The Application of Handheld Spectrum Analyzers in Interference Testing

Overview

With the rapid development of wireless mobile communication networks, mobile phones have become an indispensable communication tool in people's daily lives. At the same time, market competition between the wireless communication operators has relentlessly increased. This competition has lead those operators to make on-going efforts to optimize their networks to provide better communication quality, and improved customer satisfaction leading to potential gains in market share.

On the one hand, increased capacity using new technologies, such as GPRS, EDGE and 3G, as well as the increased data traffic based on these technologies, has required stricter SNR (signal-to-noise ratio) in the wireless environment.

On the other hand, because of greater distribution and density of base stations as well as a growing number of legal and illegal installations utilizing of broadband technologies, various types of interference can be produced throughout communication systems and constrain the quality of the wireless network interface.

Additionally, with the government, commercial enterprises and the general public awareness of the need for confidentiality and security, increased use of special communication jammers are being used, For example, in military and political organizations or even gas stations, etc., communication jammers have become a common source of interference because of confidentiality and security needs. The impact of this inter-system interference on the quality of communication has become more serious, and is difficult to predictand control. Detection of the source of inter-system interference has become one of the largest headaches for engineers in the maintenance and optimization of their networks.

The classification (i.e. source) of interference signals

We can classify interference signals in a number of different ways, including frequency, frequency band, direction of interfering signals, etc. Typical classifications include the following:

- In-band interference
- Out-of-band interference
- Co-channel interference
- Adjacent channel interference
- Uplink interference
- Downlink interference

Classifications by the source of interference signals include:

- System internal interference
- External interference

Intra-system interferences are mostly caused by the inherent frequency division multiplexing (FDM) of mobile communication systems. With network capacity continuing to expand, the intra-system interferences can not be avoided completely, but its harm to the system is smaller than inter-system interferences. By efficient frequency planning and careful selection of base station locations, the impact can be effectively controlled within an acceptable scope.

The primary problem disturbing system engineers is the inter-system interference, which is mainly illegally installed or unqualified repeaters temporary communication jammers installed by various enterprises, as well as the leakage of sideband, harmonic and intermodulation products from other communication systems into the mobile frequency bands. Among these, the interference from communication jammers, illegal and unqualified repeaters, etc. are usually high-power, broadband signals, which often result in a communications blockage of one or more areas.

Usually, communication system interference can also be divided into uplink and downlink interference.

Downlink interference is namely the interference to the mobile phone receiver. Because of the relatively wide spaced distribution of mobile phones, the downlink interference of a single cellular area only impacts a minority of mobile users which has limited impact on the communication quality of the whole system.

However, uplink interference disturbs the base station receiver. Once the base station receiver is compromised, it leads to receiving code errors for the whole base station and the site's entire service area is degraded including its network and service key performance indicator (KPI) parameters. Of course, customer satisfaction is negatively impacted.

Tools for detecting and monitoring interference

Of the various tools available for monitoring and detecting interference, the spectrum analyzer is the most widely used type of test equipment. Because the inter-system uplink interference has the most serious impact to the network, the remainder of this paper focuses on the methods for detecting inter-system uplink interference using a handheld spectrum analyzer.

The requirements of interference test for a spectrum analyzer

Usually, interference testing is done in the outdoor, mobile environment, so portability is a basic requirement; that is, it should be handheld and battery-powered.

While emphasizing portability, even more important for interference testing is the performance of the instrument, such as its sensitivity. For modern communication systems, broadband digital modulation technology is widely employed, creating a signal bandwidth several hundred KHz to tens of MHz wide. This leads to low density of power in the spectrum; as a result, it requires the spectrum analyzer to have sufficient noise figure and sensitivity. However, not all of handheld spectrum analyzers' performance can meet these interference testing requirements due to the analyzer's technology, volume, weight, etc.

There are many factors affecting the sensitivity of a spectrum analyzer, but for the testing of modern communication systems, the most important is the noise figure or Displayed Average Noise Level (DANL) of the instrument itself.

There is a typical misunderstanding of the requirements for specifying spectrum analyzer sensitivity. Taking a GSM signal as an example, the effective uplink signal power should generally be higher than -95 dBm, but the system also requires the SNR to be at least 9 dB. So normally, engineers need to consider a range of signal power below to -100dBm at the minimum. However, the sensitivity (i.e. DANL) of a typical portable spectrum analyzer can typically range from about-110 dBm to about -130 dBm. A common misunderstanding is that using a spectrum analyzer with sensitivity equal to -130dBm would easily detect and measure the -100 dBm GSM signal, but that is not necessarily true.

