Practical Tips on Measuring Interference

/Inritsu

SPECTRUM MASTER™ MS2711B

1.0 Introduction

This is a practical **Interference Measurement Procedures** note. It accompanies a companion Anritsu application note, "*Fundamentals of Interference in Wireless Networks.*" For your copy of "*Fundamentals of Interference in Wireless Networks,*" request Anritsu Publication No. 11410-00302.

The objective of this note is to present measurement tips and procedures which will help a field technician measure signal interference in operating communications systems.

The individual measurement procedures described herein relate to a variety of interference causes and sources referenced in the "*Fundamentals of Interference in Wireless Networks*" application note. Outline numbers for those references are in **bold type** in the following format: (**Ref. Fund. 3.4.1**).

1.1 Unlicensed Data Communication Systems can be Primary Sources of Interference

By utilizing the ISM (Industrial-Scientific-Medical) frequency bands, the wireless industry has been able to exploit the increasing popularity of unlicensed communication systems. However, their unlicensed nature carries with it the seeds of serious signal interference problems. As described in the Fundamentals Note (**Ref. Fund. 2.2**), such ISM system designs are type-approved but are then installed by unlicensed owners or contractors. These conditions sometimes lead to signal configurations that unintentionally interfere.

When ISM technologies are applied to Wireless LAN applications, the radiated signals are essentially contained within one building. Even though other systems may be installed on adjacent floors or even on the same floor, those systems are designed to perform well in proximity to each other. Transmitter power is low, antenna gain is minimal, and modulation schemes are designed to overlap without interfering with each other.

When the ISM technologies are applied to microwave data links, trouble may result when multiple systems are installed near each other. Although the FCC (Federal Communications Commission) specification limit for transmitter power is 1 Watt, the system operator can choose to use very high gain antennas. These provide higher EIRP (Effective Isotropic Radiated Power) and can cause interference for other systems in or near their path.

Spectrum Master

Since these microwave data link ISM systems have the highest incidence of interference reports, this note will focus on these systems. Operationally, if the antenna gain is increased by 3 dB, the FCC rules require backing off the transmit power by 1 dB which still allows a net increase of radiated power and increases the chance of creating unwanted interference.

Although both Frequency-Hopping (FHSS) and Direct Sequence (DSSS) Spread Spectrum technologies work well in the ISM band, DSSS has tended to win out in the commercial race. Nevertheless, there are still a significant number of FHSS systems in place, most of which will stay in place as long as they deliver their specified data performance. These "legacy" systems continue to be possible sources of signal interference.

2.0 Finding The Interference

2.1 Connecting the Field Spectrum Analyzer

The Anritsu MS2711B Spectrum Master™ Handheld Spectrum Analyzer is the ideal tool for trouble-shooting interfering signals in the field because it is a lightweight, portable, calibrated measurement receiver. Since the interfering process usually involves overlapping frequencies, a spectrum analyzer is the one instrument which conveniently captures and displays such signal overlaps. The MS2711B exhibits approximately the same sensitivity as a typical affected system receiver and can be connected into the communication system antenna in place of the affected system receiver.

Figure 1 shows the "front ends" of two different types of communication systems. Figure 1(a) shows a typical cellular base station where the antenna signal is split into multiple receiver channels using a passive signal combiner/splitter. The measuring spectrum analyzer connection is made by unscrewing the signal cable at the receiver input and connecting it to the spectrum analyzer input.

Figure 1(b) shows a typical configuration of a microwave data link system, revealing how a microwave circulator component permits the use of a common antenna for both transmit and receive functions. The transmit and receive frequencies are offset into different band assignments. The transmit signal goes up in the direction of the circulator arrow and out the antenna. The received signal comes down from the antenna and follows the circulator arrow to the input of the receiver. Two bandpass filters are used. One cleans up the transmitter output spectrum and the other rejects the image frequency of the receiver, as discussed in the Fundamentals Note (**Ref. Fund. 3.1**).
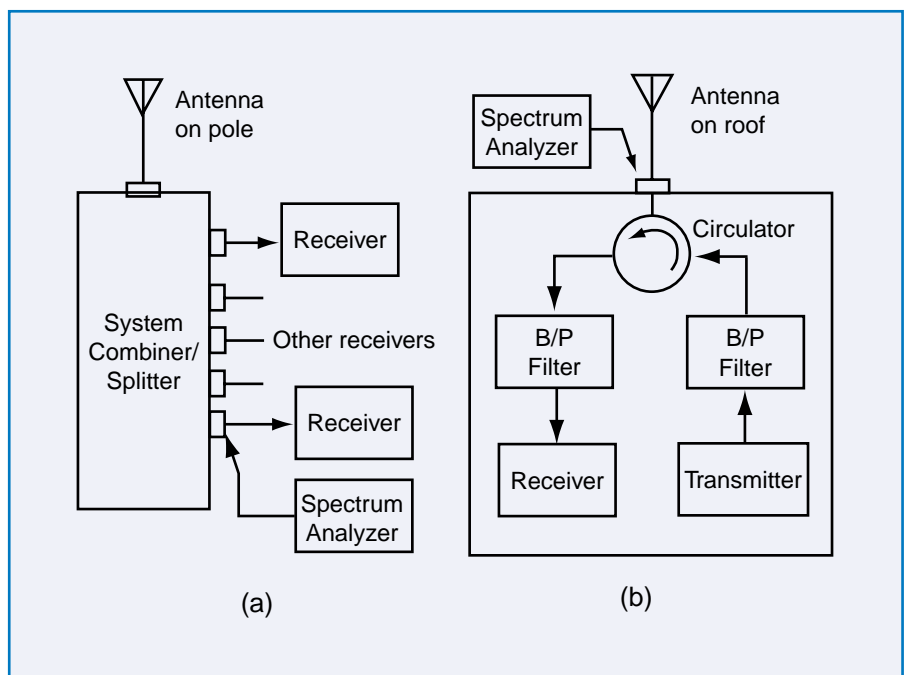

