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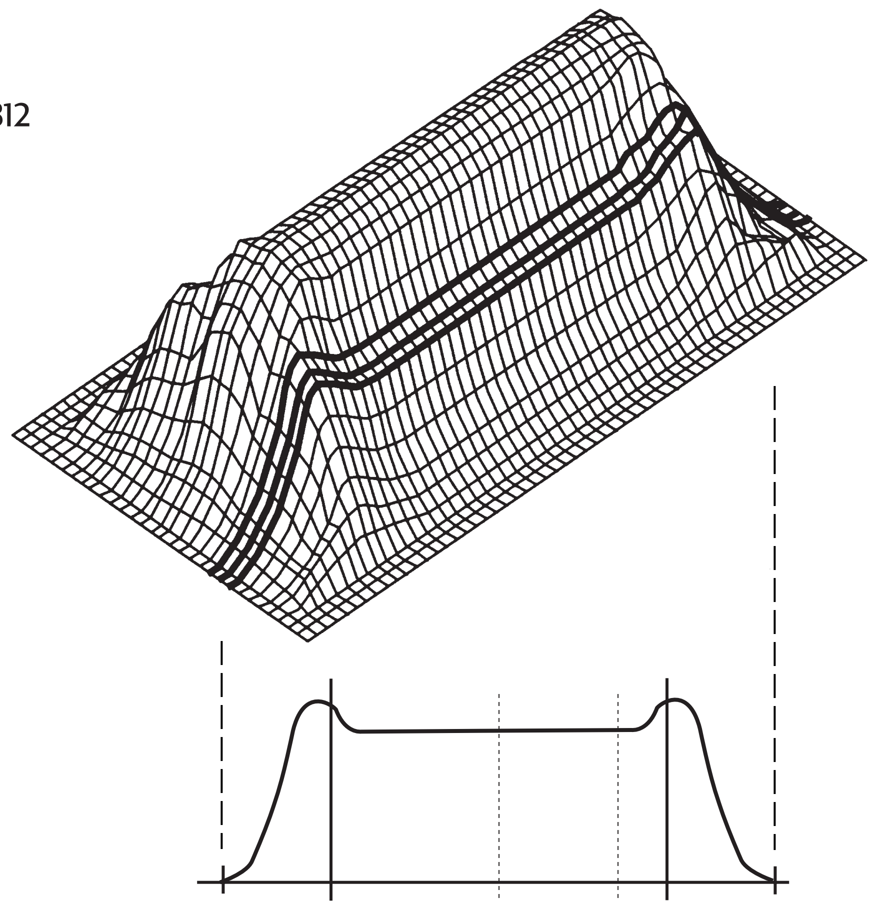
Understanding GSM Transmitter Measurements for Base Transceiver Stations and Mobile Stations

Application Note 1312



GSM®

GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

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1. Introduction

This application note presents the fundamental RF parametric measurements necessary to characterize GSM900, DCS1800 and PCS1900 transmitters in both base transceiver stations and mobile stations.

These measurements are widely used today, but new test equipment is making them easier to perform, faster and more precise. This paper aims to enhance the readers' understanding of GSM transmitter 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.

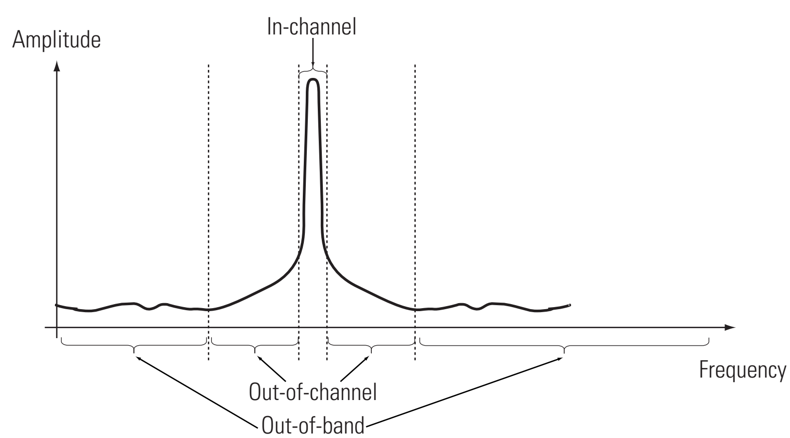
As far as possible, graphics are used to represent the theory behind the measurements in question and the test limits applied. For each measurement, pictorial examples of setup, method and specification limits are given. These have been derived from the ETSI and ANSI standards.

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 frequency channels and timeslots allocated to others.

Transmitter 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



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 in question 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 in question causes other users of the radio spectrum (military, aviation, police):

Other spurious (cross band and wideband)

Origin of measurements

GSM transmitter (and other) measurements originate from the following ETSI and ANSI standards:

GSM 05.05/ETS 300-577.	GSM and DCS1800 Radio transmission and reception.
GSM 11.10/ETS 300-607.	GSM and DCS1800 Mobile Station (MS) conformance specification. Part 1: Conformance specification.
GSM 11.21/ETS 300-609.	Base Station System (BSS) equipment specification. Part 1: Radio aspects.
ANSI J-STD-007.	PCS1900. Air Interface Specifications.

It is worth noting that these specifications were written for the purposes of full type approval and they are, therefore, extensive. It is not practical to make the whole suite of measurements in most application areas. In manufacturing, for example, where throughput and cost are key drivers it is necessary to use a subset of the measurements defined in the specifications above. Optimization is the key here; the objective should always 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 every phone or infrastructure component shipped. This is discussed in more detail in the following sections.

The standards are difficult to understand and there is always a danger that independent parties will interpret them differently. Hewlett-Packard Company uses the standards as a basis from which to design measurement algorithms and has worked for many years with many industry leaders to minimize these problems.

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

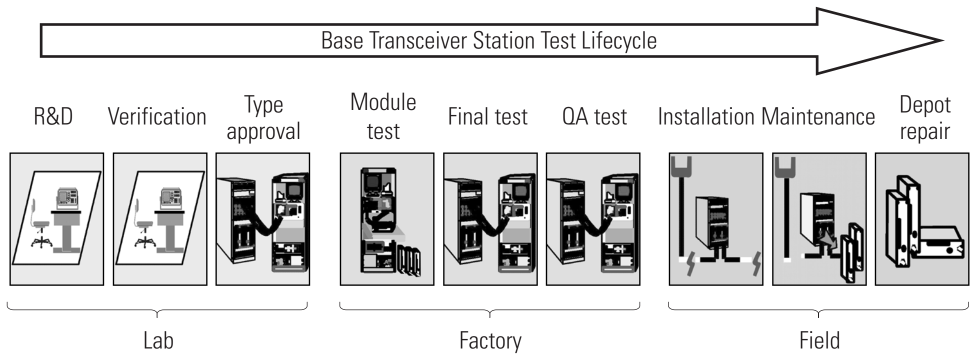
Choosing transmitter measurements

As mentioned the ETSI and ANSI specifications have been devised for type approval purposes. It is not practical to perform the complete set in every environment; GSM equipment manufacturers and network operators must balance test coverage with other factors such as cost and time. Nobody prescribes the specific measurement set to be used at any one point in the GSM lifecycle[1]—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 GSM lifecycle for base transceiver stations (BTS) and mobile stations (MS) is summarized in the following diagrams:

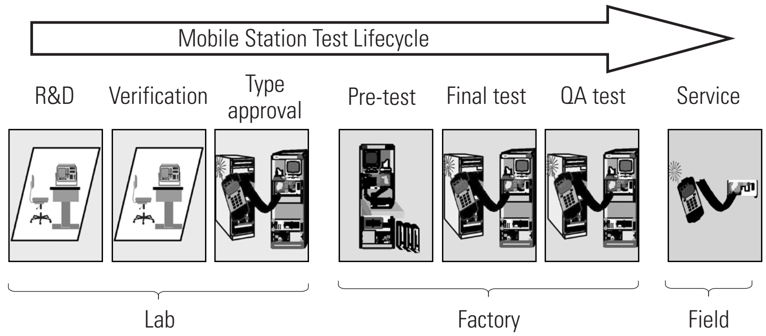
Figure 2.
BTS lifecycle



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
Installation	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

1. There are a couple of exceptions here. First, as stated the ETSI and ANSI specs do define the test suite for type approval. Also, in certain countries regulatory bodies do recommend a test list for mobile station manufacturing final test and also for installation and maintenance test.