Please see table 1:

Table 1

	Spectrum Analyzer Sensitivity	GSM Signal Power
Definition	Using the minimum resolution bandwidth filter (RBW) available, the displayed average noise level (DANL) of the instrument itself	In general, it is channel power (CP), for GSM, it is total power of signal integrated within the bandwidth of 200KHz
Typical Expression	DANL=-130 dBm @ RBW=100Hz	-100 dBm/200kHz BW
Normalized density of power in a 1 Hz bandwidth	-150dBm/Hz	-153dBm/Hz

The sensitivity index of a spectrum analyzer means the noise power (DANL) displayed by the instrument under certain test conditions and with its resolution bandwidth filter (RBW) set to the minimum, is the total integrated power in the resolution bandwidth filter. The minimum RBW of a handheld spectrum analyzer is typically 100 Hz. In reference to GSM signal power, it means the channel power of GSM or the total integrated power at a bandwidth of 200 KHz. As the bandwidth is different for specifying the analyzer's noise power (i.e. sensitivity/DANL) versus measuring the GSM channel power, we can not directly compare the value of spectrum analyzer sensitivity at its minimum RBW to channel power values at a different bandwidth. The valid comparison method is to compare them after normalizing the value of power, i.e., the density of power in a 1 Hz bandwidth.

Table 2 lists the requirements for the sensitivity of a spectrum analyzer while testing various common communication signals. If the given specified condition of sensitivity is different from that defined in the table (such as different RBW values), we can compare the equivalent sensitivity by a simple conversion of bandwidth utilizing the formula 10 log (BW2/BW1). Where BW1 is the starting RBW and BW2 is the ending RBW.

Table 2

Signal type	Bandwidth of signal	Typical range of power	Minimum density of signal power (1 Hz BW)	Required instrument sensitivity
GSM	200 kHz	-60 to -100 dBm	-153 dBm/Hz	-133 dBm @ RBW=100 Hz
WCDMA	3.75 MHz	-60 to -100 dBm	-166 dBm/Hz	146 dBm @RBW=100 Hz
CDMA	1.25 MHz	-60 to - 100 dBm	-161 dBm/Hz	-141 dBm @ RBW=100 Hz

It can be seen from table 2 that: the channel power is the same, but different signal bandwidth requires different analyzer sensitivity. The greater the signal bandwidth is, the higher the required sensitivity is, i.e. the lower the required DANL is.

Because of the field working environment, engineers usually are also concerned about the measurement speed of the analyzer. But, the practical measurement speed (e.g. sweep time) always conflicts with the sensitivity/DANL. For better sensitivity, one often needs to decrease the RBW, while at the same time, the measurement time will increase. Therefore, we have to balance the sensitivity and measurement speed in practice.

General steps and method of interference testing

(1) When communication quality is getting lower, suspect there is interference:

If the system is suffering from inter-system interference, at least partial degradation of the communication quality will occur. Network maintenance and optimization engineers can find the potential interference from user complaints, routine tests, network monitoring systems, etc. For uplink interference, the monitoring system of the network itself is the most useful tool and method. At the same time, user complaints, routine driving tests and call quality test (CQT) tests mainly reflect partial and downlink interference.

(2) Analyze and confirm the existence of an interference signal:

Through the GSM control system, we can easily obtain the following information:

The reception power level, quality and idle time slot power of each carrier frequency.

The typical phenomena when the system has interference is higher reception level, with poor quality and higher level of the idle time slot.

If just several carrier frequencies exhibit the phenomena that the reception level is satisfactory but reception quality is poor and the level of idle time slot is relatively high, we should primarily consider co-frequency interference and adjacent frequency interference with the need to check the wireless frequency planning of the network.

If multiple (or all) carrier frequencies, or even other adjacent base stations show evidence of interference, this is a typical indication of broadband interference outside the system, for which, the source of interference is often a broadband transmitting device, such as illegal repeaters or communication jammers.

