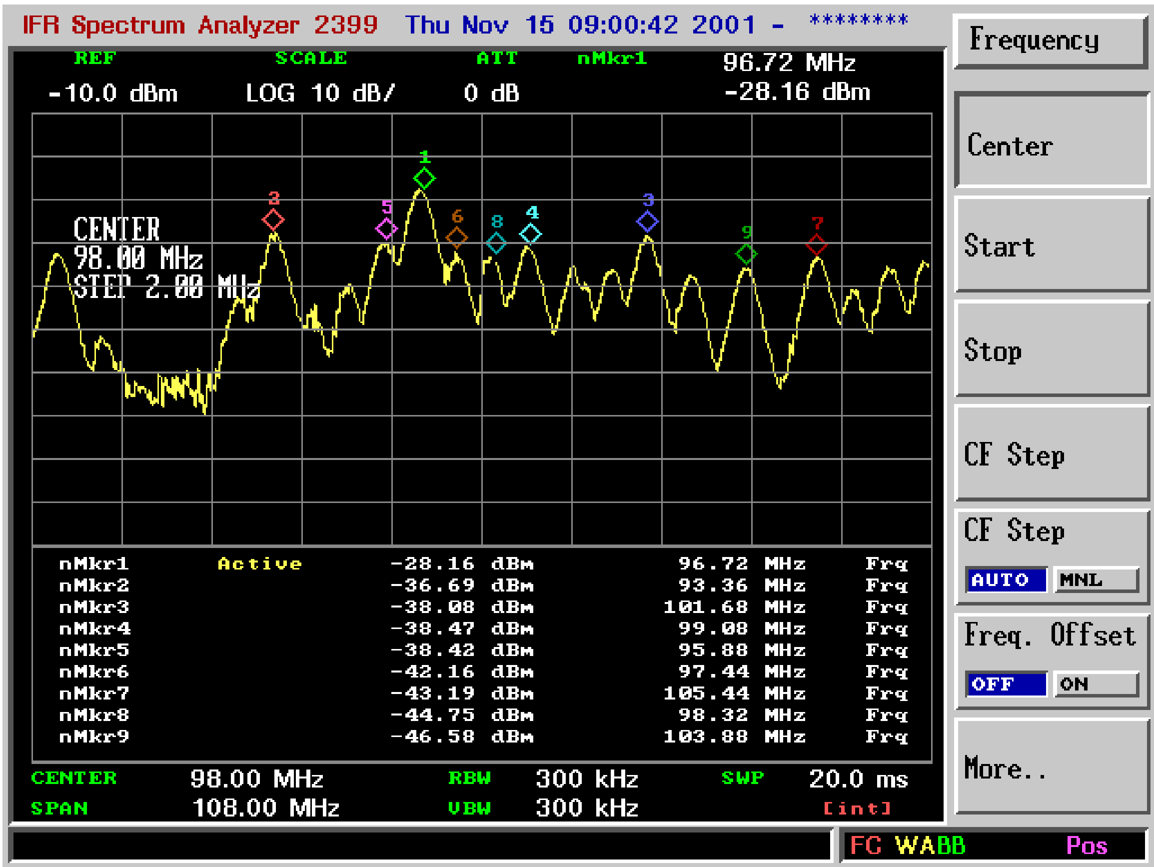

Fig. 1

2 ANTENNAS

2.1 Directional antennas will assist in pinpointing a problem. Triangulating a location using a minimum of three fixes will improve the speed and success rate of finding a problem. Writing down the location, direction and level of the frequency found at three locations will direct you to the general location of the offending transmitter.

2.2 In a pinch any antenna will provide some results. For the best results, use an antenna tuned to the proper frequency range. Antennas tuned to the wrong range will attenuate signal levels not in its bandpass, making the interference harder to find.

3 COMPUTER REQUIREMENT

3.1 Computer control of the spectrum analyzer can be performed by almost any computer, as long as it fulfils the software's requirements and has the proper I/O port. Speed of the PC is of little importance. Generally it will take the spectrum analyzer longer to sweep the spectrum, digitize the trace and send the data through the system than the PC takes to refresh its screen. Sending the trace to another location via a telephone line will increase the delay of the update.

