VOR/ILS Testing with Signal Generator SMT

Application Note 1GPAN09E

H.-G. Titze 06.94

Products:

Signal Generator SMT

ROHDE&SCHWARZ

This application note describes the capabilities of the Signal Generator SMT for testing VOR/ILS air navigation receivers. To be able to generate air navigation waveforms the SMT has to be equipped with option **Multifunction Generator SM-B6** as an internal modulation source.

Thanks to the use of modern state of the art signal processor techniques and its optimized AM performance the Signal Generator SMT provides VOR/ILS signals with highest precision and reliability.

The sophisticated menu concept of the SMT allows for even complex settings to be easy to control.

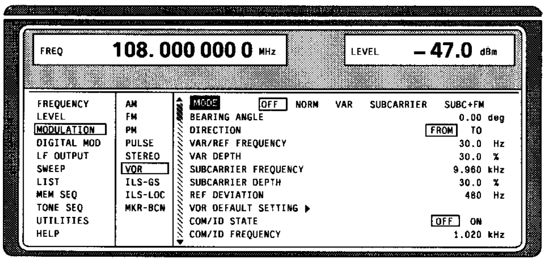

Fig. 1: Operating Menu of SMT

The versatile way of varying all test parameters allows fast functional testing as well as in depth analysis by simply recalling preset standard settings according to ARINC 578 and 579.

The large LC graphics display makes it possible to display all important parameters on one screen making the operation of the SMT simple and clear.

This application note is part of a series of three application notes on air navigation receiver testing with the Signal Generator SMT.

The use of the SMT as a test source for air navigation receiver tests is described in detail in the following two appliction notes:

VOR Receiver Tests using the Signal Generator SMT (Application Note 1GPAN10E)
and
ILS Receiver Tests using the Signal Generator SMT (Application Note 1GPAN11E).

System Basics

VOR Navigation

The VOR (VHF Omnidirectional Radiorange) System consisting of many strategically located transmitter stations supports air traffic with directional information. By demodulating the signal of a VOR transmitter station the VOR receiver on board an aircraft is able to provide bearing information relative to the transmitter station. By receiving two or more VOR stations the pilots can determine their exact location by triangulation.

The directional information is derived by comparing the phase between a 30 Hz reference signal and a 30 Hz variable phase signal.

The 30 Hz reference signal is placed on a 9960 Hz subcarrier using frequency modulation with a peak deviation of 480 Hz. The frequency modulated subcarrier is amplitude modulated on the VOR carrier. The variable phase signal is directly amplitude modulated on the VOR carrier. The amplitude modulation of the variable phase signal is generated by a special antenna array which produces a rotating cardioid shaped antenna pattern rotating at a 30 Hz rate.

Due to this rotation the phase between both 30 Hz signals is proportional to the bearing of the transmitter.

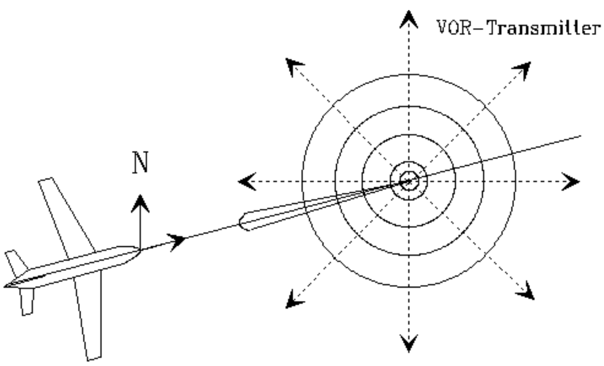

Fig. 2: Principle of the VOR-System

In addition to the VOR multiplex signal a three letter Morse coded signal of 1020Hz is placed on the carrier to identify the transmitting station.

The VOR carrier frequencies are located in the 108 MHz to 118 MHz band.

Table 1 shows the VOR carrier frequencies in use.

