Contents - Chapter 2 "Getting Started"

2 Getting Started

Chapter 2 explains how to operate the FSP using typical measurements as examples. Chapter 3 describes the basic operating steps such as selecting the menus and setting parameters, and explains the screen structure and displayed function indicators.
Chapter 4 describes all the menus and FSP functions.

All of the following examples are based on the standard settings of the analyzer. These are set with the *PRESET* key. A complete listing of the standard settings can be found in chapter 4, section "Preset settings of the FSP – *PRESET key"*.

Level and Frequency Measurements

Measuring the frequency and level of a signal is one of the most common purposes for the use of a spectrum analyzer. For unknown signals, the spectrum analyzer default settings (PRESET) are a good starting point for the measurement.
If signal levels at the RF input are expected to be above 30 dBm (= 1 W), a power attenuator must be connected to the RF input of the spectrum analyzer. Please note that the total powar of all applied signals must be taken into account concerning this limit. If a power attenuator is not used, signal levels above 30 dBm can destroy the RF attenuator or the input mixer.

Measurement Example 1 – Measuring Frequency and Level using Markers

It is easy to measure the level and frequency of a sinewave carrier with the marker function. At the marker position, the FSP indicates the signal's amplitude and frequency. The accuracy of the frequency measurement is determined by the FSP reference frequency, the resolution of the marker frequency display and the resolution of the screen.

In the example, the frequency of the 128-MHz internal reference generator is displayed using the marker.

1. ***Set the spectrum analyzer to its default settings.***
   - Press the *PRESET* key.
2. ***Connect the test signal to the RF INPUT on the instrument front panel.***
3. ***Switch on the internal reference generator.***
   - Press the *SETUP* key.
     The *SETUP* menu opens.
   - Press the *SERVICE soft*key.
     The *SETUP - SERVICE* menu opens.
   - Press the *INPUT CAL soft*key.
     The internal reference generator is turned on.
     The FSP's RF input is turned off.
4. ***Set the center frequency to 128 MHz.***
   - Press the *FREQ* key.
   - The entry field for the center frequency is displayed on the screen.
   - Enter *128* from the numeric keypad and terminate the entry with the *MHz* key.

5. ***Reduce the measurement frequency range (SPAN) to 1 MHz.***

- Press the *SPAN* key.
- Enter *1* from the numeric keypad and terminate the entry with the *MHz* key.

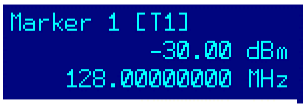
> ***Note:*** *If the SPAN is changed, the resolution bandwidth (RES BW), the video bandwidth (VIDEO BW) and the sweep time (SWEEP TIME) are also set to new values because they are defined as coupled functions in the standard PRESET settings.*

6. ***Measure the level and frequency using the marker and read off the results from the screen.***

- Press the MKR key.
  The marker is switched on and automatically jumps to the trace peak.

> ***Note:*** *When a marker is switched on for the first time, it automatically performs the PEAK SEARCH function (as in this example).*
> *If a marker is already active, the PEAK softkey in the MKR-> menu must be pressed in order to set the currently active marker onto the displayed signal maximum.*

The level and frequency indicated by the marker are displayed in the marker info field at the upper edge of the screen. These are the measurement results.



```
Marker 1 [T1]
       -30.00 dBm
128.00000000 MHz
```

The info-field header indicates the number of the marker (`MARKER 1`) and the number of the trace on which the marker is positioned (`[T1]` = Trace 1).

Increasing the Frequency Resolution During a Frequency Measurement with a Marker

The frequency resolution of the marker is determined by the pixel resolution of the trace. The FSP uses 501 pixels for a trace, i.e. at a frequency span of 1 MHz each pixel corresponds to a frequency range of approx. 2 kHz. This gives a maximum error of 1 kHz.
To increase the pixel resolution of the trace, the frequency span has to be reduced.

7. ***Reduce the frequency span to 10 kHz.***

- Press the *SPAN* key.
- Enter *10* from the numeric keypad and terminate the entry with the *kHz* key.

> ***Note:*** *If the SPAN is changed, the resolution bandwidth (RES BW), the video bandwidth (VIDEO BW) and the sweep time (SWEEP TIME) are also set to new values because they are defined as coupled functions in the standard PRESET settings.*

The internal reference signal is measured with a span of 10 kHz. The pixel resolution of the trace is now approx. 20 Hz (10 kHz span / 501 pixel), i.e. the accuracy of the marker frequency display is increased to approx. 10 Hz.

8. ***Switch on the RF input again for normal operation of the analyzer.***

- Press the *PRESET* key <u>or</u> press the *SETUP* key and the *SERVICE* softkey.
- Press the *INPUT RF* softkey.
  The internal signal path of the FSP is switched back to the RF input in order to resume normal operation.

Measurement Example 2 – Measuring Frequency with the Frequency Counter

With the internal frequency counter, frequencies can be measured more accurately than with the marker. The frequency sweep is stopped at the marker position and the FSP measures the frequency of the corresponding signal. If an analog bandwidth (≥300 kHz) is used, the frequency is measured by counting the zero-crossings of the last IF. With digital resolution bandwidths (10 Hz to 100 kHz), the frequency measurement is performed in the IQ baseband by a special approximation algorithm.

The resolution range for the frequency measurement is 0.1 Hz to 10 kHz. At bandwidths ≥300 kHz, the time required for the FSP to perform the frequency measurement is dependent on the selected counter resolution (1/(frequency resolution in Hz)). The digital frequency approximation takes about 30 ms to perform a frequency measurement irrespective of the selected resolution.
The frequency measurement accuracy is determined by the reference frequency of the FSP and the selected counter resolution.

In the example, the frequency of the 128-MHz internal reference generator is displayed with the marker.

1. ***Set the spectrum analyzer to the default settings.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Switch on internal reference generator***

   ➢ Press the *SETUP* key.

   ➢ Press the softkeys *SERVICE - INPUT CAL*.
   The internal 128 MHz reference generator is now on. The FSP's RF input is turned off.

3. ***Set the center frequency and the frequency span***

   ➢ Press the *FREQ* key and enter *128 MHz*.
   The FSP center frequency is set to 128 MHz.

   ➢ Press the *SPAN* softkey and enter *1 MHz*.
   The FSP frequency span is set to 1 MHz.

4. ***Switch on the marker***

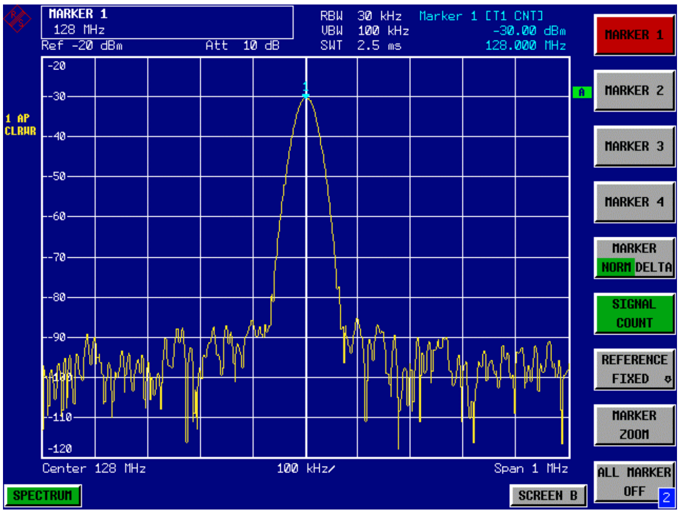
   ➢ Press the *MKR* key.
   The marker is switched on and set to the signal maximum. The level and the frequency at the marker are displayed in the marker-info field.

5. ***Switch on the frequency counter.***

   ➢ Press the *SIGNAL COUNT* softkey in the marker menu.
   The frequency count is displayed in the marker field at the top of the screen along with the set resolution (1 kHz is the default setting).
   The sweep stops at the marker position and the FSP measures the frequency of the corresponding signal. The frequency is output in the marker info field. To distinguish the signal count result from the normal marker frequency display, the marker is labeled with CNT.

6. Set the resolution of the frequency counter to 1 Hz.

- ➢ Press the *NEXT* key.
- ➢ Press the *CNT RESOL 1 Hz* softkey.



MARKER 1
128 MHz
Ref -20 dBm Att 10 dB
RBW 30 kHz
VBW 100 kHz
SWT 2.5 ms
Marker 1 [T1 CNT]
-30.00 dBm
128.000 MHz
Center 128 MHz 100 kHz/ Span 1 MHz

Fig. 2-1 Frequency measurement with a frequency counter

Note:	*The frequency measurement with the integral frequency counter only gives correct results for RF sinewaves or discrete spectral lines. To meet the specified measurement accuracy, the marker should be more than 25 dB above noise.*

7. Switch on the RF input again for normal operation of the analyzer.

- ➢ Press the *PRESET* key <u>*or*</u> press the *SETUP* key and the *SERVICE* softkey.
- ➢ Press the *INPUT RF* softkey.
  The internal signal path of the FSP is switched back to the RF input in order to resume normal operation.

Hint:	For bandwidths between 300 kHz and 10 MHz, the FSP uses a frequency counter at an IF of 20.4 MHz. The time for measuring the frequency is, therefore, inversely proportional to the selected resolution, i.e. at a resolution of 1 Hz a gate time of 1 second is required for the counter. For digital bandwidths below 300 kHz, the frequency is measured in the baseband by digital frequency approximation. The time required for measuring the frequency is approx. 30 ms irrespective of the selected resolution. When measuring the frequency of a sinewave carrier at a high resolution it is, therefore, best to set a resolution bandwidth of 100 kHz or less. The measurement time will then be reduced to a minimum.

Measurement of Harmonics

Measuring the harmonics of a signal is a frequent problem which can be solved best by means of a spectrum analyzer. In general, every signal contains harmonics which are larger than others. Harmonics are particularly critical regarding high-power transmitters such as transceivers because large harmonics can interfere with other radio services.

Harmonics are produced by nonlinear characteristics. They can often be reduced by lowpass filters. Since the spectrum analyzer has a nonlinear characteristic, e.g. in its first mixer, measures must be taken to ensure that harmonics produced in the analyzer do not cause spurious results. If necessary, the fundamental wave must be selectively attenuated with respect to the other harmonics with a highpass filter.

When harmonics are being measured, the obtainable dynamic range depends on the K2 intercept of the spectrum analyzer. The K2 intercept is the virtual input level at the RF input mixer at which the level of the 2nd harmonic becomes equal to the level of the fundamental wave. In practice, however, applying a level of this magnitude would damage the mixer. Nevertheless the available dynamic range for measuring the harmonic distance of a DUT can be calculated relatively easily using the second harmonic intercept.

As shown in Fig. 2-2, the level of the 2nd harmonic is reduced by 20 dB if the level of the fundamental wave is reduced by 10 dB.

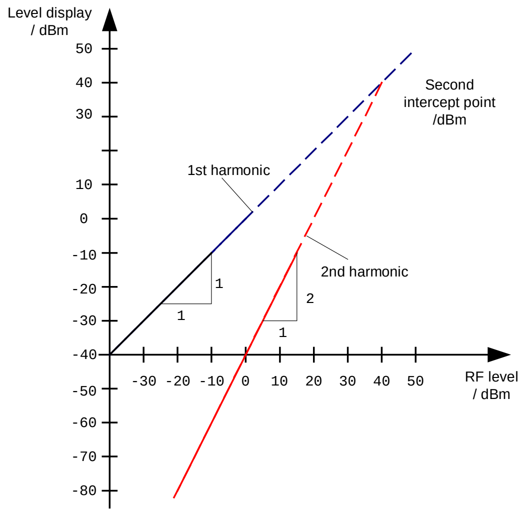


Fig. 2-2 Extrapolation of the 1st and 2nd harmonics to the second harmonic intercept at 40 dBm

The following formula for the obtainable harmonic distortion d_2 in dB is derived from the straight-line equations and the given intercept point:

$$d_2 = S.H.I - P_I \qquad (1)$$

d_2 = harmonic distortion
P_I = mixer level/dBm
S.H.I. = second harmonic intercept

Note: *The mixer level is the applied RF level minus the set RF attenuation.*

The formula for the internally generated level P_1 at the 2nd harmonic in dBm is:

$$P_1 = 2 \cdot P_I - S.H.I. \qquad (2)$$

The lower measurement limit for the harmonic is the noise floor of the spectrum analyzer. The harmonic of the measured DUT should – if sufficiently averaged by means of a video filter – be at least 4 dB above the noise floor so that the measurement error due to the input noise is less than 1 dB.

The following rules for measuring high harmonic ratios can be derived:

1. Select the smallest possible IF bandwidth for a minimal noise floor.
2. Select an RF attenuation which is high enough to just measure the harmonic ratio.

The maximum harmonic distortion is obtained if the level of the harmonic equals the intrinsic noise level of the receiver. The level applied to the mixer, according to (2), is:

$$P_I = \frac{P_{noise} / dBm + IP2}{2}$$

At a resolution bandwidth of 10 Hz (noise level -143 dBm, S.H.I. = 40 dBm), this level is –51.5 dBm. According to (1) a maximum measurable harmonic distortion of 91.5 dB minus a minimum S/N ratio of 4 dB is obtained.

Hint: If the harmonic emerges from noise sufficiently (approx. >15 dB), it is easy to check (by changing the RF attenuation) whether the harmonics originate from the DUT or are generated internally by the spectrum analyzer. If a harmonic originates from the DUT , its level remains constant if the RF attenuation is increased by 10 dB. Only the displayed noise is increased by 10 dB due to the additional attenuation. If the harmonic is exclusively generated by the spectrum analyzer, the level of the harmonic is reduced by 20 dB or is lost in noise. If both – the DUT and the spectrum analyzer – contribute to the harmonic, the reduction in the harmonic level is correspondingly smaller.

Measuring Harmonics with Frequency Sweeps

There are advantages in performing harmonic measurements with a single frequency sweep, provided that the harmonic distance is in a way that a resolution bandwidth can be selected which is wide enough to give an acceptably short sweep time.

Measurement Example – Measuring the distance between fundamental wave and the 2nd and 3rd harmonics of the internal reference signal

1. ***Set the spectrum analyzer to the default settings.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Switch on the internal reference generator***

   ➢ Press the *SETUP* key.
   Press the softkeys *SERVICE - INPUT CAL*.
   The internal 128 MHz reference generator is now on. The FSP's RF input is switched off.

3. ***Set the start frequency to 100 MHz and the stop frequency to 400 MHz***

   ➢ Press the *FREQ* key.

   ➢ Press the *START* softkey and enter *100 MHz*.

   ➢ Press the *STOP* softkey and enter *400 MHz*.
   The FSP displays the fundamental and the 2nd and 3rd harmonics of the input signal.

4. ***Set the RF attenuation to 0 dB to obtain maximum sensitivity***

   ➢ Press the *AMPT* key.

   ➢ Press the *RF ATTEN MANUAL* softkey and enter *0 dB*.

5. ***Reduce the video bandwidth to average (suppress) noise.***

   ➢ Press the *BW* key.

   ➢ Press the *COUPLING RATIO* softkey.

   ➢ Select *RBW/VBW NOISE [10*] using the cursor keys.

   The video bandwidth (VBW) will now always be set to a value which is 10 times smaller than the resolution bandwidth (RBW).

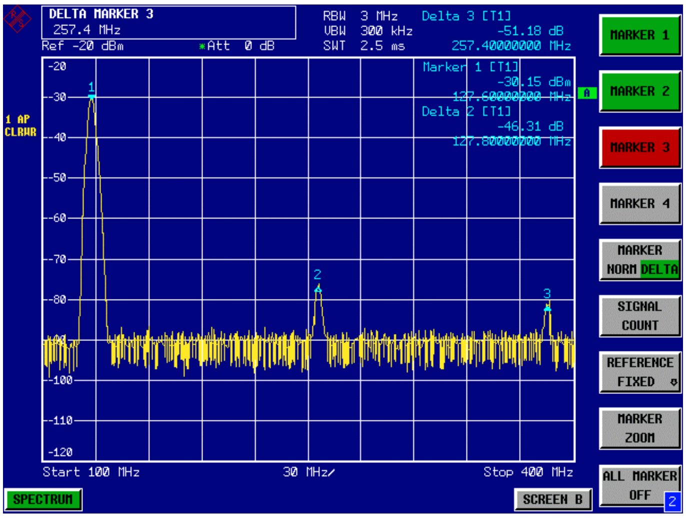
6. ***Switch on the marker***

   ➢ Press the *MKR* key.
   Marker 1 is switched on and is positioned on the signal maximum (fundamental wave at 128 MHz). The level and the frequency of the marker are displayed in the marker info field.

7. Switch on the delta marker and measure the harmonic distance

➢ Press the *MARKER 2* softkey in the marker menu.
Marker 2 is activated as a delta marker (Delta 2 [T1]). It appears automatically on the largest harmonic of the signal. The frequency and level, related to marker 1, are indicated in the marker field at the top of the screen.

➢ Press the *MARKER 3* softkey in the marker menu.
Marker 3 is activated as a delta marker (Delta 3 [T1]). It appears automatically on the next largest harmonic of the signal. The frequency and level, related to marker 1 on the fundamental wave, are displayed in the marker info field at the top of the screen (see Fig. 2-3).



DELTA MARKER 3
257.4 MHz

Ref -20 dBm *Att 0 dB

RBW 3 MHz
VBW 300 kHz
SWT 2.5 ms

Delta 3 [T1]
-51.18 dB
257.40000000 MHz

Marker 1 [T1]
-30.15 dBm
127.60000000 MHz

Delta 2 [T1]
-46.31 dB
127.80000000 MHz

Start 100 MHz 30 MHz/ Stop 400 MHz

Fig. 2-3 Measuring the harmonic distance of the internal reference generator. Delta marker 2 [T1] and Delta marker 3 [T1] indicate the distance between the fundamental wave and the 2nd and 3rd harmonics.

In order to make the harmonics grow out of the noise, the following things can be done:

- Reducing the video bandwidth
- Averaging the trace
- Reducing the resolution bandwidth

The noise of the analyzer or the DUT (depending on which one is higher) is suppressed by reducing the video bandwidth and by averaging the trace. Especially for low S/N ratios, the measurement uncertainty is reduced using the two averaging methods since the signal under test is also freed from noise.

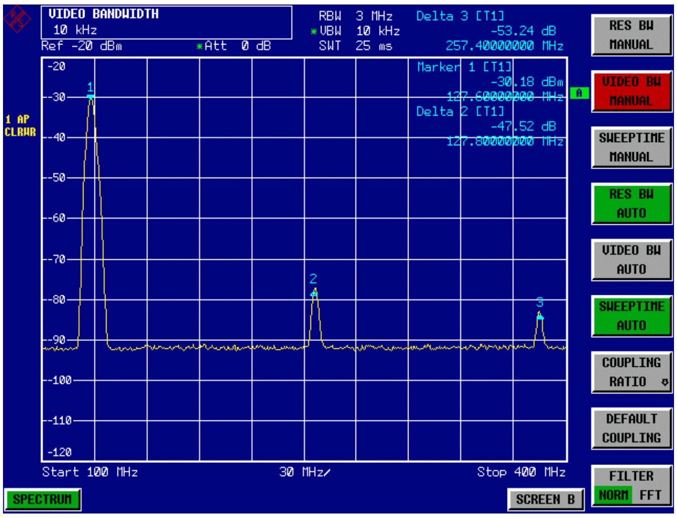
8. Reduce noise by reducing the video bandwidth

➢ Press the *BW* key.

➢ Press the *VIDEO BW MANUAL* softkey.

➢ Reduce the video bandwidth, e.g. to 10 kHz, using the spinwheel (turn knob counterclockwise), or enter *10 kHz.*

The noise is clearly smoothed and the sweep time is increased to 25 ms, i.e. the measurement lasts longer. The displayed video bandwidth is marked with an asterisk (*VBW) to indicate that it is no longer coupled to the resolution bandwidth (see Fig. 2-4).



VIDEO BANDWIDTH
10 kHz

Ref -20 dBm *Att 0 dB
RBW 3 MHz
*VBW 10 kHz
SWT 25 ms

Delta 3 [T1] -53.24 dB 257.40000000 MHz
Marker 1 [T1] -30.18 dBm 127.60000000 MHz
Delta 2 [T1] -47.52 dB 127.80000000 MHz

Fig. 2-4 Suppression of noise during harmonic measurement by reducing video bandwidth

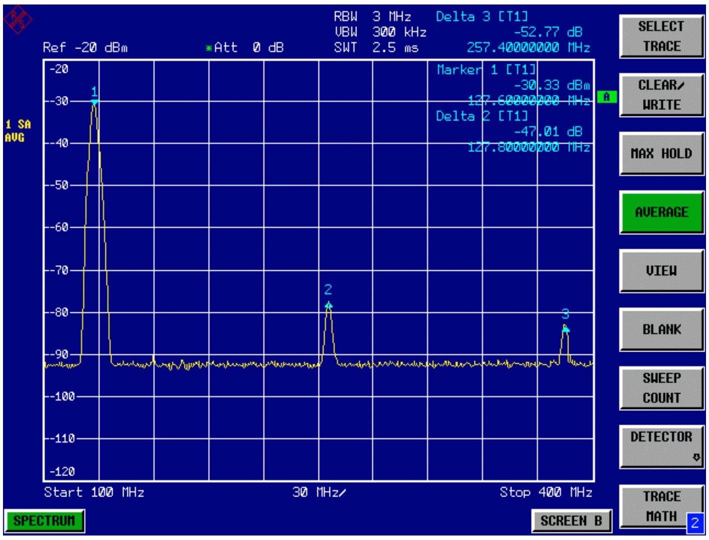
9. Coupling the video bandwidth to the resolution bandwidth again.

➢ Press the *VIDEO BW AUTO* softkey.

10. Reduce noise by averaging the trace

➢ Press the *TRACE* key.

➢ Press the *AVERAGE* softkey.
The noise component of the trace is smoothed by averaging 10 consecutive traces.



