ROHDE&SCHWARZ
INSTRUMENTS DIVISION

APPLICATION NOTE

SME with Option DM Coder
Hints for Using the Data Generator

Products:

***Signal Generator SME 02** 5 kHz - 1.5 GHz*

***Signal Generator SME 03** 5 kHz - 3.0 GHz*

1G18-03-0294-e

1. Introduction

A programmable data generator such as the combination of SME with option SME-B11 is a novelty with signal generators. To make it easy for the user to get acquainted with the option and to ensure efficient operation, possible applications are described below.
The data generator is used for producing binary data as well as control signals for level switching whenever digitally modulated signals are used.
For a start we should like to deal in brief with the various settings available for digital modulation. Taking GSM as an example, the programming of data lists will be described next. The description for GSM can be easily applied to other digital networks as well.
Next the generation of level bursts and the extension of data generator memory with option SME-B12 are described. The last section deals with special subjects such as FSK using data rates below 400 bits/s and pulse-amplitude modulation.
A basic knowledge on digital modulation and TDMA will be sufficient to follow the topics.

2 Settings Available for Digital Modulation

2.1 Selection of Modulation Parameters

Selecting one of the digital modulation modes in the SME menu opens a window in which the parameters for digital modulation can be set. When a special modulation standard, eg GSM, is selected with SELECT STANDARD, the correct modulation parameters (data rate, filter, frequency deviation) are set automatically. This has no effect on the data generator.

2.2 Source Selection

When a source (EXT, DATA, PRBS) is selected, the SME automatically switches to digital modulation.
PRBS activates the pseudo-random data generator which generates a periodic pseudo-random data sequence of variable length (adjustable between 2^9 and 2^{23}). The data sequence continues periodically. If a data list has been selected with SELECT LIST (see also section 3.1), the burst control signals defined in the selected list are activated too. Thus the TDMA structure will be performed in correspondence to the data list while digital modulation data are pseudo random.
If DATA is selected in the menu, the SME uses the binary modulation data defined in the active list and also the burst signals in the list.

2.3 Level switching

To generate burst signals the output level of the SME must be switched on and off, while the instrument continues to transmit digital modulated data. SME offers two burst control signals: BURST and LEVATT.
Both control signals are programmed together with the binary modulation data by entries in the data lists.
The SME uses 3 methods of level switching:

1) LEVEL ATTENUATION

The menu item "LEVEL ATTENUATION" permits a defined level variation to be entered with a resolution of 0.1 dB. Level variations up to 50 dB are possible, the level error increasing with increasing attenuation. Up to 30dB attenuation the level error is less than 1 dB typically. With high demands on accuracy, level variations should be calibrated prior to switching the burst mode on (see section 6.4 for calibration procedure). Level switching is controlled with the LEVATT signal from the selected data list. In the SME, level variation is carried out by the built-in amplitude modulator in combination with ALC loop. Delay and rise time of the amplitude modulator is approx. 1 to 2 µs.

2) BURST with pulse modulator

If the pulse modulator of the SME is used, level variations of more than 80dB are possible. Rise and fall times are below 10ns. Switching is controlled with the BURST signal from the selected data list. The generated signal is available at the rear of the SME.
Proceed as follows:

➢ Connect the BURST output to the PULSE input
➢ Switch on pulse modulation with MODULATION - PULSE - SOURCE - EXT

In the second menu line set the polarity compatible to the programmed BURST signal in the selected data list - refer also the example in the following section.

3) Combination of LEVEL ATTENUATION and BURST

The two methods may be combined.
The diagram in Fig. 1 shows signal processing in the SME for generating digital modulation and for level switching.

