Product: Spectrum Analyzer FSU

Spurious Emission Measurement on 3GPP Base Station Transmitters

Application Note

This application note provides information about the spurious emission measurement on 3 GPP base station transmitters. The basic requirements and the limiting factors of a spectrum analyzer are explained in detail. Dynamic range calculations with measurement examples show the practical realisation of spurious emission measurements.

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Contents

1 Overview

Testing for spurious emissions is one of the most demanding measurements on base station (BS) transmitters, regardless of the technology used. It requires spectrum analyzer with extremely high dynamic range. Normally, additional equipment like notch filters and low noise pre-amplifiers are necessary to meet the demands. With the CDMA signals used for the 3GPP WCDMA system the demands are even higher, due to the nature of the signal. The spectrum analyzer needs to handle the peak amplitudes of the signal 8 to 12 dB higher than the mean power.

This application note explains the requirements for spurious emission measurements according to the 3GPP standards (TS25.104 and TS25.141). The parameters of the spectrum analyzer affecting its dynamic range are discussed and recommendations for the optimum setup of the analyzer are derived from these parameters. The recommended setups are supported by practical measurements on a base station simulated by a signal generator in the last section. Examples for practical test setups with external equipment requirements are presented to facilitate the planning of test setups for spurious emission measurements.

2 Requirements

Spurious emissions are caused by unwanted transmitter effects such as harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out of band emissions. Spurious emissions are measured at the base station RF output port.

Spurious emission is defined as transmission outside the frequency band 12.5 MHz below the first carrier and 12.5 MHz above the last carrier transmitted by a base station. Within this frequency band, a spectrum emission mask is defined for the measurement of "Out-of-Band emissions". Out-of-Band emissions are unwanted emissions immediately outside the channel bandwidth resulting from the modulation process and non-linearity in the transmitter but excluding spurious emissions. The Out-of-Band emission requirement is specified both in terms of a spectrum emission mask and Adjacent Channel Power Ratio for the transmitter.

The frequency range for spurious emission measurement is specified from 9 kHz to 12.75 GHz. TS25.104 states two categories of limits to be fulfilled by the base station. Category A applies in general and specifies relaxed limits compared to category B, which applies only for Europe. The difference is about 23 dB. All limits are specified as absolute values in dBm. This results in requirements harder to meet with high power base stations.

Unless otherwise stated, all limits refer to mean power measurements.

TS25.141 defines four different test models for the 3GPP base station conformance test. For the spurious emission measurements test model 1 shall be used. It consists of the organization channels and 64 traffic channels using 15 kbps transmission rate, each defined with its code number, a power level and a timing offset.
Some of the spurious emission limits are dependent on the frequency allocation of the base station, described in TS25.104 subclause 5.2. This application note assumes the following frequency allocation:

1920 – 1980 MHz:	Up-link (Mobile transmit, base receive)
2110 – 2170 MHz:	Down-link (Base transmit, mobile receive)

Mandatory Requirements

The power of any spurious emission shall not exceed the values shown below:

Table 1: BS Mandatory spurious emissions limits, Category B

Band	**Maximum Level**	**Measurement Bandwidth**
9 kHz ↔ 150 kHz	-36 dBm	1 kHz
150 kHz ↔ 30 MHz	-36 dBm	10 kHz
30 MHz ↔ 1 GHz	-36 dBm	100 kHz
1 GHz ↔ Fc1 - 60 MHz or 2100 MHz *whichever is the higher*	-30 dBm	1 MHz
Fc1 – 60 MHz or 2100 MHz *whichever is the higher* ↔ Fc1 – 50 MHz or 2100 MHz *whichever is the higher*	-25 dBm	1 MHz
Fc1 – 50 MHz or 2100 MHz *whichever is the higher* ↔ Fc2 + 50 MHz or 2180 MHz *whichever is the lower*	-15 dBm	1 MHz
Fc2 + 50 MHz or 2180 MHz *whichever is the lower* ↔ Fc2 + 60 MHz or 2180 MHz *whichever is the lower*	-25 dBm	1 MHz
Fc2 + 60 MHz or 2180 MHz *whichever is the lower* ↔ 12.75 GHz	-30 dBm	1 MHz

Fc1: Center frequency of emission of the first carrier transmitted by the BS.
Fc2: Center frequency of emission of the last carrier transmitted by the BS.

Additional Regional Requirements

Some requirements in TS 25.104 may only apply in certain regions.

The following table lists the requirements for spurious emission limits which are used in this application note. These are typical BS environments and take different types of users into account (GSM900, DCS1800, UTRA-TDD, and others). Refer to TS 25.104 for a complete list of regional requirements.

Table 2: Additional regional BS Spurious emissions limits (sample)

Band	Maximum Level	Measurement Bandwidth	Note
876 ↔ 915 MHz	-98 dBm	100 kHz	protection of the GSM 900 BTS receiver
921 ↔ 960 MHz	-57 dBm	100 kHz	geographic coverage area of GSM 900 MS receiver
1710 ↔ 1785 MHz	-98 dBm	100 kHz	BS co-located with DCS 1800 BTS
1805 ↔ 1880 MHz	-47 dBm	100 kHz	geographic coverage area of DCS 1800 MS receiver
1893.5 ↔ 1919.6 MHz	-41 dBm	300 kHz	geographic coverage area of PHS
1900 ↔ 1920 MHz	-52 dBm	1 MHz	geographic coverage area of UTRA-TDD
1920 ↔ 1980 MHz	-96 dBm	100 kHz	Protection of the BS receiver
2010 ↔ 2025 MHz	-52 dBm	1 MHz	geographic coverage area of UTRA-TDD

The following drawing shows these requirements in graphical format:

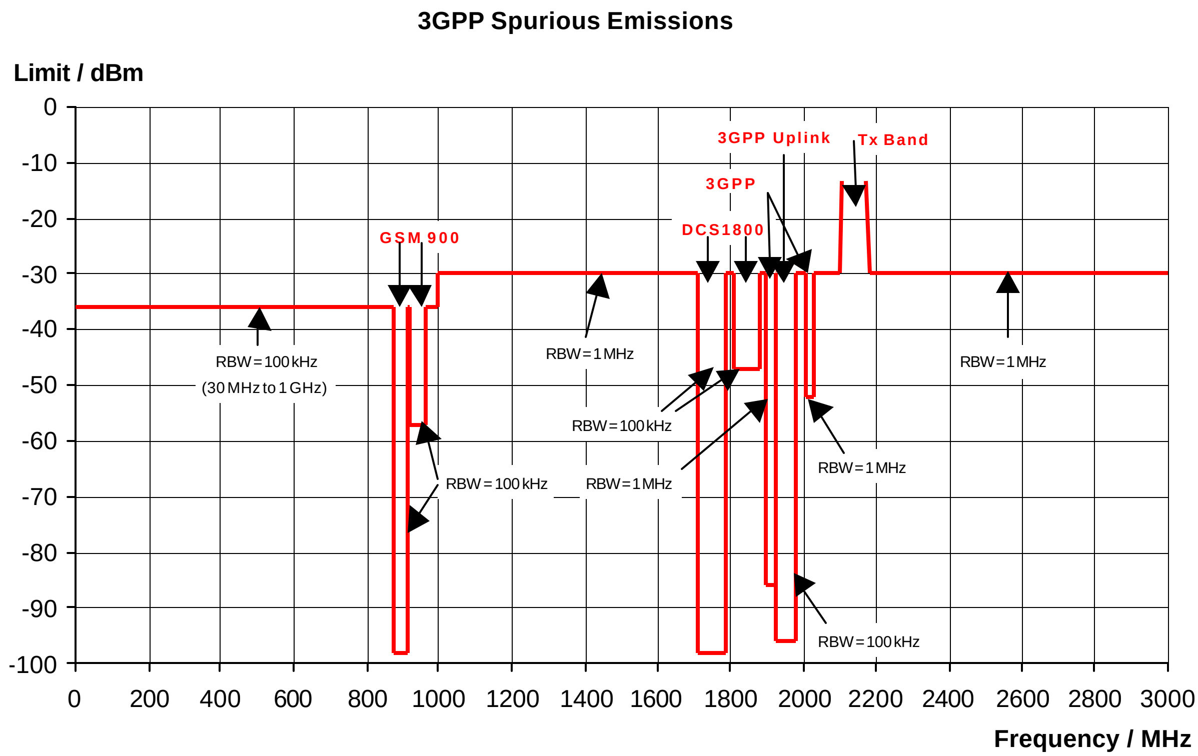

Fig. 1 Limits for spurious emissions in the Frequency range up to 3 GHz.

3 Spurious Measurement

The spurious emission measurement requires a spectrum analyzer with very high dynamic range, especially for high power levels from the base station. The limiting factors of the spectrum analyzer are its inherent thermal noise floor and its phase noise on the lower end, and its level compression on the upper end of the level range.

