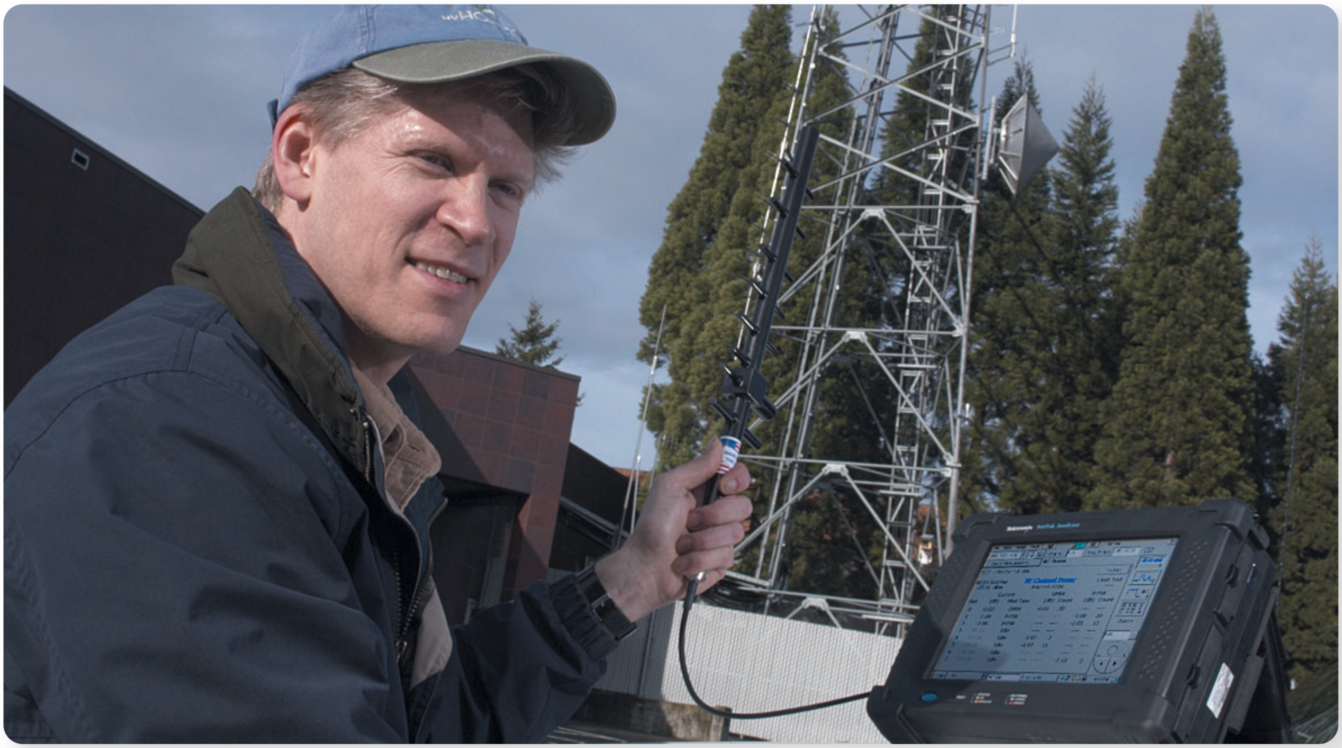
EDGE Wireless Networks: Challenges in Maintenance and Testing



Cellular networks continue to grow at a rapid pace around the world. In many parts of the world, network operators are now putting, or have put, EDGE (Enhanced Data rates for Global Evolution) networks into commercial service, as part of the evolution towards third generation (3G) networks. The term EDGE is used in this application note to refer to a GSM (Global System for Mobile communications) and GPRS (General Packet Radio Service) wireless network that has been upgraded with EDGE capability and is also called Enhanced GPRS (EGPRS).

This application note will describe the areas of concern and the important service and maintenance measurements for EDGE base stations, in order to be able to ensure high Quality of Service. Examples of these measurements will be made using the Tektronix NetTek® Base Station Test field portable test tool. The Tektronix NetTek provides comprehensive GSM, GPRS, and EDGE testing. The Tektronix NetTek also provides co-channel and out of channel RF interference testing.

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A major driver for mobile devices today is access to the Internet and Web-based applications. Customer demand for internet based data services is driving the wireless service providers to upgrade their networks to be able to accommodate this new demand. Data services are packet based and tolerate latency well, but work best with high throughput. GSM (Global System for Mobile communication) on the other hand, is a circuit switched network designed for low latency and low data rates, which is optimized for voice traffic. However, GSM is not ideal for high throughput data traffic. GPRS and EDGE provide the advances in technology to enable these new data services.

Cell phone users have come to depend on high quality cellular voice service to conduct business and stay in contact. For customers to come to depend on wireless data services, it is essential that wireless service providers design and maintain their cellular network to ensure high data rates and other Quality of Service (QoS) measures. The traditional QoS measures, such as the dropped call rate, do not necessarily reflect the quality of a customer's data session experience.

Migration of GSM to EDGE

GSM was introduced for mobile telephony in the mid-1980s. GSM improved speech quality over older analog techniques. In addition, a uniform international standard allowed a single telephone number and mobile phone to be used around the world. GSM proved to be very successful. The European Telecommunications Standardization Institute (ETSI) adopted the GSM standard in 1991 and it is now used in over 160 countries with over 350 million subscribers worldwide.

GSM, a second generation (2G) technology, improved connectivity and voice quality while at the same time; it added a wide range of services, including low speed data. Increased demand for higher speed data and additional services has led to further development. Prominent among these developments to be adopted was the 2.5G cellular technology, GPRS and the following cellular enhancement, EDGE. GPRS provides somewhat higher data rates for mobile users. From a simplistic viewpoint, it installs a packet switch network on top of the existing GSM circuit switched network without altering the radio interface. EDGE implements a new modulation technique and improved link adaptation mechanisms, which increase spectral efficiency and enables enhanced data applications, such as wireless Internet access and email.

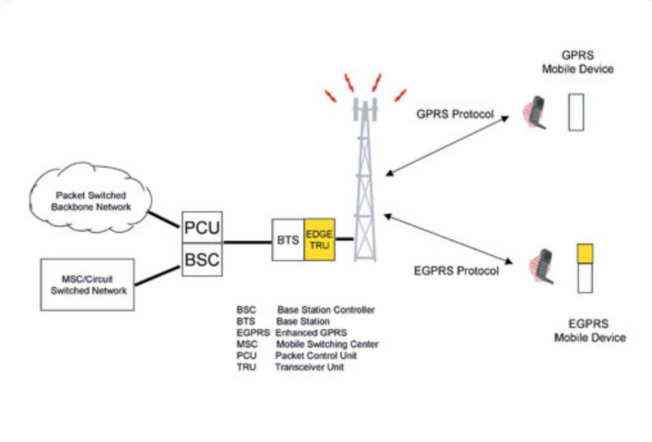
Overview of EDGE

This section will briefly review the technology and concepts of EDGE, from the air access interface perspective. A more detailed discussion of GPRS and EDGE networks and technology may be found in the Tektronix Technical Brief, "EDGE Wireless Networks", publication number 2EW-17610-0. In this application note, the terms BTS (Base Transceiver Station) and BSS (Base Station System) will be used interchangeably with base station.

Overview – The RF interface

From an air interface perspective, GSM and GPRS have the same RF interface. As mentioned earlier, the key difference in the migration from GSM to GPRS is in the core network. GSM is based upon a circuit switched network. GPRS introduces packet-switched data into the GSM core networks. The GPRS air interface will dynamically allocate time slots (resources) for voice and packet data channels.

EDGE introduces a new method to increase the data rate over the GSM/GPRS air interface. EDGE brings a new modulation technique and new channel coding that can be used to transmit both packet-switched data services (Figure 1). EDGE can be viewed as an "add on" to GPRS and the combination of EDGE and GPRS is referred to as EGPRS (Enhanced GPRS). In this application note, we will continue to use the term EDGE to refer to an EGRPS enabled wireless network.



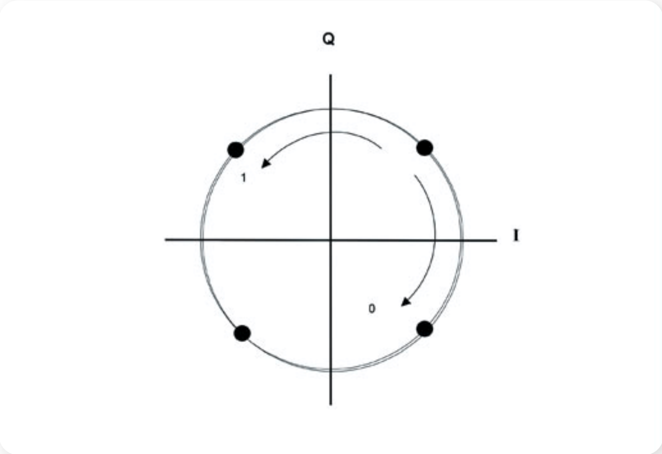
▶ **Figure 1.** *EDGE incremental add-on to GPRS system.*

Another advantage to EDGE is that it can be deployed by operators without W-CDMA RF spectrum licenses. EDGE is attractive in that it allows performance somewhat like 3G, in the existing 2G spectrum. EDGE can also provide an interim step in an overall strategy to deploy 3G technology.

