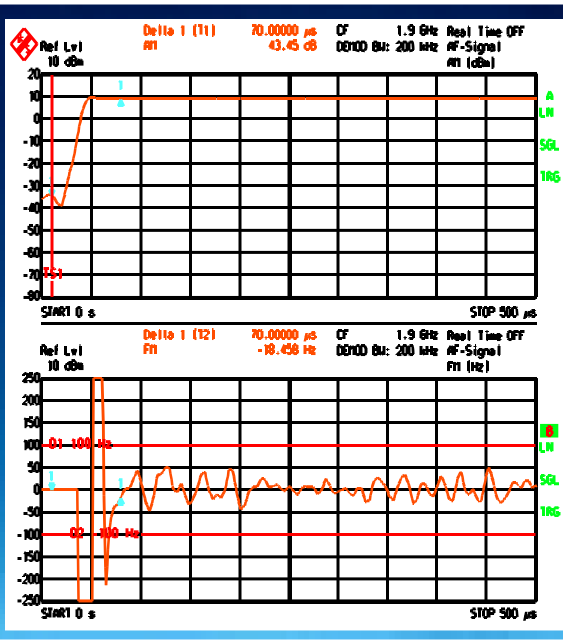

Products: FSE

Measuring Frequency Settling Time for Synthesizers and Transmitters

An FSE Spectrum Analyser equipped with the Vector Signal Analysis option (FSE-B7) can measure oscillator settling time or transmitter attack and release times with high accuracy up to 40 GHz. No additional measurement equipment is needed.

Subject to change – **Herbert Schmitt/Roland Minihold 02.99 - Application Note 1MA15_0E**

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1 Overview

Modern digital mobile communication systems like GSM use slow frequency hopping to overcome fading in the channel used, to increase transmission quality and channel capacity However, frequency hopping sets high demands on the synthesizer settling time in both the transmitter and the receiver.

To avoid interfering with other users, a transmitter must be on its assigned channel before generating noticeable output power and must switch off its output power before leaving the channel. The attack time of a transmitter is the time to switch on its output power, the release time is the time to switch off the output power.

Attack and release time measurement is necessary for a wide range of devices, ranging from low-cost remote control door openers for garages and cars to analog and digital radios.

An FSE Spectrum Analyser equipped with the Vector Signal Analysis option (FSE-B7) can measure oscillator settling time or transmitter attack and release times with high accuracy up to 40 GHz. All necessary modulation measurements on digital or analog modulation signals are provided too.

2 Concept of analog demodulation

For both analog and digital demodulation the FSE operates like a fixed frequency receiver. The IF selection is determined by the set resolution bandwidth and the demodulation bandwidth. To minimize phase and amplitude distortion, the resolution bandwidth is preset to the widest resolution bandwidth available (10 MHz). With the selection of the demodulation bandwidth the bandwidth of a digital filter is set which precedes the digital AM, FM or PM demodulator in the circuit (see Fig. 1). This filter is implemented in the baseband with very low amplitude ripple (< 0.1 dB) and high phase linearity, which assures a high accuracy when measuring modulation. Analog demodulation can be performed in real time or off-line up to 200 kHz demodulation bandwidth. For demodulation bandwidths from 300 kHz to 5 MHz demodulation is off-line. With real time demodulation, the RF input signal is demodulated continuously so that an audio output is provided. The maximum audio frequency is 20 kHz. For frequency transient measurement off-line demodulation is appropriate as it provides high audio bandwidth and either the video or an external trigger can be used. With off-line demodulation samples are stored in the internal memory, then post-processed.