This section explains the behavior of the FSU spectrum analyzer at the lower and the upper end of the dynamic range, in order to derive a guideline for setting up the spectrum analyzer correctly.

Maximum Mixer Level

In order to obtain the maximum dynamic range for spurious measurement, the spectrum analyzer has to be loaded with the maximum possible level at the input mixer, without compressing the transmit signal. The level at the input mixer (mixer level) is the level applied to the RF input of the spectrum analyzer minus the RF attenuation. In other words, the RF attenuation has to be set to the minimum possible value that does not result in compression of the analyzer signal path.

The maximum mixer level depends on the carrier offset from the frequencies measured by the spectrum analyzer. The reason for this behavior can be seen from the simplified block diagram in the following figure.

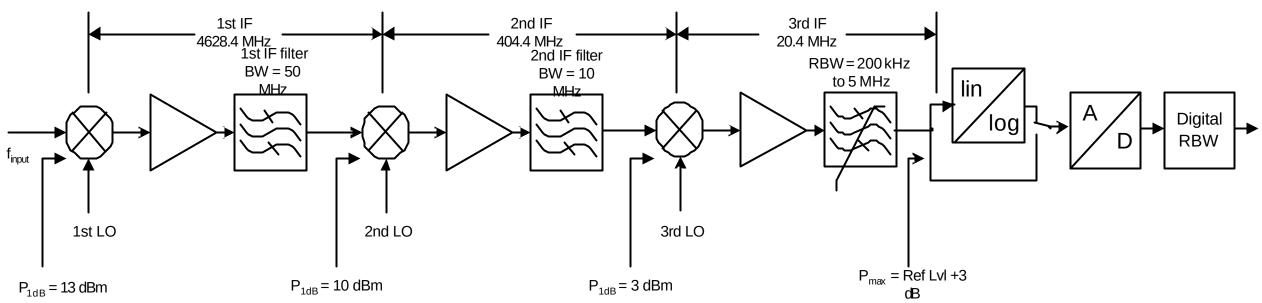

Fig 2 Simplified FSU RF block diagram

The FSU uses a triple conversion receiver concept. Following each conversion a bandpass filter is available for image frequency rejection. At the 1st IF the bandwidth of this filter is 50 MHz. This filter is also used as 50 MHz resolution bandwidth filter. Signals outside the 50 MHz bandwidth are attenuated and rejected from the 2nd mixer. The same applies to the 2nd IF with the 10 MHz wide IF filter. Signals outside the 10 MHz filter are attenuated and do not load the 3rd mixer. In the 3rd IF signal chain, the resolution bandwidths between 200 kHz and 5 MHz are implemented. With 1 MHz resolution bandwidth necessary in some frequency ranges, the spectrum is limited to 1 MHz in the 3rd IF before it is applied to the logarithmic converter and digitizer. This is also valid for the 300 kHz resolution bandwidth necessary for spurious measurement in the PHS band. For narrower resolution bandwidths (10 Hz to 100 kHz) the bandpass in the 3rd IF is used as a pre-filter for limiting the bandwidth in front of the A/D Converter and thus minimizing the signal load. The resolution bandwidths themselves are implemented digitally in an ASIC following the A/D converter. Fig. 2 also shows the 1-dB compression points of the different IF stages. All level values are related to the level at the input mixer.

Regarding the different bandwidths of the IF-stages the maximum level at the input mixer is dependent on the frequency offset from the TX signal. For offsets > 50 MHz from the TX signal only the 1st mixer is loaded with the TX signal. When the TX signal is closer to the measured frequency range (between 50 MHz and 20 MHz offset), also the 2nd mixer is loaded more and more. The 1st IF filter does not attenuate the TX signal for these frequency offsets any more. With TX signal offsets less than 20 MHz the 3rd IF stages are loaded also and contribute to the 1dB compression point of the analyzer.

The FSU provides an overload detector in each IF stage. If a signal is close to the 1 dB compression point an overload warning "OVLD" is displayed on the screen. Due to the different load capability of the IF stages the level for an overload warning is dependent on the frequency offset of the TX signal.

In order to perform a correct spurious emission measurement the input signal power to the analyzer must not exceed a certain level, which is below the 1 dB compression point of the analyzer. An acceptable value for the optimum level is for example the 0.2 dB desensitization point. It is defined as the level at the input mixer which influences a low level signal by less than 0.2 dB. This means that the high output level of the base station influences the accuracy of the spurious emission measurement by less than 0.2 dB.

The following graph shows the compression of a -40 dBm CW signal versus the level of a 3GPP WCDMA signal with 20 and 100 MHz offset (each with positive and negative offset). In addition the compression with the FSU preamplifier switched on is shown (available with the option FSU-B25). The markers in the graph show the level where an overload message appears on the FSU screen.

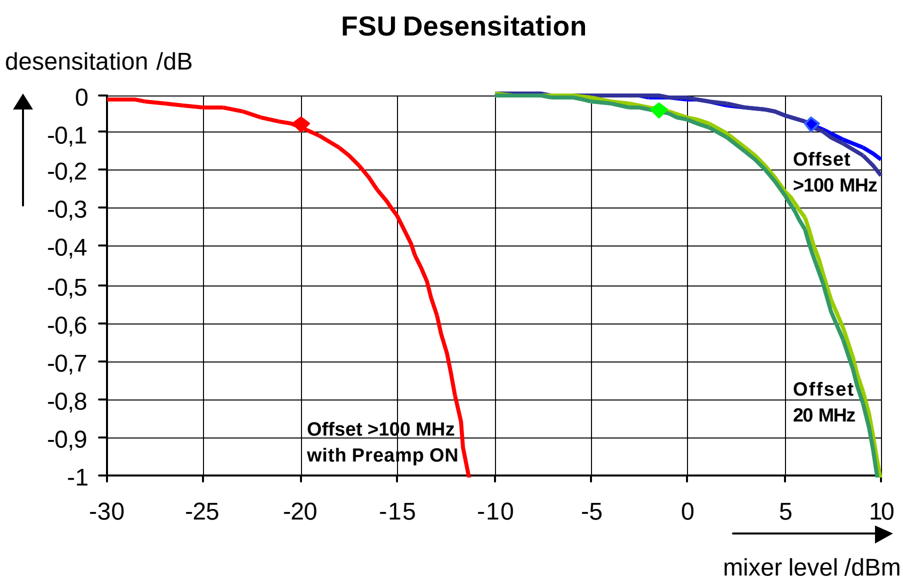

Fig. 3 Desensitization of a -40 dBm CW signal dependent on the level and offset of a WCDMA down-link signal (crest factor ~ 10.5 dB)

Depending on the frequency offset, the low level CW signal is compressed for example by 0.2 dB in the presence of a WCDMA signal with 20 MHz offset at a level of about 3 dBm. In other words, with a mixer level of 3 dBm the measured values for spurious emissions are reduced by 0.2 dB due to compression of the FSU. In practice this should be an acceptable value, especially when considering the influence of the inherent thermal noise of the FSU, which tends to increase the displayed level of spurious emissions.

Regarding the overload detectors, the FSU shows an overload message at different input levels dependent on the offset frequency. This overload message occurs due to the fact that the signal path is loaded to its full capacity. The level in the graph above is showing the signal power (mean power) of the input signal. In the case of a WCDMA signal, peak power is much higher (crest factor 8...10 dB) than mean power. The peaks can generate an overload message while measuring very close to the carrier even if the signal is not compressed in the mixer. This prevents the signal path being overloaded even in the presence of signal peaks.

Thermal Noise Floor

At the lower end of the dynamic range the thermal noise floor of the spectrum analyzer is the most important limiting factor. It needs to be 10 dB below the limits for spurious emissions, for an error of 0.5 dB due to signal to noise ratio.
The thermal noise floor of the FSU is specified as the Displayed Average Noise Level (DANL) in 10 Hz resolution bandwidth. The guaranteed value is <-143 dBm, typically it is at -148 dBm. To determine the actual noise floor for spurious measurement the DANL in 10 Hz resolution bandwidth (RBW) has to be corrected due to the actual bandwidth required by the 3GPP standard and due to the requirement to measure the mean power level of the spurious emissions.
For correction of the resolution bandwidth the following formula applies:

$$\mathrm{DANL(n\ Hz)} = \mathrm{DANL(10Hz)} + 10 \cdot \log\left[\frac{\mathrm{RBW / Hz}}{\mathrm{10\ Hz}}\right] \qquad (1)$$

Where:

DANL(n Hz) = Displayed average noise level in n Hz bandwidth
DANL(10 Hz) = Displayed average noise level in 10 Hz bandwidth
RBW / Hz = Resolution bandwidth for DANL (n Hz)

For example, with 1 MHz bandwidth the displayed average noise floor has to be corrected by 50 dB.

