PRELIMINARY

RF Center Frequency and Interference Analysis Guidelines

Reference: RF Center Frequency and Interference Analysis

These guidelines are intended for an experienced and Cisco qualified specialist Field Engineer to gather data for RF Engineering purposes. The procedures that are described are performed in order to make a determination of basestation center frequency and possible interference points. Please refer to all regulatory information for your region prior to performing these procedures.

Before You Start

Overview

An RF interference analysis is usually called for under two conditions. One is when it is used for evaluating a candidate BWX 8415 Basestation (BS) site prior to deployment of equipment. We refer to the interference testing under these circumstances as a Pre-installation Test. The second is the Post-installation Test, when data is collected to determine (a) if there is any interference in the area at all; or (b) the source, or cause, of known interference in the area of the installed and operational site. As is obvious from the name of this test, it occurs after the basestation has been deployed and turned up.

The instructions in this document assume the Field Engineer is at the BS site where the testing will take place. The data the Field Engineer gathers using the Interference Sweep procedure in this document will be evaluated and used in the calibration of the basestation. The data will help verify and plan for noise in the area.

To get the most benefit from this procedure, we suggest you follow these high-level steps:

Step 1: Read the entire procedure.

Step 2: Choose the correct Test configuration setup, per this procedure.

Step 3: Perform the Interference Sweep procedure.

Step 4: Send the results to Cisco or your RF Engineer.

PRELIMINARY

Required Equipment

You will need the equipment shown in Table D-1 to complete the interference testing.

Table D-1   Required Equipment

Equipment	Comments
HP4404B, FSH3, or FSH6 Spectrum Analyzer (or equivalent)	**NOTE 1:** If checking for 3.4/3.5 GHz spectrum, make sure the Spectrum Analyzer reads up to 4 GHz. **NOTE 2:** An equivalent analyzer must have the following functions: Screen Save abilities, Max-hold function, Peak search, and ability to operate in the required frequency range
BWX Basestation Antenna Test Box	
QMA, N Type Connectors, and different RF cables to make the connections	
Test antenna in the given frequency range	Cisco BWX Basestation Antenna
LNA in the given frequency range	- With a standard antenna you need an additional 30 dB of gain

Spectrum Analyzer Settings

There are two types of interference tests conducted under either the Pre-installation or Post-installation situation: Frequency Domain test and Time Domain test. The following section explains some specific settings on the Spectrum analyzer, and what effects they will have on these tests.

Frequency Domain Test

The Frequency Domain test is a measurement of the amplitude of an incoming signal across a given frequency span. Setup for the Spectrum Analyzer:

- Frequency = the channel to be tested (refer to frequency charts later in procedure)
- Bandwidth (BW) = 100 KHz or lower
- Reference Level = –50 dBm
- Attenuation = 0 dB
- Preamp, if available = on
- Span = determined by the start and stop frequencies

For the Frequency Domain test, the two parameters most frequently configured incorrectly are Reference Level and Bandwidth. To help the user determine the best settings, this section gives a short description as to what changes will be seen on the display if the parameter is changed.
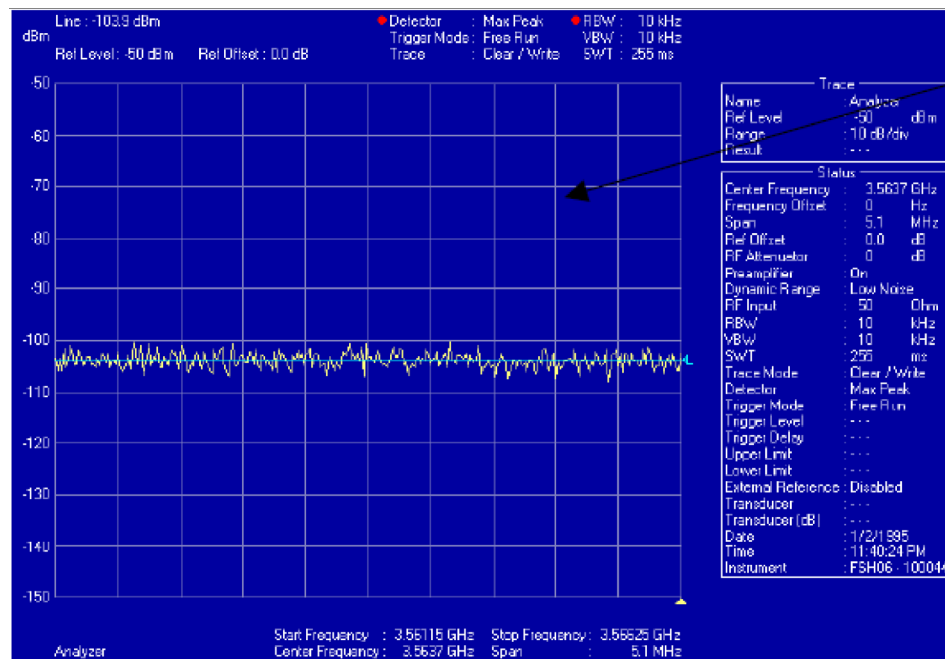
P R E L I M I N A R Y

Reference Level

This parameter sets the level of the top line of the Spectrum analyzer display (Figure D-1). Figure E-1 shows a display with the reference level set to –50 dB and the noise floor at –104 dB. The Blue line is a display line showing a level of –103.9 dB.

As you can see, the top-level line displays –50dB. On most Spectrum Analyzers the RF noise floor is coupled with the Reference Level line. A Spectrum Analyzer will try and display the noise floor on screen. If the reference level is set at a level that is too high for the Spectrum Analyzer to display the noise floor, it will automatically change the displayed level for the noise floor (Figure D-2).