Figure 3.
MS lifecycle



Lifecycle Phase	Purpose of Test
R&D	Create and optimize design Stress test design/find corner cases Prove compliance
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
Service	Find and repair faults Minimize no-fault-found (NFF) loop

Tradeoffs 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 tradeoffs:

Test cost
Test coverage
Test throughput
Test system flexibility

It is sensible to consider test cost on a 'cost-per' basis. For example, in mobile station manufacturing, think in terms of test cost-per phone first, and capital expenditure second. Test cost-per can be minimized by ensuring that only measurements that truly reveal something about the device under test are performed, that is the ones that have a real possibility of failing or are required for device calibration.

2. RF Parametric Transmitter Measurements in GSM

Phase error and mean frequency error

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

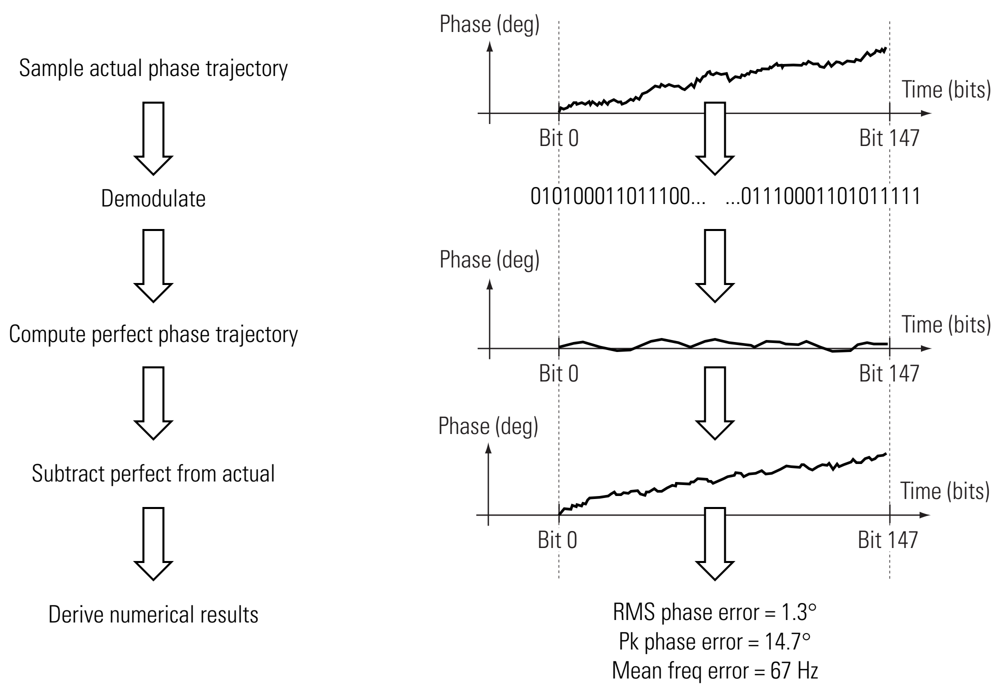
Purpose of measurement—what it proves

Phase error is the fundamental parameter used in GSM to characterize modulation accuracy. These measurements reveal much about a transmitters' modulator performance. Poor phase error indicates a problem with the I/Q baseband generator, filters or modulator in the transmitter circuitry. The output amplifier in the transmitter can also create distortion that causes unacceptably high phase error. In a real system, poor phase error will reduce the ability of a receiver to correctly demodulate, especially in marginal signal conditions. This ultimately affects range.

Frequency error measurements indicate synthesizer/phase lock loop performance. This is especially important either in an MS where the synthesizer constantly hops between Tx and Rx, or 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 a multitude of problems, for example, the target receiver may be unable to gain lock and the transmitter may cause interference with other users. If the latter is the case, other measurements will show this for sure.

Explanation of theory in pictures

Figure 4. Phase error and mean frequency error, theory



Phase and frequency error measurements are complex, however modern test equipment can perform all of the necessary signal processing and mathematics automatically. Figure 4 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.

Graphical view of limits/specs

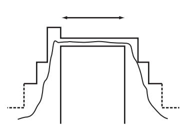
The ETSI and ANSI specifications define test limits for both base transceiver stations and mobiles. Phase and frequency error measurements should be performed over multiple bursts, and on multiple channels. Actual transmitter performance will vary with frequency.

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

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

Hopping:
Off or On

Detection:
Measured over useful part of burst (gated)



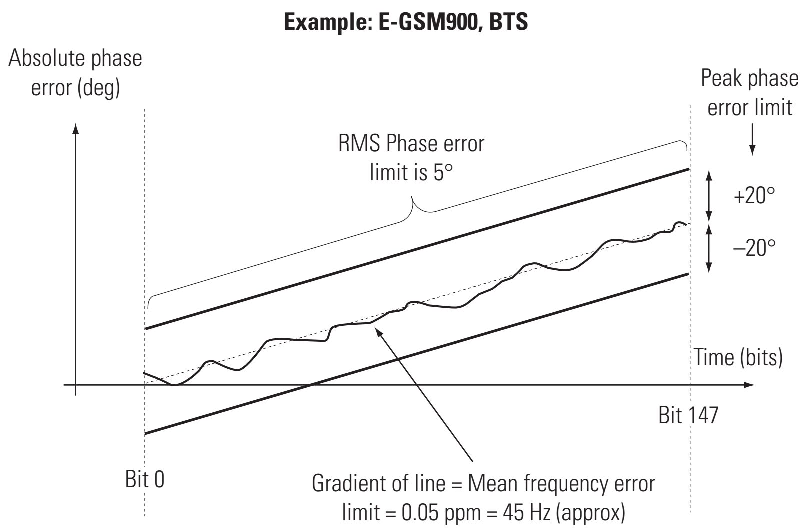
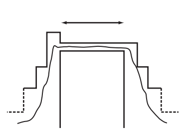


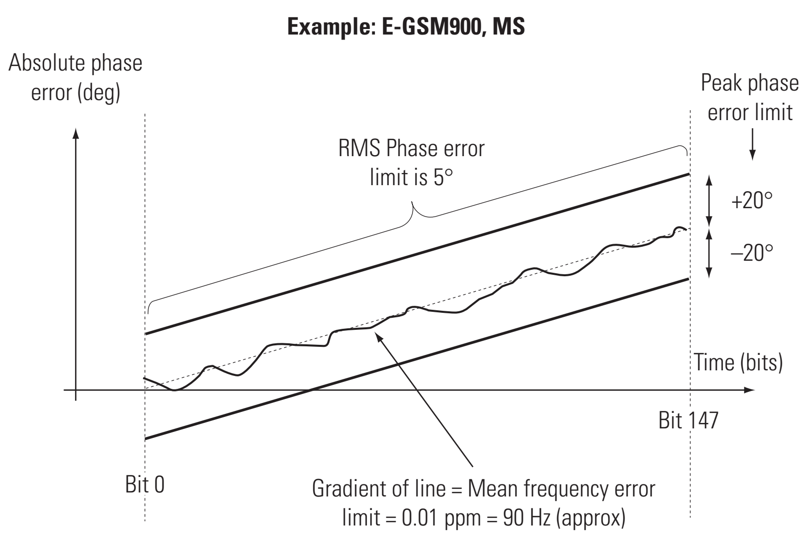
Figure 6. Phase error and mean frequency error, MS, limits

Channels:
B, M, T. Single carrier

Hopping:
Off or On

Detection:
Measured over useful part of burst (gated)





It is worth noting that for frequency error the pass/fail limit is expressed in terms of ppm (parts per million) and applies across GSM900, DCS1800 and PCS1800. The phase error limits are also common across the three systems.

