NTP and ACP Measurements to ETS 300 175-2 for DECT using Spectrum Analyzer FSE

Application Note 1EF42_0E

Subject to change

24 March 1998, Robert Obertreis

Products:

NTP Measurement:
FSEx with Option FSE-B7

ACP Measurement:
FSEA 20/30 (FSE-B7 not required)

ROHDE&SCHWARZ

1. Introduction

DECT standard ETS 300 175-2 [1] prescribes among others measurement of the transmit power and the unwanted power in adjacent channels. Following a brief introduction into DECT, this Application Note describes the standard-conforming measurement of the normal transmit power NTP and the unwanted adjacent-channel power ACP using a spectrum analyzer from the FSE family (firmware version 1.63 and higher).

Option FSE-B7 (Vector Signal Analyzer) is required for measuring the normal transmit power NTP since the signal must be demodulated for this measurement.

Due to the wide dynamic range of FSEA20 and FSEA30, the adjacent channel power ACP can be measured without bandpass filters suppressing the transmit channel. Option FSE-B7 is not required for measuring the adjacent-channel power.

2. Introduction into DECT

The band between 1880 MHz and 1900 MHz is reserved for DECT. The modulation mode used with DECT is GFSK (Gaussian frequency shift keying). The maximum FM deviation is 288 kHz.

The DECT band is divided into 10 equal subbands. The center frequency f_c of the respective channel is defined by

$f_c = f_0 - c \cdot 1728\,\text{kHz}$, where $f_0 = 1897.344\,\text{MHz}$ and $c = 0,1,\ldots,9$.

Depending on the channel number c, the following center frequencies are obtained:

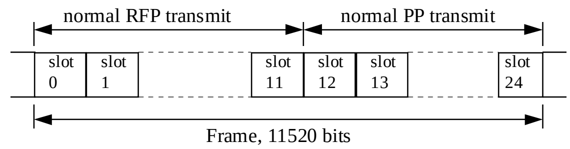
c	f_c / MHz
0	1897.344
1	1895.616
2	1893.888
3	1892.160
4	1890.432
5	1888.704
6	1886.976
7	1885.248
8	1883.520
9	1881.792

Table 1: DECT center frequencies

With DECT, up to ten connections to a base station can be set up simultaneously. Within a frequency channel, transmit and receive channel are separated by time slots. This method is referred to as TDMA (time division multiple access). A TDMA frame contains 11520 bits with a transfer rate r = 1152 bit/s[1]. The time period of a frame is obtained from

$$\frac{\text{Frame length}}{\text{Transfer rate}} = \frac{11520\,\text{bit}}{1152\,\text{kbit / s}} = 10\,\text{ms}\,.$$

A frame is subdivided into 24 full slots, as shown in the following illustration.



RFP : Radio fixed part (base station)
PP: Portable part (mobile phone)

Fig. 1: TDMA frame with DECT

Within a full slot having a length of 480 bits the data are transferred in form of a socalled *physical packet*.

DECT standard ETS 300 175-2 defines various physical packets which differ in their length. For communication, the *basic physical packet P32* as shown in Fig. 2 is mostly used.

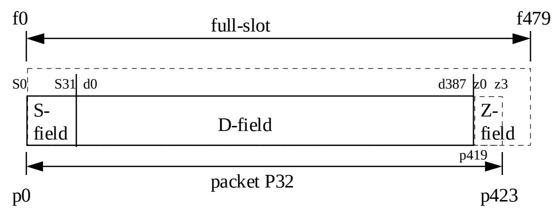


Fig. 2: Basic physical packet

The following table gives an overview of the various physical packets with their bit length as defined in the standard.

	S-field	D-field	Z-field
P00	32 bit	64 bit	0 bit
P32	32 bit	388 bit	4 bit
P08j	32 bit	148 bit	4 bit
P80	32 bit	868 bit	4 bit

Table 2: Physical packets

The socalled S-field contains a 32-bit synchronization sequence which is different for the base station (RFP) and the mobile phone (PP):

RFP sequence:
1010 1010 1010 1010 1110 1001 1000 1010

PP sequence:
0101 0101 0101 0101 0001 0110 0111 0101

[1] With GFSK modulation as used for DECT the bit rate is equal to the symbol rate.

