How to measure on a GSM product

Subject:

Revision: 1.6
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Last Updated: 31/01/2003 03:37
Last Updated By: FSS
Printout Date: 06/03/2003 02:51
File: X:\Projects\Projects Common\Measurements\How to measure on a GSM product\How to measure on a GSM product V1.8.doc

1 Introduction

The present document includes a detailed description of measurements, which should be performed to verify that the phone fulfills GSM specifications related to the RF performance. The measurements are roughly divided to Receiver, Transmitter, Synthesizer, and Antenna measurements in accordance with the functionality of the part measured. This division is applied for system-based measurements as well as block-based measurements.

System measurements Ch 2 to Ch 4 are mainly concentrated on GSM 05.05 specifications. The measurements at DWD are done in a semi-automatic measurement system shown in Figure 1.1 where almost all 05.05 measurements are included.

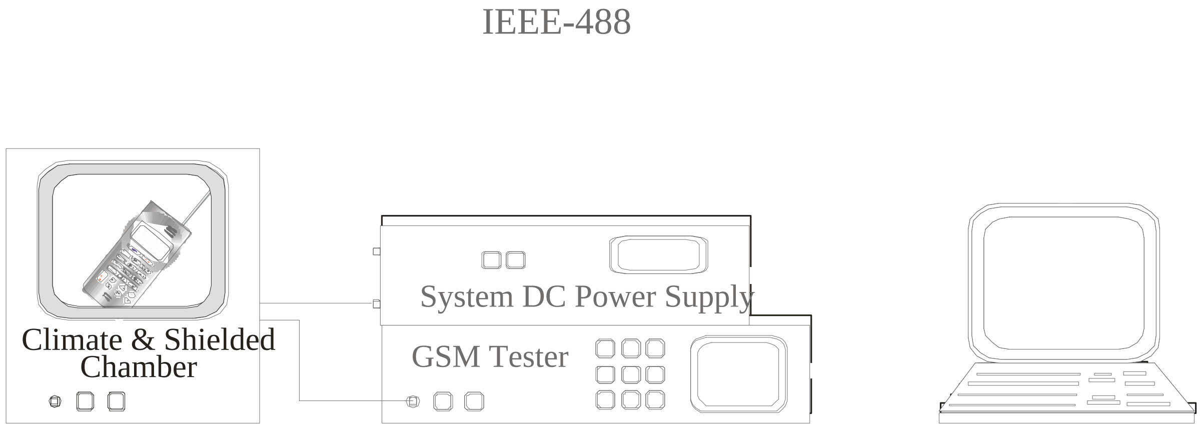


Figure 1.1 Setup for conducted system measurements. The climatic chamber is a Voetch VT4002. The power supply is an Agilent E3631A and the GSM tester is a R&S CMU200.

The module measurements Ch 5 to Ch 8 are based on traditional RF measurements, (e.g. gain, linearity, noise performance) on linear and nonlinear circuits and are used to verify different functional blocks' performance in the entire system. These measurement are also based on the GSM 05.05 specifications but require extra knowledge of the System budgets where the individual module specifications are calculated.

2 Receiver System measurements

The Receiver quality is measured as a BER (Bit Error Rate) where CLII BER < 2.4% (Class 2 Bit Error Rate)

2.1 Sensitivity

2.1.1 Conducted

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.2	Controlled

The conducted sensitivity performance is measured with the automatic system measurement setup shown in Figure 1.1. This test-setup only tests the static BER and not the BER under multipath condition as specified in the GSM rec. 05.05.
The reason for this is mainly that the BER performance under fading is set by the equalizer in the baseband chip (i.e. EGOLD+) and if the static performance is met with a margin of approximately 3dB, then the multipath performance will be within the GSM rec. 05.05 specifications.

2.1.2 Air Interface

FTA	Document	Chapter	Environment
None	GSM 11.10	14.2	Variable

For the air interface BER measurement it is recommended to use a shielded box with build-in antenna coupler. The test setup is shown in Figure 2.1.

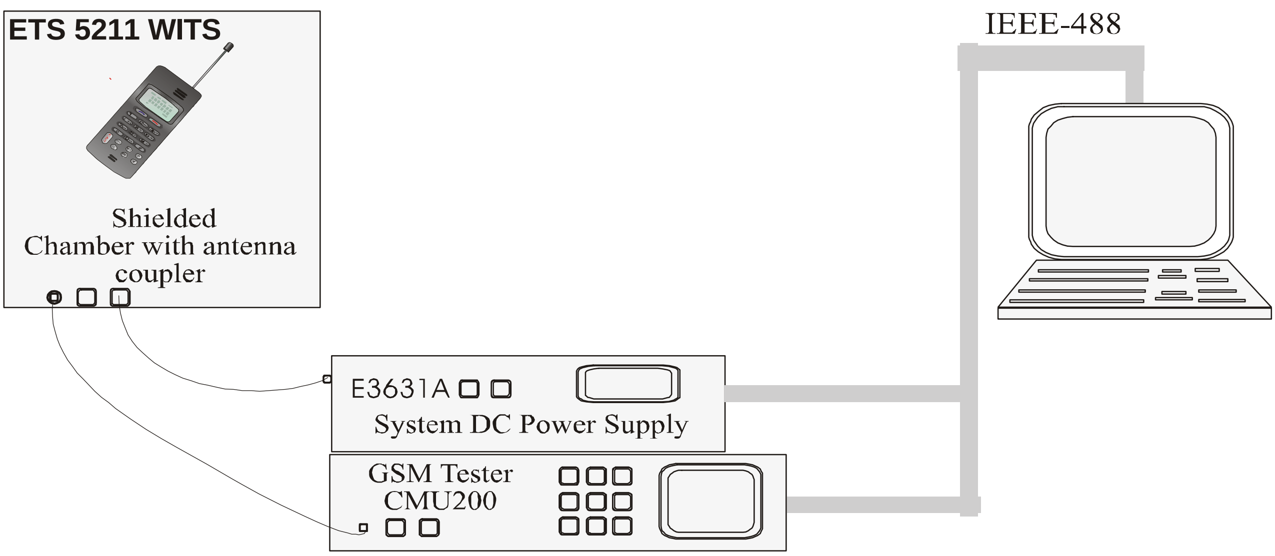


Figure 2.1 Setup for radiated system measurements.