The displayed average noise floor stated in the data sheet is measured with the sample detector using video or trace averaging. Due to the logarithmic scaling of the trace and the averaging process the DANL is 2.51 dB lower than the noise power. Therefore the DANL has to be corrected by 2.51 dB for the noise power.

In addition, the inherent noise power of a spectrum analyzer is dependent on the resolution bandwidth setting and the reference level setting. The influence of the resolution bandwidth is due to the different noise figures of the different implementations of the resolution bandwidths. The dependency on reference level setting is caused by the IF gain setting in the last IF when switching the reference level.

Fig. 4 shows the noise figure dependency on the resolution bandwidth of the FSU. The triangles (red) marked RBW´s are the bandwidths typically used in 3GPP spurious emission measurements.

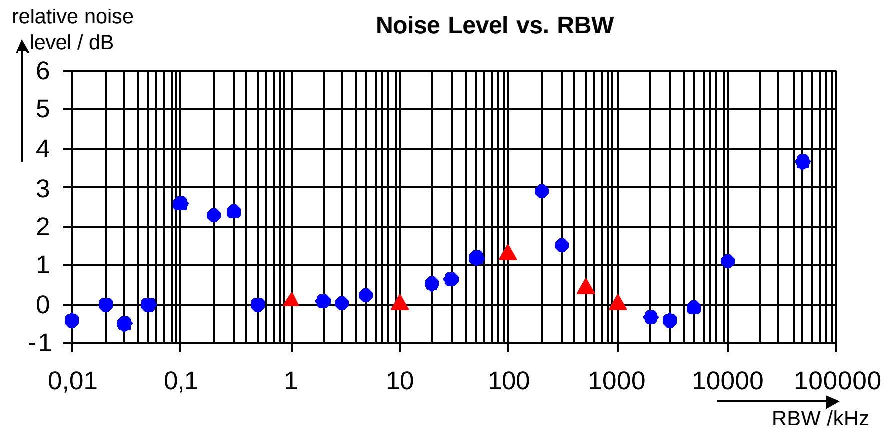

Fig. 4 Inherent noise floor of the FSU dependent on the resolution bandwidth (reference is 10 kHz RBW)

With higher reference levels at fixed RF attenuator settings the noise figure of the FSU increases. The noise figure dependency on the reference level of the FSU is shown in Fig. 5.

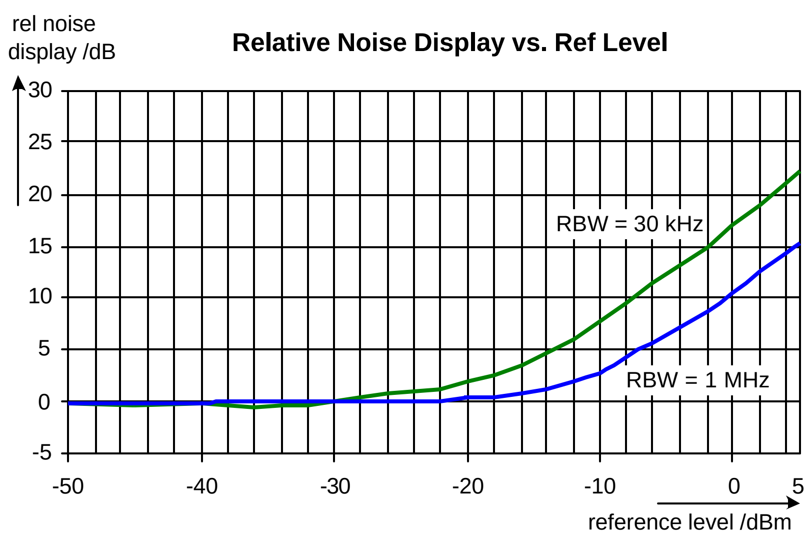

Fig. 5 Inherent noise floor of the FSU dependent on the reference level (reference is -30 dBm reference level)

The increase of noise figure with digital-implemented resolution bandwidths up to 100 kHz is higher than with analog-implemented resolution bandwidths. The reason is the noise contribution of the A/D Converter used with the digital resolution bandwidth. The consequence of figure 5 is: In order to attain the lowest inherent noise power display of the FSU, reduce the reference level as much as possible.

Phase Noise

Spurious emission measurements are always performed at frequency offsets greater than 12.5 MHz from the carrier. This means that only phase noise far from the carrier has to be considered. At 10 MHz offset the FSU provides a phase noise of -162 dBc/(1 Hz). This results in a noise level of -102 dBc in 1 MHz bandwidth. For a base station mean output power of 47 dBm (=50 W) the FSU noise floor due to phase noise is lower than -55 dBm in 1 MHz bandwidth.

Mean Power Measurement, RMS Detection

The spurious emission measurement requires the measurement of mean power. For noise or modulated signals the peak detectors are not appropriate, as the peak voltage is not related to the power of a signal. For power measurements the FSU provides the sample detector or the RMS detector. The sample detector samples the IF envelope voltage once per measurement point (pixel). With the RMS detector the envelope signal is sampled at the full sample rate of the AD converter (32 MHz in the FSU) and all samples are used for the RMS calculation.

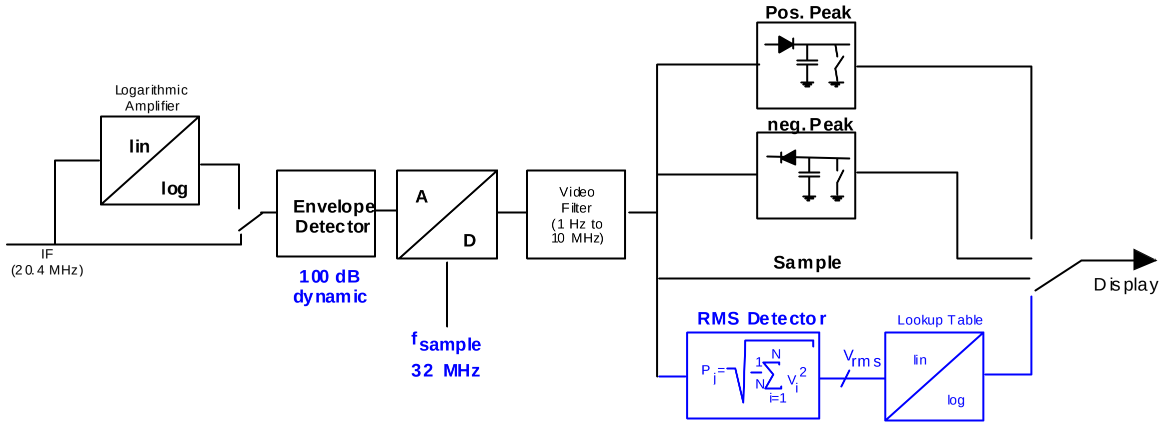

Fig. 6 Block diagram of the detectors in the FSU spectrum analyzer family.

The above simplified block diagram shows the implementation of the RMS detector in the FSU spectrum analyzer. The RMS detector measures the power of the spectrum represented by a pixel by applying the power formula to all samples. For higher repeatability the number of samples per pixel can be controlled by the sweep time. With higher sweep time the time for power integration for each pixel increases.

The RMS detector takes the RMS value of all samples linearly represented by a single pixel on the screen according to the formula:

$$P_{rms} = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{N} s_i^2}\,, \qquad (2)$$

where:

- P_{rms} = level value of a single pixel
- N = number of samples represented by the pixel
- s = sample from A/D converter

Modern spectrum analyzers display the spectrum or the waveform of a signal in time domain using a raster scan CRT or a LC display. Characteristic for these displays is that the number of pixels in the level axis as well as in the frequency or time axis is limited. This leads to limited resolution for both level and frequency or time. Especially limited frequency resolution may cause loss of signals on screen, when measuring wide frequency ranges with narrow resolution bandwidth (narrower than one pixel). This happens if a wide frequency span has to be measured with a given, narrow RBW setting like in the spurious signal measurement.