Figure D-1   -50 Reference Level
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PRELIMINARY
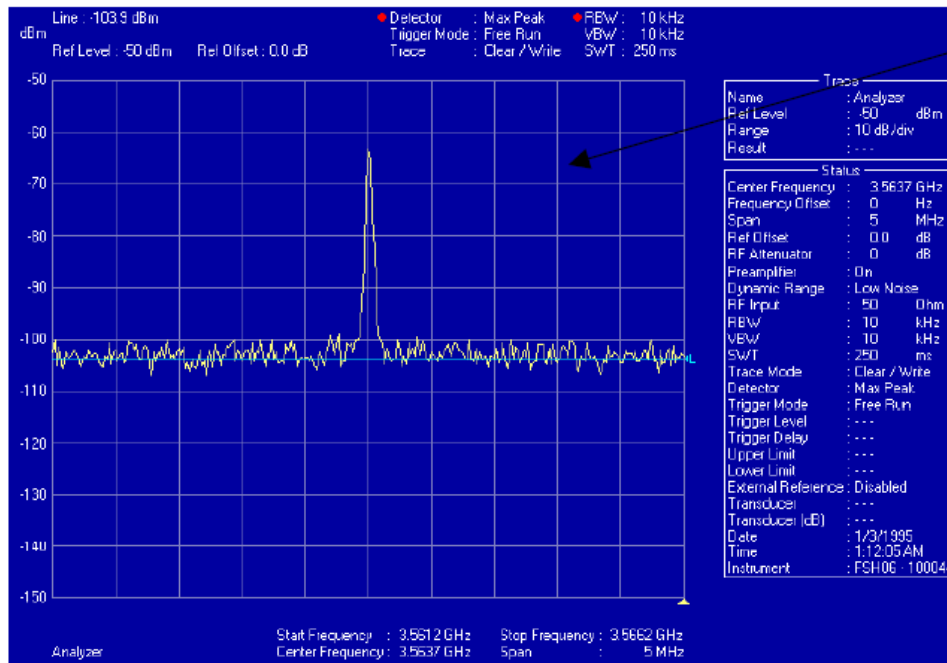
Figure D-2   -10 Reference Level
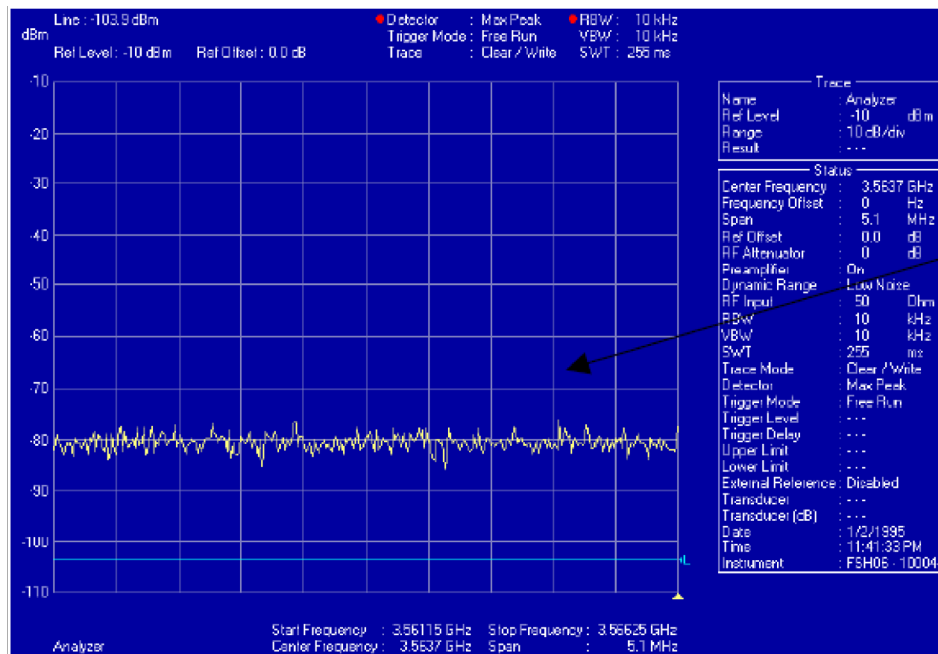
Bandwidth

Figure D-2 shows a reference level setting that was manually raised in the Spectrum Analyzer to –10. The blue line is the display line that was set with the original noise floor at the –50 reference level. When the reference level was raised from –50 to –10 the displayed noise floor also raised approximately 25 dB By setting the reference level to a lower value, the Spectrum Analyzer is able to display a noise floor that is closer to the actual digital noise floor of the equipment.

Figure D-3 and Figure D-4 show the reason the reference level is important for capturing data for interference measurements. In Figure D-3, the reference was set at –50 dB level. A –65 dB signal was injected into the Spectrum Analyzer. In Figure D-4 the same –65 dB signal level was injected into the Spectrum Analyzer, but the reference level was changed from –50 dB to –10 dB.

Figure D-4 still shows the –65 dB signal but only at 18 above the noise floor; whereas Figure D-3 shows the –65 dB signal at 40 dB above the noise floor. While measuring interference, if the reference level were set to –10 dB the Spectrum Analyzer would not display any signal levels below the displayed noise floor level, effectively masking any interference in that area.
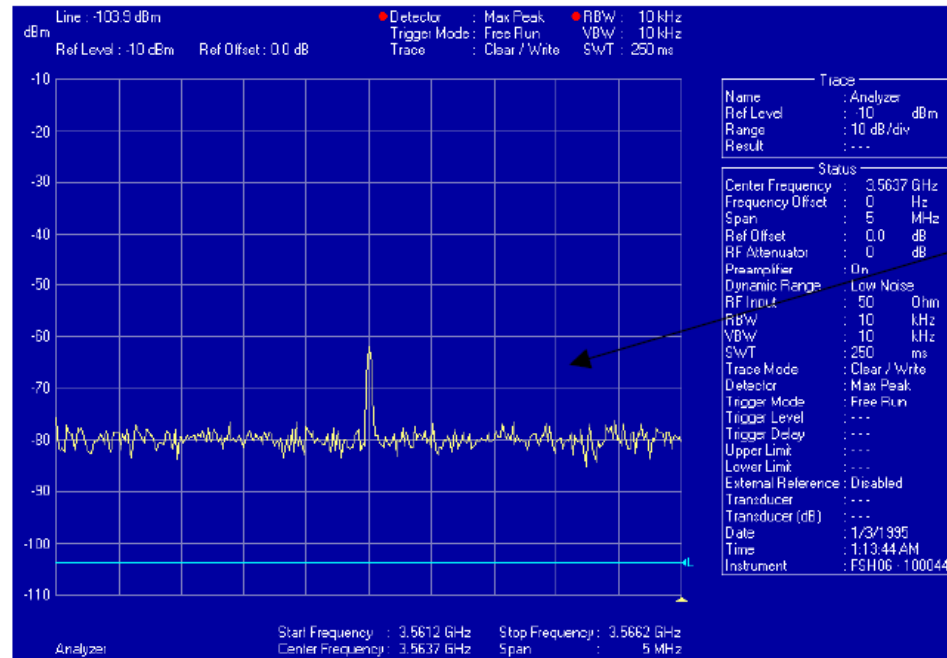
PRELIMINARY

Figure D-3   -50 dB Reference Level with Injected Signal

Figure D-4   -10 dB Reference Level with Injected Signal

PRELIMINARY

The bandwidth parameter is used for the measurement and display of the signal level across a given range or span of frequencies. Within a given bandwidth there are 2 settings — one is Resolution bandwidth, and the other is Video bandwidth. To discuss bandwidth, an understanding of the Spectrum Analyzer display is needed. The display is broken out into frequencies and signal strength levels. Frequencies are displayed left to right, which is called the Span. The signal level is displayed from top to bottom and is shown with a signal strength level on the left side of the display.