Practical measurements

As mentioned, modern test equipment performs the necessary signal processing automatically making these measurements straight forward 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 may fail the prescribed limits at only one point in the burst, for example, at the beginning. This could indicate a problem with the transmitter power ramp or some undesirable interaction between the modulator and power amplifier.

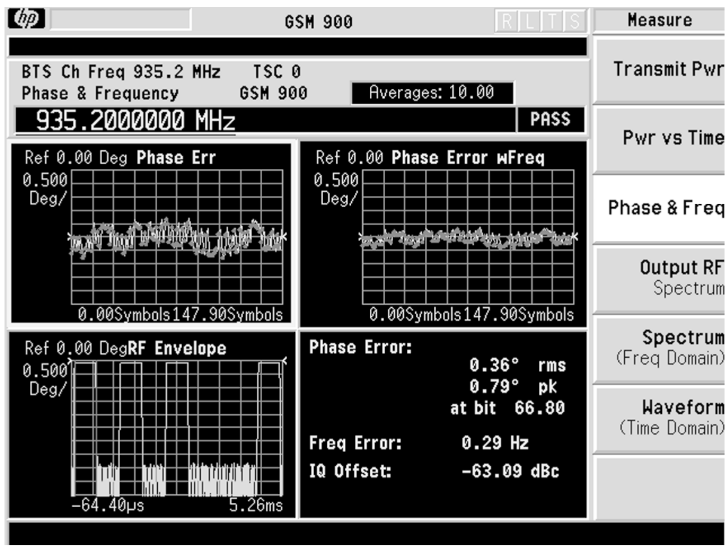


Figure 7.
HP E4406A VSA-Series transmitter tester screen shot, quad display with/without frequency error

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

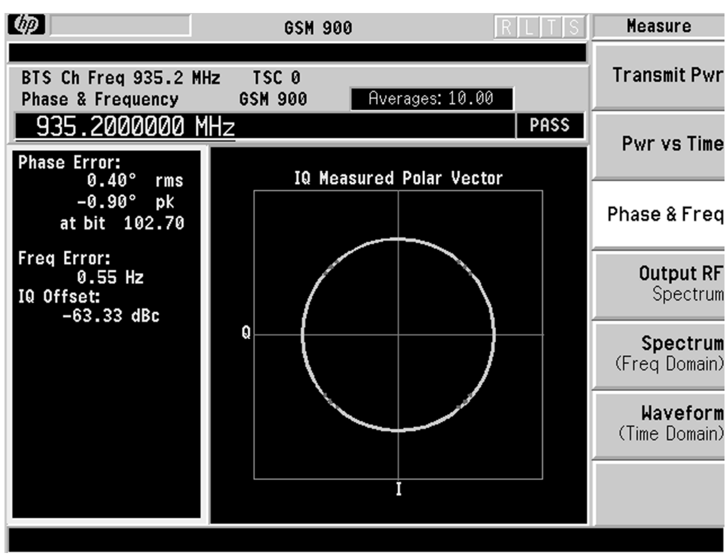


Figure 8.
HP E4406A VSA-Series transmitter tester screen shot, constellation diagram

When to use the measurement

Because phase and frequency error measurements can capture a large spread of fault types and prove that any I/Q calibration process has been successfully performed they are typically used at every stage in the MS and BTS lifecycle. Modern test equipment can make these measurements very rapidly and with good accuracy (typically the test equipment should be 10x more accurate than the specification limit so measurement results can be attributed to the device under test (DUT) 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 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.

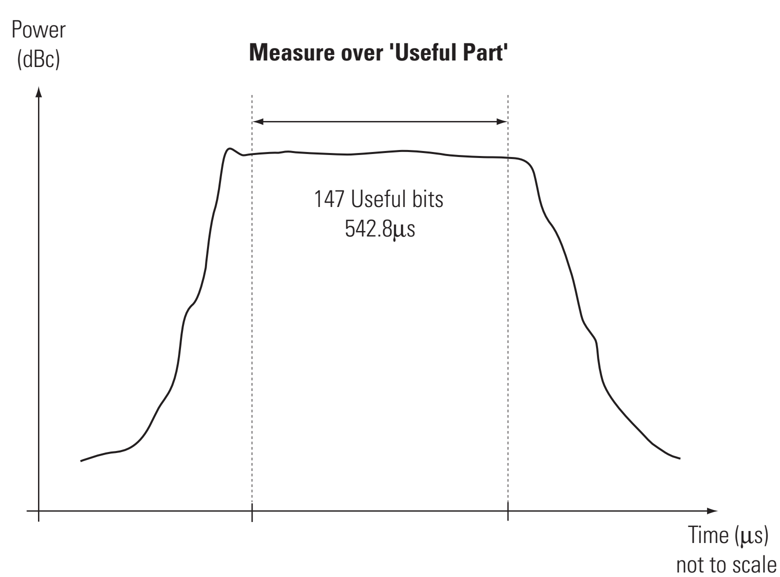
Output power therefore, is controlled within tight limits. If a transmitter produces too little power, link performance is compromised; too much, and interference to others may be too high and battery life too short.

Common practical transmitter implementations require output power calibration in manufacturing to meet the GSM 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 afore mentioned calibration tables. They can also provide early indication of a fault with the power supply, such as the battery in the case of mobile stations.

Explanation of theory in pictures

Figure 9. Mean transmitted RF carrier power, theory



Conceptually, the mean power measurement in GSM is straight forward. It is defined simply as the mean power during the useful part of the GSM burst. The ETSI and ANSI 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.

Because all mobile stations and most base transceiver stations implement dynamic power control it is necessary to make multiple power measurements at several power levels and several frequencies in order to test for proper operation.

Graphical view of limits/specs

The ETSI and ANSI specifications define power limits both in terms of absolute accuracy and relative accuracy (between power levels or ‘steps’).

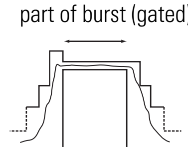
The examples given in Figures 10 and 11 are for transmitters of a specific type and class. Absolute limits depend on the type and class of the device under test.

Figure 10. Mean transmitted RF carrier power, BTS, limits

Channels:
B, M, T. Single carrier
At least three slots on

Hopping:
On

Detection:
Measured over useful part of burst (gated)



Log average

Notes: Absolutes depend on power class of BTS. The six or more ‘power settings’ for radio planning are neglected here.

Example: E-GSM900, Class 5 BTS with dynamic power control, normal conditions
Note: typical max power for a GSM BTS TRX = 43 dBm

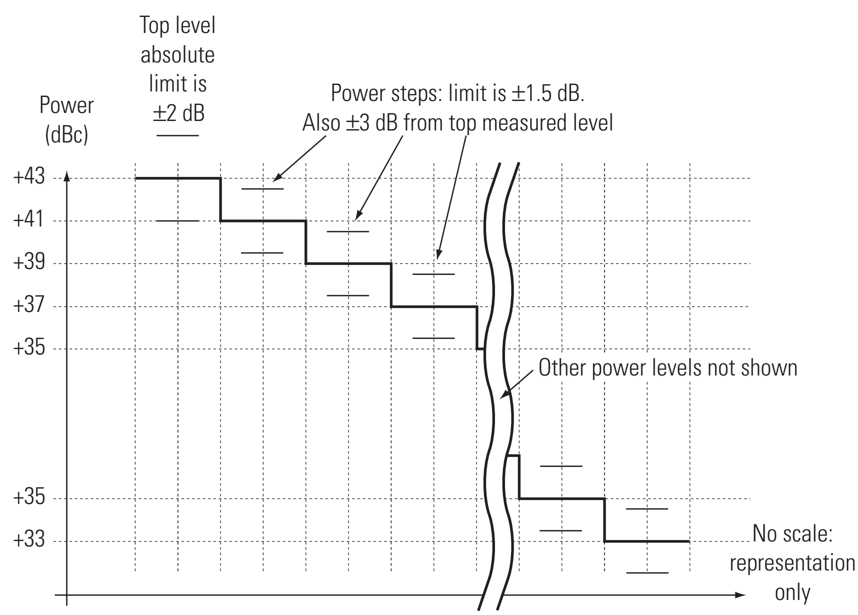
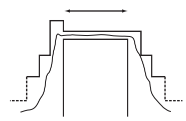