VOR carrier frequencies (MHz)				
108.00	111.20	113.20	114.80	116.40
108.05	111.25	113.25	114.85	116.45
108.20	111.40	113.30	114.90	116.50
108.25	111.45	113.35	114.95	116.55
108.40	111.60	113.40	115.00	116.60
108.45	111.65	113.45	115.05	116.65
108.60	111.80	113.50	115.10	116.70
108.65	111.85	113.55	115.15	116.75
108.80	112.00	113.60	115.20	116.80
108.85	112.05	113.65	115.25	116.85
109.00	112.10	113.70	115.30	116.90
109.05	112.15	113.75	115.35	116.95
109.20	112.20	113.80	115.40	117.00
109.25	112.25	113.85	115.45	114.05
109.40	112.30	113.90	115.50	117.10
109.45	112.35	113.95	115.55	117.15
109.60	112.40	114.00	115.60	117.20
109.65	112.45	114.05	115.65	117.25
109.80	112.50	114.10	115.70	117.30
109.85	112.55	114.15	115.75	117.35
110.00	112.60	114.20	115.80	117.40
110.05	112.65	114.25	115.85	117.45
110.20	112.70	114.30	115.90	117.50
110.25	112.75	114.35	115.95	117.55
110.40	112.80	114.40	116.00	117.60
110.45	112.85	114.45	116.05	117.65
110.60	112.90	114.50	116.10	117.70
110.65	112.95	114.55	116.15	117.75
110.80	113.00	114.60	116.20	117.80
110.85	113.05	114.65	116.25	117.85
111.00	113.10	114.70	116.30	117.90
111.05	113.15	114.75	116.35	117.95

Table 1

SMT VOR performance

With option Multifunction Generator SM-B6 installed, the Signal Generator SMT becomes a high precision test source for VOR receivers.

In addition to the RF signal the VOR modulation signal is available at the LF output of the SMT.

Fig. 3 shows the VOR menu of the SMT.