The reason for testing the air interface BER is to ensure that the MS (mobile station) has no self-interference problems (i.e. a spurious on a GSM channel radiated from the mobile itself and then interfering with the wanted signal).
The BER may not be the same over the entire bandwidth of the GSM band as the matching of the antenna over the band influences the loss from the tester to the MS.

2.2 RX level performance

FTA	Document	Chapter	Environment
Required	GSM 11.10	21.1	Controlled

The RXLEVEL performance is measured with the automatic system measurement setup shown in Figure 1.1. Two measurements are performed.

1) A call is established at a fixed channel (center) and the RXlevel is measured for RF-input levels –110 to –48dBm. The results show receiver gain linearity performance. (*Input level vs. Reported level*)
2) A call is established with fixed input level (-70dBm) and the Rxlevel is measured over the frequency band. The results show receiver gain frequency ripple performance. (*Reported level vs. Frequency*)

2.3 Co-channel rejection

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.4	Controlled

The Co-channel rejection is measured at a GSM test house and not internally at DWD. To do the Co-channel measurement a GSM channel simulator is needed (e.g. SMIQ with fading option).

2.4 Adjacent channel rejection

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.5	Controlled

The adjacent channel rejection is measured at a GSM test house and not internally at DWD. To do the adjacent cannel measurement a GSM channel simulator is needed (e.g. SMIQ with fading option).

2.5 Intermodulation rejection

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.6	Controlled

The intermodulation rejection is measured with the test-setup shown in Figure 2.2. The PC controls the generators, the climatic chamber, the power supply and the CMU200 GSM tester.

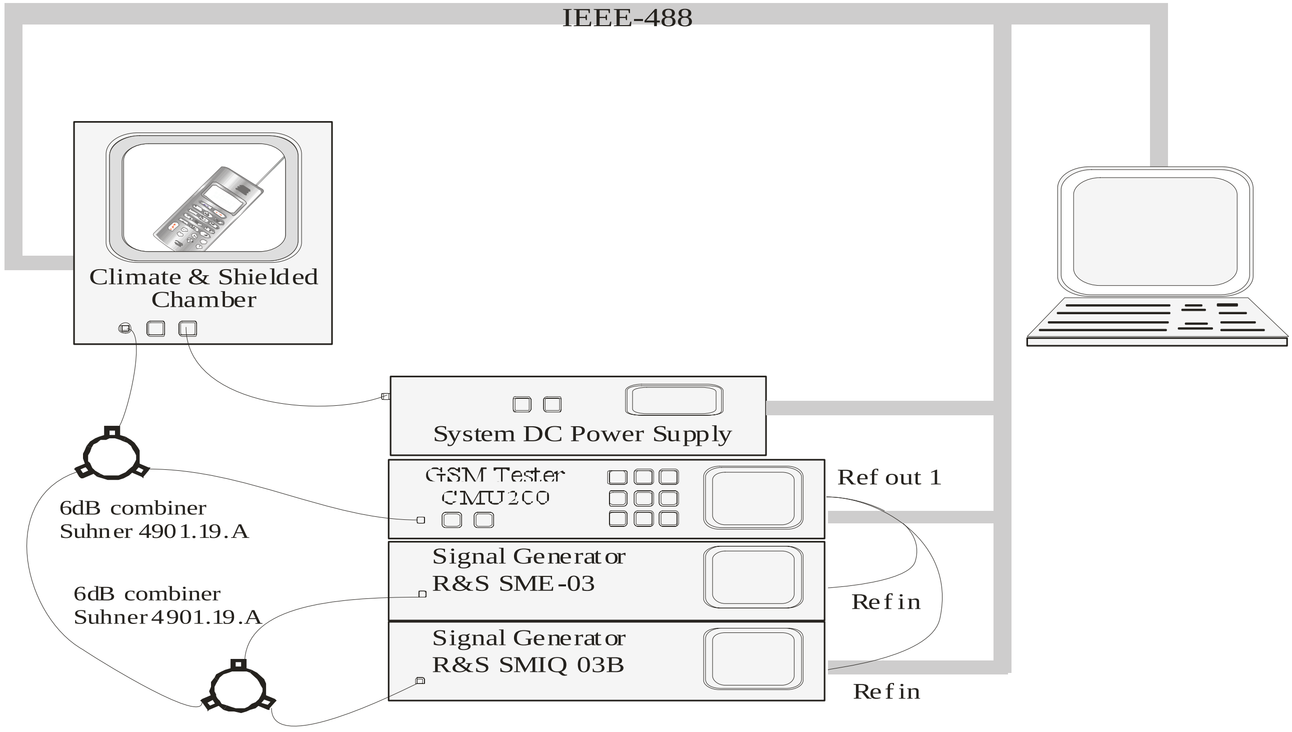


Figure 2.2 Setup for Intermodulation rejection measurement. The Climatic chamber is a Voetch VT4002.

The following is testet:

Generator 1	Generator 2	Low channel	Mid channel	High channel
ARFCN - 4	ARFCN –8	CLII BER < 2%	CLII BER < 2%	CLII BER < 2%
ARFCN + 4	ARFCN +8	CLII BER < 2%	CLII BER < 2%	CLII BER < 2%

- The wanted signal level is set to 3 dB above the sensitivity level, i.e. –99 dBm.
- Generator 1 generates a continuous static sine wave at frequency as in the table above and with a level of 64 dBμV (emf) i.e. –49 dBm.
- Generator 2 generates a GMSK modulated at frequency as in the table above and with a level of 64 dBμV (emf) i.e. –49 dBm.

The BER should not fail in nominal as well as extreme conditions when the two interferers are present at the input. ARFCN is the channel number (EGSM 975-124) (GSM1800 512-885).

For Manual testing to find the margin, using the CMU200, select Application and BER Average to see the results continuously as you increase the Generator level.

2.6 Blocking and spurious response

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.7	Controlled

This can be seen as comparable to the Analog Receiver selectivity measurement.

The following section describes the measurement setups for in-band as well as out-of-band blocking measurement. The system should cover both EGSM900 and GSM1800 bands. The block diagram shown on the next pages summarizes the equipments applied.