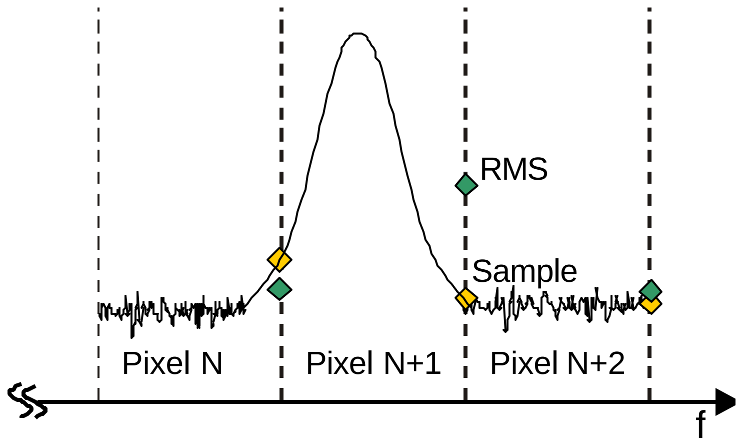

Fig 7 Illustration of sample and RMS results in a pixel

The above illustration shows the effect with a setting where the RBW is much smaller than the width of one measurement pixel. The width of one measurement pixel can be calculated by the following formula:

$$\text{Measurement pixel width} = \frac{\text{frequency span}}{\text{number of pixels}} \qquad (3)$$

Using the sample detector, the A/D Converter samples the video signal only once per pixel in the x-axis, for example the last sample within the pixel. This of course can cause a total loss of signal information, because the complete information is reduced to the number of samples corresponding to the number of pixels available in the x-axis of the screen. However, the sample detector is the only detector available for power measurement of non-CW signals as noise or digital modulated signals in many other spectrum analyzers.

Using the RMS detector, the spectrum analyzer will show the RMS value corresponding to the pixel content. Depending on the ratio of the measurement pixel width / RBW, the RMS calculation will cause a level error. The following graph shows the level error due to the measurement pixel width / RBW ratio:

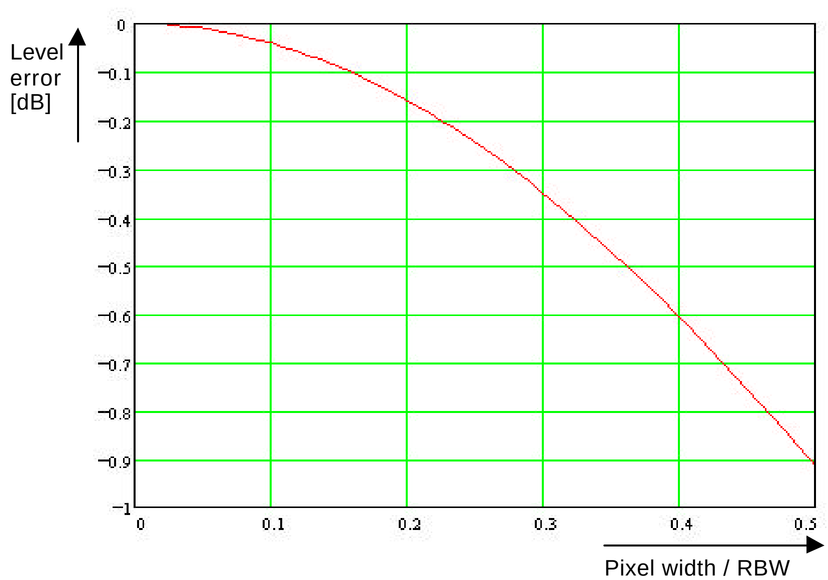

Fig 8 Level error depending on the pixel width / RBW ratio

With the standard number of measurement points (625 in case of the FSU) the span is limited depending on the acceptable level error. For a level error of 0.2 dB, the pixel width to RBW ratio must not exceed a factor of ~ 0.23. For a RBW setting of 1 MHz and 625 measurement points, the maximum span would be around 140 MHz. A wider frequency range has to be split into several sub-bands for a correct measurement of spurious emissions.

To overcome this limitation, the FSU provides a setting for the number of measurement points. The number of points in the FSU can be changed from the standard 625 points to 155/313/625/1251/2501/5001/ and 10001 measurement points per sweep. With this function the measurement of large frequency spans with the RMS detector is no problem anymore and can be done in one sweep. The measurement points are displayed by using the maximum value of all the values contributing to a pixel. Depending on the acceptable level error, the number of necessary measurement points can be calculated with the following procedure:

1. Define the acceptable level error, for example 0.2 dB.
2. Determine the pixel width / RBW ratio with the above chart: ~ 0.23
3. Calculate the necessary number of measurement points:

$$\text{Number of points} = \frac{\text{Span}}{0.23 * \text{RBW}} \qquad (4)$$

For 1 GHz span and 1 MHz RBW with the above assumptions, the measurement requires the use of minimal 4348 measurement points. The FSU spectrum analyzer can solve this task with the variable number of measurement points function (available only with FW version 1.41 and higher in the FSU).

Signal Distortion in the Spectrum Analyzer

The spurious emission measurement requires the highest possible dynamic range available in a spectrum analyzer. The spectrum analyzer has therefore to be loaded with very high levels at the input mixer to obtain this goal. Due to the non-linearities in a spectrum analyzer signal path (input mixer, etc.) these high level input signals will generate different inherent spurious signals in the spectrum analyzer, which will influence the usable dynamic range for spurious emissions measurements.

Well-known spurious products are third order intermodulation products and harmonic distortion products. The intermodulation products are close to the carriers and are limiting the measurements with narrow spans, such as ACPR measurement. With spurious measurement a wide frequency range has to be covered and therefore other distortion products, such as harmonics are more important.

The 2nd and 3rd harmonic signals are the signals with the most influence on dynamic range limitations since these harmonics have the highest level. The appearance of these harmonics is dependent on the level at the non-linear device, such as the input mixer. For frequencies above 3.6 GHz the FSU spectrum analyzer uses a preselected input mixer concept. In this concept a tuned preselector (YIG-filter) is connected in front of the mixer, avoiding loading the mixer with signals different than the actual receive frequency. For the measurement of spurious emissions this concept avoids limiting the dynamic range with inherent harmonics in the spectrum analyzer input mixer.

The "second harmonic intercept point" thus is specified with > 50 dBm nominal in the FSU, typically the FSU reaches values of more than 80 dBm for the second harmonic intercept point.

The harmonic distortion is well known as harmonic signals appearing at N times the input frequency on the spectrum analyzer screen. But there are also other spurious responses due to the frequency conversion concept of RF spectrum analyzers. Especially important for spurious measurement are mixing products from harmonics of high frequency input signals with the internal 1st local oscillator. The harmonics of the input signals may even be outside the frequency range of the spectrum analyzer. These mixing products typically are found at low input frequencies. These harmonics are still converted to an IF frequency with the harmonics of the internal local oscillators, since the input mixer of a spectrum analyzer is a nonlinear device and all input signals to the mixer (RF input and local oscillator) will generate harmonics. This happens in any spectrum analyzer with a first intermediate frequency above the upper frequency limit of the analyzer. This is a common design in RF spectrum analyzers. For the FSU the high IF concept is used in the frequency range up to 3.6 GHz. With information about the signal frequencies and the 1st IF, the frequency of these spurious signals can be predicted.

The following description lists some of the most important inherent spurious signals in case of the FSU. The level of the inherent spurious signal is dependent on the harmonic number of the signal. Generally, low harmonic numbers generate higher spurious levels. The most disturbing harmonics are therefore the second and third harmonic of both the input signal and the 1st local oscillator at the input mixer. The 2nd harmonic of both signals (input and 1st local oscillator) will generate a spurious signal at a frequency according to the formula:

$$\text{Spurious frequency}_{(2,2)} = 2 * F_{in} - \frac{1^{st}\ IF}{2} \qquad (5)$$

where:

Spurious frequency$_{(2,2)}$ = frequency, where this spur will appear
F_{in} = frequency of the input signal
1st IF = 1st IF of the spectrum analyzer, 4628.4 MHz with the FSU.

The next important spurious signal is the product of the 3rd harmonic of the input signal and the 2nd harmonic of the local oscillator:

$$\text{Spurious frequency}_{(3,2)} = 1.5 * F_{in} - \frac{1^{st}\ IF}{2} \qquad (6)$$

where:

Spurious frequency$_{(3,2)}$ = frequency, where this spur will appear
F_{in} = Frequency of the input signal
1st IF = 1st IF of the spectrum analyzer, 4628.4 MHz with the FSU

The level of these spurious signals is related to the input signal and follows a higher order characteristic (N dB spurious level change for 1 dB level change of the input signal). Due to this behavior, lowering the input signal level at the mixer can optimize the dynamic range; the level of the spurious signal can be reduced to be lower or equal to the noise level. With an input signal at 2152.5 MHz and a mixer level of 0 dBm at the FSU the spurious signal$_{(2,2)}$ will appear at 1990.9 MHz with a typical level of -80 dBc and the spurious signal$_{(3,2)}$ will appear at 914.65 MHz with a typical level of -80 dBc.