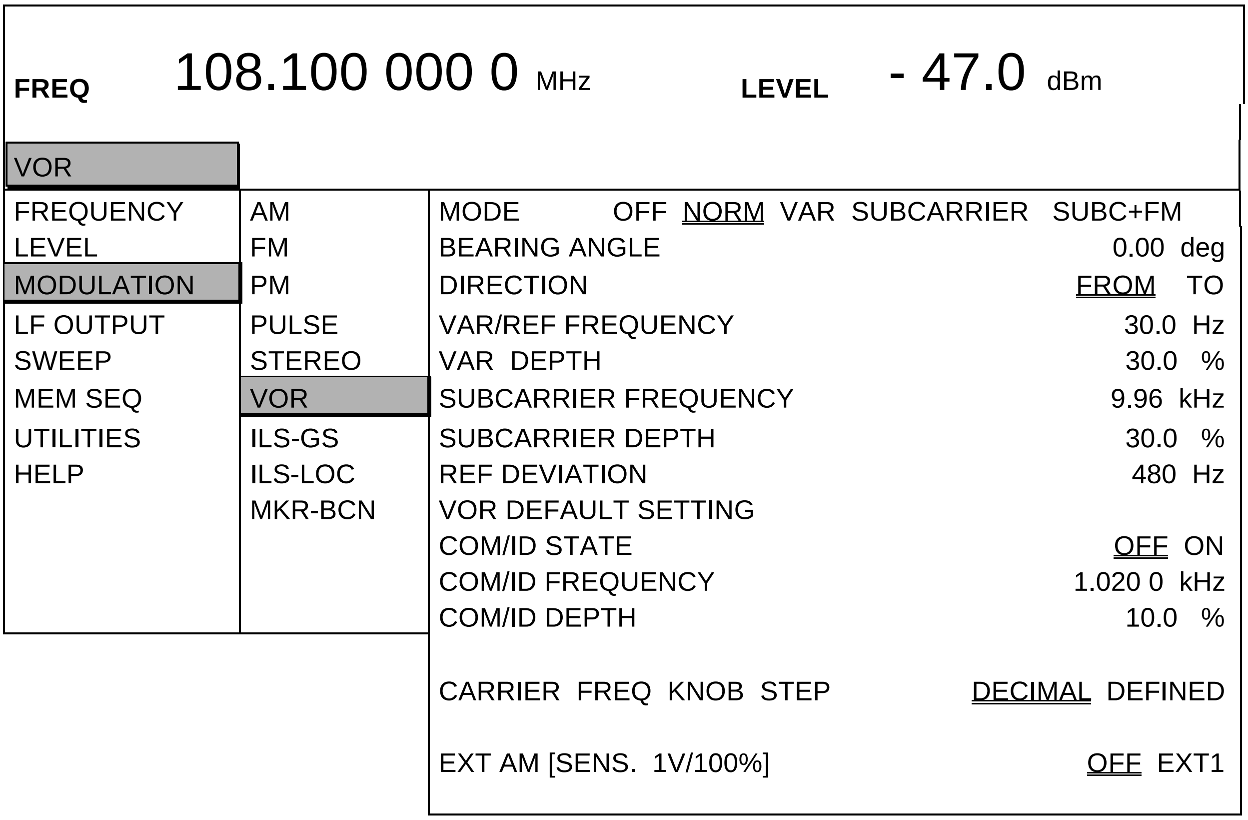

Fig. 3: VOR Menu

The VOR menu provides 4 VOR modes: NORM, VAR, SUBCARRIER and SUBC + FM.

In the NORM mode the SMT generates a standard VOR signal with a default VOR bearing of zero degrees.

In order to test the VOR receiver's alarm system each component of the VOR multiplex signal can be suppressed by setting the VOR mode to VAR, SUBCARRIER or SUBC + FM.

The VOR menu allows all parameters to be varied with high resolution and accuracy.

The VOR bearing can be set with a resolution of 0.01°. The typical bearing error of the VOR signal is less than 0.05°.

By changing DIRECTION from TO to FROM the bearing can be inverted.

Using the DEFAULT SETTING function the VOR default settings can easily be restored at any time.

A voice or identity signal (COM/ID) with variable frequency can be added to the VOR modulation signal switching COM/ID STATE to ON.

By switching CARRIER FREQUENCY KNOB STEP to DEFINED, the internally stored VOR carrier frequencies are recalled by simply using the rotary encoder of the SMT.

Using the MEMORY SEQUENCE function of the SMT the COM/ID signal can be Morse coded to identify the transmission source. The application note "VOR Receiver Test using the Signal Generator SMT" gives an example how to program a Morse coded VOR identify signal.

Setting EXT AM to EXT1 enables an external AF-signal to be superimposed to the VOR modulation signal.

Below a summary of the the VOR data of the SMT signal generator is given.

VOR-Data Summary of SMT

VOR-Modes

NORM	VOR-Signal+ COM/ID-Tone
VAR	30 Hz-VAR-Tone
SUBCARRIER	9.96 kHz-carrier, unmodulated
SUBC+F	9.96 kHz-carrier, FM-modulated

Modulation tones

30 Hz (VAR/REF Frequency)

Range	20 ... 40 Hz
Resolution	0.1 Hz

9.96 kHz FM Subcarrier Frequency

Range	5 ... 15 kHz
Resolution	10 Hz
Ref Deviation (30Hz)	0 ... 960 Hz
Default setting	480 Hz
Resolution	1 Hz
Error	< 1 Hz

Bearing Angle

Default setting	0.00°
Range	0 ... 360°
Resolution	0.01°
Error	
Modulation signal	< 0.01°
RF-Signal	< 0.05°, typ. 0.01°

COM/ID-Ton

Default setting	1020 Hz
Range	0.1 Hz ... 20 kHz
Resolution	0.1 Hz

Distortion

30 Hz-VAR-Tone	< 0.1%
9.96 kHz-FM-Subcarrier	< 0.1%
COM/ID-Tone	< 0.1%

System Basics

ILS, Instrument Landing System

The ILS system was developed to assist aircraft in landing during periods of poor weather. It provides the pilot with information of the aircraft's position relative to the ideal landing course. The system consists of 5 different signals: the Localizer signal, the Glide Slope signal, the Outer, Middle and Inner Marker.

Localizer

The Localizer signal provides the pilot with information about the aircraft's horizontal deviation of the ideal landing course. The Localizer signal consists of two amplitude modulated carriers operating at the same frequency in the 108 MHz to 112 MHz range.

