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Additional Information to the Service Documents Concerning the Digital Modulation of the SME

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Appendix: 1 copy of the paper from the 27.04.93 (13 pages)

2 iq demodulator circuit diagram

3 iq demodulator module MIQA-10D data sheet

4 DQPSK spectrum at the output FDDS of the module DSYN with the PRBS sequence

5 DQPSK spectrum at the output CODAM (X80A.9, motherboard, 50Ohm load) of the module DSYN with the data sequence "0111".

1 Paper for the service training at the 27.04.93

One can find the copy of the paper in the appendix 1.
In the following are some important comments to the paper:

1.1 Some basics about the various digital modulations

The pictures on page 2 to 8 describe the basic principles of the various digital modulation types.

The constellation diagram (ger.: Zustandsdiagramm) showes the graph of the q signal (quadrature signal) over the i signal (inphase signal).
The eye pattern (ger.: Augendiagramm) is the oscilloscoped demodulated signal (FM respectively i and q signal for DQPSK), triggered by the clock of the digital data signal.

One will find more informations about the basics of digital modulation in the following literature:
- "Einstieg in die digitalen Modulationsverfahren", Sonnde/Hoeckstein, Franzis-Verlag München, 1992.

- "Digitale Modulationsverfahren", Rudolf Mäusel, Dr. Alfred Hüthig Verlag Heidelberg, 1988.

1.2 The modules DIGITAL SYNTHESIS and DM-CODER

Page 9 of the paper shows a simplified functional circuit diagram of the modules DIGITAL SYNTHESIS (DSYN), SUMMING LOOP (SUM) and OUTPUT UNIT (OPU). The detailed functional circuit diagrams are in the service manual.

The module option DM-CODER (DCOD) is a submodule of DSYN and is the source of all the digital modulations.

For DQPSK modulation, the AM-Signal comes in analog form via the motherboard to the module OPU (OUTPUT UNIT), to controle there the AM loop
(0V-->normal level, 1V-->level off, -1V-->double level).

The FM-signal comes in a digital parallel form to the DDS gatearray (DDS-GA) on the module DSYN (DIGITAL SYNTHESIS). The DDS-GA generates a digital FM modulated sinewave between 14.1 and 15.6MHz. The clock has the frequency of 50MHz and comes from the module REFERENCE/STEP SYNTHESIS (REFSS). DCOD is also clocked by this signal. After DA converting and lowpassfiltering, the analog FM-Signal goes to the phase detector of the module SUM (SUMMING LOOP), where it is converted to the octave 750...1500MHz by a phase locked loop with a step recovery sampler. The bandwith of this loop is switched between 200kHz and 2MHz depending of the bandwith of the digital modulation.
On DSYN its possible to lead the FM signal via a so called BUFFER LOOP, to filter nonharmonic spurious from the DDS. In cw mode, the bandwith is switched to 1kHz. In case of 4FSK and FFSK

modulation, the bandwith is 100kHz. For all other dig. modulations, the loop is switched off.

After the N divider on SUM, the frequency varies from 93.7 to 1500MHz. The output level and the AM is then controlled by the AM loop on OPU, which has a bandwith of about 500kHz.

1.3 Measurements to test, if the SME meets the data sheet

The table on page 10 gives an overview on all the important measurements.
The measurement of the clock frequency at the plug CLOCK, spectral measurements, deviation meas., phase and vector error measurements are described in the service manual. Additional measurement methodes are described in the following section.

Page 11 and 12 of the paper showes typical spectral maesurements and eye patterns for GFSK and DQPSK modulation. For DQPSK the raised cosinus filter (not the default square root raised cosinus filter) is activated to simulate the receiver filter, so the points of intersection are focused.

2 Measurements, which are not described in the service manual

2.1 The constellation diagram (ger.: Zustandsdiagramm)

Appendix 2 shows the measurement assembly with the iq demodulator module MIQA-10D from MINI CIRCUITS (MCL). Appendix 3 showes the data sheet of this module. Cause the SME has no coherent carrier output like the SMHU.58 (unmodulated carrier with the same frequency like the modulated carrier), the 10MHz reference signal is used and the carrier frequency is set to 10MHz. The i and q lowpass filters with 1MHz 3dB frequency remove the summing products at 20MHz. The bandwith of the DQPSK modulation for the standards ADC and JDC is about 24kHz so this signals pass the lowpass filters without distortion.

The constellation diagram allows a qualitative test of the vector error of DQPSK modulation, which should be <2.5%RMS according to the SME data sheet. The exact measurement, described in the service manual, is possible with the HP-70000-System, which is expensive and often not present.
According to the EIA Document IS-54, the vector error is the RMS (radian mean square) value of the differnce between the measured "constellation point" and the demanded constellation point (eight points on a circle with 45° offset) in the sampling times related to the amplitude of the carrier when the modulation is switched off. One has to average over 162 symbols of one slot. A constant amplitude , i ,q , phase and frequency offset is allowed and should be substracted.

To make a qualitative test of the vector error with the oscilloscoped constellation. diagr., one should set the SME as follows:

+ DIG MOD - DQPSK - SOURCE - DATA
- FILTER/ROLL OFF - COS/0.35

+ Edit with the LIST EDITOR a 324 Bit long pseudorandom data sequence.

+ Set the carrier frequ. to 10MHz + 5.9Hz (frequency offset caused by calculation errors of the digital signal processing).

One should see a standing picture like that on page 12 of the paper.
The curve should go through eight points on a circle with a phase difference of 45°. A constant phase offset is possible, cause the phase between modulated signal and coherent carrier is not defined. This eight points should be close focused. The thickness of the points is a qualitative estimate of the RMS vector error.

If a pseudorandom sequence is used, which is longer than 324 Bit, for example the internal 9 Bit PRBS Sequence, one will see a jitter in the phase. The jitter is rising with the length of the sequence and is caused by accumulated frequency errors of the dig. sign. proc.