To understand essential testing differences between GSM/GPRS and EDGE, it is necessary to have some understanding about the differences in the modulation schemes of the two standards.

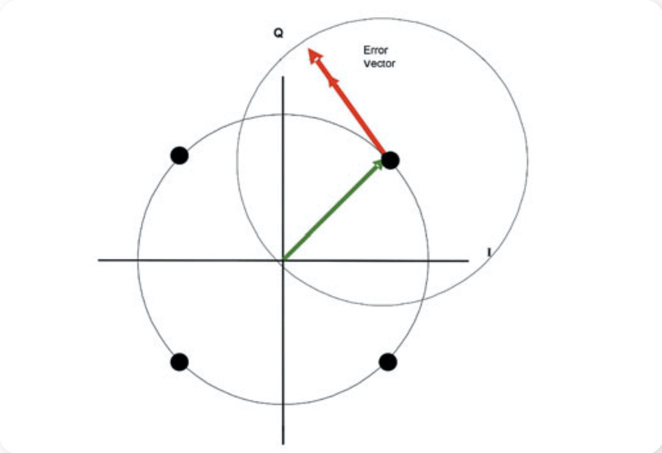
RF Modulation Method – GSM and GPRS

GSM and GPRS use a modulation method called GMSK (Gaussian Minimum Shift Keying) to encode the data stream information onto the RF signal. This is a phase modulation method that transmits one bit per phase shift. Figure 2 shows a GMSK I/Q diagram, which is a useful way to represent phase and amplitude modulation. Phase shifts are measured around the central circle, while amplitude is measured as the distance from the origin. GMSK modulation is represented by four different phase states (the black dots) on the constellation diagram. The sized and shape of the phase states is influenced by the amount of intersymbol interference and other factors. Positive phase shifts are encoded as a 0 and negative phase shifts are encoded as a 1.



▶ **Figure 2.** GMSK modulation I/Q diagram.

The designers of GMSK chose to use only 90 degree phase shifts in the interest of reliability. Phase shifts of 180 degrees would require the amplitude of the RF carrier to go to zero as the phase trajectory crosses the origin. This would create a need for a high speed, large, amplitude change in the RF carrier, which would stress the base station power amplifier, leading to a less reliable signal. By choosing to allow only 90 degree phase shifts, and one transmitted bit per phase shift, the designers of GSM/GPRS created a lower speed, but robust, transmission system for digitized voice.



▶ **Figure 3.** GMSK modulation I/Q diagram with phase and error vectors.

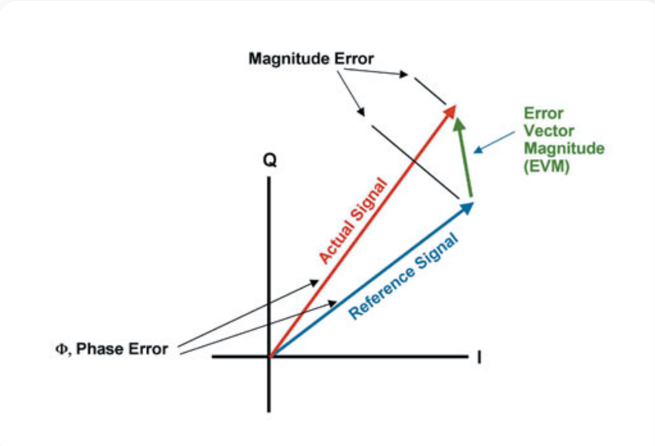
Another reason GMSK modulation scheme is robust, is that rather large phase and amplitude errors can occur during signal generation and transmission without confusing the receiver. In other words, the error vector (the red vector in Figure 3) can be as large as shown in Figure 3, and can be anywhere in the error circle, without generating an error.

A final benefit is that if a phase decoding error occurs, then only one data bit will be lost. The tradeoff for all this reliability is a relatively low data rate. While a low data rate and reliable transmission is good for voice, it is not so good for data sessions.

EVM – Error Vector Magnitude

EVM is a measurement which evaluates the signal quality.

EVM is computed from the vector difference between the actual received signal and a calculated, ideal reference signal (Figure 4).



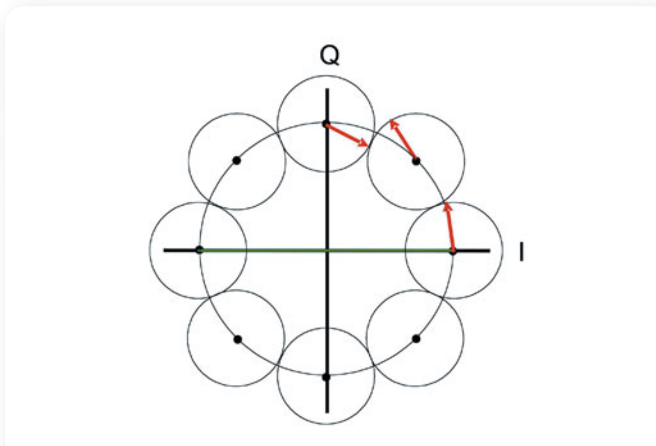
▶ **Figure 4.** EVM measurement Concept.

To measure EVM, the Tektronix NetTek, or any analyzer, must first demodulate the received signal and from this data, reconstruct an ideal phase and amplitude modulated signal. From this, it is possible to measure the difference between the ideal reference signal and the actual received signal. EVM is a useful measure of distortion in phase modulated signals such as 8-PSK signals.

Modulation Method - EDGE

To achieve higher bit rates per timeslot, EDGE was specified to include an 8 PSK (Phase Shift Keying) modulation. EDGE is also specified to work with the existing GSM/GPRS channel structure, channel width, channel coding and the existing mechanisms and functionality of GSM/GPRS. This makes it possible to integrate EDGE time slots into an existing frequency plan.

8-PSK allows 8 different phase shifts. Since eight possible phase positions can cover every possible combination of three data bits, one combination of three data bits is assigned to each phase position (Figure 5). The data transmission rate now can be three times faster than GSM/GPRS with GMSK modulation. However, the transmission reliability has been reduced in several ways. First, the maximum permissible error vector has been reduced by more than half. Second, the effects of a decoding error may be worse. Where GSM/GPRS signals, using GMSK modulation, would lose only one bit if a single decoding error was made, 8-PSK signals may lose three bits for every decoding error. Lastly, the signal amplitude is no longer constant. Rather than staying at constant amplitude, the modulated signal now needs to be able to reach any phase position from any starting point. This means that 8-PSK signals have large amplitude changes, which stresses RF amplifiers and can cause further distortion. Consequently, much more attention must be paid to distortion, signal quality, and interference. A design enhancement for 8-PSK that reduces the large amplitude changes is 3_/8 rotation (see sidebar).



▶ **Figure 5.** 8PSK modulation I/Q diagram.

3_/8 Phase Shift

In order to avoid very large amplitude changes in 8-PSK signals, a method was devised, which rotates the I/Q axis 1.5 data points, or 3—/8 radians between every phase shift (Figure 6).

Note in Figure 6, as the phase and amplitude trajectory changes from point to point, the power does not go to zero. This reduces the stress on the RF amplifier. The rotation does not affect the maximum EVM allowable, however. Each transition still only has 8 possible destinations, so the max allowable EVM is still as shown in Figure 5.

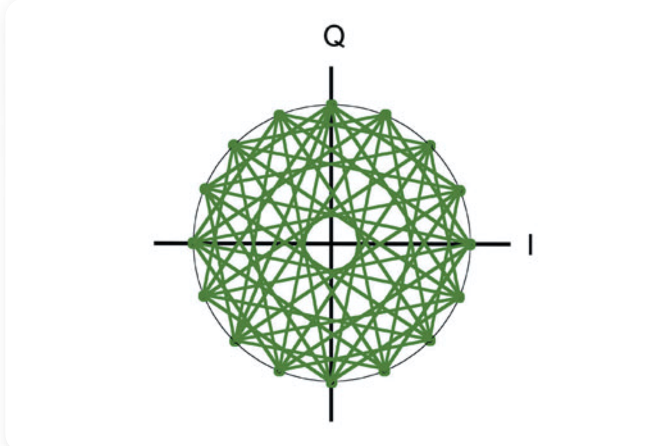


Figure 6. 8PSK Modulation with 3_/8 Phase Shift.

Coding Schemes

The distance from the cell base station transmission antennae to the mobile device greatly affects the strength of the received signal, makes interference much more likely, and increases the potential for data errors. The farther the mobile device is away from the cell tower and the stronger the interference, the lower the achievable data rate.

A set of coding schemes has been devised; each with different amounts of error-correcting coding that is optimized for different radio environments. GPRS uses four different coding schemes, designated CS1 through CS4.

EDGE has nine new modulation coding schemes, designated MCS1 through MCS9. The slower four, MCS1 to MCS4, use GMSK modulation and the faster five, use 8-PSK modulation (Figure 7). Notice on the right hand diagram in Figure 7, how the GSM/GPRS data rate is fairly stable as distance from the base station increases. On the other hand, note how the EDGE data rate degrades with distance from the base station!