The modulation frequency is 90 Hz for one and 150 Hz for the other carrier frequency.Both tones are modulated with a AM depth of 20 %.

The carriers are radiated using a separate directional antenna system directed down the center of the runway.

The antennas are arranged in a way that the 90 Hz-modulated signal is dominant on the left side of the runway while the 150 Hz-modulated signal is dominant on the right side with an equal intensity zone of approximately 3 to 6 degrees in between.

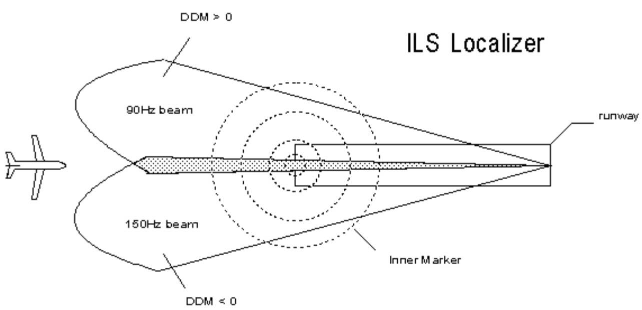

Fig. 4: ILS-Localizer Principle

By demodulating the received Localizer signal and evaluating the difference in depth of modulation (DDM) of the resulting 90 Hz and 150

Hz signals, the ILS-Receiver is able to provide the pilot with on course information.

In addition to the 90 Hz and 150 Hz navigation signals a three letter Morse code signal of 1020 Hz is placed on the Localizer beacon to identify the transmission source.

Glide Slope

The Glide Slope system provides the pilot with information about the aircraft's vertical deviation of the ideal approach to the runway. With the 90 Hz-modulated signal being stronger above the ideal course and the 150 Hz-modulated signal being stronger below the ideal course, the Glide Slope system provides the same type of information as the Localizer.

The Glide Slope system operates in the 329.9 MHz to 335 MHz band.

The AM modulation depth used is 40% for each tone. The Glide Slope signal does not contain voice or identity signals.

Localizer and Glide Slope carrier frequencies are used in pairs so that each Localizer carrier frequency has its corresponding Glide Slope counterpart (see Table 2).

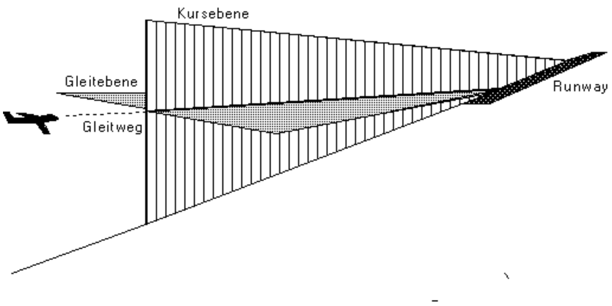

Fig. 5 Principles of the ILS-System

Localizer (MHz)	Glide Slope (MHz)	Localizer (MHz)	Glide Slope (MHz)
108.10	334.70	110.10	334.40
108.15	334.55	110.15	334.25
108.30	334.10	110.30	335.00
108.35	333.95	110.35	334.85
108.50	329.90	110.50	329.60
108.55	329.75	110.55	329.45
108.70	330.50	110.70	330.20
108.75	330.35	110.75	330.05
108.90	329.30	110.90	330.80
108.95	329.15	110.95	330.65
109.10	331.40	111.10	331.70
109.15	331.25	111.15	331.55
109.30	332.00	111.30	332.30
109.35	331.85	111.35	332.15
109.50	332.60	111.50	332.90
109.55	332.45	111.55	332.75
109.70	333.20	111.70	333.50
109.75	333.05	111.75	333.35
109.90	333.80	111.90	331.10
109.95	333.65	111.95	330.95

Table 2: ILS-Localizer and corresponding Glide Slope-carrier frequencies (MHz).

SMT ILS performance

With option SM-B6 installed the SMT is able to generated precise ILS signals. In addition to the RF-signal the ILS-modulation signal is available at the LF output of the signal generator.

Fig. 6 shows the ILS-LOC-menu of the SMT.