Figure 11. Mean transmitted RF carrier power, MS, limits

Channels:
B, M, T. Single carrier

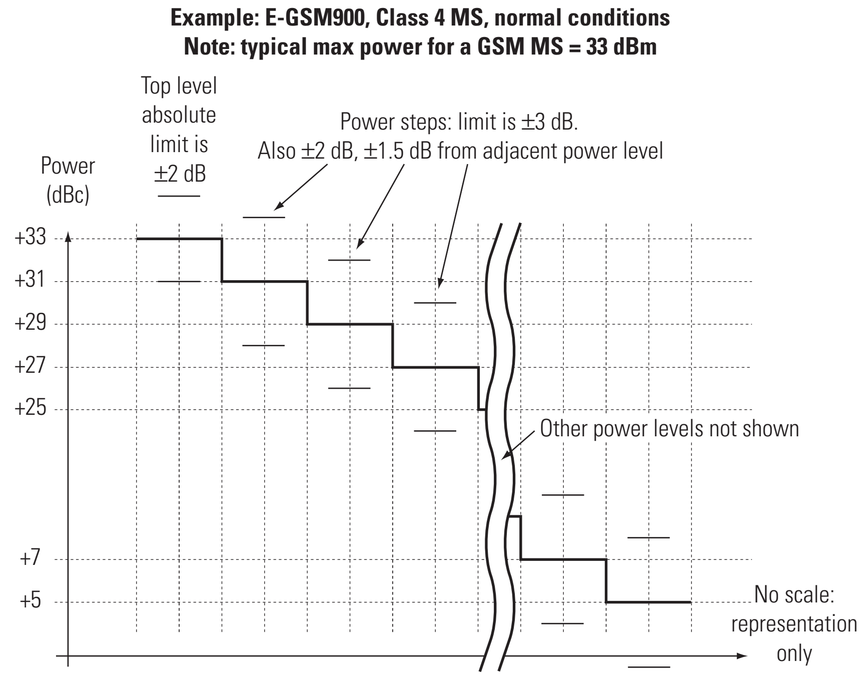
Hopping:
On

Detection:
Measured over useful part of burst (gated)



Log average

Notes: Absolutes depend on power class of MS.



Practical measurements

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

It is possible to make power measurements in GSM systems by triggering off the rising edge of the signal instead of the bit 13/bit 14 transition, although this method will result in increased levels of uncertainty.

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, however. Peak power sensors will capture the overshoot at the top of the bursts ramp up giving incorrect readings, and 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 R&D, manufacturing and installation and maintenance can make this measurement as defined in the ETSI and ANSI specifications by demodulating and gating.

One more note of caution here: 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 MS and BTS lifecycle. Typically accuracy, linearity and repeatability requirements are more stringent in R&D and less stringent in installation and maintenance. Or put another way, moving through the lifecycles from left to right the requirement becomes less stringent—see Figures 2 and 3.

In manufacturing where power calibration is required, measurement speed is a significant factor. To fully calibrate and characterize, for example, a GSM BTS transceiver in manufacturing may 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 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 may 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, for all intents and purposes, complete.

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

This measurement does not test to see if the transmitter ramps power too quickly; this has the effect of spreading energy across the spectrum causing interference, and is tested for with the 'spectrum due to switching' measurement.

Explanation of theory in pictures

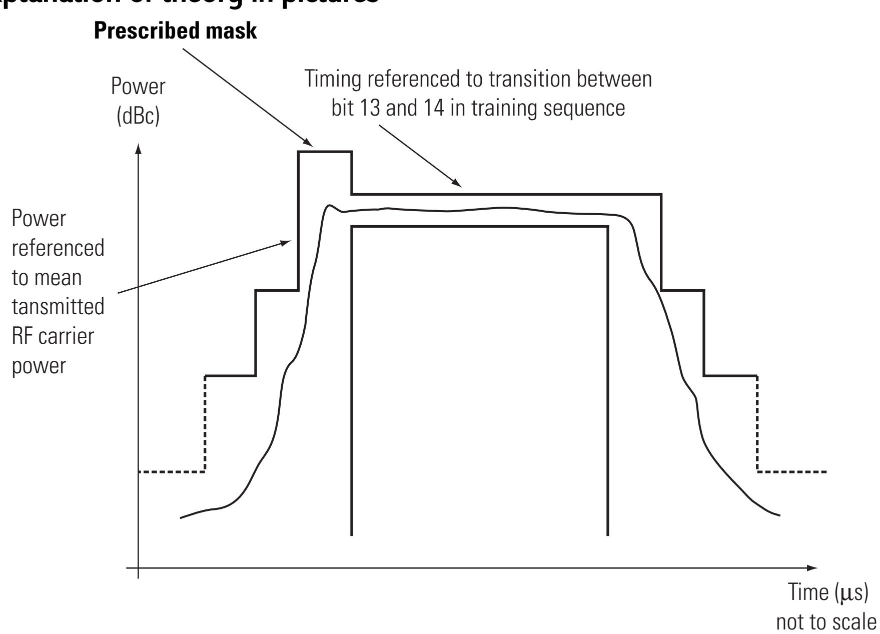


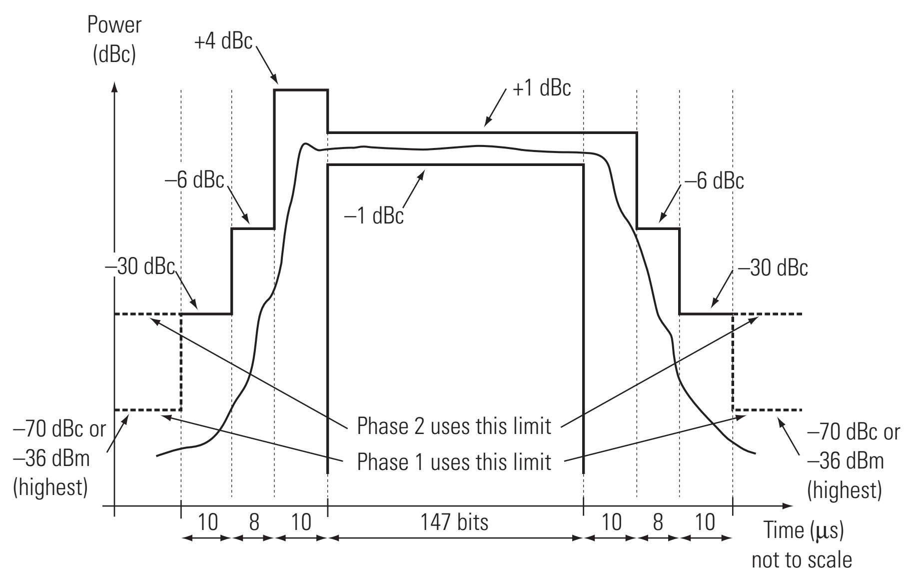
Figure 12. Transmitted RF carrier power versus time, theory

The measurement 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 bits 13 and 14 of the training sequence (so 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 mean transmitted RF carrier power measurement.