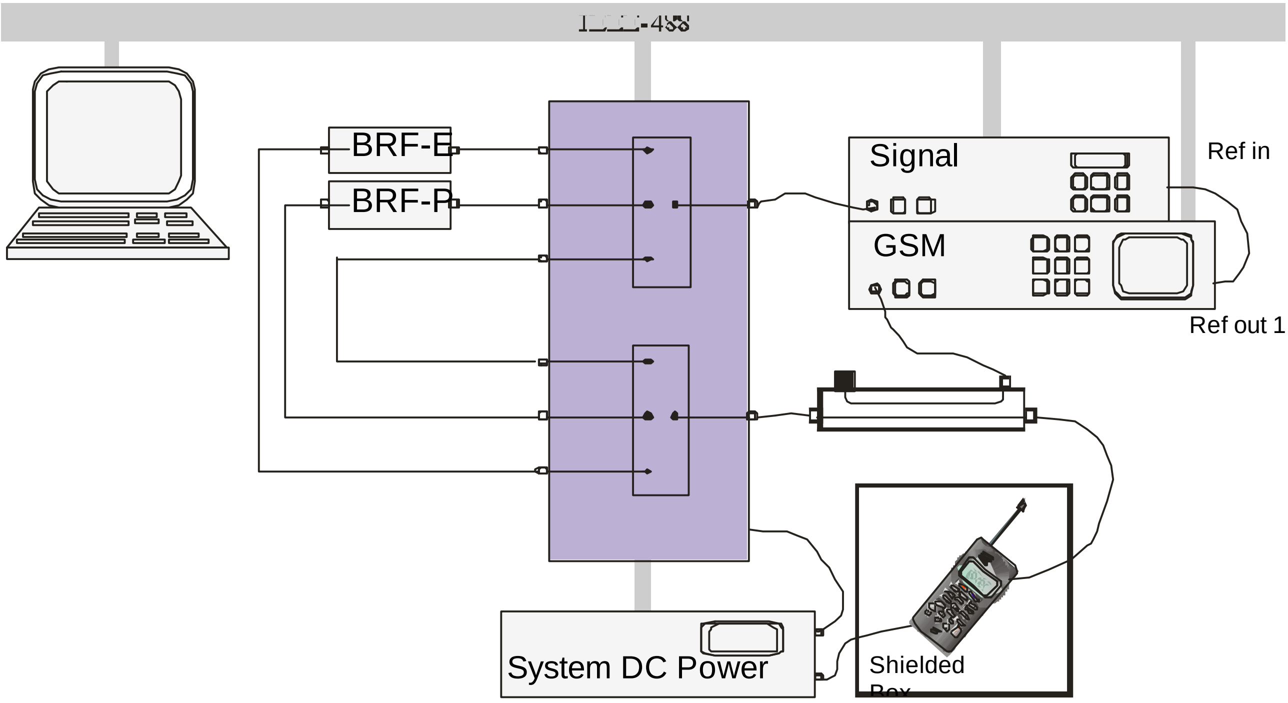


Figure 2.3 Measurement setup for blocking. The power supply is an Agilent E3631A and the GSM tester is a R&S CMU200. For the correct Signal Generator see paragraph below.

Signal Generator

The applied generator should be chosen such that it has the correct dynamic range to cover the blocking and spurious signal levels. This requires a dynamic range between –43 to –23 dBm for in-band blocking and –43 to o dBm for out-of-band blocking according to GSM specification 05.05. Furthermore, the phase noise, especially the SSB phase noise, should be low to minimize measurement inaccuracy.

Two signal generators applied at DWD are:

1) SME03E, 5kHz to 2.2GHz (PS! SMT03 has very bad spurious performance!)
2) SMR20, 1GHz to 20GHz.

SMR20 is used for the out-of-band blocking measurements, while SME03E is applied in-band blocking measurements since this has much better SSB phase noise close to the desired frequency.

The generators in the setups must be frequency locked.

Filters

When measuring the out-of-band blocking frequencies lower than the desired GSM signal a notch or band reject filter is desired at the output of the generator to attenuate the generators harmonics that may fall together with the received GSM signal.

2.7 AM suppression

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.8	Controlled

This is a special form of what could also be described as a Adjacent Channel rejection measurement.

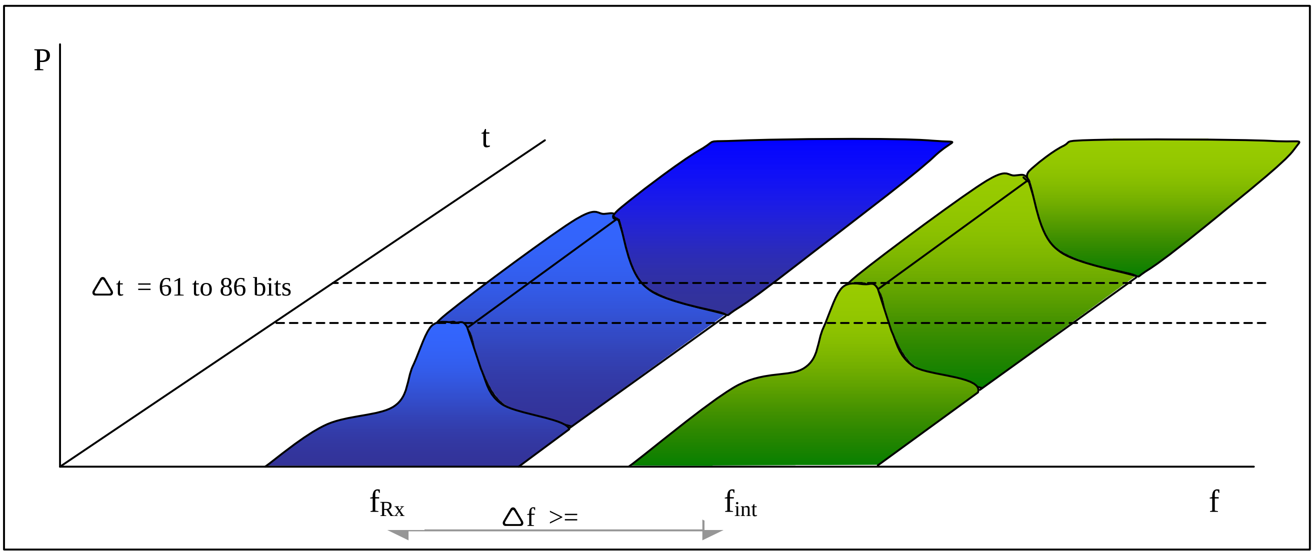
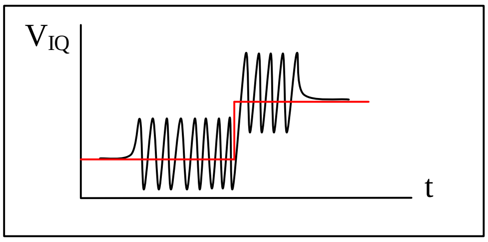


Figure 2.4 AM-suppression

The interference signal is defined in its worst case as a GSM modulated signal, which is 6 MHz from the wanted Rx signal. Furthermore, the signal burst is offset by 61 to 86 bits.