FREQ	108.100 000 0 MHz	LEVEL	- 47.0 dBm
VOR			
FREQUENCY	AM	MODE	OFF NORM 90Hz 150Hz
LEVEL	FM	DDM	0.000 0
MODULATION	PM	DDM	0.00 µA
LF OUTPUT	STEREO	DDM	0.0 dB
SWEEP	VOR	FLY	LEFT RIGHT
MEM SEQ	ILS-GS	SUM OF DEPTH	40.0 %
UTILITIES	ILS-LOC	LEFT FREQUENCY	90.0 Hz
HELP	MKR-BCN	RIGHT FREQUENCY	150.0 Hz
		LEFT/RIGHT PHASE	0.0 deg
		ILS DEFAULT SETTING	
		COM/ID STATE	OFF ON
		COM/ID FREQUENCY	1.020 kHz
		COM/ID DEPTH	10.0 %
		DDM KNOB STEP	DECIMAL DEFINED
		CARRIER FREQ KNOB STEP	DECIMAL DEFINED
		EXT AM [SENS. 1V/100%]	OFF EXT1

Fig. 6 ILS-LOC-menu of the SMT

In the NORM mode the SMT generates a standard ILS-Localizer signal.

To test the ILS receivers' alarm system the 90 Hz and 150 Hz modes provide an easy way to suppress one of the ILS modulation tones without having to vary the DDM setting.

The menu allows all ILS parameters to be varied with high resolution and accuracy.

Fig. 6 shows the parameters' default settings. Using the DEFAULT SETTING function this setting can easily be restored at any time.

DDM is defined as the Difference in Depth of Modulation of the 90 Hz and the 150 Hz signal:

DDM = [AM(90 Hz) - AM(150 Hz)] / 100%

Positive DDM values indicate a course deviation to the left (up for Glide Slope), negative values to the right (down) of the ideal landing course.

The SMT provides three ways to enter a DDM setting: directly as numerical value according to the above formula, in dB or as equivalent current of the ILS indicator.

The DDM value can easily be inverted using the FLY parameter.

By changing the FLY parameter from LEFT to RIGHT the DDM signage is automatically adjusted from negative to positive values.

Changing DDM VAR STEP from DECIMAL to DEFINED allows the user to easily call up predefined standard DDM values using the generators rotary knob.

With CARRIER FREQUENCY KNOB STEP set to DEFINED, the carrier frequency can be changed to the next frequency in use by the ILS system in a similar way.

CARRIER KNOB STEP DEFINED also triggers an automatical adjustment to the corresponding carrier frequency when changing from Localizer to Glide Slope or vice versa.

SUM OF DEPTH allows a variation of both modulation signals without changing the DDM setting.
The AM depth of the ILS Localizer and Glide Slope is dependend on the Phase relation of the modulation signals.

The phase between the two signals can be set using the LEFT/RIGHT or UP/DOWN parameter.

A voice or identity signal (COM/ID) with variable frequency can be added to the ILS modulation signal by switching COM/ID STATE to ON. Using the MEMORY SEQUENCE function of the SMT the COM/ID signal can be Morse coded to simulate the identification the transmission source.

The application note **"ILS Receiver Tests Using the Signal Generator SMT (Application Note 1GPAN11E)"** gives an example of how to program a Morse coded ILS identify signal.

Setting EXT AM to EXT1 enables an external AF signal to be superimposed to the ILS modulation signal.

Below a summary of the ILS data of the SMT signal generator is given.

<u>ILS-Data Summary of the SMT.</u>

ILS-Modes ILS-LOC/ILS-GS

NORM	Localizer/Glide Slope-Signal + COM/ID-tone
90 Hz	suppression of 50 Hz-tone
150 Hz	suppression of 90 Hz-Tone

ILS-Modulation Tones *)

90 Hz-tone	
Range	60 ... 120 Hz
Resolution	0.3 Hz
150 Hz-tone	
Range	100 ... 200 Hz
Resolution	0.5 Hz
COM/ID-tone	
Range	0.1 Hz ... 15 kHz
Resolution	0.1 Hz

*) Changing the frequency of either tone results automatically in a proportional setting of the other tone providing a constant frequency relation of 3 to 5 between both frequencies.

