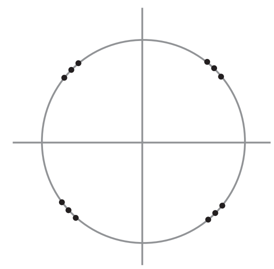
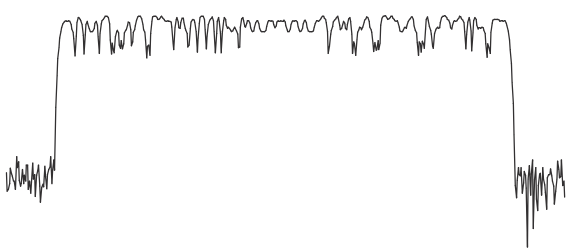
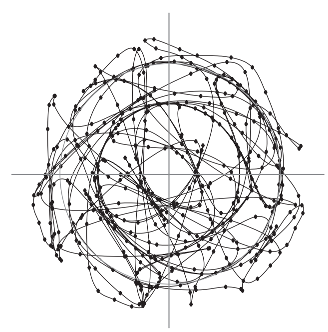
Keysight Technologies

Understanding GSM/EDGE Transmitter and Receiver Measurements for Base Transceiver Stations and their Components







Application Note

Table of Contents

Introduction

This application note presents the fundamental RF parametric measurements necessary to characterize GSM/EDGE base transceiver stations and their components. The principles cover all GSM bands (P-GSM900, DCS1800, E-GSM900, R-GSM900, GSM450, GSM480, GSM850, MXM850, PCS1900 and MXM1900). Specific examples reference E-GSM900.

These measurements are widely used today, but new test equipment is making them easier to perform, faster and more precise. This note aims to enhance the reader's understanding of GSM/EDGE measurements so they can be used and optimized appropriately. It is also intended as a useful reference for engineers in manufacturing, research and development and field service.

As far as possible, graphics are used to represent the theory behind each measurement and the test limits applied. For each measurement, pictorial examples of setup, method and specification limits are given. These have been derived from the ETSI and ANSI standards.

Why measure?

The GSM standards define a radio communications system that works properly only if each component part operates within precise limits. Essentially, a compromise is established between the link quality experienced by an individual user and the level of interference experienced by others. Mobiles and base stations must transmit enough power, with sufficient fidelity to maintain a call of acceptable quality, without transmitting excessive power into the frequency channels and timeslots allocated to others. Receivers must have adequate sensitivity and selectivity to acquire and demodulate a low-level signal.

Transmitters

Performance is critical in three areas: in-channel, out-of-channel, and out-of-band.

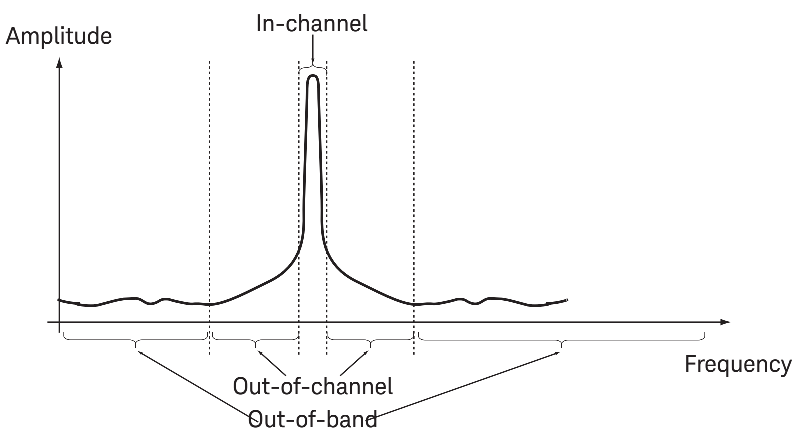


Figure 1. In-channel, out-of-channel, out-of-band measurements

In-channel measurements determine the link quality seen by the user in question:

- Phase error and mean frequency error
- Mean transmitted RF carrier power
- Transmitted RF carrier power versus time

Out-of-channel measurements determine how much interference the user causes other GSM users:

- Spectrum due to modulation and wideband noise
- Spectrum due to switching
- Tx and Rx band spurious

Out-of-band measurements determine how much interference the user causes other users of the radio spectrum (military, aviation, police):

- Other spurious (cross band and wideband)

Receivers

Performance is critical in the following area: sensitivity. Sensitivity measurements determine the link quality seen by the user in low signal level conditions:

- Static reference sensitivity level

Origins of measurements

GSM transmitter and receiver measurements originate from the following ETSI 3GPP standards:

3GPP TS 05.05.V8.12.0	Radio access network; radio transmission and reception (release 1999).
3GPP TS 11.21 V8.6.0	Base station system (BSS) equipment specification; radio aspects (release 1999).

It is worth noting that these specifications were written for the purposes of full type approval and they are extensive. It is not practical to make the whole suite of measurements in most application areas. For example, in manufacturing where throughput and cost are key drivers, it is necessary to use a subset of the measurements defined in the specifications above. Optimization is key; the objective should be to test sufficiently to prove correct assembly, perform correct calibration and assure correct field operation, but with a minimum of expense. It is not necessary to type approve infrastructure component shipped.

This application note aims to help the reader to interpret the standards and apply tests appropriately.

The standards can be difficult to understand, and independent parties might interpret them differently. Keysight Technologies, Inc. uses the standards as a basis from which to design measurement algorithms.

3GPP TS 11.21 V8.6.0 reference	Test name	Commonly performed test covered in this paper
6.1	Static layer 1 functions	In effect
6.2	Modulation accuracy	Yes
6.3	Mean transmitted RF carrier power	Yes
6.4	Transmitted RF carrier power versus time	Yes
6.5	Adjacent channel power	Yes
6.6	Spurious emissions from the transmitter antenna connector	Yes
6.7	Intermodulation attenuation	No
6.8 to 6.10	Intra base station system intermodulation attenuation	No
7.1	Static layer 1 receiver functions (nominal error ratios)	In effect
7.2	Erroneous frame indication performance	In effect
7.3	Static reference sensitivity level	Yes
7.4	Multipath reference sensitivity level	No
7.5	Reference interference level	No
7.6	Blocking characteristics	No
7.7	Intermodulation characteristics	No
7.8	AM suppression	No
7.9	Spurious emssions from the receiver antenna connector	No

Table 1. GSM/EDGE transmitter and receiver tests. 3GPP TS 11.21

Choosing measurements

As mentioned, ETSI 3GPP specifications are devised for type approval purposes. It is not practical to perform the complete set in every environment; GSM/EDGE equipment manufacturers and network operators must balance test coverage with other factors such as cost and time. Nobody prescribes the specific measurements set to be used at any one point in the GSM/EDGE lifecycle (except in type approval). Measurements must be chosen for each requirement. At each stage in the development, manufacturing and maintenance cycles, measurements and measuring equipment must be chosen according to need.

Test phases

At a high level, the lifecycle for base transceiver stations (BTS) is summarized in the following diagram and table:

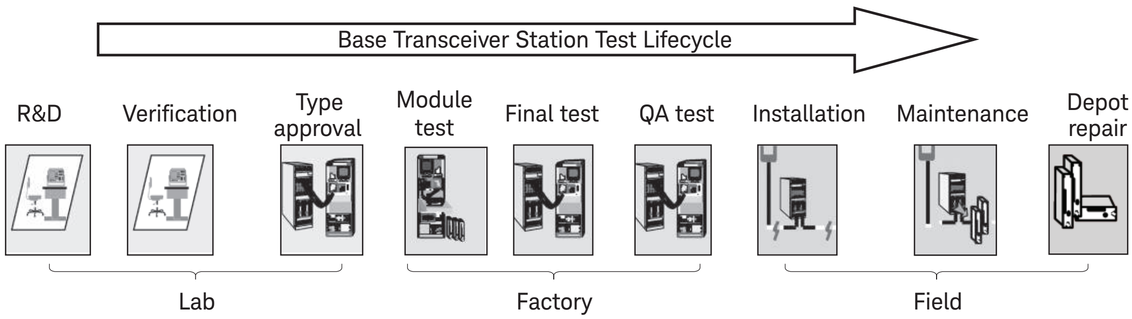


Figure 2. BTS lifecycle

Lifecycle phase	Purpose of test
R&D	Create and optimize design Stress-test design/find corner cases
Verification	Prove compliance before submitting to type approval Find faults
Type approval	Prove absolute compliance
Module test	Calibration (manual and electronic) Prove correct assembly and performance
Final test	Prove correct assembly and performance Configure and prove configuration Confidence
QA test	Quality control Prove compliance/confidence End-customer demonstration
nstallation	Prove correct field operation Configure and prove configuration
Maintenance	Monitor performance degradation and repair/swap out as required
Depot repair	Repair/recalibrate modules for field

Table 2. BTS lifecycle

Trade-offs and compromises

It is not necessary or practical to make the whole suite of measurements, with the same integrity (accuracy, dynamic range and number of averages) at each point in the lifecycle. Generally the following factors are subject to trade-offs:

- Test cost
- Test coverage
- Test throughput
- Test system flexibility

The test cost of each unit can be reduced by performing measurements only on the devices that have a real possibility of failing or performing only the measurements required for device characterization.

GSM/EDGE BTS Transmitter Measurements

Modulation accuracy

Note: For each measurement, process and limits vary between device type.

Purpose of measurement—what it proves

Phase error (GMSK) and EVM (8-PSK) are fundamental parameters used in GSM to characterize modulation accuracy. These measurements reveal much about a transmitter's performance. Poor phase error or EVM indicates a problem with the I/Q baseband generator, filters, modulator or amplifier in the transmitter circuitry. In a real system, poor phase error or EVM will reduce the ability of a receiver to correctly demodulate, especially in marginal signal conditions. This ultimately affects range.

Frequency error measurements indicate poor synthesizer/phase lock loop performance. This is especially important in a BTS with frequency hopping active. Poor frequency error measurements can show, for example, that a synthesizer is failing to settle quickly enough as it shifts frequency between transmissions. In a real system poor frequency error can cause many problems. For example, the target receiver might be unable to gain lock and the transmitter might cause interference with other users. If the latter is the case, other measurements can determine this with certainty.