This is an important test case for the Direct Conversion architecture. Since the LO is in-band and the input at the mixer is matched for the band, the interference signal (also in-band) can self-mix in the mixer, resulting in an unwanted signal at the IQ output. The Self-mixing level is, however, much smaller than the LO level, hence, the unwanted mixed output will not effect the wanted IQ but it will add an additional DC voltage offset. When the interfere is time shifted by worst-case 61-86 bits, this DC voltage offset will occur in the middle of the received signal. This DC jump must be compensated for in the BB.



(For the SMARTi DC a AM trigger signal tells the BB when the above DC offset occurs and the BB can then perform a new averaging to improve the BER.)

The AM-suppression is measured applying the setup shown in Figure 2.5. The interference signal should be a GSM modulated signal. This signal should be applied together with the desired signal and inside the same RX burst with a delay of 61-86 bit period. A trigger signal, IQON, can be taken from the mobile to trig the signal generator, which generates a GSM signal with the specified delay. A more convenient way is to use the GSM tester auxiliary signal output (AUX1 on CMU200).

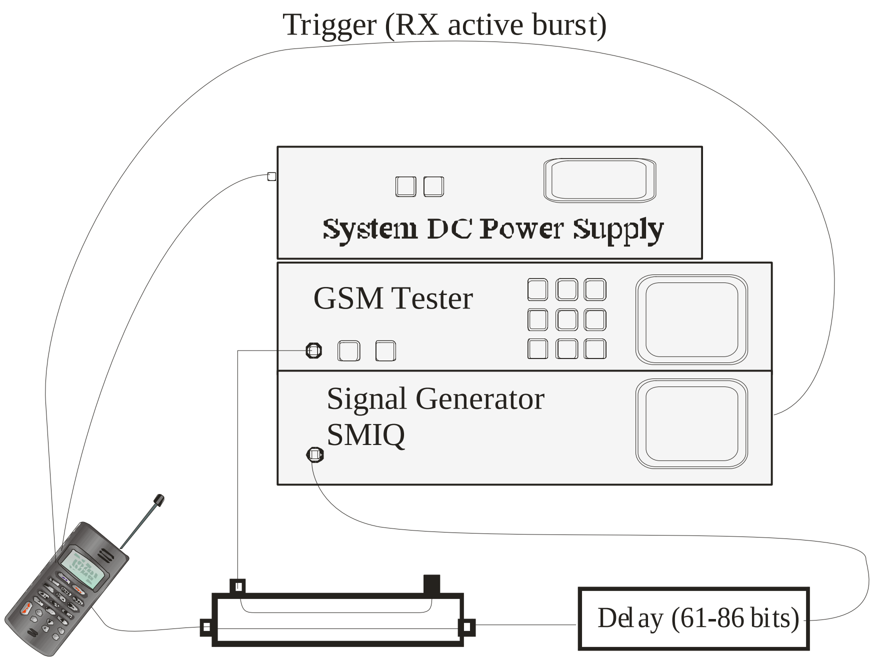


Figure 2.5 Measurement setup for AM-suppression.

If the generator SMIQ from R&S with a trigger signal from CMU200 or IQON from the MS, the following setup should be applied:

- CMU200 -> Connect ctrl -> Page2
  - AUX1 set to default
  - For every
- Digital STD -> GSM/Edge
  - State -> ON
  - Modulation -> GMSK/8PSK Edge
  - Trig mode -> Retrig
  - Trigger -> Ext at parallel data (Pin 14 at par-data on generator)
    - Trigger Source -> Ext
    - Ext trigger delay -> 950-960 symb
  - Ext. Inputs...
    - Threshold -> 1 V
    - Impedance -> 1k/gnd
    - Clock slope -> free
    - Trig slope -> Neg. for CMU200 trigger and Pos. for IQON trigger

The bit error rate should not exceed 2.4% when a desired signal at –99 dBm is present at the antenna input together with an AM interferer of –31 dBm at frequency f, where $|f-f_o|$ >=6MHz. The following table show example with the frequency settings of the AM-signal for some channels.
Use as high a power level as possible without getting an error on the generator.

EGSM900					
Channel	**975**	**20**	**62**	**80**	**124**
Frequency [MHz]	925.2	939.0	947.4	951.0	959.8
-6MHz	919.2	933.0	941.4	945.0	953.8
+6MHz	931.2	945.0	953.4	957.0	965.8
GSM1800					
Channel	**512**	**600**	**699**	**810**	**885**
Frequency [MHz]	1805.2	1822.8	1842.6	1864.8	1879.8
-6MHz	1799.2	1816.8	1836.6	1858.8	1873.8
+6MHz	1811.2	1828.8	1848.6	1870.8	1885.8

3 Transmitter System measurements

3.1 Power & template

FTA	Document	Chapter	Environment
Required	GSM 11.10		Controlled

The PA ramp-up and ramp down has to conform to a specified template. It serves the purpose of defining when exactly a MS must and can transmit and when to stop transmission. The template is a measure of Output Power vs. Time.
Satisfying the template does not suffice the PA ramp up performance. The ramp up and ramp down of the PA must conform to the template while also minimizing the spurious emission as a result of the switching transient. That is a Spectrum measurement, see 3.3

This measurements is performed using the automatic measurements setup shown in Figure 1.1

3.2 Phase & frequency error

The phase and frequency error is the measure of the transmission quality and can be seen equivalent to the BER, which is the measure of the Receiver quality.