Graphical view of limits/specs

Figure 13. Transmitted RF carrier power versus time, BTS, limits

Example: E-GSM900, BTS



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

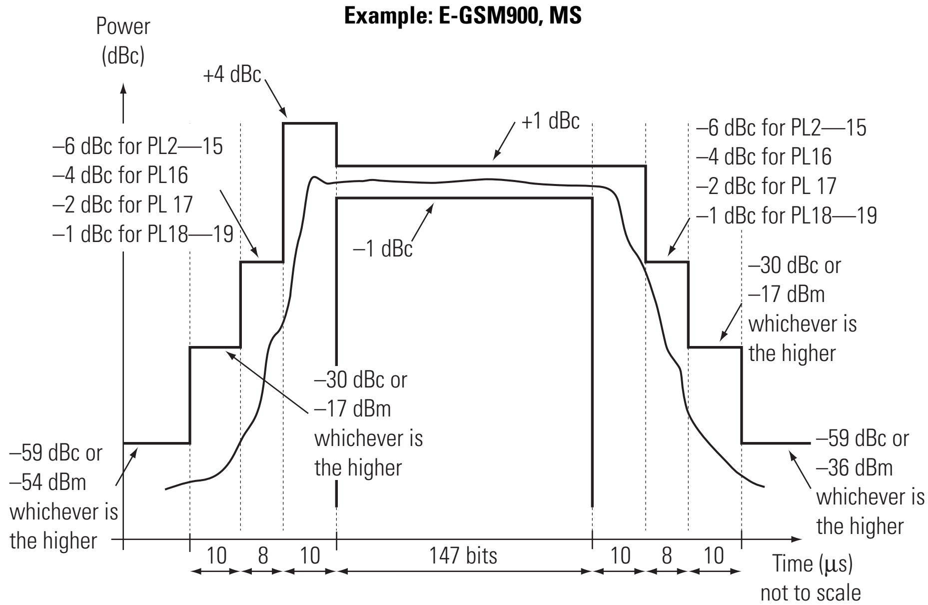
Hopping:
On

RBW:
=> 300 kHz

Detection:
Zero span

Figure 14. Transmitted RF carrier power versus time, MS, limits

Example: E-GSM900, MS



Channels:
B, M, T. Single carrier

Hopping:
On

RBW:
=> 300 kHz

Detection:
Zero span

As shown in Figures 13 and 14, the limit lines for MS and 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 system—Figures 13 and 14 show limits for E-GSM900. DCS1800 and PCS1900 use slightly different pass/fail criteria.

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 MS and BTS lifecycle, to ensure that the turn on/turn off ratio is sufficient. For this measurement the analyzer used must have plenty of 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.

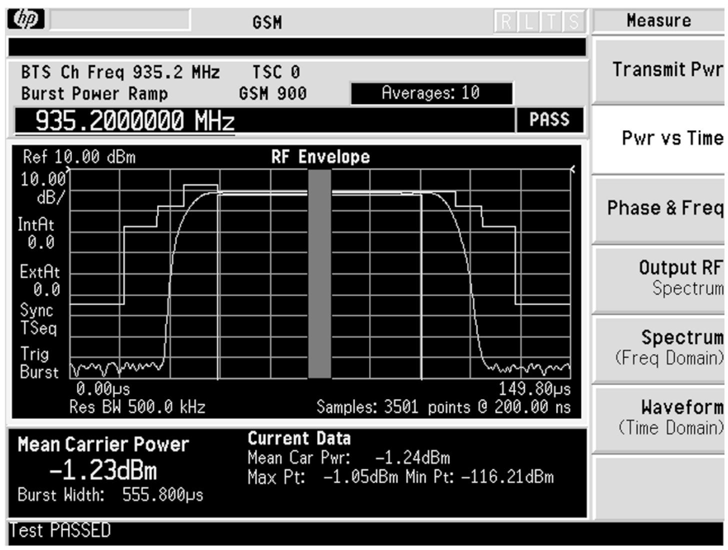


Figure 15. HP E4406A VSA-Series transmitter tester screen shot, PVT, high dynamic range-rising and falling edge

When to use the measurement

Power versus time measurements are used universally in GSM to check the health of transmitters from R&D through to installation and maintenance, and service.

Spectrum due to modulation and wideband noise

Purpose of measurement—what it proves

This measurement and the next entitled 'spectrum due to switching' are often grouped together under the title 'output RF spectrum' (ORFS).

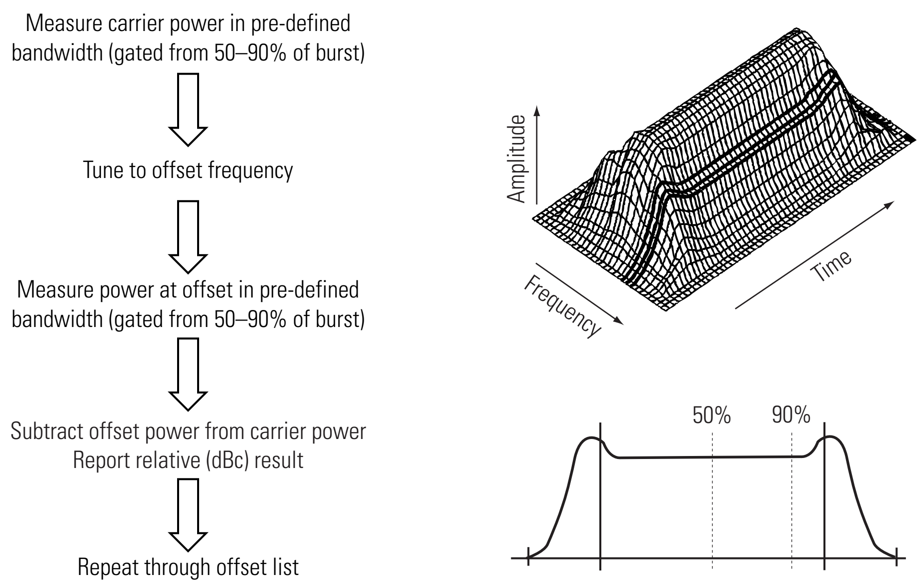
The modulation process in a transmitter causes the continuous wave (CW) carrier to spread spectrally. The 'spectrum due to modulation and wideband noise' measurement is used to ensure that this process does not cause excessive spectral spread. If it did, other users operating on different frequencies would experience interference. It 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 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.

Explanation of theory in pictures

Figure 16. Spectrum due to modulation and wideband noise, theory



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: despite the fact the result of the measurement set 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/specs

Figure 17. Spectrum due to modulation and wideband noise, normal BTS, limits.

Channels:
- B, M, T. Signal carrier
- All slots on

Hopping:
- Off

RBW:
- 30 kHz and 100 kHz

VBW:
- =RBW

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

Filter:
- 5-pole sync tuned

Notes:
- For low O/P power levels further conditions apply (limits are less demanding).