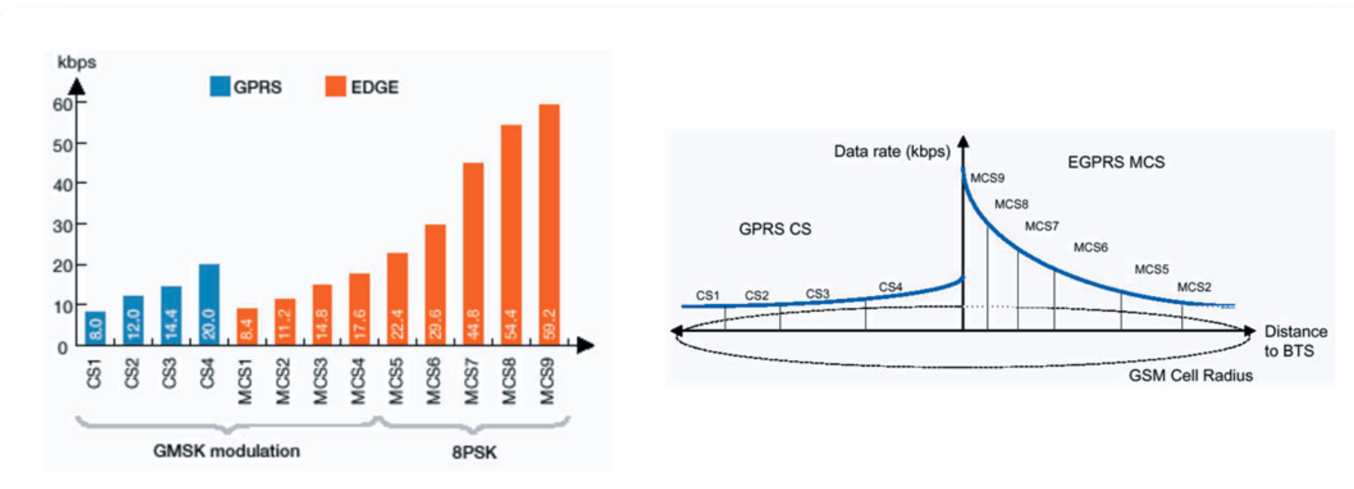


Figure 7. Comparison of distance from BTS, coding scheme, modulation type, and data rate.

The slower EDGE coding schemes have built in error correction, which increases their robustness. To increase transmission rates, the error correction is progressively removed. Let's take a look at how this works. In the table below, the column labeled "code rate" shows the amount of protection, or error correction, applied to the signal.

Table 1. EDGE/EGPRS Data Rates and Coding Schemes (adopted from 3GPP spec. TS 05.01, Nov 2001).

Coding Scheme	Code Rate	Modulation	Data Rate (kbps)
MCS-9	1.0	8PSK	59.2
MCS-8	0.92		54.4
MCS-7	0.76		44.8
MCS-6	0.49		29.6
MCS-5	0.37		22.4
MCS-4	1.0	GMSK	17.6
MCS-3	0.85		14.8
MCS-2	0.66		11.2
MCS-1	0.53		8.8

Consider first MCS-1, which uses GMSK modulation and has the slowest rate. It has a code rate of 0.53, which means that the error correction encoding slows the transmission down to 53% of the un-encoded rate. 47% of the bits sent are error protection bits, so for every 53 bits sent, another 47 bits are sent explaining what the first 53 bits were trying to say. The penalty for this much redundancy is the 8.8 kbps per time slot overall transmission rate. When we move up to MCS-4, the protection is gone. The data rate, as a result, moves to 17.6 kbps per time slot. Consider now MCS-5. Here, the modulation changes to 8-PSK, allowing 3 bits to be sent for every phase change. This triples the data rate. However, the code rate changes to 0.37, which means that 63% of the data sent is error correction bits. This gives us a more error prone modulation method, quite a bit more protection, with the result that the data rate is approximately the same as MCS-4. Now, consider MCS-9, the fastest data rate. This data rate has zero error correction bits, and the least robust transmission rate (8-PSK). We need a very clean signal, with low interference, to achieve 59.2 kbps per timeslot.

Dynamic Radio Environment

GSM/GPRS mobile devices measure the radio environment by analyzing the radio link for carrier strength and bit error rate. EDGE allows faster data rates, and also, increases the susceptibility for errors by decreasing the margins for error. Therefore, radio link analysis becomes even more important. EDGE uses incremental redundancy, discussed above, and link adaptation to transmit at the highest possible data rate for the existing reception conditions. Consider link adaptation for a moment.

Link adaptation uses the radio link quality, measured either by the mobile device downlink or by the base station uplink, to select the most suitable modulation coding scheme to use for transmission of the next sequence of data frames or packets. As the radio link varies, the base station communicates to the mobile device which coding scheme to use for transmission of the next sequence of data.

Downlink RF Power Control

RF power control is a critical part of the optimal operation of the cellular system. Base stations can optionally utilize downlink RF power control. In addition to the traditional, static downlink RF power settings, the base station may support up to 15 steps of power control levels with a step size of 2 dB ± 1.5 dB.

Each mobile device monitors the received power of the RF downlink signal transmitted by the base station. The mobile device communicates back via the uplink the power information. The base station responds by adjusting the downlink RF time slot power in a way that minimizes the downlink transmit power, while ensuring the quality of the radio link. By minimizing transmit power levels, interference among co-channel users can be reduced and system capacity increased. For circuit-switched services, the base station controls the power level to be used by the mobile device. For packet services (GPRS/EDGE), the mobile device controls the process.

The Problem Statement

The challenge of the network operations manager is to deliver high Quality of Service (QoS) consistently and cost effectively. QoS, as experienced by the mobile device user, is evaluated on the basis of parameters such as dropped calls, blocked calls, lack of signal, and data throughput.

In the case of EDGE, the main risk is not that the call will be dropped. The risk is disappointingly slow data rates.

As signal quality declines, the user is automatically moved to slower and slower, increasingly reliable data rates. Frustration on the part of the mobile user will then increase and interest in the data service will decrease. The higher the received signal quality, the higher the data rate can be. Of great importance, then, is measuring and analyzing the signal quality. This is done by measuring EVM (Error Vector Magnitude) and Phase Error routinely and keeping it at the best possible level. This is very important in EDGE systems. The next section looks at why EVM is so important.

Error Vector Magnitude (EVM) and Signal Quality

The transmitted signal from the base station is either GMSK or the more complex 8-PSK modulation method. The symbols represented by the modulated signal need to be demodulated and decoded within discrete decision points in the constellation in order to be error free. Increasing degradation of received RF signal, due to impairments such as interference or noise, will spread the points out until errors begin to occur. At the base station transmitter, poor modulation accuracy of the transmitter or distortion along the RF path may cause the points to spread. EVM is the measurement which evaluates this spread.

By design, GSM using GMSK modulation has a very robust signal and has a high immunity to phase errors. GMSK has a large error vector margin and if an error does occur, then only 1 bit is lost. Consequently, due to the robustness of GMSK, there is less need to test for distortions. The trade-off for robustness is a low data rate, suited to voice only communications.

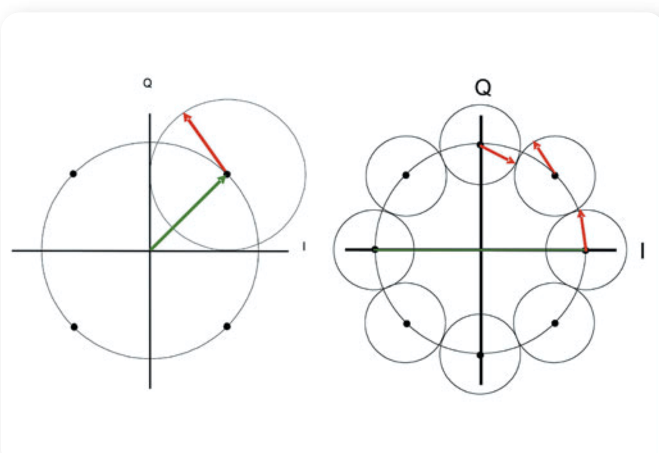


Figure 8. Comparison of error vector margin in GMSK (left) and 8-PSK (right).

With the higher speed EDGE transmissions using 8-PSK, the error vector margin is reduced and therefore the probability of errors occurring is greatly increased (Figure 8). Note that, unlike GMSK, both the phase and amplitude of the 8-PSK signal change. This stresses RF amplifiers and can cause further distortion. In addition, if a symbol decoding error does occur in 8-PSK, then there is a potential of three data bits may be lost, not one, as in GMSK. So 8-PSK has tighter EVM specifications and EVM measurements are critical. In order to maintain faster data rates, much more attention must be paid to distortion, signal quality, and interference. This is done with the EVM measurement for 8-PSK and Phase Error measurement for GMSK.

The Solution – Transmitter Testing

Selecting the right Test Tool

In-the-field measurements of base station transmitted RF signals and other, possibly interfering RF signals, can provide the basic information needed to evaluate the RF components related to QoS and data throughput. Traditionally these tests have been performed either by complex compliance testers, which can be difficult to use, or very simple testers, such as area testers or cell phones, which can identify the existence of problems, but are not so useful when it is time to correct the problems.

The Tektronix NetTek YBT250 field transmitter and interference tester is optimized to provide the right set of tests for field maintenance technicians and RF engineers to maintain and troubleshoot EDGE base station transmitters. A series of basic Pass/Fail tests summarizes base station performance and pinpoints problems. In addition, in-depth tests are a great help for those more difficult problems.