3.2.1 Phase & frequency error, conducted

FTA	Document	Chapter	Environment
Required	GSM 11.10		Controlled

First the Transmitter hardware without the antenna must be tested for phase and frequency error. This is done by connecting the MS via a Coax connector and cable to the GSM Tester or Spectrum Analyzer.

This measurements can also b performed using an automatic measurement setup shown in Figure 1.1

3.2.2 Phase & frequency error, air interface

FTA	Document	Chapter	Environment
Required	GSM 11.10		Variable

When the measurement in 3.2.1 is within the Specification, the measurement is repeated but now by disconnecting the coax and using the MS antenna (air interface). The MS is placed inside a shielded case with a measuring antenna. Here any phase or frequency error that is additional to the one measured in 3.2.1 is probably due to the radiation of the MS antenna on the MS Circuit. However the error could also be due to the multiple reflection inside the case, which could again affect the MS circuit. Its best to repeat this measurement with various shielded cases of different dimensions and measurement antenna types.
Since this is a uncontrolled environment, and not FTA required it merely serves to test for any feedback problems that may occur due to the antenna.

3.2.3 Phase & frequency error, air interface, front of MS on metal plate.

FTA	Document	Chapter	Environment
Required	GSM 11.10	14.6	Controlled

The measurement in 3.2.2 can be repeated by placing a metal plate in close proximity to the MS. This can be seen as a emulation of placing the MS on a metal table. Here the radiation from the antenna can travel along the metal plate and so couple back into the MS circuit.

3.3 Spectrum measurements

3.3.1 Harmonics & Spurious

FTA	Document	Chapter	Environment
Required	GSM 11.10	12.1.1	Controlled

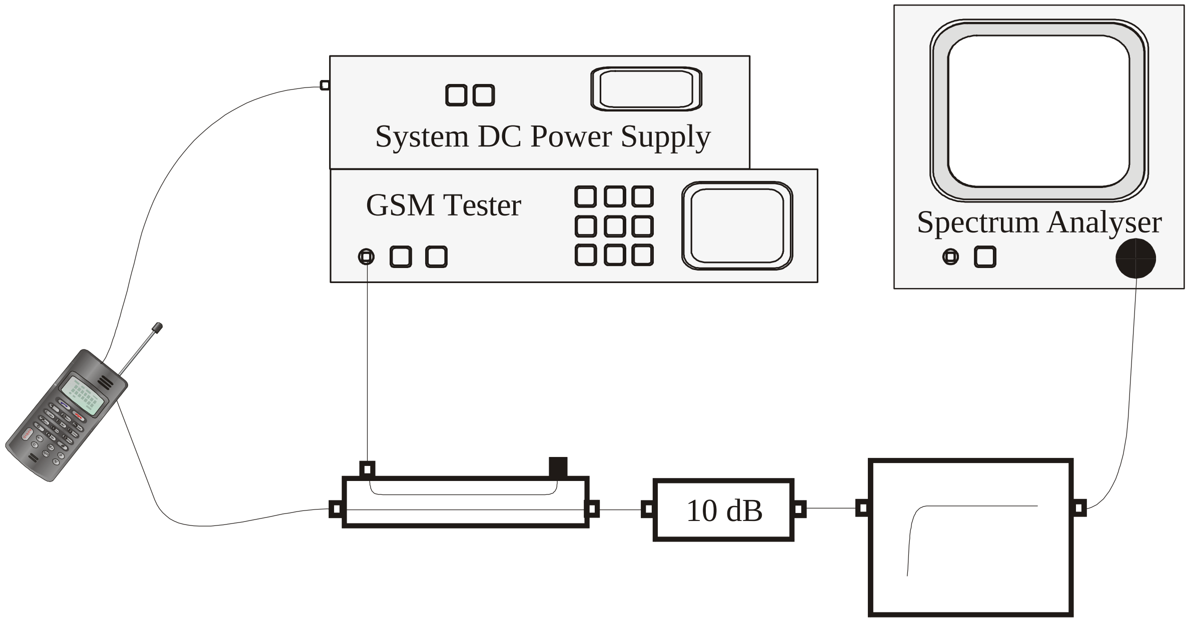


Figure 3.1. Setup for measuring harmonic distortion.

3.3.1.1 GSM900 harmonics:

Use the measurement setup as shown in Figure 3.1.
Instrument setup:

Power Supply:
Use e.g. Agilent E3631A
Norm. voltage 3.8 V DC.
Connect to the battery connectors on the MS.

Directional Coupler:
Use e.g. Arra 2-3174-20. 0.5 GHz…20 GHz, 20 dB.
Use an antenna connecter to connect the MS to the directional coupler.

High Pass Filter:
Use e.g. 1.4 GHz HP filter for 2. harmonic GSM900 and 2.4 GHz HP filter for all other measurements – model Bundgaard, loss 2-3 dB
Insert a 10 dB attenuator between the high pass filter and the directional coupler.

GSM Tester:
Use e.g. Rohde & Schwarz Univerversal Radio Communication tester CMU 2000
Connect the GSM tester to the directional coupler.
Set Power Control Level (PCL) at 5, equals max power / 33 dBm.

Set traffic channel at 62, equals center frequency at 902.4 MHz.
Adjust the Ext. Att. Output to match the attenuation from the GSM tester to the MS. (About 21 dB).

Spectrum Analyzer:
Use e.g. Rohde & Schwarz Spectrum analyzer 9 kHz…7 GHz. FSP.
Connect the spectrum analyzer to the output of the high pass filter
Set RBW and VBW at 3 MHz.
Set Reference Level Offset to match the attenuation form the MS to the spectrum analyzer. (About 13 dBm).
Set span at 50 MHz.
Use the max hold setting.
Use peak search.

A call is set up between the GSM-tester and the MS.

Measure the harmonic emission at center frequency equals harmonic frequencies.

Harmonic	Frequency (Mhz)	Maximum level (dBm)
2	1804.8	-30
3	2707.2	-30
4	3609.6	-30
5	4512.0	-30
6	5414.4	-30

3.3.1.2 GSM1800 harmonics:

Use the same setup as in measurements of the GSM 900 harmonics.

GSM Tester:
Set Power Control Level (PCL) at 0, equals max power / 30 dBm.
Set traffic channel at 699, equals center frequency at 1747.6 MHz.
Adjust the Ext. Att. Output to match the attenuation from the GSM tester to the MS. (About 21 dB).