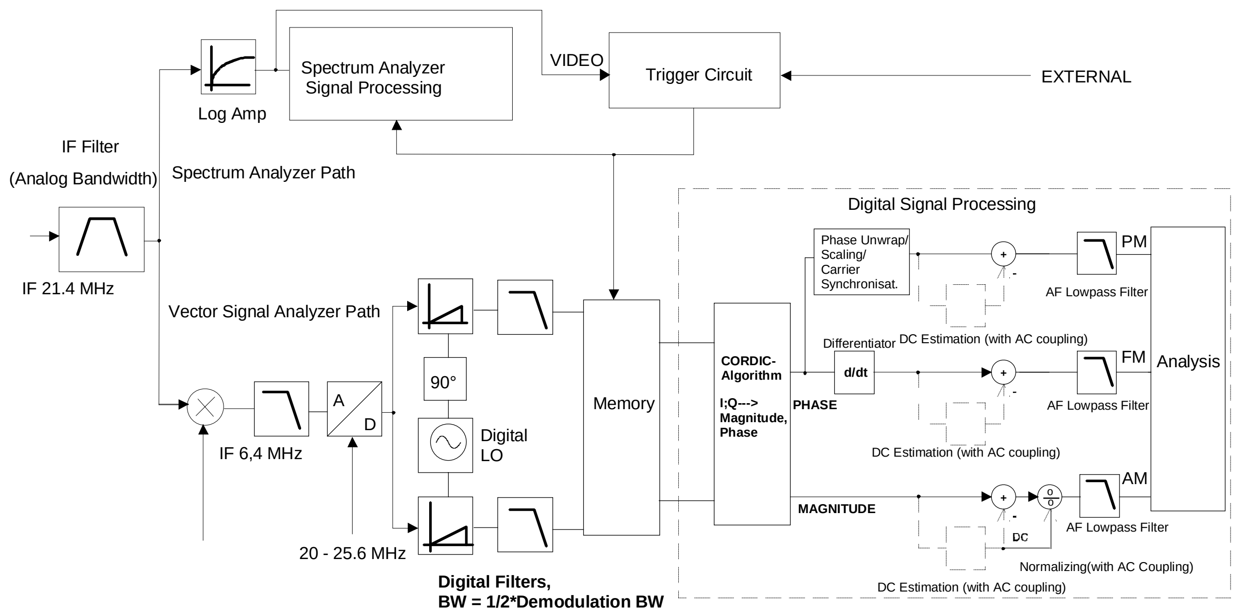

Fig. 1 Simplified schematic diagram of IF processing and the off-line analog demodulator (off-line) with FSE-B7

3 Demodulation bandwidth and sweep time considerations

The following relationships must be applied when measuring frequency transients:

- The maximum frequency deviation which can be measured is half of the demodulation bandwidth, which also influences the demodulator inherent settling time. The inherent settling time is inversely proportional to the demodulation bandwidth and additionally dependent on the AF lowpass filter. Table 1 gives an approximate comparison between demodulation bandwidth, the lowpass filter used and inherent settling time *(Demod BW = Demodulation Bandwidth)*

Table 1: Inherent settling time for the FSE, as effected by the demodulation bandwidth and AF lowpass filter

DEMOD BW	**Lowpass 10 % of Demod BW**	**Lowpass 25 % of Demod BW**	**Lowpass NONE**
20 kHz	1.2 ms	700 µs	600 µs
200 kHz	100 µs	70 µs	60 µs
2 MHz	8 µs	4 µs	3.5 µs
5 MHz	3 µs	1.5 µs	1.3 µs

- The demodulation bandwidth determines the AD sampling rate and influences the maximum sweep time range due to the fixed length of the internal memory (8k). A higher demodulation bandwidth with a higher AD sampling rate will fill the memory faster than a lower one. The maximum sweep time is specified by equation (1):

$$SWT_{max} = \frac{5000 * 0.7}{B_{Dem}} \qquad (1)$$

whereas the minimum sweep time is:

$$SWT_{min} = \frac{10 * 0.7}{B_{Dem}}$$

(SWT= Sweep time,

B_{Dem} = Demodulation bandwidth)

Table 2 shows the possible range of the sweep time at different demodulation bandwidths:

Table 2: Range of sweep time versus demodulation bandwidth

DEMOD BW	SWT min	SWT max
5 kHz	1.4 ms	700 ms
10 kHz	700 µs	350 ms
20 kHz	350 µs	175 ms
30 kHz	233.3 µs	116,6 ms
50 kHz	140 µs	70 ms
100 kHz	70 µs	35 ms
200 kHz	35 µs	17,5 ms
300 kHz	23,33µs	11,66 ms
500 kHz	14	7 ms
1 MHz	7 µs	3.5 ms
2 MHz	3.5 µs	1.75 ms
3 MHz	2.33 µs	466.66 µs
5 MHz	1.4 µs	280 µs