In these next sections, we will look in detail at the measurement methods and the results of these measurements for optimizing EDGE base stations.

Accessing the signal

The Tektronix NetTek can be used to make measurements and perform evaluations in either a direct connect configuration or an over-the-air configuration using a directional receive antennae. The direct connect to the base station transmitter RF output would provide the most accurate measurements. On the other hand, over-the-air measurements can be more convenient and faster. The over-the-air measurements can be used to conduct first level performance or “wellness” checks on the base station transmitters.

When making over-the-air measurements, good judgment and technique should be exercised in order to ensure repeatable, meaningful results. This will be addressed in more detail later.

Direct Connect Measurements

This section is an overview of key base station maintenance tests for QoS programs, routine maintenance, diagnostics, and repair. A regular testing regime with an appropriate integrated test set can ensure a level of base station performance that meets customer expectations.

Measurements can be made by connecting the analyzer directly to the RF output of the transmitter (using attenuators when appropriate), a test port, or to the receive antennas (Figure 9).

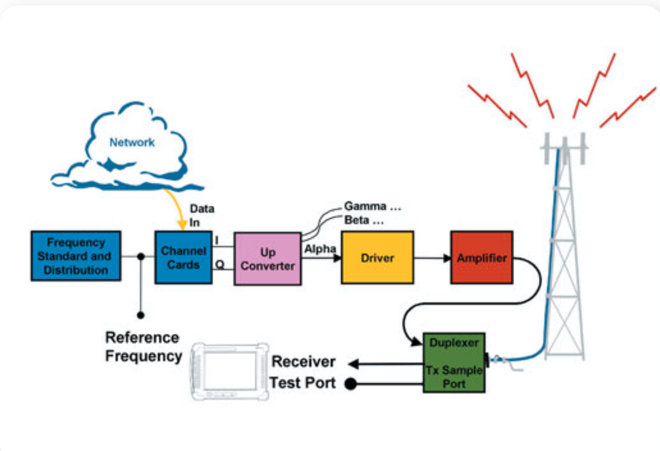


Figure 9. Direct connect measurements.

After connecting to the base station, the Tektronix NetTek EDGE measurements are available from the menu shown in Figure 10.

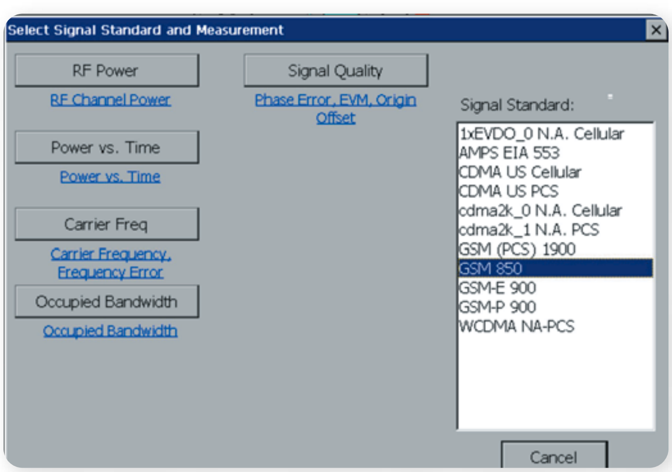


Figure 10. EDGE Measurements Selection Window.

RF Power Measurements

This section will describe each common EDGE direct connected measurement in turn, describing what is being measured, why the test is needed, pass/fail guidelines if appropriate, and common sources of problems, if any.

Base Station RF Channel Power

Correct RF power levels are essential for the optimal performance of the base station and cell site of interest, as well as the neighboring cells. The Tektronix NetTek can be configured to evaluate the BCCH (Broadcast Control Channel) control channel as well as the various traffic channels being transmitted from the base station.

Setup

For the more in-depth power measurements, time slot timing is derived from the BCCH so the NetTek needs to be told which RF channel has the BCCH reference. As can be seen in Figure 11, the choices for the selection of the location of BCCH can be made.

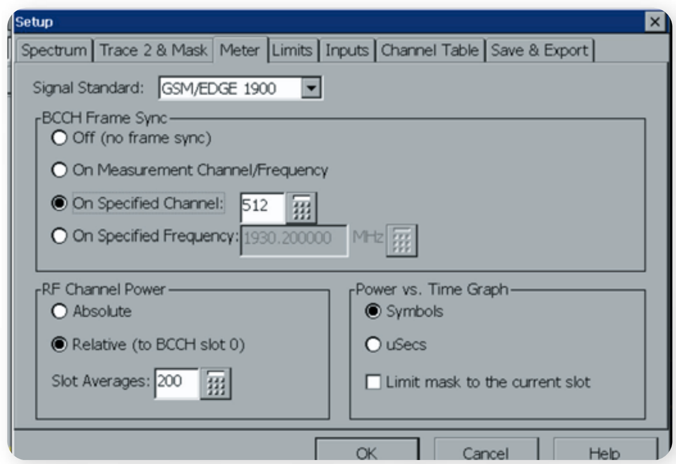
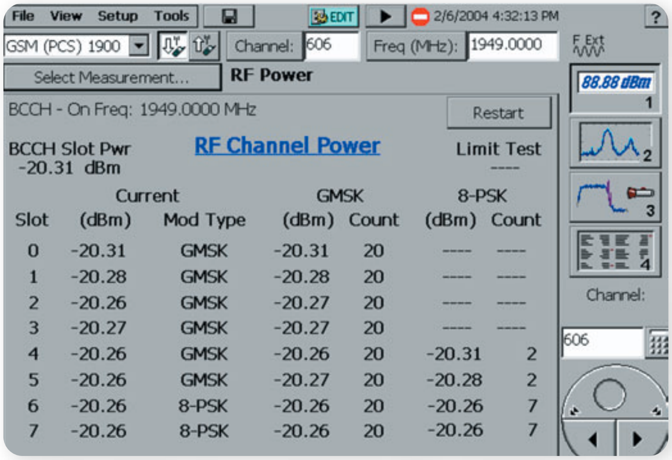


Figure 11. BCCH setup.

The selection, 'On Measurement Channel' assumes that the current RF channel is the BCCH. The selections 'On Specified Channel' or 'On Specified Frequency' will tell the NetTek a specific channel or frequency for the BCCH. This is very useful when evaluating traffic-only channels.

BCCH Channel Power Measurement

What is being measured? The GSM/EDGE RF Power measurement evaluates the power of each of the time slots (or bursts) of the frame of the RF channel selected. In Figure 12, the measurement is evaluating the BCCH. For each time slot, the display provides the current power and modulation type (the two columns under "Current"), a running average of the GMSK slots (under the heading GMSK), and a running average of the 8-PSK slots (under the column 8-PSK). The column "Count" shows the number of averages that have contributed to the running averages.



▶ **Figure 12.** RF Power Measurement, BCCH

To get the time slot information, the Tektronix NetTek must listen to the BCCH channel. In this example, the BCCH is on channel 606 and is also the RF channel that is being measured. This is the simplest case. The BCCH Slot 0 power was measured at -20.31 dBm. The measurement results can be either in dBm, as shown here, or in dB relative to the BCCH Slot 0 power, which is useful for slot power leveling. This relative power setting works very well with the limit settings we will discuss later.

Why do I need to test? The RF power level of BCCH Slot 0 sets the size of the cell and must be properly adjusted. High power levels will make the cell's coverage area larger, leading to an overloaded cell. Low power levels will decrease the cell's coverage area, and cause dead spots.

For each base station sector, there is one fixed frequency RF carrier whose Timeslot 0 is dedicated to carrying the BCCH (logical) channel reference for that sector. Time slots 1-7 may be either traffic channels or Dummy Bursts. All time slots on the BCCH channel are "always on" and therefore each timeslot must either be a BCCH time slot, traffic, with GMSK or 8-PSK modulation, or Dummy Bursts, which are GMSK only. There is never an idle time slot in a BCCH channel.

Time slot leveling is a process that makes sure each time slot is producing the same power. If they are not, this display will help to diagnose the problem. Some networks have downlink power control enabled. This allows traffic only channels (not BCCH channels) to change their power in 2dB or greater steps, depending on the band. This action can also be viewed on this screen.

What are the guidelines? The guideline is that the measured power should be between ± 2 dB of the specified power. The power should be leveled between time slots to ± 2 dB. These are from the standard, but network operator requirements may be tighter.

What are potential sources of faults? Areas to examine are the power differences caused by channel elements. If leveling between RF carriers, check the power settings of each radio and amplifier.

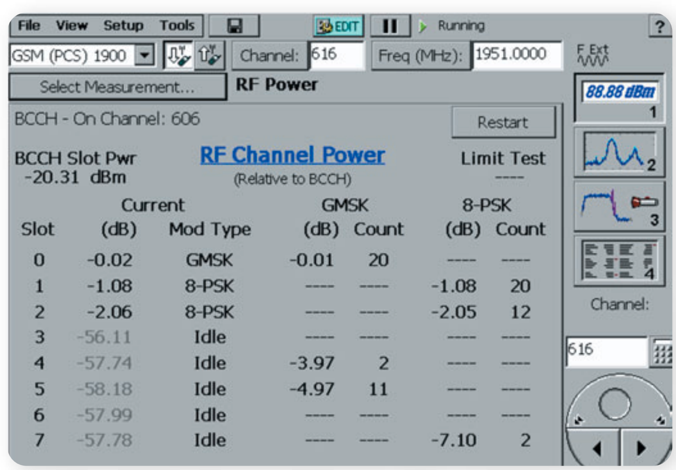
Traffic Channel RF Power Measurement

What is being measured? The GSM/EDGE RF Power Measurement evaluates the power of each of the eight time slots (or bursts) of the RF channel selected. In Figure 13, the measurement is evaluating a Traffic Channel and taking its timing reference from the associated BCCH channel.