A call is set up between the GSM-tester and the MS.

Measure the harmonic emission at center frequency equals harmonic frequencies. I.e. 2. harmonic at 3495.2 MHz and 3. harmonic at 5242.8 MHz.

3.3.2 Noise in RX

FTA	Document	Chapter	Environment
Required	GSM 11.10	13.4	Controlled

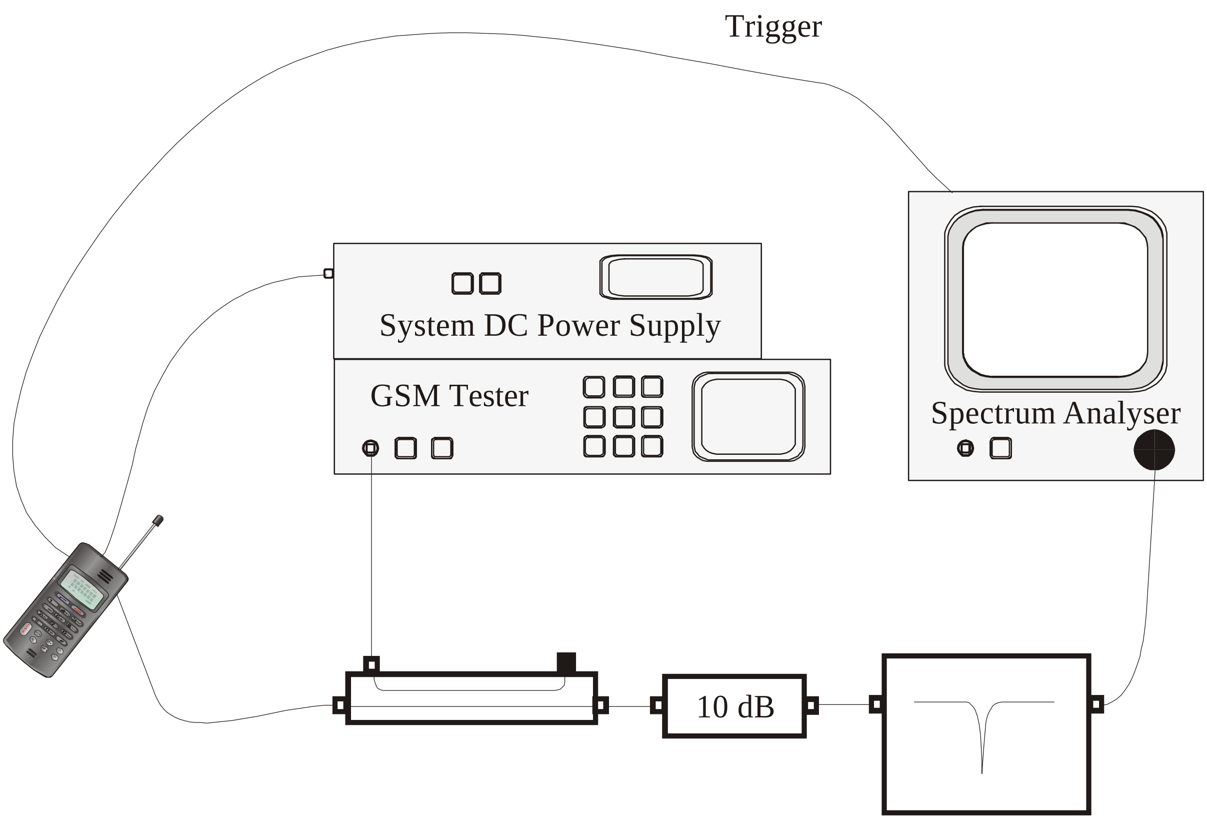


Figure 3.2 Setup for measuring noise in RX.

3.3.2.1 GSM900:

Use the measurement setup as shown in Figure 3.2.
First calibrate the spectrum analyzer.

Calibration:

Signal Generator:
Use e.g. Rohde & Schwarz Signal Generator. 5kHz…3 GHz, SMT03.
Set frequency at 930 MHz.
Set power level at –50 dBm.

Apply the signal generator at the MS reference plane
Adjust the reference level offset on the spectrum analyzer to marker level equals –50 dBm at 930 MHz.

Instrument Setup:

MS under test:
Solder wire to pin 8 on IC4 (the control signal for the PA controller), use as trigger to the spectrum analyzer.

Power Supply:
Use e.g. Agilent E3631A
Norm. voltage 3.8 V DC.
Connect to the battery connectors on the MS.

Directional Coupler:
Use e.g. Arra 2-3174-20. 0.5 GHz…20 GHz, 20 dB.
Use an antenna connecter to connect the MS to the directional coupler.

Notch Filter:
Tuned to max loss at 902.4 MHz

GSM Tester:
Use e.g. Rohde & Schwarz Univerversal Radio Communication tester CMU 2000
Connect the GSM tester to the directional coupler.
Set Power Control Level (PCL) at 5, equals max power / 33 dBm.
Set traffic channel at 62, equals center frequency at 902.4 MHz.
Adjust the Ext. Att. Output to match the attenuation from the GSM tester to the MS. (About 21 dB).

Spectrum Analyzer:
Use e.g. Rohde & Schwarz Spectrum analyzer 9 kHz…7 GHz. FSP.
Use gated sweep, see figure 4. Setup:
- Set center frequency at 902.4 MHz and set span at 0 MHz.
- Gate delay 500 us.
- Gate length 125 us.
- External trigger.