If the picture is rotating around the zero point, there is a frequency error, which should be about -5.9Hz, when the frequ. is set to exact 10MHz.

If the eight points on the scope are not focused, the vector error is increased and that can have following causes:

+ the filter is not set to COS (nyquist filter) but to the default filter SQR COS.

+ The DQPSK calibration (Delay between FM and AM path) is not correct. To correct the calibration, set the SME to UTILITIES - CALIB - DQPSK - CLIBRATION DATA and adjust the time, until the spektrum in the neighbour channels (+-30kHz) is symmetrically (see page 12 of the paper).
An other criteri to adjust the time is the constelation diagram with the data sequence "0111" (+-135°-sequence). The curve should run on a line, when the calibration is correct. Otherwise it runs on a eight formed line like in the picture on page 13 of the paper (1.5us deviation from the optimal value).
Note, that the optimal delay can change with the carrier frequency. To adjust the delay with the above methode at the frequency around 850MHz for the standards ADC and JDC, it is necessary to mix down the modulated signal (RF signal) from 850MHz to 10MHz bye a mixer.

+ The bandwith of the AM loop isn't set to AUTO or 500kHz.

+ Bad frequency characteristic of the SUMMINGLOOP PLL or the AM loop.

+ Defect in the ALIASING FILTER on the module DSYN.

2.2 Eye pattern (ger.: Augendiagramm)

For all FSK Modulations (GMSK, GFSK, 4FSK ...), one gets the eye pattern by FM demodulating the RF signal and measuring by a oscilloscope, which is triggered by the CLOCK signal of the digital data signal (output CLOCK). On page 6 of the paper you find the eye pattern of 4FSK Modulation for example.
In the eye pattern all possible state transitions of the for states (levels) are visible.
The eye pattern of GMSK and GFSK have only two states and are plotted on page 5 and 11 of the paper.
The 3db bandwidth of the demodulator must be 3MHz/1MHz/20kHz for GFSK/GMSK/4FSK modulation. So its only possible to measure 4FSK with the FMB, whose bandwidth is limited to 100kHz.

For DQPSK modulation one gets the two eye patterns by ocilloscoping the i and the q signal, triggering with the CLOCK signal (page 8 of the paper). You will find five states per eye pattern and focused points of intersection, when the nyquist filter COS/0.35 is switched on.

If the points of intersection are not focused, or if one can see overschooting in the eye pattern, then the frequency characteristic of the SUMMINGLOOP PLL isnt't correct.
(for example groupdelay distortion, which isn't visible in the spectrum).

For GFSK modulation, an error in the pattern of 20kHz/288kHz=7% is allowed.
The allowed error for GMSK modulation is defined as a phase error of <3°peak, which cannot be estimated by the eye pattern. The exact error can be measured by the radio communication tester CMTA94 like described in the service manual or with the HP-70000-system.

2.3 Test of all the different standards by the Modulationanalyser FMB

With the modulation analyzer FMB it's possible to test all the different standards rawly but quick and to test whether the correct baseband filter in the eproms is switched on.

The newly implemented standards CT2, CT3, CDPD, MC9 and MOBITEX 1200 (REV >2) are also listed.

Settings:

- Basic settings of the SME: FREQUENCY 900MHz, LEVEL 0dBm, DIGITAL MOD, GFSK, SOURCE DATA, DIFF ENCODER OFF

- Insert N times "1" and N times "0" by the list editor. N is listed in the following table (for example when N=4, "11110000" is to edit).

- Further settings of the SME and the FMB LP filter setting is listed below. The FMB HP filter is to set to 10Hz. DIFF ENCODER should be set to OFF, after every change of the standard at the SME.

- The FM peak deviations in the table should be measured. The difference to the nominal deviation comes from overschooting of the FMB LP filter.

- For DQPSK modulation the data pattern "0111" is to use (+-135°-sequence). After selecting the standard TFTS, DIFF ENCODER should be set to ADC to get the +-135°-sequence.

SME-settings Modul./ SEL. STAND.	FMB bandw. in kHz	N	deviation in kHz +-3%	modulation frequ. in kHz +-1%
GFSK / DECT	100	32	352	18
GFSK / CT2	100	4	18.25	9
GFSK / USER BITRATE: 72kbps FIL./DEV: 0.5/202kHz	100	4	200.5	9
GFSK / CT3	100	20	195	16
GMSK / GSM	no Filter	4	67.7	33.85
GMSK / CDPD	100	4	4.9	2.4
GMSK / MC9	23	4	2	1
GMSK / MOBITEX-8000	23	4	2	1
FSK / CITYRUF-1200		Bitrate 270,83		0.6
FSK / POCSAC-2400		100 4 67,7 ? 76,8 ? 33,85		1.2
FSK / USER BITRATE: 20kbps HUB: 100kHz	1(	Diff. encoder	%	10
DQPSK / ADC	1(			12.15
DQPSK / JDC	100	0111	33.4	10.5
DQPSK/TFTS (D.E. ADC)	100	0111	34.6	11.05
DQPSK / TETRA	100	0111	28.6	9.0
4FSK / ERMES	100	0111	1.64	1.5625

- To test the AM modulation of DQPSK/ADC-modulation, insert with the list editor the data "0111" to get the +-135° sequence and set the FMB to AM demodulation and switch on the 100kHz LP Filter.

- The modulation index should be 50+-2% (nearly a sinewave signal) and the modulation frequency 24.3kHz.

2.4 Measurements at the outputs of the module DSYN

With the carrier frequency set to 1350.2MHz, the freqency at the output FDDS (X89) is 14.351MHz. The level at FDDS should be 1.5dBm+-1.5dB.

For all FSK modulations, the spectrum at FDDS should be nearly identical with the spectrum at the RF output for offset frequencies below 2MHz (+-1dB deviation between the two outputs).

For DQPSK/ADC modulation with AM-modulation, the spectrum at FDDS is for offset frequencies greater 12.15kHz different to the RF output, because the AM-modulation does not exist there. The spectrum must look like the plot in appendix 4, when PRBS sequence is on.