The D-field is provided for data transmission and the 4-bit Z-field may be used for additional synchronization tasks.

3 Normal Transmit Power (NTP)

3.1 Definition

NTP (normal transmit power) is the transmitted power averaged over a physical packet from bit p0 to the end of the packet. The mean transmitted power with DECT should not exceed 250 mW (24 dBm).

To enable correct power measurement, the exact position of the first bit p0 within a packet has to be determined.

3.2 Measurement of NTP using FSE

This measurement can be performed quickly and accurately with the aid of the vector signal analyzer in the FSE. The predefined digital standards facilitate synchronization of the burst.

Prerequisite for this measurement is an external trigger signal to establish the time reference to the burst, as shown in Fig. 3.

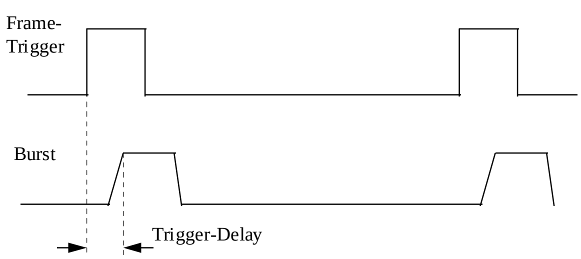


Fig. 3: Frame trigger

The following settings have to be made on FSE in the stated order.

SYSTEM - PRESET: *(resetting the FSE by preset)*
FREQUENCY - CENTER: (*input of channel frequency)*
LEVEL - REF: (*input of maximum signal power*[2]*)*

- Change to vector analyzer mode:

CONFIGURATION - MODE:
VECTOR ANALYZER:
DIGITAL STANDARDS: DECT
⇑ *(menu up)*

By selecting the digital standard DECT, all settings required for measurement of a basic physical packet (423 bits) are made. If another physical packet is to be measured, the result length must be varied manually. To do so, the following settings have to be made in the Vector Analyzer menu:

CONFIGURATION - MODE:
MEAS RESULT:
RESULT LENGTH[3]: (length of physical packet)

For synchronization of the signal the following settings are required in the Trigger menu.

SWEEP - TRIGGER:

TRIGGER: EXTERN
FIND BURST: (on)
FIND SYNC: (on)

Should SYNC NOT FOUND be indicated in the display, the synchronization pattern has to be changed. For DECT, different patterns are already available for the base station FP and the mobile phone PP.

These patterns can be selected in the Trigger menu as follows:

SWEEP - TRIGGER:
SYNC PATTERN:
PATTERN NAME: (dect_fp or dect_pp)

- The MAGNITUDE CAP BUFFER softkey can be used to display the magnitude of the signal stored in the measurement result memory in the time domain.

CONFIGURATION - MODE:
MEAS RESULT: MAGNITUDE CAP BUFFER

If prior to the synchronization sequence a socalled start-up bit sequence is transmitted, this sequence has to be considered in the demodulation. Otherwise the rising edge of the burst would appear in the display and the power measurement is incorrect. SYNC OFFSET can be used to used to vary the trace position within the demodulated signal.

[2] The following settings allow the maximum signal level to be determined:

FREQUENCY - SPAN: (10 MHz)

TRACE - 1: MAX - HOLD

[3] Due to the limited capacity of the FSE memory and the given symbol rate of 1.152 Mbit/s the length of the result is limited to 600 symbols. Physical packets containing more than 600 symbols (P80) therfore cannot be completely demodulated.

SWEEP - TRIGGER:

SYNC OFFSET: *(number of bits ahead of synchronization sequence)*

The demodulated signal is shown in the illustration below. The x axis extends from symbol p0 to symbol p423.