To confirm inter-system interference of a base station, the most straightforward way is to disconnect the antenna interface of the affected base station or sector, and directly connect the spectrum analyzer to the receiving antenna interface to monitor the RF signals and noise level in, and confirm whether the signals are abnormal. Generally, the RF signal and noise levels should be less than -105dBm (RBW of instrument is set to 300KHz). Attention should be given to the internal DANL of the analyzer itself at the same value of RBW.

For a CDMA network, one can also apply a similar method. Using the monitoring system of the base station, the measured value of uplink receiving power by the base station can be acquired. When the uplink receiving power is too high (in urban areas, usually -70~-80 dB above), it means that there is uplink interference in the area covered by the base station. If supported by the monitoring function, Eb/No and frame error ratio (FER) also are two good statistical parameters that can indicate whether there is interference. It can be seen from the system statistics that interference will increase the call drop rates, decrease the access success rate and influence user satisfaction.

At the same time, during the driving test, too much reverse transmitter power and too high of a forward frame error rate are both likely to be caused by interference of the reverse or forward frequency bands.

Because connecting the analyzer to the receiving antenna interface of a base station will cause business interruption, another common method is to use a portable spectrum analyzer with a directional antenna to look for signal interference near the base station receiving antenna.

Figures 1 and 2 are typical spectrums for GSM and CDMA signals. If there are other types of spectral images detected by the spectrum analyzer and the total power is higher, we can regard this signal as inter-system interference.

Figure1

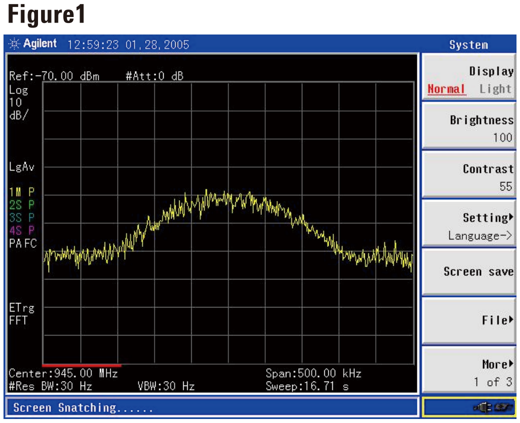
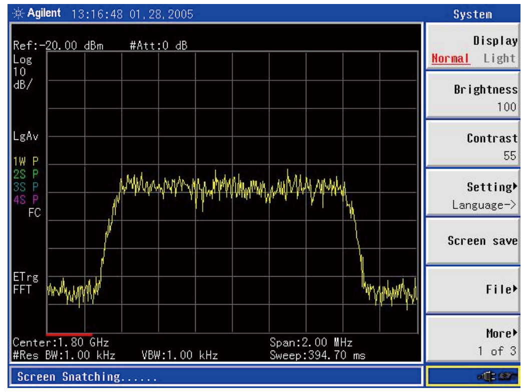


Figure 2



(3) Detect the source of interference:

Once it is confirmed that the system has interference, the next step is to detect its source.

Step 1: Confirm the source direction and type of interference. Experience suggests testing at a location as high as possible and using a directional antenna to confirm the source of interference. The reason for testing at a high location is to avoid direction changes of the interfering signal caused by building reflections and multi-path transmissions. Another reason is to minimize the transmission loss of the suspect signal by utilizing a straight line-of-sight path, so even if the testing spot is far away from the interference source, the signal can still be detected easily.

Finally, test at several locations to triangle-late the direction of the interference source. , Plot their vectors on the map, and consider where the vectors cross as the likely location of the interference source.

Step 2: After preliminarily confirming the location of the interference source, the next step is to repeatedly walk or drive around this suspect area carrying the spectrum analyzer. Because this ground level testing is lower and the interference signal may be reflected by buildings or travel through walls several times, even though the analyzer is closer to the interference source, there is usually less of an interference signal level to work with. At this point, a more sensitive analyzer has obvious benefits finding the interference source quickly.

Due to the complexity of the test environment and the signal itself, the engineer's experiences for judging and finding the interference signal also plays a crucial role.

Operational instructions

The operation examples in this section refer to the Agilent N9340B handheld spectrum analyzer. Although the operation of other instruments may not be the same, the concept is the same.

1. Optimize the analyzer for high sensitivity

Finding and analyzing the interference signal will use an antenna to measure the wireless signal, requiring the instrument to be optimized for maximum sensitivity.