Figure 1. Search for interference usually starts with substituting the spectrum analyzer for the affected receiver by connecting its input at the receiver terminal. (a) The signal comes through a signal combiner/splitter. (b) Diagram shows a typical ISM data link where a common antenna is used for both transmit and receive. This is called a duplex antenna.

2.2 Some Useful Interferer Search Tips

The Anritsu MS2711B has powerful measurement functions and control key routines which enhance the operator's time and skills. Some of the most useful measurement routines are contained within lower levels of menus. So it is important to learn about them and how to use them to make many interference searches faster and less frustrating. A comprehensive explanation of the Anritsu MS2711B critical parameters and functional controls that are useful for interference diagnostics is presented in the *Fundamentals Note* (**Ref. Fund 4.2**). A few of them are repeated here for your convenience.

Markers – Set up the display to show the affected receiver's intended signal spectrum, and adjust the **Span** such that it is wide enough to show other overlapping/interfering signals. Use the Marker controls to identify the frequency of the interferer. If the interfering signal is higher than the intended affected channel signal, use the **Marker to Peak** soft key. Access it by using the blue **Marker** hard key, then **M1** soft key, and then **Marker to Peak** which will place the M1 cursor at the center of the highest interferer signal. An annotation on the display will show the frequency and power level of the signal at the M1 marker position.

If the interferer signal is smaller in amplitude than, but still overlapping the affected channel signal, use the **Edit** soft key to move the **M1** marker cursor right or left. Do this by pressing the **Up/Down** arrow key on the right side of the panel. Once **M1** is moved to the center of the smaller interferer signal, read the **M1** frequency and power level from the display readout. Move it to the center of the display by pressing the **Marker Freq to Center** soft key, after which you can spread out the span containing the interferer signal to measure or identify it.

Max Hold – For a number of system signals, such as cellular phone conversations, the signal transmission is intermittent. When you tune the spectrum analyzer to a channel full of such random calls, the spikes of signals come and go, rise and fall. This is a time to use the **Max Hold** soft key, which is accessed by pressing the **BW/Sweep** hard key. The display then shows the highest signal measured over multiple sweeps at each frequency across the band. Wireless channel spectrums slowly fill in and show the time-lapsed activity on those frequencies providing far more insight to the maximum signals present in that band.

Setup Save/Recall Menus – The MS2711B leverages the measurement power of a skilled operator by storing the instrument's many control settings in up to 10 different non-volatile data registers. Use the **Save Setup** and **Recall Setup** mode. To make quick changes between commonly-used measurement configurations. Setup location 0 contains the factory-preset control state.

Such **Save/Recall** procedures, which pre-set all the instrument controls to user-defined settings, are quite useful when the field job is routine and repetitive. You can pre-set the analyzer for standardized frequencies and band-widths of assigned communication systems. If done before driving to the field, this means minimum keyboard setup times for measuring quantities like carrier level in frequency-allocated channel assignments. For example, one **Save/Recall** instrument setting might measure carrier power in an assigned band, and a second **Save/Recall** instrument setting might measure the noise across the same span or the interference levels within that span.

Display Capture – A very important feature of the MS2711B is the ability to digitally capture spectrum displays which are measured during a long day in the field. Use the **Save Display** function. This permits the operator to take many measurements, name each one for the measured situation, and bring the instrument back to the office to download the display data. The beauty of this function is that all the numerical annotations of each saved display are available later to aid diagnostic work. Center frequency, span, RBW, and the amplitude settings are all there. The **Recall Display** key brings an index list to the screen for selecting and recalling saved waveforms. Up to 200 screen displays may be stored for later reference.

Preamplifier – When received signals are weak, which is often the case for field measurements, the pream-plifier function becomes important. The preamplifier adds 20 dB of gain right at the front end input. It is not wired in permanently because it can be saturated by other larger signals anywhere in its 1 to 3000 MHz input range. It must therefore be used judiciously and with knowledge of the signal environment. Turn on the preamp function by pressing the **Meas** hard key, then the **Preamp** soft key. When the preamp is engaged, the display shows an annotation **AMP** on the left lower side. If the preamplifier becomes saturated, an **AMP SAT** notation will appear in place of **AMP**. Eliminate the saturation by turning off preamp.

Demodulator – When the interferer signal seems like it might contain AM or FM modulation, such as in the case of a powerful AM or FM station tower nearby, use the **Demodulator** function to help identify the signal. Enable it by pressing the **Meas** hard key, next the **More** soft key, then the **AM/FM Demod** soft key. Use the **Demod Type** soft key to obtain a display list of modulation types. Pick AM or FM, based on the RF frequency characteristics (**Ref. Fund. 5.1**) and press the **Enter** hard key. Use the **Volume** soft key followed by the **Up/Down** arrow key to set the desired volume. You can hear the audio on the internal speaker or a plug-in headset.