Bandwidth in the Frequency Domain test is tied to the span function. Resolution bandwidth is the measurement steps or slices that the Spectrum Analyzer uses while sweeping across the span of frequencies. The Video bandwidth is the steps that the Spectrum Analyzer displays to the screen as it sweeps across the span of frequencies.

Two different bandwidths are used in the following examples. One is 10 KHz in a 5 MHz span (Figure D-5), and the second is 100 KHz in a 5 MHz span (Figure D-6). With the 10 KHz bandwidth, the Spectrum Analyzer will make 500 steps to sweep the 5 MHz span, whereas on the 100 KHz bandwidth only 50 steps are made.

With a wider bandwidth (100 KHz) the receiver front-end of the Spectrum Analyzer is opened wider, **allowing for more noise to be input**. With the smaller bandwidth (10 KHz) the Spectrum Analyzer receiver is narrower and less susceptible to outside noise, thus giving a more accurate measurement. The drawback to a smaller bandwidth is the sweep time for the Spectrum Analyzer to step across the span. The sweep time increases, affecting the amount of time to perform the tests.

Figure D-5 and Figure D-6 show the effect on the noise floor by increasing the bandwidth from 10 KHz up to 100 KHz. The setup in Figure D-5 is a 10 KHz resolution and video bandwidth, and a span of 5 MHz. In Figure D-6 the bandwidth was increased from 10 KHz to 100 KHz. By raising the bandwidth in Figure D-6, more noise was seen by the Spectrum Analyzer, in effect raising the noise floor and hiding over 10 dB of signal from view. When measuring for interference, this configuration can result in measurement error, giving the view that the interference is not as bad as it truly is.

Figure D-5   10KHz Bandwidth Setting
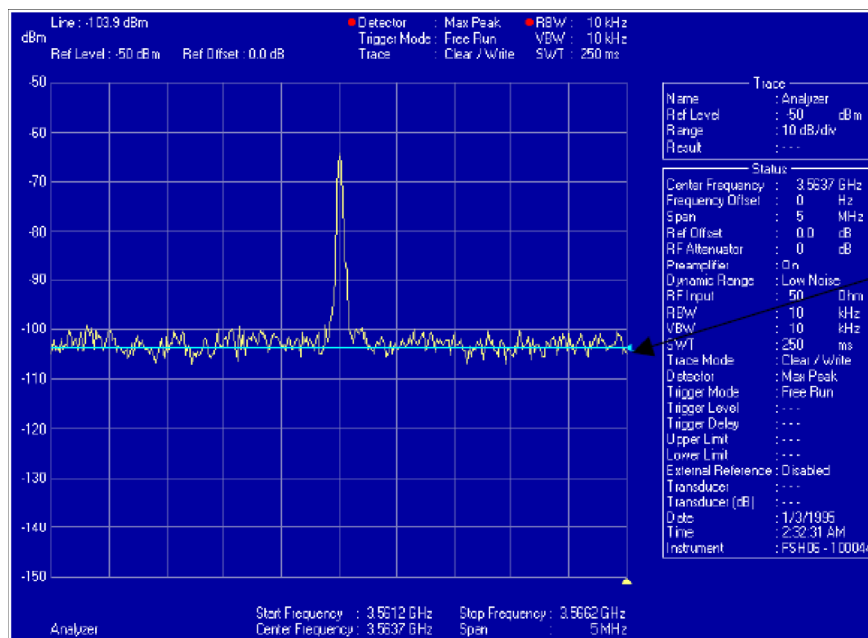
PRELIMINARY

Figure D-6   100KHz Bandwidth Setting
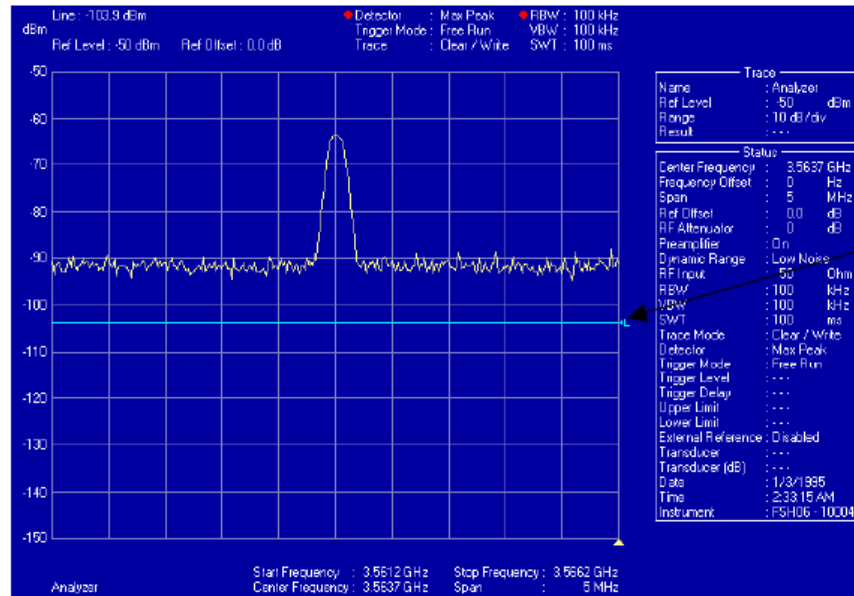
Time Domain Test

The Time Domain test (Figure D-7) is a measurement of the duration of an incoming signal across a given bandwidth. The duration of an incoming signal affects the number of packet errors that are generated over a given period of time. The longer the duration of the signal the more packet errors are generated. The number of packet errors will directly affect the data throughput rates of the system.

Setups for the Spectrum Analyzer are as follows:

- Frequency = center frequency to be tested

- Span = 0 Hz

- Video Bandwidth = 1 MHz

- Resolution Bandwidth = 1 MHz or 5 MHz

- Sweep Time = 40 ms and 400 ms

- Preamp if available = on

- Attenuation = 0 dB

- Reference Level = -40 dB

The following is a description of the parameters of the Spectrum Analyzer during the Time Domain test versus the Frequency Domain test, and what effects they will have if they are changed for the testing.