4 Performing the Measurements

Test Setup

This section shows how to set up the FSU for spurious emission measurement in the different frequency ranges. For the measurement examples the R&S signal generator SMIQ is used to simulate the base station signal. The output signal is a WCDMA signal according to TS 25.141, test model 1. In order to measure the limits of the FSU, the SMIQ output signal is cleaned up by a cavity bandpass filter with a center frequency of 2152.5 MHz and a bandwidth of 10 MHz. This filter suppresses all unwanted broadband noise and spurious signals from the signal generator output.

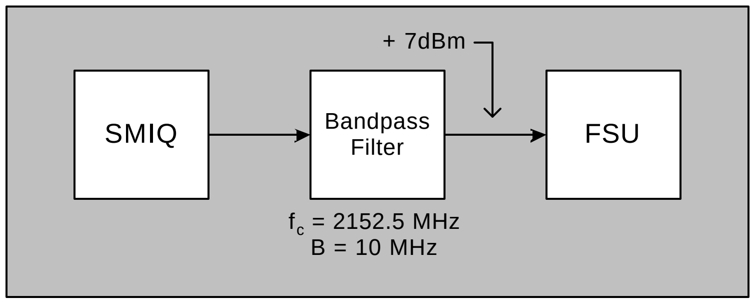

Fig. 9 Test setup for the measurement examples

The base station output power is assumed to be 50 W (=47 dBm) for the following considerations. The output power of the SMIQ is set to generate +7 dBm (after the filter). The actual base station output power is simulated by defining a level offset in the FSU, equivalent to the amount of the external attenuation necessary for use with a real base station. In this example, the reference level offset for the FSU is 40 dB, which corresponds to an output power of the base station of 47 dBm with 40 dB of attenuation between the base station and the FSU.

Measurement examples

Spurious emission specifications start outside ± 12.5 MHz offset from the transmit channel. Within ± 12.5 MHz the ACLR and spurious emission mask specification applies. The requirements for spurious emissions are described in TS25.104 subclause 6.6.3.1.1x. Spurious emissions must be measured with different resolution bandwidth settings in the various bands. Unless otherwise noted, all measurements require the reading of mean power, in other word the use of a true RMS detector.

The measurements can roughly be divided into the following categories defined by the very different spurious emissions limits in various bands:

- Measurements close to the transmit channel with offsets within the 3GPP FDD frequency band, which have relaxed limits compared to the limits outside the 3GPP frequency band.
- Measurements in the receive bands of other co-existent mobile phone systems (like DCS1800, PHS and others). These measurements require more dynamic range due to lower limits.
- Measurements in the receive band of the BS and the receive bands of other co-located base station receivers (like GSM900, DCS1800, and

others). These measurements require the highest dynamic range due to very low limits in order to prevent the receiver being desensitized.

- Measurements in all other frequency bands (9 kHz to 12.75 GHz). These measurements require special care due to the broadband frequency range and the use of RMS detection.

For each of the described measurements the following chapter describes the calculation of the necessary dynamic range and explains how to obtain the measurement, with results.

Measurements close to the 3GPP Transmit Channel

The Measurements close to the TX band start at ± 12.5 MHz offset from the transmit channel. For the described setup (carrier at 2152.5 MHz), the following limits from the requirements in TS 25.104 apply for this band (additional regional requirements may apply, for example the protection of adjacent band services):

Table 3: Limits for spurious emissions close to the 3GPP transmit channel.

Band	Maximum Level	Measurement Bandwidth
1000 MHz ↔ 2100 MHz	-30 dBm	1 MHz
2100 MHz ↔ 2102.5 MHz (Fc1 - 50 MHz)	-25 dBm	1 MHz
2102.5 MHz ↔ 2140 MHz	-15 dBm	1 MHz
2140 MHz ↔ 2165 MHz	47 dBm (TX signal)	n/a
2165 MHz ↔ 2180 MHz	-15 dBm	1 MHz
2180 MHz ↔ 12.75 GHz	-30 dBm	1 MHz

The requirements result in the following limit line graph for spurious emissions:

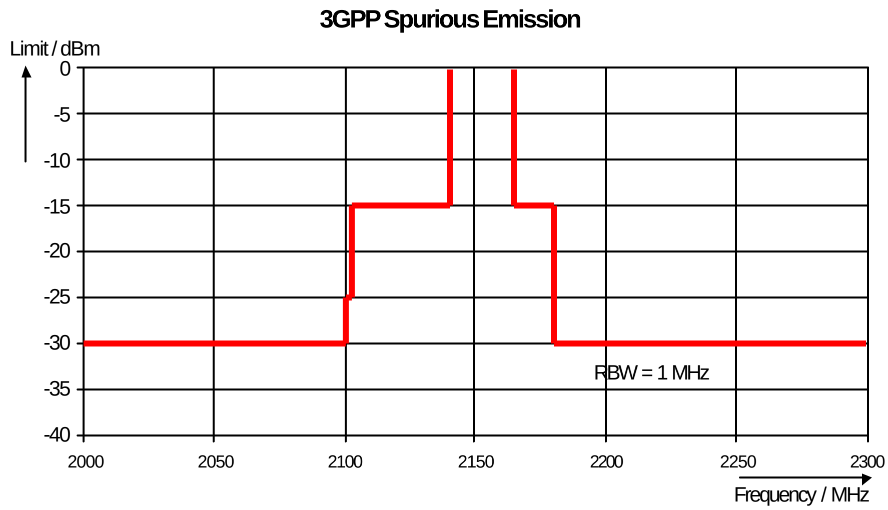

Fig 10 Spurious emissions close to the 3GPP transmit band (BTS transmit frequency = 2152.5 MHz)

These limit values represent the demand on the dynamic range of the spectrum analyzer used, especially for base stations with high output power (the limits are absolute limits). With the assumption of a base station output power of 47 dBm and a spurious emission limit of -30 dBm, this results in a minimum dynamic range of 77 dB.

Dynamic range calculation for the FSU

The ability of the spectrum analyzer to cover the dynamic range requirements can easily be calculated with the knowledge of the spectrum analyzer characteristics, described in subclause "Spurious Measurement". The resulting dynamic range is limited by two important factors:

- the maximum input power to the mixer without signal compression
- the displayed noise level in the presence of a large input signal.

The maximum input power to the mixer causes signal compression in the measured spurious signals. Due to the high 1 dB compression point of the input mixer, the FSU can be loaded up to 2 dBm for measurements close to the carrier (offset < 20 MHz, see subclause "Maximum Mixer Level"). This example with the assumption of 47 dBm base station output power, would require the use of 45 dB RF attenuation between the base station output and the input mixer (47 dBm base station power **-** 45 dB attenuation = 2 dBm mixer level).

However, due to the signal statistics with 10 dB more peak power, the FSU will show an overload message on random peaks. This does not affect the capability of a correct measurement of the spurious power, as described in the subclause "Maximum Mixer Level". To avoid this overload message the level at the input mixer can be reduced. As described above, with an input level of -3 dBm the overload message can be avoided.

The other important factor is the displayed noise of the spectrum analyzer. The dynamic range calculation for this setup is done for the case that no overload message appears in the measurement, using a -3 dBm mixer level. This requires 50 dB attenuation in front of the mixer.

Since both the useful signal and the spurious emissions are attenuated, the limit for spurious emissions is shifted by the amount of attenuation to -80 dBm (see figure left). The displayed noise floor of the spectrum analyzer defines the margin of the resulting measurement. It can be calculated as follows:

DANL = -145 dBm + 50 dB +2.5 dB = -92.5 dBm (7)

where:

DANL	=	displayed average noise floor
-145 dBm	=	typical DANL of FSU 3/8 in 10 Hz bandwidth, f < 2 GHz
50 dB	=	10 * log (1 MHz / 10 Hz)
2.5 dB	=	difference DANL to RMS noise power

The FSU thus provides a margin of **12.5** dB relative to the required limit.

Due to the low noise level of the FSU the measurement still has enough dynamic range to cover the dynamic range requirements. However, the dynamic range can be further improved by using up to 2 dBm mixer level. This will result in 5 dB more dynamic range for the measurement of spurious emissions close to the carrier.

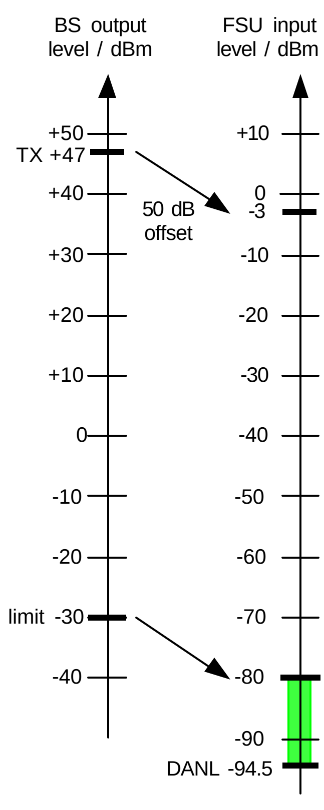

Fig 11 Dynamic range calculation chart

The following figure shows the measurement result of the spurious emissions close to the TX band for the described test setup. The FSU is set to -3 dBm mixer level. The marker measurement at 2180 MHz shows the margin of 14 dB to the limit line, a very good match to the predicted value.