Ref -20 dBm *Att 0 dB
RBW 3 MHz
VBW 300 kHz
SWT 2.5 ms

Delta 3 [T1] -52.77 dB 257.40000000 MHz
Marker 1 [T1] -30.33 dBm 127.60000000 MHz
Delta 2 [T1] -47.01 dB 127.80000000 MHz

Fig. 2-5 Suppression of noise during harmonic measurements by averaging the trace

11. Switch off trace averaging again.

➢ Press the *CLEAR/WRITE* softkey.

12. Reduce noise by reducing the measurement bandwidth.

If the resolution bandwidth is decreased, noise is reduced proportionally, i.e. if the resolution bandwidth is reduced by a factor of 10, the noise is also reduced by the same factor (corresponds to 10 dB). The amplitude of a sinusoidal signal is not changed by reducing the resolution bandwidth.

13. Set the resolution bandwidth to 10 kHz.

- ➢ Press the *BW* key.
- ➢ Press the *RES BW MANUAL* softkey and enter *10 kHz*.
  The noise is reduced by approx. 25 dB compared to the previous setting. Since the video bandwidth is coupled to the resolution bandwidth, it is reduced to 1 kHz – the same proportional reduction as the resolution bandwidth. The sweep time is therefore increased to 60 seconds.

14. Reset the resolution bandwidth again (coupling to span).

- ➢ Press the *RES BW AUTO* softkey.

If you want to stop the harmonics measurement on the internal reference generator at this point, switch the FSP's RF input on again with the following key sequence.

- ➢ Press the *SETUP* key and the softkey sequence *SERVICE - INPUT RF* or press the *PRESET* key.

High-Sensitivity Harmonics Measurements

If harmonics have very small levels, the resolution bandwidth required to measure them must be reduced considerably. The sweep time is, therefore, also increased considerably. In this case, the measurement of individual harmonics is carried out with the spectrum analyzer set to a small span. Only the frequency range around the harmonics will then be measured with a small resolution bandwidth.

Measurement Example

1. Set the spectrum analyzer to its default settings.

- ➢ Press the *PRESET* key.
  The FSP is in its default state.

2. Switch on the internal reference generator.

- ➢ Press the *SETUP* key.
- ➢ Press the softkeys *SERVICE - INPUT CAL*.
  The internal 128 MHz reference generator is now on. The FSP's RF input is switched off.

3. Set the center frequency to 128 MHz and the span to 100 kHz.

- ➢ Press the *FREQ* key.
  The frequency menu opens.
- ➢ Enter *128* in the entry field from the numeric keypad and terminate with the *MHz* key.
- ➢ Press the *SPAN* key.
- ➢ Enter *100* in the entry filed from the numeric keypad and terminate with the *kHz* key.
  The FSP displays the reference signal with a span of 100 kHz and resolution bandwidth of 3 kHz.

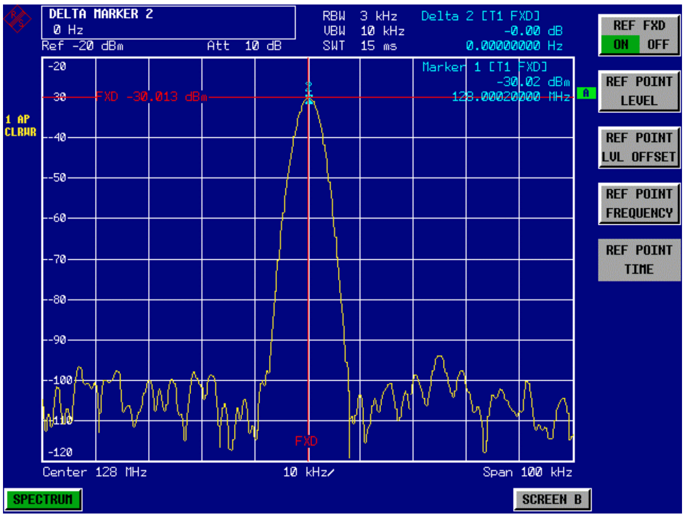
4. Switching on the marker.

- ➢ Press the *MKR* key.
  The marker is positioned on the trace maximum.

5. Set the measured signal frequency and the measured level as reference values

- ➢ Press the *REFERENCE FIXED* softkey.

- ➢ The position of the marker becomes the reference point. The reference point level is indicated by a horizontal line, the reference point frequency with a vertical line. At the same time, the delta 2 marker is switched on at the marker position.



DELTA MARKER 2
0 Hz

Ref -20 dBm Att 10 dB

RBW 3 kHz
VBW 10 kHz
SWT 15 ms

Delta 2 [T1 FXD]
-0.00 dB
0.00000000 Hz

Marker 1 [T1 FXD]
-30.02 dBm
128.00020000 MHz

FXD -30.013 dBm

Center 128 MHz 10 kHz/ Span 100 kHz

Fig. 2-6 Fundamental wave and the frequency and level reference point

6. Make the step size for the center frequency equal to the signal frequency

- ➢ Press the *FREQ* key.
  The frequency menu opens.

- ➢ Press the *CF STEPSIZE* softkey and press the **=***MARKER* softkey in the submenu.
  The step size for the center frequency is now equal to the marker frequency.

7. Set the center frequency to the 2^nd^ harmonic of the signal

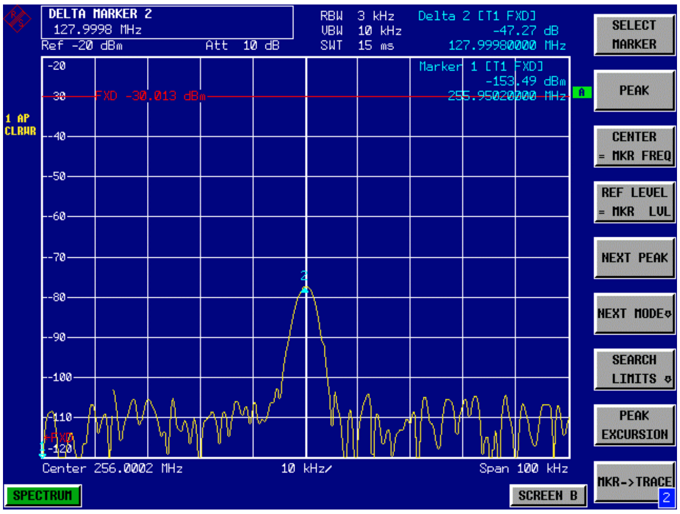
- ➢ Press the *FREQ* key.
  The frequency menu open. s

- ➢ Press the up cursor key (below the spinwheel) once.
  The FSP's center frequency is set to the 2nd harmonic.

8. Place the delta marker on the 2nd harmonic.

- ➢ Press the *MKR* → key.

- ➢ Press the *PEAK* softkey.
  The delta marker jumps to the maximum of the 2nd harmonic. The displayed level result is relative to the reference point level (= fundamental wave level).



DELTA MARKER 2
127.9998 MHz
Ref -20 dBm Att 10 dB
RBW 3 kHz
VBW 10 kHz
SWT 15 ms
Delta 2 [T1 FXD]
-47.27 dB
127.99980000 MHz
Marker 1 [T1 FXD]
-153.49 dBm
255.95020000 MHz
FXD -30.013 dBm
Center 256.0002 MHz 10 kHz/ Span 100 kHz

Fig. 2-7 Measuring the level difference between the fundamental wave (= reference point level) and the 2nd harmonic

The other harmonics are measured with steps 6 and 7, the center frequency being incremented or decremented in steps of 128 MHz using the up or down cursor key.

Measuring the Spectra of complex Signals

Separating Signals by Selecting an Appropriate Resolution Bandwidth

One basic characteristics of the spectrum analyzer is that it can separate the spectral components of a composite signal. The resolution with which the individual components are separated is determined by the resolution bandwidth. If the resolution bandwidth is too large, spectral components may no longer be distinct, i.e. they are displayed as a single component.

An RF sinewave signal is displayed on the screen of the spectrum analyzer with the passband characteristics of the set resolution filter (RBW). It is the 3 dB bandwidth of the filter that is displayed.

Two signals with the same amplitude can be resolved if the resolution bandwidth is less than or equal to the signals' frequency difference. If the resolution bandwidth and the frequency difference are equal, a 3 dB level dip can be seen in the middle between the two signals. The smaller the resolution bandwidth, the deeper the level dip and the better the signal resolution.

If there are large level differences between signals, the resolution is determined by selectivity as well as by the resolution bandwidth that has been selected. The measure of selectivity used for spectrum analyzers is the ratio of the 60 dB bandwidth to the 3 dB bandwidth (= shape factor).

For the FSP, the shape factor for bandwidths up to 100 kHz is < 5 and for larger bandwidths < 15, i.e. the 60 dB bandwidth of the 30 kHz filter is < 150 kHz and that of the 300 kHz filter is < 4.5 MHz. Although the 3 dB bandwidths only differ by a factor of 10, the 60 dB bandwidths differ by a factor of 30.

The higher spectral resolution with smaller bandwidths has to be traded off against longer sweep times for the same span. The sweep time required to allow the resolution filters to settle during a sweep at all signal levels and frequencies to be displayed is given by the following formula.

$$\mathrm{SWT} = k \bullet \mathrm{Span}/\mathrm{RBW}^2 \qquad (1)$$

SWT = max. sweep time for correct measurement
k = factor depending on type of resolution filter
= 2.5 for analog IF filter (≥300 kHz)
= 1 for digital IF filters (≤ 100 kHz)
Span = frequency display range
RBW = resolution bandwidth

If the resolution bandwidth is reduced by a factor of 3, the sweep time is increased by a factor of 9.

Note: *The impact of the video bandwidth on the sweep time is not taken into account in (1). For the formula to be valid, the video bandwidth must be ≥ 3 x the resolution bandwidth.*

For bandwidths > 300 kHz, the FSP uses 4pole, single-section filters. They require a k factor of 2.5 to settle during the frequency sweep. Digital filters with a Gaussian characteristic are used below a bandwidth of 300 kHz (up to 100 kHz). These filters settle at a k factor of 1, i.e. the sweep time is 2.5 times shorter than with conventional 4 or 5 pole, single-section filters.

FFT filters can be used for resolution bandwidths up to 30 kHz. Like digital filters, they have a shape factor of less than 5 up to 30 kHz. For FFT filters, however, the sweep time is given by the following formula:

$$\mathrm{SWT} = k \cdot \mathrm{span}/\mathrm{RBW} \qquad (2)$$

i.e. if the resolution bandwidth is reduced by a factor of 3, the sweep time is increased by a factor of 3 only

Measurement Example - Resolving two signals with a level of –30 dBm each and a frequency difference of 30 kHz

Example:

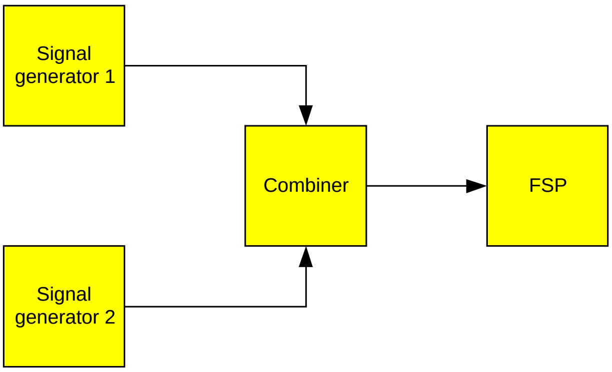


Fig. 2-8 Test setup for generating two signals

Signal generator settings (e.g. SMIQ):

	Level	**Frequency**
Signal generator 1	-30 dBm	100.00 MHz
Signal generator 2	-30 dBm	100.03 MHz

FSP measurement sequence:

1. Set the spectrum analyzer to its default settings.

➢ Press the *PRESET* key.
The FSP is in its default state.

2. Set the center frequency to 100.015 MHz and the frequency span to 300 kHz.

➢ Press the *FREQ* key and enter *100.015 MHz*.

➢ Press the *SPAN* key and enter *300 kHz*.

3. Set the resolution bandwidth is to 30 kHz and the video bandwidth to 1 kHz.

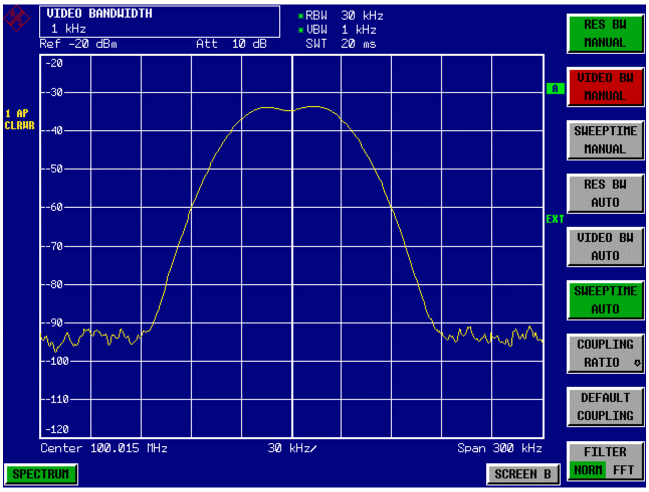
➢ Press the *BW* key.

➢ Press the *RES BW MANUAL* softkey and enter *30 kHz*.

➢ Press the *VIDEO BW MANUAL* softkey and enter *1 kHz*.

➢ The two signals are clearly separated by a 3 dB level dip in the middle of the screen.

> ***Note:*** The video bandwidth is set to 1 kHz to clearly display the level dip in the middle between the two signals. At larger video bandwidths, the video voltage which arises from envelope detection is not sufficiently suppressed. Therefore, additional voltages occur between the two signals and can be seen on the trace.



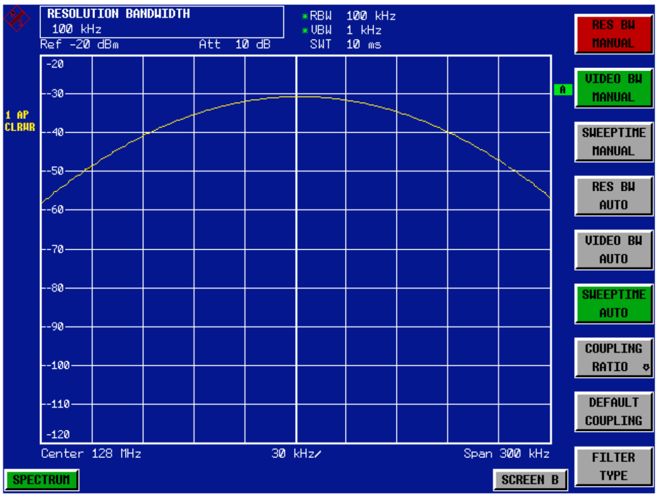
VIDEO BANDWIDTH
1 kHz
RBW 30 kHz
VBW 1 kHz
SWT 20 ms
Ref -20 dBm
Att 10 dB
Center 100.015 MHz
30 kHz/
Span 300 kHz

Fig. 2-9 Measurement of two RF sinewave signals with the same level using a resolution bandwidth which corresponds to the frequency difference of the signals.

> **Note:** *The level dip is only exactly in the middle of the screen if the generator frequencies exactly correspond with the frequency display of FSP. To ensure this, the generators and the FSP must have their frequencies synchronized.*

4. Set the resolution bandwidth to 100 kHz.

➢ Press the *RES BW MANUAL* softkey and enter *100 kHz*.
The two generator signals can no longer be clearly distinguished.



RESOLUTION BANDWIDTH
100 kHz
RBW 100 kHz
VBW 1 kHz
SWT 10 ms
Ref -20 dBm
Att 10 dB
Center 128 MHz
30 kHz/
Span 300 kHz

Fig. 2-10 Measurement on two RF sinewave signals with the same level using a resolution bandwidth which is greater than their frequency difference.

The resolution bandwidth (RBW) can be reduced again by turning the spinwheel counterclockwise to obtain a higher frequency resolution.

5. Set the resolution bandwidth to 1 kHz.

➢ Turn the spinwheel counterclockwise until a bandwidth of 1 kHz is displayed.
The two generator signals are displayed at high resolution. The sweep time increases considerably (600 ms) because it increases by 1/ RBW$^{2.}$ The noise floor also goes down at small resolution bandwidths (10 dB per bandwidth factor of 10).

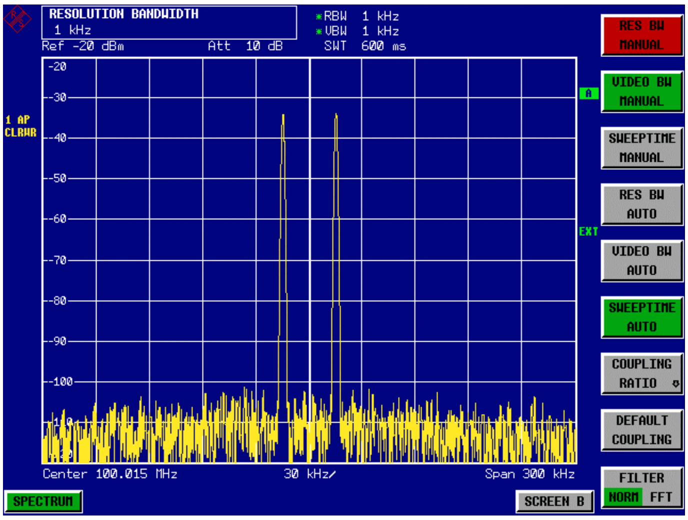

RESOLUTION BANDWIDTH
1 kHz
RBW 1 kHz
VBW 1 kHz
SWT 600 ms
Ref -20 dBm
Att 10 dB
Center 100.015 MHz
30 kHz/
Span 300 kHz

Fig. 2-11 Measurement on two RF sinewave signals with the same level using a resolution bandwidth (1 kHz) which is far below their frequency difference.

6. Switch on the FFT bandwidths.

➢ Set the *FILTER* softkey to *FFT*.
IF filtering is now carried out with the FFT algorithm. The sweep time is considerably reduced from 600 ms to 15 ms (factor of 40). The update rate of the display is increased in almost the same proportion.

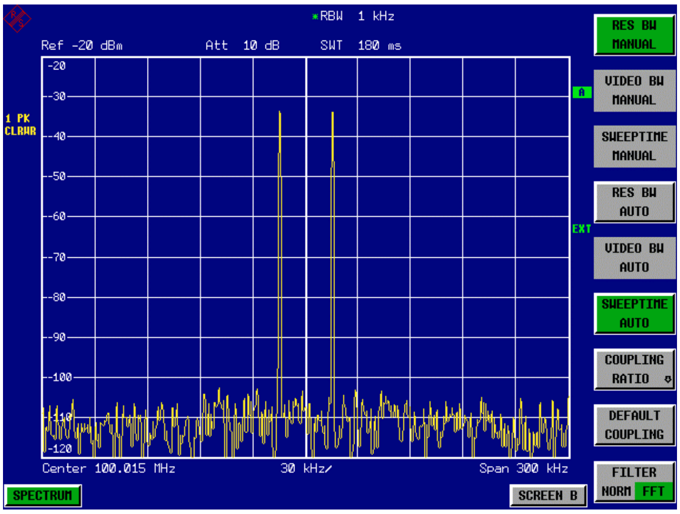

RBW 1 kHz
Ref -20 dBm
Att 10 dB
SWT 180 ms
Center 100.015 MHz
30 kHz/
Span 300 kHz

Fig. 2-12 Measurement with FFT filters gives a considerably shorter sweep time and a higher refresh rate.

Intermodulation Measurements

If several signals are applied to a DUT with non-linear characteristics, unwanted mixing products are generated – mostly by active components such as amplifiers or mixers. The products created by 3rd order intermodulation are particularly troublesome as they have frequencies close to the useful signals and, compared with other products, are closest in level to the useful signals. The fundamental wave of one signal is mixed with the 2nd harmonic of the other signal.

$$f_{s1} = 2 \cdot f_{u1} - f_{u2} \qquad (1)$$

$$f_{s2} = 2 \cdot f_{u2} - f_{u1} \qquad (2)$$

where f_{s1} and f_{s2} are the frequencies of the intermodulation products and f_{u1} and f_{u2} the frequencies of the useful signals.

The following diagram shows the position of the intermodulation products in the frequency domain.

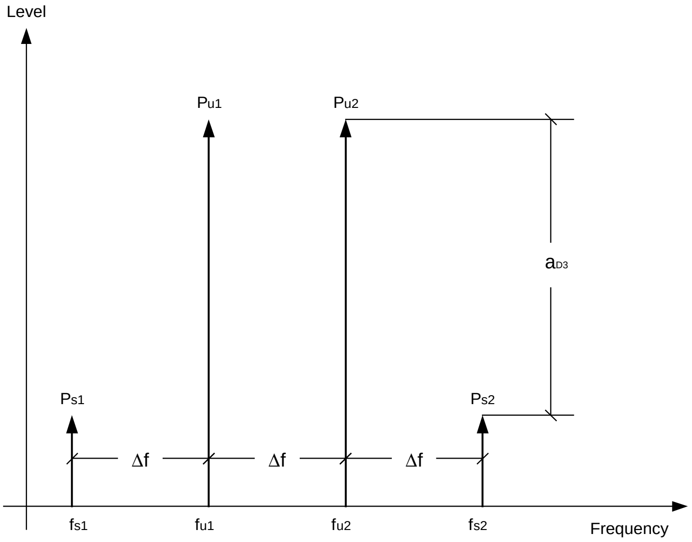


Fig. 2-13 3rd order intermodulation products

Example: f_{u1} = 100 MHz, f_{u2} = 100.03 MHz
$f_{s1} = 2 \cdot f_{u1} - f_{u2} = 2 \cdot 100$ MHz – 100.03 MHz = 99.97 MHz
$f_{s2} = 2 \cdot f_{u2} - f_{u1} = 2 \cdot 100.03$ MHz – 100 MHz = 100.06 MHz

The level of the intermodulation products depends on the level of the useful signals. If the level of the two useful signals is increased by 1 dB, the level of the intermodulation products is increased by 3 dB. The intermodulation distance d_3 is, therefore, reduced by 2 dB. Fig. 2-14 shows how the levels of the useful signals and the 3rd order intermodulation products are related.