4 SOFTWARE PROGRAM

4.1 The software program to control the spectrum analyzer should be simple and flexible, since you never know what tomorrow's requirements will bring. The ability to quickly include custom applications increases the need for program simplicity. Most avid users of any program will always find a better way to do it. EasySpan software from IFR, Wichita, KS, is a simple program with RS-232 control of the instrument.

4.2 Time and date stamping is important. While monitoring a site for several weeks you find the problem only occurs on Thursday around 2:47 AM. To evaluate the problem you should visit the site early Thursday morning. It may be a truck driver making his weekly coast to coast run, talking on his 3000 watt Citizens Band Radio. In any case, it will give you a better insight into what may be causing the problem.

4.3 Markers are important when evaluating the displayed trace. Generally, you can never have enough markers. Markers display frequency and level of a particular signal differentiating it from a legal channel. Markers should be moveable after the traces are extracted from the spectrum analyzer. Delta markers are used to display the difference of the level and frequency of two markers. They are great for looking at periodic problems such as harmonics, channels and intermodulation.

4.4 Keyboard shortcuts decrease the time needed to evaluate the saved traces. Marker to peak and selecting previous or next trace with one keystroke are real time savers when evaluating hundreds of traces.

4.5 Limit lines and save features allow automated, unattended saving of traces exceeding a predetermined limit line. Man-hours add up quickly when waiting for an intermittent problem. The number of stored waveforms should be limited only by the size of available memory on the PC's hard drive.

4.6 Saved traces format is important. They should be saved in a compact format, since thousands of traces may be required to ensure an interference free site. The program should enable traces to be exported in various formats to facilitate other requirements: .bmp, .jpeg, .gif and others. It is important to have access to the raw data for spreadsheet programs. Copy to clipboard capability will enable you to add the trace to a word processor type document.

4.7 Mapping the results is not always a requirement, but saving latitude and longitude information should be included with the trace data. Mapping will require only part of the information saved, marker frequency/level and latitude/longitude.

4.8 Information should be available on the trace about the instrument and settings to help reproduce the same results in the future. It may be a requirement for verification of the interference to the FCC. The ability to add other information such as marker comments will help identify the problems to a person evaluating the trace at a later date.