Remember that a spectrum analyzer is a sweeping superheterodyne receiver. It electrically sweeps just like mechanically spinning the tuning dial of a regular AM or FM radio. To hear modulation, the automatic sweeping must be stopped. Bring the interferer signal into the center of the display and set the **RBW** resolution bandwidth to 100 kHz so that wideband FM signals can be properly demodulated. If you are listening on the earphones while the display sweeps, you will hear snippets of audio as the display sweeps through signal spectrum on the display. Once the offending modulated signal is centered, press the **Scan** soft key, then **Zero span**, which fixes the analyzer receiver bandwidth on a single frequency.

Antenna Accessories – Many field interference measurements will be made with an independent antenna when not connected to the communication system antenna. The most versatile kind of antenna is the so-called "whip" design. A whip antenna is a linear conductor connected to the coaxial input connector on the MS2711B. They are sized for ¼ wavelength at the specified center frequency. Some whips are also "inductive-loaded" which simply means that their physical length is not equal to the ¼ electrical wavelength just mentioned. Whip designs are omnidirectional and thus insensitive to directional effects. The following table lists available MS2711B antenna option numbers and their band coverage. Other manufacturers can serve for other bands, and one Radio Shack model is mentioned for reference.

For additional diagnostic power in certain interference measurement situations, the operator will need to use a directional antenna. Microwave data systems are an example where the system antenna directional performance is highly critical. In those cases, a directional antenna attached to the spectrum analyzer can help determine the direction from which an interfering signal is arriving.

Part Number	Frequency Range
Anritsu	**MHz**
2000-1200	806 – 869
2000-1035	902 – 960
2000-1030	1710 – 1880
2000-1031	1850 – 1990
2000-1032	2400 – 2500
Radio Shack	
20-034	27 – 940

Table 1. MS2711B Antenna Options.

Field Strength Parameters – In many cases interference measurements made with optional whip antennas do not need to be absolutely calibrated for measuring the field strength parameter. Searching out interferer signals often only requires relative quantities (affected signal vs. interferer signal), and can simply be measured in dB ratios. However, there are occasions when you will wish to measure absolute field strength units, for example -(x) dBm/meter. In that case, press the **Meas** hard key, then the **Field Strength** soft key, then the **Select Antenna** soft key. If the antenna is not in the list, upload the appropiate antenna via Handheld Software Tools. From the displayed list of standard or custom antennas, find the proper antenna option part number, and press **Enter**. This engages the proper amplitude calibration data for that whip antenna.

One example of when you might measure field strength is when you wish to determine the field strength present at the affected receiver signal in front of its system antenna. This would be best measured with a directional antenna kit using data calibration numbers uploaded to the spectrum analyzer before going into the field. If you are using a non-Anritsu antenna, you can upload that antenna sensitivity database using your PC and furnished Handheld Software Tools. While not directly an interference type of measurement, it could still be useful for troubleshooting a downed receiver by assuring that an adequate system signal is indeed present at the receiver antenna.

Occupied Bandwidth and Channel Power – The MS2711B spectrum analyzer features two computational modes which are very powerful for measurements on wideband data channels such as ISM data links.

Occupied Bandwidth (OBW) allows the operator to define the band edges of an occupied band by defining the power points. After the measurement, the **M1** and **M2** markers show as annotated frequencies on the display and define the band edges where the signal is 20 dB below the carrier. There is more detail on this feature below in section 5.3.

Channel Power arithmetically computes the integrated power contained within its defined bandwidth. This mode integrates the power contained within the defined **OBW**. See section 5.4.

3.0 Two Basic Types of Interference

Causes and sources of interference are covered extensively in the Fundamentals Note (**Ref. Fund 3.0**). This section will briefly review the two basic types of interference.

For both licensed and unlicensed systems, there are two basic types of interference:

    a) In-channel signals and noise, and
    b) Out-of-channel signals.

3.1 In-Channel Interference Causes

3.1.1 Licensed Interfering Signals
In most licensed systems, the frequency allocation process and antenna positioning application and approvals prevent overlapping signal paths and unexpected interference. No two systems are deliberately licensed to use identical channels and physically-interfering signal paths. So, in-channel interference from other systems is basically not to be expected, although unintended antenna misalignment can put signals where they don't belong. If licensed systems interact, the likely cause is out-of-channel signal effects.

3.1.2 ISM-band Signal Conflicts
In the ISM bands, signal interference is inherent because the installation of systems is uncontrolled except for the general type-approval of the basic specifications of the design. Wireless LANs and short-range microwave data links are common here and are installed by companies wishing to create a convenient and relatively inexpensive communications capability, such as an Ethernet bridge.

3.1.3 Intermodulation (Transmitted)
Intermodulation cross-products can be inadvertently transmitted by the power amplifiers of wireless system base stations (**Ref. Fund. 3.1.2**). The final power amplifier circuit configurations are designed with many amplifier sub-modules running in parallel amplifying a common signal. That way, if one sub-module fails, the entire base station keeps operating, at some reduced power level 1-2 dB down from the specified output level. The result, however, is that the dynamic range of the power amplifier combination degrades which can cause non-linear performance. This induces intermodulation cross-products which get transmitted. These intermodulation cross-products can fall within the pass-band of an affected receiver and interfere with the system.