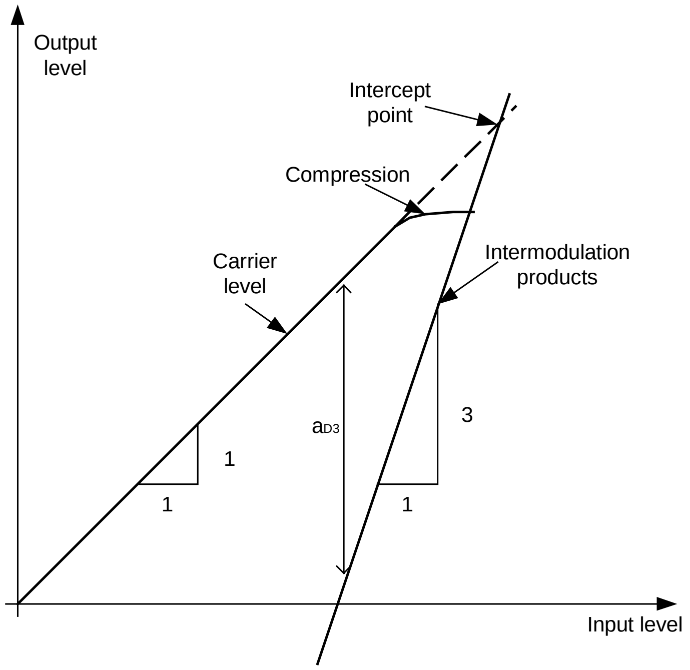


Fig. 2-14 Level of the 3rd order intermodulation products as a function of the level of the useful signals

The behavior of the signals can explained using an amplifier as an example. The change in the level of the useful signals at the output of the amplifier is proportional to the level change at the input of the amplifier as long as the amplifier is operating in linear range. If the level at the amplifier input is changed by 1 dB, there is a 1 dB level change at the amplifier output. At a certain input level, the amplifier enters saturation. The level at the amplifier output does not increase with increasing input level.

The level of the 3rd order intermodulation products increases 3 times faster than the level of the useful signals. The 3rd order intercept is the virtual level at which the level of the useful signals and the level of the spurious products are identical, i.e. the intersection of the two straight lines. This level cannot be measured directly as the amplifier goes into saturation or is damaged before this level is reached.

The 3rd order intercept can be calculated from the known slopes of the lines, the intermodulation distance d_2 and the level of the useful signals.

$$TOI = a_{D3} / 2 + P_n \qquad (3)$$

with TOI (Third Order Intercept) being the 3rd order intercept in dBm and P_n the level of a carrier in dBm.

With an intermodulation distance of 60 dB and an input level, $P_{W,}$ of –20 dBm, the following 3rd order intercept is obtained:

TOI = 60 dBm / 2 + (-20 dBm) = 10 dBm.

Measurement Example – Measuring the FSP's intrinsic intermodulation distance

To measure the intrinsic intermodulation distance, use the test setup in Fig. 2-8.

Signal generator settings (e.g. SMIQ):

	Level	**Frequency**
Signal generator 1	-10 dBm	999.9 MHz
Signal generator 2	-10 dBm	1000.1 MHz

Measurement using the FSP:

1. ***Set the spectrum analyzer to its default settings.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Set center frequency to 1 GHz and the frequency span to 1 MHz.***

   ➢ Press the *FREQ* key and enter 1 GHz.

   ➢ Press the *SPAN* key and enter 1 MHz.

3. ***Set the reference level to –10 dBm and RF attenuation to 0 dB.***

   ➢ Press the *AMPT* key and enter *-10 dBm*.

   ➢ Press the *RF ATTEN MANUAL* softkey and enter 0 dB.
   By reducing the RF attenuation to 0 dB, the level to the FSP input mixer is increased. Therefore, 3rd order intermodulation products are displayed.

4. ***Set the resolution bandwidth to 10 kHz.***

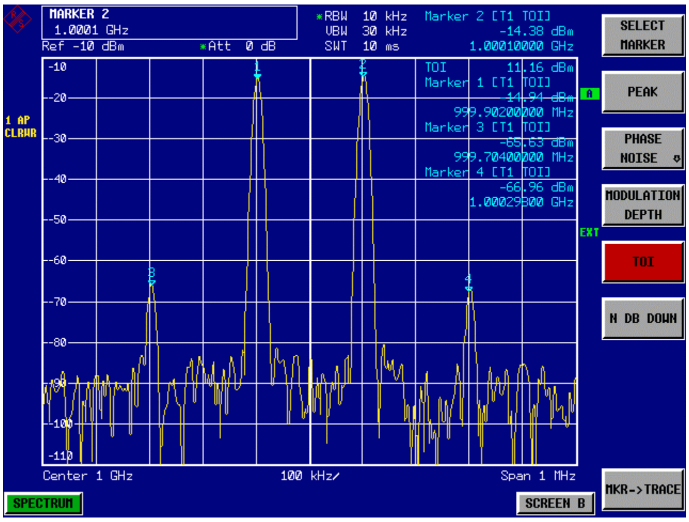
   ➢ Press the *BW* key.

   ➢ Press the *RES BW MANUAL* softkey and enter *10 kHz.*
   By reducing the bandwidth, the noise is further reduced and the intermodulation products can be clearly seen.

5. ***Measuring intermodulation by means of the 3rd order intercept measurement function***

   ➢ Press the *MKR FCTN* key.

   ➢ Press the *TOI* softkey.
   The FSP activates four markers for measuring the intermodulation distance. Two markers are positioned on the useful signals and two on the intermodulation products. The 3rd order intercept is calculated from the level difference between the useful signals and the intermodulation products. It is then displayed on the screen:



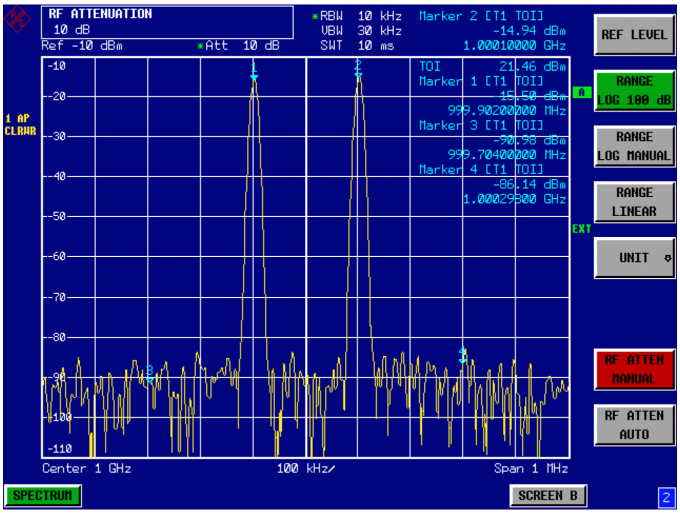
MARKER 2
1.0001 GHz
Ref -10 dBm *Att 0 dB
*RBW 10 kHz
VBW 30 kHz
SWT 10 ms
Marker 2 [T1 TOI]
-14.38 dBm
1.00010000 GHz
TOI 11.16 dBm
Marker 1 [T1 TOI]
-14.94 dBm
999.90200000 MHz
Marker 3 [T1 TOI]
-65.63 dBm
999.70400000 MHz
Marker 4 [T1 TOI]
-66.96 dBm
1.00029800 GHz
Center 1 GHz 100 kHz/ Span 1 MHz

Fig. 2-15 Result of intrinsic intermodulation measurement on the FSP. The 3rd order intercept (TOI) is displayed at the top right corner of the grid

The level of a spectrum analyzer's intrinsic intermodulation products depends on the RF level of the useful signals at the input mixer. When the RF attenuation is added, the mixer level is reduced and the intermodulation distance is increased. With an additional RF attenuation of 10 dB, the levels of the intermodulation products are reduced by 20 dB. The noise level is, however, increased by 10 dB.

6. Increasing RF attenuation to 10 dB to reduce intermodulation products.

- ➢ Press the *AMPT* key.
- ➢ Press the *RF ATTEN MANUAL* softkey and enter *10 dB*.
  The FSP's intrinsic intermodulation products disappear below the noise floor.



RF ATTENUATION
10 dB
Ref -10 dBm *Att 10 dB
*RBW 10 kHz
VBW 30 kHz
SWT 10 ms
Marker 2 [T1 TOI]
-14.94 dBm
1.00010000 GHz
TOI 21.46 dBm
Marker 1 [T1 TOI]
-15.50 dBm
999.90200000 MHz
Marker 3 [T1 TOI]
-90.98 dBm
999.70400000 MHz
Marker 4 [T1 TOI]
-86.14 dBm
1.00029800 GHz
Center 1 GHz 100 kHz/ Span 1 MHz

Fig. 2-16 If the RF attenuation is increased, the FSP's intrinsic intermodulation products disappear below the noise floor.

Calculation method:

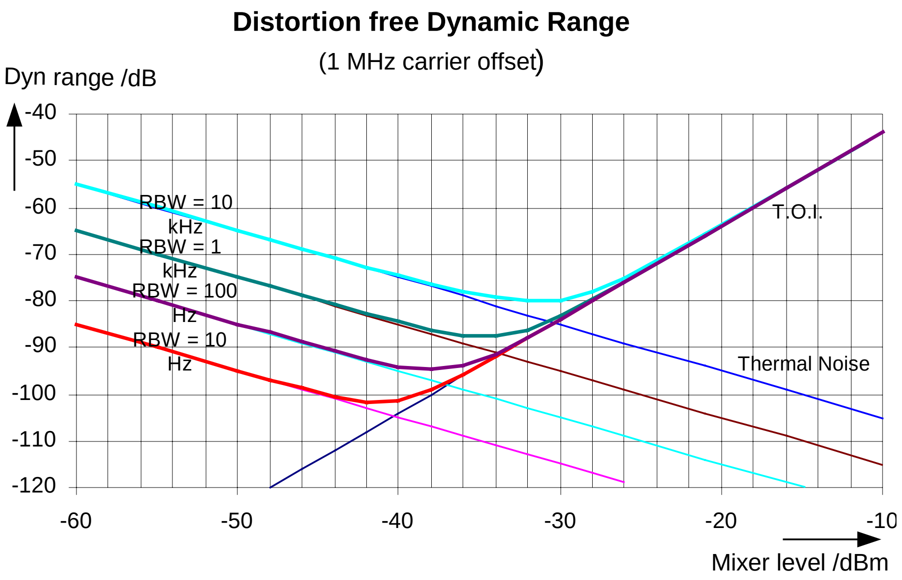
The method used by the FSP to calculate the intercept point takes the average useful signal level P_u in dBm and calculates the intermodulation d_3 in dB as a function of the average value of the levels of the two intermodulation products. The third order intercept (TOI) is then calculated as follows:

TOI/dBm = ½ d_3 + Pu

Intermodulation- free dynamic range

The **Intermodulation – free dynamic range** , i.e. the level range in which no internal intermodulation products are generated if two-tone signals are measured, is determined by the 3rd order intercept point, the phase noise and the thermal noise of the spectrum analyzer. At high signal levels, the range is determined by intermodulation products. At low signal levels, intermodulation products disappear below the noise floor, i.e. the noise floor and the phase noise of the spectrum analyzer determine the range. The noise floor and the phase noise depend on the resolution bandwidth that has been selected. At the smallest resolution bandwidth, the noise floor and phase noise are at a minimum and so the maximum range is obtained. However, a large increase in sweep time is required for small resolution bandwidths. It is, therefore, best to select the largest resolution bandwidth possible to obtain the range that is required. Since phase noise decreases as the carrier-offset increases, its influence decreases with increasing frequency offset from the useful signals.

The following diagrams illustrate the intermodulation-free dynamic range as a function of the selected bandwidth and of the level at the input mixer (= signal level – set RF attenuation) at different useful signal offsets.



Distortion free Dynamic Range

(1 MHz carrier offset)

Fig. 2-17 Intermodulation-free range of the FSP3 as a function of level at the input mixer and the set resolution bandwidth (useful signal offset = 1 MHz, DANL = -155 dBm /Hz, TOI = 12 dBm; typ. values at 2 GHz)

The optimum mixer level, i.e. the level at which the intermodulation distance is at its maximum, depends on the bandwidth. At a resolution bandwidth of 10 Hz, it is approx. –42 dBm and at 10 kHz increases to approx. -32 dBm.

Phase noise has a considerable influence on the intermodulation-free range at carrier offsets between 10 and 100 kHz (Fig. 2-18). At greater bandwidths, the influence of the phase noise is greater than it would be with small bandwidths. The optimum mixer level at the bandwidths under consideration becomes almost independent of bandwidth and is approx. –40 dBm.

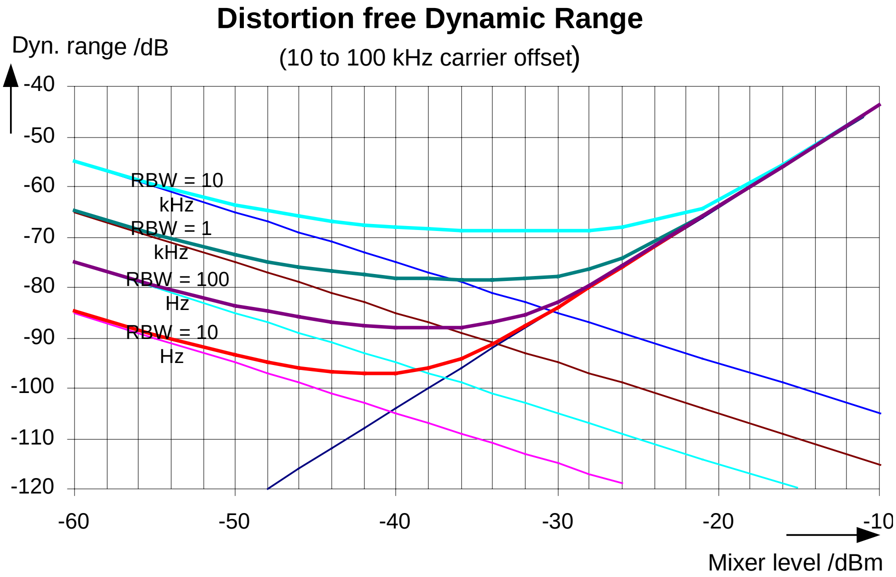


Fig. 2-18 Intermodulation-free dynamic range of the FSP3 as a function of level at the input mixer and of the selected resolution bandwidth (useful signal offset = 10 to 100 kHz, DANL = -155 dBm /Hz, TOI = 12 dBm; typ. values at 2 GHz).

Hint: If the intermodulation products of a DUT with a very high dynamic range are to be measured and the resolution bandwidth to be used is therefore very small, it is best to measure the levels of the useful signals and those of the intermodulation products separately using a small span. The measurement time will be reduced– in particular if the offset of the useful signals is large. To find signals reliably when frequency span is small, it is best to synchronize the signal sources and the FSP.

Measuring Signals in the Vicinity of Noise

The minimum signal level a spectrum analyzer can measure is limited by its intrinsic noise. Small signals can be swamped by noise and therefore cannot be measured. For signals that are just above the intrinsic noise, the accuracy of the level measurement is influenced by the intrinsic noise of the spectrum analyzer.

The displayed noise level of a spectrum analyzer depends on its noise figure, the selected RF attenuation, the selected reference level, the selected resolution and video bandwidth and the detector. The effect of the different parameters is explained in the following.

Impact of the RF attenuation setting

The sensitivity of a spectrum analyzer is directly influenced by the selected RF attenuation. The highest sensitivity is obtained at a RF attenuation of 0 dB. The FSP's RF attenuation can be set in 10 dB steps up to 70 dB (5 dB steps up to 75 dB with option *Electronic Attenuator* FSP-B25. Each additional 10 dB step reduces the FSP's sensitivity by 10 dB, i.e. the displayed noise is increased by 10 dB.

Impact of the reference level setting

If the reference level is changed, the FSP changes the gain on the last IF so that the voltage at the logarithmic amplifier and the A/D converter is always the same for signal levels corresponding to the reference level. This ensures that the dynamic range of the log amp or the A/D converter is fully utilized. Therefore, the total gain of the signal path is low at high reference levels and the noise figure of the IF amplifier makes a substantial contribution to the total noise figure of the FSP. Fig. 2-(21) below shows the change in the displayed noise depending on the set reference level at 10 kHz and 300 kHz resolution bandwidth. With digital bandwidths (≤ 100 kHz) the noise increases sharply at high reference levels because of the dynamic range of the A/D converter.

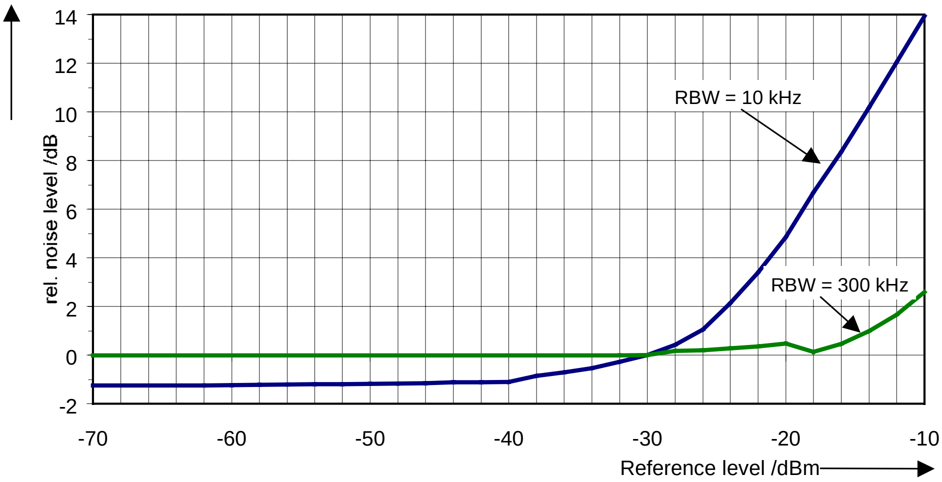


Fig. 2-19 Change in displayed noise as a function of the selected reference level at bandwidths of 10 kHz and 300 kHz (-30 dBm reference level)

Impact of the resolution bandwidth

The sensitivity of a spectrum analyzer also directly depends on the selected bandwidth. The highest sensitivity is obtained at the smallest bandwidth (for the FSP: 10 Hz, for FFT filtering: 1 Hz). If the bandwidth is increased, the reduction in sensitivity is proportional to the change in bandwidth. The FSP has bandwidth settings in 1, 3, 10 sequence. Increasing the bandwidth by a factor of 3 increases the displayed noise by approx. 5 dB (4.77 dB precisely). If the bandwidth is increased by a factor of 10, the displayed noise increases by a factor of 10, i.e. 10 dB. Because of the way the resolution filters are designed, the sensitivity of spectrum analyzers often depends on the selected resolution bandwidth. In data sheets, the displayed average noise level is often indicated for the smallest available bandwidth (for the FSP: 10 Hz). The extra sensitivity obtained if the bandwidth is reduced may therefore deviate from the values indicated above. The following table illustrates typical deviations from the noise figure for a resolution bandwidth of 10 kHz which is used as a reference value (= 0 dB).

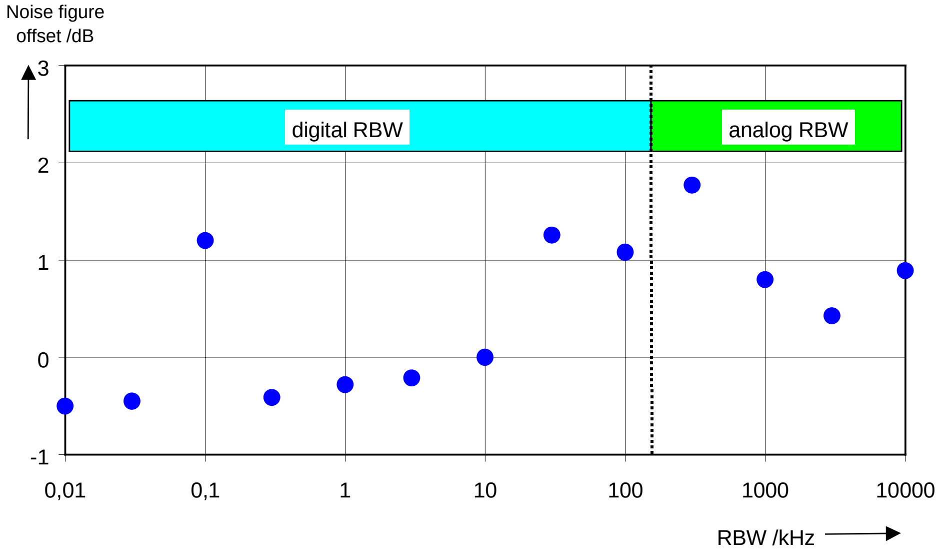


Fig. 2-20 Change in FSP noise figure at various bandwidths. The reference bandwidth is 10 kHz

Impact of the video bandwidth

The displayed noise of a spectrum analyzer is also influenced by the selected video bandwidth. If the video bandwidth is considerably smaller than the resolution bandwidth, noise spikes are suppressed, i.e. the trace becomes much smoother. The level of a sinewave signal is not influenced by the video bandwidth. A sinewave signal can therefore be freed from noise by using a video bandwidth that is small compared with the resolution bandwidth, and thus be measured more accurately.

Impact of the detector

Noise is evaluated differently by the different detectors. The noise display is therefore influenced by the choice of detector. Sinewave signals are weighted in the same way by all detectors, i.e. the level display for a sinewave RF signal does not depend on the selected detector, provided that the signal-to-noise ratio is high enough. The measurement accuracy for signals in the vicinity of intrinsic spectrum analyzer noise is also influenced by the detector which has been selected. The FSP has the following detectors:

Maximum peak detector

If the max. peak detector s selected, the largest noise display is obtained, since the spectrum analyzer displays the highest value of the IF envelope in the frequency range assigned to a pixel at each pixel in the trace. With longer sweep times, the trace indicates higher noise levels since the probability of obtaining a high noise amplitude increases with the dwell time on a pixel. For short sweep times, the display approaches that of the sample detector since the dwell time on a pixel is only sufficient to obtain an instantaneous value.