Span

The span function in the Frequency Domain test determines the start and stop range that the Spectrum Analyzer looks at for a given sweep time. By setting the Span to 0 Hz for the Time Domain test the Spectrum Analyzer looks at one specific frequency for a given amount of time.

PRELIMINARY

Resolution Bandwidth

The resolution bandwidth parameter for the Time Domain test acts similarly to the span function in the Frequency Domain test. The bandwidth parameter opens up the receiver of the Spectrum Analyzer to look at all signals across that bandwidth for the given sweep time. The smaller the bandwidth, the more accurate the readings displayed.

This parameter also determines the frequencies that are to be tested for a given range. The BS uses a 5 MHz channel. If the Spectrum Analyzer can be programmed with a bandwidth of 5 MHz, then the center frequency to be tested is every 5 MHz. Some analyzers are only able to be programmed to 1 MHz, resulting in a center frequency test step of 1 MHz. This results in more frequencies to be tested, but a more accurate indication of where the interference is located in the spectrum.

Frequency examples:

| 5 MHz Resolution Bandwidth	1 MHz Resolution Bandwidth
3.4025 GHz	3.4GHz
3.4075 GHz	3.401GHz
3.4125 GHz	3.402GHz

Sweep Time

The sweep time parameter is the amount of time that it takes the analyzer to scan the set bandwidth. One transmit and receive frame on the Cisco system is 10 ms, so a sweep time of 40 ms shows 4 frames, and 400 ms shows 40 frames.

Figure D-7   Example of a Time Domain Test
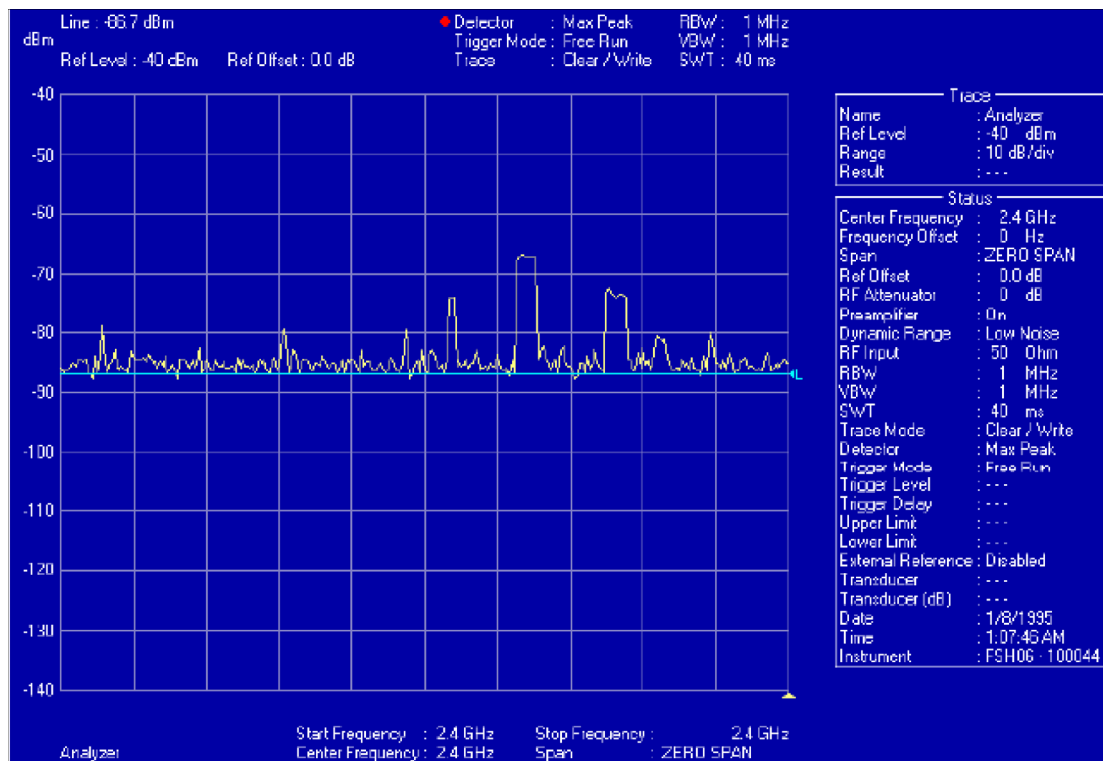
PRELIMINARY

Test Configurations

There are two configuration scenarios used for interference testing:

- Pre-installation Testing Configuration
- Post-installation Testing Configuration

Pre-installation Testing covers the initial equipment configurations when testing for interference at a site in order to determine whether or not the site is a good candidate for placing the BS. It describes the interference measurements prior to the installation of any BS equipment. The Post installation Testing section covers the measurements using the BWX Basestation Antenna after it has been installed on the radio tower or building. Use whichever configuration setting is appropriate to the type of data you are trying to collect, prior to performing the Interference Sweep procedure.

Pre-installation Test

Following is the setup of the interference test equipment prior to the installation of the BS equipment. This test is used to help determine if the site that has been selected is usable for the Cisco equipment, and what possible frequencies can be used after the installation.

Required Equipment

- Spectrum Analyzer (4404 or R&S FSH)
- Testing antenna
- RF cable
- LNA as required

Setup

Refer to for the setup. The Test antenna on the tower is at the proposed installation elevation for the BWX Basestation Antenna. The RF cable will run from the Test antenna to the Low Noise Amplifier (LNA) or Spectrum Analyzer. The LNA may be required in order to add gain to the system to compensate for any losses that are added to the test by the RF cable or Spectrum Analyzer. The typical loss for a Spectrum Analyzer is around 30 dB. The RF cable losses will vary depending on the size and type of cable and on the length of the cable. In the example below, the total system loss would be 39 dB.

Example:

- Antenna Gain: 0 dB
- Cable Loss: 9 dB
- Loss in Spectrum Analyzer: 30 dB

PRELIMINARY

In the example above, there is 39 dB of loss. In order for the interference measurements to give an accurate indication of the environmental noise, an additional gain of over 39 dBi would need to be injected into the test. The best location for the optional LNA would be at the top of the tower prior to the main run of RF cable. In this location the noise will be amplified prior to the loss through the RF cable. If the optional LNA is only installed at the lower end of the tower, the noise is reduced by the loss in the cable and would lose 9 dB of resolution.