3.1.4 Harmonics and Parasitics
It is possible for base station power stages to also create spurious signals or harmonics which are random signals that can be launched at relatively high power levels. Likewise, other powerful transmitters, like broadcast emitters, might deteriorate to produce harmonics or parasitics which fall in-channel.

3.2 Out-of-Channel Interference Causes

Out-of-channel signals which happen to cause problems for an affected receiver are generally found in areas close to high-power transmitters. These conditions are not unusual when the affected communications system shares common real estate with the high-power transmitters such as the tops of urban mountains that are prized for the large signal footprint they afford broadcast stations. There are primarily two interference mechanisms caused by high power signals; desensitization and intermodulation.

3.2.1 Desensitization
This mechanism for interference is that the legal high power transmitted signal enters the typical affected receiver and overpowers the designed rejection capability of the front end RF filter. The RF filter is intended primarily to reject signals and noise outside the passband of a superheterodyne receiver (**Ref. Fund. 3.2.1**). Desensitization can happen even though the affected receiver is designed to reject interfering signals.

As the high power comes in, the AGC (automatic gain control) of the affected receiver cuts back its own amplification. In that action, it reduces the amount of gain required for proper signal-to-noise processing of the needed data. It can also clip off the crest factor peaks of digitally-modulated signals, inducing bit errors.

You might have experienced this effect while riding in your vehicle listening to a favorite AM radio station. As you drive close to the broadcast tower of a different radio station, its powerful signal pushes through the front-end RF rejection filter and causes your receiver's AGC to reduce the sensitivity to the station you are tuned to. As its audio becomes weaker, the audio of the interferer predominates until you drive a half-mile or so away. Then the regular RF input filter begins to work again with more reasonable signal levels.

This out-of-channel effect does not show up as an interfering signal inside the passband of the affected receiver. If you were to tune your diagnostic spectrum analyzer to the band of the affected receiver, you would see no interferer signal there.

3.2.2 Intermodulation (re-transmitted)

A second way out-of-channel signals interfere is that high-power, out-of-channel transmitters can interact together to create new signals which do appear in the passband of the affected receiver. In order for such signals to intermodulate, there must be an external electrical non-linear element present. This means it is apart from the affected receiver itself. This could be an appearance of the "rusty fence" syndrome (**Ref. Fund. 3.2.1**).

In crowded real estate with many high power transmitters, non-linear detection can cause the re-generation of multiple intermodulation cross-products. If any of these fall within the affected receiver passband, they reduce the Carrier-to-Noise ratio (C/N) of the system.

4.0 Why the Carrier/Interference Ratio is Important

Every communications system is designed to reliably transmit and receive data (or voice) at some warranted data rate and with a specified data bit-error rate for a reasonable price. For example, one manufacturer of a point-to-point microwave system in the 5.8 GHz ISM band uses QPSK modulation for robustness in operation, and requires only a 13.5 dB average C/N ratio. This system delivers a warranted, uncorrected BER (bit-error-rate) of 1×10^{-6}.

The terms Signal and Carrier tend to be used interchangeably. We will use the term Carrier. The parameters Carrier-to-Noise ratio (C/N) and Carrier-to-Interference ratio (C/I) are both important as system specifications and as measured quantities in an interference situation. Since this is an interference note, we will focus on C/I.

Noise and interference both degrade the performance of an operating system. Interference tends to produce a slightly worse effect since it is coherent and the affected receiver tries to lock on to it. The result is inter-symbol errors. Once your field test determines the C/I ratio as measured at the receiver input connector, you can learn whether there is enough carrier margin for reliable data transfer by referring to the manufacturer's required C/I ratio specification.

5.0 An Example of Measuring Carrier/Interference Ratio

This measurement example will describe a typical DSSS link system which we define as operating in the 2.4 – 2.5 GHz ISM band. We will use selected parameters to describe the affected system characteristic. The spread spectrum affected system will operate with a center frequency of 2450 MHz and with an emission band of 25 MHz.

5.1 Setup

Connect the system antenna to the spectrum analyzer in place of the transceiver as shown in Figure 1(b) on page two.

> Use the **Freq/Span** key to access the **Center** frequency soft key. Use the numeric keys to enter the frequency value and the "terminator" keys, such as MHz, to attach the unit value.
>
> Key in 2450 and then press the **MHz** soft key.
>
> Choose a **Span** width which will display both the affected channel and the expected interferer frequencies. Use the **Span** soft key to set the span.
>
> Key in 50 and then press the **MHz** soft key.

5.2 Sweep with the Affected Carrier Turned On

To minimize the sweep time, the resolution bandwidth **RBW** can be set to its widest possible value, in this case 1 MHz. Use the **BW/Sweep** hard key to access the **RBW** soft key. Press the **Manual** soft key to access the edit function and then use the **Up/Down** arrow key to set the **RBW** to 1 MHz. Set the video bandwidth **VBW** to 300 kHz in the same manner.

Figure 2 shows a drawing of the broadband power spectrum nominally centered at 2450 MHz with a slightly-rising power on the right side of the affected receiver's signal profile. This slight rise is caused by the interfering signal which will be described below.

Although this rise might seem like a small effect on the overall channel power, it should not be trivialized since adding the power profiles of multiple signals on a logarithmic display is not intuitive. (See "Interpreting Displays" on page 8 to gain a better understanding of the magnitude of the effect of the interfering signal.)