The AM signal comes via the output X80A.9 to the motherboard. With a load of 50Ohm (normal spectrum analysator), the spectrum must look like the plot in appendix 5, when the data sequence "0111" is sent.

appendix 1

(page 1 - 13)

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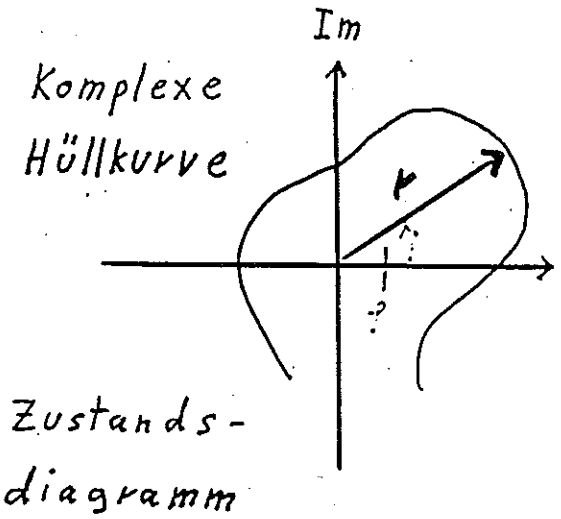
The Digital Modulation of the Signalgenerator SME

(1) Some basics about the various digital modulations.

(2) The modules DIGITAL SYNTHESIS and DM-CODER.

(3) Measurements to test, if the SME meets the data sheet.

Digitale Modulation allgemein :

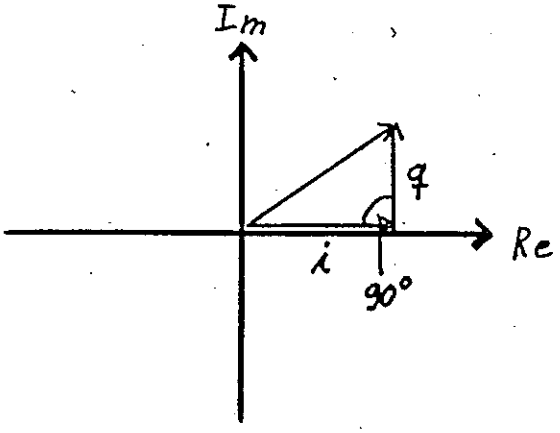


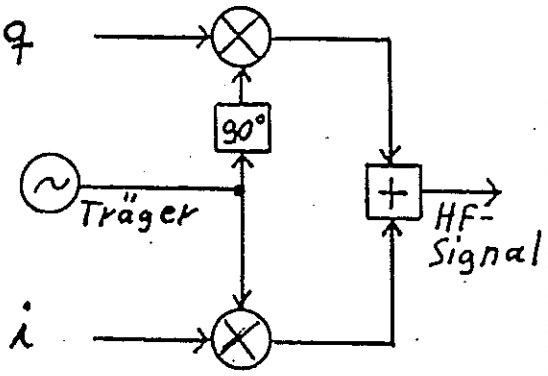
Amplitudenmodulation (AM)

Phasenmodulation (PM)

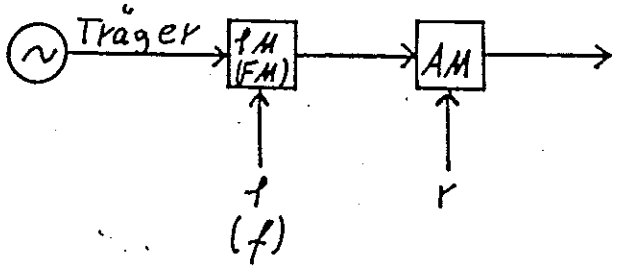
Frequenzmodulation (FM)

IQ-Modulator : SMHU.58





PM (FM) + AM : SME



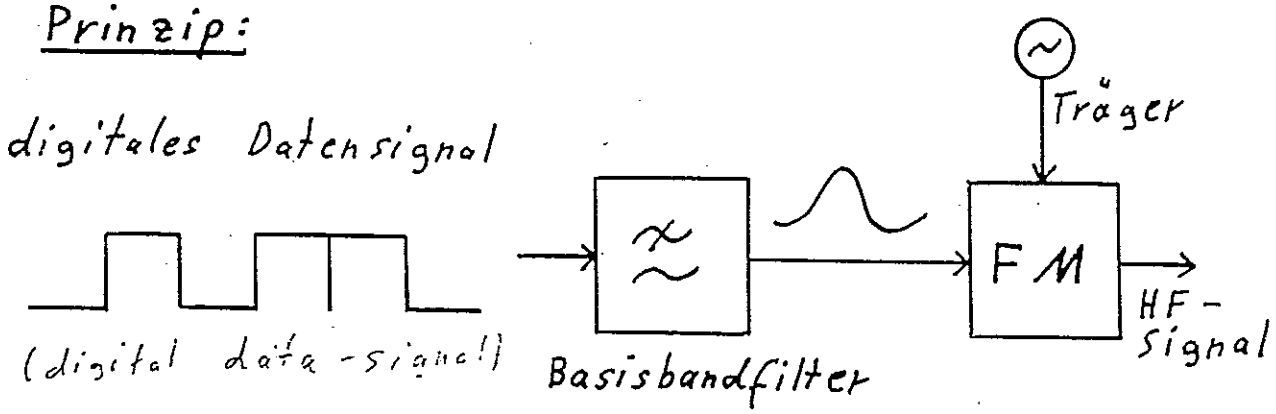
Modulationsarten beim SME:

- Gruppe der FSK-Modulationen
  (GMSK, GFSK, FSK)
  (Gaussian - Minimum / Frequency - Shift - keying)
- 4FSK (4-Level - Frequency-Shift-keying)
- FFSK (Fast - Frequency-Shift-keying)
- $\frac{\pi}{4}$-DQPSK ($\frac{\pi}{4}$ - Differential - Quadrature - Phase - Shift - keying)