Figure D-8   *Pre-Installation Test Setup*
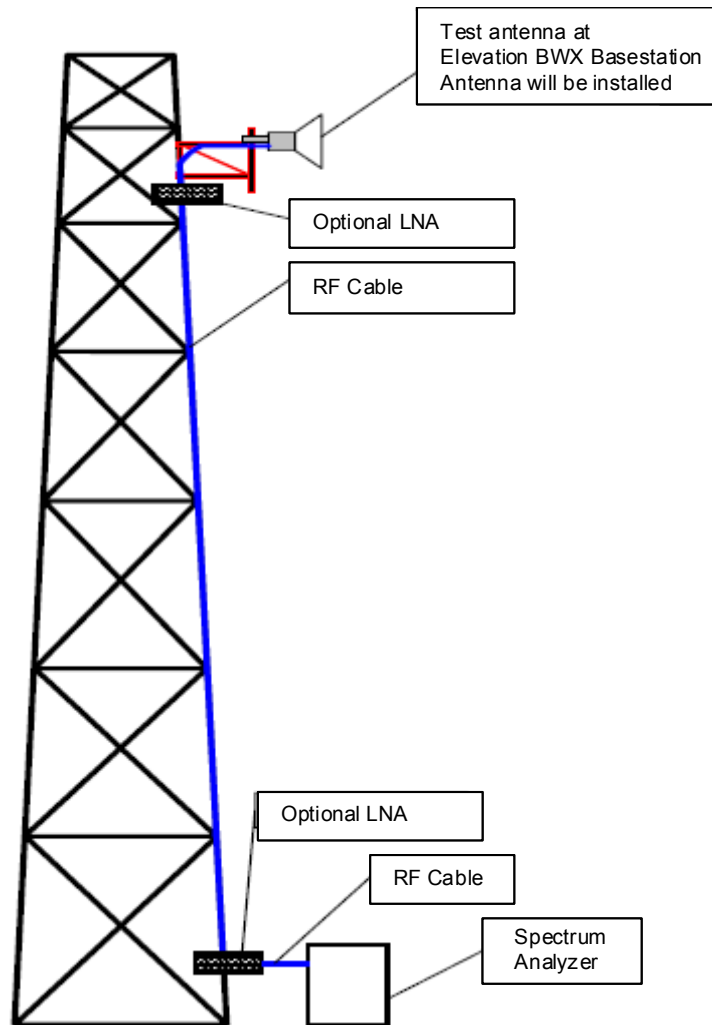
Procedure

The setup shown in Figure D-8 and the information below are for the initial (pre-installation) configuration. It gives you a starting point for this procedure. During the later steps, the configuration will change. Configure the test equipment and antenna as depicted in Figure D-8.

PRELIMINARY

Step 1 Program the initial Spectrum Analyzer settings, per the following:

  a. Resolution Bandwidth = 30 KHz

  b. Video Bandwidth = 30 KHz

  c. Attenuation = 0 db

  d. Ref Level = -50 db

  e. Sweep Time = auto

  f. Detector Mode = positive peak

  g. Frequency = determined by which step you are on in the procedure

Step 2 Set the frequency sweep range, as follows. This depends on the frequency you are investigating.

  a. Licensed 2.6 GHz = sweep for range 2.596 GHz to 2.644 GHz

  b. Other Licensed Frequencies (i.e., 2.3, 2.5, 3.4, 3.5 GHz) = sweep the center frequency plus 6 MHz to check for adjacent channels

Step 3 Proceed to the "*Interference Sweep Procedure*" section of this document.

Post-installation Test

The post-installation test is used to help verify the operational frequency that the BS will use. If the system performance has degraded, this test can determine if there is another carrier causing problems in the RF environment.

Required Equipment

  • Spectrum Analyzer (4404 or R&S FSH)

  • BWX Basestation antenna

  • RF cable connected to antenna

  • RFS Test Box

  • External LNA, as required

Set-up

Refer to Figure D-9 for the setup. In this setup, the BWX Basestation antenna is installed on the tower or building. The RF main feeder cable connects to the optional LNA or to the Spectrum Analyzer. The LNA may be required to add gain to the system to compensate for any losses that are added to the test by the RF cable or Spectrum Analyzer. The typical loss for a Spectrum Analyzer is around 30 dB. The RF cable losses will vary depending on the size and type of cable and on the length of the cable. In this example, the total system loss would be 19 dB.

Example:

  - Antenna Gain: 20 dBi

  - Cable Loss: 9 dB

  - Loss in Spectrum Analyzer: 30 dB

Using this example, with a loss of 19 dB, in order for the interference measurements to give an accurate indication of the environmental noise, an additional gain of over 19 dBi needs to be injected into the test.
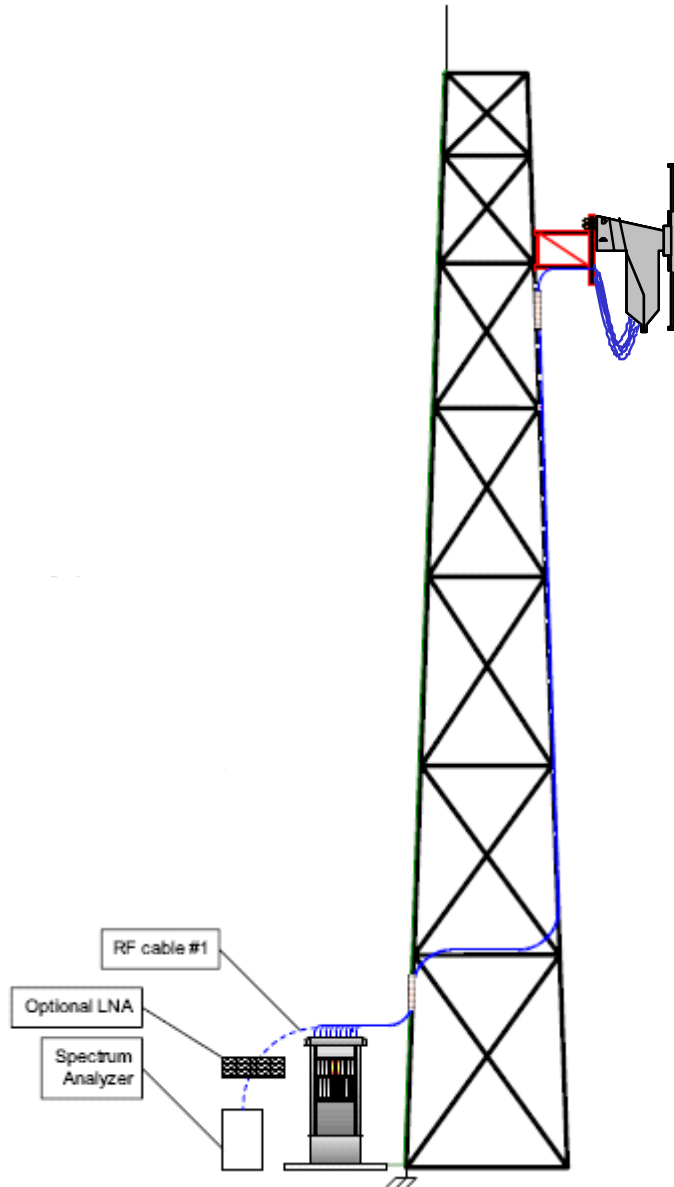
PRELIMINARY