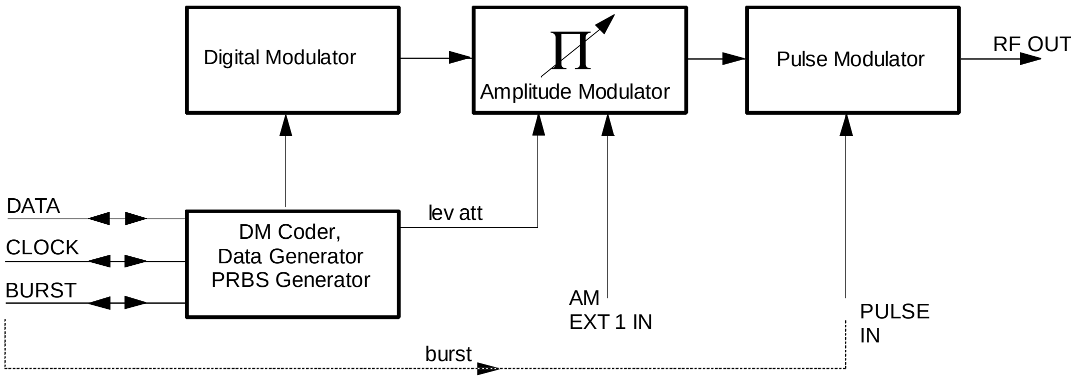

Fig. 1: Generation of digital modulation and burst in the SME

3. Programming Data and Level Switching

3.1 Programming and Storing Data Lists

The data memory in the DM coder can be edited directly from the SME front panel. To this end data lists may be generated and stored.
A new list is generated with:

➢ SELECT LIST - NEW LIST

Each list may be edited (FUNCTION - EDIT/VIEW) and defines 3 signals arranged in three columns:

- DATA holds the modulation data
- LEV ATT defines the switch signal for the level variation (LEVEL ATTENUATION)
- BURST defines another switch signal which is available at the BURST socket.

The BURST can be used as an input signal for the pulse modulator for obtaining level variations of more than 80 dB. Section 5.1 describes another use of the BURST signal as a trigger signal.
The data memory is bit-parallel for all 3 signals, ie in the case of a two-digit modulation, eg 4FSK, two data bits are available for each modulation symbol.
The list editor is described in detail in the Operating Manual, section 2.2.4.
The freely programmable data generator may be used for a variety of applications.
An example is described below.

Example: Pseudo-random data in one time slot

➢ Program the signal LEV ATT for level switching for one frame (Fig. 2).
➢ Select the internal PRBS generator as a data source with SOURCE - PRBS

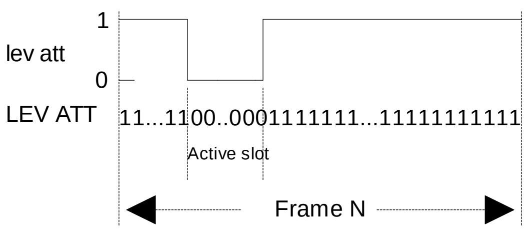

Fig. 2: Level switching with LEVATT signal

Level switching is activated by entering a value above 0 dB at LEVEL ATTENUATION.
Of course, several active time slots can be programmed in this way.

3.2 Programming a TDMA Frame for GSM

This section describes programming of a TDMA frame with one active time slot. GSM has been used as an example but the procedure is applicable to other applications as well, eg DECT or NADC.

1) Basic considerations

- Frame length = 1250 bit
- One frame contains 8 time slots which means that each time slot is 156.25bit long.

The first time slot in the frame (slot 0) is assumed to be active (level ON).
During transmission of the other 7 time slots the level should be reduced by >70 dB (Slots 1 to

7 level OFF). Since this attenuation cannot be achieved with LEVEL ATTENUATION, the BURST signal is programmed (1250bits); it will be used later on for switching the SME pulse modulator.

2) BURST

In order to safely comply with the power/time template defined in the GSM specifications, the BURST signal has to be programmed for 151 bits with ON level.

Because of the baseband filters used with digital modulation, modulation of the RF carrier is delayed against the modulation data in the DATA list. This delay is a function of the type of modulation and the filters used and may be neglected if only pseudo-random data (PRBS) are to be modulated. In all other cases it has to be considered when the BURST signal is defined.

The delays for the various modulation standards are listed in the Operating Manual, Section 2.6.3.3, Table 2-5.