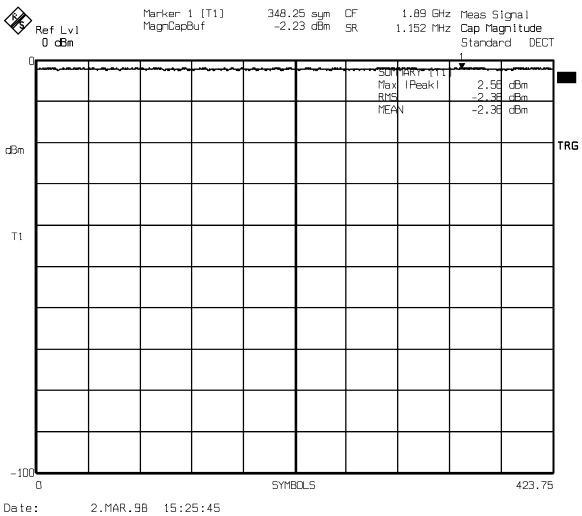


Fig. 4: DECT signal in *Magnitude Cap Buffer* display mode

- Measure the power in the Marker menu:

MARKER - SEARCH:

SUMMARY MARKER: MEAN

The MEAN power indicated on the top right is the power averaged from bit p0 to bit p423 in line with the standard.

4. Unwanted Power in the Adjacent Channels due to Modulation

4.1 Definition

The power emission in adjacent channels caused by frequency modulation is to be measured. Since the DECT signal is pulsed, the signal components caused by switching the carrier on and off have to be ignored. To this end the measurement has to be stopped outside the burst.

The **DECT standard** prescribes the following settings and limit values for the measurement:

Upon transmission of the frequency channel M in successive frames the power in the adjacent channels Y should not exceed the specified values.

Emission in RF channel	**Maximum power**
$Y = M \pm 1$	160 µW
$Y = M \pm 2$	1 µW
$Y = M \pm 3$	40 nW
Y = any other DECT channel	20 nW

Table 3: Permissible adjacent-channel power caused by modulation

The power in a frequency channel Y is defined by integration over the power density. The integration range has a width of 1 MHz and lies at the center frequency F_Y. Averaging should be made over a range of at least 60% to max. 80% of the length of the physical packet. Measurement should start before 25% of the physical packet has been emitted, but after the 32-bit synchronization word.

FSE allows the measurement to be stopped by a gate in case of an inactive gate signal. It is thus possible to display the spectrum of pulsed RF carriers without superimposed frequency components caused by switching the carrier on and off.

The permissible gate settings are graphically shown in Fig. 5. The position of the gate lines should be within the cross-hatched field. The times for a basic physical packet are indicated in parentheses.

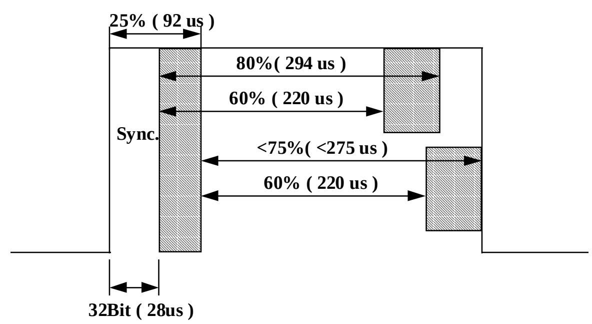


Fig. 5: Gate settings

4.2 Dynamic range of FSE

The usable dynamic range of a spectrum analyzer is limited by the *phase noise* of the local oscillator, the *thermal input noise* (and the dynamic response towards high levels).

Investigation of the short-term stability of an oscillator in the frequency range leads to the **definition of phase noise**. An ideal oscillator produces a line in the spectrum while a real oscillator produces a continuous noise spectrum symmetrically to the carrier frequency (Fig. 6).

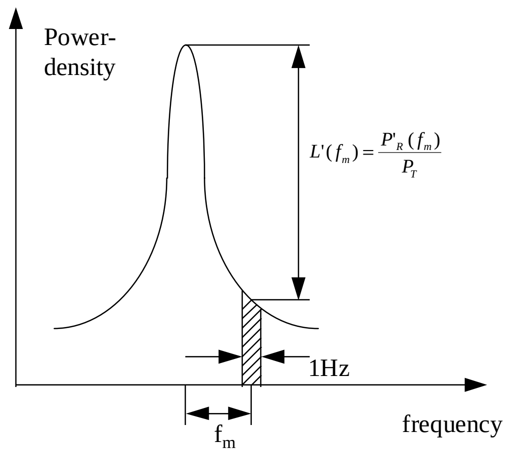


Fig. 6: Signal spectrum and SSB phase noise density

The usual definition of phase noise refers the single-sideband noise power $P'_R(f_m)$ in 1 Hz bandwidth at an offset frequency f_m from the carrier to the carrier power P_T. This relationship is logarithmized to yield

$$L(f_m) = 10 \cdot \lg L'(f_m) \text{ dBc (1Hz)}$$

in dBc(Hz), ie the noise level in 1 Hz bandwidth below the carrier level.