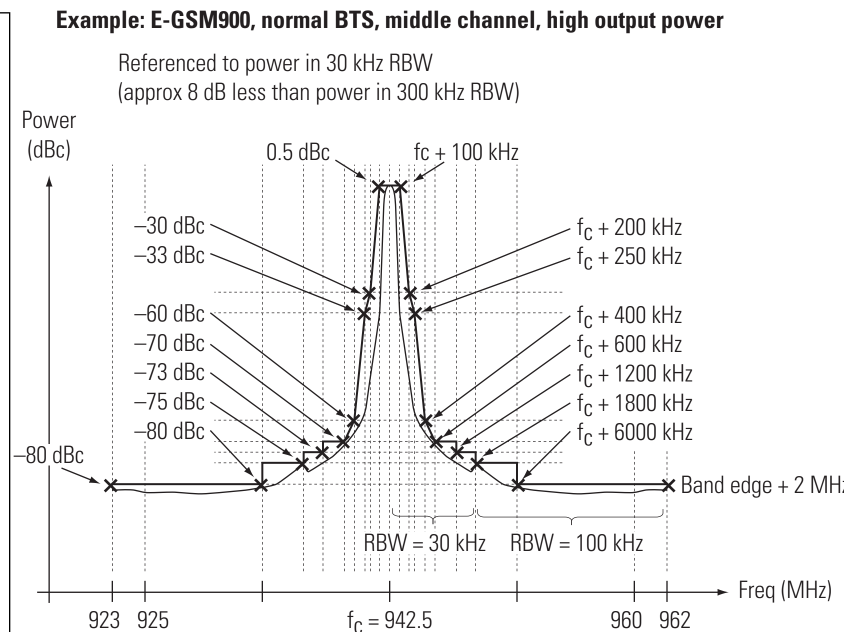


Figure 18. Spectrum due to modulation and wideband noise, MS, limits

Channels:
- B, M, T. Signal carrier

Hopping:
- Off

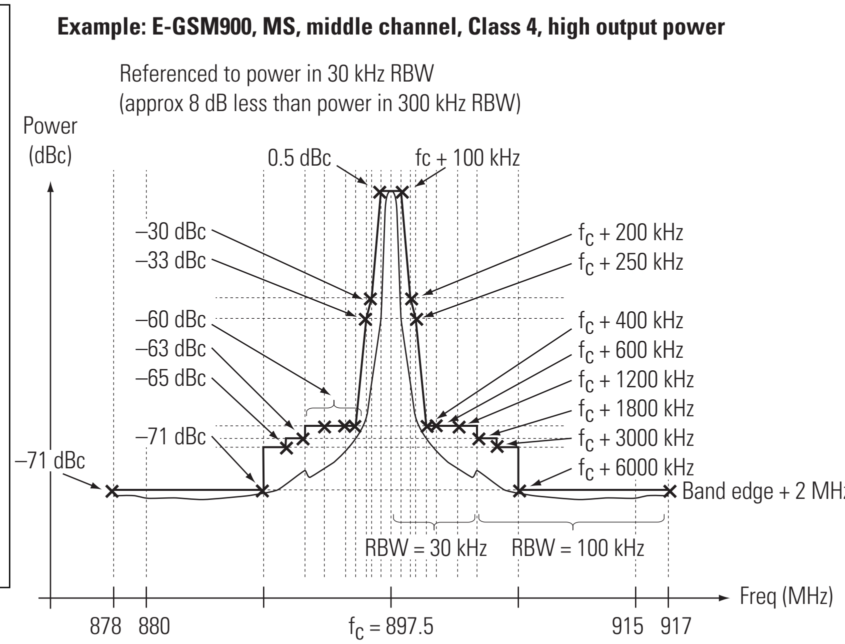
RBW:
- 30 kHz and 100 kHz

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).



As with other measurements the actual limits depend on many factors, namely, class, type, system and power level. Figures 17 and 18 give example limits for E-GSM900 MS and Normal BTS at high power.

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 great deal of processing if they are to be achieved rapidly. For these reasons, in some applications such as MS manufacturing, 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 technique requires a series of separate measurements to be performed and a lot of re-tuning. This takes time. Hewlett-Packard Company has developed two innovative 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 giving 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%–90% of the burst. This is only feasible with the architecture of some analyzers.

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

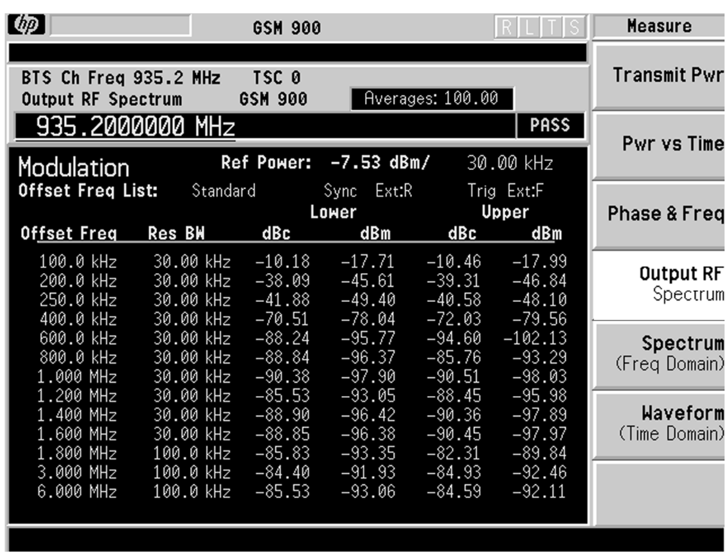


Figure 19.
HP E4406A VSA-Series transmitter tester screen shot, output RF spectrum due to modulation

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 both BTS and MS 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 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 quickly 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 transmitters’ output power amplifier or leveling loop.

Explanation of theory in pictures

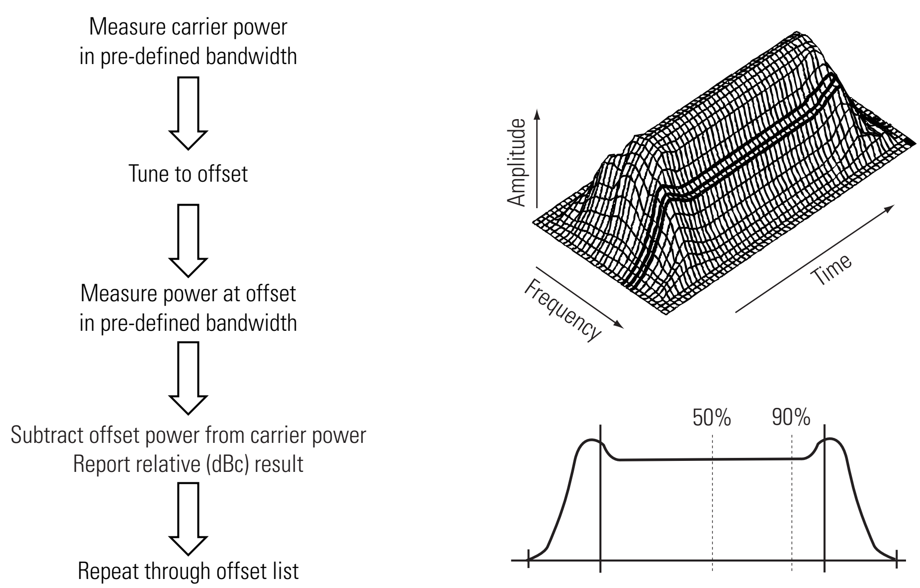


Figure 20. Spectrum due to switching, theory

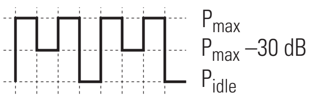
Spectrum due to switching measurements are performed in a similar fashion to the spectrum due to modulation and wideband noise measurements in that the analyzer is tuned to and measures at multiple offset frequencies in zero span mode. In this case no time gating is used so power from both the ramping 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 different to 'mean transmitted RF carrier power' in the way that it is measured (resolution bandwidth = 300 kHz).

Graphical view of limits/specs

Figure 21. Spectrum due to switching, BTS, limits

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



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).