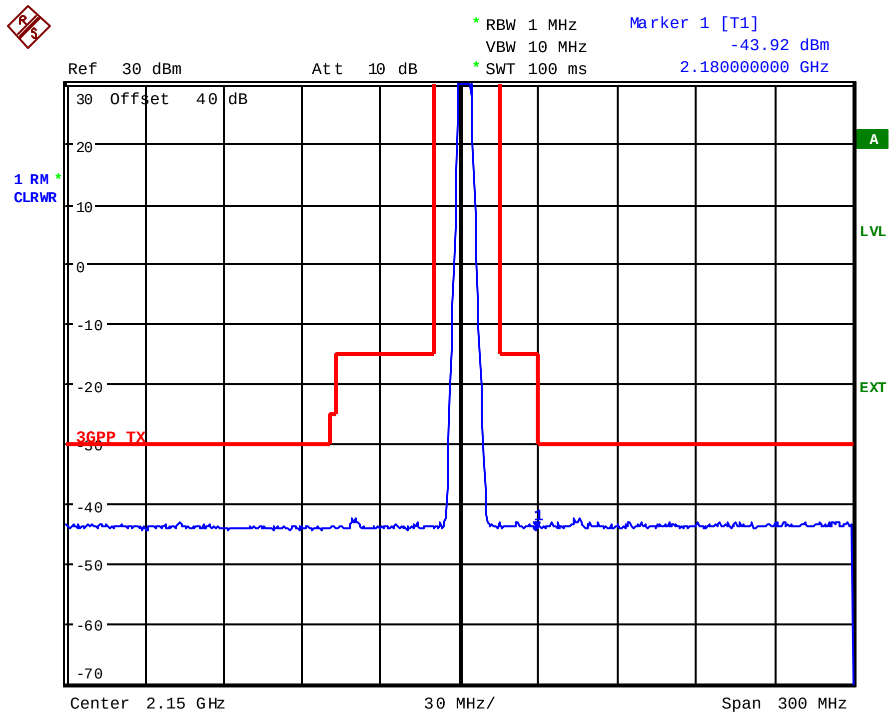

Fig 12 Spurious emission measurement close to the TX band.

Measurement in the Bands of Other Co-Existent Mobile Phone Systems (i.e. PHS, DCS 1800)

These measurements are very similar to the measurements close to the transmit channel, but require more dynamic range due to lower limits. For the setup described (carrier at 2152.5 MHz), the following limits from the requirements in TS 25.104 apply for this band; depending on the vicinity, additional regional requirements may apply:

Table 4: Regional BS Spurious emissions limits.

Band	**Maximum Level**	**Measurement Bandwidth**	**Note**
1805 ↔ 1880 MHz	-47 dBm	100 kHz	geographic coverage area of DCS 1800 MS receiver
1893.5 ↔ 1919.6 MHz	-41 dBm	300 kHz	geographic coverage area of PHS

The demand on the dynamic range of the spectrum analyzer can be calculated from the above shown limit values. The most stringent case in this example is the DCS 1800 MS receiver band with a spurious emission limit of -47 dBm in 100 kHz bandwidth.

Dynamic range calculation for the FSU

The dynamic range calculation for this case follows the rules already described, with some minor differences.

The maximum input power to the mixer can be higher due to the higher frequency offset from the TX channel. The FSU mixer can be loaded up to 2 dBm without an overload message for these measurements (see subclause "Maximum Mixer Level"). In this example with the assumption of 47 dBm base station output power, this would require the use of 45 dB attenuation between the base station output and the input mixer (47 dBm base station power **-** 45 dB attenuation = 2 dBm mixer level).

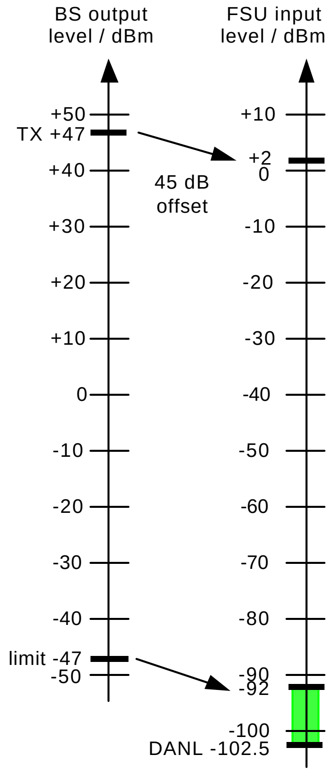

Fig 13 Dynamic range chart

Since both the useful signal and the spurious emissions are attenuated, the limit for spurious emissions is shifted by the amount of attenuation to a value of -92 dBm (-47 dBm (limit) - 45 dB attenuation), see figure 13.

The displayed noise floor of the spectrum analyzer defines the margin of the resulting measurement. It can be calculated as follows:

$$\text{DANL} = -145\text{ dBm} + 40\text{ dB} + 2.5\text{ dB} = -102.5\text{ dBm} \qquad (8)$$

where:

DANL	=	displayed average noise floor
-145 dBm	=	DANL of FSU 3/8 in 10 Hz bandwidth, f < 2 GHz
40 dB	=	10 * log (100 kHz / 10 Hz)
2.5 dB	=	difference DANL to RMS noise power

The FSU thus has a margin of **10.5** dB relative to the required limit.

The following graph shows the measurement result of the spurious emissions for the described test. The FSU is set to 2 dBm mixer level. The Marker measurement at 1845 MHz shows the margin of 11 dB to the limit.

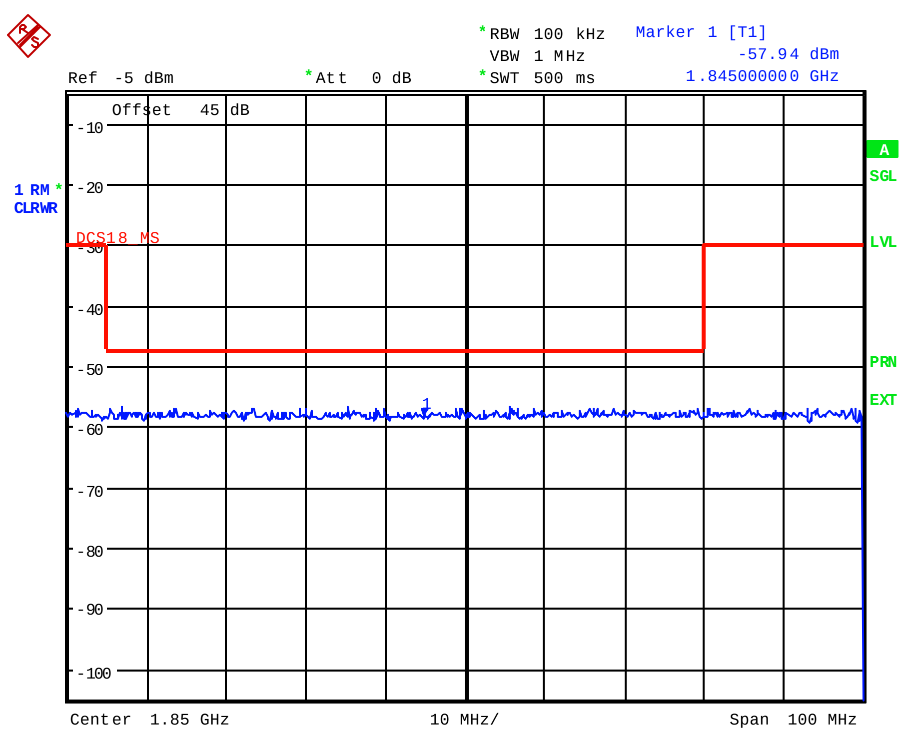

Fig 14 Spurious emission measurement in the DCS 1800 MS band.

Measurement in the Receive Band of the BS and the Receive Bands of Co-Located Base Station Receivers

These measurements require the highest dynamic range due to very low limits. For the described setup the following limits from the requirements in TS 25.104 apply for these bands; depending on the vicinity, additional regional requirements may apply:

Table 5: Regional BS Spurious emissions limits in the RX bands.