Theory in pictures: GMSK

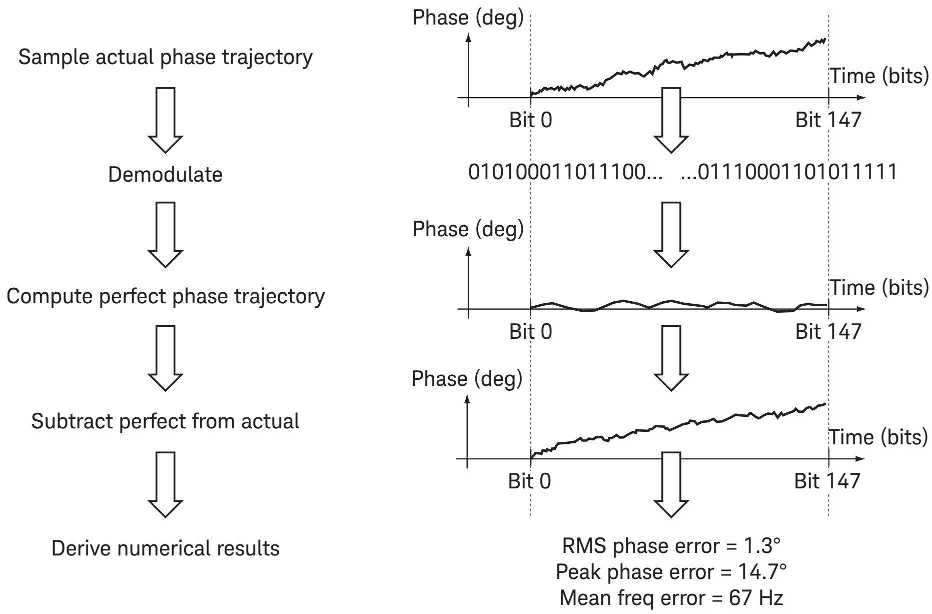


Figure 3. Theory of phase error and mean frequency error: GMSK

Phase and frequency error measurements are complex, however modern test equipment can perform all of the necessary signal processing and mathematics automatically. Figure 3 shows how the measurement works. The test receiver or analyzer samples the transmitter output in order to capture the actual phase trajectory. This is then demodulated and mathematically the ideal phase trajectory is derived. Subtracting one from the other results in an error signal. The mean gradient of this signal (phase/time) gives frequency error. The variation of this signal is defined as phase error and is expressed in terms of root mean squared (rms) and peak.

Theory in pictures: 8-PSK

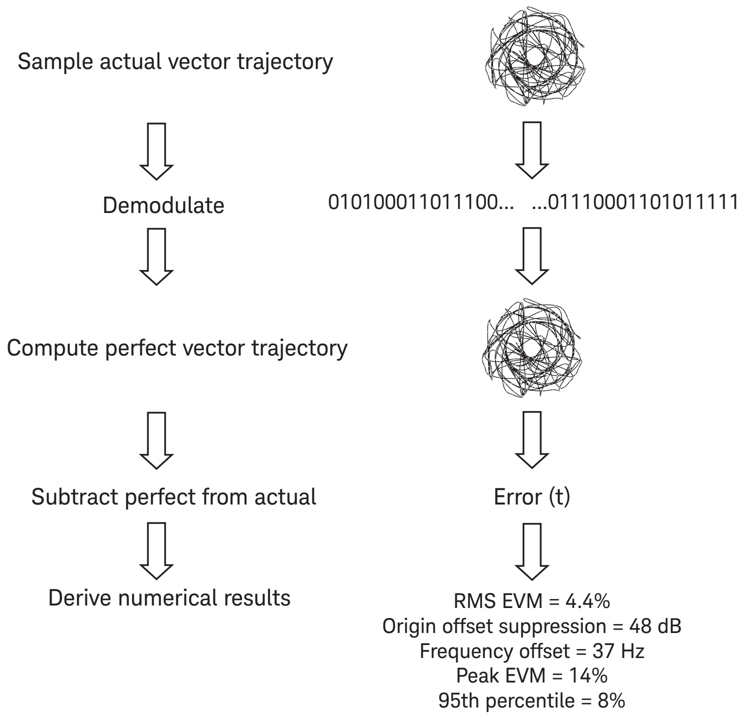


Figure 4. Theory of EVM, origin offset and frequency offset (8-PSK)

Error vector magnitude measurements are derived using a method similar to that of phase and frequency error measurements. Figure 4 shows how the measurement works. The test receiver or analyzer samples the transmitter output and captures the actual vector trajectory (both magnitude and phase information). This is then demodulated and the ideal vector trajectory is derived. Subtracting one from the other results in an error signal. The required statistical values are then calculated from this signal. EVM is expressed as a percentage of the nominal signal vector magnitude and RMS, peak and 95th percentile values are required. The 95th percentile is defined as the percent value that 95% of the EVM samples are below, and is, therefore, always larger than the RMS value and smaller than peak.

Origin offset is also derived as part of the modulation accuracy measurement. This is a measure of the DC offset in the I and Q paths of the transmitter and is expressed in dB (as a ratio of nominal signal vector magnitude). Frequency error is also derived from this measurement.

Graphical view of limits and specifications: GMSK

The ETSI 3GPP specifications define test limits for base transceiver stations. Phase and frequency error measurements should be performed over multiple bursts, and on multiple channels. Actual transmitter performance will vary with frequency.

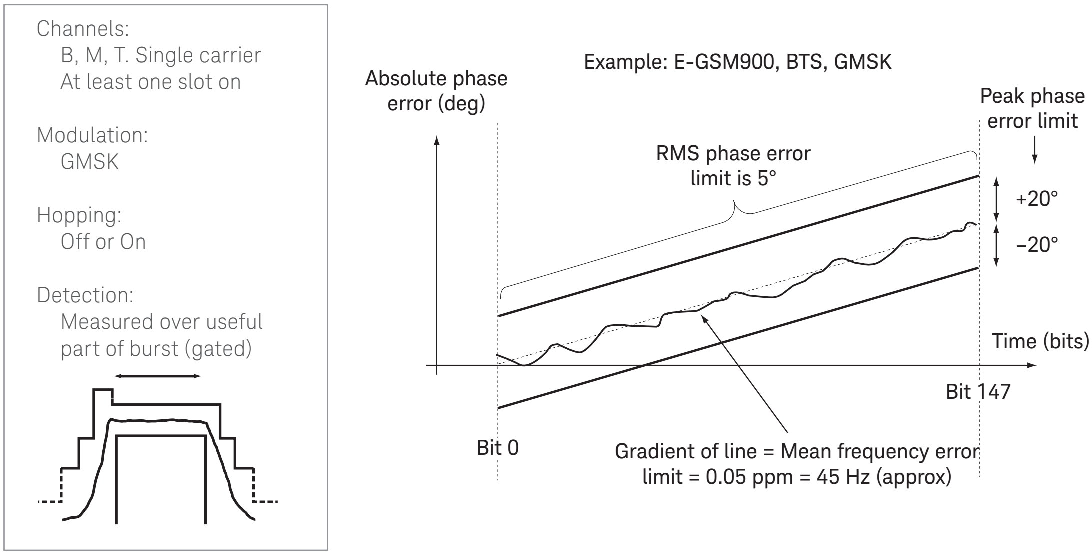


Figure 5. Phase error and mean frequency error, BTS, limits

It is worth noting that for frequency error the pass/fail limit is expressed in terms of ppm (parts per million) and applies across all frequency bands. The phase error limits are also common across all bands.

Graphical view of limits and specifications: 8-PSK

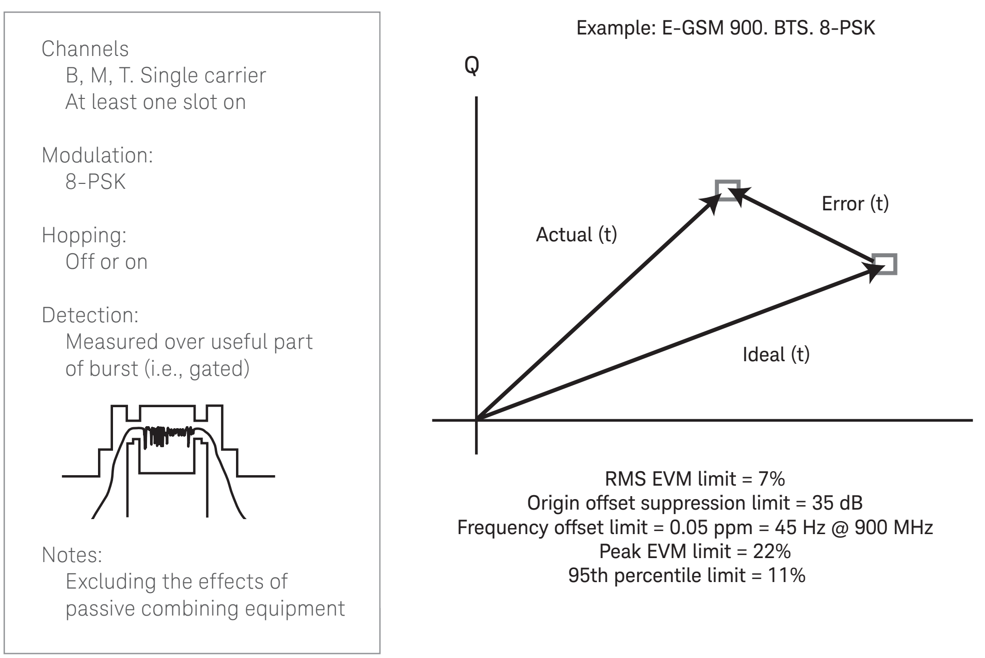


Figure 6. EVM, origin offset and frequency offset, BTS, limits

As with phase and frequency error measurements (GMSK), EVM, origin offset and frequency offset measurements (8-PSK) should be performed over multiple bursts and on multiple channels. All related pass/fail limits are common across all bands.

Practical measurements: GMSK

As mentioned, modern test equipment performs the necessary signal processing automatically, making these measurements straightforward and fast. It is also useful to view phase error versus time—especially in R&D and when fault finding. For example, a phase and frequency error test might fail the prescribed limits at only one point in the burst — at the beginning. This could indicate a problem with the transmitter power ramp or some undesirable interaction between the modulator and power amplifier.

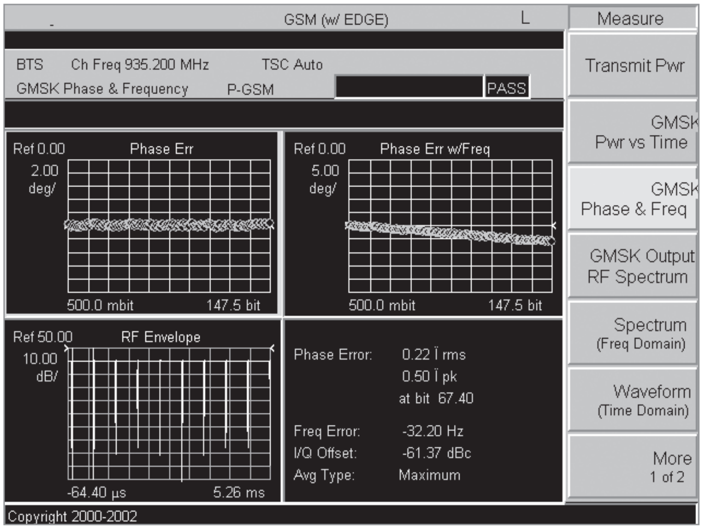


Figure 7. Quad display of the Keysight E4440A PSA series spectrum analyzer showing GMSK modulation metrics graphics of phase error with and without frequency error

Constellation diagrams can also be used to observe some aspects of modulation accuracy and can reveal certain fault mechanisms such as I/Q amplitude imbalance or quadrature imbalance.