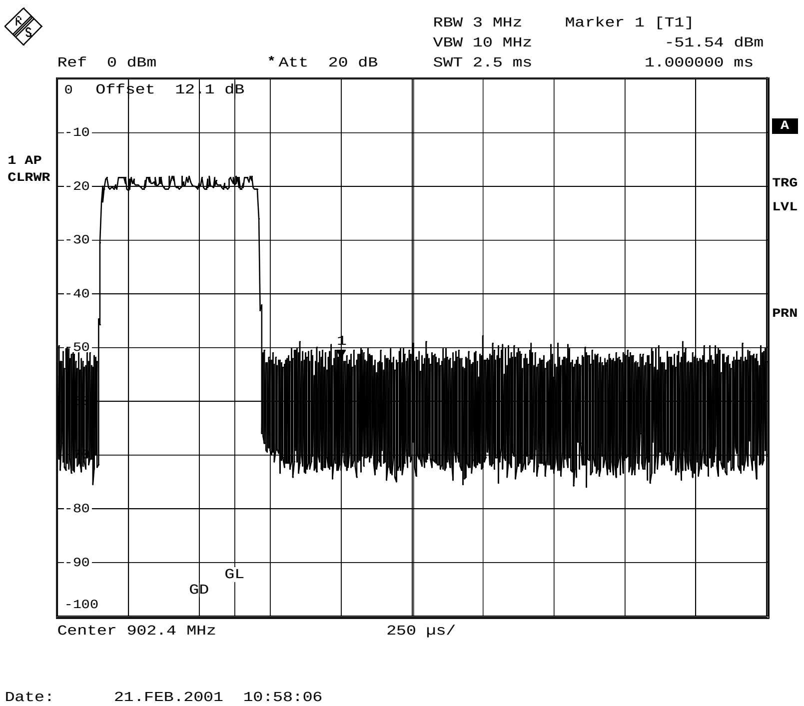


Figure 3.3 The gated sweep setup on the spectrum analyser. GD is the gate delay and GL is the gate length.

Set RBW and VBW at 100 kHz.
Set reference level at –10 dBm.
Set Fstart at 925 MHz.
Set Fstop at 960 MHz.
Set sweep counts at 100.
Use the average settings.

Make a hardcopy of the screen.

3.3.2.2 GSM1800:

Use the same setup as in measurement on GSM900.
First calibrate the spectrum analyzer.

Calibration:

Signal Generator:
Set frequency at 1810 MHz.
Set power level at –50 dBm.

Apply the signal generator at the MS reference plane
Adjust the reference level offset on the spectrum analyzer to marker level equals –50 dBm at 1810 MHz.

Instrument setup:

Notch Filter:
Tuned to max loss at 1747.6 MHz

GSM Tester:
Connect the GSM tester to the directional coupler.
Set Power Control Level (PCL) at 0, equals max power / 30 dBm.
Set traffic channel at 699, equals center frequency at 1747.6 MHz.
Adjust the Ext. Att. Output to match the attenuation from the GSM tester to the MS. (About 21 dB).

Spectrum Analyzer:
Use the same gate settings as in measurements on GSM900.
Set Fstart at 1805 MHz.
Set Fstop at 1880 MHz.

Make a hardcopy of the screen.

3.3.3 Modulation Spectrum

FTA	Document	Chapter	Environment
Required	GSM 11.10		Controlled

3.3.4 Switching Spectrum

FTA	Document	Chapter	Environment
Required	GSM 11.10		Controlled

3.4 Stability measurement

FTA	Document	Chapter	Environment
None			Controlled

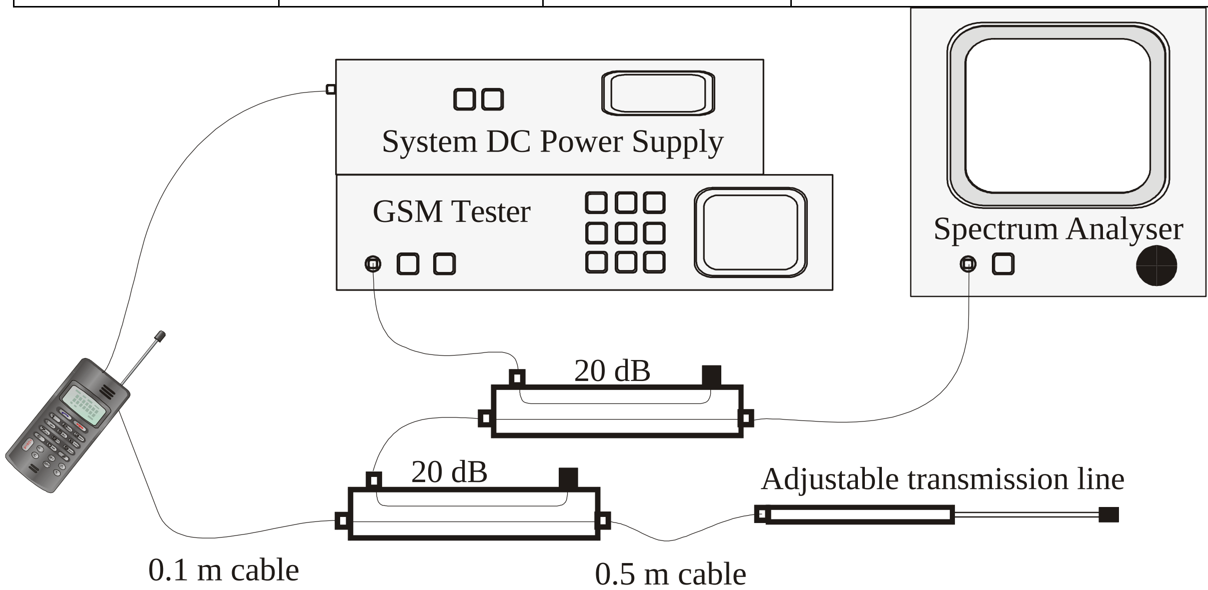


Figure 3.4. Setup for stability measurements.

3.4.1.1 GSM900

Use the setup as shown in Figure 3.4.

Instrument Setup:
Power Supply:
Use e.g. Agilent E3631A
Norm. voltage 3.8 V DC.
Connect to the battery connectors on the MS.

Directional Coupler:
Use e.g. Arra 2-3174-20. 0.5 GHz…20 GHz, 20 dB.
Use an antenna connecter to connect the MS to the directional coupler.

GSM Tester:

Use e.g. Rohde & Schwarz Univerversal Radio Communication tester CNU 2000
Connect the GSM tester to the power divider.
Set Power Control Level (PCL) at 5, equals max power / 33 dBm.
Set traffic channel at 62, equals center frequency at 902.4 MHz.
Adjust the Ext. Att. Output to meet the power level at 33 dBm. (About 41 dB).
Reduce the TCH Level to match the noise level on the spectrum analyzer. (About –60 dBm)

Spectrum Analyzer:
Use e.g. Rohde & Schwarz Spectrum analyzer 9 kHz…7 GHz. FSP.
Set RBW and VBW at 3 MHz.
Set reference level to match the attenuation form the MS to the spectrum analyzer. (about 21 dBm).
Set center frequency at 902.4 MHz.
Set span at 1 GHz.
Use the max hold setting.