Minimum peak detector

The min. peak detector indicates the minimum voltage of the IF envelope in the frequency range assigned to a pixel at each pixel in the trace. The noise is strongly suppressed by the minimum peak detector since the lowest noise amplitude that occurs is displayed for each test point. If the signal-to-noise ratio is low, the minimum of the noise overlaying the signal is displayed too low.
At longer sweep times, the trace shows smaller noise levels since the probability of obtaining a low noise amplitude increases with the dwell time on a pixel. For short sweep times, the display approaches that of the sample detector since the dwell time on a pixel is only sufficient to obtain an instantaneous value.

Autopeak detector
The Autopeak detector displays the maximum and minimum peak value at the same time. Both values are measured and their levels are displayed on the screen joint by a vertical line.

Sample detector
The sample detector samples the logarithm of the IF envelope for each pixel of the trace only once and displays the resulting value. If the frequency span of the spectrum analyzer is considerably higher than the resolution bandwidth (span/RBW >500), there is no guarantee that useful signals will be detected. They are lost due to undersampling. This does not happen with noise because in this case it is not the instantaneous amplitude that is relevant but only the probability distribution.

RMS detector
For each pixel of the trace, the RMS detector outputs the RMS value of the IF envelope for the frequency range assigned to each test point. It therefore measures noise power. The display for small signals is, however, the sum of signal power and noise power. For short sweep times, i.e. if only one uncorrelated sample value contributes to the RMS value measurement, the RMS detector is equivalent to the sample detector. If the sweep time is longer, more and more uncorrelated RMS values contribute to the RMS value measurement. The trace is, therefore, smoothed. The level of sinewave signals is only displayed correctly if the selected resolution bandwidth (RBW) is at least as wide as the frequency range which corresponds to a pixel in the trace. At a resolution bandwidth of 1 MHz, this means that the maximum frequency display range is 501 MHz.

Average detector
For each pixel of the trace, the average detector outputs the average value of the linear IF envelope for the frequency range assigned to each test point. It therefore measures the linear average noise. The level of sinewave signals is only displayed correctly if the selected resolution bandwidth (RBW) is at least as wide as the frequency range which corresponds to a pixel in the trace. At a resolution bandwidth of 1 MHz, this means the maximum frequency display range is 501 MHz.

Quasi peak detector
The quasi peak detector is a peak detector for EMI measurements with defined charge and discharge times. These times are defined in CISPR 16, the standard for equipment used to measure EMI emissions.

Measurement example – Measuring the level of the internal reference generator at low S/N ratios

The example shows the different factors influencing the S/N ratio.

1. ***Set the spectrum analyzer to its default state.***

   - Press the *PRESET* key.
     The FSP is in its default state.

2. ***Switch on the internal reference generator***

   - Press the *SETUP* key.
   - Press the softkeys *SERVICE - INPUT CAL*.
     The internal 128 MHz reference generator is on.
     The FSP's RF input is off.

3. ***Set the center frequency to 128 MHz and the frequency span to 100 MHz.***

   - Press the *FREQ* key and enter *128 MHz*.
   - Press the *SPAN* key and enter *100* MHz.

4. Set the RF attenuation to 60 dB to attenuate the input signal or to increase the intrinsic noise.

- ➢ Press the *AMPT* key.
- ➢ Press the *RF ATTEN MANUAL* softkey and enter *60 dB*.
  The RF attenuation indicator is marked with an asterisk (*Att 60 dB) to show that it is no longer coupled to the reference level. The high input attenuation reduces the reference signal which can no longer be detected in noise.

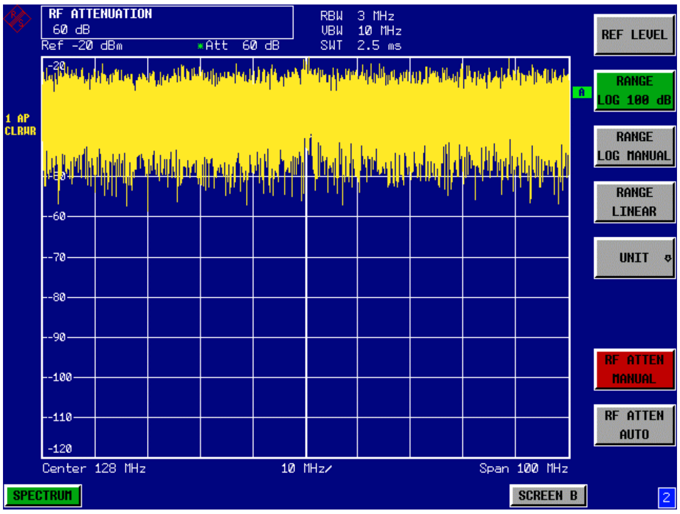

RF ATTENUATION
60 dB
Ref -20 dBm *Att 60 dB
RBW 3 MHz
VBW 10 MHz
SWT 2.5 ms
Center 128 MHz 10 MHz/ Span 100 MHz

Fig. 2-21 Sinewave signal with low S/N ratio. The signal is measured with the autopeak detector and is completely swamped by the intrinsic noise of the spectrum analyzer.

5. To suppress noise spikes the trace can be averaged.

- ➢ Press the *TRACE* key.
- ➢ Press the *AVERAGE* softkey.
  The traces of consecutive sweeps are averaged. To perform averaging, the FSP automatically switches on the sample detector. The RF signal, therefore, can be more clearly distinguished from noise.

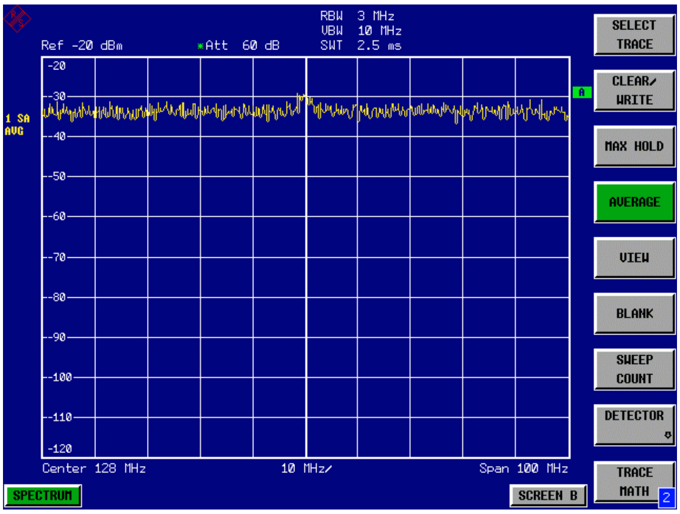
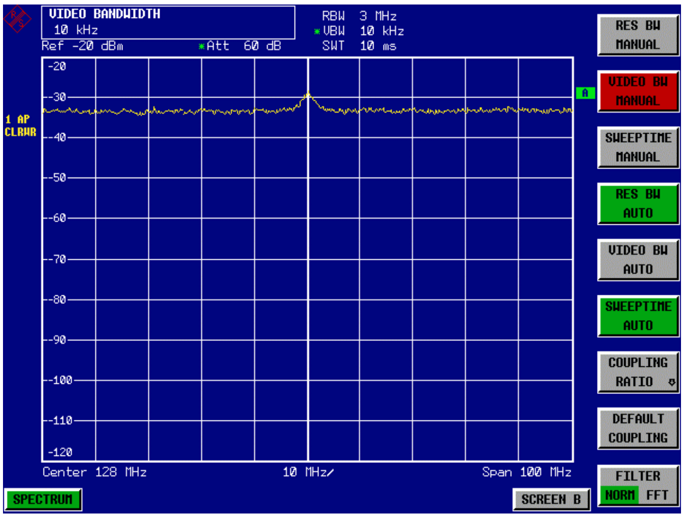

Ref -20 dBm *Att 60 dB
RBW 3 MHz
VBW 10 MHz
SWT 2.5 ms
Center 128 MHz 10 MHz/ Span 100 MHz

Fig. 2-22 RF sinewave signal with low S/N ratio if the trace is averaged.

6. Instead of trace averaging, a video filter that is narrower than the resolution bandwidth can be selected.

- ➢ Press the *CLEAR/WRITE* softkey in the trace menu.
- ➢ Press the *BW* key.
- ➢ Press the *VIDEO BW MANUAL* softkey and enter *10 kHz*.
  The RF signal can be more clearly distinguished from noise.

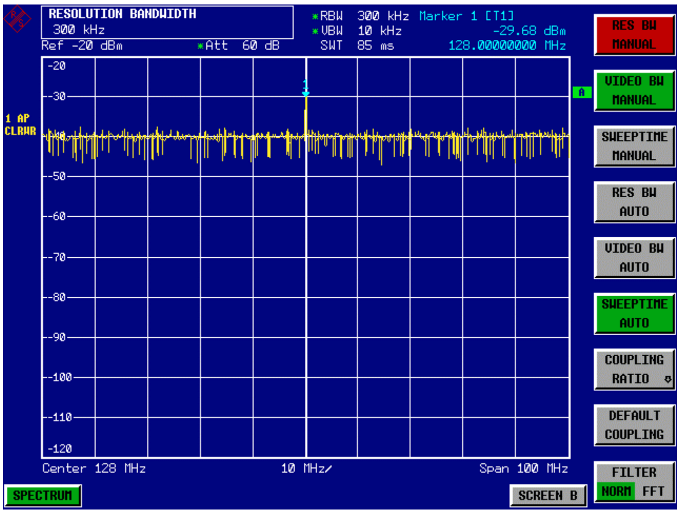


VIDEO BANDWIDTH
10 kHz
Ref -20 dBm *Att 60 dB
RBW 3 MHz
*VBW 10 kHz
SWT 10 ms
Center 128 MHz 10 MHz/ Span 100 MHz

Fig. 2-23 RF sinewave signal with low S/N ratio if a smaller video bandwidth is selected.

7. By reducing the resolution bandwidth by a factor of 10, the noise is reduced by 10 dB.

- ➢ Press the *RES BW MANUAL* softkey and enter *300 kHz*.
  The displayed noise is reduced by approx. 10 dB. The signal, therefore, emerges from noise by about 10 dB. Compared to the previous setting, the video bandwidth has remained the same, i.e. it has increased relative to the smaller resolution bandwidth. The averaging effect is, therefore, reduced by the video bandwidth. The trace will be noisier.



RESOLUTION BANDWIDTH
300 kHz
Ref -20 dBm *Att 60 dB
*RBW 300 kHz
*VBW 10 kHz
SWT 85 ms
Marker 1 [T1]
-29.68 dBm
128.00000000 MHz
Center 128 MHz 10 MHz/ Span 100 MHz

Fig. 2-24 Reference signal at a smaller resolution bandwidth

Noise Measurements

Noise measurements play an important role in spectrum analysis. Noise e.g. affects the sensitivity of radiocommunication systems and their components.

Noise power is specified either as the total power in the transmission channel or as the power referred to a bandwidth of 1 Hz. The sources of noise are, for example, amplifier noise or noise generated by oscillators used for the frequency conversion of useful signals in receivers or transmitters. The noise at the output of an amplifier is determined by its noise figure and gain.

The noise of an oscillator is determined by phase noise near the oscillator frequency and by thermal noise of the active elements far from the oscillator frequency. Phase noise can mask weak signals near the oscillator frequency and make them impossible to detect.

Measuring noise power density

To measure noise power referred to a bandwidth of 1 Hz at a certain frequency, the FSP has an easy-to-use marker function. This marker function calculates the noise power density from the measured marker level.

Measurement example – Measuring the intrinsic noise power density of the FSP at 1 GHz and calculating the FSP's noise figure.

1. ***Set the spectrum analyzer to its default state.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Set the center frequency to 1 GHz and the span to 1 MHz.***

   ➢ Press the *FREQ* key and enter *1 GHz*.

   ➢ Press the *SPAN* key and enter *1 MHz*.

3. ***Switch on the marker and set the marker frequency to 1 GHz.***

   ➢ Press the *MKR* key and enter *1 GHz*.

4. ***Switch on the noise marker function.***

   ➢ Press the *NOISE MARKER* softkey.
   The FSP displays the noise power at 1 GHz in dBm (1Hz).

   Since noise is random, a sufficiently long measurement time has to be selected to obtain stable measurement results. This can be achieved by averaging the trace or by selecting a very small video bandwidth relative to the resolution bandwidth.

5. ***The measurement result is stabilized by averaging the trace***

   ➢ Press the *TRACE* key.

   ➢ Press the *AVERAGE* softkey.
   The FSP performs sliding averaging over 10 traces from consecutive sweeps. The measurement result becomes more stable.

Conversion to other reference bandwidths

The result of the noise measurement can be referred to other bandwidths by simple conversion. This is done by adding 10 · log (BW) to the measurement result, BW being the new reference bandwidth.

Example:

A noise power of –150 dBm (1 Hz) is to be referred to a bandwidth of 1 kHz.
$P_{[1kHz]}$ = -150 + 10 * log (1000) = -150 +30 = -120 dBm(1 kHz)

Calculation method:

The following method is used to calculate the noise power:

If the noise marker is switched on, the FSP automatically activates the sample detector. The video bandwidth is set to 1/10 of the selected resolution bandwidth (RBW).

To calculate the noise, the FSP takes an average over 17 adjacent pixels (the pixel on which the marker is positioned and 8 pixels to the left, 8 pixels to the right of the marker). The measurement result is stabilized by video filtering and averaging over 17 pixels.

Since both video filtering and averaging over 17 trace points is performed in the log display mode, the result would be 2.51 dB too low (difference between logarithmic noise average and noise power). The FSP, therefore, corrects the noise figure by 2.51 dB.

To standardize the measurement result to a bandwidth of 1 Hz, the result is also corrected by –10 * log (RBW_{noise}), with RBW_{noise} being the power bandwidth of the selected resolution filter (RBW).

Detector selection

The noise power density is measured in the default setting with the sample detector and using averaging. Other detectors that can be used to perform a measurement giving true results are the average detector or the RMS detector. If the average detector is used, the linear video voltage is averaged and displayed as a pixel. If the RMS detector is used, the squared video voltage is averaged and displayed as a pixel. The averaging time depends on the selected sweep time (=SWT/501). An increase in the sweep time gives a longer averaging time per pixel and thus stabilizes the measurement result. The FSP automatically corrects the measurement result of the noise marker display depending on the selected detector (+1.05 dB for the average detector, 0 dB for the RMS detector). It is assumed that the video bandwidth is set to at least three times the resolution bandwidth. While the average or RMS detector is being switched on, the FSP sets the video bandwidth to a suitable value.

The Pos Peak, Neg Peak, Auto Peak and Quasi Peak detectors are not suitable for measuring noise power density.

Determining the noise figure:

The noise figure of amplifiers or of the FSP alone can be obtained from the noise power display. Based on the known thermal noise power of a 50 Ω resistor at room temperature (-174 dBm (1Hz)) and the measured noise power P_{noise} the noise figure (NF) is obtained as follows:

$NF = P_{noise} + 174 – g$,
where g = gain of DUT in dB

Example: The measured internal noise power of the FSP at an attenuation of 0 dB is found to be –153 dBm/1 Hz. The noise figure of the FSP is obtained as follows

NF = -153 + 174 = 19 dB

Note: If noise power is measured at the output of an amplifier, for example, the sum of the internal noise power and the noise power at the output of the DUT is measured. The noise power of the DUT can be obtained by subtracting the internal noise power from the total power (subtraction of linear noise powers). By means of the following diagram, the noise level of the DUT can be estimated from the level difference between the total and the internal noise level.

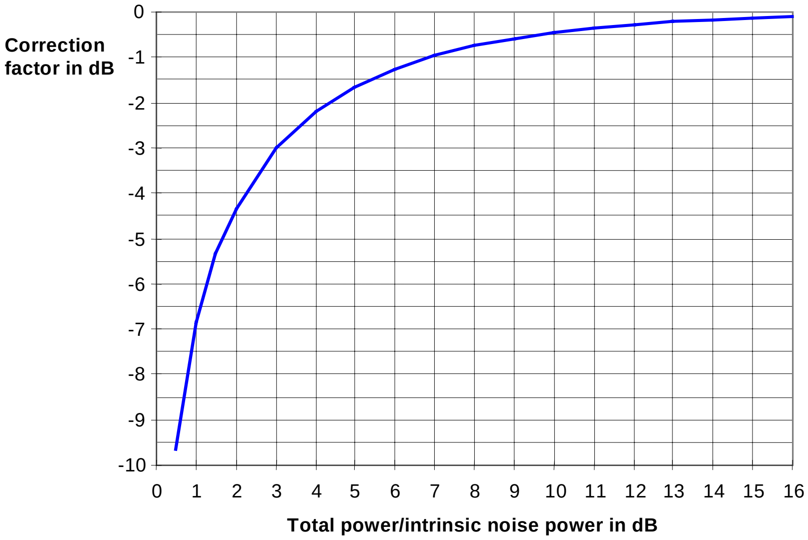


Fig. 2-25 Correction factor for measured noise power as a function of the ratio of total power to the intrinsic noise power of the spectrum analyzer.

Measurement of Noise Power within a Transmission Channel

Noise in any bandwidth can be measured with the channel power measurement functions. Thus the noise power in a communication channel can be determined, for example. If the noise spectrum within the channel bandwidth is flat, the noise marker from the previous example can be used to determine the noise power in the channel by considering the channel bandwidth. If, however, phase noise and noise that normally increases towards the carrier is dominant in the channel to be measured, or if there are discrete spurious signals in the channel, the channel power measurement method must be used to obtain correct measurement results.

Measurement Example – Measuring the intrinsic noise of the FSP at 1 GHz in a 1.23 MHz channel bandwidth with the channel power function

Test setup:

The RF input of the FSP remains open-circuited or is terminated with 50 Ω.

Measurement with the FSP:

1. Set the spectrum analyzer to its default state.

- ➢ Press the *PRESET* key.
  The FSP is in its default state.

2. Set the center frequency to 1 GHz and the span to 1 MHz.

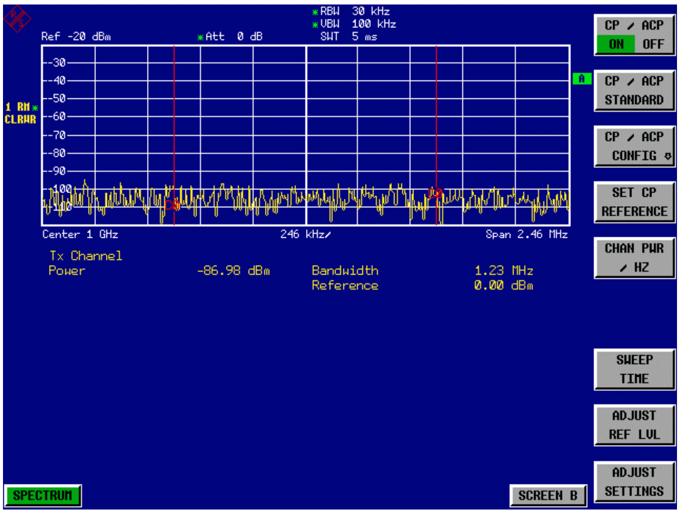
- ➢ Press the *FREQ* key and enter *1 GHz.*
- ➢ Press the *SPAN* key and enter *2 MHz*.

3. To obtain maximum sensitivity, set RF attenuation on the FSP to 0 dB.

- ➢ Press the *AMPT* key.
- ➢ Press the *RF ATTEN MANUAL* softkey and enter *0 dB*.

4. Switch on and configure the channel power measurement.

- ➢ Press the *MEAS* key.
- ➢ Press the *CHAN POWER / ACP* softkey.
  The FSP activates the channel or adjacent channel power measurement according to the currently set configuration.
- ➢ Press the *CP/ACP CONFIG ⇩* softkey.
  The FSP enters the submenu for configuring the channel.
- ➢ Press the *CHANNEL BANDWIDTH* softkey and enter *1.23 MHz*.
  The FSP displays the 1.23 MHz channel as two vertical lines which are symmetrical to the center frequency.
- ➢ Press the *PREV* key.
  The FSP returns to the main menu for channel and adjacent channel power measurement.
- ➢ Press the *ADJUST SETTINGS* softkey.
  The settings for the frequency span, the bandwidth (RBW and VBW) and the detector are automatically set to the optimum values required for the measurement.


RBW 30 kHz
VBW 100 kHz
SWT 5 ms
Ref -20 dBm
Att 0 dB
1 RM
CLRWR
Center 1 GHz
246 kHz/
Span 2.46 MHz

Tx Channel
Power -86.98 dBm
Bandwidth 1.23 MHz
Reference 0.00 dBm

Fig. 2-26 Measurement of the FSP’s intrinsic noise power in a 1.23 MHz channel bandwidth.

5. Stabilizing the measurement result by increasing the sweep time

- Press the *SWEEP TIME* softkey and enter *1 s*.
  By increasing the sweep time to 1 s, the trace becomes much smoother thanks to the RMS detector and the channel power measurement display is much more stable.

6. Referring the measured channel power to a bandwidth of 1 Hz

- Press the *CHAN PWR / Hz* softkey.
  The channel power is referred to a bandwidth of 1 Hz. The measurement is corrected by -10 * log (ChanBW), with ChanBW being the channel bandwidth that was selected.

Method of calculating the channel power

When measuring the channel power, the FSP integrates the linear power which corresponds to the levels of the pixels within the selected channel. The analyzer uses a resolution bandwidth which is far smaller than the channel bandwidth. When sweeping over the channel, the channel filter is formed by the passband characteristics of the resolution bandwidth (see Fig. 2-27).