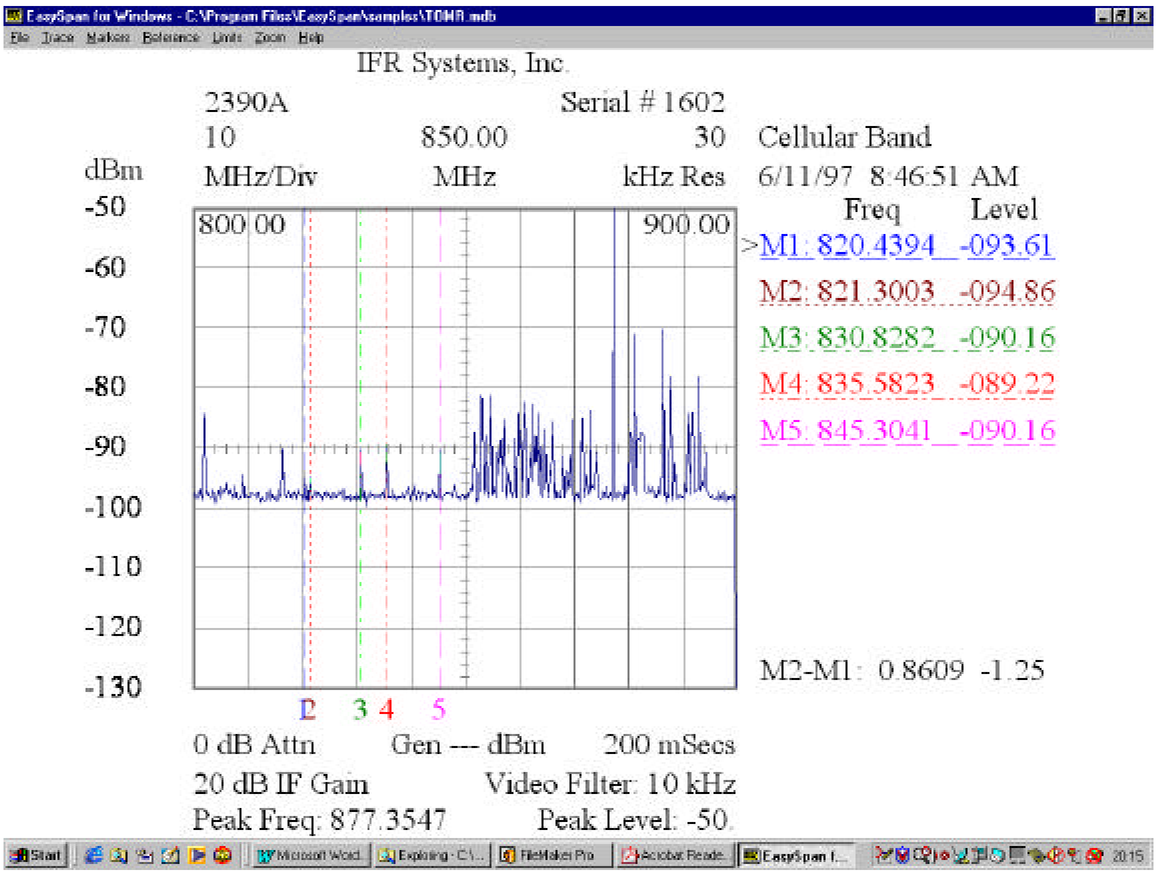

Fig. 2

4.9 Fig. 2 is an example of a trace displayed on a PC that was extracted from a spectrum analyzer. The model doing the testing is a 2390A, serial number 1602. The date and time is 6/11/97 and 8:46:51 respectively. The markers easily show frequency and level of five different channels. The difference or delta information of marker one and two is 860 KHz. The complete setup of the spectrum analyzer is shown on the screen.

5 MACRO

5.1 Macro capability in a program allows a person to write his own application to perform a specific test. This results in accurate, repeatable test results even an unskilled operator can perform. The application will follow a sequence that is unassisted and without human intervention. Pictures can be inserted to show setup/connections and calibration.

5.2 A radio engineer was using his spectrum analyzer to look at the spectrum of their channels as they were driving around their network. He was being proactive, looking for future interference problems. With the spectrum analyzer in peak hold mode, it enabled him to find levels of frequencies with sufficient amplitude to cause interference. He was not only looking for signal levels that could interfere with his channels, but to find problems they might be causing to other radio systems.

5.3 Since a spectrum analyzer’s peak hold mode is not dynamic it will not show a reference of what one signal is to another at a particular time. The trace is a composite of the maximum levels built up over a period of time. It will show the frequency and indicate a possible source of problems.

5.4 The solution is a simple macro written to save all traces that have a signal level greater than –85 dBm on the screen. This will give the engineer an ability to see the interference referenced to their channel at a particular time. As he drives around, traces are saved for evaluation at another time. The database can also be sent to other engineers.

5.5 The limit line is easily entered into a table. After selecting that all traces be saved that exceed the limit, the application is selected and run. The number of times the program is repeated is written into the end of the program.

5.6 At the present time there is no requirement or long-range plan for using the LAT/LON information that may be saved with each trace for mapping purposes. With some work, it could be used in conjunction with a map program to pinpoint locations of possible interference, using the traces saved that exceed the limit.

5.7 The macro below shows the simplicity of the test program written to obtain the desired results. The spectrum analyzer will be set to a span of 250 KHz, attenuator to zero and the reference level to –30 dBm. The spectrum analyzer is then instructed to stop at each of the channels for six seconds and save any traces that exceed a limit of –85 dBm. Additional channels can be added by copying the center frequency and free run commands for the additional channels.

5.8

```
SP 250KHz
AT 0
RL -30dBm

CF 851.0875MHz
#TRACE:FREERUN .1

CF 851.0875MHz
#TRACE:FREERUN .1

CF 851.6125MHz
#TRACE:FREERUN .1

CF 852.1375MHz
#TRACE:FREERUN .1
#REPEAT 1 100
```

