Measurement of Spurious Emissions of GSM, DCS 1800 and PCS 1900 Transmitters with Spectrum Analyzers of the FSE Family

Application Note 1EPAN17E

Subject to Change

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Products:

FSEA 20/30, FSEB 20/30

ROHDE&SCHWARZ

Overview

Measuring the spurious emissions of transmitters used in GSM, DCS 1800 and PCS 1900 networks requires highly complex test setups since conventional spectrum analyzers do not have the necessary dynamic range. To obtain this range, notch filters are used to suppress the useful signal. The spectrum analyzers of the FSE family make it possible for the first time to verify compliance with stipulated limit values for spurious emissions within the transmission band and outside the reception band without the use of notch filters.

The measurement problem and its solution by means of FSE are described in the following by way of the example of a GSM base station.

Measured Quantities

In radiocommunication systems, not only the correct transmission of speech or data in the useful channel is important, it is also necessary to prevent impairment of other subscribers or radio services. To ensure unperturbed radiocommunication in adjacent channels and for neighbouring services, spurious emissions must be kept to a minimum. Measuring the spurious emissions of mobile and base stations of GSM, DCS 1800 and PCS 1900 networks makes exacting demands on the dynamic range of the spectrum analyzer used.

Relevant specifications differentiate between three different frequency bands, to which different test setups and limit values apply:

- transmission band of the base station or mobile station
- reception band of the base station or mobile station and
- all other frequencies between 9 kHz and 12.75 GHz.

Transmission Band of Base Station

Spurious emissions must be measured with different resolution bandwidths depending on the offset from the carrier.

The permitted maximum power is -36 dBm irrespective of the output power of the base station. The measurement must be made with peak hold.

Offset from transmission frequency	Resolution bandwidth
≥ 600 kHz	10 kHz
≥ 1.8 MHz	30 kHz
≥ 6 MHz	100 kHz

Reception Band of Base Station

The measurement must be made with a resolution bandwidths of 30 kHz. The limit value is -103 dBm, measured with peak hold. This value corresponds to the limit of sensitivity of the base station receiver.

Other Frequencies

Spurious emissions are measured with the following bandwidths depending on the offset from the transmission band:

Offset from transmission band	Resolution bandwidth
≥ 2 MHz	30 kHz
≥ 5 MHz	100 kHz
≥ 10 MHz	300 kHz
≥ 20 MHz	1 MHz
≥ 30 MHz	3 MHz

The measurement must be made with peak hold. Up to 1 GHz the level of spurious emissions may be max. -36 dBm, from 1 GHz max. -30 dBm.

The stipulated limit values for spurious emissions represent exacting demands on the dynamic range and the sideband noise of a spectrum analyzer, especially if the power level of the base station is high. For example, when measuring a base station with an output power of 20 W (corresp. to 43 dBm) in the transmission band with a carrier offset of 6 MHz, the following requirements have to be met:

A signal spaced 79 dB from the carrier must be measured with peak hold at a resolution bandwidth of 100 kHz.

At a maximum mixer level of -10 dBm, a noise level of -99 dBm (peak value for 100 kHz bandwidth) is required for the FSE noise floor to be 10 dB from the limit value. The spectrum analyzer therefore must have a noise figure of approx. 15 dB according to the following formula:

NF = -174 dBm + 10 x log(100 kHz / 1 Hz) + 10 dB - (-99 dBm) = **15 dB**, where

-174 dBm = thermal noise of 50-Ω resistance for 1-Hz bandwidth

50 dB = 10 x log(100 kHz / 1 Hz) = noise increase for 100-kHz bandwidth compared with 1-Hz bandwidth

10 dB = difference between noise peak and rms value

99 dBm = max. peak noise value

Phase noise at 43 dBm transmitter power must not exceed 149 dBc/Hz for 10-dB spacing from the limit value.

Lc = 43 dBm - (-36 dBm) + 10 dB1) + 10 dB2) + 50 dB = **149 dBc/Hz**,

where

Lc = SSB phase noise of spectrum analyzer

43 dBm = transmitter power of base station

-36 dBm = limit value for spurious emissions

10 dB1) = difference between noise peak and rms value

10 dB2) = level of noise floor from limit value

50 dB =10 x log(100 kHz / 1 Hz) = noise increase for 100-kHz bandwidth compared with 1-Hz bandwidth

Conventional spectrum analyzers do not meet noise floor and phase noise requirements. They therefore use narrowband notch filters to suppress the useful signal. The filters are in the form of mechanical cavity resonators to satisfy the stringent quality demands. The high requirements regarding noise floor and phase noise are no longer relevant as only a small amount of the useful power is applied to the input of the spectrum analyzer.