Band	Maximum Level	Measurement Bandwidth	Note
876 ↔ 915 MHz	-98 dBm	100 kHz	protection of the GSM 900 BTS receiver
921 ↔ 960 MHz	-57 dBm	100 kHz	geographic coverage area of GSM 900 MS receiver
1710 ↔ 1785 MHz	-98 dBm	100 kHz	BS co-located with DCS 1800 BTS
1900 ↔ 1920 MHz	-52 dBm	1 MHz	geographic coverage area of UTRA-TDD
1920 ↔ 1980 MHz	-96 dBm	100 kHz	Protection of the BS receiver
2010 ↔ 2025 MHz	-52 dBm	1 MHz	geographic coverage area of UTRA-TDD

The necessary dynamic range for these measurements is more than a spectrum analyzer can handle. To obtain this dynamic range, a notch filter is used to suppress the TX channel. The available dynamic range is dependent from the carrier suppression and the spectrum analyzer characteristics, which are described in subclause "Spurious Measurement".

With the assumption of a base station output power of 47 dBm, the most stringent case is the protection of the GSM900 and DCS1800 BTS receiver with a spurious emission limit of -98 dBm in 100 kHz bandwidth, and also the protection of the BS receiver itself.

Dynamic range calculation for the FSU

The dynamic range calculation for this case has some differences to the ones described above. The resulting dynamic range is still limited by the two important factors:

- the displayed noise level
- the maximum power to the spectrum analyzer w/o signal compression.

The DANL will limit the ability to measure the very low limits in the receive bands. The displayed noise floor of the spectrum analyzer defines the margin of the resulting measurement. A typical test setup will also have some attenuation between the base station output and the spectrum analyzer input. Since both the useful signal and the spurious emissions are attenuated, the limit for spurious emissions is shifted by the amount of attenuation. With the assumption of 10 dB attenuation the limit will be shifted to a value of -108 dBm, see figure 15. To handle these low levels, a preamplifier has to be used in the spectrum analyzer to reach the required sensitivity for this measurement. The FSU provides an internal preamplifier with the Option FSU-B25.

The resulting DANL can be calculated as follows:

DANL = -157 dBm + 40 dB +2.5 dB = -114.5 dBm (9)

where:

DANL	=	displayed average noise floor
-152 dBm	=	typ. DANL of FSU in 10 Hz RBW, f < 2 GHz, Preamp ON
40 dB	=	10 * log (100 kHz / 10 Hz)
2.5 dB	=	difference DANL to RMS noise power

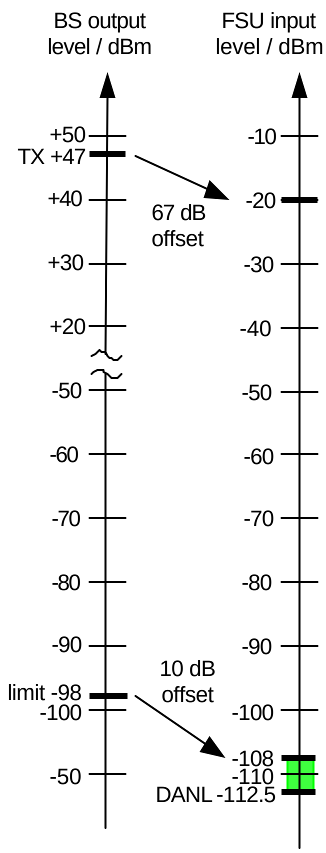

Fig 15 Dynamic range chart

The FSU thus has a margin of **6.5** dB relative to the required limit. This margin is not as high as in the other bands, but no special components and complicate test setups have to be used to reach this margin. If possible, the amount of attenuation between the base station output amplifier and the notch filter can further be reduced to have more margin.

The amount of attenuation in the notch filter can be calculated with the information as described in subclause "Spurious Measurement" and the knowledge from the test setup. The FSU can handle up to -20 dBm input power to the preamplifier, as shown in the compression chart. With the assumption of 47 dBm base station output power and the use of 10 dB attenuation, the input power to the notch filter will be 37 dBm. The required notch filter attenuation can be calculated as follows:

Attenuation = 37 dBm - (-20 dBm) = 57 dB (10)

The following graph shows the measurement result of the spurious emissions for the described test setup. The FSU is set to -23 dBm mixer level (notch filter attenuation 60 dB). The Marker measurement at 898 MHz shows the margin of 7 dB to the limit line. With the information provided in the chapter "Signal Distortion in the Spectrum Analyzer" a spurious signal in the frequency range of interest can be found which will limit the dynamic range. This signal can be seen in the measurement at the upper end of the GSM 900 BS band.

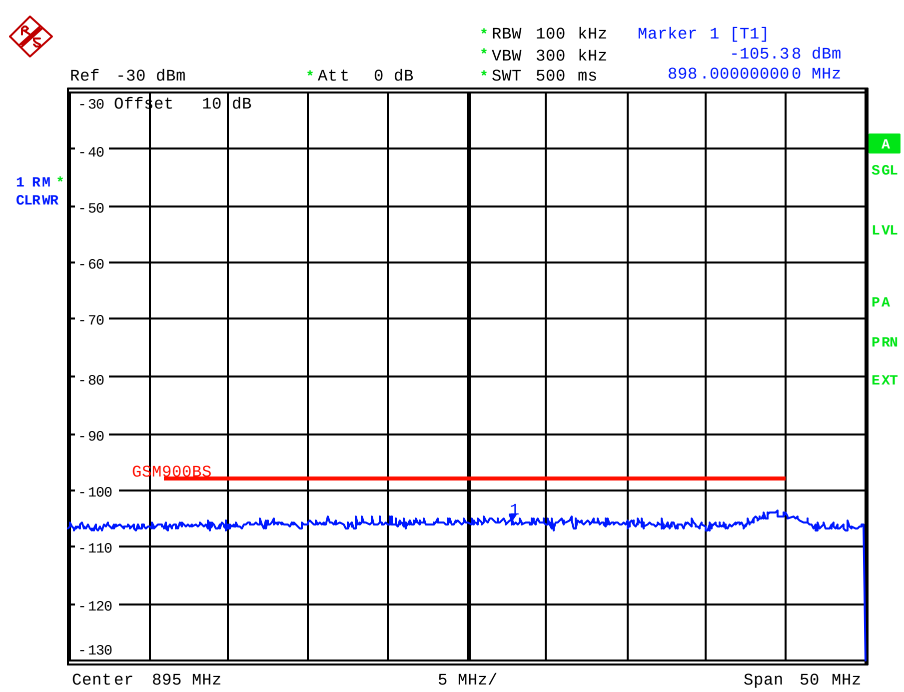

Fig 16 Spurious emission measurement in the GSM900 band.

Measurements in all Other Frequency Bands (9 kHz to 12.75 GHz)

These measurements require special care due to the broadband frequency range and the use of the RMS detector. As described in chapter "Mean Power Measurement, RMS Detection", the use of RMS detectors requires special care if wide frequency ranges have to be measured. In the case of spurious emissions measurement according to TS25.104, the following bands are of special interest:

Table 6: BS Mandatory spurious emissions limits, Category B

Band	Maximum Level	Measurement Bandwidth
9 kHz ↔ 150 kHz	-36 dBm	1 kHz
150 kHz ↔ 30 MHz	- 36 dBm	10 kHz
30 MHz ↔ 1 GHz	-36 dBm	100 kHz
1 GHz ↔ Fc1 - 60 MHz or 2100 MHz *whichever is the higher*	-30 dBm	1 MHz
Fc2 + 60 MHz or 2180 MHz;*whichever is the lower* ↔ 12.75 GHz	-30 dBm	1 MHz

Fc1: Center frequency of emission of the first carrier transmitted by the BS.
Fc2: Center frequency of emission of the last carrier transmitted by the BS.

The first step is to check the frequency range / measurement bandwidth ratio, whether it complies with the rules for the use of the RMS detector. The important issue is the necessary number of measurement points, which are usually limited in a spectrum analyzer. For a given level inaccuracy of 0.2 dB, for example, the minimum number of points is:

$$\text{Number of points} = \frac{\text{Frequency range}}{0.23 * \text{RBW}} \quad (11)$$

For the above listed frequency bands, this results in the following table:

Table 7: Minimum number of points in the different bands

Band	Minimum number of points
9 kHz ↔ 150 kHz	613
150 kHz ↔ 30 MHz	12979
30 MHz ↔ 1 GHz	42173
1 GHz ↔ 2.1 GHz	4783
2.18 GHz ↔ 12.75 GHz	45957

Spectrum analyzers usually have a very limited number of measurement points, coupled to the available number of pixels on the screen. The available number of measurement points is therefore limited to numbers much lower than 1000 points, which would require to split these measurements into several subbands to overcome the RMS detector limitations. The FSU provides a setting for the number of measurement points of up to 10001 points. With this function the measurement with the RMS detector is possible for much broader frequency spans. The measurement points are displayed by using the maximum value of all values contributing to one pixel.

Dynamic range calculation for the FSU

The dynamic range calculation for this case is comparable to the above described bands. The broadband measurement can be divided in to two areas:

- measurements close to the TX channel
- measurements far off the TX channel.