With a maximum transmitter power of +24 dBm, the power emission in remote adjacent channels caused by modulation (see Table 3) should not exceed a value of 20 nW (≙ -47 dBm), ie the required dynamic range is 71 dBc. This value corresponds to the required minimum spacing between the noise power densities $P'_R(f_m)$ and P_T.

Accordingly, for a required resolution bandwidth of 100 kHz (50 dB shape factor) the specified phase noise of the spectrum analyzer in the adjacent channel must be smaller than -121 dBc(Hz).

The DECT standard prescribes measurement of the adjacent-channel power according to the max-hold method. Since the maximum phase noise level is approx. 10 dB above the value stated above, the phase noise of the spectrum analyzer must be lower than -131 dBc(Hz). Table 4 gives some typical phase noise values of different analyzer models for 5 MHz carrier spacing at a carrier frequency f = 3.5 GHz:

FSEA20	FSEB20 FSEM20 FSEK20	FSEA30	FSEB30 FSEM30 FSEK30
-147 dBc(Hz)	-141 dBc(Hz)	-145 dBc(Hz)	-140 dBc(Hz)

Table 4: Typical phase noise values of FSE spectrum analyzers

Therefore phase noise is not a limiting parameter for the measurement of adjacent channel power with the FSE

Like phase noise, the **thermal input noise** also limits the usable dynamic range of the spectrum analyzer. With a resolution bandwidth of $100\,\text{kHz}$ as prescribed by DECT a lower sensitivity limit of

$$NF = -174 \text{ dBm} + F_{Analyzer} + \\ + 10 \lg \frac{100 \text{ kHz}}{1 \text{ Hz}} \text{ dB} + a_0 .$$

is obtained as a function of the noise figure of the spectrum analyzer and the attenuation a_0.

The noise figure of the spectrum analyzer is influenced by the selected reference level. With a high reference level, the internal gain is small and the noise of the IF stages has a greater effect on the overall noise of the FSE.

To minimize the noise figure of FSE, the first mixer can be overdriven up to +0 dBm[4] for measurement of the adjacent-channel power. With a maximum input power of +24 dBm, 10 dB reference level and 30 dB attenuation of the FSE the mixer level is -6 dBm. In this case the IF noise is negligible.

The displayed average noise level N_0 differs for the various FSE models, some values being given in the table below.

[4] The intermodulation-free range for mixer levels of 0 dBm is smaller than the dynymic range required for adjacent-channel measurements. Since only one frequency is applied at a time, this value may be exceeded.

FSEA20, FSEA30	**FSEB20, FSEB30**	**FSEM20, FSEM30, FSEK20, FSEK30**
<-75 dBm typ. -80 dBm	<-72 dBm typ. -77 dBm	<-68 dBm typ. -70 dBm

(RBW = 100 kHz, 30 dB RF attenuation, *f* = 1.9 GHz).

Table 4: Displayed average noise level of FSE

Due to the max-hold method being used for the measurement, the displayed noise level is approx. 10 dB higher.

The power in the adjacent channels is determined by integration of the noise density over the channel bandwidth $CHBW = 1\,\mathrm{MHz}$. Since without signal applied the noise density is approximately constant, the FSE noise level in a channel can be calculated as follows, taking into account the channel bandwidth:

$$L_{\mathrm{CHBW}} = N_0 + 10\lg\frac{CHBW}{RBW}\,\mathrm{dB} = N_0 + 10\,\mathrm{dB}$$

With a selected resolution bandwidth $RBW = 100\,\mathrm{kHz}$ and a channel bandwidth $CHBW = 1\,\mathrm{MHz}$, the channel noise power is $10\,\mathrm{dB}$ above the displayed noise level N_0.

Considering all settings (max hold, integration over $1\,\mathrm{MHz}$), the channel noise power is -55 dBm The measured (single sweep) channel noise power is -54.4 dBm and in good agreement with the calculated value (Fig. 7).