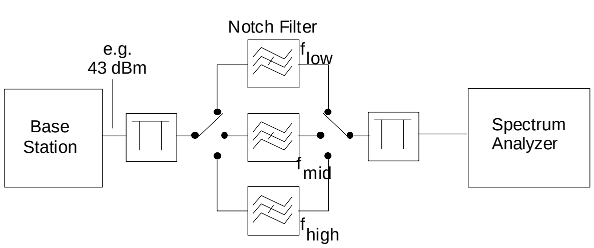

FIG 1 Conventional test setup for measuring spurious emissions in transmission band according to Rec 11.20

Measurements in the transmission band of a base station require at least three notch filters as specifications stipulate measurements in the lowest, a middle and the highest channel. In automatic measurements, eg in production, this necessitates the use of relay switches, which is problematic if only for the limited service life of such mechanical parts.

Dynamic Range of FSE

The wide dynamic range and low phase noise of FSE make it possible to verify compliance with stipulated limit values without the use of notch filters. This considerably simplifies the test setup.

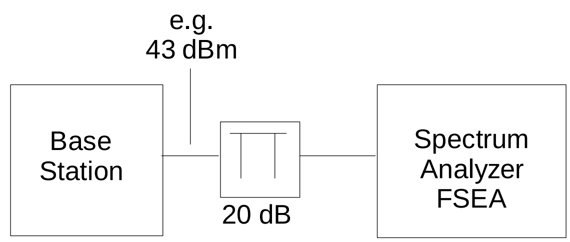

FIG 2 Test setup with FSEA for measuring spurious emissions in transmission band in line with Rec 11.20

For example, a base station operates with an output level of 43 dBm. A 20-dB power attenuator must be connected between the RF output of the base station and the input of FSE to prevent damage to the RF input of FSE. The level at the RF input of FSE is thus +23 dBm.

Since both the useful signal and spurious emissions are attenuated by 20 dB, the limit value for spurious emissions is -56 dBm.

Due to the high overload capacity of the signal path up to the IF filter, the RF input can be overdriven by at least 15 dB without compression occurring. Thus, with an RF attenuation of 0 dB, the maximum input level is +5 dBm (= maximum mixer level of -10 dBm plus 15 dB overload margin). If overload occurs in the signal path up to the IF filter, FSE signals overload (OVLD) on the monitor or via the remote control interface.

With an input level of 23 dBm, an RF attenuation of no more than 20 dB is required. The mixer level is thus +3 dBm. The displayed noise floor with this setting is -75 dBm as follows.

-75 dBm = -145 dBm + 40 dB + 20 dB + 10 dB,

where

-145 dBm = guaranteed displayed noise floor of FSEA at 10-Hz bandwidth

40 dB = 10 x log (100 kHz / 10 Hz)

20 dB = RF attenuation

10 dB = difference between peak and rms noise floor

FSEA thus has a margin of 19 dB relative to the limit value of -56 dBm. The specified noise floor of FSEB is 3 dB higher, resulting in a margin of min. 16 dB relative to the limit value.

The second quantity determining the dynamic range, ie the phase noise, is as follows:

Phase noise at 6 MHz from the carrier is typ. -153 dBc/Hz for FSEA, for FSEB -147 dBc/Hz due to internal frequency doubling. For an offset of 6 MHz from the carrier, a resolution bandwidth of 100 kHz is stipulated. For an input level of 23 dBm at FSE, the following noise level is obtained:

P_{noise} = 23 dBm - (153 dBc/Hz - 10 x log (100 kHz / 1 Hz) - 10 dB)

= **-70 dBm**,

where

23 dBm = level at RF input of FSE

153 dBc/Hz = SSB phase noise of FSE

50 dB = 10 x log (100 kHz /1 Hz)
= increase of noise at 100-kHz bandwidth relative to 1-Hz bandwidth

10 dB = difference between peak and rms noise floor

FSEA thus has a margin of 14 dB relative to the limit value of -56 dBm. This margin is 8 dB in the case of FSEB because its phase noise is 6 dB higher. The margin increases or decreases proportionally to the transmitter power. For example, with a transmitter power as low as 39 dBm, the margin increases by 4 dB to 18 dB or 12 dB, respectively.

FIG 3 illustrates the phase noise of FSEA for carrier offsets between 0.6 and 25 MHz.