Amplitude Modulation Data**)

Sum of depth (SOD) 90 Hz and 150 Hz tone	
Range	0 ... 100%
Resolution	0.1%
Error	typ < 0.5% of AM setting
Default AM settings	
Localizer	40%
Glide Slope	80%

**) The specified error ratings are valid in the RF frequency range of 108 MHz ... 118 MHz and 329 MHz ... 335 MHz, and for ATTENUATOR MODE AUTO

Differece in Depth of Modulation (DDM)

Localizer (ILS-LOC) und Glide Slope (ILS-GS)	
Range	0 ... +/- SOD
Resolution	0.0001
DDM-Error	
Modulation signal	< 0.005*DDM + 0.0002
RF Signal	< 0.01*DDM + 0.0004
DDM-Error at 0 DDM	
Modulation signal	< 0.0002, typ. 0.0001
RF Signal	< 0.0004, typ. 0.0001

Phase Setting 90 Hz / 150 Hz Signal *)**

Range	0 ... 120°
Resolution	0.01°
Error	
Modulationssignal	< 0.02°
HF-Signal	< 0.05°

***) The phase setting is defined in degrees of the 150Hz modulation signal. Reference is the zero crossing of the 150Hz signal.

<u>Marker Beacons</u>

The Marker Beacons indicate the distance of the aircraft relative to the threshold of the runway. All three markers operate at carrier frequencies in the range from 74.6 to 75.4 MHz. The carriers are transmitted through vertical antenna arrays which project a fan-shaped pattern.

The outer marker being located 5 miles from the runway is amplitude modulated with a 400Hz tone, the middle marker, 3500 feet from the runway, is modulated with a 1300Hz tone.For a normal landing, the aircraft should be at an altitude of 200 feet by the time the middle marker is reached.The inner marker modulated with a 3000Hz tone is situated at the threshold of the runway.The AM depth for all three marker beacons is 95 % .

To give additional aid to the pilot the modulation tones are pulsed on and off, so that the different colored marker lights of the ILS display are flashed when passing through a marker beacon. Table 3 shows the Marker Beacon frequencies used.

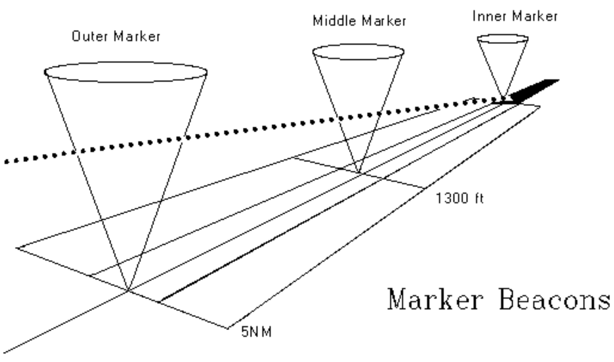

Fig. 7: Marker Beacons

74.600	74.775	74.950	75.125	75.300
74.625	74.800	74.975	75.150	75.325
74.650	74.825	75.000	75.175	75.350
74.675	74.850	75.025	75.200	75.375
74.700	74.875	75.050	75.225	75.400
74.725	74.900	75.075	75.250	
74.750	74.925	75.100	75.275	

Table 3: Marker Beacon Frequencies (MHz)

FREQ 75.000 000 0 MHz		LEVEL - 47.0 dBm	
MKR-BCN			
FREQUENCY	AM	MARKER BEACON STATE	OFF ON
LEVEL	FM		
MODULATION	PM	MARKER FREQ	400 1300 3000 Hz
LF OUTPUT	STEREO	MARKER DEPTH	95.0 %
SWEEP	VOR		
MEM SEQ	ILS-GS	COM/ID STATE	OFF ON
UTILITIES	ILS-LOC	COM/ID FREQUENCY	1.020 0 Hz
HELP	**MKR-BCN**	COM/ID DEPTH	5.0 %
		CARRIER FREQ KNOB STEP	DECIMAL DEFINED

Fig. 8: Marker Beacon Menu of the SMT

Literature:

Lüttich F.; Klier J.: Signal Source for Receiver and EMS Measurement up to 3 GHz SMT. News from Rohde & Schwarz (1993) Nr. 142, P. 13-15