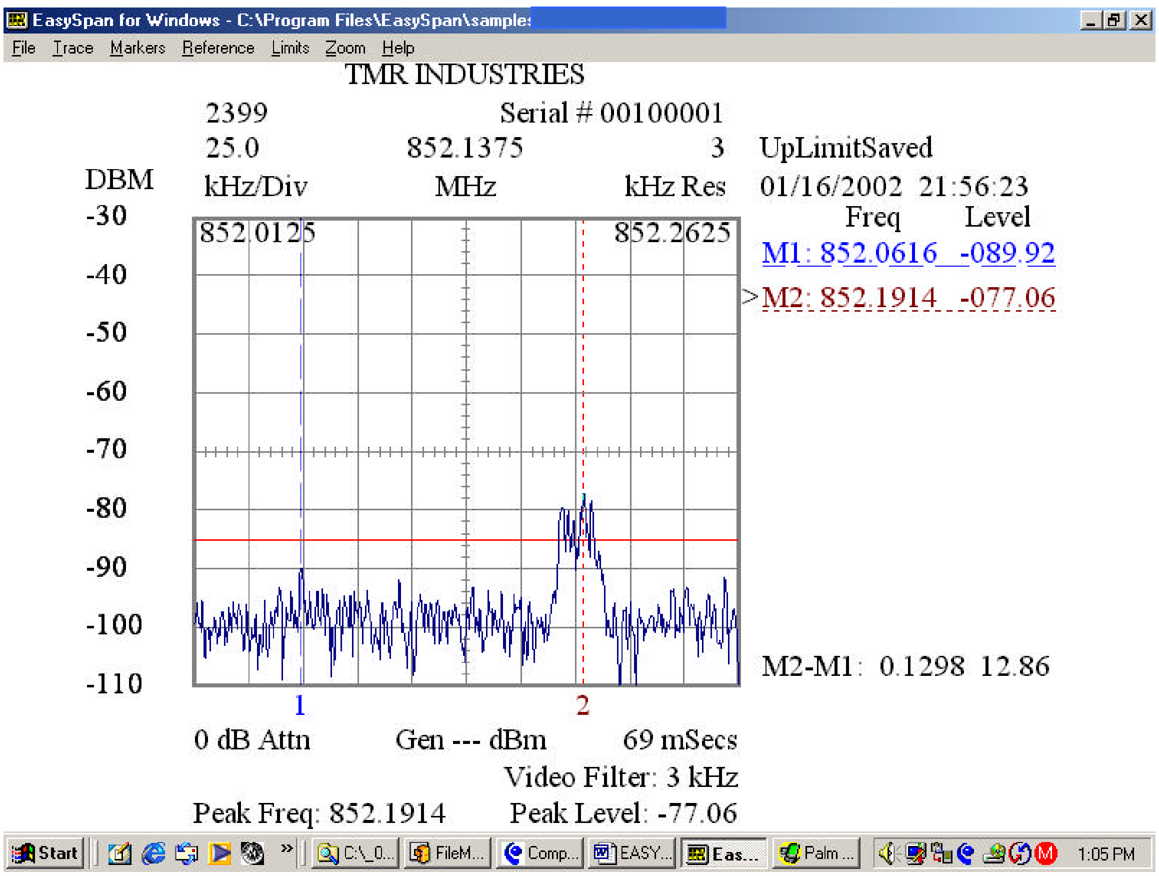

Fig. 3

5.9 Fig. 3 is a typical trace saved by the above macro. It indicates a signal of concern exceeding the horizontal –85 dBm limit line, at marker number two (M2 = 852.0616 MHz, -77.06 dBm). Without an indication of having an active channel at the center of the screen, there is no reason for concern. If an active channel were present, the engineer would take action to move his channel to another frequency or ask his neighbor to select another channel.

6 TEST TECHNIQUES

6.1 When looking for interference, connect an antenna to the input of the spectrum analyzer and look at the RF spectrum around the device exhibiting the problem. Center your signal on the screen. Set the span wide enough to include the full bandwidth of your signal and examine the trace for anything that looks suspicious. All dubious signals should be marked and recorded for evaluation. Change the spectrum analyzer's center frequency to each of the suspicious signals for closer examination. Change the center frequency of the spectrum analyzer to one of the previously recorded frequencies and change the span and resolution bandwidth (RBW) settings for a better view. Use the features of the spectrum analyzer to evaluate, spectrum shape, periodic pulse, audio demodulation, zero span for data, to help determine its origin. After the interference has been identified, a directional antenna will add the ability to see the direction of the interference.

6.2 Comparison to a similar trace dated before the onset of the interference will speed up the process of finding the problem. The latest trace will show evidence of a new or previous signal change of frequency or level. Transmitters are often reset to new levels or frequencies to improve coverage and avoid problems with service at another location. If the interference is entering the device under test from its antenna port, turning off any transmitter feeding the device and setting the spectrum center and span parameters similar to those of the device may yield the best results when investigating the RF spectrum for interference.