Gruppe der FSK-Modulationen:

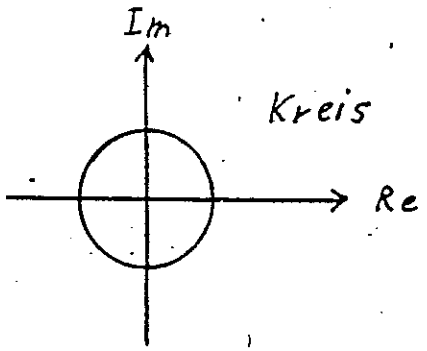
(GMSK, GFSK, FSK)

Prinzip:



Zustandsdiagramm:

(constellation-diagram)



Netze:

(standards)

GSM, DCS 1800, DECT, POCSAC

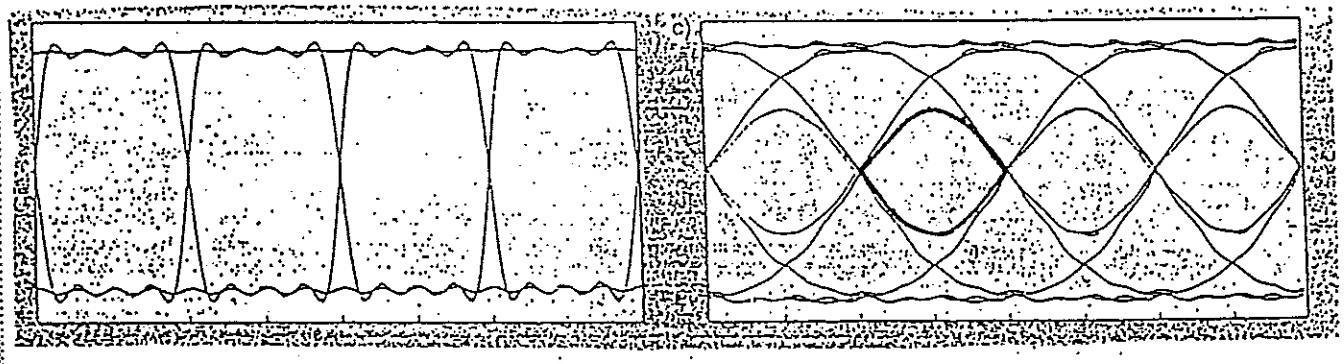
Basisbandfilter:

Gauß – Tiefpaß

Augendiagramm:
(eye-pattern)