5.3 Determine the Band Edge Frequencies of the Affected Channel

Some ISM data links have their "emission bandwidth" defined by the FCC as the –20 dBc

Figure 2. A drawing of the ISM affected receiver spectrum profile showing some interference effect on the right side of the spectrum

level (dB relative to the carrier). Others are –26 dBc. This step will determine the frequencies of the two band edges which occur at –20 dBc. The **Occupied Bandwidth (OBW)** function of the MS2711B is particularly useful since it is designed to find the band edges of the affected channel automatically based on the user definitions and the shape of the wideband signal.

> Press the **BW/Sweep** hard key and check that the **RBW** and **VBW** settings are for 1 MHz and 300 kHz, respectively. A 1 MHz setting for RBW assures that the full signal powers get displayed. **VBW** can also be set to Auto, which optimizes the VBW setting for the selected RBW setting, and in this case will set 300 kHz.
>
> Press the **Meas** hard key, and select the **OBW** soft key. In this case, we are defining the band edges as the –20 dBc points.
>
> Press the **dBc** soft key. Key in 20 (the MS2711B only looks for dB below the carrier) and press **Enter**.
>
> Now press the Measure **On/Off** hard key to initiate the measurement. The MS2711B will automatically search for the peak level in the band and find that little hump for the "reference" level. From Figure 2, the reference level will be just about at –50 dBm. Then the MS2711B finds the –20 dBc points.
>
> This will result in a affected channel power display with two marker vertical lines plotted at the –20 dBc points on the band slopes as shown in Figure 2.
>
> Press the **Marker** hard key to annotate the two emission band edge frequencies as **M1** and **M2**. M1 will be the *low* band edge (2437.5 MHz) and M2 the *high* band edge (2462.5 MHz). Record them for Step 5.4.

5.4. Measure the Affected Channel Power
(This will be the "C" of the "C/I ratio".)

The MS2711B **Channel Power** measurement mode computes an integrated channel power over a defined band.

> Set the Start and Stop values for the measurement using the M1 *low* and M2 *high* values of Step 5.3.
>
> Press the **Freq/Span** hard key, then the **Start** soft key.
>
> Key in 2437.5 and then press the **MHz** soft key.
>
> Press the **Stop** soft key, then 2462.5 and **MHz**.
>
> Press the **Meas** hard key, and then the **Channel Power** soft key. This will automatically convert the display annotations to show the **Center** frequency as 2450 MHz.
>
> Press the **Integration Bandwidth (Int BW)** soft key, and key in the computed difference between the previously measured and recorded M1 and M2, 2462.5 – 2437.5 = 25 MHz.
>
> Verify on the display annotations that the **Int BW** and **Span** numbers are the same, 25 MHz.
>
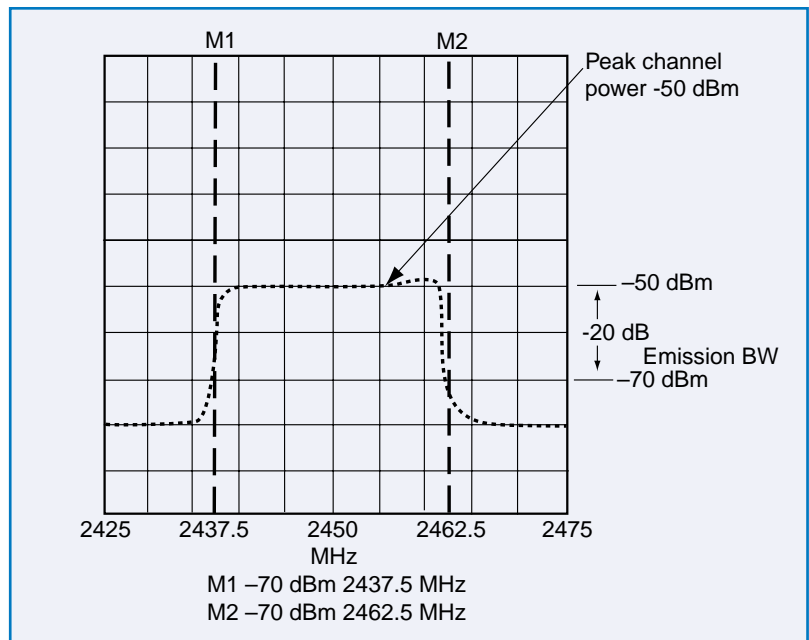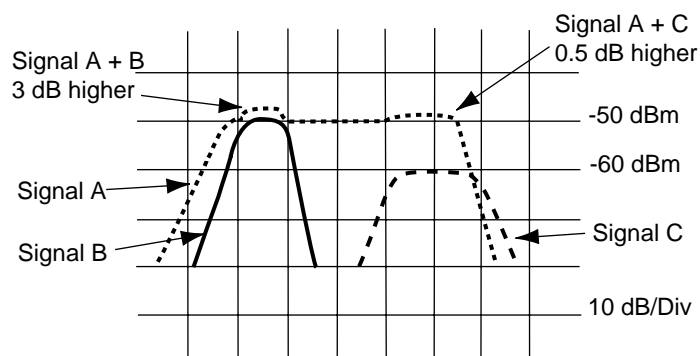> Next, enable the **Channel Power** measurement by pressing the **Measure On/Off** soft key.