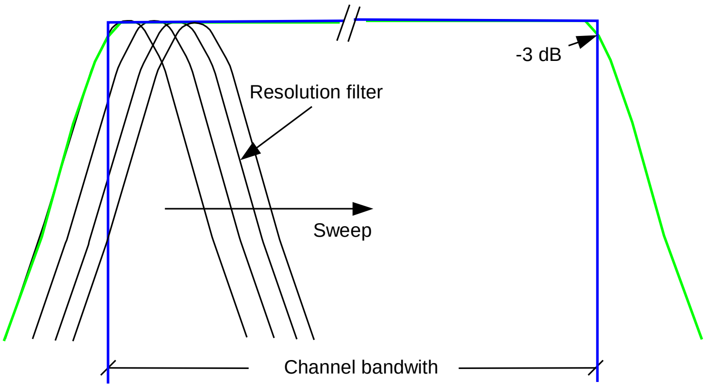


Fig. 2-27 Approximating the channel filter by sweeping with a small resolution bandwidth

The following steps are performed:

- The linear power of all the trace pixels within the channel is calculated.

  $P_i = 10^{(L_i/10)}$

  where P_i = power of the trace pixel i

  L_i = displayed level of trace point i

- The powers of all trace pixels within the channel are summed up and the sum is divided by the number of trace pixels in the channel.
- The result is multiplied by the quotient of the selected channel bandwidth and the noise bandwidth of the resolution filter (RBW).

Since the power calculation is performed by integrating the trace within the channel bandwidth, this method is also called the IBW method (**I**ntegration **B**and**w**idth method).

Bandwidth selection (RBW)

For channel power measurements, the resolution bandwidth (RBW) must be small compared to the channel bandwidth, so that the channel bandwidth can be defined precisely. If the resolution bandwidth which has been selected is too wide, this may have a negative effect on the selectivity of the simulated channel filter and result in the power in the adjacent channel being added to the power in the transmit channel. A resolution bandwidth equal to 1% to 3% of the channel bandwidth should, therefore, be selected. If the resolution bandwidth is too small, the required sweep time becomes too long and the measurement time increases considerably.

Detector selection

Since the power of the trace is measured within the channel bandwidth, only the sample detector and RMS detector can be used. These detectors provide measured values that make it possible to calculate the real power. The peak detectors (Pos Peak, Neg Peak and Auto Peak) are not suitable for noise power measurements as no correlation can be established between the peak value of the video voltage and power.

With the **sample detector,** a value (sample) of the IF envelope voltage is displayed at each trace pixel. Since the frequency spans are very large compared with the resolution bandwidth (span/RBW >501), sinewave signals present in the noise might be lost, i.e. they are not displayed. This is not important for pure noise signals, however, since a single sample in itself is not important - it is the probability distribution of all measured values that counts. The number of samples for power calculation is limited to the number of trace pixels (501 for the FSP).

Note: *To increase the repeatability of measurements, averaging is often carried out over several traces (**AVERAGE** softkey in the **TRACE** menu). This gives spurious results for channel power measurements (max. –2.51 dB for ideal averaging). Trace averaging should, therefore, be avoided.*

With the **RMS detector,** the whole IF envelope is used to calculate the power for each trace pixel. The IF envelope is digitized using a sampling frequency which is at least five times the resolution bandwidth which has been selected. Based on the sample values, the power is calculated for each trace pixel using the following formula:

$$P_{RMS} = \sqrt{\frac{1}{N} \cdot \sum_{i=1}^{N} s_i^2}$$

s_i = linear digitized video voltage at the output of the A/D converter
N = number of A/D converter values per pixel of the trace

P_{RMS} = power represented by a trace pixel

When the power has been calculated, the power units are converted into decibels and the value is displayed as a trace pixel.

The number of A/D converter values, N, used to calculate the power, is defined by the sweep time. The time per trace pixel for power measurements is directly proportional to the selected sweep time. The RMS detector uses far more samples for power measurement than the sample detector, especially if the sweep time is increased. The measurement uncertainty can be reduced considerably. In the default setting, the FSP therefore uses the RMS detector to measure the channel power.

For both detectors (sample and RMS), the video bandwidth (VBW) must at least be three times the resolution bandwidth, so that the peak values of the video voltage are not cut off by the video filter. At smaller video bandwidths, the video signal is averaged and the power readout will be too small.

Sweep time selection

If the sample detector is used, it is best to select the smallest sweep time possible for a given span and resolution bandwidth. The minimum time is obtained if the setting is coupled. This means that the time per measurement is minimal. Extending the measurement time does not have any advantages as the number of samples for calculating the power is defined by the number of trace pixels in the channel.

When using the RMS detector, the repeatability of the measurement results can be influenced by the selection of sweep times. Repeatability is increased at longer sweep times.
Repeatability can be estimated from the following diagram:

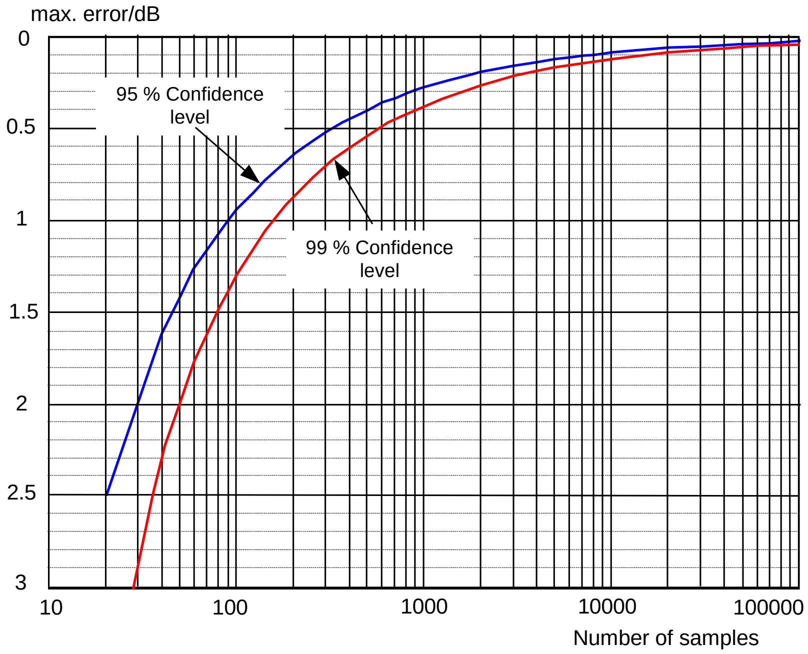


Fig. 2-28 Repeatability of channel power measurements as a function of the number of samples used for power calculation

The curves in Fig. 2-28 indicates the repeatability obtained with a probability of 95% and 99% depending on the number of samples used.
The repeatability with 600 samples is ± 0.5 dB. This means that – if the sample detector and a channel bandwidth over the whole diagram (channel bandwidth = span) is used - the measured value lies within ± 0.5 dB of the true value with a probability of 99%.

If the RMS detector is used, the number of samples can be estimated as follows:

Since only uncorrelated samples contribute to the RMS value, the number of samples can be calculated from the sweep time and the resolution bandwidth.

Samples can be assumed to be uncorrelated if sampling is performed at intervals of 1/RBW. The number of uncorrelated samples (N_{decorr}) is calculated as follows:

$N_{decorr} = SWT \cdot RBW$

The number of uncorrelated samples per trace pixel is obtained by dividing N_{decorr} by 501 (= pixels per trace).

Example:

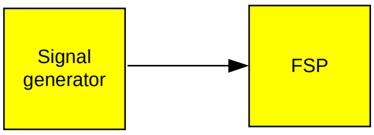
At a resolution bandwidth of 30 kHz and a sweep time of 100 ms, 3000 uncorrelated samples are obtained. If the channel bandwidth is equal to the frequency display range, i.e. all trace pixels are used for the channel power measurement, a repeatability of 0.2 dB with a confidence level of 99% is the estimate that can be derived from Fig. 2-28.

Measuring Phase Noise

The FSP has an easy-to-use marker function for phase noise measurements. This marker function indicates the phase noise of an RF oscillator at any carrier in dBc in a bandwidth of 1 Hz.

Measurement Example - Measuring the phase noise of a signal generator at a carrier offset of 10 kHz.

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	0 dBm

Measurement using FSP:

1. ***Set the spectrum analyzer to its default state***

   - ➢ Press the *PRESET* key.
     FSP is in its default state.

2. ***Set the center frequency to 100 MHz and the span to 50 kHz***

   - ➢ Press the *FREQ* key and enter *100 MHz.*
   - ➢ Press the *SPAN* key and enter *50 kHz.*

3. ***Set the FSP's reference level to 0 dBm (=signal generator level)***

   - ➢ Press the *AMPT* key and enter *0 dBm.*

4. Enable phase noise measurement

- Press the *MKR FCTN* key.
- Press the *PHASE NOISE ⇩* softkey.
  The FSP activates phase noise measurement. Marker 1 (=main marker) and marker 2 (= delta marker) are positioned on the signal maximum. The position of the marker is the reference (level and frequency) for the phase noise measurement. A horizontal line represents the level of the reference point and a vertical line the frequency of the reference point. Data entry for the delta marker is activated so that the frequency offset at which the phase noise is to be measured can be entered directly.

5. 10 kHz frequency offset for determining phase noise.

- Enter *10 kHz*.
  The FSP displays the phase noise at a frequency offset of 10 kHz . The magnitude of the phase noise in dBc/Hz is displayed in the delta marker output field at the top right of the screen (delta 2 [T1 PHN]).

6. Stabilize the measurement result by activating trace averaging.

- Press the *TRACE* key.
- Press the *AVERAGE* softkey.

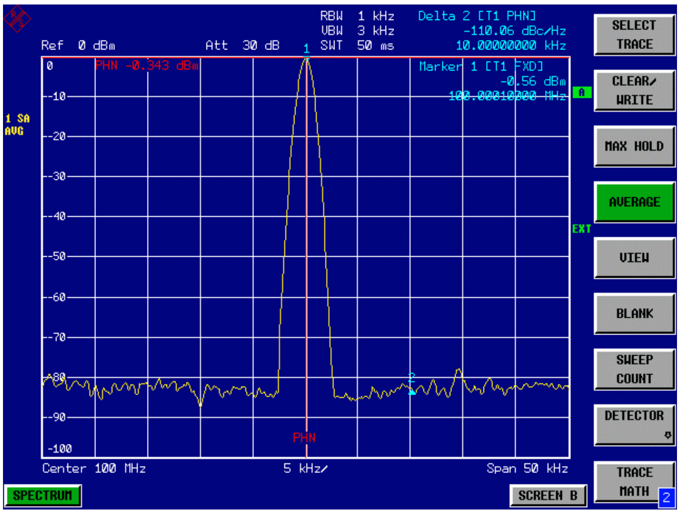


Fig. 2-29 Measuring phase noise with the phase-noise marker function

The frequency offset can be varied by moving the marker with the spinwheel or by entering a new frequency offset as a number.

Measurements on Modulated Signals

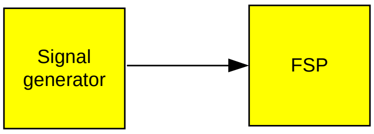
If RF signals are used to transmit information, an RF carrier is modulated. Analog modulation methods such as amplitude modulation, frequency modulation and phase modulation have a long history and digital modulation methods are now used for modern systems. Measuring the power and the spectrum of modulated signals is an important task to assure transmission quality and to ensure the integrity of other radio services. This task can be performed easily with a spectrum analyzer. Modern spectrum analyzers also provide the test routines that are essential to simplify complex measurements.

Measurements on AM signals

The spectrum analyzer detects the RF input signal and displays the magnitudes of its components as a spectrum. AM modulated signals are also demodulated by this process. The AF voltage can be displayed in the time domain if the modulation sidebands are within the resolution bandwidth. In the frequency domain, the AM sidebands can be resolved with a small bandwidth and can be measured separately. This means that the modulation depth of a carrier modulated with a sinewave signal can be measured. Since the dynamic range of a spectrum analyzer is very wide, even extremely small modulation depths can be measured accurately. The FSP has a test routine which measures the modulation depth in %.

Measurement Example 1 – Displaying the AF of an AM signal in the time domain.

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	0 dBm
Modulation:	50 % AM, 1 kHz AF

Measurement with the FSP:

1. ***Set the spectrum analyzer to its default state***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Set the center frequency to 100 MHz and the span to 0 kHz***

   ➢ Press the *FREQ* key and enter *100 MHz*.

   ➢ Press the *SPAN* key and enter *0 Hz*.

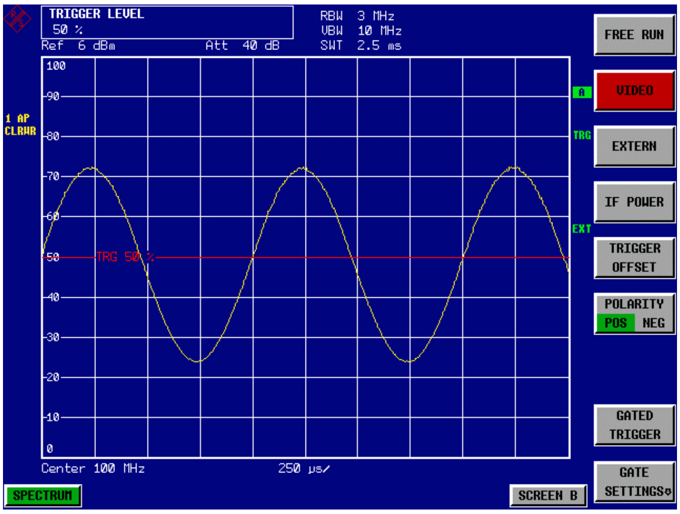
3. ***Set the reference level to +6 dBm and the display range to linear***

   ➢ Press the *AMPT* key and enter *6 dBm*.

   ➢ Press the *RANGE LINEAR* softkey.

4. Use the video trigger to trigger on the AF signal in order to obtain a stationary display

- ➢ Press the *TRIG* key.
- ➢ Press the *VIDEO* softkey.
  The video trigger level is set to 50% if the instrument is switched on for the first time. The trigger level is displayed as a horizontal line across the graph. The FSP displays the 1 kHz AF signal stably in the time domain.



TRIGGER LEVEL
50 %
RBW 3 MHz
VBW 10 MHz
SWT 2.5 ms
Ref 6 dBm
Att 40 dB
Center 100 MHz
250 µs/

Fig. 2-30 Measuring the AF signal from a 1 kHz AM carrier

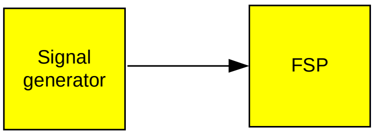
If the FSP is equipped with the AM/FM Demodulator option (FSP-B3), the AF can be monitored on the built-in loudspeaker.

5. Switch on the internal AM demodulator

- ➢ Press the *MKR FCTN* key.
- ➢ Press the *MKR DEMOD* softkey.
  The FSP switches the AM demodulator on automatically.
- ➢ Turn up volume control.
  A 1 kHz tone is output by the built-in loudspeaker.

Measurement Example 2 - Measuring the modulation depth of an AM carrier in the frequency domain.

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	-30 dBm
Modulation:	50 % AM, 1 kHz AF

Measurement with the FSP:

1. *Set the spectrum analyzer to its default state*

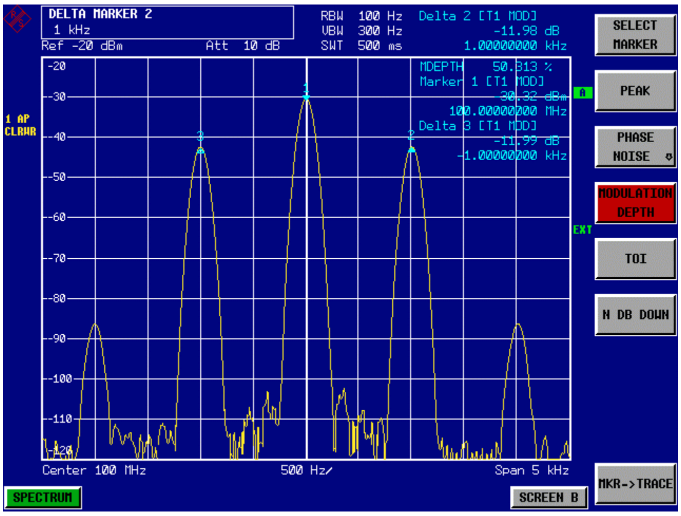
- ➢ Press the PRESET key.
  The FSP is in its default state.

2. *Set the center frequency to 100 MHz and the span to 0 kHz*

- ➢ Press the *FREQ* key and enter *100 MHz*.
- ➢ Press the *SPAN* key and enter *5 kHz*.

3. *Activate the marker function for AM depth measurement*

- ➢ Press the *MKR FCTN* key.
- ➢ Press the *MODULATION DEPTH* softkey.
  The FSP automatically positions a marker on the carrier signal in the middle of the graph and one delta marker on each of the lower and upper AM sidebands. The FSP calculates the AM modulation depth from the ratios of the delta marker levels to the main marker level and outputs the numerical value in the marker info field



```
DELTA MARKER 2
 1 kHz
Ref -20 dBm          Att  10 dB
RBW  100 Hz   Delta 2 [T1 MOD]
VBW  300 Hz            -11.98 dB
SWT  500 ms       1.00000000 kHz
MDEPTH      50.313 %
Marker 1 [T1 MOD]
             -30.32 dBm
       100.00000000 MHz
Delta 3 [T1 MOD]
             -11.99 dB
       -1.00000000 kHz
Center 100 MHz      500 Hz/      Span 5 kHz
```

Fig. 2-31 Measurement of AM modulation depth. The modulation depth is indicated by MDEPTH. The frequency of the AF signal is indicated by the delta markers

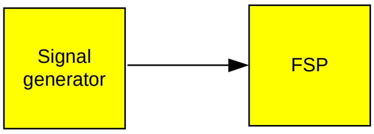
Measurements on FM Signals

Since spectrum analyzers only display the magnitude of signals by means of the envelope detector, the modulation of FM signals cannot be directly measured as is the case with AM signals. With FM signals, the voltage at the output of the envelope detector is constant as long as the frequency deviation of the signal is within the flat part of the passband characteristic of the resolution filter which has been selected. Amplitude variations can only occur if the current frequency lies on the falling edge of the filter characteristic. This effect can be used to demodulate FM signals. The center frequency of the analyzer is set in a way that the nominal frequency of the test signal is on the filter edge (below or above the center frequency). The resolution bandwidth and the frequency offset are selected in a way that the current frequency is on the linear part of the filter slope. The frequency variation of the FM signal is then transformed into an amplitude variation which can be displayed in the time domain.

The FSP's analog 4th order filters with frequencies from 300 kHz to 3 MHz have a good filter-slope linearity, if the frequency of the FSP is set to 1.2 times the filter bandwidth below or above the frequency of the transmit signal. The useful range for FM demodulation is then almost equal to the resolution bandwidth.

Measurement Example - Displaying the AF of an FM carrier

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	-30 dBm
Modulation:	FM 0 kHz deviation (i.e., FM = off), 1 kHz AF

Measurement with the FSP:

1. Set the spectrum analyzer to its default state

- Press the *PRESET* key.
  The FSP is in its default state.

2. Set the center frequency to 99.64 MHz and the span to 300 kHz.

- Press the *FREQ* key and enter *99.64 MHz.*
- Press the *SPAN* key and enter *300 kHz*.

3. Set a resolution bandwidth of 300 kHz.

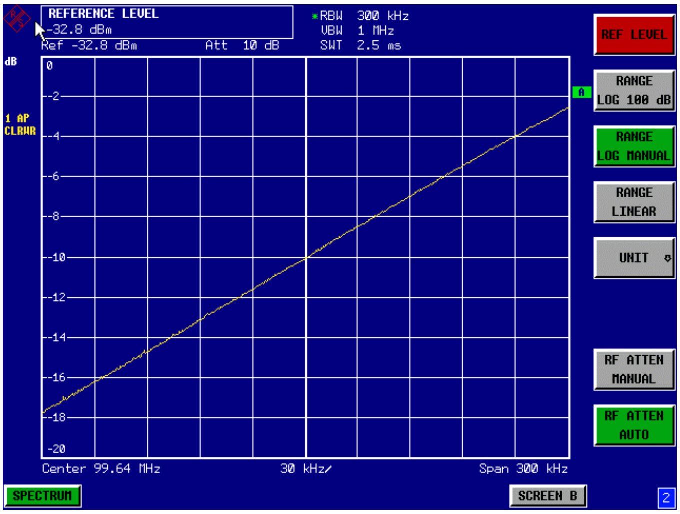
- Press the *BW* key.
- Press the *RES BW MANUAL* softkey and enter *300 kHz*.

4. Set a display range of 20 dB and shift the filter characteristics to the middle of the display.

- Press the ***AMPT*** key.
- Press the *RANGE LOG MANUAL* softkey and enter *20 dB*.
- Press the ***NEXT*** key.
- Set the *GRID* softkey to *REL*.

- ➢ Press the *PREV* softkey.
- ➢ Using the spinwheel, shift the reference level so that the filter edge intersects the - 10 dB level line at the center frequency.

  The slope of the 300 kHz filter is displayed. This corresponds to the demodulator characteristics for FM signals with a slope of approx. 5 dB/100 kHz.