The most stringent case in this example is the higher frequency band due to the lowest limits (with consideration of the measurement bandwidth) and the fact that the DANL in the spectrum analyzer will rise with higher input frequencies. Due to the fact that the measurement has to be made in several sub-bands because of the RMS-detector limitations, the rise of the DANL over the input frequency can be covered with the use of higher mixer levels in the bands far off the TX channel. A good compromise for the splitting could be a measurement in 3 bands of about 4 GHz for each band from 1 GHz to 12.75 GHz. With the information provided in chapter "Mean Power Measurement, RMS Detection" the additional level error due to the limited number of measurement points can be calculated. The pixel width / RBW ratio is:

$$\text{Pixel width / RBW} = \frac{\text{frequency span}}{\text{number of pixels * RBW}} \qquad (12)$$

With the use of a 4 GHz frequency band, 1 MHz measurement bandwidth and 10001 points, this results in a pixel width / RBW ratio of about 0.4, which will cause an additional level measurement error due to the RMS detector of 0.6 dB. This level error can be covered by an increase in the measurement margin.
The dynamic range calculation for the measurement in the first band (i.e. 1 to 5 GHz) is equal to the rules already described in the chapter "Measurements close to the 3GPP Transmit Channel", the limit for spurious emissions is shifted by the amount of attenuation (50 dB) to -80 dBm. The displayed noise floor of the spectrum analyzer defines the margin of the resulting measurement. It can be calculated as follows:

$$\text{DANL} = -144\text{ dBm} + 50\text{ dB} + 2.5\text{ dB} = -91.5\text{ dBm} \qquad (13)$$

where:

DANL	=	displayed average noise floor
-144 dBm	=	typical DANL of FSU 3/8 in 10 Hz bandwidth, f > 3.6 GHz
50 dB	=	10 * log (1 MHz / 10 Hz)
2.5 dB	=	difference DANL to RMS noise power

The FSU thus provides a margin of **11.5** dB relative to the required limit. Due to the low noise level of the FSU the measurement still has enough dynamic range to cover additional error due to the RMS detector.

The next band can be measured with higher mixer level due to the high frequency offset from the TX channel. In this case, a mixer level of 2 dBm is possible without any compression, compensating the higher DANL for these input frequencies. The overall margin stays constant with this measure.

The following graph shows the measurement result of the spurious emissions for the first band for the described test setup. The FSU is set to -3 dBm mixer level. The marker measurement at 4305 MHz is showing the margin of 11 dB to the limit line, a very good match the predicted value. The marker is positioned on the frequency of the 2nd harmonic (2 * input frequency), showing the good suppression of the harmonic due to the FSU hardware concept with the tracking preselector.

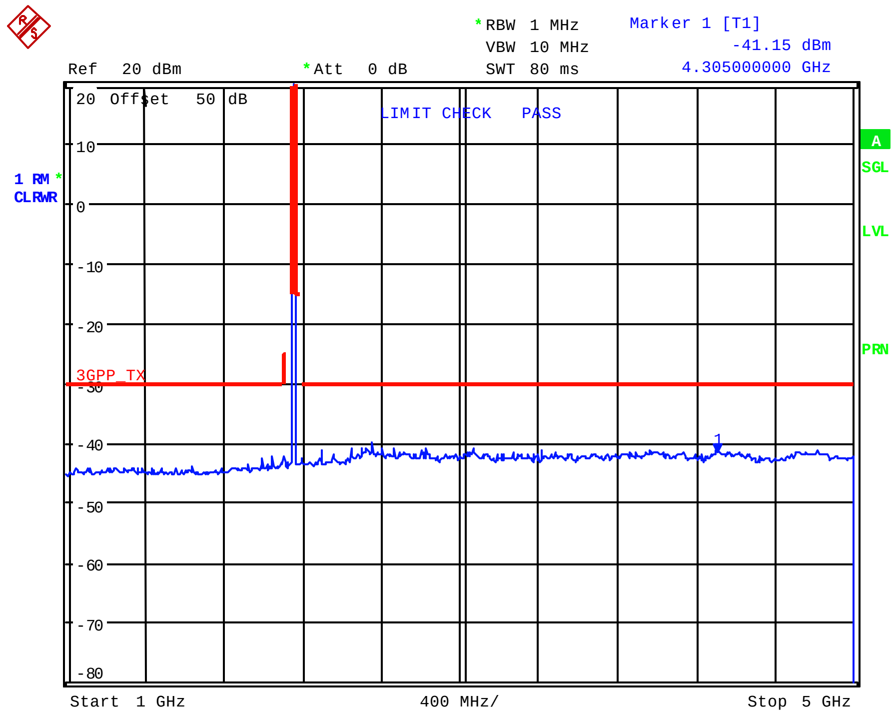

Fig 17 Spurious emission measurement in the 1 to 5 GHz band.

A Practical Test Setup

Measuring spurious emissions requires very high dynamic range from the spectrum analyzer used. The FSU spectrum analyzer family from Rohde & Schwarz can handle this task with a simple test setup. All measurements in the transmission band and outside the base station receive bands of other wireless communication systems can be performed with the FSU spectrum analyzer stand alone, without any additional notch filters. The measurements in the receive bands can be performed with one single band-stop filter covering the transmission frequency range of the base station. The requirements for this filter are described and filters fulfilling these requirements are commonly available.

A practical approach to cover all of the above-discussed requirements is presented in the following block diagram:

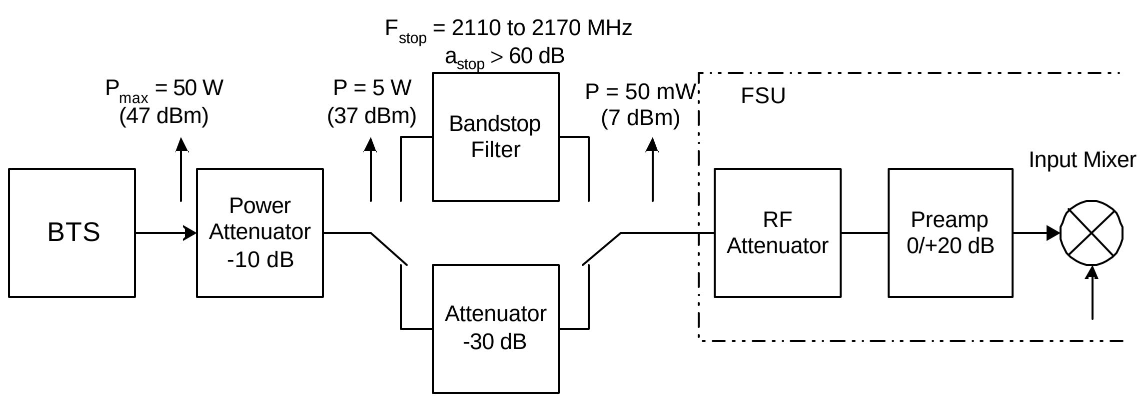

Fig. 18 Diagram of a test setup for spurious emission measurements.

The output from the base station usually needs a good load in order to guarantee stable operation of the output amplifier. For this reason the output is connected to a power attenuator, which handles the high output power from the output amplifier (50 W) and also offers a broadband load for the output amplifier of the base station. Another approach would be an isolator to de-couple the base station from the test setup, which is more complex due to the wide frequency range which must be covered for the spurious emission measurements. The next module in the signal path is a switch to choose between an attenuator or the notch filter, depending on the actual measurement requirements. The output signal then is routed to the FSU spectrum analyzer, which handles the rest of the necessary amount of attenuation and also offers a preamplifier (Option FSU-B25). With this test setup all requirements for spurious emissions measurements are fulfilled.

5 Literature

[1] Technical Specification TS 25.101 V 3.1.0, 3rd Generation Partnership Project (3GPP), Technical Specification Group (TSG) RAN WG4, UE Radio transmission and Reception (FDD)

[2] Application Note 1GP39_0E, W-CDMA Signal Generator Solutions by Rohde & Schwarz

[3] Application Note 1EF40_E, Measurement of Adjacent Channel Power on Wideband CDMA Signals

[4] Josef Wolf and Bob Buxton, ”Measure Adjacent Channel Power With a Spectrum Analyzer, ” *Microwaves & RF*, January 1997, pp. 55-60.

[35] Application Note 1EPAN17E, "Measurement of spurious emissions of GSM, DCS1800 and PCS1900 transmitters with the spectrum analyzers of the FSE family"

6 Ordering information

Type of instrument

		Order number
FSU3	20 Hz to 3.6 GHz	1129.9003.03
FSU8	20 Hz to 8 GHz	1129.9003.08
SMIQ 03 B	300 kHz to 3.3 GHz	1125.5555.03

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