Taking the delay into account (example GSM):

- Delay 14 µs (acc. to Table 2-5)
- Bit duration = 3.7 µs
- Delay 14/3.7 = 3.8 bits
- ➢ 3 bits are selected

A delay of 3 bits as against the DATA signal should therefore be programmed for the BURST signal ("0" corresponds to ON)

Bit position	**BURST**	**Remarks**
1 to 3	111	3 bits delay
4 to 154	00 to 00	151 bits level ON
155 to 1250	11 to 11	Level OFF

3) DATA (Normal burst)

If specific data are to be modulated, the DATA signal has to be programmed too. Example:

Bit position	**DATA**	**Remarks**
1	1	Guard
2 to 4	000	Tail
5 to 61	XXX...XXX	Any data
62	1	Flag
63 to 88	001001011 100001000 10010111	Training sequ. Midamble 0
89	1	Flag
90 to 146	XXX...XXX	Any data
147 to 149	000	Tail
150 to 156	1111111	Guard
157 to 1250	XXX... XXX	Random data

For programming extended 1 or 0 sequences, editor functions FILL and INSERT may be used.

On the SME the first page of the data list looks as follows:

-NR-	DATA	LEV ATT	BURST
0001	10001110	00000000	11100000
0009	10010001	00000000	00000000
0017	00101010	00000000	00000000
0025	11110010	00000000	00000000
0033	00101100	00000000	00000000
0041	11000010	00000000	00000000
0049	11010011	00000000	00000000
0057	00010100	00000000	00000000

4) Switching on modulation with level switching

- ➢ For switching on the modulation select GMSK - SOURCE - DATA
- ➢ Connect the BURST output to the PULSE input
- ➢ Switch on pulse modulation with MODULATION - PULSE - SOURCE - EXT
- ➢ Invert pulse polarity with PULSE - POLARITY - INV

4. Generation of Burst Signals

4.1 Several Active Time Slots using Different Levels

In radio networks using TDM, reception and demodulation of data transmitted in a time slot may be impaired by data in the adjacent slots. For this reason measurements of the suppression of adjacent time slots are prescribed. For instance, GSM specifications (ETSI/GSM 11.20) stipulate for base stations BER tolerances for a time slot in the presence of a 30-dB higher level in the adjacent time slots.

This measurement problem can be solved with the SME when LEVEL ATTENUATION and BURST are combined. Fig. 3 shows how LEV ATT and BURST signals should be programmed and the resulting envelope curve of the RF signal.

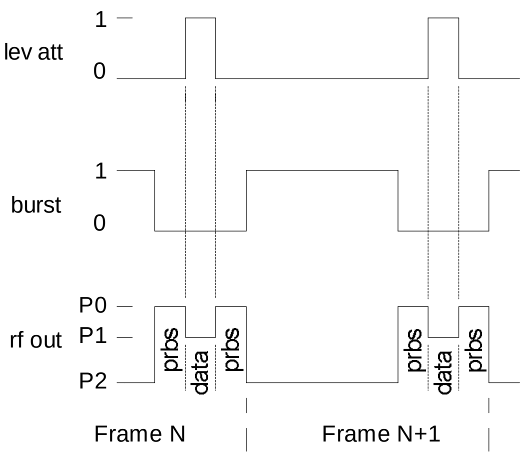

Fig. 3: Programming the measurement of interference caused by adjacent time slots

The time slot carrying level P1 is the channel used. P0 is the output level set on the SME, P1 the result obtained from P0 and the level reduction set with LEVEL ATTENUATION. P2 is obtained when the pulse modulator is switched off and is therefore more than 80dB below P0.
If high demands are set on the accuracy of the 30-dB level reduction, the latter should be calibrated prior to switching on the burst mode (section 6.4).
Furthermore, for measurements on GSM base stations the SME should be synchronized to the frame rate of the base station. This can only be done when option SME-B12 is used. For details refer to section 5.1.