Example: E-GSM900, normal BTS, middle channel, high output power

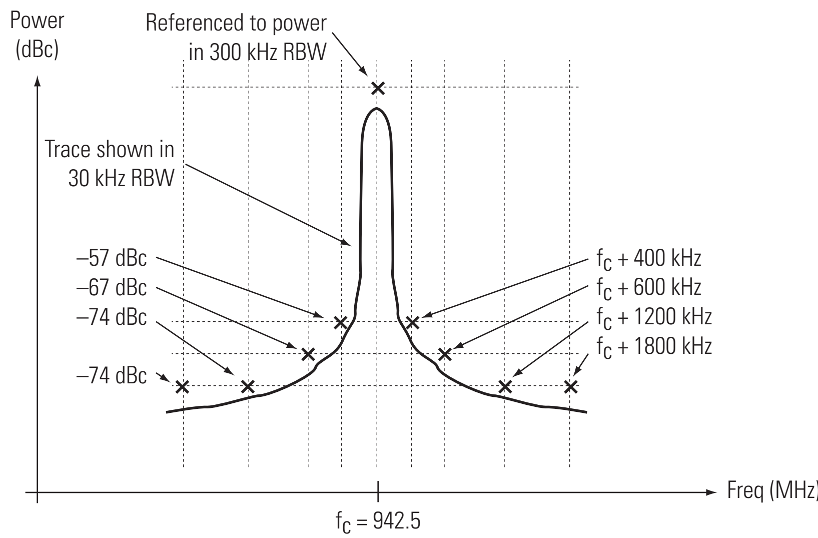


Figure 22. Spectrum due to switching, MS, limits

Channels:
B, M, T. Single carrier

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

RBW:
30 kHz

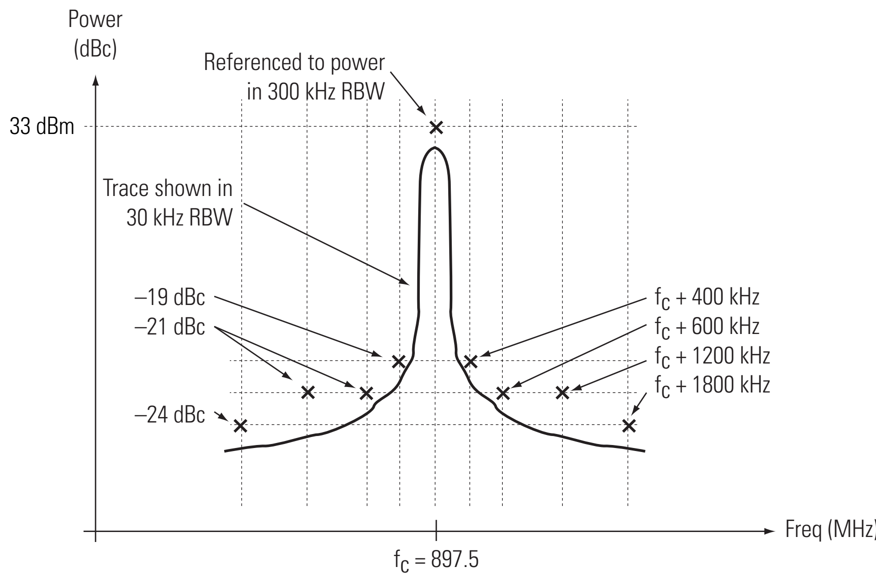
VBW:
100 kHz

Detection:
Peak hold
Zero span

Filter:
5-pole sync tuned

Notes:
For low O/P power levels further conditions apply (limits are less demanding).

Example: E-GSM900, MS, middle channel, Class 4, high output power



As with other measurements the actual limits depend on many factors, namely, class, type, system and power level. Figures 21 and 22 give example limits for E-GSM900 normal BTS and MS 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.

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 application 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 (GSM900 into DCS1800).
Out-of-band spurious	wideband spurious that affects other users of the radio spectrum.

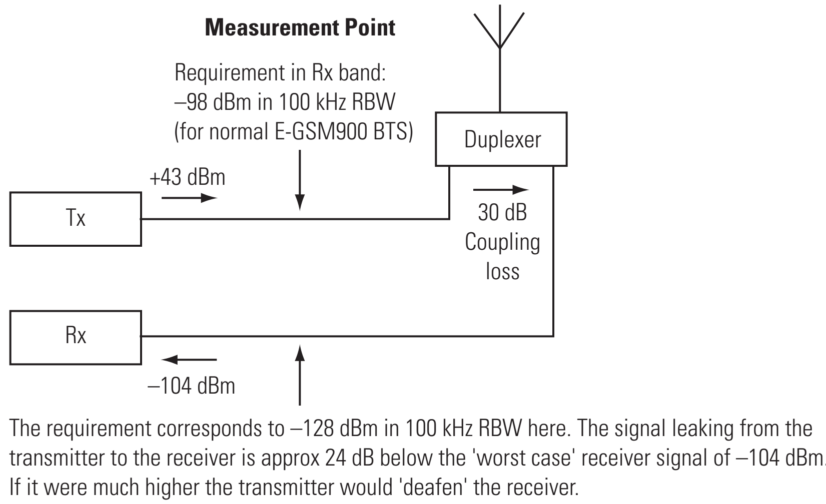
All of the spurious measurements are defined in ETSI and ANSI specifications as standard spectrum analyzer measurements, that is, a band is swept (with certain filter/speed settings) and a pass/fail limit applied.

Tx and Rx band spurious

Explanation of 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.

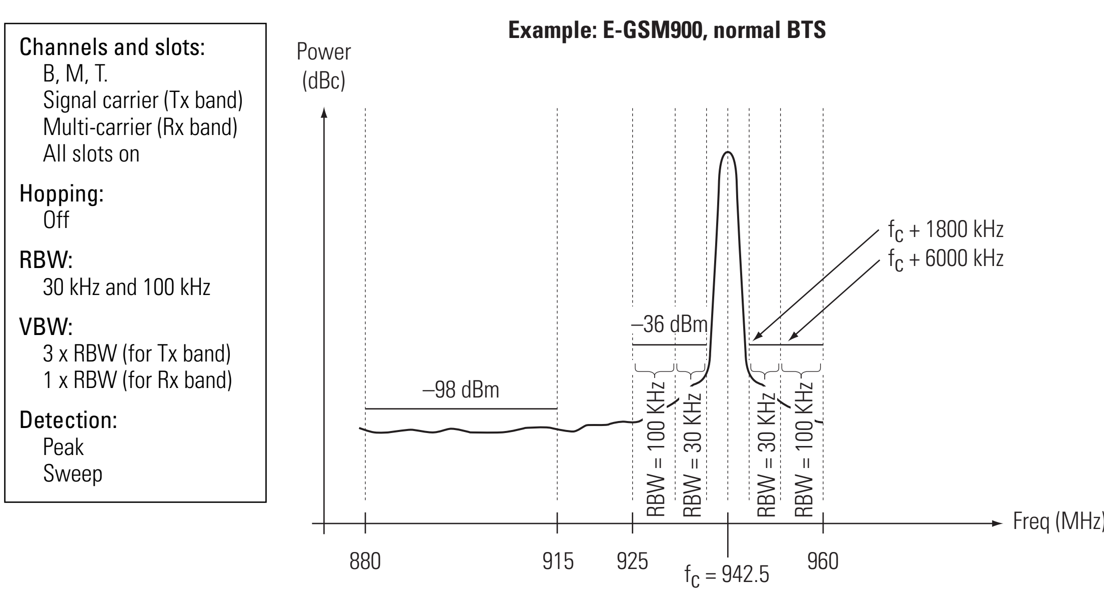
The Rx band spurious measurement deserves special attention. This is a measure of how much energy the transmitter puts into the Rx band (880–915 MHz for E-GSM) and the specification is extremely stringent. The reasons for this are clear; potentially spurious from the transmitter can 'jam' or 'deafen' the receiver making the system useless. The Rx band spurious measurement deserves a special explanation. See Figure 23.

Figure 23. Rx band spurious, theory



Graphical view of limits/specs

Figure 24. Tx and Rx band spurious, BTS, limits



For mobile stations the Tx and Rx band requirements are stated as extensions to the spectrum due to modulation and wideband noise measurements. These are not detailed in this paper.

Practical measurements. To date, no analyzer has sufficient dynamic range to measure Rx band spurious to the ETSI and ANSI 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 for example, 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 and then test only at these frequencies to minimize test time.

When to use the measurement. The application of Tx band spurious measurements should be considered alongside 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 band spurious 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 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.