REFERENCE LEVEL
-32.8 dBm

Ref -32.8 dBm Att 10 dB

RBW 300 kHz
VBW 1 MHz
SWT 2.5 ms

Center 99.64 MHz 30 kHz/ Span 300 kHz

Fig. 2-32 Filter edge of a 300 kHz filter used as an FM-discriminator characteristic

5. Set an FM deviation of 100 kHz and an AF of 1 kHz on the signal generator

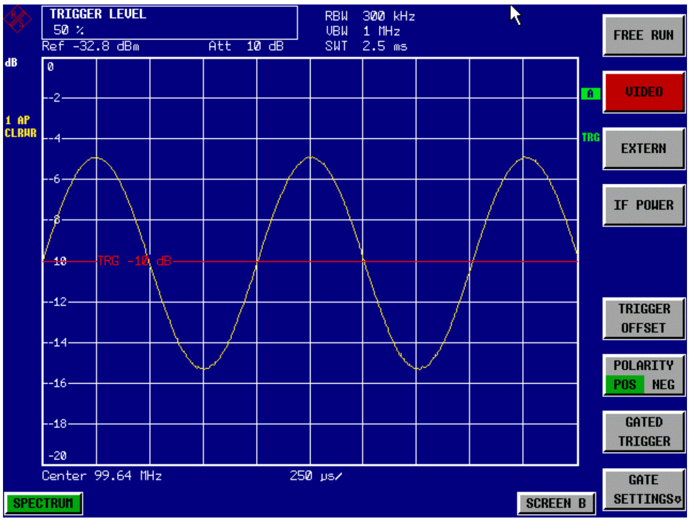
6. Set a frequency deviation of 0 Hz on the FSP

- ➢ Press the SPAN key.
- ➢ Press the ZERO SPAN.
  The demodulated FM signal is displayed. The signal moves across the screen.

7. Creating a stable display by video triggering

- ➢ Press the TRIG key.
- ➢ Press the VIDEO softkey.
  A stationary display is obtained for the FM AF signal

Result (-10 ± 5) dB; this means that a deviation of 100 kHz is obtained if the demodulator characteristic slope is 5 dB/100 kHz



TRIGGER LEVEL
50 %

Ref -32.8 dBm Att 10 dB

RBW 300 kHz
VBW 1 MHz
SWT 2.5 ms

Center 99.64 MHz 250 µs/

Fig. 2-33 Demodulated FM signal

Measuring Channel Power and Adjacent Channel Power

Measuring channel power and adjacent channel power is one of the most important tasks in the field of digital transmission for a spectrum analyzer with the necessary test routines. While, theoretically, channel power could be measured at highest accuracy with a power meter, its low selectivity means that it is not suitable for measuring adjacent channel power as an absolute value or relative to the transmit channel power. The power in the adjacent channels can only be measured with a selective power meter.

A spectrum analyzer cannot be classified as a true power meter, because it displays the IF envelope voltage. However, it is calibrated such as to correctly display the power of a pure sinewave signal irrespective of the selected detector. This calibration is not valid for non-sinusoidal signals. Assuming that the digitally modulated signal has a Gaussian amplitude distribution, the signal power within the selected resolution bandwidth can be obtained using correction factors. These correction factors are normally used by the spectrum analyzer’s internal power measurement routines in order to determine the signal power from IF envelope measurements. These factors are valid if and only if the assumption of a Gaussian amplitude distribution is correct.
Apart from this common method, the FSP also has a true power detector, i.e. an RMS detector. It correctly displays the power of the test signal within the selected resolution bandwidth irrespective of the amplitude distribution, without additional correction factors being required. With an absolute measurement uncertainty of < 0.5 dB and a relative measurement uncertainty of < 0.2 dB (each with a confidence level of 95%), the FSP comes close to being a true power meter.

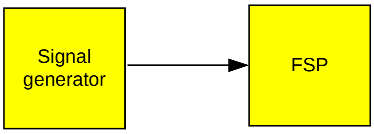
There are two possible methods for measuring channel and adjacent channel power with a spectrum analyzer:
The IBW method (**I**ntegration **B**andwidth **M**ethod) in which the spectrum analyzer measures with a resolution bandwidth that is less than the channel bandwidth and integrates the level values of the trace versus the channel bandwidth. This method is described in the section on noise measurements.

Measurement using a channel filter.
In this case, the spectrum analyzer makes measurements in the time domain using an IF filter that corresponds to the channel bandwidth. The power is measured at the output of the IF filter. Until now, this method has not been used for spectrum analyzers, because channel filters were not available and the resolution bandwidths, optimized for the sweep, did not have a sufficient selectivity. The method was reserved for special receivers optimized for a particular transmission method.

The FSP has test routines for simple channel and adjacent channel power measurements. These routines give quick results without any complex or tedious setting procedures.

Measurement Example 1 - ACPR measurement on an IS95 CDMA Signal

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	850 MHz
Level:	0 dBm
Modulation:	CDMA IS 95

Measurement with the FSP:

1. ***Set the spectrum analyzer to its default state.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Set the center frequency to 850 MHz and frequency deviation to 4 MHz.***

   ➢ Press the *FREQ* key and enter *850 MHz*.

3. ***Set the reference level to +10 dBm.***

   ➢ Press the *AMPT* key and enter *10 dBm*.

4. ***Configuring the adjacent channel power for the CDMA IS95 reverse link.***

   ➢ Press the *MEAS* key.

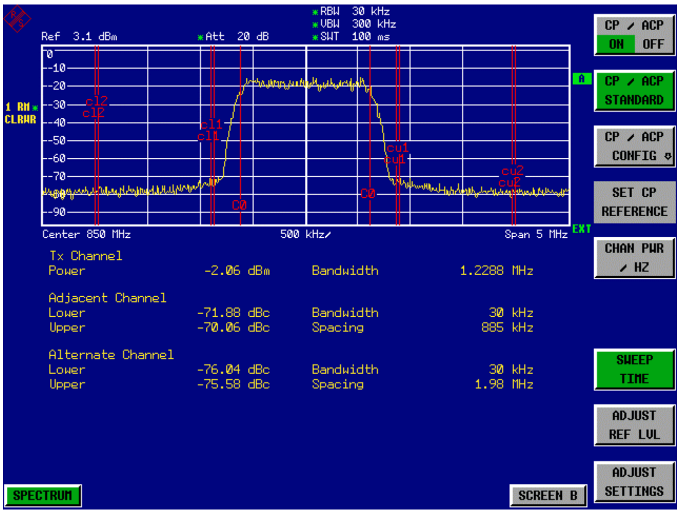
   ➢ Press the *CHAN PWR ACP ⇩* softkey.

   ➢ Press the *CP/ACP STANDARD* softkey.

   From the list of standards, select *CDMA IS95A REV* using the spinwheel or the cursor down key below the spinwheel and press *ENTER*.
   The FSP sets the channel configuration according to the IS95 standard for mobile stations with 2 adjacent channels above and below the transmit channel. The spectrum is displayed in the upper part of the screen, the numeric values of the results and the channel configuration in the lower part of the screen. The various channels are represented by vertical lines on the graph.
   The frequency span, resolution bandwidth, video bandwidth and detector are selected automatically to give correct results. To obtain stable results - especially in the adjacent channels (30 kHz bandwidth) which are narrow in comparison with the transmission channel bandwidth (1.23 MHz) - the RMS detector is used.

5. Set the optimal reference level and RF attenuation for the applied signal level.

- Press the *ADJUST REF LVL* softkey.
  The FSP sets the optimal RF attenuation and the reference level based on the transmission channel power to obtain the maximum dynamic range. The following figure shows the result of the measurement.



```
                                    RBW   30 kHz
                                    VBW   300 kHz
Ref  3.1 dBm           Att  20 dB   SWT   100 ms

Center 850 MHz                 500 kHz/                   Span 5 MHz

Tx Channel
Power                -2.06 dBm     Bandwidth          1.2288 MHz

Adjacent Channel
Lower               -71.88 dBc     Bandwidth              30 kHz
Upper               -70.06 dBc     Spacing               885 kHz

Alternate Channel
Lower               -76.04 dBc     Bandwidth              30 kHz
Upper               -75.58 dBc     Spacing              1.98 MHz
```

Fig. 2-34 Adjacent channel power measurement on a CDMA IS95 signal

The repeatability of the results, especially in the narrow adjacent channels, strongly depends on the measurement time since the dwell time within the 30 kHz channels is only a fraction of the complete sweep time. A longer sweep time may increase the probability that the measured value converges to the true value of the adjacent channel power, but this increases measurement time.

To avoid long measurement times, the FSP measures the adjacent channel power in the time domain (FAST ACP). In the FAST ACP mode, the FSP measures the power of each channel at the defined channel bandwidth, while being tuned to the center frequency of the channel in question. The digital implementation of the resolution bandwidths makes it possible to select a filter characteristics that is precisely tailored to the signal. In case of CDMA IS95, the power in the useful channel is measured with a bandwidth of 1.23 MHz and that of the adjacent channels with a bandwidth of 30 kHz. Therefore the FSP jumps from one channel to the other and measures the power at a bandwidth of 1.23 MHz or 30 kHz using the RMS detector. The measurement time per channel is set with the sweep time. It is equal to the selected measurement time divided by the selected number of channels. The five channels from the above example and the sweep time of 100 ms give a measurement time per channel of 20 ms.

Compared to the measurement time per channel given by the span (= 5 MHz) and sweep time (= 100 ms, equal to 1.66 ms per 30 kHz channel) used in the example, this is a far longer dwell time on the adjacent channels (factor of 12). In terms of the number of uncorrelated samples this means 20000/33 µs = 606 samples per channel measurement compared to 1667/33µs = 50.5 samples per channel measurement.

Repeatability with a confidence level of 95% is increased from ± 1.4 dB to ± 0.38 dB as shown in Fig. 2-28. For the same repeatability, the sweep time would have to be set to 1.2 s with the integration method. The following figure shows the standard deviation of the results as a function of the sweep time.

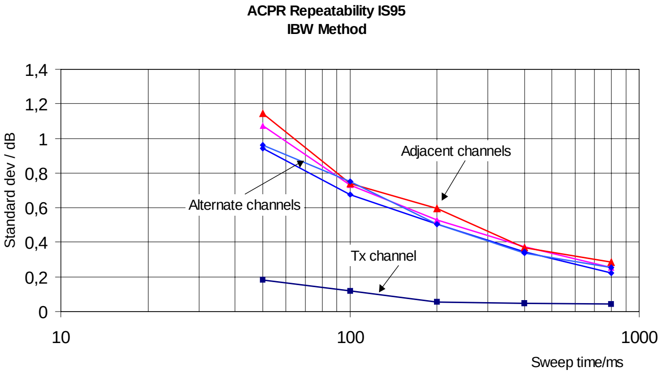
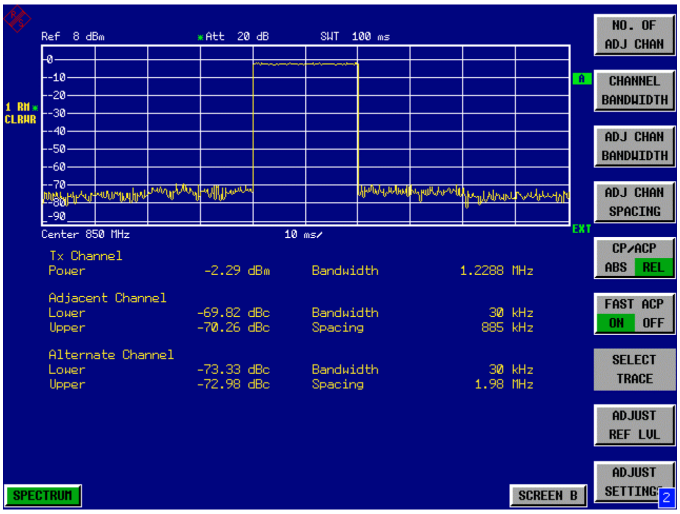


Fig. 2-35 Repeatability of adjacent channel power measurement on IS95-standard signals if the integration bandwidth method is used

6. Switch to Fast ACP to increase the repeatability of results.

➢ Press the *CP/ACP CONFIG ⇩* softkey.

➢ Set the *FAST ACP* softkey to *ON*.
The FSP measures the power of each channel in the time domain. The trace represents power as a function of time for each channel (see Fig. 2-36). The numerical results over consecutive measurements become much more stable.



```
Ref  8 dBm            *Att  20 dB       SWT  100 ms
Center 850 MHz                 10 ms/

Tx Channel
Power              -2.29 dBm     Bandwidth          1.2288 MHz

Adjacent Channel
Lower             -69.82 dBc     Bandwidth              30 kHz
Upper             -70.26 dBc     Spacing               885 kHz

Alternate Channel
Lower             -73.33 dBc     Bandwidth              30 kHz
Upper             -72.98 dBc     Spacing              1.98 MHz
```

Fig. 2-36 Measuring the channel power and adjacent channel power ratio for IS95 signals in the time domain (Fast ACP)

The following figure shows the repeatability of power measurements in the transmit channel and of relative power measurements in the adjacent channels as a function of sweep time. The standard deviation of measurement results is calculated from 100 consecutive measurements as shown in Fig. 2-35. Take scaling into account if comparing power values.

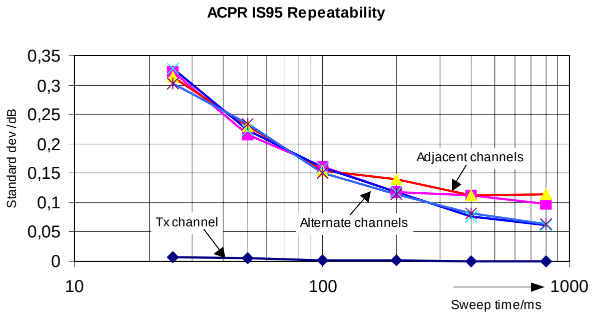


Fig. 2-37 Repeatability of adjacent channel power measurements on IS95 signals in the Fast ACP mode

Note on adjacent channel power measurements on IS95 base-station signals:

When measuring the adjacent channel power of IS95 base-station signals, the frequency spacing of the adjacent channel to the nominal transmit channel is specified as ±750 kHz. The adjacent channels are, therefore, so close to the transmit channel that the power of the transmit signal leaks across and is also measured in the adjacent channel if the usual method using the 30 kHz resolution bandwidth is applied. The reason is the low selectivity of the 30 kHz resolution filter. The resolution bandwidth, therefore, must be reduced considerably, e.g. to 3 kHz to avoid this. This causes very long measurement times (factor of 100 between a 30 kHz and 3 kHz resolution bandwidth).

This effect is avoided with the time domain method which uses steep IF filters. The 30 kHz channel filter implemented in the FSP has a very high selectivity so that even with a ± 750 kHz spacing to the transmit channel the power of the useful modulation spectrum is not measured.

The following figure shows the passband characteristics of the 30 kHz channel filter in the FSP.

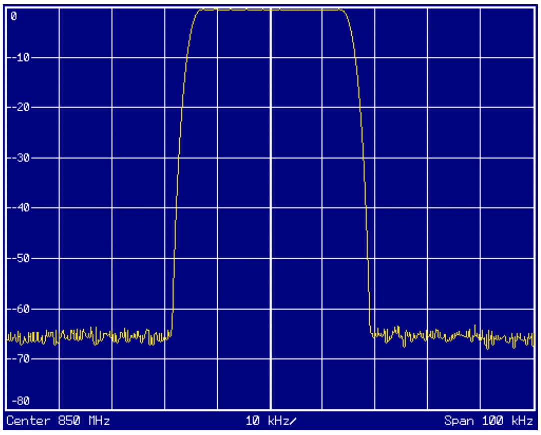
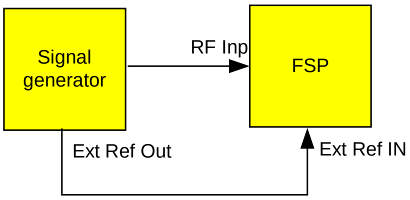


Fig. 2-38 Frequency response of the 30 kHz channel filter for measuring the power in the IS 95 adjacent channel

Measurement Example 2 – Measuring the adjacent channel power of an IS136 TDMA signal

Test setup:



> **Note:** *As the modulation spectrum of the IS136 signal leaks into the adjacent channel, it makes a contribution to the power in the adjacent channel. Exact tuning of the spectrum analyzer to the transmit frequency is therefore critical. If tuning is not precise, the adjacent channel power ratios in the lower and upper adjacent channels become asymmetrical. The FSP's frequency and the generator frequency are therefore synchronized.*

Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	850 MHz
Level:	-20 dBm
Modulation:	IS136/NADC

Measurement with the FSP

1. ***Set the spectrum analyzer to its default state.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Set up the FSP for synchronization to an external reference frequency.***

   ➢ Press the *SETUP* key.

   ➢ Set the *REFERENCE* softkey to *EXT*.

3. ***Set the center frequency to 850 MHz-***
   Press the FREQ key and enter *850 MHz*.

4. ***Configure adjacent channel power measurement for IS136 signals.***

   ➢ Press the *MEAS* key.

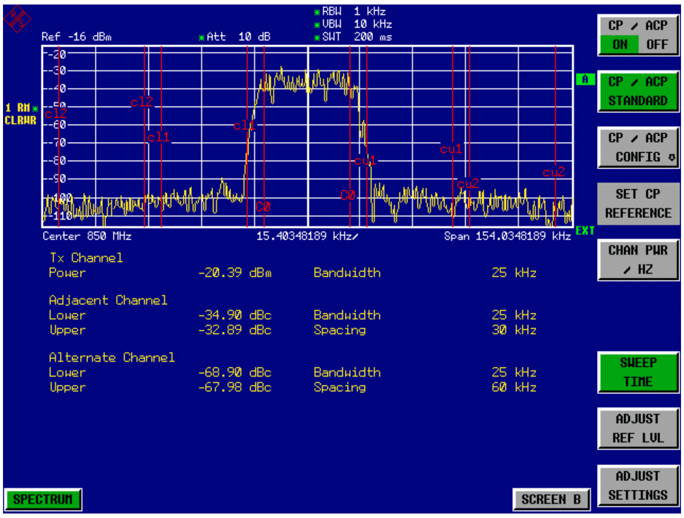
   ➢ Press the *CHAN PWR ACP* ⇩ softkey.

   ➢ Press the *CP/ACP STANDARD* softkey.

   ➢ Select *NADC IS136* from the list of standards and press *ENTER*.
   The FSP performs the power measurement in 5 channels (in the useful channel and in the two upper and two lower adjacent channels).

5. Setting the optimum reference level and RF attenuation for the measurement

- ➢ Press the *ADJUST REF LEVEL* softkey.
  The FSP sets the optimum RF attenuation and the optimum reference level on the basis of the measured channel power.



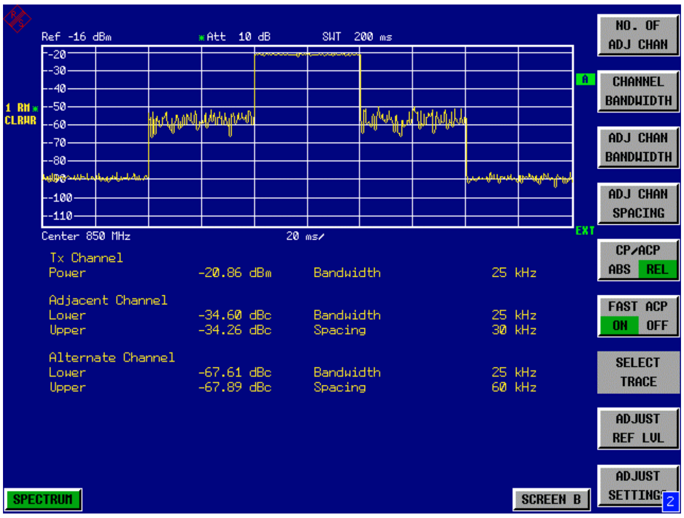
```
Tx Channel
Power                 -20.39 dBm      Bandwidth           25 kHz

Adjacent Channel
Lower                 -34.90 dBc      Bandwidth           25 kHz
Upper                 -32.89 dBc      Spacing             30 kHz

Alternate Channel
Lower                 -68.90 dBc      Bandwidth           25 kHz
Upper                 -67.98 dBc      Spacing             60 kHz
```

Fig. 2-39 Measuring the relative adjacent channel power of an NADC signal in each of the two adjacent channels below and above the transmit channel.

To increase repeatability - especially in the adjacent channels - the FSP’s Fast ACP routine is recommended.

6. Switching on the Fast ACP routine.

- ➢ Press the *CP/ACP CONFIG ⇩* softkey
- ➢ Set the *FAST ACP* softkey to *ON.*
  The FSP makes consecutive measurements on the 5 channels in the Zero Span mode using the receive filter specified in IS 136 to define the resolution bandwidth. The power in each channel is displayed on the graph as a function of time



```
Tx Channel
Power                 -20.86 dBm      Bandwidth           25 kHz

Adjacent Channel
Lower                 -34.60 dBc      Bandwidth           25 kHz
Upper                 -34.26 dBc      Spacing             30 kHz

Alternate Channel
Lower                 -67.61 dBc      Bandwidth           25 kHz
Upper                 -67.89 dBc      Spacing             60 kHz
```

Fig. 2-40 Measuring adjacent channel power in time domain (Fast ACP)

As the resolution bandwidth is much wider than the one used for the integration method, the results are much more stable when compared at the same sweep time.

Repeatability can be influenced by the selected sweep time. The results become much more stable if long sweep times are selected. Since the amplitude distribution is different in different channels (part of the modulation spectrum falls within the first adjacent channel), the repeatability depends on the spacing of the measured channel from the transmit channel.
Fig. 2-41 below shows the standard deviation of results in the different channels as a function of the selected sweep time. The standard deviation for the various sweep times was recorded using a signal generator as a source. With real DUTs the amplitude distributions in adjacent channels may be different so that the standard deviation could differ from that shown in Fig. 2-41. To evaluate the correct measuring time for time-critical measurements at a given standard deviation, the standard deviation of the ACP values at the output of the real DUT must be determined.