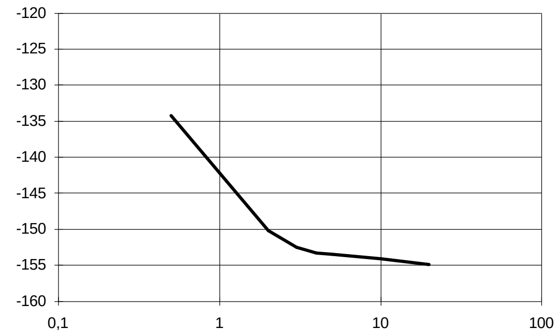

FIG 3 SSB phase noise as a function of offset from carrier (X axis in kHz; Y axis: dBc)

Measurements with FSE

In the following example, SMHU from Rohde & Schwarz is used as a signal generator. To demonstrate the characteristics of FSEA, a 2-MHz bandpass filter tuned to the transmit frequency is connected between the signal generator output and the FSEA input to clear the transmitted signal from broadband noise. For relatively small carrier offsets, the phase noise of SMHU is low enough to demonstrate the characteristics of FSE. If another signal generator is used, it must be ensured that results are not affected by its phase noise. SMHU is operated at an output level of +13 dBm, which corresponds to a base station transmitting at 43 dBm, with a 30-dB at tenuator connected between the base station and FSE.

- Bring FSE to its basic setting by pressing key [**PRESET**].
- Connect transmitter output with RF input. Important: when measurements are made on a base or mobile station, the transmitter power may in no case exceed 30 dB. If this is the case, connect a power attenuator between the signal generator output and the RF input.
- Set frequency of 935.2 MHz and level of +13 dBm on SMHU.
- Set start frequency on FSE to 941.2 MHz: [**START**: *941.2* MHz].
  Set stop frequency to 960 MHz: [**STOP**: *960* MHz].
- Set RF attenuation of FSE to 10 dB: [**REF**: ATTEN MANUAL: *10* dB]

*Note: With a signal generator power of 13 dBm and an RF attenuation of 10 dB, the signal path of FSE up to the IF filter will not be overloaded (power level at input mixer = 3 dBm). Any overload condition would be indicated by the message **OVLD** in the upper left of the screen.*

- Set level offset of 30 dB on FSE: [**REF**: REF LEVEL OFFSET: *30* dB]

  Note: the level offset makes up for the 30-dB attenuator in the level display of FSE.
- Set resolution bandwidth to 100 kHz [**COUPLING**: RBW MANUAL: 100 kHz: VBW MANUAL: 300 kHz]

  and select RBW/VBW coupling ratio of 0.3: [**COUPLING**: COUPLING RATIO: RBW/VBW MANUAL *0.3* **ENTER**].
- Set weighting to peak hold: [**TRACE 1**: DETECTOR: SAMPLE: ⇑: MAX HOLD]

Limit Values

The limit value for spurious emissions is -36 dBm in the frequency range under consideration. Due to the level offset entered, the limit value remains constant irrespective of the attenuator used. The offset need only to correspond to the attenuation between the signal generator output and the FSE input.

The limit value may be defined and displayed as a limit line. FSE can perform limit-value monitoring in automatic measurements, eg in production, by means of the limit check function. When this function is active, FSE signals

"*Limit Pass*" when limits are complied with and

"*Limit Fail*" when limits are exceeded.

Defining limit values:

- Press key [LIMITS].
- Softkeys [NEW LIMIT LINE: NAME]: enter name, domain, scaling, unit, limit and, if desired, comment for limit value as shown by the table below.
- Softkey [VALUES]: enter points for limit value as shown by the table below.
- Softkey [SAVE LIMIT LINE]: store limit line on FSE harddisk under the defined name.

Table of Limit Values

Name:	GSM_SPUR
Domain:	Freq
Scaling:	Absolute
Unit:	dBm
Limit:	Upper

Frequency	Limit
9 kHz	-36 dBm
890 MHz	-36 dBm
890 MHz	-103 dBm
915 MHz	-103 dBm
915 MHz	-36 dBm
12.75 GHz	-36 dBm

Note: the above table defines the complete limit line from 9 kHz to 12.75 GHz including the low limit value for the reception band of the base station. The definition can thus be used for measurements in all frequency ranges specified.

Switching on Limit Lines:

- Press key [**LIMITS**].
- Place cursor on GSM_SPUR.
- Press ENTER. GSM_SPUR will be marked by a tick.
- Press key [**CLR**] twice. The limit-line table and the limit menu will disappear from the screen.

FIG 4 below shows the displayed noise floor of FSEA when measuring spurious emissions in the transmission band of a GSM base station using the above test setup.