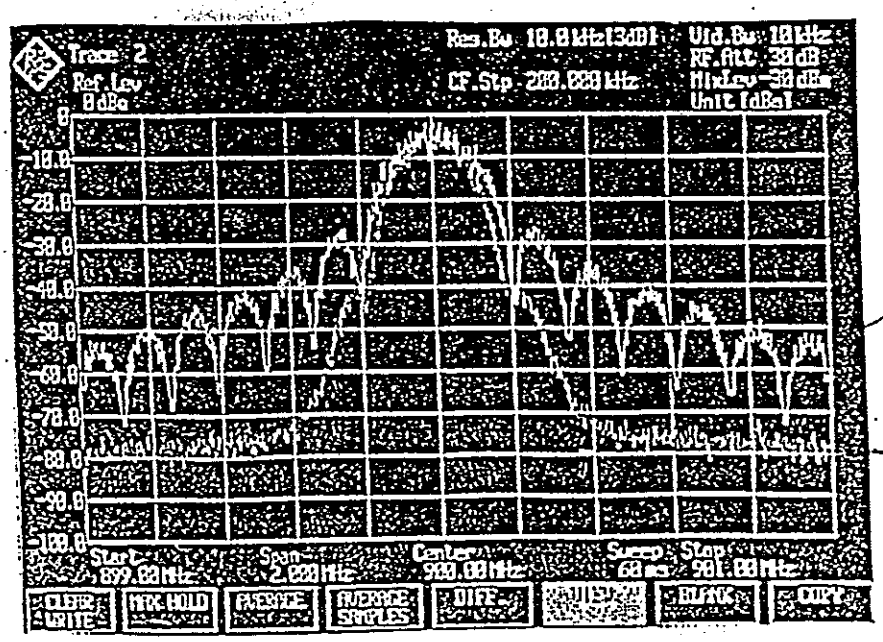
MSK

GMSK , BT = 0,3



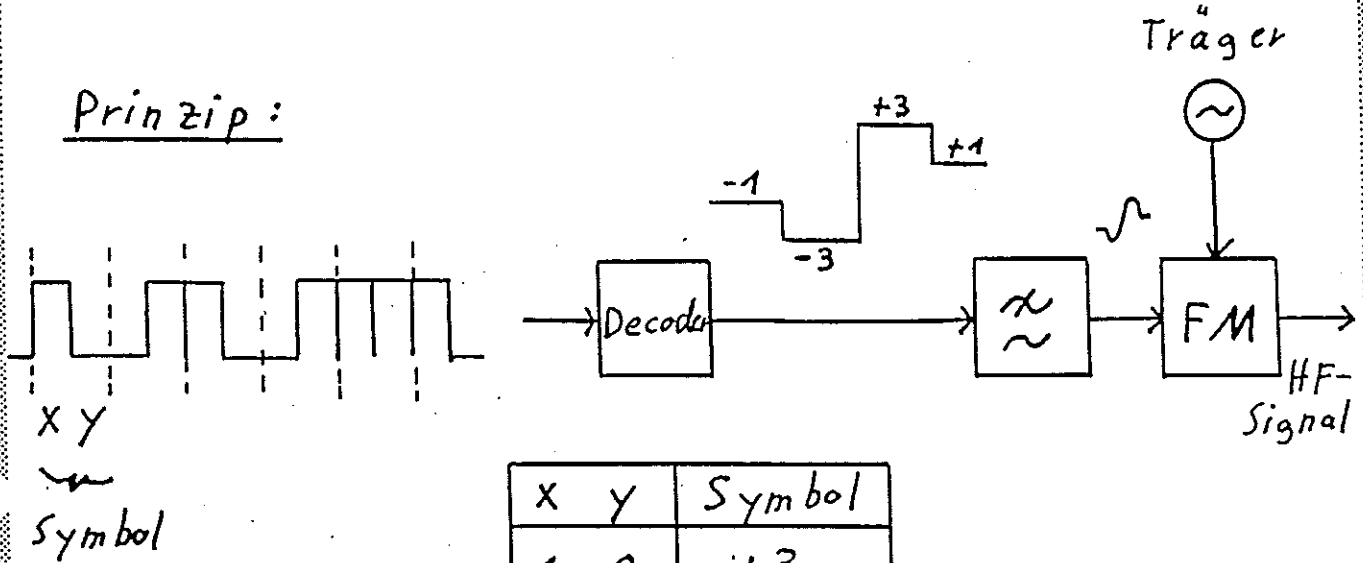
Auge geöffnet

HF-Spektrum:



4FSK:

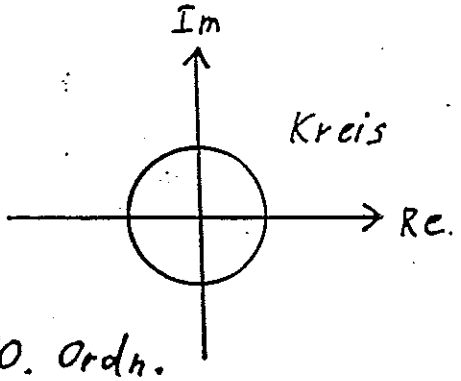
Prinzip:



x	y	Symbol
1	0	+3
1	1	+1
0	1	-1
0	0	-3

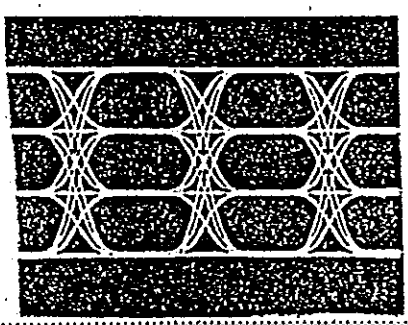
Netze: ERMES

Zustandsdiagramm:



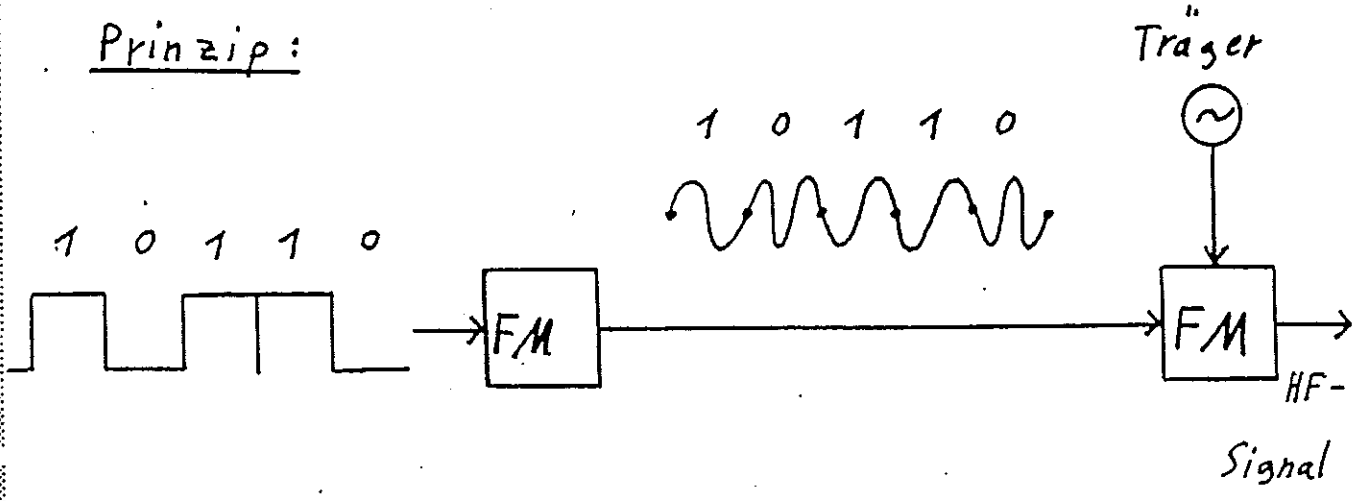
Basisbandfilter: Bessel-Tiefpaß 10. Ordn.

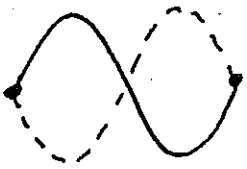
Augendiagramm:



FFSK :

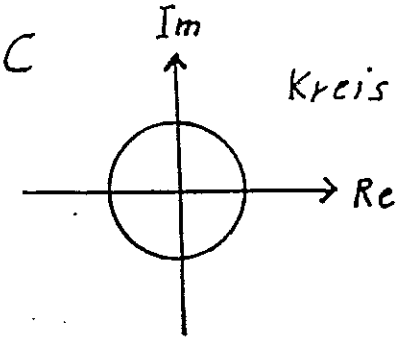
Prinzip :