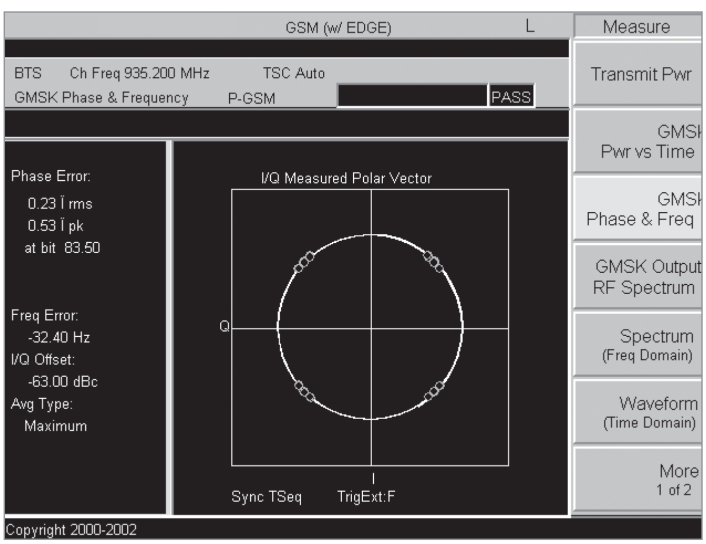


Figure 8. Constellation diagram on the Keysight E4440A PSA series spectrum analyzer showing GMSK modulation

Practical measurements: 8-PSK

Modern test equipment reports all of the necessary parameters to test modulation accuracy on 8-PSK signals and sometimes provides various views and additional parameters to assist troubleshooting. It can be especially useful to separate phase and magnitude errors (both contributors to overall EVM). For example, a poor EVM due to poor magnitude accuracy suggests a compression problem (something that is also possible to test for when making power measurements).

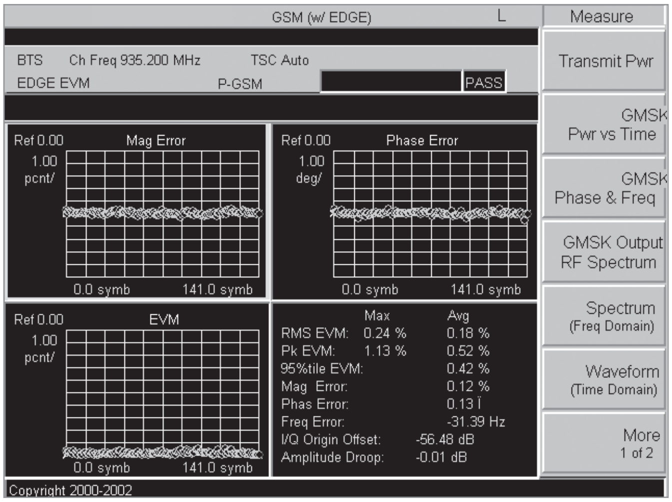


Figure 9. Quad display of the Keysight E4440A PSA series spectrum analyzer showing EDGE modulation metrics and separate magnitude and phase error

Take special care when using EDGE constellation diagrams. Due to the filtering method used in EDGE, the signal has a great deal of inherent inter-symbol interference. This means the signal does not (and isn't intended to) pass close to the 8-PSK 'targets'. It is hard to gain information from a raw IQ plot of an EDGE signal and it is now standard practice to plot and view EDGE signals on a 'virtual' IQ plot where the error vectors at the symbol decision points are plotted from the traditional 16-PSK 'targets' (there are 16 rather than eight due to the 3PI/8 rotation in EDGE modulation). This is a useful way of viewing this signal. Problems such as excess noise or interfering spurs can be observed using this method. Due to the 3PI/8 rotation in EDGE, the filter used, as well as the plotting method used, it is not possible to assess the signal’s proximity to symbol decision thresholds as easily as with other modulation schemes.

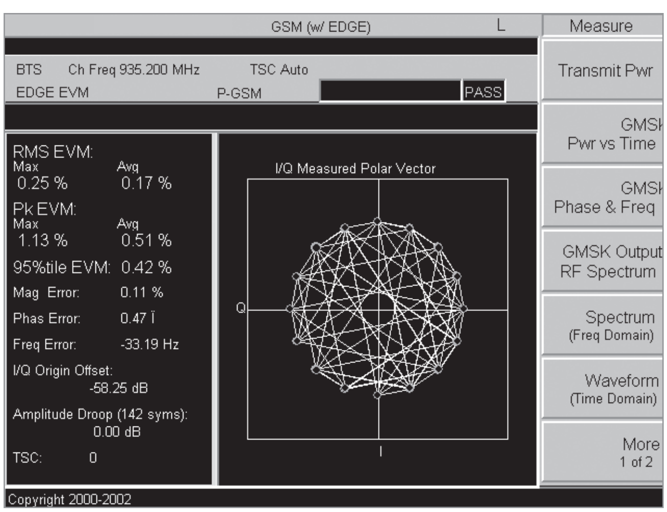


Figure 10. Constellation diagram on the Keysight E4440A PSA series spectrum analyzer showing EDGE/8-PSK modulation

When to use the measurement

Phase and frequency error measurements (GMSK) and EVM, origin offset and frequency offset measurements (8-PSK) can caputre a large spread of fault types. They are also the fundamental method for verifying I/Q calibration processes, if used, are working. These measurements are typically used at every stage in the BTS lifecycle. Modern test equipment can make these measurements quickly and accurately. (Typically, the test equipment should be 10x more accurate than the specification limit so measurement results can be attributed to the device under test and not the test system.)

Mean transmitted RF carrier power

Purpose of measurement—what it proves

Output power is a fundamental transmitter characteristic and is linked directly to range. GSM/EDGE systems use dynamic power control to ensure that each link is maintained sufficiently with a minimum of power. This gives two fundamental benefits: overall system interference is kept to a minimum and, in the case of mobile stations, battery life is maximized.

Therefore, output power is controlled within tight limits. If a transmitter produces too little power, link performance is compromised; too much, and interference to others might be too high and battery life too short.

Common practical transmitter implementations require output power calibration in manufacturing to meet the GSM/EDGE specifications (this allows low-cost components to be used). This calibration process involves the construction of a table of calibration factors for power steps and frequency. Power calibration corrects for the effects of component variation.

Out-of-specification power measurements indicate a fault, usually in the power amplifier circuitry or the calibration tables. They can also provide early indication of a fault with the power supply.

Theory in pictures

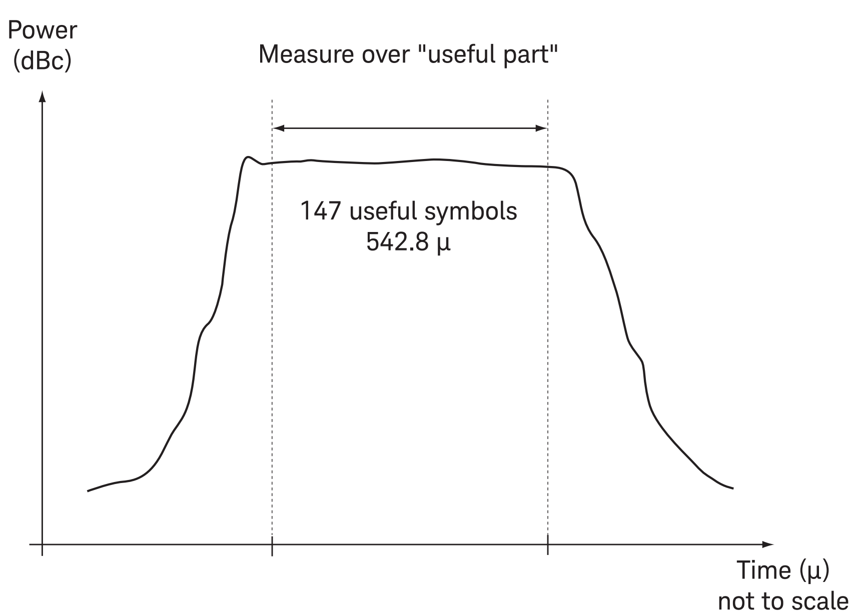


Figure 11. Theory of mean transmitted RF carrier power

Conceptually, the mean power measurement in GSM/EDGE is straightforward. It is defined as the mean power during the useful part of the GSM burst. The ETSI 3GPP specifications define that in type approval (at least) test equipment must be capable of deriving the correct timing reference by demodulating the incoming signal, and gating over the useful part only.

Most base transceiver stations implement dynamic power control. This makes it necessary to make multiple power measurements at several power levels and several frequencies in order to test for proper operation.

Graphical view of limitations and specifications

The ETSI 3GPP specifications define power limits both in terms of absolute accuracy and relative accuracy (between power levels or 'steps').

The examples given in Figure 12 are for transmitters of a specific type and class. Absolute limits depend on the type and class of the device under test.