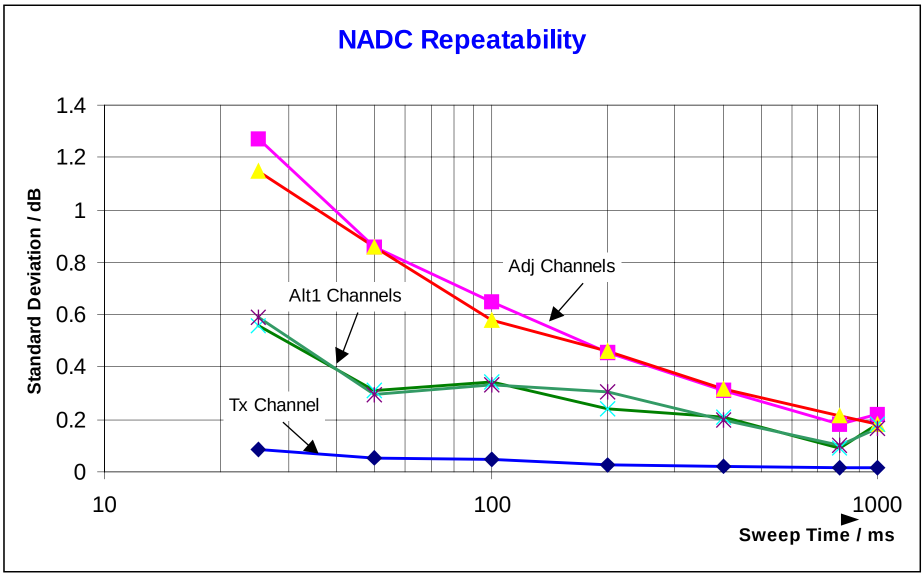


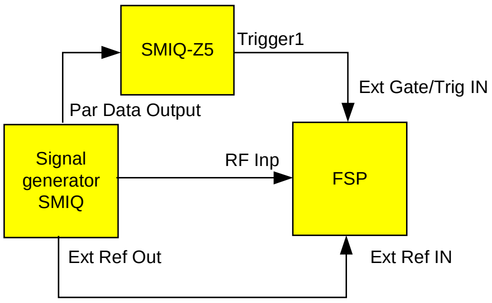
Fig. 2-41 Standard deviation of the results of Fast ACP measurement as a function of selected sweep time evaluated from 100 measurements per sweep time

Measurement Example 3 - Measuring the Modulation Spectrum in Burst Mode with the Gated Sweep Function

Since transmission systems compliant to IS136 use a TDMA method, the adjacent channel power must also be measured in burst mode. An IS136 TDMA frame is divided into 6 time slots. Two of these slots are assigned to a subscriber. This means that the ratio of transmit time to off-time for IS136 mobile phones is only 1:3 (e.g. time slots 1 and 4)

The FSP supports the measurement of the adjacent channel power in the TDMA mode with the Gated Sweep function.

Test setup with the R&S Signal Generator SMIQ:



The SMIQ has to be equipped with options SMIQ-B10 or SMIQ-B20 (modulation coder) and SMIQ-B11 (data generator).

Option SMIQ-Z5 is required to trigger the FSP. This option is connected to the SMIQ's parallel output port. The BNC output Trigger 1 of the SMIQ-Z5 provides a TTL trigger signal on the rising edge of the IS136 burst, which is used to start the FSP sweep in the Gated Sweep mode.

Note: *The FSP's IF power trigger is not suitable for IS136. It triggers on every level edge of the input signal. Since the modulation of the IS136 signal causes level dips even during the transmit burst, there is no way of ensuring that the FSP is only triggered on the burst edge.*

Settings on signal generator SMIQ:

Switch the signal generator to the IS136 burst mode (time slots 1 and 4 are switched on, the other time slots are switched off).

The SMIQ is set as follows to generate the signal :

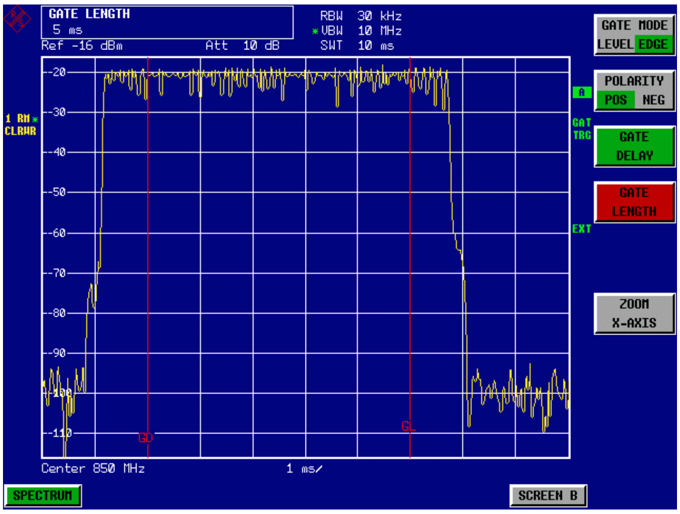
- ➢ Press the *PRESET* key.
- ➢ Press the *FREQ* key and enter 850 MHz.
- ➢ Press the *LEVE*L key and enter -20 dBm.
- ➢ Press the *RETURN* key.
- ➢ Select *DIGITAL STANDARD* using the spinwheel and press the *SELECT* key.
- ➢ Select *NADC* using the spinwheel and press the *SELECT* key.
- ➢ Press the *SELECT* key.
- ➢ Select *ON* using the spinwheel and press the *SELECT* key.
- ➢ Press the *RETURN* key.
- ➢ Keep turning the spinwheel until *SAVE/RECALL FRAME* appears in the list and select the menu item *SAVE/RECALL FRAME* using the *SELECT* key.
- ➢ The cursor is set to *GET PREDEFINED FRAME*.
- ➢ Press the *SELECT* key.

- ➢ Select *UP1TCH* using the spinwheel and press the *SELECT* key.

In the following operating sequence for the FSP, it is assumed that steps 1 to 6 of the previous example (example no. 2) have already been performed.

1. Configuring the Gated Sweep function on the FSP.

- ➢ Press the *TRIG* key.
- ➢ Press the *GATED TRIGGER* softkey.
- ➢ Press the *EXTERN* softkey.
- ➢ Press the *GATE SETTINGS* ⇩ softkey.
  The FSP switches to time domain measurement so that the setting of the Gated Sweep parameters can be checked visually.
- ➢ Press the *ZOOM X-AXIS* softkey and enter *10 ms*.
  Exactly one TDMA burst will be displayed.
- ➢ Press the *GATE DELAY* softkey and enter *2 ms* or set the Gate Delay using the spinwheel so that the burst is reliably detected.
- ➢ Press the *GATE LENGTH* softkey and enter *5 ms* or set the vertical line for the gate length using the spinwheel so that the burst is reliably detected.



GATE LENGTH
5 ms
Ref -16 dBm
Att 10 dB
RBW 30 kHz
VBW 10 MHz
SWT 10 ms
Center 850 MHz
1 ms/

Fig. 2-42 Setting the parameters Gate Delay and Gate Length in time domain. The time interval required to measure the spectrum is indicated by two vertical lines.

- ➢ Press the *PREV* key.
  The FSP now performs the ACP measurement only during the switch-on phase of the TDMA burst. The measurement is stopped during the switch-off phase.

Note: *The selected sweep time is the net sweep time, i.e. the time during which the FSP is actually measuring. The complete frame of an IS136 signal takes 40 ms. In the above example, measurement only takes place for 2x5 ms within a frame. The FSP is therefore only measuring for 25 % of the frame duration. The total measuring time is therefore four times that for the CW mode.*

Measurement Example 4 - Measuring the Transient Spectrum in Burst Mode with the Fast ACP function

In addition to the modulation spectrum or adjacent channel power from the modulation of the RF carrier, the spectrum or adjacent channel power generated by burst edges is also to be measured in TDMA systems. The spectrum is a pulse spectrum and must be measured with the peak detector. With the usual IBW method, only the power of the continuously modulated signal can be measured properly. Even if the modulation spectrum is transmitted in the TDMA mode, the measurement of the modulation spectrum will work because the burst edges are blanked out for the measurement by means of the Gated Sweep function. The spectrum analyzer performs measurements only if the modulation spectrum is continuous when the burst is on.

However, the IBW method fails for the spectrum created by the burst edges. As the measurement is carried out with resolution bandwidths that are very small compared to the signal bandwidth, a spurious amplitude distribution is obtained in the defined measurement channel because of the resolution bandwidth. The small resolution bandwidth cannot settle to the peak amplitudes of the test signal. This problem is avoided in the FSP by performing time domain measurements with the root raised cosine filter specified in the IS136 standard.

If the peak detector is used instead of the default RMS detector (which is selected when the standard is selected), the true adjacent channel power generated by the burst edges can also be measured.

Test setup: The test setup for this example and the settings for SMIQ are identical to those in the previous example.

Measurement with the FSP:

1. ***Set the spectrum analyzer to its default state.***

   ➢ Press the *PRESET* key.
   The FSP is in its default state.

2. ***Synchronize the FSP to an external reference frequency.***

   ➢ Press the *SETUP* key.

   ➢ Set the *REFERENCE* softkey to *EXT*.

3. ***Set the center frequency to 850 MHz***

   ➢ Press the *FREQ* key and enter *850 MHz*.

4. ***Configure the adjacent channel power measurement for IS136 signals in Fast ACP mode.***

   ➢ Press the *MEAS* key.

   ➢ Press the *CHAN PWR ACP ⇩* softkey.

   ➢ Press the *CP/ACP STANDARD* softkey.

   ➢ Select *NADC IS136* from the list of standards and press *ENTER*.

   ➢ Press the *CP/ACP CONFIG ⇩* softkey.

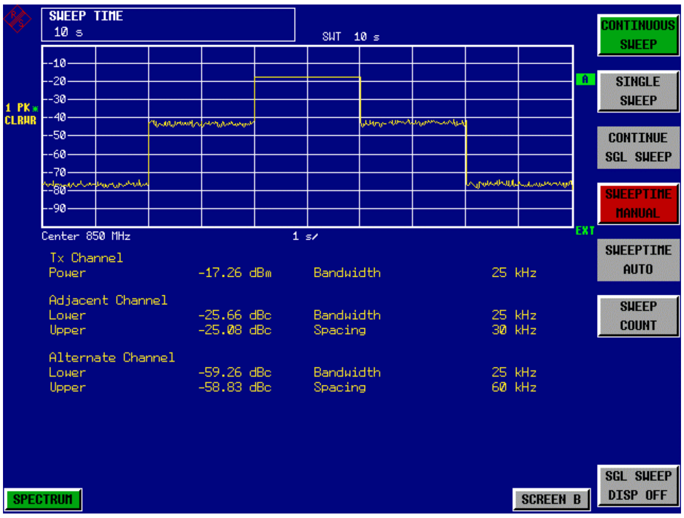
   ➢ Set the *FAST ACP* softkey to *ON*.
   The FSP performs the power measurement in 5 channels (in the useful channel and in the two upper and lower adjacent channels).

5. ***Set the optimum reference level and RF attenuation for the measurement.***

   ➢ Press the *ADJUST REF LEVEL* softkey.
   The FSP sets the optimum RF attenuation and the optimum reference level on the basis of the measured channel power.

6. Select the peak detector and increase the sweep time to 10 s.

- Press the *TRACE* key.
- Press the *DETECTOR* softkey.
- Press the *PEAK* softkey.
- Press the *SWEEP* key.
- Press the *SWEEP TIME* softkey and enter *10 s*.
  The FSP measures the adjacent channel power generated by the burst edges and the modulation.



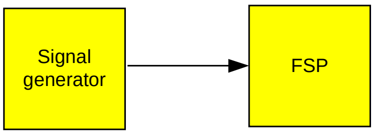
```
SWEEP TIME
 10 s
                         SWT  10 s

Center 850 MHz              1 s/

 Tx Channel
 Power           -17.26 dBm     Bandwidth           25 kHz

 Adjacent Channel
 Lower           -25.66 dBc     Bandwidth           25 kHz
 Upper           -25.08 dBc     Spacing             30 kHz

 Alternate Channel
 Lower           -59.26 dBc     Bandwidth           25 kHz
 Upper           -58.83 dBc     Spacing             60 kHz
```

Fig. 2-43 Adjacent channel power due to modulation spectrum and transient spectrum

Note: *The peak power display depends on the selected sweep time. The longer the sweep time, the higher the probability of measuring the highest peak amplitude of the signal.*
With shorter sweep times, level dips can be seen in the time domain traces. These level dips come from the burst charactercics of the signal. The numerical results, however, indicate the peak amplitudes during the measurement in the corresponding channel.

Measurement Example 5 - Measuring adjacent channel power of a W-CDMA uplink signal

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	1950 MHz
Level:	4 dBm
Modulation:	3GPP W-CDMA Reverse Link

Measurement with the FSP:

1. ***Set the spectrum analyzer to its default state.***

   - Press the *PRESET* key.
     The FSP is in its default state.

2. ***Set the center frequency to 1950 MHz.***

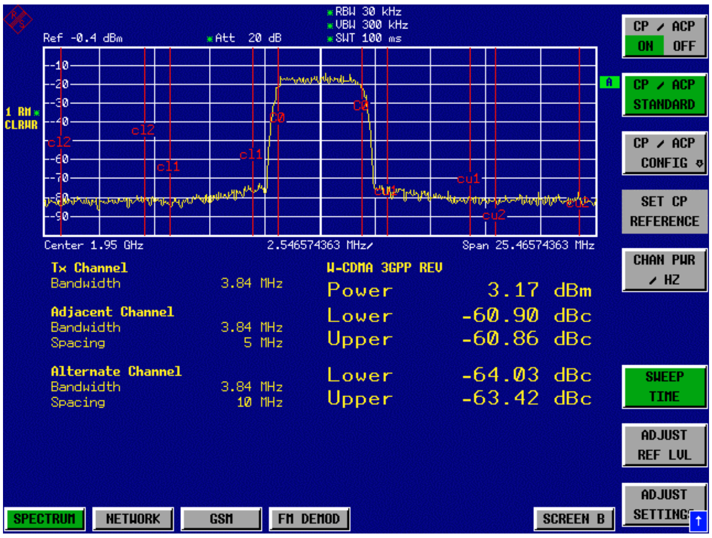
   - Press the *FREQ* key and enter *1950 MHz*.

3. ***Switch on the ACP measurement for W-CDMA.***

   - Press the *MEAS* key.
   - Press the *CHAN PWR ACP* ⇩ softkey.
   - Press the *CP/ACP STANDARD* softkey.
   - From the list of standards, select *W-CDMA 3GPP REV* using the spinwheel or the cursor down key below the spinwheel and press *ENTER*.
     The FSP sets the channel configuration to the 3GPP W-CDMA standard for mobiles with two adjacent channels above and below the transmit channel. The frequency span, the resolution and video bandwidth and the detector are automatically set to the correct values. The spectrum is displayed in the upper part of the screen and the channel power, the level ratios of the adjacent channel powers and the channel configuration in the lower part of the screen. The individual channels are displayed as vertical lines on the graph.

4. ***Set the optimum reference level and the RF attenuation for the applied signal level.***

   - Press the *ADJUST REF LEVEL* softkey.
     The FSP sets the optimum RF attenuation and the reference level for the power in the transmission channel to obtain the maximum dynamic range. The following figure shows the result of the measurement:



Tx Channel
Bandwidth 3.84 MHz

Adjacent Channel
Bandwidth 3.84 MHz
Spacing 5 MHz

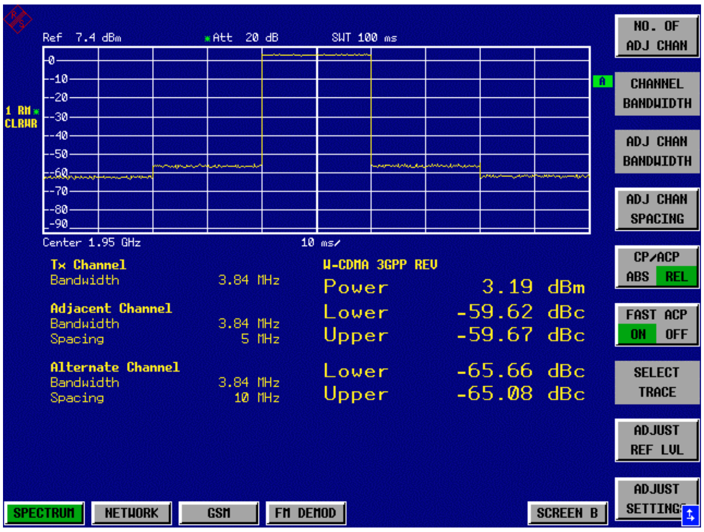
Alternate Channel
Bandwidth 3.84 MHz
Spacing 10 MHz

W-CDMA 3GPP REV
Power 3.17 dBm
Lower -60.90 dBc
Upper -60.86 dBc
Lower -64.03 dBc
Upper -63.42 dBc

Fig. 2-44 Measuring the relative adjacent channel power on a W-CDMA uplink signal

5. *Measuring adjacent channel power with the Fast ACP method.*

- ➢ Press the *CP/ACP CONFIG* ⇩ softkey.
- ➢ Set *FAST ACP* softkey to *ON*.
- ➢ Press the ADJUST REF LVL softkey.
  The FSP measures the power of the individual channels in the time domain. A root raised cosine filter with the parameters $\alpha = 0.22$ and chip rate 3.84 Mcps (= receive filter for 3GPP W-CDMA) is used as the channel filter.



Tx Channel
Bandwidth 3.84 MHz

Adjacent Channel
Bandwidth 3.84 MHz
Spacing 5 MHz

Alternate Channel
Bandwidth 3.84 MHz
Spacing 10 MHz

W-CDMA 3GPP REV
Power 3.19 dBm
Lower -59.62 dBc
Upper -59.67 dBc
Lower -65.66 dBc
Upper -65.08 dBc

Fig. 2-45 Measuring the adjacent channel power of a W-CDMA signal with the Fast ACP method

Note: *With W-CDMA, the FSP's dynamic range for adjacent channel measurements is limited by the 12-bit A/D converter. The greatest dynamic range is, therefore, obtained with the IBW method.*

Optimum Level Setting for ACP Measurements on W-CDMA Signals

The dynamic range for ACPR measurements is limited by the thermal noise floor, the phase noise and the intermodulation (spectral regrowth) of the spectrum analyzer. The power values produced by the FSP due to these factors accumulate linearly. They depend on the applied level at the input mixer. The three factors are shown in the figure below for the adjacent channel (5 MHz carrier offset)

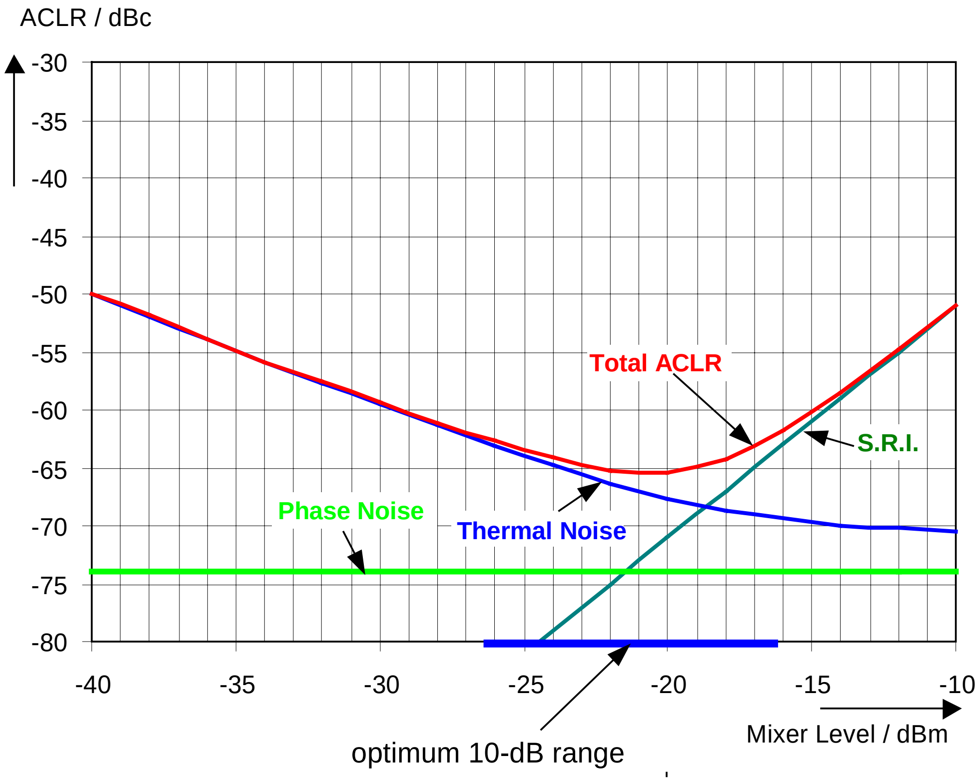


Fig. 2-46 The FSP's dynamic range for adjacent channel power measurements on W-CDMA uplink signals is a function of the mixer level.

The level of the W-CDMA signal at the input mixer is shown on the horizontal axis, i.e. the measured signal level minus the selected RF attenuation. The individual components which contribute to the power in the adjacent channel and the resulting relative level (total ACPR) in the adjacent channel are displayed on the vertical axis. The optimum mixer level is –21 dBm. The relative adjacent channel power (ACPR) at an optimum mixer level is –65 dBc. Since, at a given signal level, the mixer level is set in 10 dB steps with the 10 dB RF attenuator, the optimum 10 dB range is shown in the figure: it spreads from –16 dBm to –26 dBm. The obtainable dynamic range in this range is 62 dB.

To set the attenuation parameter manually, the following method is recommended:

- Set the RF attenuation so that the mixer level (= measured channel power – RF attenuation) is between -11 dBm and -21 dBm.
- Set the reference level to the largest possible value where no overload (IFOVLD) is indicated.

This method is automated with the FSP's ADJUST REF LEVEL function. Especially in remote control mode, e.g. in production environments, it is best to correctly set the attenuation parameters prior to the measurement, as the time required for automatic setting can be saved.

Note: *To measure the FSP's intrinsic dynamic range for W-CDMA adjacent channel power measurements, a filter which suppresses the adjacent channel power is required at the output of the transmitter. A SAW filter with a bandwidth of 4 MHz, for example, can be used.*

Amplitude distribution measurements

If modulation types that do not have a constant envelope in the time domain are used, the transmitter has to handle peak amplitudes that are greater than the average power. This includes all modulation types that involve amplitude modulation -QPSK for example. CDMA transmission modes in particular may have power peaks that are large compared to the average power.