0		1800 Hz $1\frac{1}{2}$ Perioden
1		1200 Hz 1 Periode

Netze : CITYRUF, POCSAC

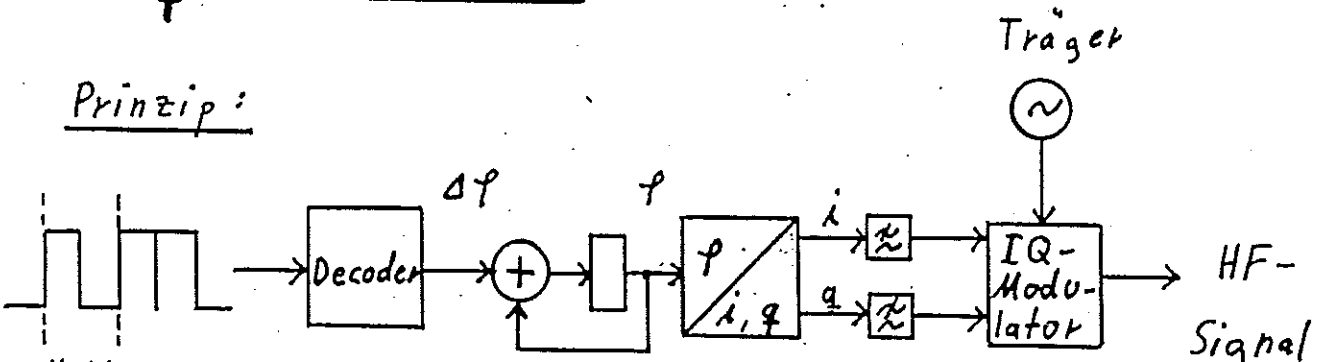
Zustandsdiagramm :

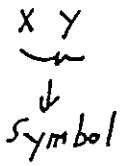


Basisbandfilter : keines

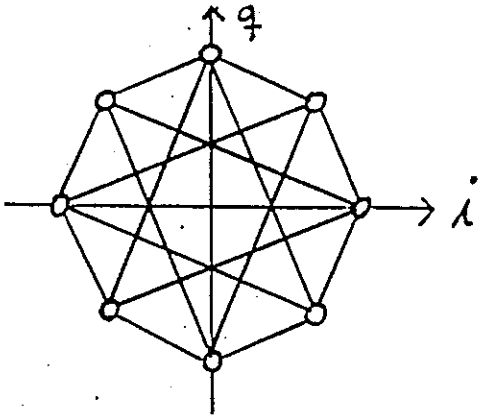
$\frac{\pi}{4}$ - DQPSK

Prinzip:





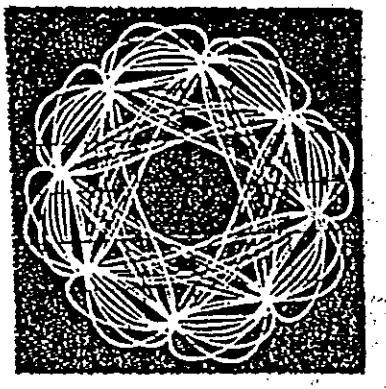
XY	Δφ
0 0	45°
0 1	135°
1 0	-45°
1 1	-135°