Note   When you are calculating whether you need to add additional LNA, you need to have the following information.

- 3.4 and 3.5 TTA LNA ~45 gain

- Most Spectrum Analyzers have an internal noise figure of –30

*Figure D-9   Post-Installation Test Setup*

PRELIMINARY

Procedure

The setup shown in Figure D-10 and the information below are for the post-installation test configuration.

Step 1   Configure the test equipment as depicted in Figure D-10.

Step 2   Program the initial Spectrum Analyzer settings, per the following.

    a. Resolution Bandwidth = 30 KHz

    b. Video Bandwidth = 30 KHz

    c. Attenuation = 0 db

    d. Ref Level = -50 db

    e. Sweep Time = auto

    f. Detector Mode = positive peak

    g. Frequency = determined by which step you are on in the procedure

Step 3   Set the frequency sweep range, as follows. This depends on the frequency you are investigating:

    a. Licensed 2.6 GHz = sweep for range 2.596 GHz to 2.644 GHz

    b. Other Licensed Frequencies (i.e., 2.3, 2.5, 3.4, 3.5 GHz) = sweep the center frequency plus 6 MHz to check for adjacent channels

    c. BWX Basestation Antenna Test Box for any system needs to be set in Rx mode only

Figure D-10   *Initial Configuration*
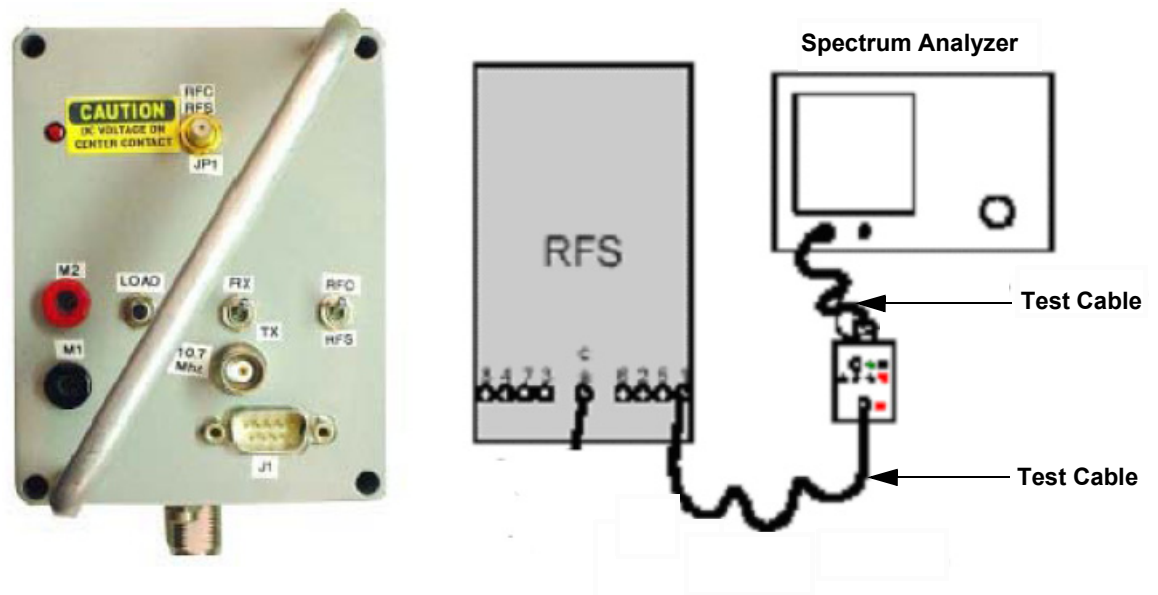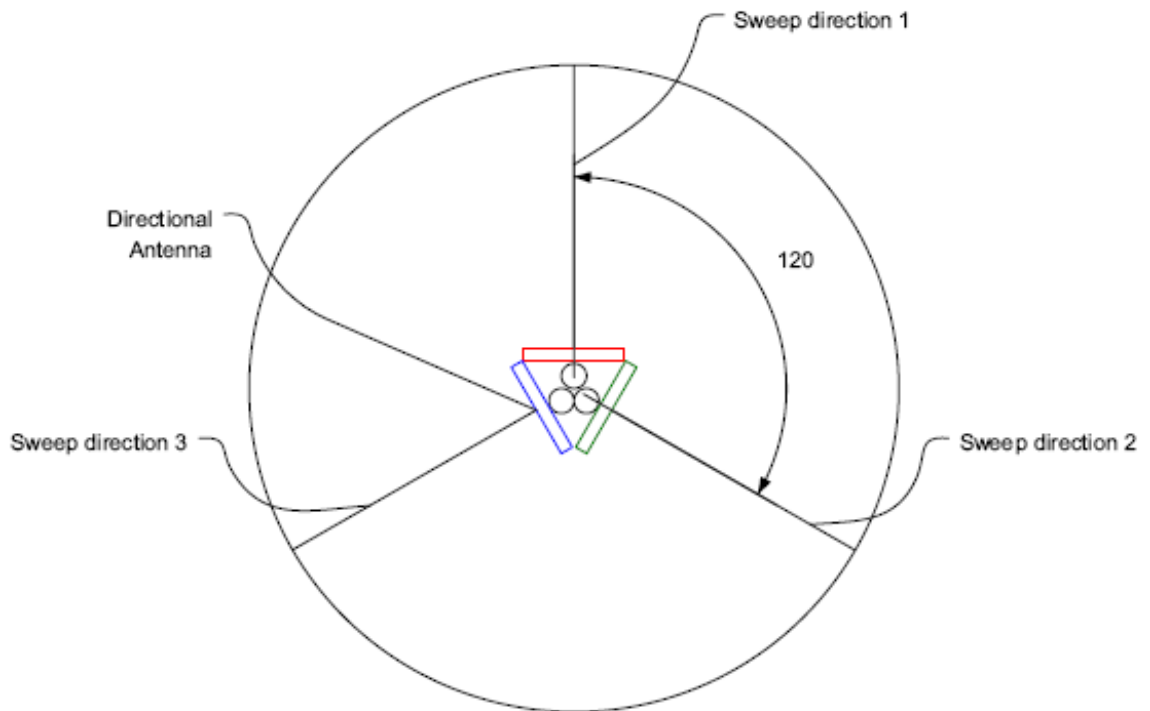
PRELIMINARY