Slowly change the length of the transmission line.

Check for any resonance in the frequency range.

3.4.1.2 GSM1800

Use the same setup as for GSM900.

Instrument Setup:

GSM Tester:
Set Power Control Level (PCL) at 0, equals max power / 30 dBm.
Set traffic channel at 699, equals center frequency at 1747.6 MHz.
Adjust the Ext. Att. Output to meet the power level at 30 dBm. (about 41 dB).
Reduce the TCH Level to match the noise level on the spectrum analyzer. (About –60 dBm)

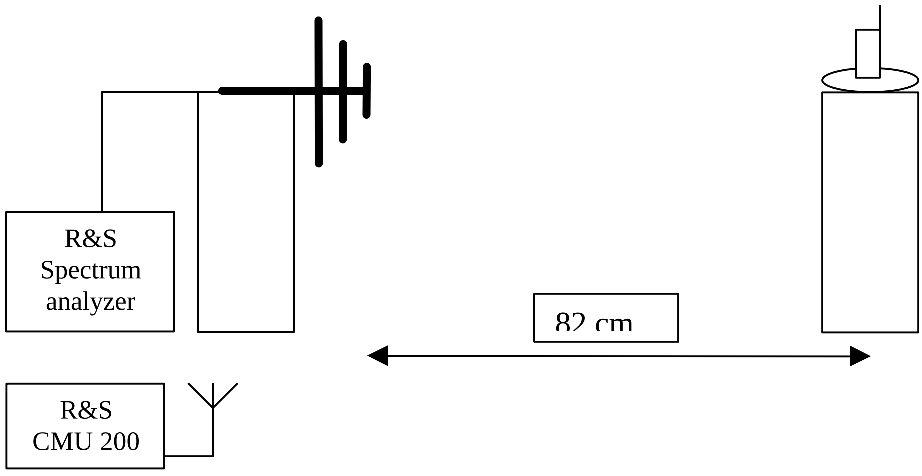
Spectrum Analyzer:
Set center frequency at 1747.6 MHz.
Set span at 1 GHz.
Use the max hold setting.

Slowly change the length of the transmission line.
Check for any resonance in the frequency range.

4 Antenna System measurements

4.1 Antenna room setup

1. Phone tower must be placed in corner of absorbing walls.
2. Antenna tower must be placed with an angle of 45° to both of the walls.
3. The distance must be 82 cm from end of log-periodic antenna to center of phone tower.
4. Any conducting objects must be removed from the antenna room and the surroundings.
5. The control cables must be placed together and on the 45° line away from the phone tower.
6. The log-periodic antenna is connected to the spectrum analyzer via a notch filter.
7. THE 2 YAGI ANTENNAS ARE CONNECTED TO THE CMU 200.
8. THE PC IS CONNECTED TO THE CONTROL BOX, THE CMU AND THE SA.



4.2 Antenna room calibration

- The harmonics below 4 GHz are calibrated.
- The test channel is no. 62 for EGSM 900 and channel 699 for DCS 1800.
- 900 MHz notch filter is used at EGSM 900.
- 1800 MHz notch filter is used at DCS 1800.
- A cable is positioned along the control cables, up in the phone tower.
- For each harmonic a reference dipole is used.
- A generator is setup for the right frequency.
- The power at the end of the cable is adjusted for –2.1 dBm.
- The reference dipole is attached and positioned in vertical position, like the log-periodic antenna.
- The spectrum analyzer is set to the right frequency, 0 Hz bandwidth, 3 MHz RF bandwidth and 3 MHz video bandwidth.
- The attenuation of the spectrum analyzer is set to 0 dB.
- The trace is set to max. hold and peak search.
- The calibration figure is calculated by [GENERATOR LEVEL – SA LEVEL].
- The figures are used in the antenna simulation program.

GSM	Frequency	Signal generator level	Cable loss	Input level at antenna	Antenna gain	Output antenna	Airlink and cable loss	Measured SA level without HP-filter	HP-filter loss measuerd	HP-filter loss calculated	Measured SA level incl. HP-filter	Measurement offset
1. Harmonic	902.4	11.1	-3.2	7.9	2.1	10	-28.6	-18.6	-65.6	-55.6	-74.2	**-94.2**
2. Harmonic	1804.8	-27	-5.1	-32.1	2.1	-30	-32.1	-62.1	-0.7	-0.1	-62.2	**-32.2**
3. Harmonic	2707.2	-25.1	-7	-32.1	2.1	-30	-36.7	-66.7	-0.2	-0.1	-66.8	**-36.8**
4. Harmonic	3609.6	-23.1	-9	-32.1	2.1	-30	-38.7	-68.7	-0.7	-0.7	-69.4	**-39.4**
DCS												
1. Harmonic	1747.6	12	-4.1	7.9	2.1	10	-40	-30	-35.8	-33.3	-63.3	**-73.3**
2. Harmonic	3495.2	-23.8	-8.3	-32.1	2.1	-30	-37.7	-67.7	-0.5	-0.3	-68	**-38**

Latest calibration 2002-07-04 by LG

4.3 Antenna radiation pattern

FTA	Document	Chapter	Environment
Required	GSM 11.10		Semi-Controlled

The mobile is rotated through 360° , while level is measured.

4.4 Antenna spurious measurements

FTA	Document	Chapter	Environment
Required	GSM 11.10		Semi-Controlled

The spurious signals from the MS are measured by scanning with the spectrum analyzer set to zero span, and measuring at every ...... Hz.

4.5 SAR

FTA	Document	Chapter	Environment
None			Controlled

This measurement is done out of house. It is required by the US only at the moment.

5 Receiver module measurements

5.1 Receiver block measurements

6 Transmitter module measurements

6.1 Modulator measurements

6.1.1 Modulator spectrum

6.1.2 Modulator lock-up time

6.2 Power amplifier measurements

6.2.1 Control loop

6.2.2

7 Syntheziser module measurements

7.1 LO1 measurements

7.1.1 LO1 spectrum

7.1.2 LO1 lock-up time

7.2 LO2 measurements

7.2.1 LO2 spectrum

7.2.2 LO2 lock-up time

8 Antenna module measurements

8.1 Antenna matching