The residual FM limits the usable frequency resolution (Y per div). It should be lower than 1/10 of a display division. The higher the demodulation bandwidth the higher the inherent residual FM will be. Table 3 lists residual FM (Peak residual FM) for different demodulation bandwidths and AF low pass filters:

Table 3: Residual FM (Pk Value) of FSE at different demodulation bandwidths and AF lowpass filters

DEMOD BW	**Res FM, Lowpass 10 %**	**Res FM, Lowpass 25 %**	**Res FM, Lowpass NONE**
2 MHz	< 200 Hz	< 400 Hz	< 1.5 kHz
200 kHz	< 20 Hz	< 50 Hz	< 100 Hz
20 kHz	< 2 Hz	< 4 Hz	< 8 Hz

Fig. 2 shows as an example the inherent settling time and residual FM for a demodulation bandwidth of 200 kHz, an AF lowpass filter of 10 % of the demodulation bandwidth and a high frequency resolution.

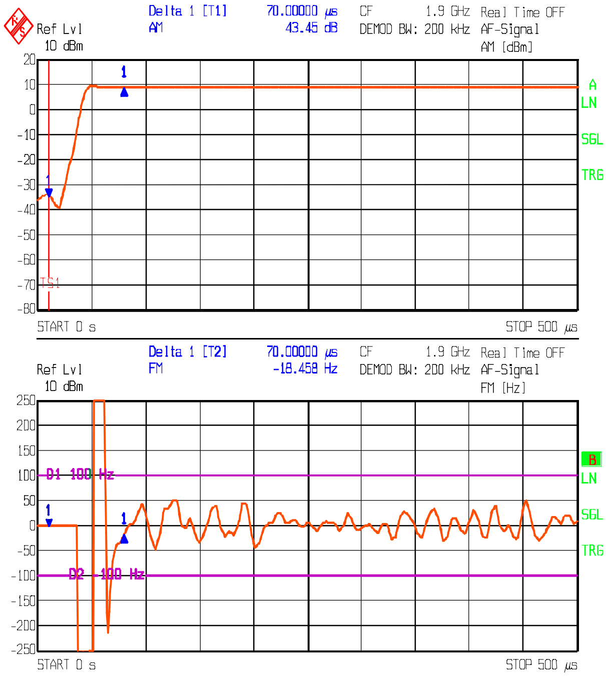

Fig. 2: Inherent settling time and residual FM of FSE/FSE-B7 with demodulation bandwidth 200 kHz and AF lowpass filter of 10 % of the demodulation bandwidth.

To reduce the residual FM use either LP 10 % DEMOD BW or LP 25 % DEMOD BW as AF lowpass filter although the influence of LP 25 % DEMOD BW on the inherent settling time can be ignored, it reduces the residual FM by a factor of 2. The LP 10 % DEMOD BW reduces the residual FM by a factor of 4, increasing the inherent settling time by a factor of approximately 2.

Note: *The values in Table 3 are given for the FSEA30 at 1.9 GHz. Values for FSEB30 and FSEM30 are higher by a factor of 2, values for models 20 are higher by a factor of 10 for < 200 kHz demodulation bandwidth and comparable for higher demodulation bandwidths.*

The residual FM of the synthesizer under test, which in most cases will be higher than that of the low noise synthesizer of the FSE, will influence the usable frequency resolution as well.

4 Measuring the Frequency Settling Time of Synthesizers, PLLs and Oscillators

This measurement would previously be done using a modulation analyzer such as an R&S FMA or FMB as FM discriminator. This setup however requires an extra external oscilloscope to record the frequency transient, see application note 1EF08_1E for details).

Using the FSE with FSE-B7 no separate scope is needed. This also eliminates the need to calibrate the vertical scaling for kHz/Div.

Fig. 3 shows the test setup with an FSE.