Interference Sweep Procedure

This procedure guides you through the steps to capture the data required for the interference study. The number of steps will change with the type of antenna you are using and the frequency band you are investigating.

For the Panel antenna, the number of passes through the procedure is determined by the beamwidth of the antenna. When using a Panel antenna to pick up the interference, try to change the angle or downtilt to face a potential interference source, such as a tower or a more populated area.

A Panel antenna is used to determine where a source of interference is coming from. The beamwidth of the Panel antenna determines the number of directions that you need to sweep. For example, if the beamwidth of the Panel antenna is 120 degrees, then 3 passes of the procedure are necessary in order to cover 360 degrees. Whereas, an antenna with a 30 degree beamwidth requires 12 sets of sweeps to cover the same 360 degree area.

The smaller beamwidth requires more sweeps but gives you greater accuracy in determining the source of the interfering signal. On each pass, the Panel antenna is moved per the beamwidth. Refer to Figure D-11.

Figure D-11   Panel Sweep

PRELIMINARY

Try to determine the polarization of the interfering signals during each sweep. To do this, flip the antenna 90 degrees. All captured measurements are with the antenna in the vertical polarization position.

The frequency band to be investigated is determined by the range of the BS that is purchased by a customer. For example, the 2.6 GHz MMDS band is a licensed band, and the customer purchasing the equipment will have a license for a given 6 MHz channel.

The sweeps for licensed spectrum are performed to verify that there is not another carrier infringing on the given licensed channel. If you are performing the sweeps for a licensed channel, it will greatly reduce the number of steps that you will need to perform. For a licensed spectrum system you only need to look at 3 channels for the spectrum. You will sweep the licensed channel, as well as the channels above and below the licensed band.

For example:

If you have an E3 license (2.620 GHz – 2.626 GHz), you will sweep E3 plus F2 (2.614 GHz– 2.620 GHz) and F3 (2.626 GHz – 2.632 GHz).

You will only need the Max-hold portion of the procedure for licensed spectrum systems.

Frequency Domain (Max-hold) Test Procedure

Step 1   Check the direction of the antenna with a compass. Record the results.

Step 2   Set the "Start Frequency" to the minimum sweep range for the spectrum you are testing.

Step 3   Set the "Stop Frequency" to the maximum sweep range for the spectrum you are testing.

Step 4   Replace the antenna with a terminator to get a noise floor level. Save a screen capture.

Step 5   Turn on the "Max-hold" feature and acquire the signal for two minutes, and again for 30 seconds. Save a screen capture in Tiff or Gif format.

Step 6   Run "Single Sweep" 2 times, saving the screen captures for both sweeps. This gives a reference for the worst case that is shown with the "Max-hold" in Step 5. You can save time on this step if the Spectrum Analyzer is equipped with a Dual Trace option. Turn on Trace 2 to constant sweep and Trace 1 on Max-hold. After the Max-hold has acquired a signal for two minutes, press the single sweep. Save the screen capture. Refer to Figure D-12, Max-hold Screen Capture.

PRELIMINARY

Figure D-12   Max-hold Screen Capture
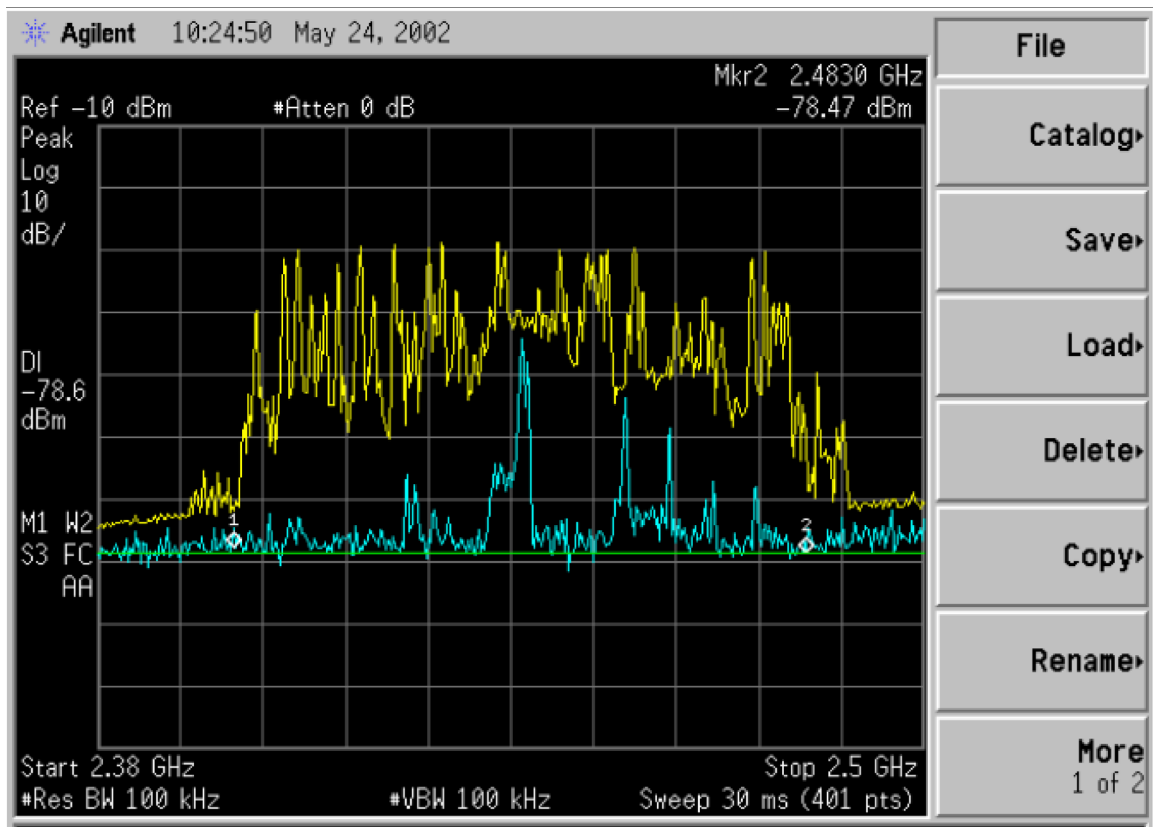
Step 7   Repeat steps 5 and 6 with the following Start and Stop frequencies. Refer to Table D-2 below, as examples.