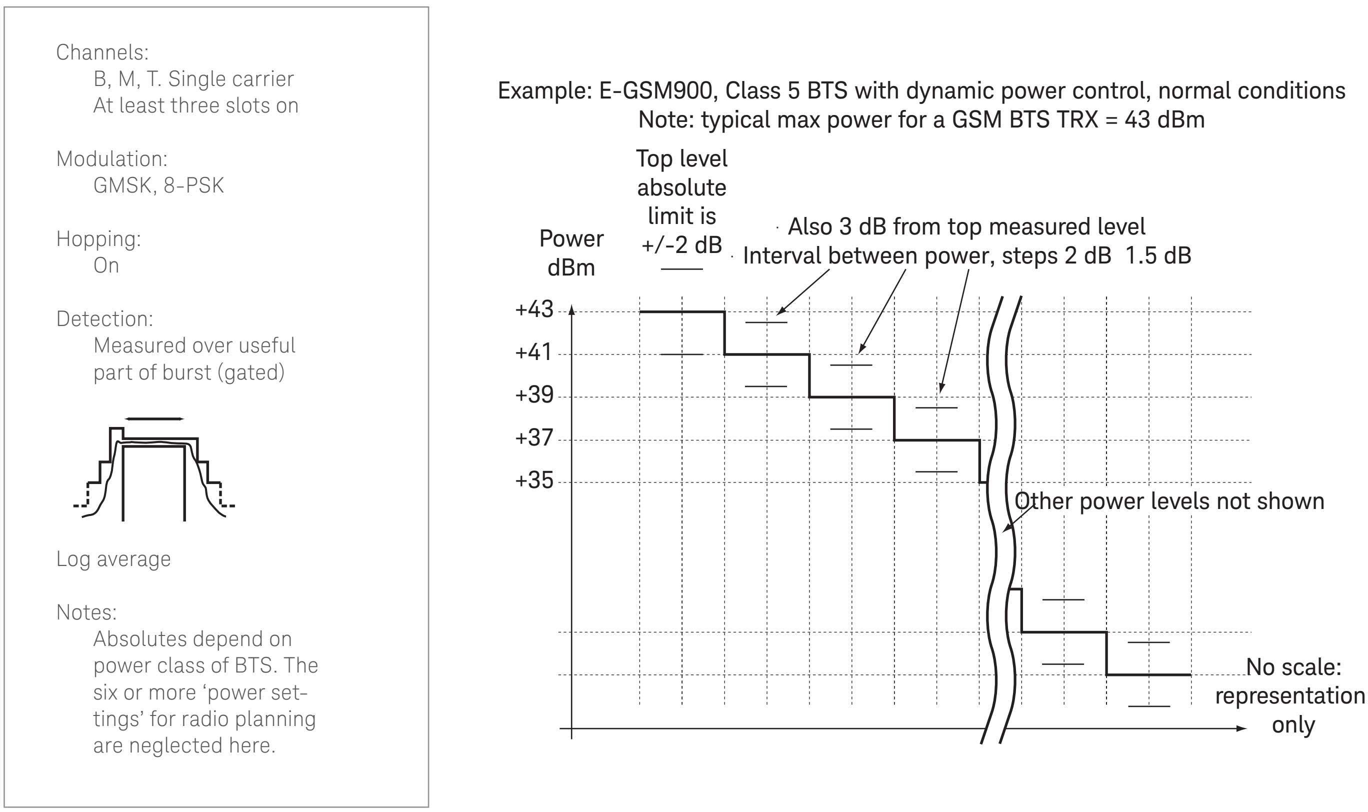


Figure 12. Mean transmitted RF carrier power, BTS, limits

Practical measurements

In practice, many types of test equipment can be used to make power measurements in GSM/EDGE systems. Accuracy, linearity and repeatability are key here and the perfomance required from test equipment depends on the application.

It is possible to make power measurements on GSM/EDGE signals by triggering off the rising edge of a burst (or an external clock signal if one is available) instead of the prescribed symbol 13/symbol 14 transition. This method will result in slightly increased levels of uncertainty and special care should be taken when measuring 8-PSK bursts. The amplitude changes inherent in 8-PSK modulation can cause false triggering and erroneous results.

It is also possible to use either a peak or thermal power sensor with a conventional meter. Both sensor types should be used with care. Peak power sensors will capture the overshoot at the top of the burst's ramp up and give incorrect readings. Thermal sensors will give results that are largely affected by the burst shape differences from one transmitter to the next.

Some modern test equipment, suitable for GSM/EDGE R&D, manufacturing and installation and maintenance can make this measurement as defined in the ETSI 3GPP specifications by demodulating and gating.

Note: power measurements are extremely vulnerable to mismatch. If the transmitter output to test equipment input is not matched properly, and some energy is reflected back into the transmitter, the test equipment will give a low power reading.

When to use the measurement

Power measurements are normally performed in every phase of the BTS lifecycle. Accuracy, linearity and repeatability requirements typically are more stringent in R&D than in installation and maintenance.

In manufacturing, where power calibration is required, measurement speed is a significant factor. To fully calibrate and characterize, for example, a GSM/EDGE BTS transceiver in manufacturing might require hundreds of measurements.

Transmitted RF carrier power versus time

Purpose of measurement—what it proves

This measurement assesses the envelope of carrier power in the time domain against a prescribed mask. In GSM/EDGE systems transmitters must ramp power up and down within the time division multiple access (TDMA) structure to prevent adjacent timeslot interference. If transmitters turn on too slowly, data at the beginning of the burst might be lost, degrading link quality, and if they turn off too slowly the user of the next timeslot in the TDMA frame will experience interference. This measurement also checks that the transmitters' turn off is complete.

If a transmitter fails the "transmitted RF carrier power versus time" measurement, this usually indicates a problem with the unit's output amplifier or leveling loop.

This measurement does not test to see if the transmitter ramps power too quickly, which has the effect of spreading energy across the spectrum andcausing interference. The "spectrum due to switching" measurement can be used to test for this effect.

Theory in pictures

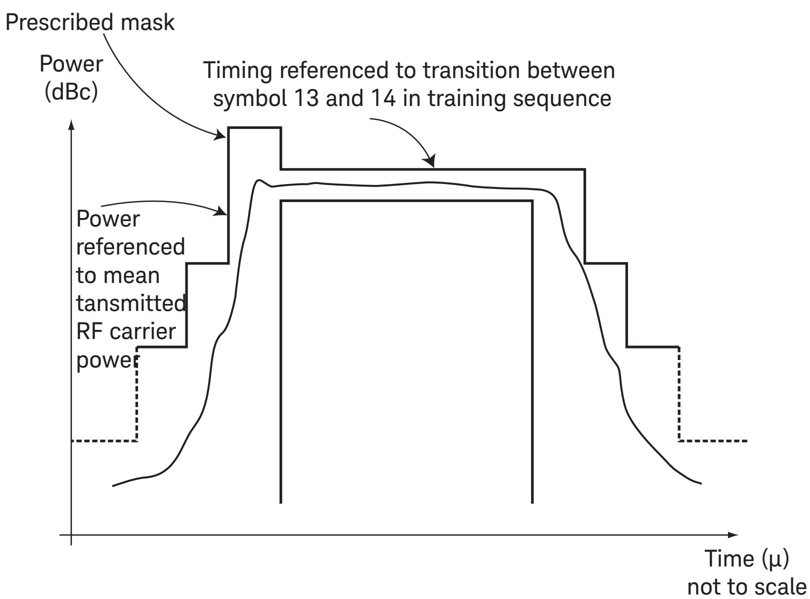


Figure 13. Theory of transmitted RF carrier power versus time

The measurement of transmitted RF carrier power versus time is made using an analyzer in zero-span mode. The pass/fail mask is placed over the measured trace and referenced in two ways. Horizontally (time axis), the measurement is referenced from the transition between symbols 13 and 14 of the training sequence. Therefore, as with mean transmitted RF carrier power, it is necessary for the test equipment to demodulate to make this measurement correctly. Vertically (power axis), the measurement is referenced against the measurement of mean transmitted RF carrier power.

Graphical view of limitations and specifications

Channels:
B, M, T. Single carrier
At least one slot on

Modulation:
GMSK

Hopping:
On

RBW:
→300 kHz

Detection:
Zero span

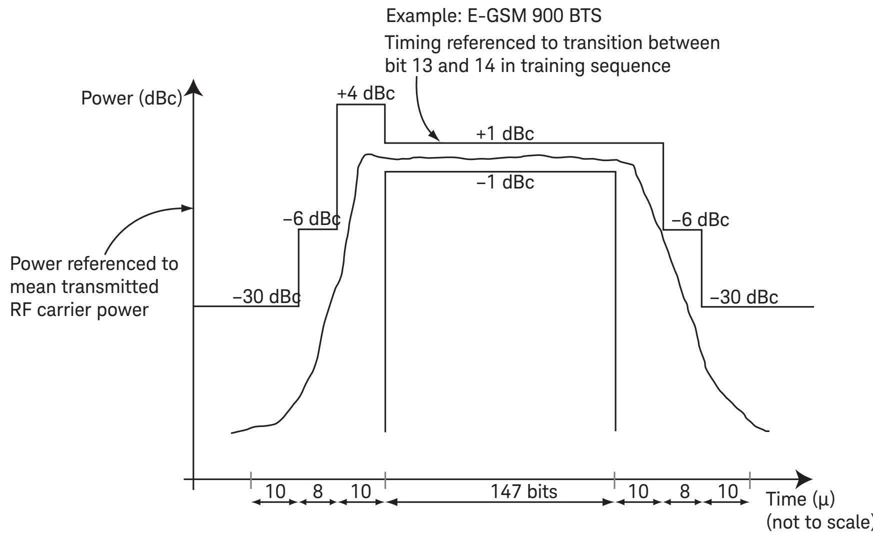


Figure 14. GMSK transmitted RF carrier power versus time, BTS, limits, GMSK

As shown in Figure 14, the limit lines for BTS are dependent on a number of factors, the most fundamental being the output power level of the transmitter. The absolute limit values are also dependent on band.

Channels:
B, M, T. Single carrier
One slot on

Modulation:

8-PSK

Hopping:
On

RBW:
→300 kHz

Detection:
Zero span
Average

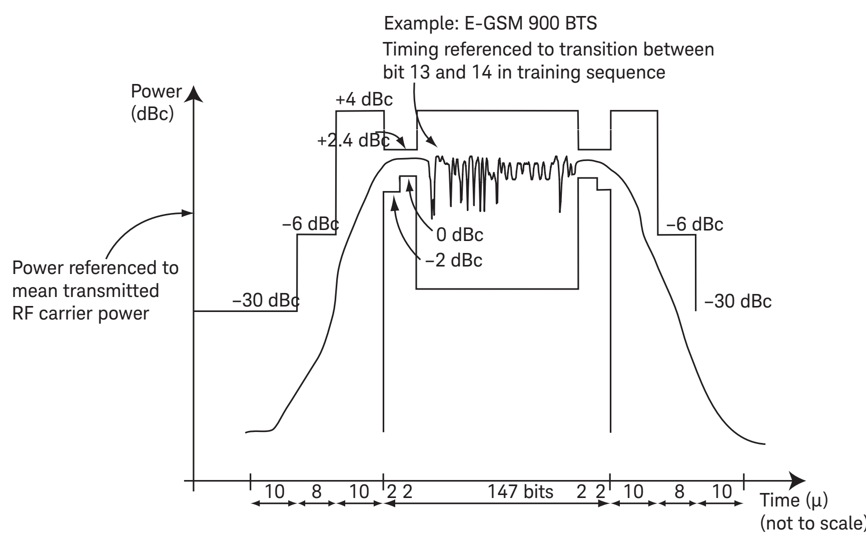


Figure 15. Transmitted RF carrier power versus time, BTS, limits: 8-PSK

Practical measurements

In practice, most power-versus-time failures occur either towards the top of the rising edge or falling edge. However, it is also important at most points in the BTS lifecycle to ensure that the turn on/turn off ratio is sufficient. For this measurement the analyzer used must have adequate dynamic range.

For the purposes of adjustment, it is extremely useful to view power versus time in real time against the prescribed mask because many GSM transmitters have multistage turn on/turn off circuits which require calibration.