To get the time slot information, the NetTek must listen to the BCCH channel. In this example, the BCCH is on channel 606 while the traffic channel that is being displayed and measured is 615. The power reference comes from the BCCH, Slot 0 so on this screen, the traffic channel power can be directly compared to the BCCH slot zero channel power. This display is useful for performing time slot leveling and diagnostics.

On traffic channels, all eight time slots may be traffic. If no traffic is present, then the time slot can be Idle.

Why do I need to test? Improper power levels cause dropped calls, either in this cell or neighboring cells. The slot type provides information about how the network is being used.



▶ **Figure 13.** RF Power Measurement, Traffic Channels

What are the guidelines? The guideline is that the measured absolute power should be between ± 2 dB of the specified power. The relative power should be ±2 dB relative to BCCH time slot 0. These are from the EDGE specifications and operator requirements may be tighter.

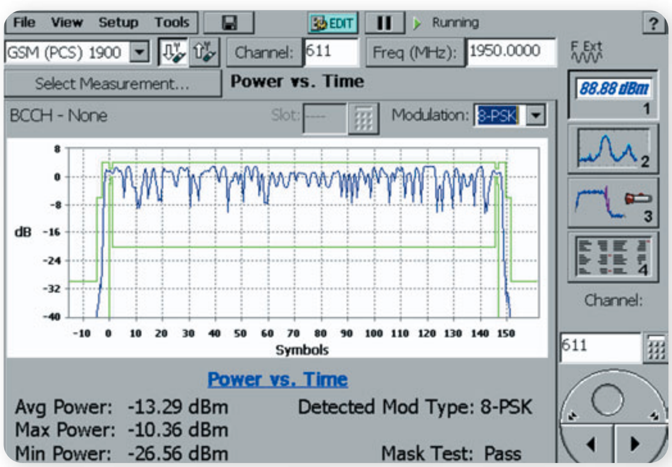
What are potential sources of faults? Areas to examine are amplifier power settings and RF path issues, such as antenna, antenna cabling, connectors, etc.

Power versus Time

What is being measured? Power versus time shows the time slot rise time and fall time, as well as what is happening while the time slot is active. Superimposed upon the results screen is the limits mask or template defined by the standards (Figure 14).

Why do I need to test? GSM/EDGE is a TDMA system and care must be taken to ensure that power is controlled carefully. The RF power must not start to ramp up too soon; otherwise there could be interference with the preceding time slot. The power must also ramp down properly to ensure no interference with the following slot. Data could be lost if the bursts interfere with one another. Too fast of rise time can lead to interference with other RF channels.

Violations of the "Useful Part" of the mask, that is, the part where the power is up and the signal is being transmitted, indicate sudden and unexpected power changes.



▶ **Figure 14.** Power versus Time showing results and standards mask.

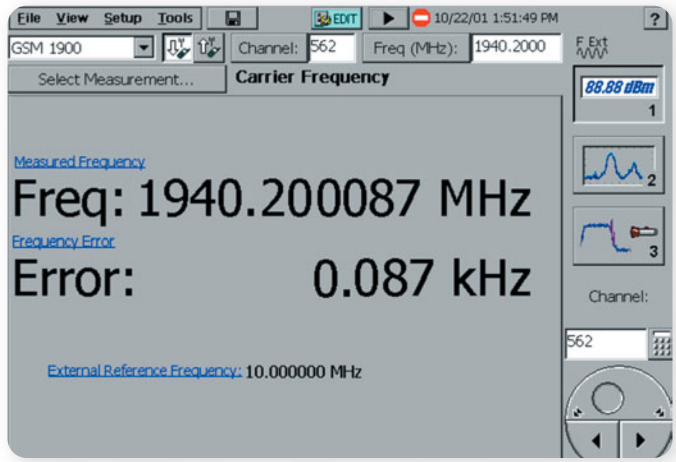
What are the guidelines? Slot power must stay within the mask (Figure 14). The mask is as per the specification.

What are potential sources of faults? Slow or fast rise time or fall time problems could be due to amplifier problems, damage to antenna or antenna cable and damage to connectors. "Useful Part" mask violations could be caused by amplifier instability, modulation problems or co-channel interference. If the timing is way off, this could be caused by BCCH timing not matching traffic channel timing or possibly co-channel interference.

Frequency Measurements

Carrier Frequency

What is being measured? Carrier frequency error is the difference between the specified and the actual center frequency of a carrier (Figure 15).



▶ **Figure 15.** Frequency and Error Measurements.

Why do I need to test? Frequency measurements are useful for finding transmitter faults and mis-configurations. Too much error will prevent proper hand offs, creating an "island cell".

What are the guidelines? The Frequency Error guideline is ± 0.05 PPM. For reference, this is 50 Hz at 1 GHz and 100 Hz at 2 GHz.

What are potential sources of faults? Look for a faulty local oscillator in a channel element or up-converter. Also check for a poor or broken base station frequency reference.

Occupied Bandwidth

What is being measured? Occupied Bandwidth (Figure 16) is the RF bandwidth of the base station carrier. The red markers on the screen designate 99.5% of the signal power and the NetTek then measures the bandwidth between the markers.

Why do I need to test? Excessive bandwidth creates interference with adjacent RF channels. This contributes to lowering system call capacity.

What are the guidelines? The guideline is that 99.5% of the RF channel power should be within 260 kHz. Each network operator may set their own limits.

What are potential sources of fault? Look for intermodulation problems, such as faulty mixers. Also, look for intermodulation generated by unintentional mixers, such as corrosion in antenna cable fittings.

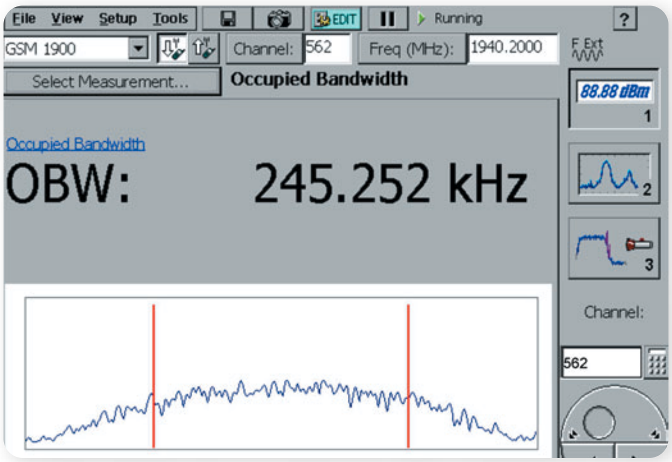


Figure 16. GSM/EDGE Occupied Bandwidth

Signal Quality

Phase Error

What is being measured? Phase Error is the RMS value of the differences between the phase angles of the received signal and those of an ideal reconstructed reference signal, in degree units, of the specified slot (Figure 17). This represents the phase instability of the received signal.

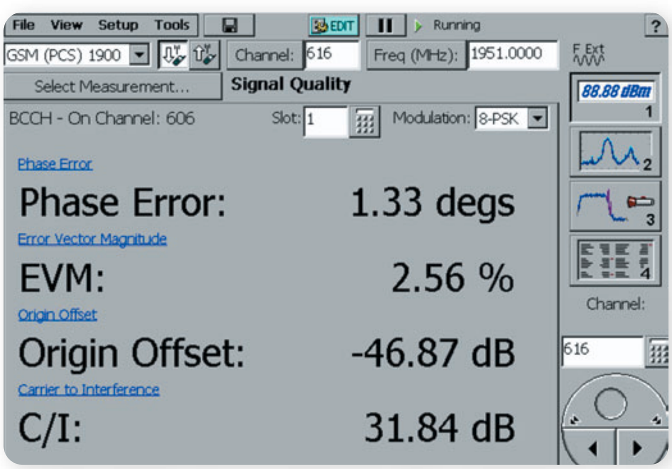


Figure 17. Signal Quality Measurements Results Window

Why do I need to test? Inaccuracies in phase will cause a high bit error rate or a high number of bad frames. The data throughput will be reduced. This is particularly relevant to GMSK signals.

What are the guidelines? Phase error shall not exceed 5.0 degrees according to the GSM/EDGE standard.

What are potential sources of faults? When connected to the base station, look for an unstable frequency reference or a local oscillator in up-converter or modulator. When testing over-the-air, look for co-channel interference from another GSM/EDGE transmitter.

Error Vector Magnitude (EVM)

What is being measured? Error Vector Magnitude (EVM) is a measurement of the distortion in the RF signal path (Figure 17). This represents the phase and amplitude instability of the received signal.