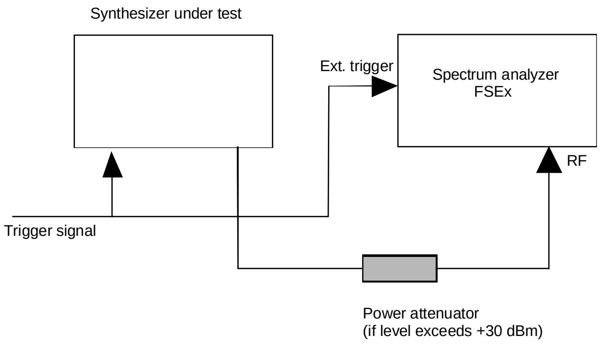

Fig 3: Test setup for frequency transient measurements

An external trigger is most appropriate for measuring frequency transients. This can be either a trigger used to initiate a frequency step in the synthesizer under test, or a trigger from the synthesizer's circuitry such as a strobe signal. In cases where no trigger signal is available the VIDEO trigger can be used together with a narrow RBW (**COUPLING**:IF BANDWIDTH MANUAL)- The RBW cannot not be set below the used demodulation bandwidth.

Measurement with FSE

This example uses an SMIQ signal generator. The signal generator generates a sweep, switching between two frequencies, separated by 100 kHz.

Frequency and level settings:

- Bring the FSE to a predefined state:
  PRESET
- Before connecting the synthesizer make sure that the maximum power at the analyzer's input is below 20 dBm. Use an external attenuator to reduce the power to a safe value.
- Set reference level according to the source level (e.g. 15 dBm):
  REF 15 dBm
- Set the FSE to the frequency the synthesizer is settling to:
  CENTER 900.1 MHz

Set up the analog demodulation:

Note: *The measurement is done in REALTIME OFF mode, which is not explicitly selected because it is the PRESET setting.*

- Switch on demodulation:
  MODE:VECTOR:ANALOG DEMOD
- Select DC coupling:
  MODE:MODULATION PARAMETERS:AF COUPL'G DC
- Change result display to FM:
  MODE:MEAS RESULT:FM SIGNAL
- Select demodulation bandwidth and lowpass filter:
  MODE:DEMOD BANDWIDTH 1 MHz:
  MODULATION PARAMETERS:LOW PASS AF FILTER 25 %

  The demodulation bandwidth must fulfil the following requirements:

  - Wide enough to cover the frequency step of 100 kHz and any overshoots.
  - Wide enough that the inherent settling time does not influence the settling time to be measured.
- Adjust the vertical scaling to match the resolution needed:
  RANGE: Y PER DIV 6 kHz
- Set the sweep time so that the settling time to be measured is approximately. 80 to 90 % of the full scale sweep time:
  SWEEP:SWEEP TIME 700 µs

Note: *It may be necessary to use a longer sweep time to provide a longer pre-trigger time.*

Set up the trigger:

- Select external trigger as trigger source
  TRIGGER: EXTERNAL
- Set the trigger level according to the available trigger signal if other than TTL level:
  TRIGGER: EXTERNAL 1 V

If an external trigger is not used and the frequency transient to be observed is wider than the analog IF bandwidth (RBW), derive a trigger from the video signal. This procedure is similar to the one described in section 5. The frequency jump will result in an amplitude step as soon as the current frequency falls within the resolution filter (setting: IF BANDWIDTH). This amplitude step is used as a trigger signal for the video trigger. The resolution filter has to be narrower than the frequency step, with the start frequency outside the resolution filter bandwidth.

- Adjust the trigger delay, so that:

  a) the time before the trigger can be observed by entering a negative trigger offset:
  TRIGGER:TRIGGER OFFSET - 100 µs

  b) any advance of the trigger signal is eliminated by a delay:
  TRIGGER:TRIGGER OFFSET 2 ms

  Note: *The longest possible negative trigger offset (pre-trigger) is half the sweep time selected. The longest possible delay (post-trigger) is 10 ms. The frequency transient to be measured has to occur in a window around the trigger signal defined by the longest pre- and post-trigger times.*

➢ Trigger the synthesizer under test, the FSE will display as shown in Fig. 4.