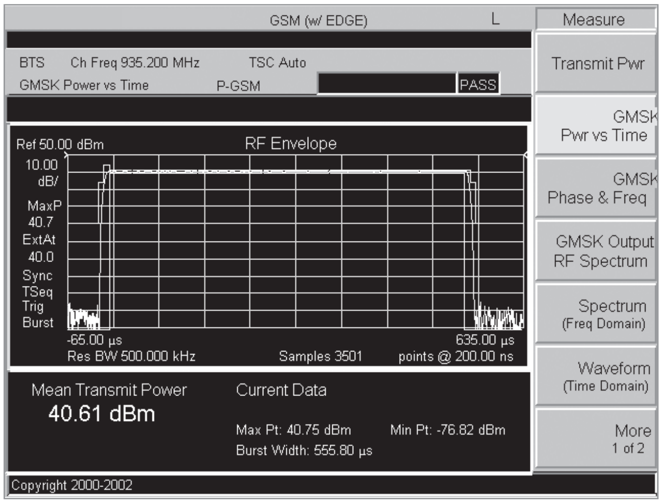


Figure 16. Power versus time on the Keysight E4440A PSA series spectrum analyzer. GMSK

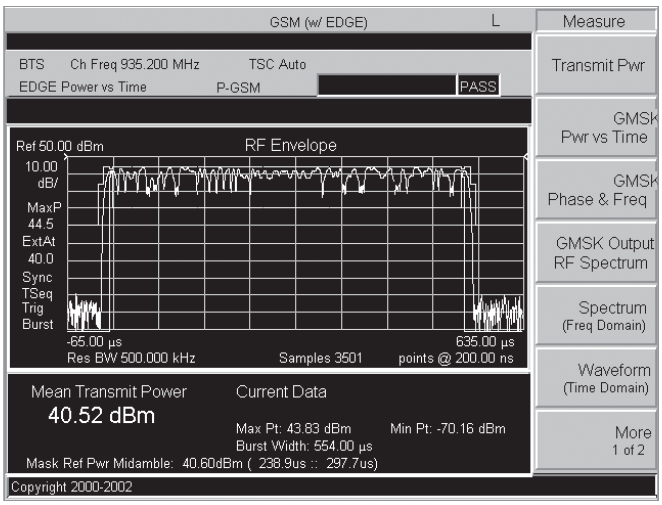


Figure 17. Power versus time on the Keysight E4440A PSA series spectrum analyzer. 8-PSK

When to use the measurement

From R&D through to installation, maintenance, and service, power-versus-time measurements are used universally in GSM/EDGE applications to check the functioning of transmitters.

Adjacent channel power

Adjacent channel power in GSM / EDGE is defined by the 3GPP as two measurements: spectrum due to modulation and wideband noise, and spectrum due to switching.

Spectrum due to modulation and wideband noise

Purpose of measurement—what it proves

This measurement and the next "spectrum due to switching," are often grouped together and called "output RF spectrum" (ORFS).

The modulation process in a transmitter causes the continuous wave (CW) carrier to spread spectrally. The "spectrum due to modulation and wideband noise" measurement is used to ensure that modulation process does not cause excessive spectral spread. If it did, other users who are operating on different frequencies would experience interference. The measurement of spectum due to modulation and wideband noise can be thought of as an adjacent channel power (ACP) measurement although several adjacent channels are tested.

This measurement, along with the phase error measurement, can reveal numerous faults in the transmit chain, for example, faults in the I/Q baseband generator, filters and modulator.

As defined, the measurement also checks for wideband noise from the transmitter. The specification requires the entire transmit band to be tested. Again, if the transmitter produces excessive wideband noise, other users will experience interference.

Theory in pictures

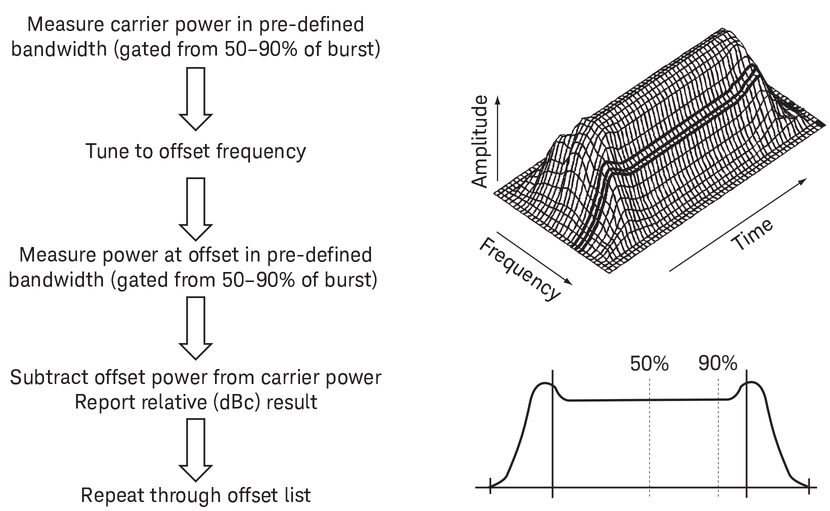


Figure 18. Theory of spectrum due to modulation and wideband noise

The measurement is defined and designed as follows. The analyzer is tuned to a spot frequency and then time-gated across part of the modulated burst. Power is then measured using this mode and then the analyzer is re-tuned to the next frequency, or offset of interest. This process continues until all offsets are measured and checked against permissible limits. What results is the "spectrum" of the signal, however, spectral components that result from the effect of bursting do not appear because the ramps are gated out.

Note: the result of the measurement is a set of frequency/power points, this is not a swept measurement (with the exception of offsets beyond 1800 kHz in the BTS case).

The test limits are mostly expressed in relative terms (dBc) so the first step of the measurement is to take a reading at the center frequency to which the transmitter is tuned. Because this measurement is gated and a different bandwidth is used, this reading will not be the same as the mean transmitted RF carrier power measurement. In practice the latter is approximately 8 dB higher but this does depend on the spectral shape of the signal.

Graphical view of limits and specifications

As with other measurements, the actual limits depend on many factors: class, type, system and power level. Figure 19 gives example limits for EGSM900 MS and normal BTS at high power.

Channels:
B, M, T. Signal carrier

Modulation:
GMSK, 8-PSK

Hopping:
Off

RBW:
30 kHz and 100 kHz

VBW:
=RBW

Detection:
Gated over 50%–90% of burst
Zero span (≤ 1800 kHz offsets)
Average

Filter:
5-pole sync tuned

Notes:
For low O/P power levels further conditions apply (limits are less demanding).
Limits are identical for GMSK and 8-PSK, except for the 400 kHz offset.

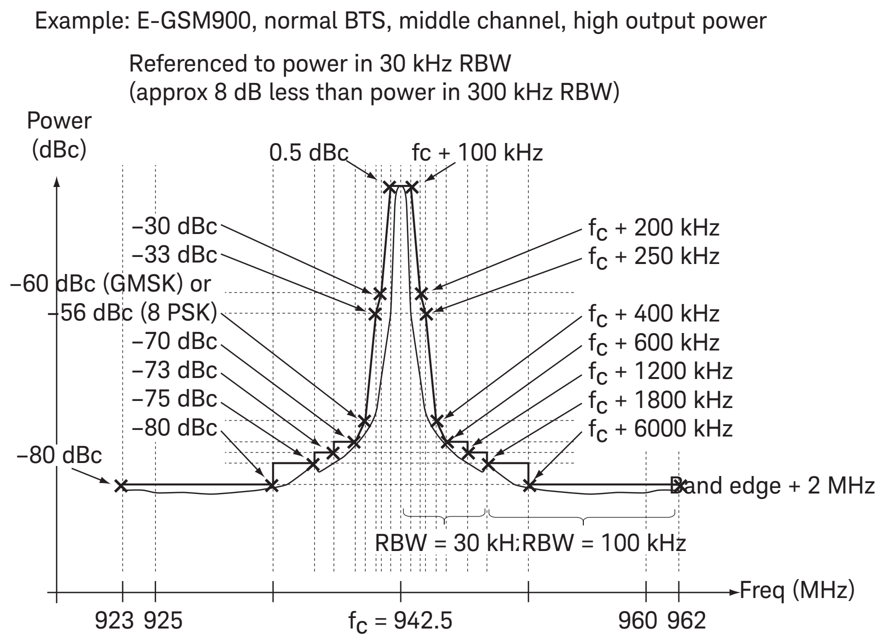


Figure 19. Spectrum due to modulation and wideband noise, normal BTS, limits

Practical measurements

Spectrum due to modulation and wideband noise measurements are both difficult and time consuming if made precisely as the ETSI and ANSI type approval specifications require. It is normal to perform some subset of the defined measurement set in most applications for time and/or cost reasons.

At wide offsets such as 600 kHz and above, these measurements require high dynamic range—this has historically been expensive. They also require a large amount of processing power if they are to be done rapidly. In some applications the complete suite of spectrum due to modulation and wideband noise measurements are only performed on a sample basis.

Historically, standard spectrum analyzers have been used, and when provided with an appropriate gate signal this method works well. However, this time-consuming technique requires a series of separate measurements and frequent re-tuning. Both the E4440A PSA series spectrum analyzer and E4406A VSA series transmitter test incorporate two techniques for overcoming this problem.

First, with a wide bandwidth sampler, it is possible to perform many of the close-in measurements up to 600 kHz, using DSP techniques—essentially FFTs. This means that several measurements can be performed on the same sample set, which results in a significant speed improvement.

A further speed improvement can be achieved by measuring over a greater portion of the burst. The standards define that these measurements should be performed over the 50%–90% portion of the burst. However, for practical speed improvement, it is quite reasonable to measure over 10% to 90% portion of the burst.

Last, at wide offsets it is possible to pre-attenuate, or notch out the central part of the GSM/EDGE signal (in the frequency domain). This gives a significant dynamic range improvement.

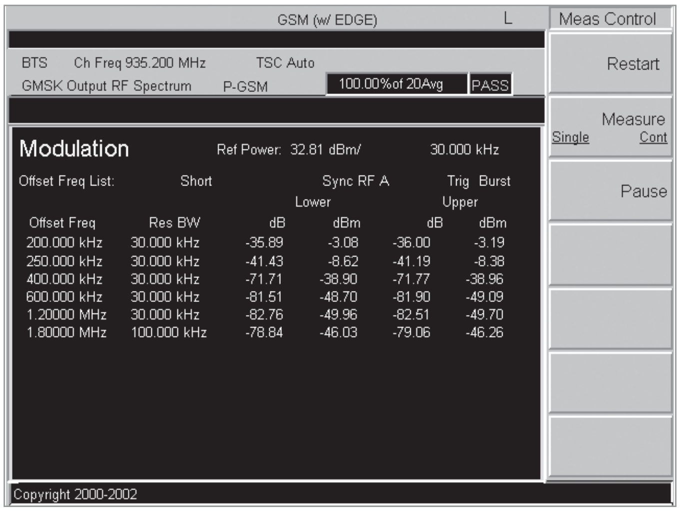


Figure 20. Spectrum due to modulation shown on the Keysight E4440A PSA series spectrum analyzer

When to use the measurement

This measurement is important because it defines how much a transmitter will interfere with other users. For this reason this measurement is commonly used in BTS R&D and manufacturing. Usually, due to time constraints, only a subset of the prescribed list of offsets is used. For example, in manufacturing, choosing an appropriate frequency offset list depends greatly on the transmitter design.