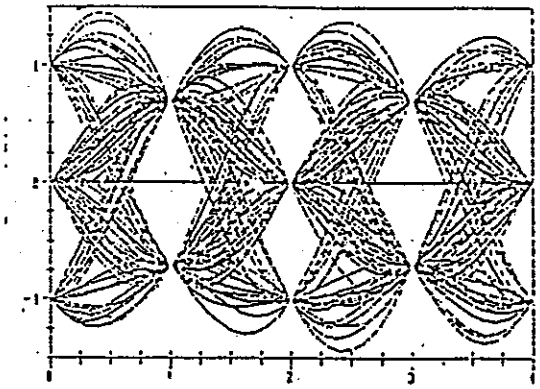
Netze: ADC, JDC, TFTS, TETRA

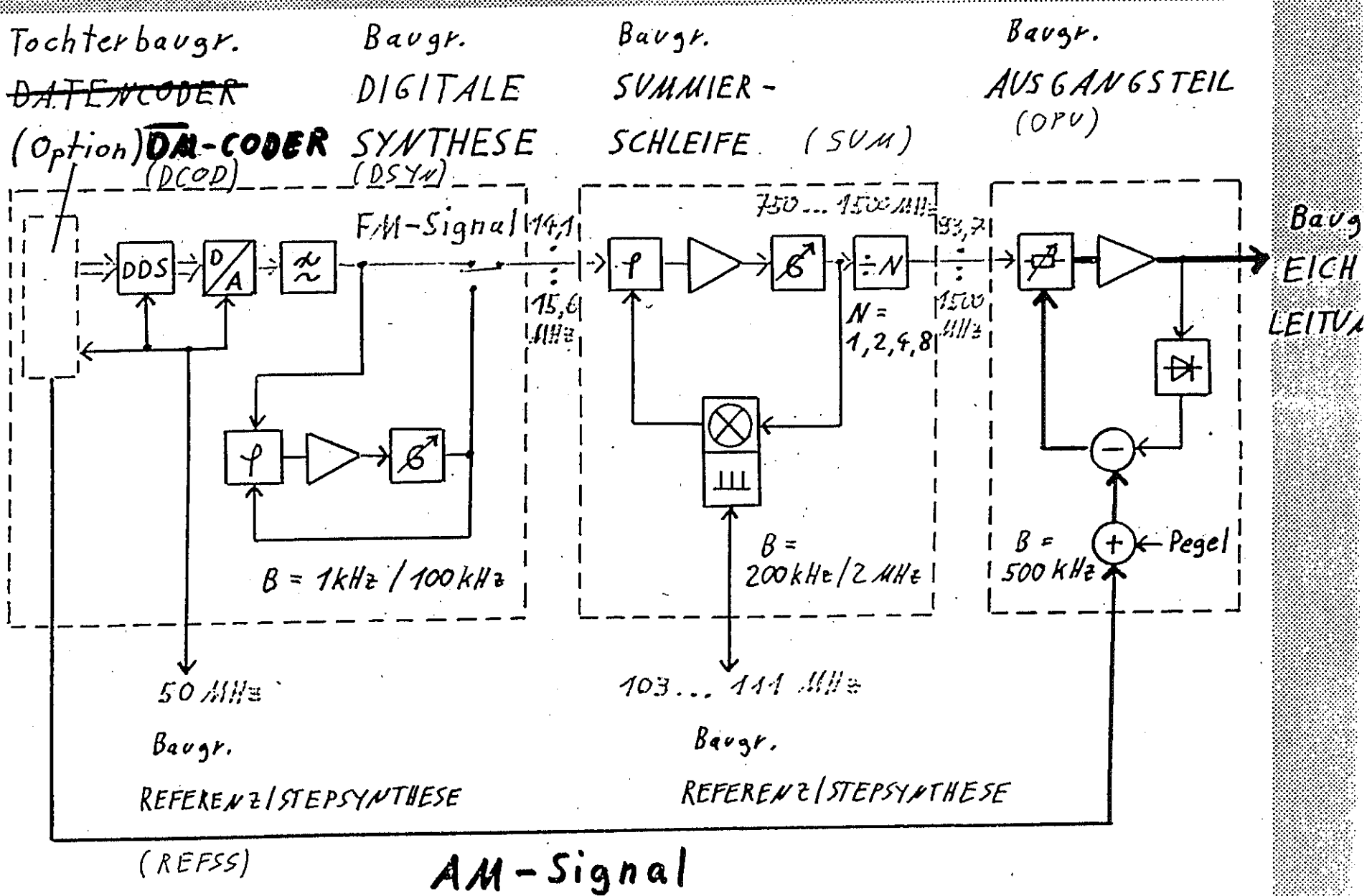
Basisbandfilter: Raised Cosinus

Zustandsdiagramm:



Augendiagramm:

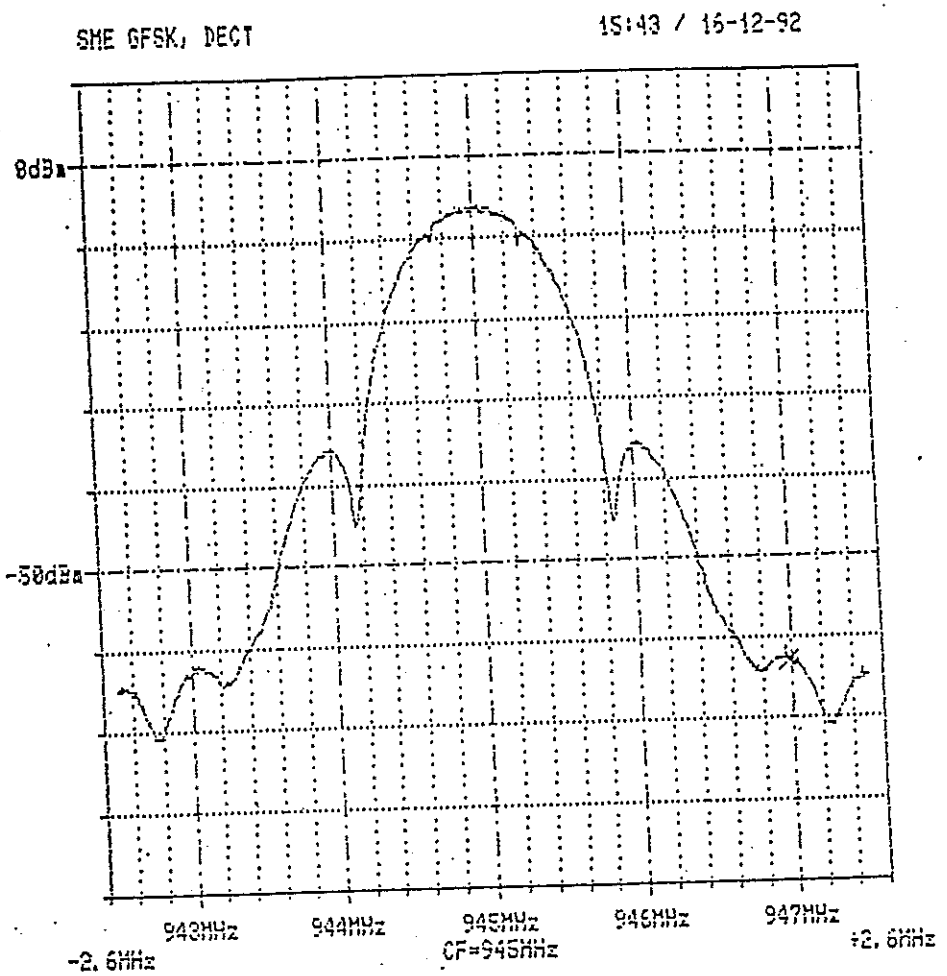



Tochterbaugr.
DATENCODER
(Option) DM-CODER
(DCOD)
Baugr.
DIGITALE
SYNTHESE
(DSYN)
Baugr.
SUMMIER-
SCHLEIFE (SUM)
Baugr.
AUSGANGSTEIL
(OPU)
DDS
D/A
FM-Signal
14,1
15,6 MHz
750 ... 1500 MHz
93,7
1500 MHz
N = 1,2,4,8
B = 1kHz / 100kHz
B = 200kHz/2MHz
B = 500 kHz
Pegel
50 MHz
Baugr.
REFERENZ/STEPSYNTHESE
(REFSS)
103 ... 111 MHz
Baugr.
REFERENZ/STEPSYNTHESE
AM-Signal