6.3 If the problem cannot be found with an antenna from outside of the system, other ports may have to be examined. Generally there are several connection points on a radio for testing frequency, power and the IF frequency that will support the low power spectrum analyze input. The interference may be generated internally by a power supply filter failure, local oscillator frequency or level change.

7 INTERFERENCE

7.1 Failing AC line insulators on ultrahigh voltage lines will allow corona to develop around it causing harmonics of the 60 Hz line voltage to be transmitted. The higher the line voltage, the higher the level of interference. Seven hundred and sixty five thousand volts can have a harmonic large enough to block a satellite signal. The higher humidity levels allow more corona, which equates to more interference. The change in humidity will have the appearance of the interference being intermittent.

7.2 Intermodulation is a source of interference everyone dislikes, because it manifests in areas not commonly scrutinized. Intermodulation problems are caused when two or more signals mixing together in a non-linear device produce an output containing other unwanted signals.

7.3 Second order intermodulation products are caused by two signals entering a device, mixing and causing a frequency array of 2 times frequency 1, 2 times frequency 2, frequency 1 plus frequency 2, and frequency 1 minus frequency 2.

7.4 Third order intermodulation products occur when the second harmonic of one of the two signals mixes with the other frequency – Fig. 4.

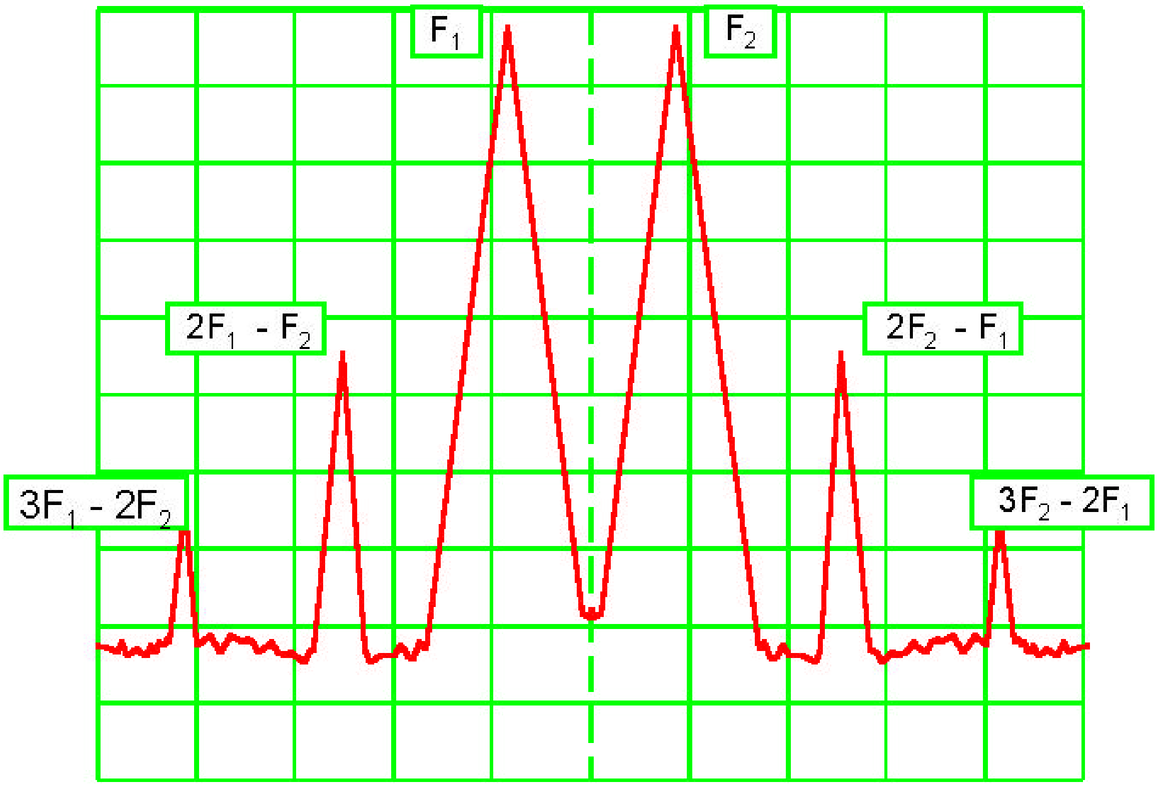

Fig. 4

7.5 Finding intermodulation products may be hampered by their low levels. When you see the unwanted signal, it is a matter of math to determine the source of the problem. If you know the frequencies in the system and the surrounding field, it is possible to calculate the interferor and take the appropriate action, i.e. change