Interpreting dB Power Displays on a Spectrum Analyzer

When multiple signals are combined on a spectrum analyzer's logarithmic display (10 dB/div for this display), the resulting combined power spectra is not intuitive.

When using a spectrum analyzer in its logarithmic display mode, typically 10 dB per division, adding the displayed signal powers from several sources is not immediately obvious. In the figure, the main affected Signal A is shown flat at –50 dBm. An interfering Signal B is shown having the same –50 dBm power level.

The sum of two different signal traces is not the added physical heights of the two displayed traces. Decibels (dBs) are logarithmic values so they add in non-linear fashion. When Signals A and B add together to form a single trace, although they create a combined linear power which is twice the amount of either, the displayed logarithmic power is just +3 dB higher.

Likewise, when Signal A combines with Signal C, since Signal C is 10 dB lower than Signal A, meaning only 1/10 the power, the combined power of A and C is 10% higher, or 1.1 times the power of Signal A. This logarithmically adds to only +0.42 dB higher than Signal A, as shown.

This explains why, in the C/I example of Figure 2, that the affected receiver spectrum rises only slightly on the right side where the interference signal is located.

Note that when the **Channel Power** measurement is enabled, the detection mode is automatically changed to **Average** (that is, the display point is the average of all the measurements associated with that point). You may need to change the detection mode to **Positive Peak** (the display point is the maximum of all the measurements associated with that point) to correctly identify your signal. To do this, press the **BW/Sweep** hard key and then the **Detection** soft key. Press the **Positive Peak** soft key.

The above channel power measurement sequence results in an integrated power measurement that is displayed as **CH PWR**. Let's assume, for this example, the displayed channel power reading is –37 dBm. Essentially, the internal MS2711B channel power measurement algorithm has computed the power across the emission (integrated) bandwidth by combining 25 of the 1 MHz power slices of the **RBW** (which is set to 1 MHz), each of which is –50 dBm, and provides a reading of –37 dBm for the 25 MHz-wide signal.

Raw affected channel power (C) = –37 dBm

5.5 Sweep with the Affected Carrier Off to Determine the Interference Signal Bandwidth

We will now measure the integrated power of the interference signal across the 2425 – 2475 MHz spectrum. To do this, it is necessary to turn off the affected receiver's transmitter at the other end of the link. When we do this, only the interference signal is visible on the display.

Figure 3 shows a drawing where the interfering signal is offset on the right side. Since the analyzer display is already set up to center in on the affected receiver band, the interfering signal may be integrated as follows.

Use the **Occupied Bandwidth** procedure of Step 5.3, above, to measure the band edge frequencies of the interference signal. From Figure 3, the reference power level would find the highest point of the interference profile (–60 dBm) at approximately 2458 MHz. **M1** and **M2** will identify the –20 dBc points at 2450 MHz and 2470 MHz, respectively. Record those numbers as inputs for Step 5.6.

5.6 Measure the Interference Channel Power
(When corrected, this power will be the I of the C/I ratio.)

Figure 3. An example interference signal. Occupied Bandwidth mode is used to determine the –20 dBc band edge frequencies, annotated as M1 and M2.

This is a rerun of the process in Step 5.4. Again, using the **Channel Power** mode, set the low and high frequencies to 2450 and 2470 MHz, respectively, and an Int BW of 20 MHz.

When the **Meas On/Off** key is pressed, the **CH PWR** annotation will show the integrated power across the measured 20 MHz spectrum. Let's assume a reading of –47 dBm, which is realistic for a peak power of –60 dBm, a sweep width of 20 MHz, and a smooth peaked profile.

Raw interference channel power (I) = –47 dBm

5.7 Calculate the Overlapping Frequency Range of the Interferer and Affected Signals

Frequency overlap = (2462.5 – 2450) MHz = 12.5 MHz, at the –20 dBc upper band edge

5.8 Normalize the Interfering Signal Power to the Overlapping Frequency Range

The interfering signal's emission bandwidth is 20 MHz, so:

Norm = 10 log (12.5/20) = –2.04 dB (You may need to use an engineering calculator to find this logarithm.) Compute the part of the interference channel power in the overlap portion:

–47 dBm –2.04 dB = –49.04 dBm

Remember that – 3 dB is half power. This calculation shows that only about half of the interferer spectrum power is inside the affected channel, so its effect is a bit more than half (–2.04 dB) as important.

5.9 Normalize the Overlapped Interfering Signal Power to its Effect on the Entire Affected Power Emission

The affected signal's emission bandwidth is 25 MHz and the overlap is 12.5 MHz, so:

10 log (12.5/25) = –3.0 dB

Overlapping interference power, normalized to affected channel width = –49.04 dBm –3 dB = –52.04 dBm