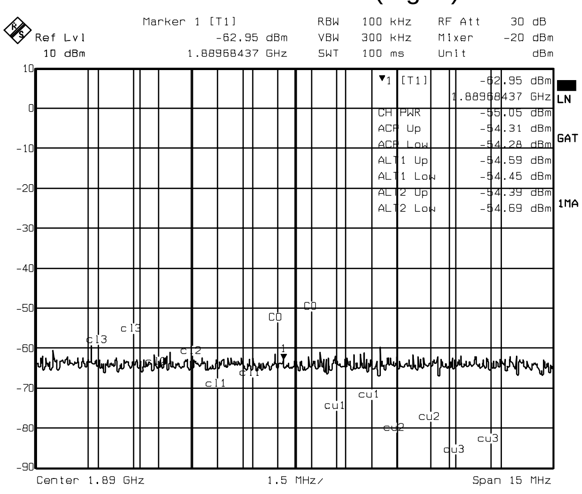


Fig. 7: Noise level and noise power of FSEA without input signal

Since the minimum allowed level to DECT is -47 dBm, the distance between noise power and the unwanted signal due to modulation is approx. +8dB.

The phase noise and the thermal input noise will affect the measurement result if the ratio of the signal level to the internal noise is not at least 20 dB. It should be noted that it is not the signal alone which is displayed, but the sum power of the phase noise of the internal oscillators, the thermal noise and the signal power.

The following diagram shows an error curve of the channel power (*CHBW* = 1 MHz) as a function of the signal-noise ratio in the transmit channel[5]. Due to the different signal statistics in the transmit and adjacent channel, this curve can be applied to the adjacent-channel power with some reservations only.

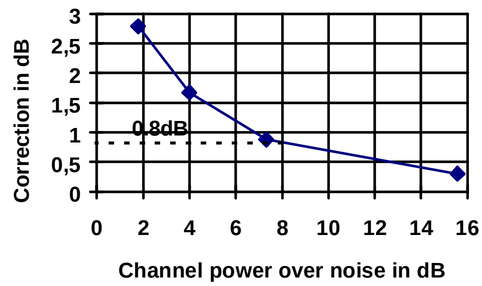


Fig. 8: Diagram for correction of signal level in transmit channel

Because of this the displayed adjacent channel power is about 0.8dB too high.

4.3 Measurement of Adjacent-Channel Power due to Modulation using the FSE

For this measurement, FSE is operated in the analyzer mode and the DECT signal is applied to the RF input. The reference level should be set first according to the maximum signal level.

An external trigger signal is to be used for the measurement.

SYSTEM - PRESET: *(resetting the FSE by preset)*
FREQUENCY - CENTER: *(input of channel frequency)*
FREQUENCY - SPAN: (15 MHz)

- Set resolution bandwidth and video bandwidth:

[5] Settings on FSE:

RBW=100 kHz, VBW=300 kHz, RF ATT=30 dB, CENTER=1.9 GHz, single sweep, channel power measured in 1 MHz bandwidth

SWEEP - COUPLING:
RES BW MANUAL: (100 kHz)
VIDEO BW MANUAL: (300 kHz)

- Set reference level and attenuation.

LEVEL - REF: (see chapter 4.2[6])
ATTEN AUTO LOW NOISE

- Set the gate:

SWEEP - SWEEP: GATE SETTINGS:
GATE ADJUST *(the display changes to the time domain)* :
GATE DELAY: (see Fig. 5)
GATE LENGTH: (see Fig. 5)

A DECT burst is shown in the following screen display. The gate settings are marked by two vertical lines designated GD and GL.