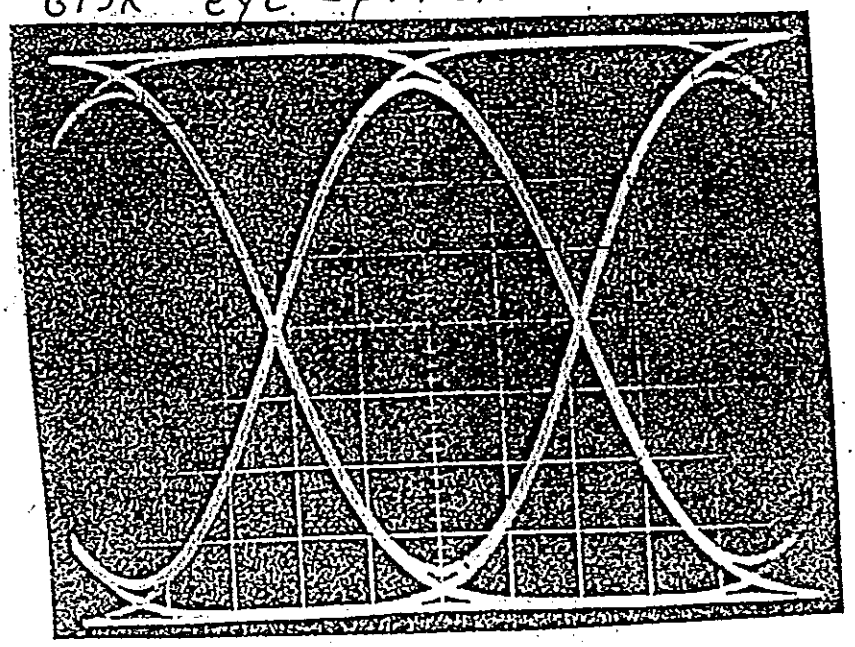
③ Measurements to test, if the SME meets the data sheet.

modulation	measurement	measurement device
all	clock frequency (CLOCK-output)	frequency-counter
all	spectrum	spectrum-analysator
GMSK	phase error	CMTA 94, HP 70 000
GFSK	eye-pattern	fm demodulator, scope (≈ 3 MHz band with) Folie
DQPSK	vector error constellation-diagram eye-pattern	HP 70 000 iq-demodulator, scope Folie iq-demod., scope
FSK, 4FSK	peak deviation eye-pattern	modulation-analysator fm demod., scope
FFSK	peak deviation identification-frequencies	modulation-analys. modulation-analys.

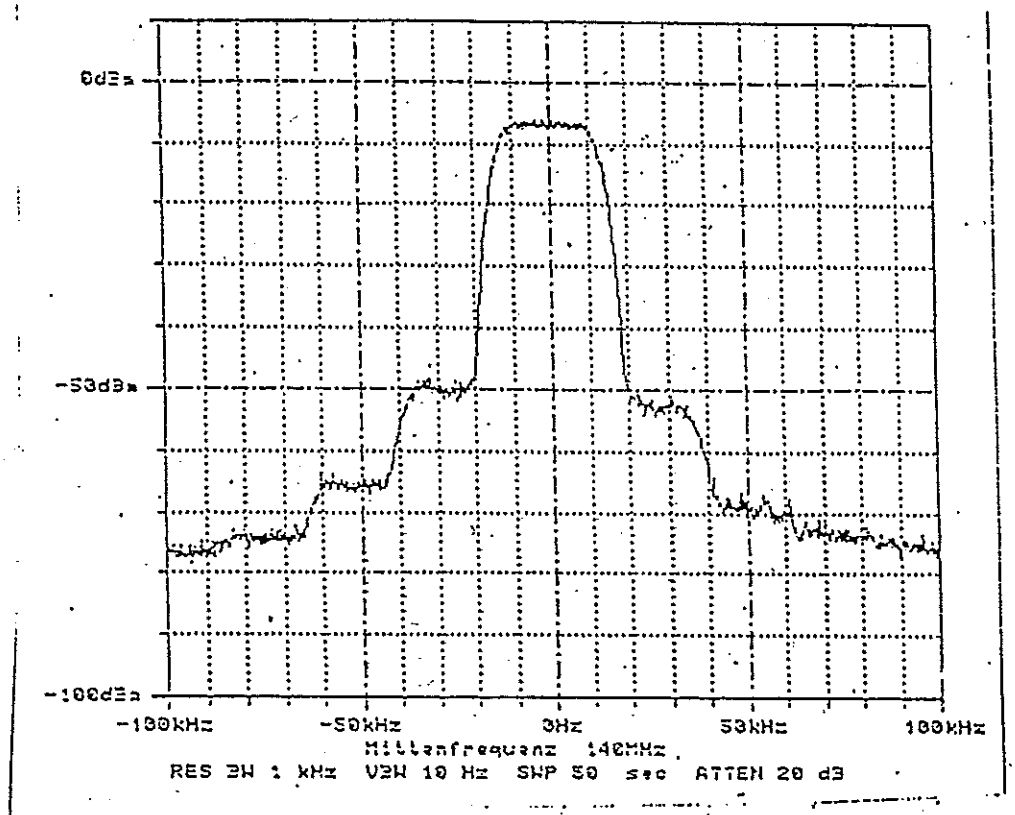
GFSK - spectrum



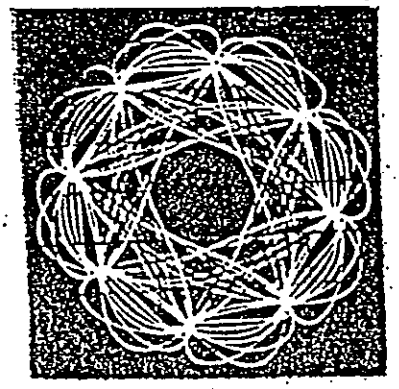
GFSK eye-pattern



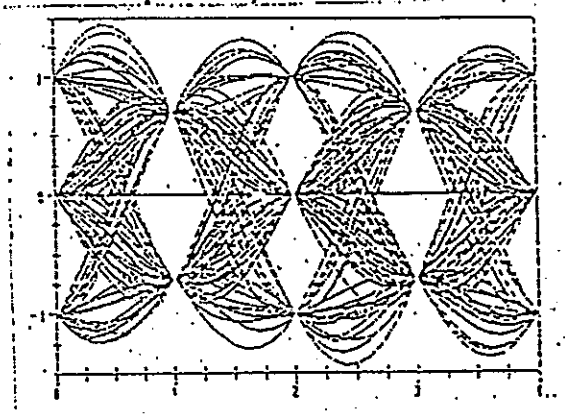
$\frac{\pi}{4}$-DQPSK - spectrum



constellation - diagram



eye - pattern



cos - Filter