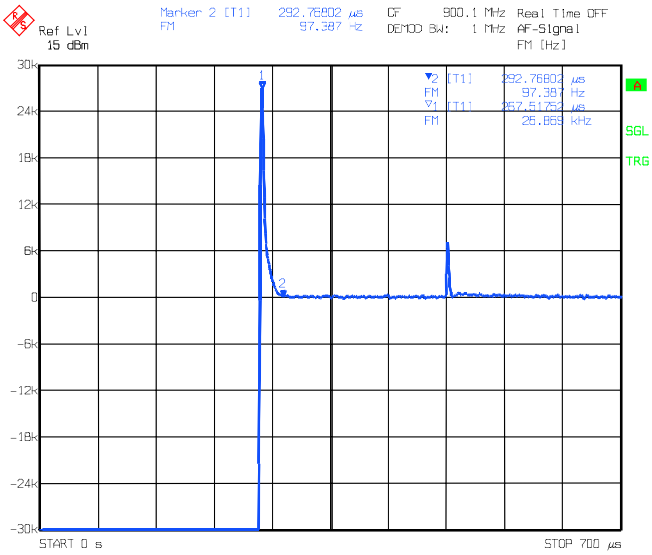

Fig. 4: Frequency transient of a 100 kHz frequency step of a signal generator

5 Measuring Transmitter Attack and Release Times

Attack time is the time a transmitter needs during switch-on to reach its final frequency. It is typically defined as the time taken from the transmitter output power exceeding a defined level (typically 30 dB below steady state power) until the frequency transient settles to within a limit value of the channel frequency. A typical test setup as defined in the regulations would consist of:

- FM demodulator for frequency display
- RF detector or spectrum analyzer for amplitude display
- storage scope for indication
- load
- signal generator to calibrate the level of the -30 dB point (level of the reference point)

With an FSEx spectrum analyzer and option FSE-B7 this set-up can be simplified as shown in Fig. 5. The FSEx with option FSE-B7 offers :

- simultaneous amplitude and frequency versus time display
- built-in trigger possibilities
- calibrated displays eliminating the need for the signal generator.

Measurement with FSE

This example uses a handheld 400 MHz transceiver. The output power is externally attenuated to provide a safe input level to the spectrum analyzer. Fig. 5 shows the suggested test setup:

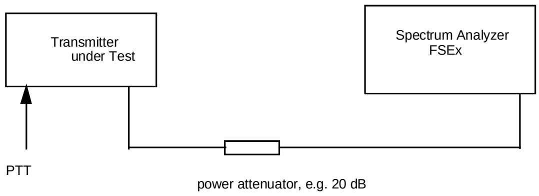

Fig. 5: Test set-up to measure transmitter attack and release times

Set the frequency and levels for the FSE:

- Bring the FSE to a predefined state:
  PRESET
- Before connecting the transmitter make sure that the maximum power at the analyzer's input is below 20 dBm. Use an external attenuator to reduce TX power to a safe value.
  Maximum rating of the RF input is:
  30 dBm with the internal RF attenuator set to 10 dB or higher,
  20 dBm with the internal RF attenuator set to
  0 dB.
- Set reference level to match the output power of the transmitter under test:
  REF 20 dBm
- Set the FSE to the nominal frequency of the transmitter under test:
  CENTER xxxx.xx MHz
- Set up the analog demodulation:
- Switch on demodulation:
  MODE:VECTOR:ANALOG DEMOD
- Select DC coupling:
  MODE:MODULATION PARAMETERS:AF COUPL'G DC
- Select the split screen mode to amplitude and frequency versus time display simultaneously:
  DISPLAY:SPLIT SCREEN
- Select the lower screen:
  TRACE 2
  this selects the bottom screen for parameter entry and is a shortcut for:
  DISPLAY: ACTIVE SCREEN B
- Change result display to FM: **MODE**:MEAS RESULT:FM SIGNAL
- Adjust the vertical scaling to match the resolution needed:
  RANGE: Y PER DIV 2 kHz
- Select the upper screen, displaying amplitude versus time
  TRACE 1
- Adjust the vertical scaling:
  RANGE:REF VALUE Y AXIS 20 dBm

- Set the sweep time so that the settling time to be measured is approximately 80 to 90 % of the full scale sweep time:
  SWEEP:SWEEP TIME 2.4 ms
- With the transmitter switched on without modulation two straight traces can now be observed

Set up the trigger:

- Select video trigger as trigger source and set the trigger level in % of display range:
  TRIGGER: VIDEO 80 ENTER
  A good point to start from is between 50 and 80 %

Note: *The video trigger is derived from the video signal in the normal spectrum analyzer signal path and is equivalent to the video trigger in analyzer mode. Changing to the analyzer mode the threshold can also be set to match the signal.*

- Adjust the trigger delay, so that pre-trigger events can be observed by entering a negative trigger offset:
  TRIGGER:TRIGGER OFFSET **-** 800 µs

Note**:** *The longest possible negative trigger offset (pre-trigger) is half the sweep time, in this example 1.2 ms.*

- Activate the squelch function to suppress the FM noise before the TX power rises:
  MODE:MODULATION PARAMETERS SQUELCH ON
- Set the squelch level to match the starting point of the measurement as defined in the applicable regulation, for instance:
  squelch level = output power -30 dB:
  MODE:MOD PARAMETERS:SQUELCH LEVEL -20 dBm
- Switch the transmitter off and on again, the FSE now displays as shown in Fig. 6.