4.2 Level Switching with Reduced Slopes - Power Ramping

The switching procedures for varying the level cause spurious in adjacent channels. Therefore, limits are specified in most cases for spurious emissions in adjacent frequency channels when mixed FDMA/TDMA radio networks are employed.
Particularly unfavourable in this aspect is level switching with a fast pulse modulator with a rise time of a few nanoseconds only.
Better results, ie less spurious emissions, are obtained with the SME's amplitude modulator. This modulator is used when LEVEL ATTENUATION is chosen for level switching.
If the ALC bandwidth of the SME is reduced, spurious emissions will be within the limits specified for DECT telephones. This is achieved as follows:

➢ LEVEL - ALC - BANDWIDTH - 100k

ETSI/GSM 11.20 specifications set high standards for spurious emissions (switching transient spectrum) for base stations in the GSM network.
The characteristic for power ramping in the time domain must remain within set tolerances (power/time template). Additionaly the upper limits of the switching spectrum are to be observed at specified frequencies of 400, 600, 1200 and 1800 kHz offset from the centre frequency of the channel.
The limits described above apply to GSM equipment. GSM specifications do not prescribe these limits for signal generators, since these requirements are irrelevant for receiver measurements.
Nevertheless it is possible to meet the specifications with the SME with the aid of an additional external GSM filter (Fig. 4).

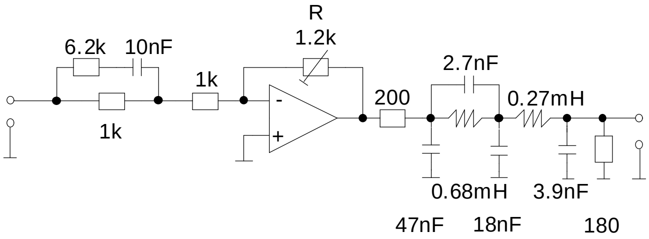

Fig. 4: GSM lowpass filter for SME

The GSM lowpass filter produces a signal with soft edges from the logic BURST signal of the SME. This signal controls the SME amplitude modulator and switches the RF level on and off with reduced steepness over a range of approx. 30 to 35 dB. The pulse modulator is used in addition in order to obtain the power ramping range of 70 dB specified for GSM base stations. The pulse generator (option SM-B4) is used for synchronizing the time for pulse and amplitude modulation .
The figure below shows the required test setup.

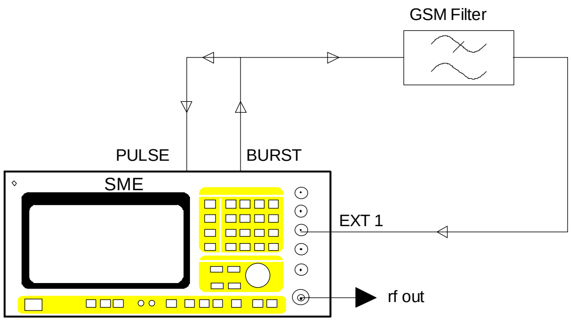

Fig. 5: Test setup - SME with external GSM filter

The output voltage of the GSM filters is set with potentiometer R (Fig. 4) so that the logic HCMOS level at the BURST output generates an output voltage of -1 V (overshoots are ignored).
Only the BURST signal has to be programmed on the SME for level switching. If specific data contents are to be transmitted, the DATA signal has to be programmed accordingly. Contrary to the example in section 3.2, no additional 3-bit delay has to be taken into account for the BURST signal since the delay of the external filter just compensates for the SME-internal delay of the modulation data.
The table below shows an example for programming with time slot 0 being active:

Bit position	**BURST**	**DATA**	**Remarks**
1	0	1	Guard
2 to 4	000	000	Tail
5 to 61	0 to 0	XXX...XXX	Data
62	0	1	Flag
63 to 88	0 to 0	001001011 100001000 10010111	Training sequence Midamble 0
89	0	1	Flag
90 to 146	0 to 0	XXX...XXX	Data
147 to 149	000	000	Tail
150, 151	00	11	Guard
152 to 156	11111	11111	Guard
157 to 1250	111 to 111	XXX...XXX	Slots 2 to 7 off

In addition to selecting frequency and level, the SME should be set as described below:

- Switch on digital modulation with
  GMSK - SOURCE - DATA (or PRBS)
- Switch on AM with
  AM - AM DEPTH - 99%
  AM - AM SOURCE EXT - EXT 1
  AM - AM EXT COUPLING - DC
- Switch on pulse modulator and generator
  PULSE - SOURCE - PULSE-GEN
  PULSE - POLARITY - NORM
  PULSE - EXT IMPEDANCE - 10 k
  PULSE - PERIOD - 5 ms
  PULSE - WIDTH - 575µs
  PULSE - PULSE DELAY - 2µs
  PULSE - TRIGGER MODE - EXT
  PULSE - EXT TRIG SLOPE - NEG
- Reduce ALC bandwidth
  LEVEL - ALC - BANDWIDTH - 100k

Figs. 6 and 7 show the characteristics for GSM power ramping measured on an SME set as described above.

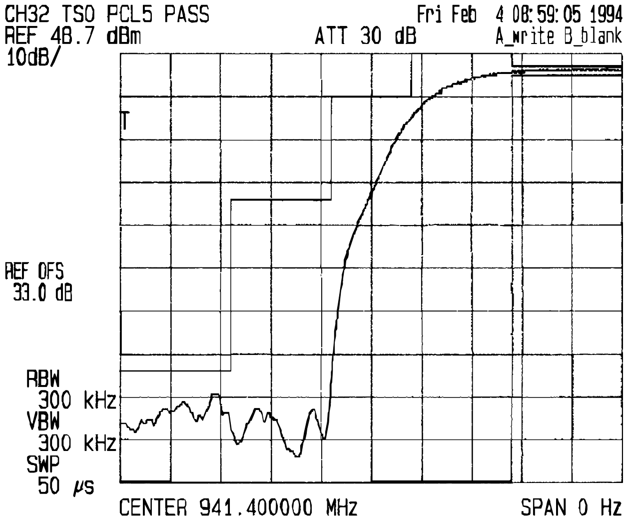

Fig. 6: Rising edge of power ramp[1]

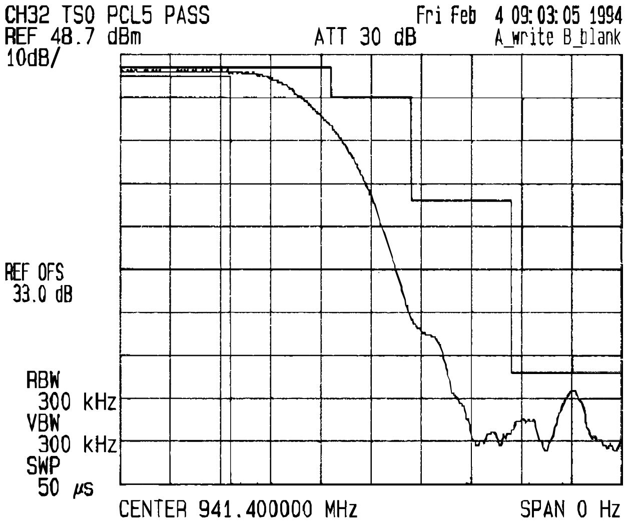

Fig. 7: Falling edge[1]

The characteristic of a power ramp is determined mainly by the parameters AM DEPTH, PULSE WIDTH and PULSE DELAY.
PULSE DELAY determines the start point of the rising edge.
AM DEPTH is to be set so that the rising edge covers a range of more than 30 dB but the switching is as soft as possible.
PULSE WIDTH is set while the falling edge is observed so that the preset tolerance mask is not exceeded (see Fig. 7).
Fig. 8 shows the switching spectrum for the GSM power ramp characteristic in the figures above.