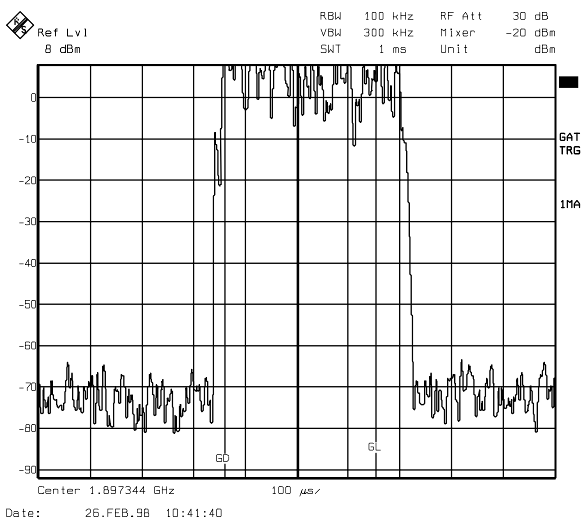


Fig. 9: DECT burst with gate settings for modulation spectrum[7]

- Set the required sweep time

SWEEP - COUPLING:
SWEEP TIME MANUAL: (1200* GATE LENGTH[8])

Typical values for a basic physical packet with a normal transmit power of +24 dBm:
LEVEL REF: (+10 dBm)
GATE DELAY: ($30\mu s$)
GATE LENGTH: ($290\mu s$)
SWEEP TIME MANUAL: ($1200 * 290\mu s = 348\,ms$)

- Select the prescribed recording mode

TRACE 1: MAX HOLD

- Perform power measurement:

MARKER - NORMAL: ⇐ (left submenu)

POWER MEAS SETTINGS:
CHANNEL BANDWIDTH: (1 MHz)
CHANNEL SPACING: (1.728 MHz)

SET NO. OF ADJ CHAN'S: (3) ⇑ (menu up)
ADJACENT CHAN POWER
CP/ACP: (ABS)

- Carry out the measurement with the given sweep time in single-sweep mode.

SWEEP - SWEEP: SINGLE SWEEP

The displayed channel power in the respective channel is the channel power density integrated between the limit lines *cu* and *cl* as specified in the standard. The measured channel power CH PWR in the transmit channel is not conform to the standard and differs from the measured NTP.

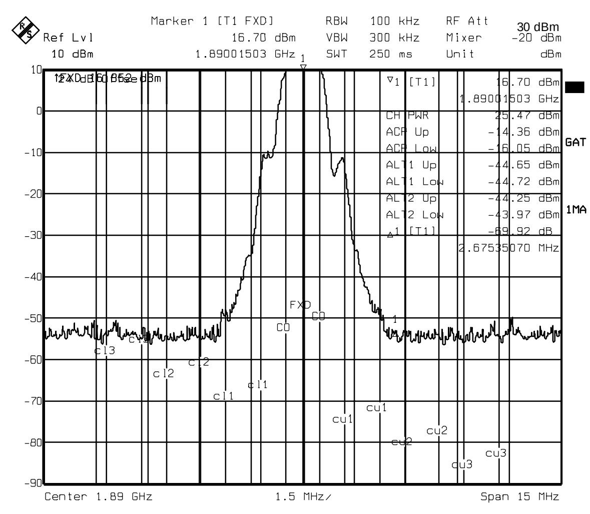


Fig. 10: Measurement of channel power in frequency range

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[6] The following settings allow the power ramp and hence the maximum signal level to be determined:

TRACE - 2: MAX HOLD

The trace can be blanked with softkey BLANK in menu TRACE 2.

[7] To display the burst in the center, a trigger delay of 340 µs was selected. In addition, the time scale was expanded to 100 µs/div.

[8] The sweep time of 12 s prescribed by the standard refers to a continuous sweep over 1200 TDMA frames. With FSE the sweep is stopped outside the gate. With the same effective measurement time, a sweep time is obtained for FSE which is 1200 times the GATE LENGTH.

5. Unwanted Power in Adjacent Channels due to Transients

5.1 Definition

According to the standard, the power levels of all modulation products in the adjacent channels including the AM products due to switching the RF carrier on and off should be smaller than the values given in the following table.

Emission in RF channel	Maximum power
$Y = M \pm 1$	250 µW
$Y = M \pm 2$	40 µW
$Y = M \pm 3$	4 µW
Y = any other DECT channel	1 µW

Table 6: Max. permissible adjacent-channel power due to transients

5.2 Measurement of Adjacent-Channel Power due to Transients using the FSE

The measurement is similar to that of adjacent-channel power due to modulation. The only difference is that the transients of the bursts have to be measured too. For this purpose the gate must be set so that the burst is completely within the window as shown in Fig. 11.