Spectrum due to switching

Purpose of measurement—what it proves

GSM/EDGE transmitters ramp RF power rapidly. The “transmitted RF carrier power versus time” measurement is used to ensure that this process happens at the correct times and happens fast enough. However, if RF power is ramped too quickly, undesirable spectral components exist in the transmission. This measurement is used to ensure that these components are below the acceptable level.

If a transmitter ramps power too quickly, users operating on different frequencies, especially those close to the channel of interest, will experience significant interference.

Failures with this measurement often point to faults in a transmitter’s output power amplifier or leveling loop.

Theory in pictures

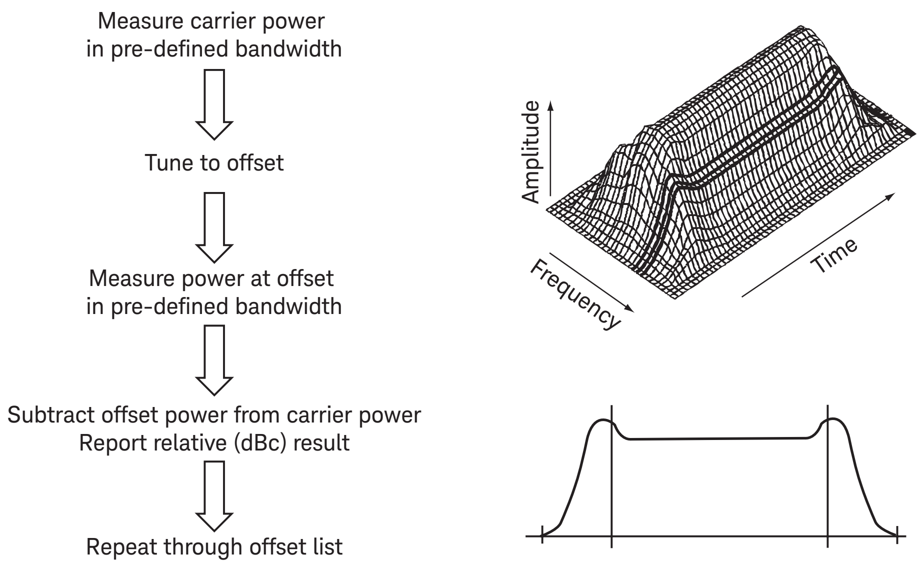


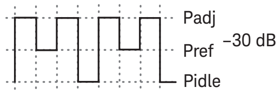
Figure 21. Theory of spectrum due to switching

Measurements of spectrum due to switching are performed in a similar fashion to the measurement of spectrum due to modulation and wideband noise. The analyzer is tuned to and measures at multiple offset frequencies in zero-span mode. In this case no time gating is used, so power from both the ramping and modulation processes affect the measurement. The effect of ramping dominates the spectrum due to switching measurements.

Again, the specifications are relative so the first step in the process is to establish a reference. This reference is once again not the same as “mean transmitted RF carrier power” in the way that it is measured (resolution bandwidth = 300 kHz).

Graphical view of limits and specifications

Channels and slots:
- B, M, T. Single carrier
- All slots on and alternate



Modulation:
- GMSK, 8-PSK

Hopping:
- Off and On (B, M, T)

RBW:
- 30 kHz

VBW:
- 100 kHz

Detection:
- Peak hold
- Zero span

Filter:
- 5-pole sync tuned

Notes:
- For low O/P power levels further conditions apply (limits are less demanding). Limits are identical for GMSK and 8-PSK.

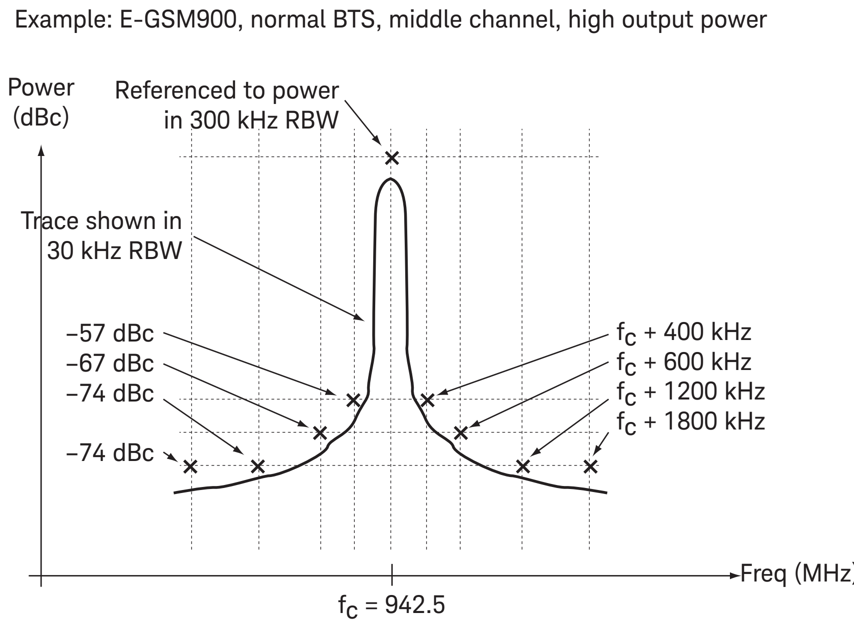


Figure 22. Spectrum due to switching, BTS, limits

As with other measurements the actual limits depend on many factors: class, type, system and power level. Figure 22 gives example limits for E-GSM900 normal BTS at high power.

Practical measurements

Spectrum due to switching measurements are less difficult and less demanding than spectrum due to modulation and wideband noise measurements. In practice, equipment that can perform the latter can easily manage the former.

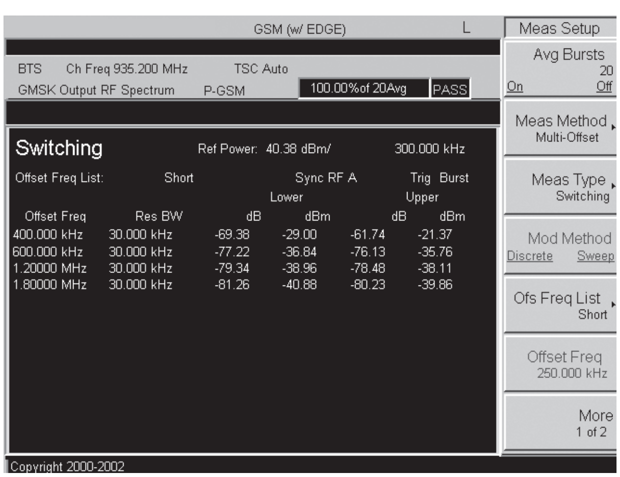


Figure 23. Spectrum due to switching shown on the Keysight E4440A PSA Series Spectrum Analyzer

When to use the measurement

Spectrum due to switching measurements are usually performed alongside spectrum due to modulation and wideband noise measurements.

Spurious

Purpose of measurements—what they prove

Spurious measurements are necessary in all radio communications systems, and in GSM they are extensive. For correct operation GSM transmitters must not put energy into the wrong parts of the spectrum. If they do, other users of the GSM system may experience interference and worse still, other users of the radio spectrum (for example, police, television, commercial radio, military and navigation) will experience degraded, or even jammed links.

Almost any fault in the transmitter circuits can manifest itself as spurious of one kind or another.

The spurious measurements discussed in this section are those defined as “conducted.” These specifications apply when the test instrumentation is connected directly to the device under test antennae connector. The ETSI and ANSI standards also defined a large number of measurements for “radiated” spurious. These are not covered in this note.

For the purposes of clarity, in terms of representing the specifications, this section is broken down as follows:

Tx and Rx band spurious	Spurious that affect the system of interest.
Cross-band spurious	Spurious that affect other GSM systems operating at different frequencies (e.g., GSM into DCS1800).
Out-of-band spurious	Wideband spurious that affects other users of the radio spectrum.

All of the spurious measurements are defined in ETSI 3GPP specifications as standard spectrum analyzer measurements, that is, a band is swept (with certain filter/speed settings) and a pass/fail limit applied.

Transmitter (Tx) and receiver (Rx) band spurious

Theory in pictures

Tx band spurious is a measurement set that checks that the transmitter does not put undesirable energy into the wrong parts of the Tx band (925–960 MHz for E-GSM). This measurement reveals little more than the switching due to modulation and wideband noise measurement, however, it is a swept measurement with no time gating.

The Rx band spurious measurement deserves special attention. This is a measure of how much energy the transmitter puts into the Rx band (880–915 MHz for E-GSM) and the specification is extremely stringent. The reasons for this are clear: potentially spuri-ous from the transmitter can “jam” or “deafen” the receiver, making the system useless. The Rx band spurious measurement deserves a special explanation. See Figure 24.

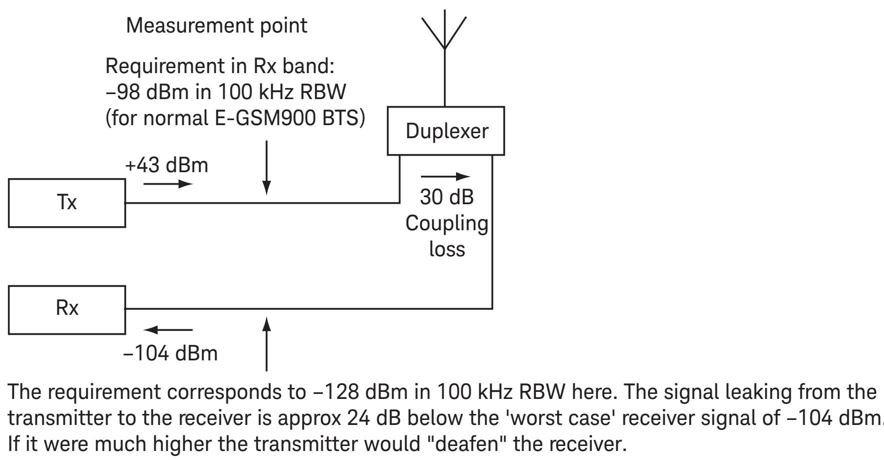


Figure 24. Theory of Rx band spurious

Graphical view of limits and specifications

Channels and slots:
- B, M, T.
- Signal carrier (Tx band)
- Multi-carrier (Rx band)
- All slots on

Modulation:
- GMSK or 8-PSK

Hopping:
- Off

RBW:
- 30 kHz and 100 kHz

VBW:
- 3 x RBW (for Tx band)
- 1 x RBW (for Rx band)

Detection:
- Peak
- Sweep

Notes:
- Limits are identical for GMSK and 8-PSK.