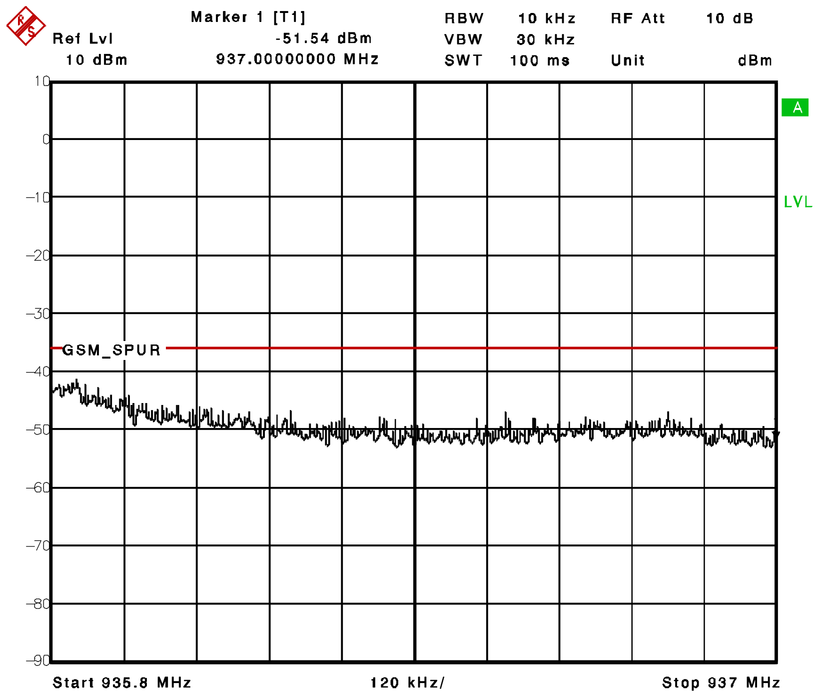

FIG 4 Displayed noise floor of FSEA relative to limit value in measuring spurious emissions in the transmission band of a GSM base station with a carrier offset of 600 kHz to 1.8 MHz (RBW = 10 kHz, VBW = 30 kHz).

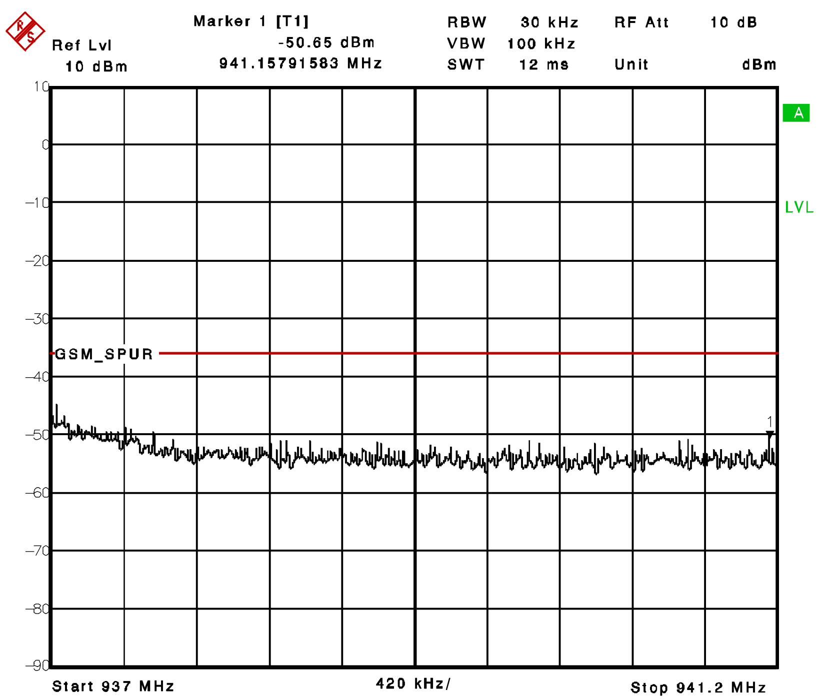

FIG 5 Displayed noise floor of FSEA relative to limit value in measuring spurious emissions in the transmission band of a GSM base station with a carrier offset of 1.8 to 6 MHz (RBW = 30 kHz, VBW = 100 kHz).