Graphical view of limits/specs

Figure 25. Cross-band spurious, BTS, limits

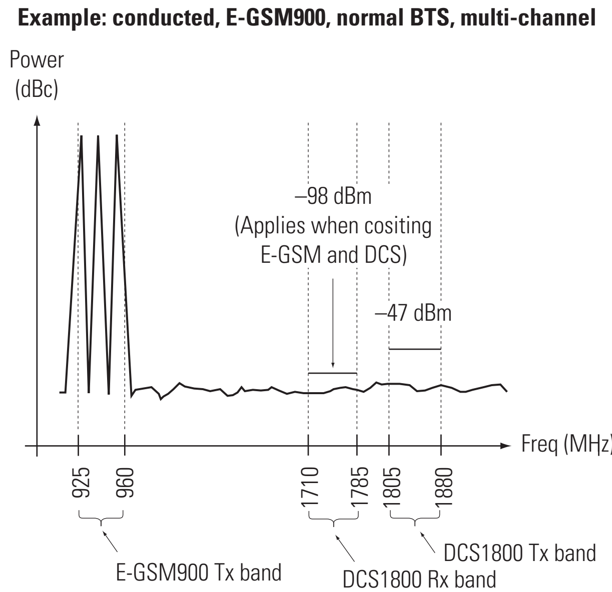
Channels and slots:
B, M, T

Hopping:
Off

RBW:
30 kHz and 100 kHz

VBW:
=RBW

Detection:
Peak
Sweep



For mobile stations the cross-band requirements are stated as extensions to the spectrum due to modulation and wideband noise measurements. These are not detailed in this application note.

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 26.

Graphical view of limits/specs.

Figure 26.
Wideband spurious,
BTS, limits

Channels and slots:
B, M, T. Multi-carrier
P_{max}
P_{idle}

Hopping:
On

RBW:
As required

VBW:
3 x RBW. Max 3 MHz

Detection:
Peak
Sweep

Example: conducted, E-GSM900, normal BTS, multi-channel

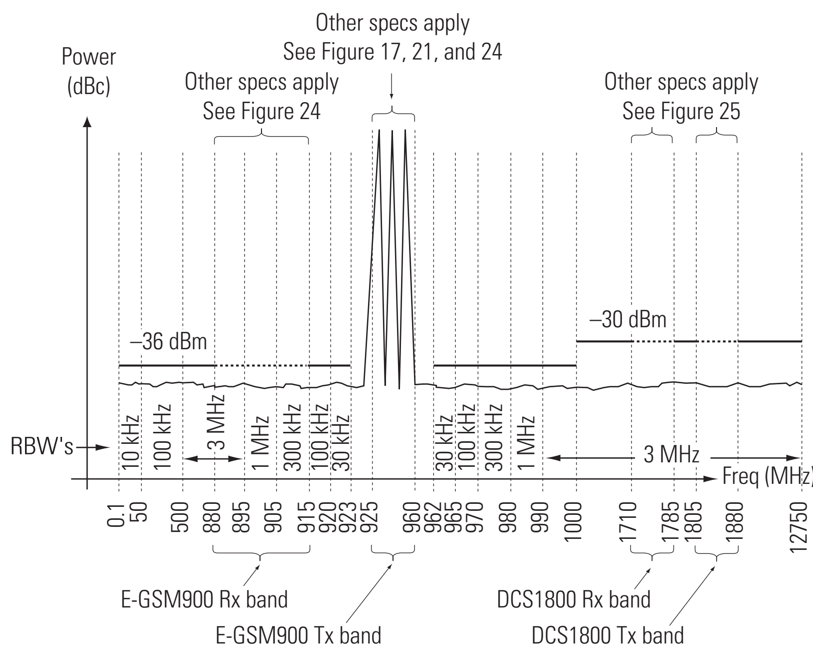


Figure 27.
Wideband spurious,
MS, limits

Channels and slots:
M

Hopping:
Off

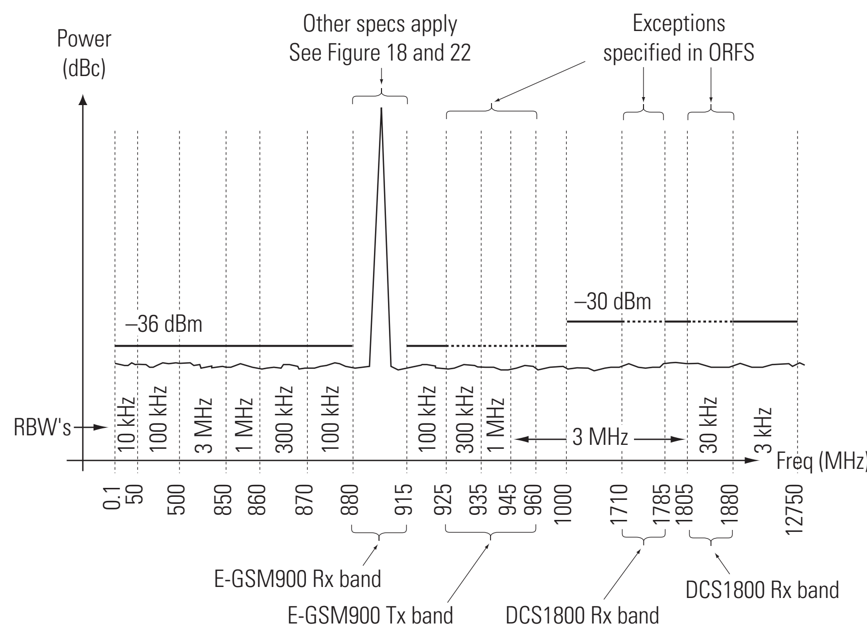
RBW:
As required

VBW:
3 x RBW. Max 3 MHz

Detection:
Peak hold
Sweep

Notes:
Other spurious specs
apply for MS in idle mode.

Example: conducted, E-GSM900, MS, channel allocation



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.

3. Choosing Transmitter Measurements for an Application

The following tables are 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, calibration requirements).

Figure 28. BTS measurements by application/lifecycle phase

BTS Lifecycle Phase	Phase error and mean frequency error	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)
R&D	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Verification	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type approval	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Module test	Yes	Yes	Yes	Most	Most	Some	Some	Few	No
Final test	Yes	Yes	Yes	Most	Most	Some	Some	Few	No
QA test	Yes	Yes	Yes	Yes	Yes	Most	Most	Some	Some
Installation	Yes	Yes	Yes	Most	Most	Some	Some	Few	Some
Maintenance	Yes	Yes	Yes	Some	Some	Some	No	No	Some
Depot repair	Yes	Yes	Yes	Most	Most	Some	Some	Few	Some

Figure 29. MS measurements by application/lifecycle phase

MS Lifecycle Phase	Phase error and mean frequency error	Mean transmitted RF carrier power	Transmitted RF carrier power versus time	Spectrum due to modulation and wideband noise	Spectrum due to switching	Wide band spurious	Other transmitter measurements (not described in this application note)
R&D	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Verification	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type approval	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pre test	Yes	Yes	Yes	Few	Few	No	No
Final test	Yes	Yes	Yes	Few	Few	No	No
QA test	Yes	Yes	Yes	Most	Most	Some	No
Service	Yes	Yes	Yes	Some	Some	No	No

4. Summary

This application note explains and describes the key transmitter measurements required for testing GSM. The ETSI and ANSI test specifications have been created for type approval purposes and are therefore extensive, however, at any stage of the BTS and MS lifecycles it is sensible to use these standards as a starting point. It is essential to optimize the transmitter 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 providing a useful reference. Modern test equipment is often designed for one or a few select applications.

5. References

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2. GSM 11.10/ETS 300-607. GSM and DCS1800 Mobile Station (MS) conformance specification. Part 1: Conformance specification.
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8. HP VSA Transmitter Tester. User's Manual. HP part number E4406-90007.
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10. HP 8922 User's Manual. HP part number 08922-90211
11. HP GSM Base Station Test Set. User's Guide. HP part number E6382-90010.

5. List of Figures

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