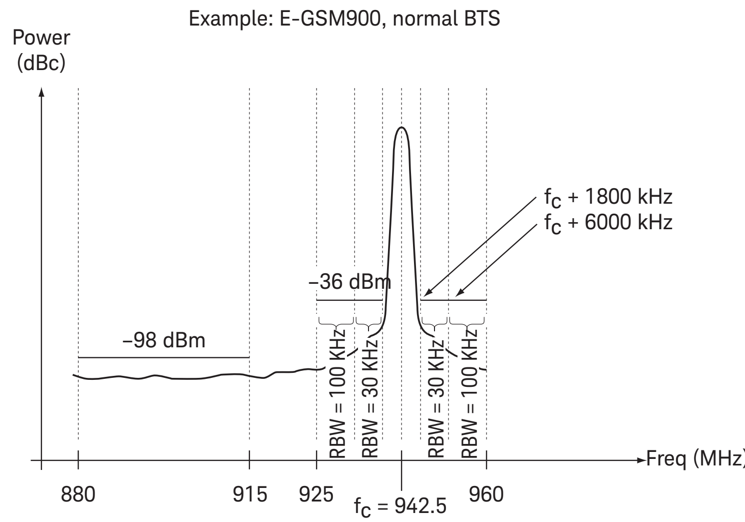


Figure 25. Tx and Rx band spurious, BTS, limits

Practical measurements

To date, no analyzer has sufficient dynamic range to measure Rx band spurious to the ETSI 3GPP specifications directly. Usually a Rx bandpass filter is used in front of the analyzer input to attenuate the Tx band signal.

As with all spurious measurements it is possible to speed up the process for BTS manufacturing by simply checking selected or “at risk” parts of the band. In other words, through design analysis and experimentation it is possible to determine at which frequencies the transmitter is most likely to fail. Test only at these frequencies to minimize test time.

When to use the measurement

The application of Tx band spurious measurements should be consideredalongside the application of spectrum due to modulation and wideband noise measurements because there is some redundancy here. It is reasonable, in manufacturing for example, to perform the spectrum due to modulation and wideband noise measurement only up to and including the 1800 kHz offset (±) and then apply the Tx band spurious measurement, if needed, to check the rest of the the Tx band.

As with spectrum due to modulation and wideband noise, Tx and Rx bandspurious measurements need not be comprehensively performed outside of R&D, verification and type approval. A limited subset of these measurements can be derived and used in manufacturing and the field service for cost and time reasons.

Cross-band spurious (for example, GSM900 into DCS1800)

In some countries GSM900 and DCS1800 systems exist together and in some cases base stations for both systems are co-sited. For this reason the ETSI 3GPP standards require specific cross-band performance. For example, GSM900 transmitters must put a minimum of energy into DCS1800 Tx and Rx bands and vice-versa. Also, in countries where GSM is required to co-exist with 3G, special conditions apply.

Graphical view of limits and specifications

Channels and slots:
- B, M, T

Modulation:
- GMSK, 8-PSK

Hopping:
- Off

RBW:
- 30 kHz and 100 kHz

VBW:
- =RBW

Detection:
- Peak
- Sweep

Note:
- Limits are identical for GMSK and 8-PSK.

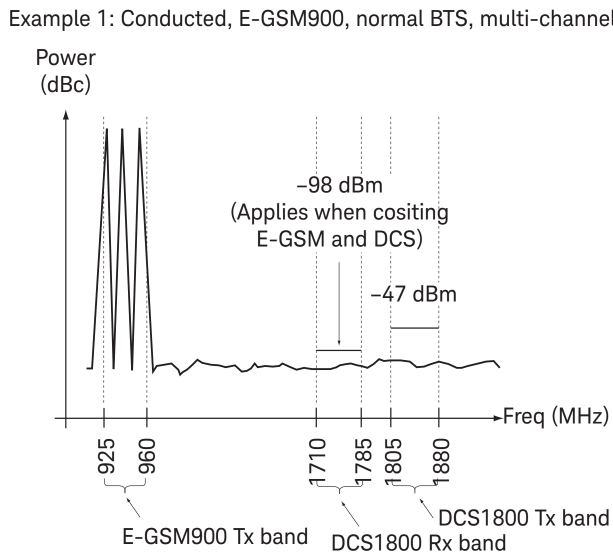


Figure 26. Cross-band spurious, GSM900 into DCS bands, BTS, limits

Channels and slots:
B, M, T

Modulation:
GMSK, 8-PSK

Hopping:
Off

RBW:
100 kHz

VBW:
= RBW

Detection:
Peak
Sweep

Note:
Limits are identical for GMSK and 8-PSK

Example 2: Conducted. E-GSM 900. Normal BTS. Multi-channel

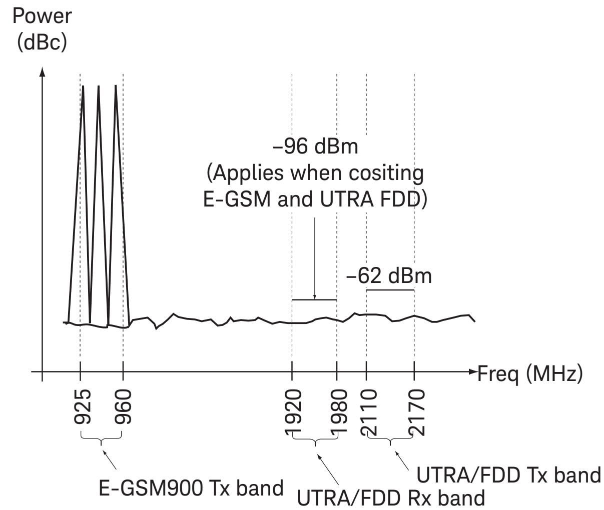


Figure 27. Cross band spurious. GSM900 into 3G bands, BTS, limits

Practical measurements

In practice cross-band spurious measurements are grouped with Tx and Rx band spurious measurements and the same techniques are used. The principles described in the explanation of theory in pictures and practical measurements in the spurious section apply.

When to use the measurement

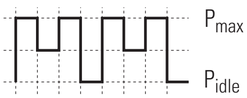
Applied as Tx and Rx band spurious.

Out-of-band spurious

The out-of-band spurious is a series of spectrum analyzer measurements over a large frequency range from 100 kHz through to 12.75 GHz (for GSM900). The settings for the measurement are seen in Figure 28.

Graphical view of limits and specifications

Channels and slots:
B, M, T. Multi-carrier



Modulation:
GMSK or 8-PSK

Hopping:
On

RBW:
As required

VBW:
3 x RBW. Max 3 MHz

Detection:
Peak
Sweep

Note:
Limits are identical for GMSK and 8-PSK.

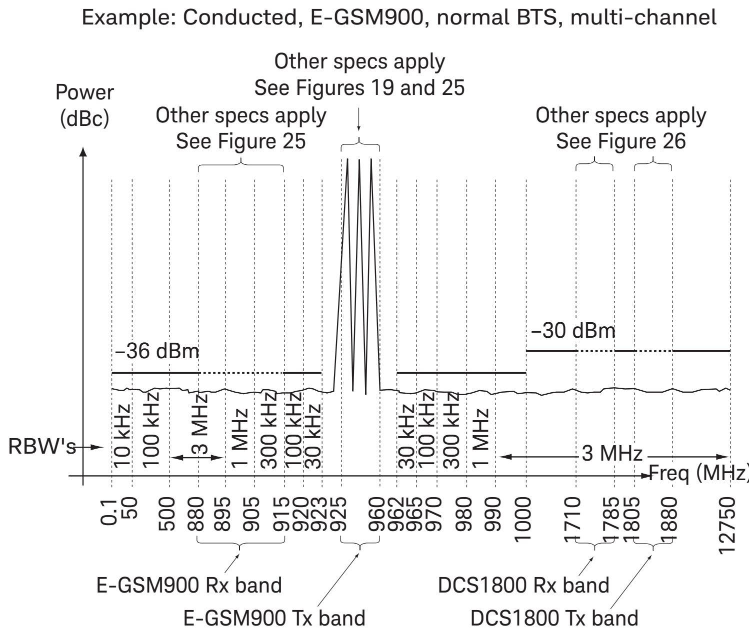


Figure 28. Wideband spurious, BTS, limits

Practical measurements

In practice, wideband spurious is in fact a series of tests and although thorough, these take some time. Some test equipment automates the process making the measurement straight forward.

When to use the measurement

Wideband spurious measurements are rarely performed in manufacturing, installation, maintenance or service, however, selected spurious measurements can be made quickly and easily. For example, transmitters are “at risk” at harmonic frequences. These can be checked easily in manufacturing without a significant time penalty.

GSM/EDGE BTS Receiver Measurements

Static reference sensitivity level

Purpose of measurement – what it proves

Sensitivity is the fundamental measure of receiver performance. This measurement reveals if a receiver is able to acquire a low level signal and correctly demodulate and decode it. Gross failures (i.e. very high bit error rates) indicate a fundamental problem in the receivers locking and synchronization hardware or a serious baseband problem. More marginal failures may result from poor signal conditioning in the receiver chain or self-interference (i.e. the receiver is being de-sensitized by an interferer generated within the BTS such as a clock signal).

Ultimately poor sensitivity equates to poor range experienced by the user.

The ETSI 3GPP standards do not specify maximum sensitivity. Indeed, it is highly desirable to have a much better sensitivity than the minimum allowed. This will result in a better user experience, especially in hostile environments.

Theory in pictures

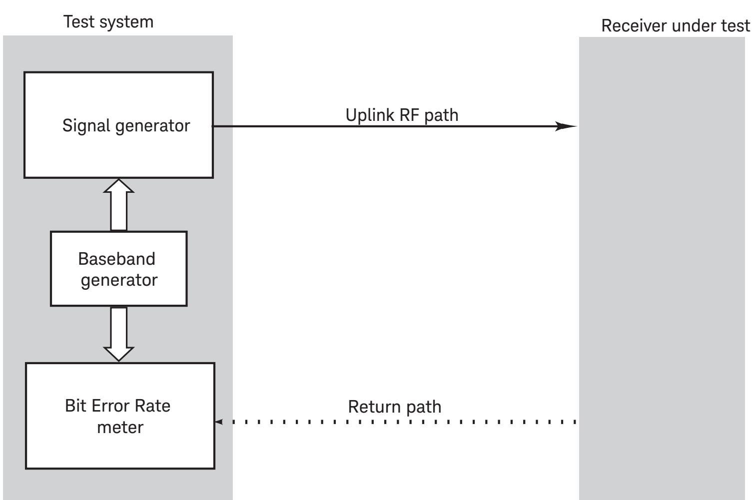


Figure 29. Theory of bit error rate

The reported value for all receiver measurements is BER (bit error rate) or a variation there of (i.e., FER (frame erasure rate) or BLER (block error rate). BER is a ratio of bits received erroneously versus total number of bits received and is measured as follows. The test system outputs a signal carrying a known bit pattern (usually a channelized PRBS). The receiver under test then attempts to demodulate and decode this pattern and via a return path sends the resultant bits back to the test system for comparison. The test system then calculates the necessary metrics. The metrics used depend on the logical channel type under test. For example: for TCH/FS it is necessary to test class II and class Ib RBER, as well as FER.