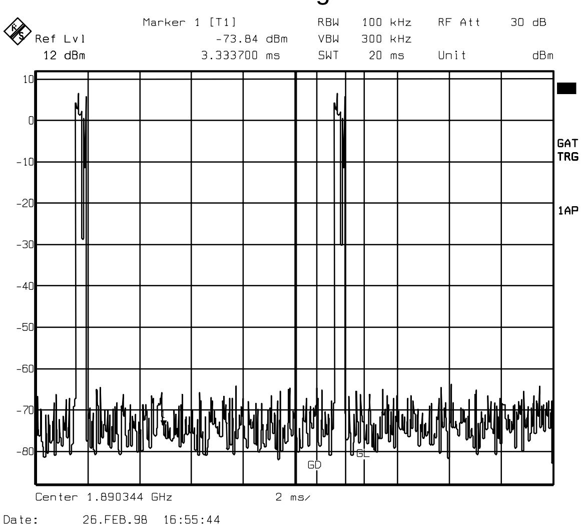

Fig. 11: Gate setting for measurement of transients spectrum

Compared to the adjacent-channel power due to modulation, the permissible power in this case is higher so that the requirements regarding the usable dynamic range are more easy to satisfy.

The settings for the gate delay are always referred to the trigger time and there are no negative values as in the case of the trigger delay.

If the time between the trigger event and the rising edge of the burst is too short, part of the rising edge will be clipped by the gate. This can be prevented by increasing the gate delay so that the second burst following the trigger event will be measured. Based on the settings for the adjacent-channel power due to modulation, the gate settings are to be varied accordingly.

- Select setting mode

SWEEP - SWEEP:
CONTINUOUS SWEEP
SWEEP TIME MANUAL (20 ms)

- Gate settings

SWEEP - SWEEP: GATE SETTINGS:
GATE ADJUST *(the display changes to the time domain)* :
GATE DELAY: (shortly before the burst[9])
GATE LENGTH: (shortly after the burst)
⇑ (menu up)
GATE EXTERN
⇑ (menu up)
GATE: (on)

Select measurement mode

SWEEP - SWEEP:
SWEEP TIME MANUAL (500 ms[10])
SINGLE SWEEP

For measuring the power, proceed as described for the adjacent-channel power due to modulation. The following illustration shows the result of an adjacent-channel power measurement in a spectrum widened by transients.

[9] For the measurement it is important that all burst components contributing to the spectrum are covered by the measurement, whereas components caused by the counterpart are not to be measured.

[10] The sweep time is not specified in ETS 300 175-2 standard for the measurement of adjacent-channel power due to transients.

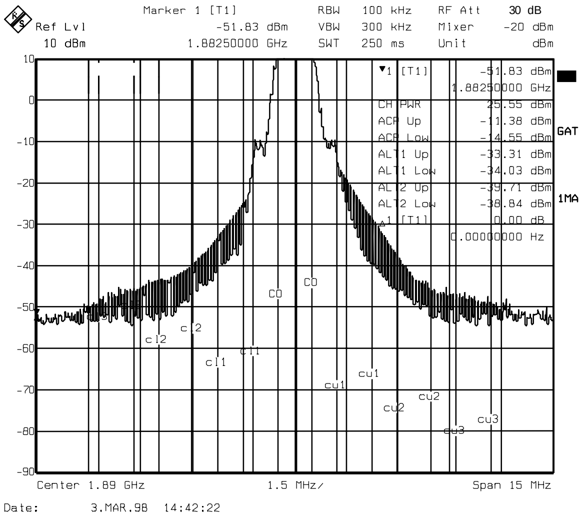

Fig. 12: Spectrum widened by transients

References

[1] European Telecommunications Standards Institute ETSI, *Radio Equipment Systems (RES); Digital European Cordless Telecommunications (DECT) Common Interface Part 2: Physical layer,* ETS 300 175-2, September 1996

[2] Josef Wolf: *Measurement of Phase Noise using Spectrum Analyzers of FSE Family,* Application Note, Rohde&Schwarz 1995

Ordering information

Spectrum Analyzer FSEA30	1065.6000.30
Option B7: Vector Signal Analyzer	1066.4317.02

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24.03.1998