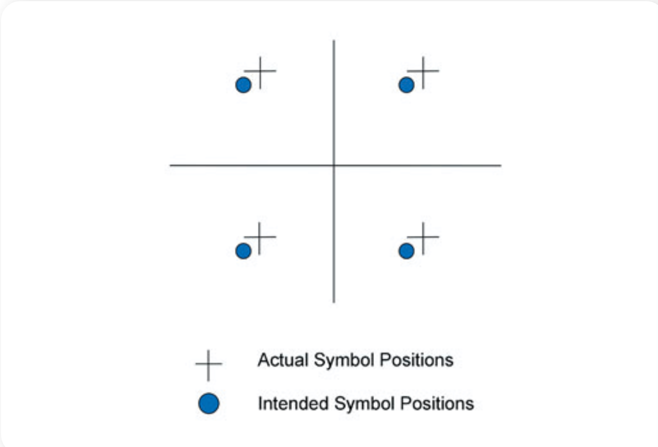
Why do I need to test? High EVM will cause high bit error rate or a high number of bad frames. EVM identifies base station and air interface issues degrading data throughput. This test is particularly relevant to 8-PSK signals.

What are the guidelines? The guidelines are 7% prior to passive combiners and 8% after passive combiners. Add 1% for "extreme conditions".

What are potential sources of fault? When connected to the base station, look for power amplifier issues, such as power settings, compression, clipping, or power supply faults. Also look for unstable frequency references and RF path issues, such as loose connectors, bad antenna cables, antenna, etc. When testing over-the-air, look for co-channel interference from another GSM/EDGE transmitter.

Origin Offset

What is being measured? Origin Offset is the ratio of unmodulated signal power to modulated signal power, in dB units (Figure 17). The measurement name refers to the offset of the signal constellation center that is caused by the unmodulated signal component (Figure 18). This is also known as carrier feedthrough or I/Q offset.



▶ **Figure 18.** Example of orgin offset on I/Q diagram.

Why do I need to test? Excessive origin offset limits data throughput, due to self-interference.

What are the guidelines? Origin offset shall be less than -35 dB.

What are potential sources of faults? Look first for faulty modulators in the radio unit.

Carrier to Interference Ratio

Traditional techniques involved measurements with and without carrier, and required taking the base station out of service. The traditional method also involves a manual calculation. This new "In-Service" technique takes advantage of the reference signal generated as part of the EVM calculation. Interference is then calculated as reference/ (reference minus received signal); C/I = Ref/(Ref-Rx).

What is being measured? Carrier to Interference ratio (C/I) is the ratio of desired signal (carrier) power to undesired signal (interference) power, in dB units (Figure 17). The NetTek C/I gives an estimate of the power-based C/I value.

Why do I need to test? Co-channel interference is the most prevalent form of GSM/EDGE interference. Co-channel interference lowers data throughput, sometimes dramatically. Lower data throughput means less network data capacity and unhappy users.

What are the guidelines? C/I should be at least 23 dB before measuring EVM over-the-air. C/I over 23 dB indicates that co-channel interference is not a large problem.

What are potential sources of faults? Look first for co-channel interference on transmit frequencies. Look for intermodulation products, or harmonics, of licensed transmitters on receive frequencies. Look for nearby off-channel strong transmissions causing receiver de-sense.

Testing Procedures

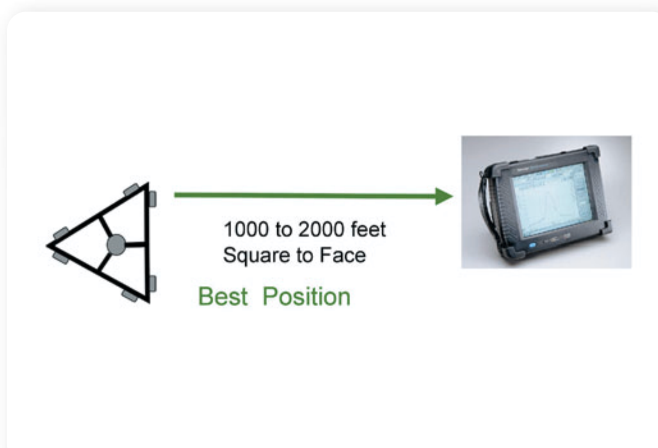
First Pass Base Station "Wellness" Check

The Tektronix NetTek can be used to evaluate received signals for unwanted interference, as well as to conduct first pass performance or "wellness" checks on base station transmitters. When making over-the-air measurements, good judgment and technique should be exercised in order to ensure repeatable, meaningful results. Environmental factors, such as variable RF path loss, interference, position, and the effect of the antennas used, need to be taken into consideration. Measurement consistency can be achieved by controlling position, measurement antenna, and attention to interference. This section will step through a process of performing a first pass base station "wellness" check.

Step 1 - Over-the air testing

To make over-the-air testing work well, it is best to locate a good testing location once, document the location, and use the location whenever further measurements are needed. This technique eliminates many of the variables in over-the-air testing. To make documentation of over-the-air testing easier, the NetTek can display GPS coordinates on printed or electronic test results. It is recommended that a band-pass filter be used.

For over-the-air measurements, find the best location (Figure 19). The guidelines for the best location are; be approx. 1,000 to 2,000 feet from the tower, square with the face, without any large elevation differences between you and the base station, and be within line-of-sight of the base station.



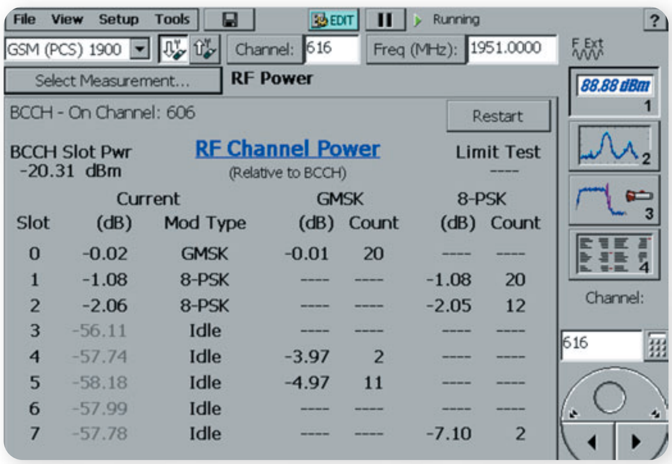
▶ **Figure 19.** Best location criteria.

Co-channel interference, described later in this application note, can affect measurement results.

Step 2 – Slot Leveling

Configure for over-the-air RF Channel Power Measurement. Do this by selecting the appropriate BCCH channel (Figure 20). Set the NetTek to relative power measurements and check slot leveling on the BCCH and any traffic channels. Downlink Power Control should be turned off for this measurement.

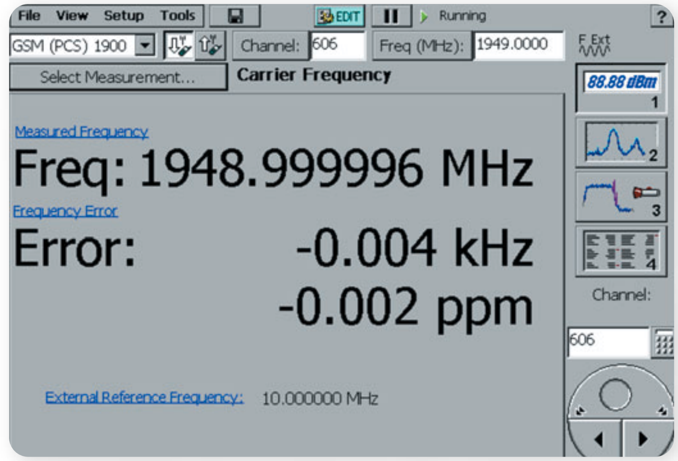
To get a good sense of the activity and nature of the traffic on the system, look for idle, GMSK and 8-PSK activity. This could suggest clues as to the health of the cell site. For example, if there are several 8-PSK traffic channels, then that would indicate the EVM is within acceptable limits and users are experiencing good data throughput.



▶ **Figure 20.** Wellness check, slot leveling

Step 3 – Carrier Frequency Error

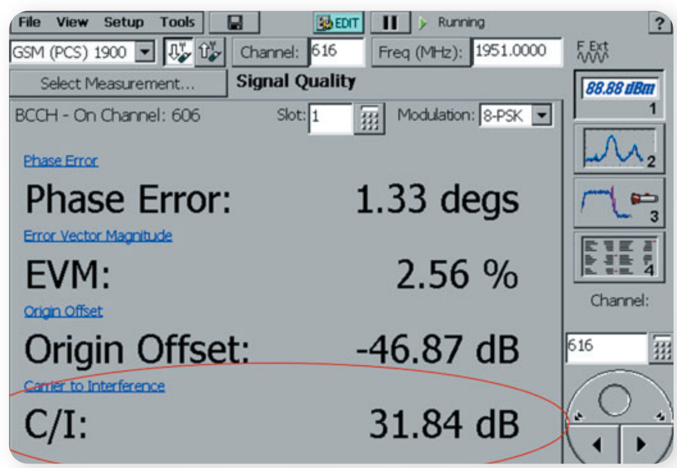
This next step checks the health of the RF carrier frequency, in order to prevent “island cells” (Figure 21). For best accuracy, the NetTek should be hooked up to an external reference frequency, or self-calibrated from that reference frequency.