This means its influence on the spread spectrum affected channel is equivalent to half the overlapping interference power.
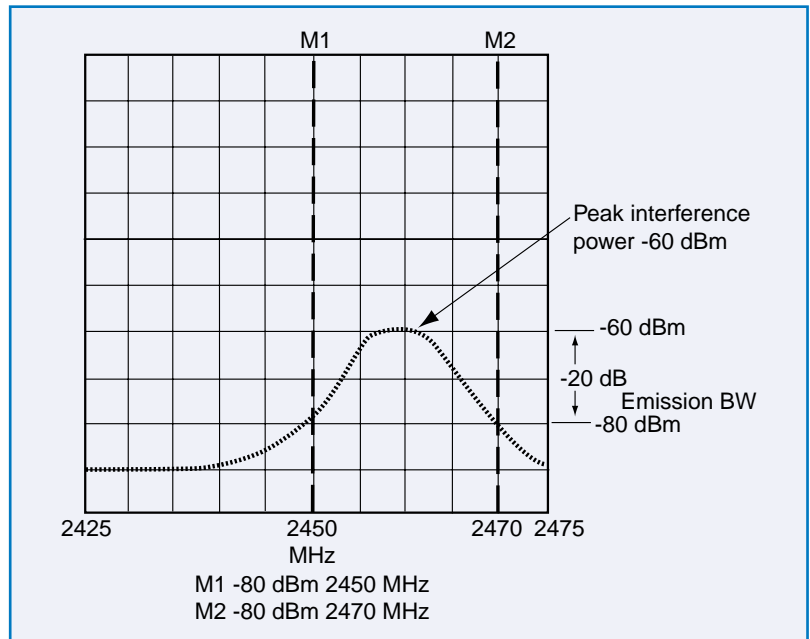
5.10 Compute the Operating C/I Ratio

Finally, to find the C/I ratio at the receiver input, subtract the dBm numbers, C/I = –37 dBm – (–52.04) dBm = 15.04 dB

Use this measured/computed ratio to check against the manufacturer's specifications. This will tell if the affected system has enough signal performance margin to operate correctly even with this amount of interference. If it's marginal, the antenna parameters or position may need to change to maximize the carrier power.

The portion of the affected channel band not occupied by the interferer below its –20 dBc emission band edges also contains noise which enters the affected receiver. There also may be other interfering signals buried down below that level which the measurement analyzer does not capture. The above measurements ignore that noise below the –20 dBc emission band edges since it is too small to dramatically influence receiver performance (–20 dB = $\frac{1}{100}$ power).

6.0 An Example for Diagnosing Desensitization Effects

By definition, desensitization is caused by a large signal getting into a receiver input enough to drive the front-end mixer or amplifier chain into saturation. This renders the amplification non-linear, and upsets the affected system communication signal and its modulation. In most cases, a desensitizing signal comes from out-of-channel since by the time an in-channel interferer gets large enough to saturate the front end, it has already disrupted the affected's signal data.

There is one case where an in-channel signal could cause desensitization, and that is in the case of the ISM band. Since most of the ISM communications systems are designed to operate spread-spectrum, they can tolerate large single-frequency interferers, such as leaking microwave ovens, which operate in the center of their band. But if an oven or other industrial microwave source leaks significantly, it might arrive in a given ISM receiver large enough to drive the receiver into saturation.

When desensitization is suspected, the best way to detect it is to connect the spectrum analyzer to the system antenna at the input connector of the affected receiver. Set the analyzer **Span** to the operating channel span of the affected receiver. Turn off the affected transmitter if you can. If you don't detect a large unexpected signal in that span, the desensitizing signal is not coming from an in-channel source.

Next, set the spectrum analyzer to its widest span, for example 0.1 to 3000 MHz, which will provide a panoramic display of the entire significant signal environment at the system antenna. By analyzing this ultra-wide display for signal strength, you should be able to identify a responsible high power emitter. If the signal strength of the possible interferer is in the range of 20-30 dB higher than the affected receiver signal, it is highly possible that is the desensitizing source. It may be necessary to scan narrower bands, instead of the full 3000 MHz in one scan, in order to give better resolution. Choose 500 MHz segments at a time.

Once a possible interferer is identified, the best way to make a final determination is to insert an external RF bandpass or highpass filter into the antenna path which passes the affected signal, but attenuates the desensitizer signal. If the system operates correctly, you can be confident that the interferer is the source of the desensitizing phenomena.

7.0 An Example for Interference in Cellular Base Stations

With an installed base of tens of thousands of wireless base stations, it is not surprising that weather and moisture would ultimately creep into the cabling and radomes of even well-designed antenna installations. One of the common outage complaints is that of intermodulation interference caused by corroded connector and other cable components.

This interference complaint is most common in systems which are designed with a so-called "duplex" antenna installation. In the duplex design, the same physical antenna is used for both the base station transmitter signal and its receiver signals, similar to the diagram of Figure 1(b). Technically, there is no inherent downside in such a design since the transmitter signal frequency is offset from its receiver frequency. With proper bandpass filters on the receiver and transmitter sections, the channel signals normally will pass in and out of the shared antenna without a problem.

The specific cause of this interference is the intermodulation from non-linear external elements, as described in section 3.2.2. What happens is that a broadband signal, say 30 MHz wide, of TDMA or CDMA spectra from a transmitter propagates to the antenna. But the signal hits a wet, corroded cable connector which acts like a detecting diode, i.e., a non-linear element. When multiple signals on a broadband channel hit a non-linear element, cross-frequency inter-modulation products are created which in effect spread out the frequency spectrum. These intermodulation products end up right in the adjacent assigned band of the base station receiver which uses the same antenna.