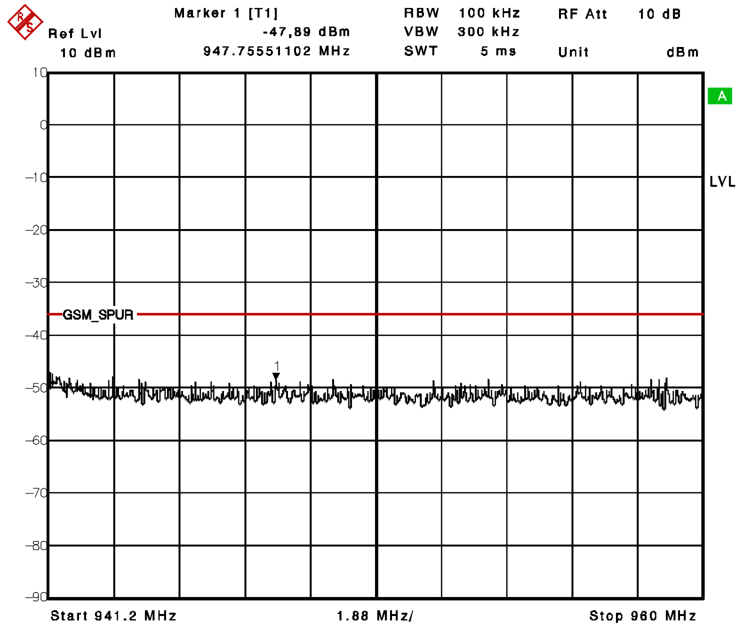

FIG 6 Displayed noise floor of FSEA relative to limit value in measuring spurious emissions in the transmission band of a GSM base station with a carrier offset of 6 to 25 MHz (RBW = 100 kHz, VBW = 300 kHz)

For measurements outside the transmission band, the considerations are virtually the same as for measurements within the transmission band. The bandwidth must be 1 MHz for carrier offsets from 20 MHz and 3 MHz for carrier offsets from 30 MHz. For this type of measurement, the thermal noise floor of FSE, not the phase noise, is the decisive factor. FIG 7 below shows the dynamic range of FSEA for a carrier offset of 30 MHz.

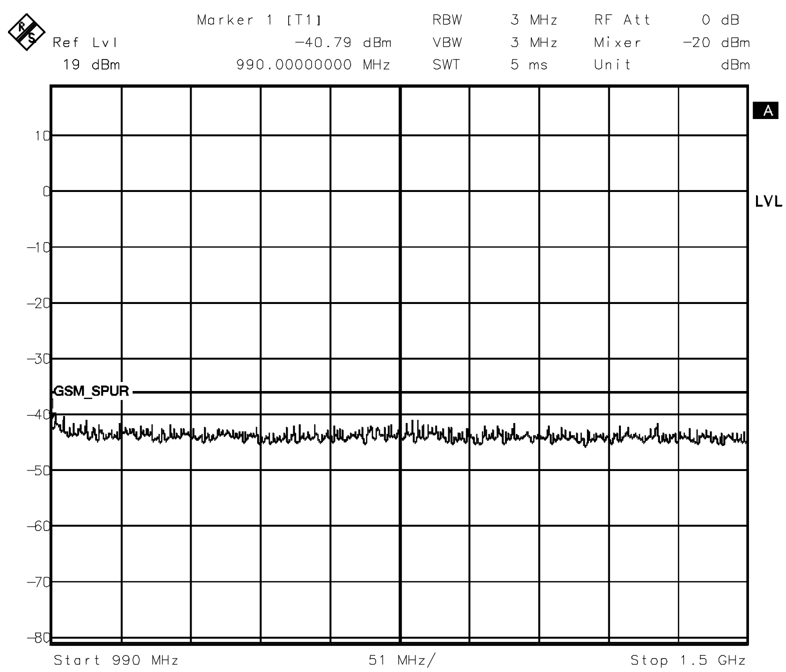

FIG 7 Displayed noise floor of FSEA relative to limit value in measuring spurious emissions of a GSM base station at offset of 30 MHz and higher from transmission band (RBW = 3 MHz, VBW = 3 MHz)

The low phase noise of FSEA provides a dynamic range wide enough to detect any spurious emissions of a transmitter exceeding specified limits.

What cannot be dispensed with is a bandstop filter for suppressing the transmitted signal in measuring spurious emissions in the reception band. The limit value for this type of measurement is -103 dBm for a bandwidth of 30 kHz, which is 67 dB lower than the limit value for frequencies outside the reception band. The bandpass filter used is however much less critical with respect to edge steepness, since in the case of GSM, the transmission and the reception band are spaced 20 MHz from each other. The entire transmission band can be suppressed by means of a single bandstop filter. Moreover, this filter suppresses the harmonics of FSE in the measurement of harmonics of the transmission frequency.

Thus, due to its high overload capacity, low noise figure and low sideband noise, FSE allows considerably simpler test setups for determining spurious emissions than conventional spectrum analyzers.

The definition of appropriate limit lines allows fast pass/fail decisions to be made in automatic operation, for example in production.

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