▶ **Figure 21.** Wellness check, Carrier Frequency Error

Step 4 – Signal Quality: Carrier to Interference Ratio

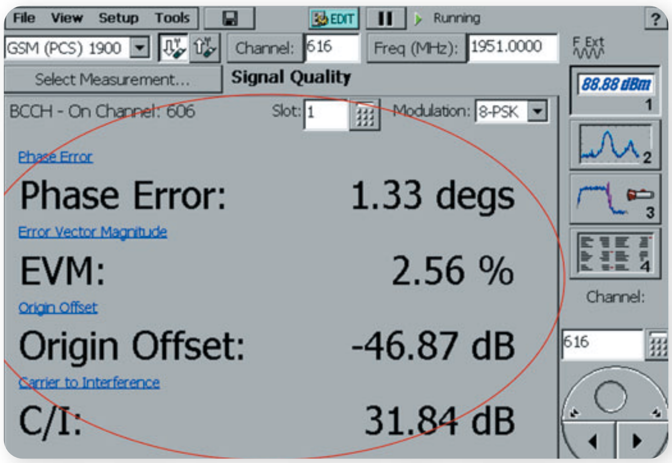
This next step gives an indication of reception conditions. Configure the Tektronix NetTek for Signal Quality measurement (Figure 22). If the C/I is better than 23 dB, this indicates that over-the-air signal quality is good and we can continue to the next step. If the C/I is worse than 23 dB, this indicates that the base station signal is distorted or there is excessive interference present, or both. In this case, further testing will be necessary to determine the cause.



▶ **Figure 22.** Wellness check, C/I

Step 5– Signal Quality: Phase Error, EVM, and Origin Offset

The Signal Quality parameters that are being considered in this step are fundamental indicators of the Air Interface and Signal Quality (Figure 23). High values indicate data throughput limitations, which could be due to the base station transmitter or to interference. If these parameters pass when measured over-the-air, then this is a strong indicator that the base station must be very clean.



▶ **Figure 23.** Wellness check, phase error, EVM, and Origin Offset

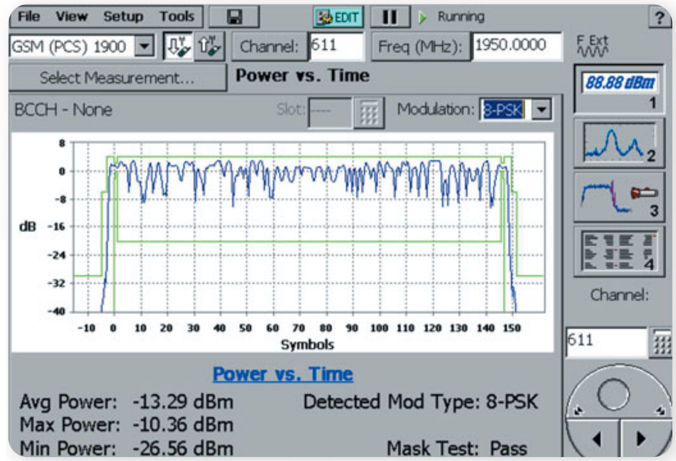
Step 6– Power versus Time

This display provides information concerning the dynamic nature of the RF power adjustments and co-channel interference (Figure 24). Configure for the Power versus Time measurement for the RF channel and time slot of interest. Select the abbreviated mask for in-service testing.

This helpful display shows a number of things:

- Average, Max Envelope and Min Envelope power per slot
- If data is being lost due to slow, or early, rise time.
- If adjacent channel interference is being created due to the rise time being too fast. Rise time which is too fast, will create harmonics or Intermodulation Distortion, giving rise to interference.
- If the on and off times are radically different than the mask, this is an indication that the timing of the traffic channel under test and the BCCH channel selected do not match.
- If a second signal is present, with different power levels and on/off time is riding on top of the desired signal. This is a sure indication of co-channel interference.
- Downlink power control activity will show up as adjacent time slots at different power levels than the time slot selected.

Perform these measurements on both GMSK and 8-PSK time slots.



▶ **Figure 24.** Wellness check, Power versus Time.

Interference

▶ **Figure 25.** Interference testing with Tektronix NetTek

Interference is a major source of cellular service degradation. Evaluation of interference from the surrounding RF environment is important to maintain high customer satisfaction. Examples of sources of spurious or interfering signals include power lines, co-located transmitters, intermodulation sources such as corroded connectors, and harmonics of GSM or broadcast stations. In addition, there are many other sources of Electro Magnetic Interference (EMI) like lighting, arc welding, high voltage power lines, and even automobile ignitions. These interfering signals may be on your RF channel, and are then referred to as co-channel interference. The interfering signals may be at somewhat removed from your RF channel and then are referred to as out-of-channel interference.

The Tektronix NetTek® YBT250, option IN1 Interference Analyst is a superb tool for identifying and locating sources of interference. A detailed analysis and application study can be found in Tektronix application notes, "Hunting for Sources of Interference in Mobile Networks", publication number 2GW-14759-0, and "Fundamentals of Interference in Mobile Networks", publication number 2GW-14758-0.

Co-Channel Interference

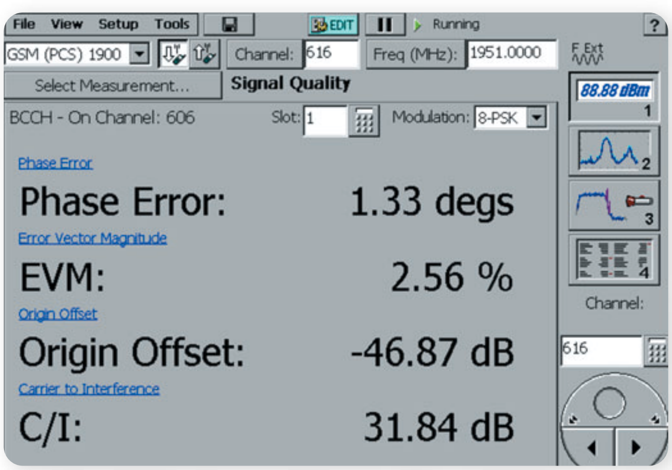
These are weak signals (or even strong ones) that are on the same frequency as the intended communications signals. In a GSM/EDGE system, the most common source of co-channel interference is other GSM/EDGE base stations. In addition, intermodulation or harmonics from co-located GSM transmitters can be a ready source of interference.

Out-of-Channel Interference

These are strong signals that are not actually on the receiver frequency, but are strong enough to either block a receiver's input or reduce its sensitivity. These signasl are within the receive band of the base station, and so within the receiver's pre-filter If they were further away, the receiver's own input pre-filter would eliminate them. Useful measurements for out-of-channel interference are signal strength, audio demodulation, and noise floor.

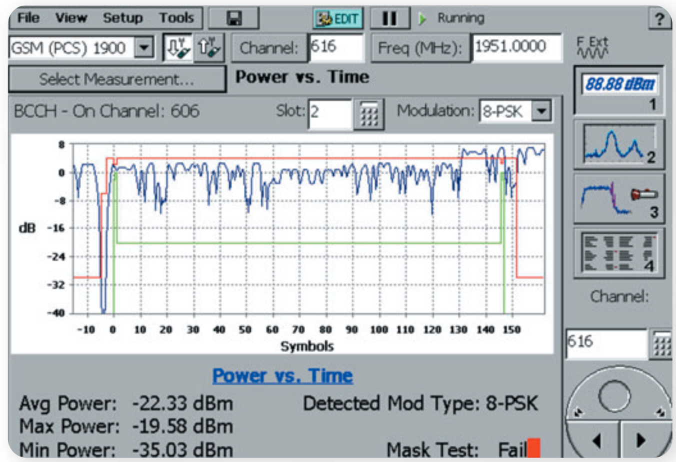
Interference Measurements: Co-Channel

The Carrier to Interference Ratio (C/I) is calculated from the EVM reference signal and the RF input (see previous measurement description). A low C/I indicates that there is more than one signal on the frequency (Figure 26).



▶ **Figure 26.** Co-channel interference indicated by C/I.

Co-channel interference can also be spotted directly from the Power versus Time measurement. The Power versus Time measurement occurs in the time domain so it is very apparent when a second signal is present. In Figure 27, the second signal is visible on the top right of the trace, as a higher power level partway through the trace, and by the signal not turning off at the end of the timeslot.



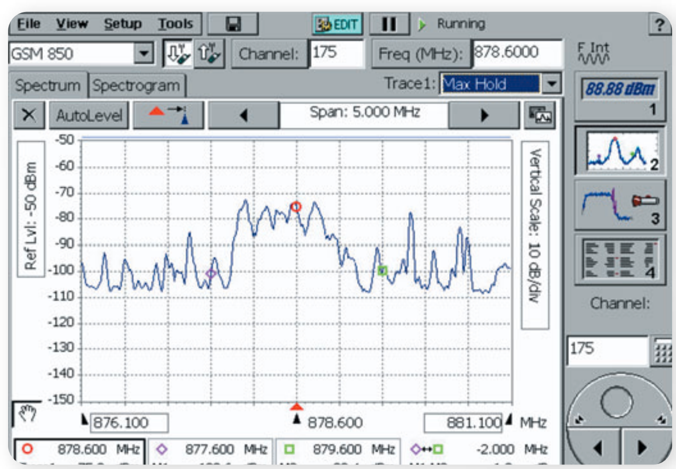
▶ **Figure 27.** Co-channel interference, time-skew detected in Power versus Time measurement.