The cross-products head back down the same cable to the base station receiver and interfere with legitimate mobile signals to the receiver. Knowing that corrosion is a common complaint, the operator can immediately use the spectrum analyzer to measure the background signal level of the assigned receiver channel. It is necessary for the operator to consult the system specifications to find the normal receiver noise level under proper operating conditions. When non-linear effects caused by corrosion are present, the noise/interference level will increase depending on the seriousness of the non-linearity. When serious, the noise level will usually be 15 – 20 dB higher than a properly operating system. An easy diagnostic test is to simply turn off the associated base station transmitter since when its broadband signal goes away, so will the intermodulation interference.

By the way, in wireless base stations which don't use the duplexed antenna design, corroded connectors can still intermodulate a transmitter signal. But those illegitimate cross-frequency interference products now have to be transmitted into space and hit some kind of reflective surface in order to come back into the receiver antenna. Therefore, this effect is mostly non-existant in systems with independent antennas.

8.0 A Measurement Example for Cellular Base Station Interference Testing

It is instructive to note that in conversations with experienced field technicians, there is little hard-and-fast test procedural information available. The main guidance is to bring good test equipment (a MS2711B Handheld Spectrum Analyzer and Anritsu SiteMaster® are a good start). Add in a directional antenna kit, a protocol analyzer for identifying specific signals, and a clear mind for working with many clues to ultimately determine an interference culprit.

The protocol analyzer is created by using a laptop hooked to a phone line. You can run software which obtains the RF signal level and neighboring base station information, as well as GPS location information. Experience shows that more interference occurs in the 800 MHz band than the 1900 MHz band, mostly because there are more shared system functions in the lower (earlier-implemented) band. As new wireless services like 3G and others crowd into the upper band, time will tell whether more interference will also arrive there.

A first line of measurement at a downed site is to use an omni-directional whip antenna on the MS2711B to see if there is a possible super-high level interferer on the air. This might be a UHF TV station with 5-50 kWatts emitted power. While this station might have been anticipated at the first installation of the base station, perhaps the TV antenna pattern has shifted or a reflecting surface of a new building has emerged in the interim. The TV transmitter also might have deteriorated, producing higher harmonics.

Another arrival procedure would be to shut down the base station transmitter and then utilize the system antenna (100 ft. up on the mast) by connecting the MS2711B to the antenna cable. Since the spectrum analyzer has a sensitivity approximating the wireless receiver, most regular environment signals and interferers can be seen on the display. By knowing ahead of time the expected mobile phone traffic levels at the assigned receiver channels, the operator can read the received channel signals by tuning the analyzer to the assigned receiver band and seeing if excessive interfering signal strengths are present.

If the outage complaint call indicates a sporadic or random interferer over long periods of time, the MS2711B can be configured into a time-lapse monitor of sorts. Set up the analyzer for **Max Hold** on the channel with random signals, and it will capture and display the maximum signals versus frequency over time. After an appropriate wait time for the random signals to accumulate, use the **Save Display** function to name and record the annotated display for downloading display captures and analysis back at the office with Handheld Software Tools.

9.0 Setting Up A Directional Signal Survey

After finding a suspected high power interferer using the affected system antenna connected as in Figure 1, disconnect the MS2711B from the system. Set up the spectrum analyzer with its own omni-directional antenna by choosing the optional Anritsu antenna which matches the affected band. Measure the affected signal amplitude using the operating antenna calibration factors of the accessory antenna. If these factors are not in memory, up-load them in the office from your lab PC using Anritsu's Handheld Software Tools. Use the procedure covered in Chapter 8 of the User's Guide of the MS2711B User's Guide, MS2711B Handheld Spectrum Analyzer, Anritsu Company, Pub. No. 10580-00074.

The display should show a simultaneous display of the affected system and the interferer. Since the receiving antenna is now omni-directional, the ratio between the affected signal and the interference will be changed. Because the spectrum analyzer is no longer directly connected to the affected system, there will be a reduction of the affected signal while the interfering signal remains about the same.

Next, replace the omni antenna with a directional antenna kit. This will permit you to diagnostically search out the direction of the interferer signal. For this step, it will also be useful to have the directional antenna factor calibration numbers uploaded into the analyzer memory. The directional antenna will have considerably more sensitivity in its "boresight" direction, so the amplitude sensitivity settings of the analyzer may need to be less sensitive.

Use the same center frequency and span settings as in the previous steps. Turn the antenna in a full 360˚ azimuth pattern while watching the amplitude changes on the display of the interferer signal. This step should identify the direction the interferer signal is coming from. The direction of the highest signal will generally be the direction of the interferer since reflections are normally not involved. It is useful to have a compass handy for plotting the direction of the interferer on a map.

Sometimes it will be necessary to drive to another receiver location in order to obtain a second directional data point. This second data point will allow you to draw two lines of interference on the map to bracket the position of the identified interferer. If the interferer is legitimate, and the transmitter is not emitting out-of-channel signals, you will have to solve the interference by other means at your own site. Perhaps more bandpass filtering or antenna realignment will work.

Some data link manufacturers supply computer-assisted program software which allows the interference sources to be plotted. These data include their coordinates of latitude and longitude, signal frequencies, strength and directions. These software routines help compute the seriousness of the various components of signal and antenna pattern overlaps.

10.0 Conclusion

This note is intended as a guide for using the Anritsu MS2711B Spectrum Master Handheld Spectrum Analyzer to search out interference sources that conflict with operating communication systems. While experienced field engineers and technicians will acknowledge that a logical measurement sequence leads to good solutions, they also admit that creativity and persistence are valuable field test traits when tracking down sources of, and solutions to, interference.

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