✎
Note   Licensed Bands – sweep only the required channel, plus the one above and the one below:

Table D-2   Frequency Domain Channel Chart

Licensed Bands					
Channel	**Start**	**Stop**	**Channel**	**Start**	**Stop**
2.3 GHz Systems (WCS)			**3.4 GHz Systems (WLL)**		
A	2.305	2.310		3.41000	3.41500
	2.310	2.315		3.41025	3.41525
B	2.350	2.355		3.41050	3.41550
	2.355	2.360		3.41075	3.41575
C	2.31425	2.31925		3.41100	3.41600
D	2.34575	2.35075		3.41125	3.41625
				3.41150	3.41650

PRELIMINARY

Licensed Bands					
Channel	**Start**	**Stop**	**Channel**	**Start**	**Stop**
				.	.
				.	.
				.	.
				-.0025	+.0025
				3.52000	3.52500
2.5 GHz Systems (MMDS)			**3.5 GHz Systems (WLL)**		
	2.5005	2.5055		3.50000	3.50500
	2.5065	2.5115		3.50025	3.50525
	2.5125	2.5175		3.50050	3.50550
	2.5185	2.5235		3.50100	3.50575
	2.5245	2.5295		3.50100	3.50600
	2.5305	2.5355		3.50125	3.50625
	.	.		.	.
	.	.		.	.
	.	.		.	.
	-.0025	+.0025		-.0025	+.0025
2.6 GHz Systems (MMDS)					
E1	2.596GHz	2.602GHz			
F1	2.602GHz	2.608GHz			
E2	2.608GHz	2.614GHz			
F2	2.614GHz	2.62GHz			
E3	2.62GHz	2.626GHz			
F3	2.626GHz	2.632GHz			
E4	2.632GHz	2.638GHz			
F4	2.638GHz	2.644GHz			
	.	.			
	.	.			
	.	.			
	-.0025	+.0025			
	2.6805	2.6855			

PRELIMINARY

Frequency Domain Interference Sweeps Analysis

The Frequency Domain Interference Sweep has two kinds of measurements, Max-hold and Single Sweep. First, we have to determine the theoretical noise floor. We will use the theoretical noise floor to interpret the Max-hold sweeps data.

Calculating the Theoretical Noise Floor

All analysis of interference is done from the theoretical noise floor. This is the best-case noise floor in a perfectly clean environment. The following algorithm is used to determine the noise floor.

Theoretical noise floor (NF) = Thermal NF @ 1 Hz and 20° C + sub-carrier channel energy + Cisco BWX Mobile WiMAX system noise figure

Thermal NF @ 1 Hz and 20° C = -174
Sub-carrier channel energy = 10log(500 KHz) = +57 dB
Cisco BWX Mobile WiMAX system noise figure = +5 dB

Resulting theoretical noise floor
-174+57+5 = **-112 dBm**

If the setting on the Spectrum Analyzer was 30 KHz and not 500 KHz, there would be a 12 dB difference in the setting, which means the thermal noise floor for 30 KHz @ 20° C would be –124 dBm.

Analyzing the Max-hold Sweeps

The BWX Basestation is able to correct for a specified level of interference. This level will vary depending on the type of system or software load that is running on the BWX Basestation.

- Licensed systems (2.3, 2.5, 2.6, 3.5 GHz) +5 dB over theoretical noise floor

This means that any signals on the capture for the Max-hold sweeps above –107 dBm for licensed bands (0 through –106.9) or –97 for unlicensed bands (0 through –96.9) are not acceptable for spectrum usage This is summarized below:

- -112 + 5 dB = -107 dB for licensed systems

✎
Note   If using 30 KHz for the bandwidth setting on the Spectrum Analyzer, the levels will need to be increased by 12 dB: -119 dB for licensed systems.

Evaluating the Signal with Additional Gain

So far all of the values that have been discussed – noise floor, signal levels, etc. – have been with no gains or losses in the test set-up. This will not be the case in the real world. In the data capture, additional gain was added to the set-up to overcome any losses that are in the system due to cable or connection losses. When analyzing the interference signals, this additional gain must be removed to determine the actual interference signal level.

PRELIMINARY

Time Domain Interference Sweeps Analysis

The Time Domain sweeps capture how the interference sources behave, if the interference is constantly there or operating in a hopping method. Time Domain sweeps are typically used for the unlicensed 2.4 GHz systems' interference measurements.

Calculating the Theoretical Noise Floor

All analysis of interference is done from the theoretical noise floor. This is the best-case noise floor in a perfectly clean environment. The following algorithm is used to determine the noise floor.

Theoretical noise floor (NF) = thermal NF @ 1 Hz and 20° C + sub-carrier channel energy + Cisco BWX Mobile WiMAX system noise figure

Thermal NF @ 1 Hz and 20° C = -174
Sub-carrier channel energy = 10log(500 KHz) = +57 dB
Cisco BWX Mobile WiMAX system noise figure = +5 dB

Resulting theoretical noise floor
-174+57+5 = -112 dBm

If the setting on the spectrum analyzer was 30 KHz and not 500 KHz, there would be a 12 dB difference in the setting, which means the thermal noise floor for 30 KHz @ 20° C would be –124 dBm. If the setting on the spectrum analyzer is set for 1 MHz and not 500 KHz, there is a 3 dB difference in the noise floor, meaning that the theoretical noise for 1 MHz @ 20° C is –109 dBm.

Analyze the Time Domain Sweeps

The BS is able to compensate for 320 µs per each 10 ms frame. This 320 µs timeframe only comes into play when the signal level of the interferer is above the levels determined in the Max-hold section. The 320 µs duration is an additive duration throughout the 10 ms timeframe. If all of the interference signals above the determined signal level add up to be longer than 320 µs, then that frame is unusable.

PRELIMINARY