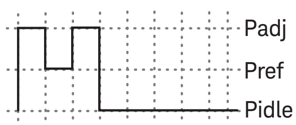
Note: The 'return path' can be realized using various methods. No single method is prescribed by the ETSI 3GPP standard. The most common method used is 'loopback'; where the device under test re-transmits the data it receives. This technique depends on a high integrity downlink (i.e. the return path must not introduce additional errors). Usually the device under test is commanded to loopback through a proprietary control program. It is worth noting that GSM / EDGE devices can typically loopback at various points in the receive / transmit chain. It is essential to loop at the appropriate point.

To perform a measurement, the RF level of the signal used to stimulate the receiver under test is set at the specified reference sensivity level (e.g. -104dBm) and the BER metrics are compared to limits.

Graphical view of limits and specifications

The ETSI 3GPP specifications for BER (and derivatives) are extensive in that they describe performance for every logical channel. For many application areas it is only necessary to test 'fundamental' performance (i.e. receiver performance on one logical channel). The basic channel types are listed below only.

Channels
B, M, T. Single carrier



Padj 50 dB higher than
Pref. TS1 shown tested

Modulation:
GMSK and 8-PSK

Hopping:
Off or on

Example: E-GSM900, BTS

Modulation	Channel type	Error parameter	Limit value	Static reference sensitivity level
GMSK	TCH/FS	FER	0.1%	-104 dBm
	- class Ib	RBER	0.4%	-104 dBm
	- class II	RBER	2.0%	-104 dBm
	PDTCH/CS-1	BLER	10%	-104 dBM
	PDTCH/CS-4	BLER	10%	-101 dBM
	PDTCH/MCS-1	BLER	10%	-104 dBM
8-PSK	E-TCH/F43.2	BLER	10%	-97 dBm
	PDTCH/MCS-5	BLER	10%	-101 dBm
	PDTCH/MCS-9	BLER	10%	-91.5 dBm

Table 3. Static reference sensitivity level, BTS, limits

Practical measurements

It is essential to establish synchronization between the device and the test system before starting a BER measurement. In an operational environment a BTS is the 'master' clock and the MS is required to synchronize to it. Similarly in a test environment, the test system must synchronize to the device under test. This is achieved by using one of two methods: BCCH (broadcast control channel) synchronization or synchronization through an external trigger signal. To achieve BCCH synchronization, the device under test (the BTS or BTS transceiver) is required to first transmit a BCCH. Once the test equipment gains lock the BTS can then be commanded to the logical channel desired (e,g, TCH/FS). The second synchronization method requires a frame trigger signal (TTL) from the device under test to the test system. This method can be easier and quicker but requires such a signal to be available.

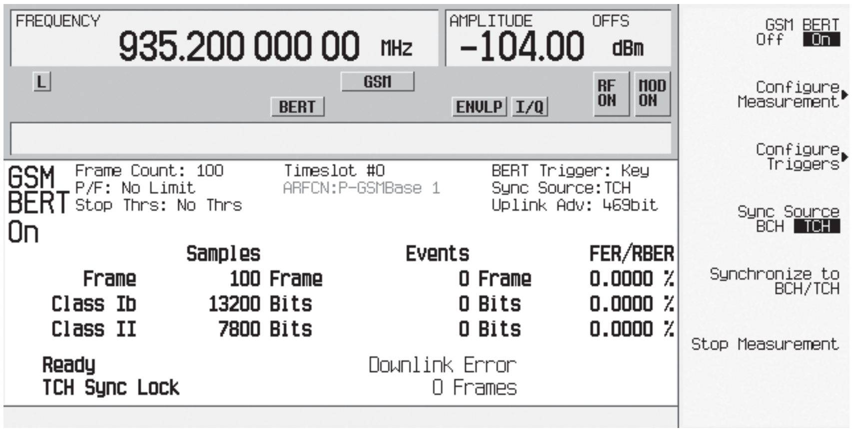


Figure 30. Reference sensitivity level on the E4438C ESG vector signal generator

Although the ETSI 3GPP specifications do not require this, it is often useful to measure 'absolute' sensitivity. i.e. to establish the RF level at which the receiver reports the maximum tolerable error rate (for a particular logical channel). This allows a margin in terms of level (dB) to be established. Some modern test equipment have search capabilities to automatically determine absolute sensitivity.

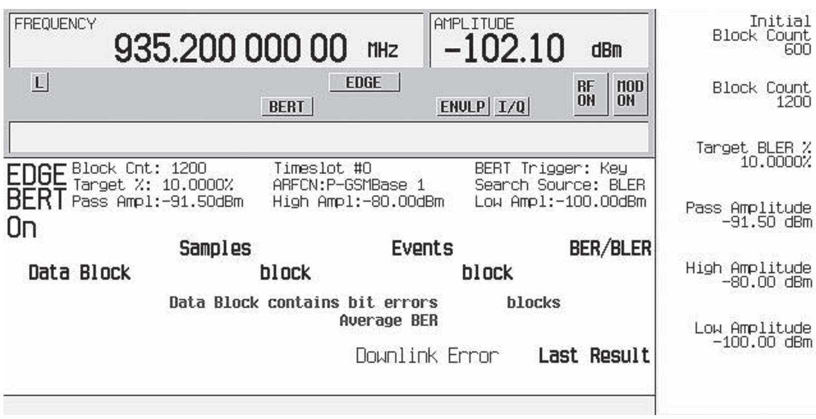


Figure 31. Absolute sensitivity level on the E4438C ESG vector signal generator

When to use the measurement

Sensitivity measurements are necessary at every stage in the BTS lifecycle. In R&D and type approval it is necessary to test a wide range of logical channels which can be extremely time consuming and laborious. In manufacturing the test list described in this paper is generally sufficient. In installation and maintenance it is sometimes sufficient to use RXLEV & RXQUAL reports to gain and indication of sensitivity. These are reports that the BTS derives itself using the data protection and correction techniques inherent in GSM / EDGE channel coding.

Choosing Transmitter and Receiver Measurements for an Application

The following table is given for guidance only and the actual measurement set used in any one application is dependent on a number of factors (for example, transmitter design, integration level, or calibration requirements).

BTS Lifecycle Phase	*Phase error and mean frequency error (GMSK) EVM, origin offset and frequency offset (8-PSK)*	*Mean transmitted RF carrier power*	*Transmitted RF carrier power versus time*	*Spectrum due to modulation and wideband noise*	*Spectrum due to switching*	*Tx and Rx band spurious*	*Cross-band spurious*	*Wide band spurious*	*Other transmitter measurements (not described in this application note)*	*Static reference sensitivity level*	*Other receiver measurements (not described in this application note)*
R&D	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Verification	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type approval	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Module test	Yes	Yes	Yes	Most	Most	Some	Some	Few	No	Yes	No
Final test	Yes	Yes	Yes	Most	Most	Some	Some	Few	No	Yes	No
QA test	Yes	Yes	Yes	Yes	Yes	Most	Most	Some	Some	Yes	Some
Installation	Yes	Yes	Yes	Most	Most	Some	Some	Few	Some	Yes	No
Maintenance	Yes	Yes	Yes	Some	Some	Some	No	No	Some	Yes	No
Depot repair	Yes	Yes	Yes	Most	Most	Some	Some	Few	Some	Yes	No

Table 4. BTS measurements by application/lifecycle phase

Summary

This application note explains and describes the key transmitter and receiver measurements required for testing GSM/EDGE. The ETSI 3GPP test specifications have been created for type approval purposes and are therefore extensive. However, at any stage of the BTS lifecycle it is sensible to use these standards as a starting point. It is essential to optimize the test suite for any one application and balance test coverage, cost, speed and test system flexibility. This application note should assist that process, as well as provide a useful reference. Modern test equipment is often designed for one or a few select applications.

References

1. 3GPP TS 05.05 V8.12.0. Radio Access Network; Radio transmission and reception (Release 1999).
2. 3GPP TS 11.21 V8.6.0. Base Station System (BSS) equipment specification; Radio aspects (Release 1999).
3. GSM Basics. Hewlett Packard Symposium. 1994.
4. Measuring EDGE Signals - New and Modified Techniques and Measurement Requirements. Application Note: 1361. Publication Number 5980-2508EN. October 2000.
5. Keysight PSA Series Spectrum Analyzers GSM with EDGE Measurement Personality. Publication Number 5988-2389E. May 2002.
6. Keysight GSM / EDGE Self-Guided Demonstration for the E4438C ESG Vector Signal Generator and the PSA Series Spectrum Analyzer. Publication Number 5988-4948EN. March 2002.
7. PSA Manuals. GSM with EDGE Guide. Part Number E4440-90115.
8. ESG Manuals. Users Guide. Part Number E4400-90503.

myKeysight

www.keysight.com/find/mykeysight
A personalized view into the information most relevant to you.

www.axiestandard.org
AdvancedTCA® Extensions for Instrumentation and Test (AXIe) is an open standard that extends the AdvancedTCA for general purpose and semiconductor test. Keysight is a founding member of the AXIe consortium. ATCA®, AdvancedTCA®, and the ATCA logo are registered US trademarks of the PCI Industrial Computer Manufacturers Group.

www.lxistandard.org
LAN eXtensions for Instruments puts the power of Ethernet and the Web inside your test systems. Keysight is a founding member of the LXI consortium.

www.pxisa.org
PCI eXtensions for Instrumentation (PXI) modular instrumentation delivers a rugged, PC-based high-performance measurement and automation system.

Three-Year Warranty
www.keysight.com/find/ThreeYearWarranty
Keysight's commitment to superior product quality and lower total cost of ownership. The only test and measurement company with three-year warranty standard on all instruments, worldwide.

Keysight Assurance Plans
www.keysight.com/find/AssurancePlans
Up to five years of protection and no budgetary surprises to ensure your instruments are operating to specification so you can rely on accurate measurements.

www.keysight.com/go/quality
Keysight Technologies, Inc.
DEKRA Certified ISO 9001:2008
Quality Management System

Keysight Channel Partners
www.keysight.com/find/channelpartners
Get the best of both worlds: Keysight's measurement expertise and product breadth, combined with channel partner convenience.

Formerly known as Application Note 1312

www.keysight.com/find/assist

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at:
www.keysight.com/find/contactus

Americas	
Canada	(877) 894 4414
Brazil	55 11 3351 7010
Mexico	001 800 254 2440
United States	(800) 829 4444
Asia Pacific	
Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Other AP Countries	(65) 6375 8100
Europe & Middle East	
Austria	0800 001122
Belgium	0800 58580
Finland	0800 523252
France	0805 980333
Germany	0800 6270999
Ireland	1800 832700
Israel	1 809 343051
Italy	800 599100
Luxembourg	+32 800 58580
Netherlands	0800 0233200
Russia	8800 5009286
Spain	800 000154
Sweden	0200 882255
Switzerland	0800 805353
	Opt. 1 (DE)
	Opt. 2 (FR)
	Opt. 3 (IT)
United Kingdom	0800 0260637

For other unlisted countries:
www.keysight.com/find/contactus
(BP-09-23-14)

Published in USA, July 31, 2014
5968-2320E
www.keysight.com