Note: *The frequency trace is zero before the trigger event, because the squelch has been set to a level of 30 dB below steady state output power. In this way the noise is not demodulated and the result can be analyzed more clearly.*

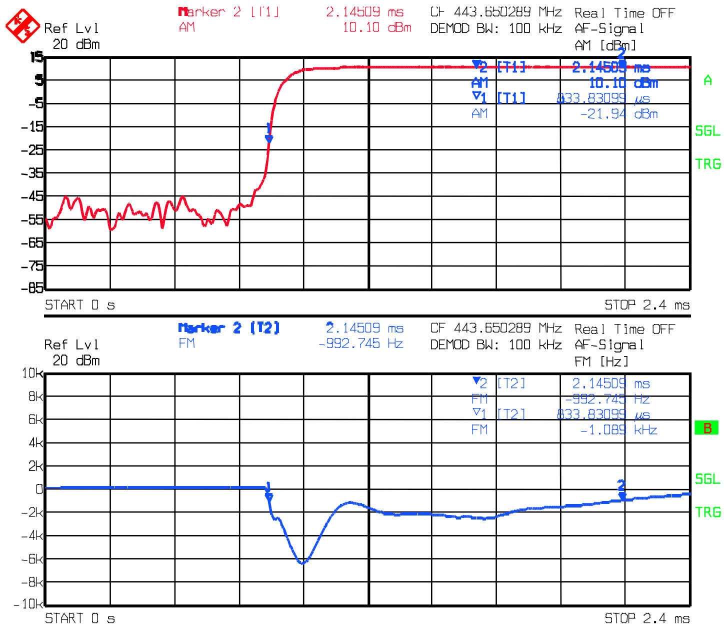

Fig. 6: Transient behaviour and attack time of transmitter under test

Determine the attack time:

- Activate the AM display screen and place a marker at the point on the curve where the level is 10 dBm - 30 dB = -20 dBm:
  TRACE 1
  [MARKER]:**NORMAL:**COUPLED MARKERS
  this activates a second marker in the second screen, both markers are coupled in their position, so placing the marker at the - 30 dB point in the amplitude display. Turn the spin wheel to mark the same point of time in the frequency display screen.
- Activate the FM display screen and place a second marker in this screen (third marker in total):
  TRACE 2
  [MARKER]:**NORMAL:**MARKER 2
- Using the spin wheel place the second marker at the point on the curve where it is within the allowed limit eg f_c +/-1 kHz.
- Activate the display of several markers within the grid:
  [MARKER] **NORMAL**:MARKER INFO
- Read out the time positions of marker 1 and 2, the time difference is the attack time

Note: *The measurement is done REALTIME OFF mode, which is not explicitly selected because this is PRESET. The demodulation bandwidth need not be changed as the PRESET value of 100 kHz satisfied the frequency resolution and settling speed needs in this case.*

The release or decay time is measured in the same way, except the trigger slope of the video trigger has to be set to negative.

Summary of important settings:

- MODULATION PARAMETERS:AF COUPL'G DC
- MEAS RESULT:REALTIME OFF (Preset value)
- DISPLAY:SPLIT SCREEN (AM and FM simultaneously)
- TRIGGER:VIDEO
- TRIGGER:TRIGGER OFFSET (negative value for pre-trigger)
- MODULATION PARAMETER:SQUELCH ON
  SQUELCH LEVEL (set for level at which attack time definition starts)

Limit values

The time mask for the transient frequency behavior can be included with limit lines. Two limit lines are required to construct the mask. An example for setting up the mask used in Fig. 6 is given below.

FSE can also provide fast PASS/FAIL information by means of the limit check function. When this function is active, FSE signals

- "*Limit Pass*" when limits are complied with and
- "*Limit Fail*" when limits are exceeded.