frequencies, filter out the unwanted signal, etc. Sometimes the troublesome signal causing the intermodulation may be hard to find. If an element of the tower becomes isolated through corrosion from the tower ground system, it can then become a sympathetic oscillator and transmit a frequency that is related to its length.

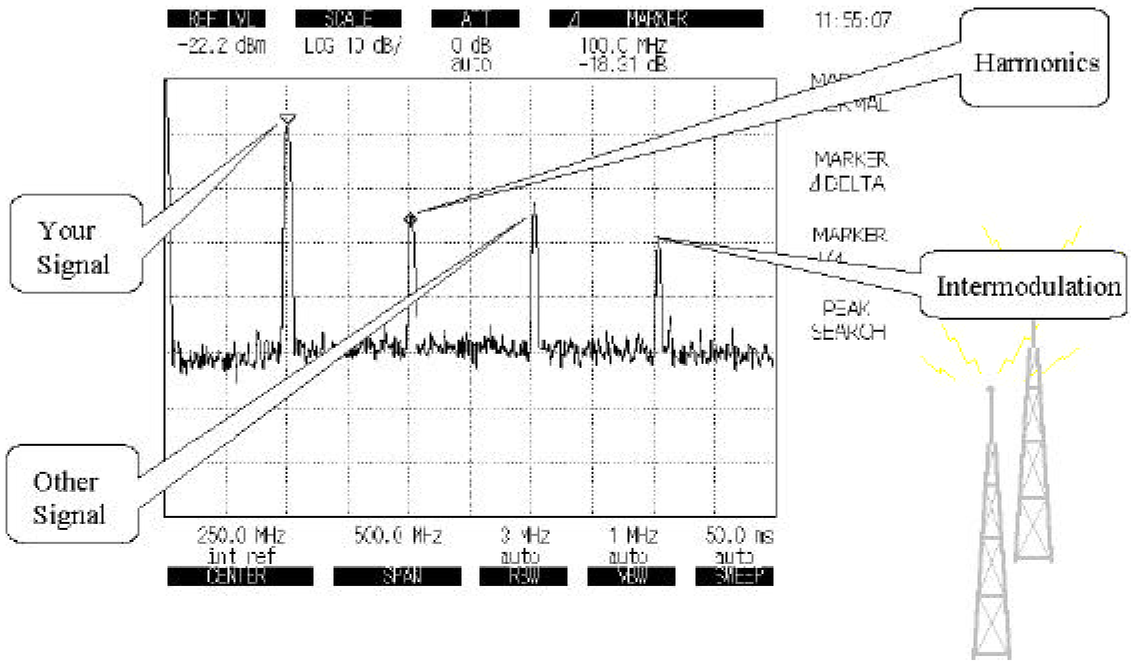

Fig. 5

7.6 Adjacent channel power is regulated and is easily tested just by looking at the spectrum beside the channel under test. It can be your channel interfering with your neighbor or vice versa. In either case, interfering with a neighbor can cause FCC intervention.

7.7 Radio transmission quality parameters, such as frequency, power and bandwidth, must be measured and maintained. If there is an intermittent condition it can have the same effect as intermittent interference and cause erratic operation of the system.

7.8 Fence chargers and electric welders are notorious for causing interference in the lower RF bands. The noise is broadband and affects many channels. Fence chargers have a 50% duty cycle and a one second pulse rate. The interference can easily be heard in your AM radio as a buzzing sound while you are driving through the countryside.

7.9 TV converters occasionally have problems and start transmitting their local oscillator frequency out the TV antenna. Even though this sounds out of the ordinary, it happens more than anyone wants to admit.

7.10 Hospital critical care telemetry systems operate on unused television channels. Recently the new Digital TV stations have been turning up their new transmitters in those previously unused channels. Originally they were doing this unannounced. After shutting down the telemetry systems in critical care wings of hospitals, people have worked out a solution before the TV transmitter is powered up the first time. Everyone in the two markets is now aware of the potential for life threatening problems.