[1]Measure with Spectrum Analyzer R3265 from Advantest and Option GSM Measurement Software (BS)

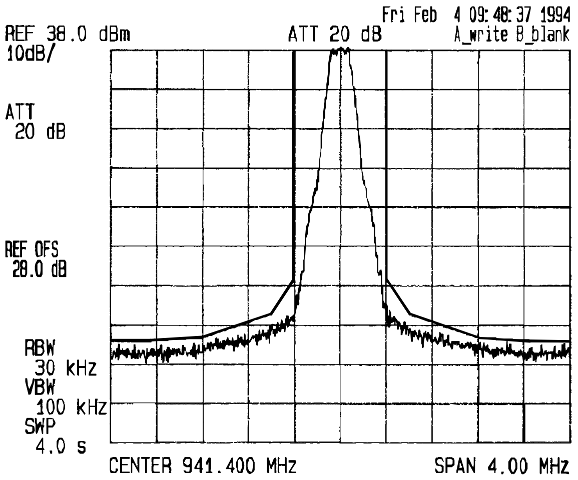

Fig. 8: GSM switching spectrum[1]

5. Extending the Data Generator Memory with Option SME-B12

Option SME-B12 extends the data memory of the data generator. With the option built-in, XMEM (E**x**tended **Mem**ory) is displayed in SELECT LIST menu as an option to be selected. Whit the memory extension, a storage capacity of up to 1 Mbit is available for each of the signals DATA, LEVATT and BURST. An alternative is the use of DATA only, hence the memory capacity of 8 Mbit. Selection is made in the CONFIG-XMEM-MEMMODE menu.
The DM memory extension is of advantage for all measurements for which extended data sequences (>8 k) are required. It may also be used for synchronizing the generated signals to an external frame clock.

5.1 Synchronization to an External Frame Clock

When carrying out measurements on GSM base stations, the data and clock signals generated in the SME must be synchronized to the frame clock of the base station.
For synchronization proceed as described below (example GSM):

- ➢ Apply the 13-MHz system clock of the base station to the REF socket at the rear of the instrument.
- ➢ Set on the SME:
  UTILITIES - REF OSC - SOURCE - EXT
- ➢ UTILITIES-REF OSC-EXT FREQUENCY 13 MHz

This basically synchronizes the frequencies of the units.
For synchronizing the SME to an external frame clock, apply this clock to the rear trigger input and select the memory extension as data source:

- ➢ DIGITAL MOD - GMSK - SELECT LIST - XMEM
- ➢ DIGITAL MOD - GMSK - CONFIG XMEM - MEM MODE 1M∗3
- ➢ DIGITAL MOD - GMSK - CONFIG XMEM- EXT TRIGGER ON

Function:
The active edge of the frame clock triggers a memory readout in the SME with the start address being read out first. Note that a delay of 500 ns plus 1 to 2 periods of the SME-internal clock occurs between the triggering frame clock and the actual start of the data transmission initiated by the memory extension. This inaccuracy is caused by the fact that SME and DUT are not synchronous in phase
The operating principle of the memory extension is that each active clock edge triggers a new start at the first memory addresse (in the START ADDRESS menu). If several frames with different data content are to be transmitted, this retriggering is undesirable.
Retriggering can be suppressed with the aid of an external AND gate and a suitably programmed BURST signal from the SME. The required test setup is shown in Fig. 9.

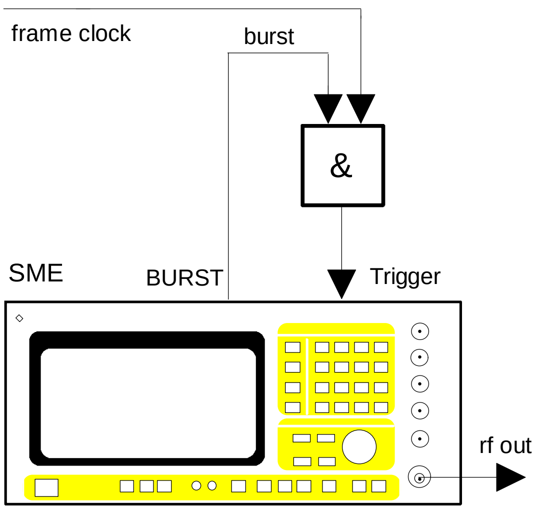

Fig. 9: SME synchronized to external frame clock

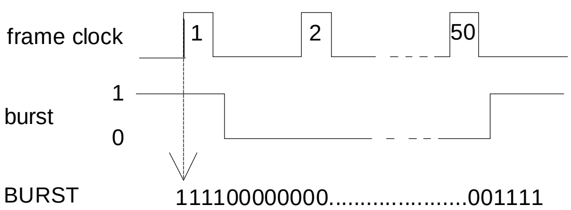

Fig. 10: Trigger mask with BURST for transmission of 50 frames

[1] Measure with Spectrum Analyzer R3265 from Advantest and Option GSM Measurement Software (BS)