For signals of this kind, the transmitter must provide large reserves for the peak power to prevent signal compression and thus an increase of the bit error rate at the receiver.
The peak power, or the crest factor of a signal is therefore an important transmitter design criterion. The crest factor is defined as the peak power / mean power ratio or, logarithmically, as the peak level minus the average level of the signal.

To reduce power consumption and cut costs, transmitters are not designed for the largest power that could ever occur, but for a power that has a specified probability of being exceeded (e.g. 0.01%). .

To measure the amplitude distribution, the FSP has simple measurement functions to determine both the APD[1] = Amplitude Probability Distribution and CCDF = Complementary Cumulative Distribution Function.

In the APD display mode, the probability of occurrence of a certain level is plotted against the level.
In the CCDF display mode, the probability that the mean signal power will be exceeded is shown in percent.

Measurement Example – Measuring the APD and CCDF of white noise generated by the FSP

1. ***Set the spectrum analyzer to its default state.***

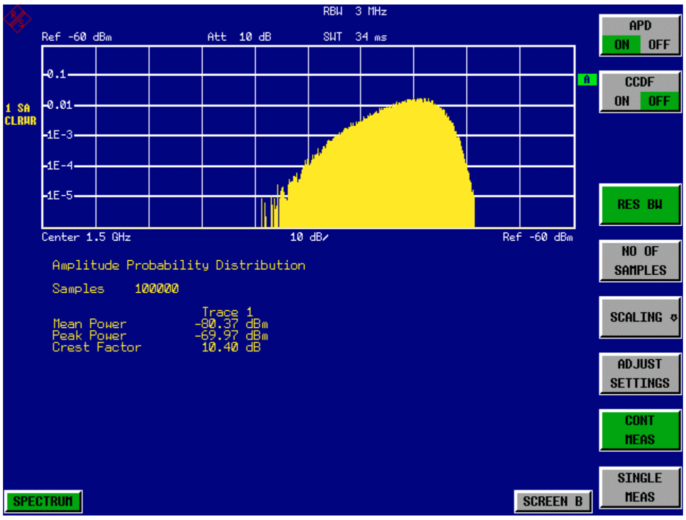
   - Press the *PRESET* key.
     The FSP is in its default state.

2. ***Configure the FSP for APD measurement***

   - Press the *AMPT* key and enter **-***60 dBm*.
     The FSP's intrinsic noise is displayed at the top of the screen.
   - Press the *MEAS* key.
   - Press the *SIGNAL STATISTIC ⇩* softkey.
   - Set the *APD* softkey to *ON*.
     The FSP sets the frequency span to 0 Hz and measures the amplitude probability distribution (APD). The number of uncorrelated level measurements used for the measurement is 100000.
     The mean power and the peak power are displayed in dBm. The crest factor (peak power – mean power) is output as well (see Fig. 2-47).

---

[1] In the literature, APD is also used for the probability of amplitude violation. This is the complimentary function to the APD function of FSP. The term PDF (=Probability Density Function) which is frequently used in the literature corresponds to the APD function of FSP.

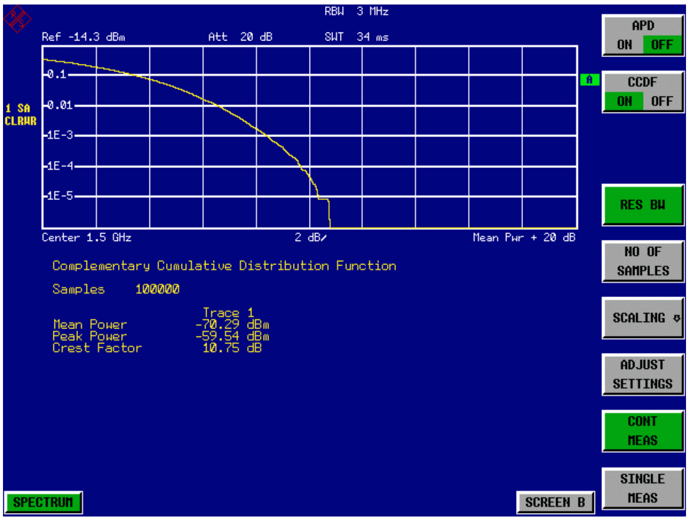

RBW 3 MHz
Ref -60 dBm Att 10 dB SWT 34 ms

```
Amplitude Probability Distribution
Samples     100000

                   Trace 1
Mean Power        -80.37 dBm
Peak Power        -69.97 dBm
Crest Factor       10.40 dB
```

Fig. 2-47 Amplitude probability distribution of white noise

3. *Switch to the CCDF display mode.*

➢ Set the *CCDF* softkey to *ON*
The APD measurement is switched off and the CCDF display mode is switched on.


RBW 3 MHz
Ref -14.3 dBm Att 20 dB SWT 34 ms

```
Complementary Cumulative Distribution Function
Samples     100000

                   Trace 1
Mean Power        -70.29 dBm
Peak Power        -59.54 dBm
Crest Factor       10.75 dB
```

Fig. 2-48 The CCDF of white noise

The CCDF trace indicates the probability that a level will exceed the mean power. The level above the mean power is plotted along the X axis of the graph.The origin of the axis corresponds to the mean power level. The probability that a level will be exceeded is plotted along the Y axis.

4. Bandwidth selection

If the amplitude distribution is measured, the resolution bandwidth must be set in a way that the complete spectrum of the signal to be measured falls within the bandwidth. This is the only way of ensuring that all the amplitudes will pass through the IF filter without being distorted. If the selected resolution bandwidth is too small for a digitally modulated signal, the amplitude distribution at the output of the IF filter becomes a Gaussian distribution according to the central limit theorem and so corresponds to a white noise signal. The true amplitude distribution of the signal therefore cannot be determined.

A video bandwidth which is large in comparison to the resolution bandwidth (≥ 3 x RBW) must be selected. This ensures that the amplitude peaks of the signal are not smoothed by the lowpass effect of the video filter. The video bandwidth is set automatically during statistics measurements.

Since the video bandwidth of the FSP is limited to 10 MHz, lowpass filtering occurs during measurements with a resolution bandwidth of 10 MHz. Additional band-limiting occurs at a resolution bandwidth of 10 MHz due to the lowpass filtering at the output of the log amplifier. The latter limits the video signal to a bandwidth of 8 MHz in order to obtain sufficient suppression of the 20.4 MHz IF. The level range of the signal amplitudes, e.g. during APD white-noise measurements, is smaller. For broadband-modulated signals such as W-CDMA signals, the effect depends on the bandwidth occupied by the signal. At a signal bandwidth of 4 MHz, the amplitude distribution can be measured correctly with the effective video bandwidth.

5. Selecting the number of samples

For statistics measurements with the FSP, the number of samples $N_{Samples}$ is entered for statistical evaluation instead of the sweep time. Since only statistically independent samples contribute to statistics, the measurement or sweep time is calculated automatically. It is indicated on the FSP display. The samples are statistically independent if the time difference is at least 1/RBW. The sweep time SWT is, therefore, expressed as follows:

$$SWT = N_{Samples} / RBW$$

Time Domain Measurements

With TDMA radiocommunication systems (e.g. GSM or IS136), the transmission quality is determined not only by the spectral characteristics, but also by the time domain characteristics. Since several users share the same frequency, a time slot is assigned to the each user. Unimpaired operation can only be ensured if each user adheres to his assigned time slot.

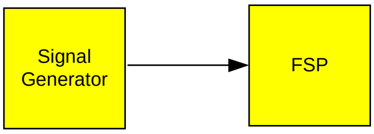
In this case, both the power during the transmit phase and the time characteristics such as duration of the TDMA burst as well as rise and fall time of the burst are relevant.

Power measurements

The FSP has easy-to-operate functions for measuring power during a given time interval.

Measurement Example – Measuring the power of a GSM burst during the switch-on phase

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	0 dBm
Modulation:	GSM, one time slot is switched on

Measurement using the FSP:

1. ***Set the spectrum analyzer to its default state.***
   - ➢ Press the *PRESET* key.
     The FSP is in its default state.
2. ***Set the center frequency to 100 MHz, the span to 0 Hz and the resolution bandwidth to 1 MHz.***
   - ➢ Press the *FREQ* key and enter *100 MHz*.
   - ➢ Press the *SPAN* key and enter *0 Hz* or press the *ZEROSPAN* softkey.
3. ***Set the FSP reference level to 10 dBm (= signal generator level +10 dB).***
   - ➢ Press the *AMPT* key and enter *10 dBm*.
4. ***Set the sweep time to 1 ms***
   - ➢ Press the *SWEEP* key and enter 1 ms.
     The FSP shows the GSM burst running across the display.

5. ***Trigger on the rising edge of the burst using the video trigger.***

➢ Press the *TRIG* key.

➢ Press the *VIDEO* softkey and enter *70%*.
The FSP displays a stable curve with the GSM burst at the beginning of the trace. The trigger level is shown as a horizontal line labeled with the absolute level for the trigger threshold.

6. ***Configure the power measurement in the time domain.***

➢ Press the *MEAS* key.

➢ Press the *TIME DOM POWER* ⇩ softkey.

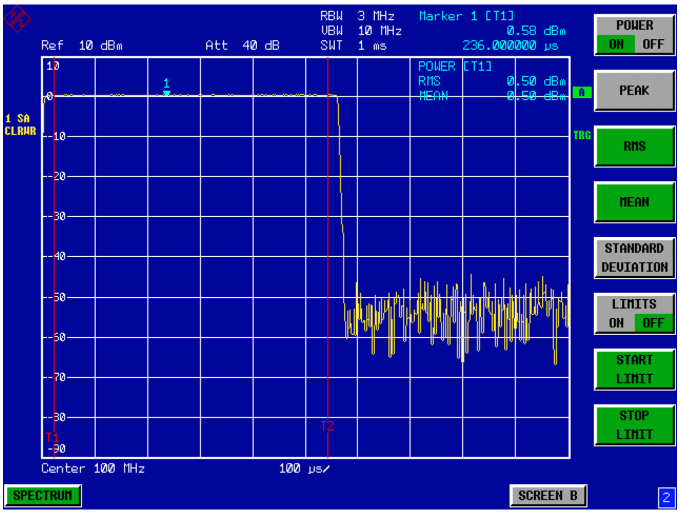
➢ Set the *LIMITS* softkey to *ON*.

➢ Press the *START LIMIT* softkey.

➢ Place the vertical line on the start of the burst by turning the spinwheel clockwise.

➢ Press the *STOP LIMIT* softkey.

➢ Place the second vertical line on the end of the burst by turning the spinwheel counterclockwise.
The FSP displays the mean power during the switch-on phase of the burst (see Fig. 2-49).



```
                          RBW  3 MHz   Marker 1 [T1]
                          VBW  10 MHz           0.58 dBm
Ref  10 dBm      Att  40 dB   SWT  1 ms      236.000000 µs

                                       POWER [T1]
                                       RMS           0.50 dBm
                                       MEAN          0.50 dBm

Center 100 MHz                100 µs/
```

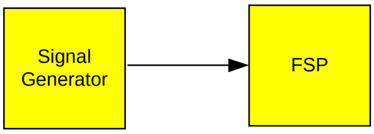
Fig. 2-49 Measuring mean power during the switch-on phase of a GSM burst

Power Ramping Measurement for Burst Signals

Since the FSP has a high time resolution at 0 Hz span, the edges of the TDMA burst can be measured accurately. The use of the trigger offset makes it possible to shift the edges onto the screen.

Measurement Example – Measurements on GSM burst edges using a high time resolution

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	0 dBm
Modulation:	GSM, one time slot is switched on

Measurement using the FSP

The settings of the example above are used to measure GSM burst power during the switch-on phase.

1. ***Switch off power measurement.***
   - ➢ Press the *MEAS* key.
   - ➢ Press the *TIME DOM POWER* ⇩ softkey.
   - ➢ In the submenu, set the *POWER* softkey to *OFF*.
2. ***Increase the time resolution to 100 µs.***
   - ➢ Press the *SWEEP* key and enter *100 µs*.
3. ***Shift the rising edge of the GSM burst to the middle of the screen using the trigger offset.***
   - ➢ Press the *TRIG* key.
   - ➢ Press the *TRIGGER OFFSET* softkey.
   - ➢ Set the trigger offset by turning the spinwheel (counterclockwise) until the burst edge is in the middle of the screen or enter **-***50 µs*.
     The FSP displays the rising edge of the GSM burst (see Fig. 2-50)

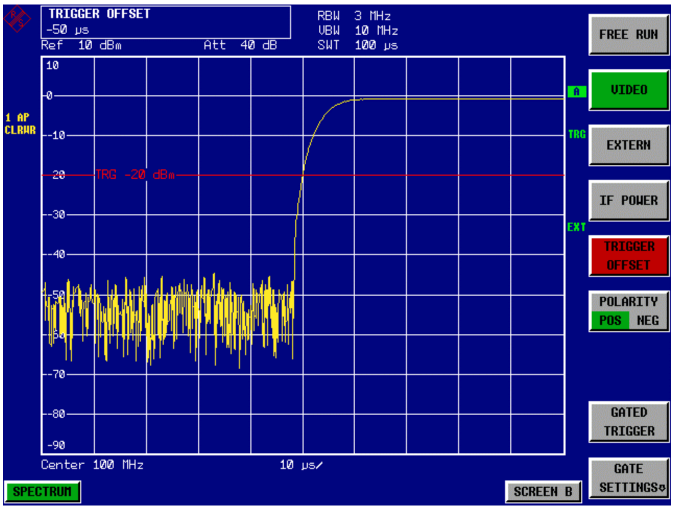

TRIGGER OFFSET
-50 µs
Ref 10 dBm Att 40 dB
RBW 3 MHz
VBW 10 MHz
SWT 100 µs
Center 100 MHz 10 µs/

Fig. 2-50 Rising edge of GSM burst at high time-resolution.

4. Shift the falling edge of burst to the middle of the screen using the trigger offset.

➢ Set the *POLARITY* softkey to *NEG*.
The FSP displays the falling edge of the GSM burst (see Fig. 2-51)

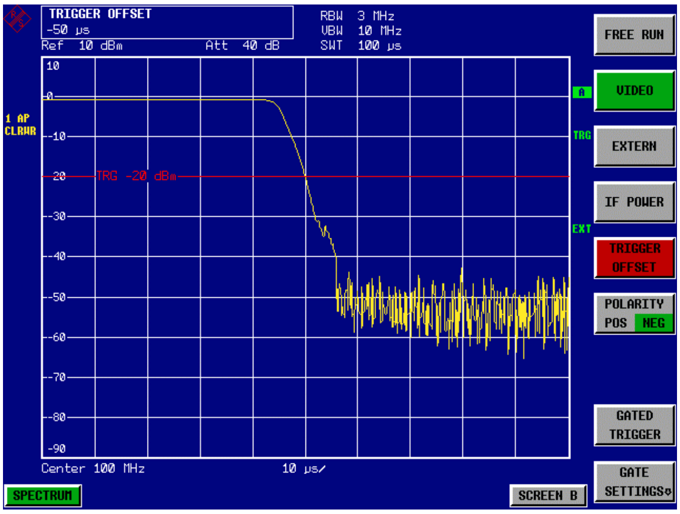

TRIGGER OFFSET
-50 µs
Ref 10 dBm Att 40 dB
RBW 3 MHz
VBW 10 MHz
SWT 100 µs
Center 100 MHz 10 µs/

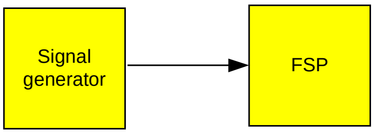
Fig. 2-51 Falling edge of GSM burst at high time resolution

Measuring the S/N Ratio of Burst Signals

For TDMA transmission methods, the S/N ratio or the switch-off range can be measured by comparing the powers during the switch-on and switch-off phase of the transmission burst. The FSP, therefore, has a function to perform absolute and relative power measurements in the time domain. The measurement is carried out as follows, using a GSM burst as an example.

Measurement Example - S/N ratio of a GSM signal

Test setup:



Settings on the signal generator (e.g. R&S SMIQ):

Frequency:	100 MHz
Level:	0 dBm
Modulation:	GSM, one time slot is switched on

Measurement using the FSP

1. ***Set the spectrum analyzer to its default state.***

   - Press the *PRESET* key.
     The FSP is in its default state.

2. ***Set the center frequency to 100 MHz, the span to 0 Hz and the resolution bandwidth to 1 MHz.***

   - Press the *FREQ* key and enter *100 MHz*.
   - Press the *SPAN* key and enter *0 Hz*
     or
   - press the *ZEROSPAN* softkey.
   - Press the *BW* key and enter *1 MHz*.

3. ***Set the reference level of the FSP to 0 dBm (= signal generator level) and the RF attenuation to 10 dB for maximum sensitivity.***

   - Press the **AMPT** key and enter 0 **dBm**.
   - Press the *RF ATTEN MANUAL* softkey and enter *10 dB*.

4. ***Set the sweep time to 2 ms.***

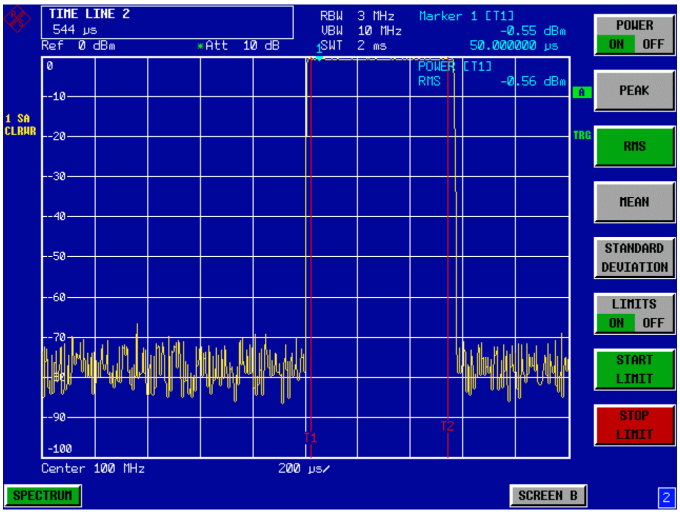
   - Press the *SWEEP* key and enter *2 ms*.
     The FSP displays the GSM burst running across the display.

5. Trigger on the rising edge of the burst using the video trigger and shift beginning of burst to the middle of the screen.

- ➢ Press the TRIG key.
- ➢ Press the VIDEO softkey and enter 70%.
  The FSP displays a stable image with the GSM burst at the start of the trace.
- ➢ Press the TRIGGER OFFSET softkey and enter -1 ms.
  The FSP displays the GSM burst in the right half of the graph.

6. Configure the power measurement in the time domain.

- ➢ Press the MEAS key.
- ➢ Press the TIME DOM POWER ⇩ softkey.
- ➢ Set the LIMITS softkey to ON.
- ➢ Press the *START LIMIT* softkey.
- ➢ Place the vertical line on the start of the burst using the spinwheel.
- ➢ Press the *STOP LIMIT* softkey.
- ➢ Place the second vertical line on the end of the burst using the spinwheel. .
  The FSP displays the power during the switch-on phase of the burst.



TIME LINE 2
544 µs
Ref 0 dBm
*Att 10 dB
RBW 3 MHz
VBW 10 MHz
SWT 2 ms
Marker 1 [T1]
-0.55 dBm
50.000000 µs
POWER [T1]
RMS -0.56 dBm
Center 100 MHz
200 µs/

Fig. 2-52 Measuring power during the switch-on phase of the burst

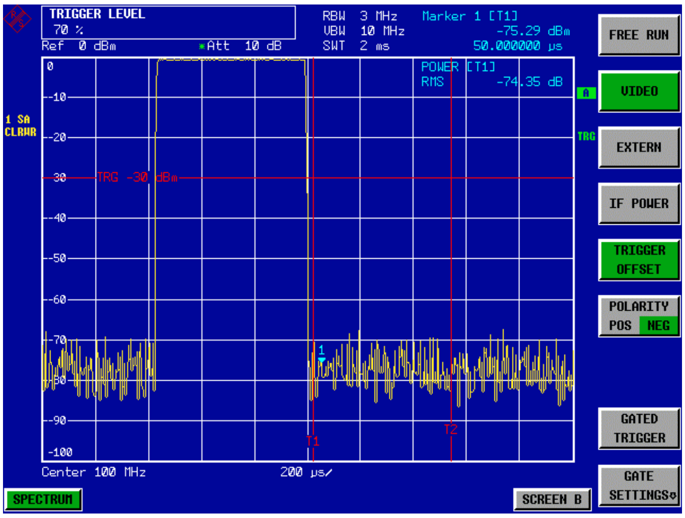
7. Define the measured power as the reference and switch on relative power measurement.

- ➢ Press the *NEXT* key.
  The side menu for setting the power measurement is opened.
- ➢ Set the *POWER ABS/REL* softkey to *REL*.
- ➢ The power relative to the power during the switch-on phase of the burst is displayed.
- ➢ Press the *SET REFERENCE* softkey.
  The measured power of the GSM burst is defined as the reference.

8. Measure the power during the switch-off phase of the burst.

➢ Press the *TRIG* key.

➢ Set the *POLARITY POS/NEG* softkey to *NEG*.
The FSP triggers on the falling edge of the burst. The burst is then shifted to the left half of the screen. The power is measured in the switch-off phase. The start of the burst is shifted to the middle of the screen and the power is measured during the switch-off phase relative to the reference power (= burst power).



TRIGGER LEVEL
70 %
Ref 0 dBm *Att 10 dB
RBW 3 MHz
VBW 10 MHz
SWT 2 ms
Marker 1 [T1]
-75.29 dBm
50.000000 µs
POWER [T1]
RMS -74.35 dB
Center 100 MHz
200 µs/

Fig. 2-53 Measuring the S/N ratio of the GSM burst signal in the time domain