7.11 Without looking at the RF spectrum and seeing the interfering signal, engineers were replacing cables and radio systems. As the new digital TV channel testing became more frequent and was powered up for longer periods of time, it was obvious the source of the problem was outside the hospital. Only then did the engineers find the source.

7.12 Cellular radios have had many problems. Cellular phones are controlled by the cell site and prevented from operation if the cell site finds them to be out of spec. However, in the case shown in Fig.6, the portable cell phone had developed a problem with its 3 watt amplifier system and was transmitting a band of frequencies 32 MHz wide in the cellular spectrum when the driver was not talking. The radio was rendering each cell site almost useless as it moved through the system. The driver of the vehicle stopped for lunch, giving the crew time to triangulate and get a fix on his position. Improper installation resulted in a major interference crisis for many people.

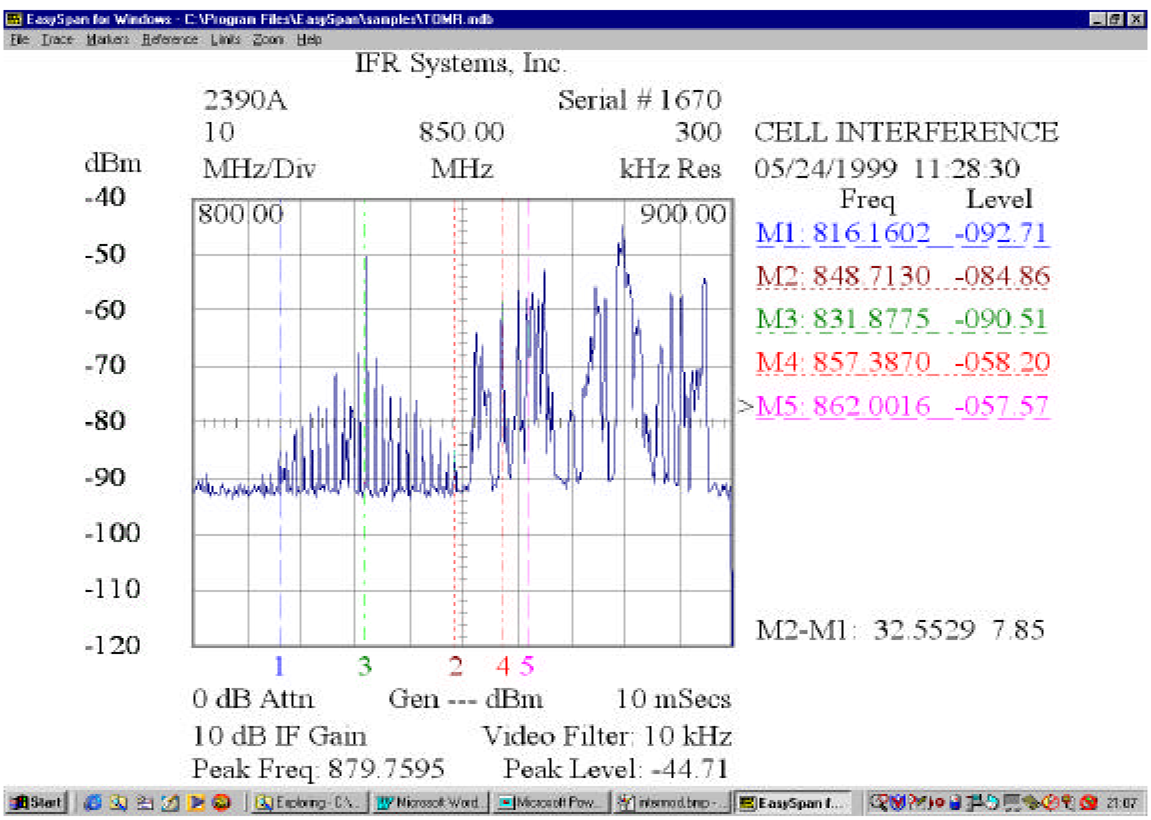

Fig. 6

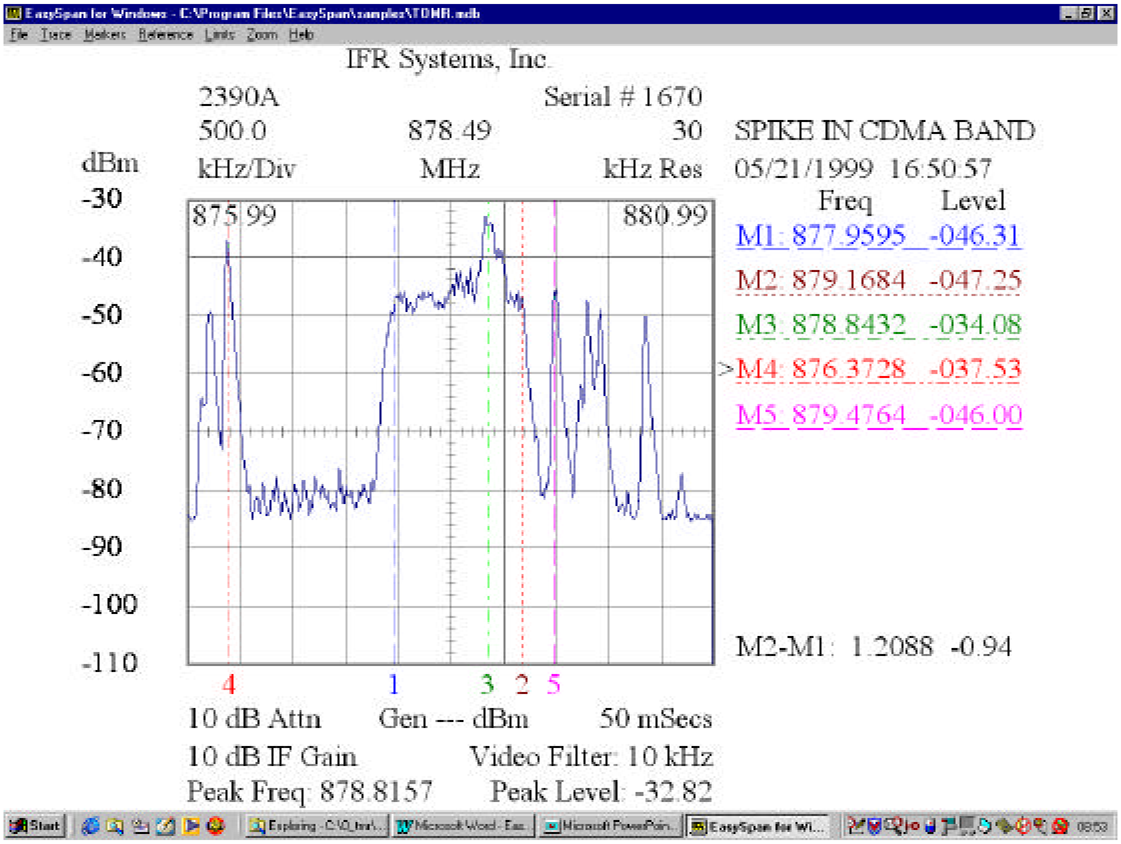

Fig. 7

7.13 Fig. 7 displays a rather obvious problem in a CDMA channel. Marker number three shows it to be at 878.8432 MHz and at a level of –34.08 dBm. The channel bandwidth indicated by the difference information of marker one minus marker two is about 1.2 MHz.

7.14 Intentional interference may be the hardest to find. One group found a simple signal source designed to step through the cellular band slow enough to cause dropped calls. There was also a timer that only allowed it to operate for 15 to 30 minutes at a time and it was not on any daily schedule. The device was found in the attic of a new house. Since it was a spec home and the device had undisturbed insulation blown over it, the homeowner was not charged with the incident. The device had been installed in the house during construction, after the electrical was installed. The device was activated when the electric company turned on the power.

7.15 The device was finally found by moving in a little closer to it each time the interference occurred. A spectrum analyzer was used to see the signal sweeping through the cellular band. With that information, the source was more easily found.

7.16 Chance sometimes plays a part in finding interference. A group of field service engineers had stopped at one location in their company trucks for coffee, when an individual, thinking he was the reason for their presence, walked up and confessed to them, explaining he was just causing the interference for fun and would never do it again.

8 The interference discussed above is just a sample of the possibilities. Remember to keep your mind open, visualize what you have and what it would take to corrupt your signal in that manner. Only then will you be able to properly utilize your tools to discover problem areas.