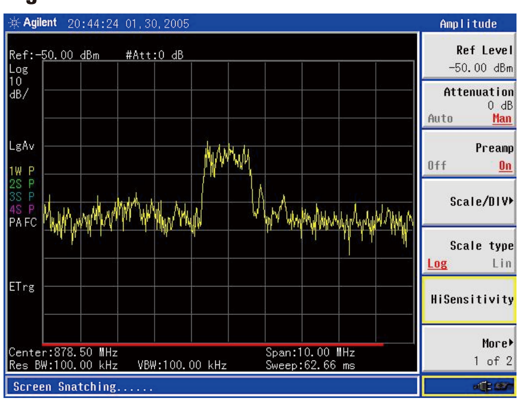
The standard method for improving the sensitivity of the spectrum analyzer:

Press the button labeled [AMP] to enter the amplitude menu:

- Set the appropriate Reference Level. A typical setting is -40 dBm to -60 dBm
- Set the Input Attenuation value to "0"dB
- Turn the Preamplifier to "on"

Even if you are unfamiliar with the operating principles of a spectrum analyzer or forget the above steps, the N9340B has set a special High Sensitivity button in the [AMP] menu, as shown in Figure 3. Using this button, the instrument will set reference level, input attenuator and preamplifier together to optimize the sensitivity

Figure3



In addition to the above parameters, RBW is also an important parameter that will affect the sensitivity or DANL of the analyzer. For each 10 X increase or decrease of the resolution bandwidth, there will be a corresponding 10 dB increase or decrease of the DANL. Assuming, other conditions allow it, the RBW should set as narrow as possible, but the following two points should be noted:

- The narrower the RBW, the slower the sweep time will be., At some combinations of span and narrow RBW, the monitoring of rapidly changing live signals will be impacted. A balance needs to be attained between RBW driven sensitivity and measurement time.
- For signals of different types, the impact of RBW is not the same. If the measured signal is narrow (bandwidth is much smaller than RBW), decreasing RBW is helpful for reducing DANL while maintaining the same level of the measured signal amplitude displayed on the analyzer and obtaining better displayed S/N. But if the measured signal is broadband (bandwidth is far greater than RBW), such as CDMA signal, decreasing RBW will lead to a simultaneous decline of the displayed signal level and DANL, so it is useless for improving displayed SNR.

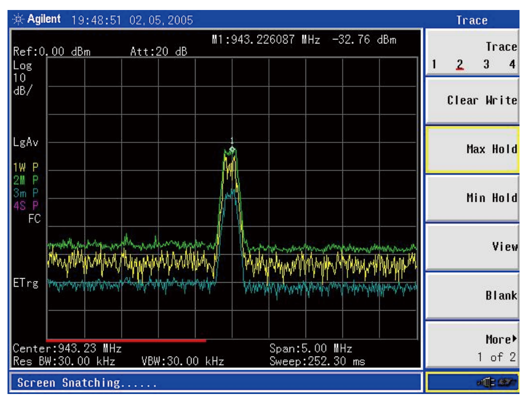
2. Monitor transient or discontinuous interference signals:

In a practical test environment, the interference signals may be intermittently transmitted. Therefore, a spectral signal may not be present, which brings certain difficulties to interference monitoring.

The N9340B analyzers apply the technology of multi-trace, simultaneous display and a Max Hold function, so it can effectively capture transient or discontinuous signals.

In [TRACE] menu, we can choose the trace and its display parameters, as shown in Figure 4:

Figure 4



Trace 1 (Yellow) in figure 4 is a standard actively updated and refreshed trace for every sweep (Clear Write), which reflects the current instant state. Trace 2 (Green) is the Max Hold trace, which records and "holds" only the highest occurring power values from sweep to sweep. Utilizing the Max Hold function, it is much easier to capture a transient signal, and up to 4 traces can be displayed at one time.

3. Save the trace and screen:

Another common task is to save the trace or screen from an interference test, which then can be used to create the reports and evidence of the interference.

The data saving types provided by the N9340 include Trace and Screen.

Standard operations are as follows:

- Choose the storage device:

Press [SYS] button, then {File}, {File Setup}, and then {Save Path}, choose USB or Local.

- Choose the storage type:

Press [SYS] button, then {File}, {File Setup}, and then {File Type}, and the available options are Trace, State, Screen, Pattern, Mask, Setup.

- Set shortcut storage type:

Press [SYS] button, then {File}, {File Setup}, and then {Shortcut Type}, choose Trace or Screen.

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