The diagram in Fig. 10 illustrates the timing:
At first, the BURST output is at 1. At this level the first positive frame clock edge in the example triggers data transmission, starting with the set start address (Data bit 1 in the example above). The BURST signal should be programmed so that it changes to 0 before the second frame clock arrives. For the transmission of 50 frames, 50• 1250 zeros have to be programmed followed by 1250 ones to make sure that the memory extension is triggered again.
DATA is programmed as required for the data transmissions.
Level switching is possible with the function LEVEL ATTENUATION and with the LEVATT signal.

5.2 Reading Data into the Memory Extension

The extension to the data generator memory is intended especially for applications requiring long data sequences. Since manual data programming on the SME would be cumbersome effort, other ways of reading in data have been provided:

1. Serial read-in from an external source via the DATA input
2. Read-in from an external source via an RS-232 interface

Of course, data can also be read in via the IEEE 488 remote-control interface.

6 Special Subjects

6.1 FSK with data rates below 400 bit/s

The clock generator of the DM coder option (SME-B11) yields data rates from 520 to 100000 bit/s for FSK[2] (without baseband filtering).
If an external data source is available, even rates below 520 bits/s may be used for modulation after setting

- DIGITAL MOD - FSK - SOURCE - EXT.

The data rate displayed in the FSK - BIT RATE menu is irrelevant for operation with external sources. Data are fed in at the DATA input. No signal is applied to the CLOCK input.
To make the internal data memory accept data rates below 520 bits/s the following trick is used:
Adjust a multiple of the required data rate (> 520 bit/s) on the SME and program the same multiple for the data bits.
Example:
Required: FSK, 200 bit/s, data 10010
Setting: 600 bit/s, data 111000000111000

[2]As from the end of 1994 after an update of the DM coder option both the upper and lower limit will be extended.

6.2 Programming Instructions for DECT

Like GSM, the DECT standard for cordless telephones defines a TDM procedure. It uses a frame length of 10 ms divided into 24 time slots. With a data rate of 1152 kbit/s, 480 bits are allocated to each time slot and 11520bits to each frame.
If no memory extension option (SME-B12) is available, it is advisable to carry out the procedure described below because of the limited memory capacity (8 kbit/s):

- Program 12 time slots only, eg time slot 1 is active, all others are disabled.

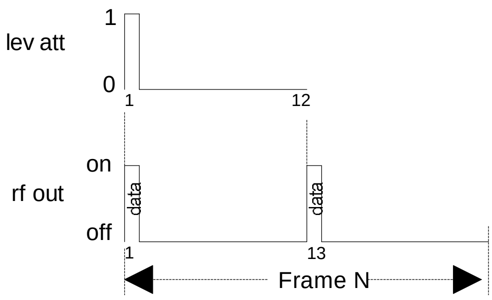

Fig. 11: Example DECT: transmissions in time slots 1 and 13

If DATA has been selected as modulation source (SOURCE DATA), the data programmed in the active data list for time slot 1 are repeated in time slot 13 for the above example.
If the PRBS generator is used as a data source, pseudo-random data are continuously transmitted in time slots 1 and 13.
The repetition of data in the second half of the frame does not cause disturbance because the receiver only "listens" to the first half of the frame anyway. With DECT equipment, the second half of the frame is used for transmissions in the opposite direction (duplex operation through TDMA).
Should the repetition of data however not be desired, the memory extension SME-B12 should be used. It also allows the SME to be synchronized to the frame clock of a DUT and permits long data sequences to be programmed, eg for BER measurements.