Interference Measurements: Out-of-Channel

The following measurements are useful in detecting and evaluating out-of-channel interference.

Spectrum Monitor

What is being measured? The RF power levels of signals as a function of frequency over the bandwidth selected.

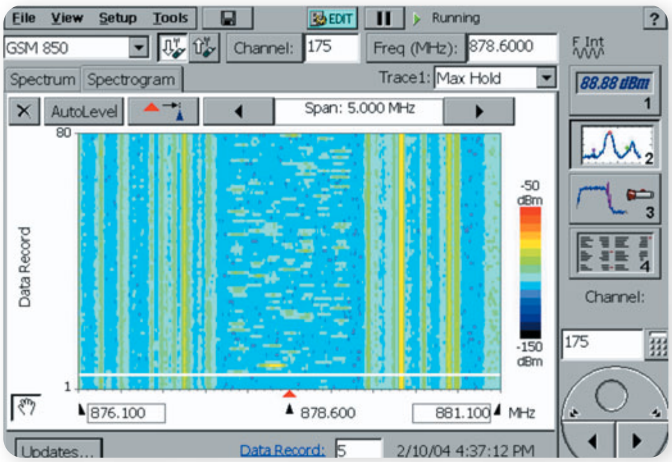


▶ **Figure 28.** Spectrum Monitor.

Why do I need to test? This screen gives you the visibility of the RF spectrum, including your carriers and any other, interfering, signals that may be present

Spectrogram

What is being measured? The spectrogram provides a view of the frequency spectrum (horizontal axis) plotted against time (vertical axis) and power (color levels). It allows viewing changes in signals over time. It is a 3-D graphical representation of signal amplitude, frequency, and time.

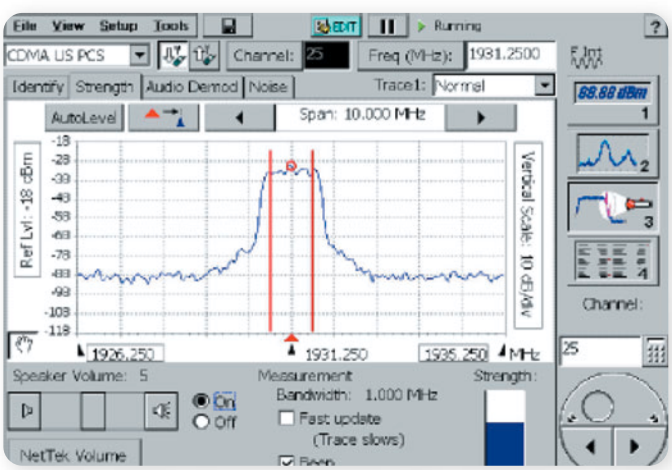


▶ **Figure 29.** Spectrogram

Why do I need to test? Spectrograms are unique in their ability to show hopping or other rapidly changing signals, such as interference. If the interference is intermittent, then it is very helpful to make the spectrogram longer.

Signal Strength

What is being measured? By attaching a directional antenna to the NetTek, you can locate the source of an interfering signal.



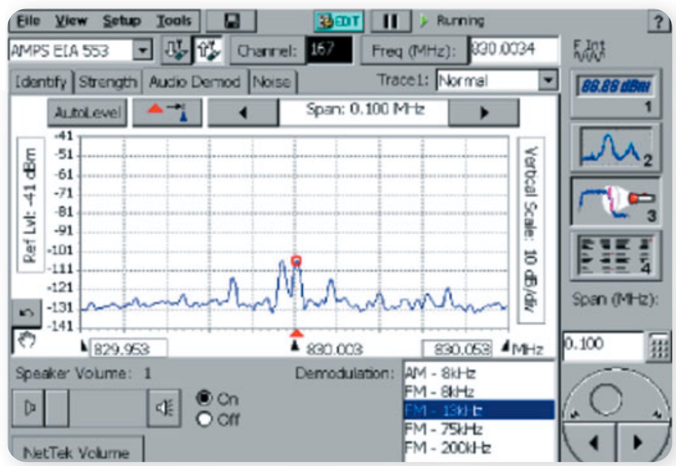
▶ **Figure 30.** Signal Strength Display

Why do I need to test? After identifying a suspect signal is a potential interferer, and placing it in the Signal Strength Display, it is possible to locate the direction and possibly identify the source of the interference. Steps can then be taken to reduce or eliminate the interference.

This is done by measuring the strength of the interfering signal in the Signal Strength display (Figure 30) using a directional antenna. By pointing the directional antenna in different directions, the tone produced by the signal strength display will change, indicating the strength of the signal. In this way, the direction of the interfering signal can be determined without needing to look at the display. Full attention can be given to looking for the signal source.

Audio Demodulation

What is being measured? One method to identify an interfering signal is to demodulate the signal (Figure 31).

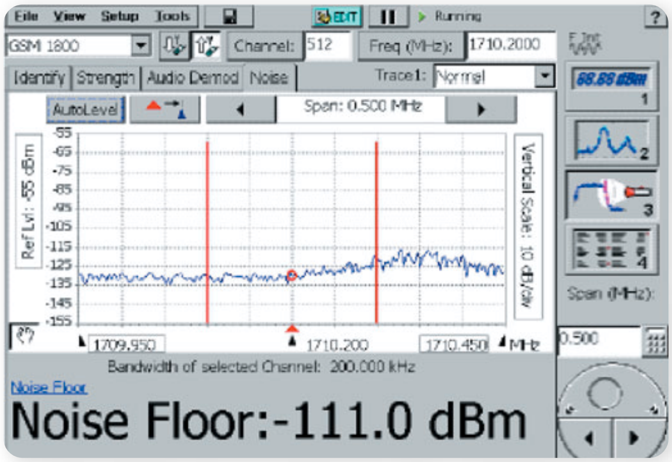


▶ **Figure 31.** Audio Demodulation

Why do I need to test? Audio Demodulation enables you to listen for any identifying information, such as a station ID, in the signal. A station ID can be particularly helpful when the interfering signal is a radio or broadcast television station. You may also be able to discriminate between possible interference sources by listening to the characteristic sounds of paging, video, GSM signals or the harmonics of other common signals.

Noise Floor

What is being measured? Noise Floor measures all the RF Power coming into the receive antenna within the frequency band of the selected channel (Figure 32). The Noise Floor is the power integrated across the selected channel. To make an accurate measurement, the Noise Floor must be measured on a receive channel.



▶ **Figure 32.** Noise Floor Measurement.

Why do I need to test? This measurement gives a single number that indicates receive channel quality. This number can be used to decide if it interference is sufficiently severe to require action.

Conclusion

EDGE provides an important evolutionary step in 3G cellular communications. Successful deployment and ongoing operations are critical to the success of wireless service providers. It is important to have effective troubleshooting and measurement tools. This shortens down time and maintenance tasks as well as ensuring customer satisfaction. In addition, a regular testing and maintenance program, with an appropriate field installation and maintenance test set, can ensure a reliably high level of network performance that meets QoS goals, particularly throughput goals. Traditional, larger, dedicated test instrumentation is too costly, heavy and complicated to use in practical applications in the field. Other testers, such as mobiles in test mode, or area testers, may indicate a fault but do not help identify the fault.

The Tektronix NetTek field portable base station tester is purpose built specifically for the base station technician and field RF engineers. It is the first to bring performance, usability and value to network operations managers. The Tektronix NetTek provides the essential testing capability for maintenance personnel to increase their productivity and effectiveness, while maintaining high QoS and customer satisfaction.

This application note has reviewed the important measurements to be made on EDGE base stations, when directly attached to the base station and over-the-air. We have provided testing guidelines, extracted from the appropriate standards and specifications. Lastly, we have identified potential sources of problems that need to be investigated and repaired or adjusted, if found to be out of specification.

Appendix

Abbreviation List

3GPP	Third-Generation Partnership Project
8-PSK	Eight – Phase Shift Keying
AMPS	Advanced Mobile Phone Service
ARIB	Association for Radio Industry and Business (Japan)
BCCH	Broadcast Control Channel
BSS	Base Station Subsystem
BTS	Base Transceiver Station
CCCH	Common Control Channel
CCITT	Committee Consultative International Telephone and Telegraph
EDGE	Enhanced Data rates for Global Evolution
EGPRS	Enhanced General Packet Radio Service
EMI	Electro-Magnetic Interference
ETSI	European Telecommunications Standardization Institute
EVM	Error Vector Magnitude
FCCH	Frequency Correction Channel
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
IMT-2000	International Mobile Telecommunication 2000
IS	Interim Standard
ITU	International Telecommunications Union
MAHO	Mobile Assisted Hand Off
NADC	North America Digital Cellular
NMT	Nordic Mobile Telephone
PCS	Personal Communications Service
PDC	Personal Digital Cellular (Japan)
PDTCH	Packet Data Traffic Channel
OTA	Over-The-Air
PBCCH	Packet Broadcast Control Channel
PCCH	Packet Common Control Channel
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
SCH	Synchronization Channel
TCH	Traffic Channel
TIA	Telecommunications Industry Association
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TS-CDMA	Time Synchronous Code Division Multiple Access
UMTS	Universal Mobile Telephone System (Europe)
UTRA	UMTS Terrestrial Radio Access
W-CDMA	Wideband Code Division Multiple Access

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