Defining limit values:

- ➢ Activate the screen displaying the transient frequency:
  TRACE 2 starting the limit line entry from this window will automatically set the domain to **time** and unit to **kHz**
- ➢ Press key **LIMITS**.
- ➢ Press the softkeys NEW LIMIT LINE: and the enter name, domain, scaling, unit, limit and, if desired, comment for the limit value as shown by the table below.
- ➢ Press the softkey VALUES: enter points for the limit value as shown by the tables below.
- ➢ Press the softkey SAVE LIMIT LINE: store the limit line on FSE hard disk under the defined name.

Switching on limit lines:

- ➢ Press the key **LIMITS**.
- ➢ Place the cursor on SETTL_U.
- ➢ Press **ENTER**. SETTL_U will be marked by a tick.
- ➢ Press the **CLR** key twice. The limit-line table and the limit menu will disappear from the screen.
- ➢ After the -30 dB point has been determined by a marker the limit lines can be shifted to start at this time:
- ➢ Read out marker time position, eg 962 µs
- ➢ Shift limit line:
  X OFFSET 962 µs

Note: *The values in the following table 4 are examples used for the result in Fig. 7 and are not taken from a regulation.*

Resulting display: see Fig. 7

Table 4: Definition of limit lines (SETTL_L, SETTL_U)

Table of	**Lower Limit Values**	**Upper Limit Values**
Name:	SETTL_L	SETTL_U
Domain:	Time	Time
X-Scaling:	Relative	Relative
Y-Scaling	Absolute	Absolute
Unit:	kHz	kHz
Limit:	lower	upper
Time	**Limit**	**Limit**
0 ms	- 25 kHz	25 kHz
5 ms	-25 kHz	25 kHz
5 ms	- 12.5 kHz	12.5 kHz
20 m	- 12.5 kHz	12.5 kHz

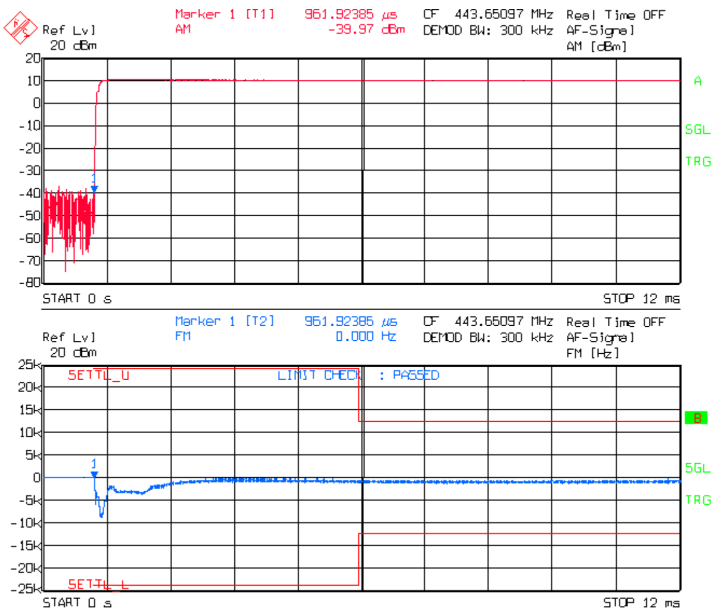

Fig. 7: Result on a crystal controlled handheld transmitter with limit check

6 Ordering information

Spectrum Analyzer

FSEA20	(9 kHz to 3.5 GHz)	1065.6000.20
FSEA30	(20 Hz to 3.5 GHz)	1065.6000.30
FSEB20	(9 kHz to 7.0 GHz)	1066.3010.20
FSEB30	(20 Hz to 7.0 GHz)	1066.3010.30
FSEM20	(9 kHz to 26.5 GHz)	1080.1505.20
FSEM30	(20 Hz to 26.5 GHz)	1079.8500.30
FSEK20	(9 kHz to 40 GHz)	1088.1491.20
FSEK30	(20 Hz to 40 GHz)	1088.3494.30

Options required for FSE:

FSE-B7	Vector Signal Analyzer	1066.4317.02

FSEx.20 models can also be used, except the residual FM will be higher (by a factor of 3 to 10 depending on the Demodulation Bandwidth).

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