6.3 Using the Data Generator without Digital Modulation - PAM as an example

The SME is designed so that the data generator and the digital modulator are switched on automatically when a data source (DATA or PRBS) is selected. If the data generator should be used separately, ie without a modulation (FSK, MSK or DQPSK), proceed as described below:

- Switch on FSK , eg
  MOD - FSK - SOURCE - DATA
- Set deviation to 0[3] by entering
  MOD - FSK - DEVIATION - 0Hz
- Adjust desired clock rate with
  MOD - FSK - BIT RATE - x.x bps

The DATA, CLOCK and BURST signals are now available at the respective outputs.
This opens up further interesting applications for the data generator.
For instance, it may be used as data source for other modulators, ie also for the SME-internal φM modulator (SME-B5). In this case only the level at the DATA output (logic HCMOS level) has to be reduced to match the required modulator input level (1V).

<u>Example for an application</u>
<u>Pulse-amplitude modulation (PAM)</u>
Signals can be **p**ulse-**a**mplitude **m**odulated when the pulse modulator of the SME is used together with the data generator. First set the data generator of the SME as described above. Then proceed as described below:

- Connect the DATA output to the PULSE input
- Switch on pulse modulation with
  MODULATION - PULSE - SOURCE - EXT

The level of the RF signal is switched as required by the data sequence applied to the PULSE input.
If the internal pulse-generator option (SME-B4) is available, the pulse width can be set.
Example:

- Switch on pulse modulation with
  MODULATION - PULSE - SOURCE - PULSE-GEN
- Set pulse generator to external triggering with
  MODULATION - PULSE - TRIGGER MODE - EXT
- Adjust pulse width, eg
  MODULATION - PULSE - WIDTH - 2µs.

Fig. 12 shows the result of the above settings:

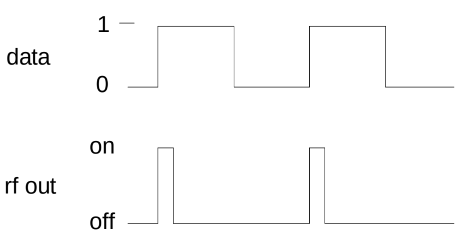

Fig. 12: Example of PAM

[3]This function will be available as from firmware version 1.50.

6.4 Calibrating the LEVEL ATTENUATION

Whenever a level variation of more than 20 dB with a setting error <1 dB is required, level switching via LEVEL ATTENUATION should be calibrated with a power meter before the burst mode is switched on.
The receiver level to be measured is normally below the measurement range of a power meter. The SME must therefore be calibrated at levels between 8 and 13 dBm. The calibration level is determined as described below:

<u>Example for level attenuation of 30 dB</u>:

- Required measurement level P_m
- Reduced level P_m - 30 dB
- Calibration level: P_m+k • 5 dB = P_{cal};
  k as integer and
  8.0 dBm < P_{cal} < 13 dBm

P_m	P_m - 30 dB	P_{cal}	P_{cal} - 30 dB
-74 dBm	- 104 dBm	11 dBm	-19 dBm
-76 dBm	- 106 dBm	9 dBm	-21 dBm
-78 dBm	- 108 dBm	12 dBm	-18 dBm

Connect a power meter to the RF output of the SME and wait 1 hour for the unit to warm up. Then proceed as described below:

- PRESET
- Set required output frequency
- DIGITAL MOD - GMSK - SOURCE - DATA
- GMSK - SELECT LIST - NEW LIST
- GMSK - FUNCTION - EDIT VIEW
  Program bit 1 = "1" at LEV ATT
- GMSK - LEVEL ATTENUATION 0 dB
- Measure output level (P_{cal})
- GMSK - LEVEL ATTENUATION -30 dB
- Measure output level (P_{cal} -30 dB)
- Vary LEVEL ATTENUATION until exactly -30 dB are obtained.

The value thus determined for LEVEL ATTENUATION should be maintained and used for the subsequent measurements.
The calibration will also be valid after a frequency change provided the difference between the new frequency and the calibration frequency is not much more than 20 MHz.
Level error is below 1 dB for temperature variations of less than 10 K.

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