PathWave Signal Generation (PWSG) for Avionics

Key features

- Generating VOR signal
- Generating ILS localizer signal
- Generating ILS glide slope signal
- Generating marker beacon signal
- Adjustable code identification (COM/ID) settings
- SCPI commands support

Introduction

PathWave Signal Generation for Avionics can create and customize signals for the aviation radio navigation test. Its touch-optimized GUI lets you easily manipulate a variety of signal parameters to simplify the signal generation for VHF Omnidirectional ranging (VOR) and instrument landing system (ILS) radio navigation receiver testing. You can generate VOR, ILS localizer and glide slope, and marker beacon signals and play the waveforms on Keysight vector signal generators. You can also use SCPI commands for remote control and test automation.

The application is enabled on M9484C VXG or N5186A MXG by required licenses:

- **N7641APPC PathWave Signal Generation for Avionics** is running as firmware inside M9484C VXG, firmware version A.15 or above
- **E7641APPC PathWave Signal Generation for Avionics** is running as firmware inside N5186A MXG, firmware version A.16 or above

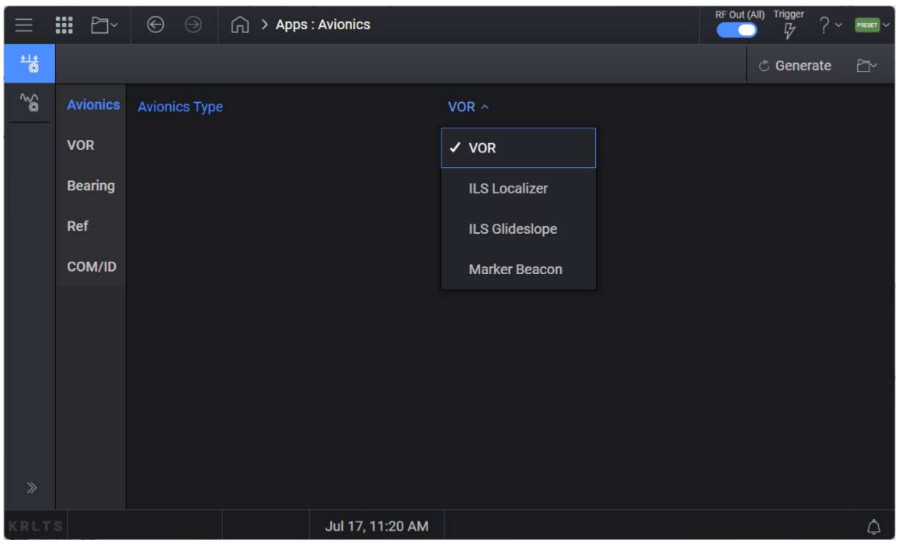

Figure 1. PathWave Signal Generation for Avionics user interface on M9484C VXG

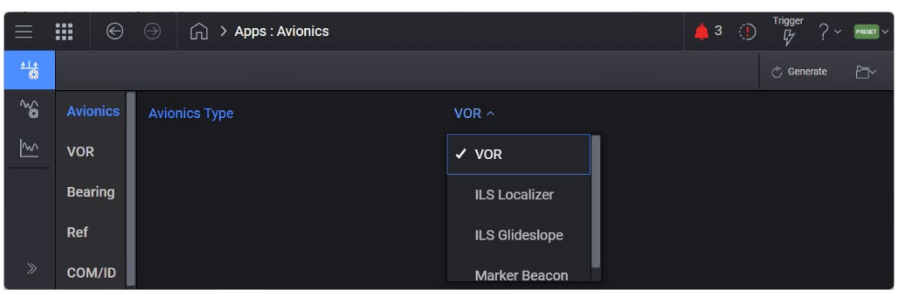

Figure 2. PathWave Signal Generation for Avionics user interface on N5186A MXG

Keysight supports tiered PathWave signal generation models with N-model applications (N7641APPC with prefix "N") for high-performance HW platforms: M9484C VXG, E-model applications (E7631APPC with prefix "E") for mid-range HW platform: N5186A MXG. Higher-tiered models can run on lower tiered HW platforms, but not vice versa. For example, N7641APPC can work on N5186A MXG, but E7641APPC cannot work on M9484C VXG.

Overview of VOR/ILS Navigation Signals

Aircraft navigation system uses Very High Frequency Omnidirectional Radio (VOR) signal to provide the aircraft directional information and uses Instrument Landing Systems (ILS) radio navigation signal to provide precision guidance to aircraft approaching and landing on a runway. VOR and ILS have excellent reliability, low cost and huge installed base, and so are still one of the most common technologies in helping navigate and land safely.

VOR signal

The purpose of the VOR system is to provide directional information for aircraft in flight. VOR transmitter stations are strategically located on the ground to provide complete coverage for air traffic.

The VOR signal is transmitted by VOR stations located on the ground, over the RF VOR carrier frequency from 108 to 118 MHz. The VOR signal transmitted by the station is modulated using two distinct parts: a reference signal and a variable phase signal. The first part is amplitude modulated (AM) onto a 9.960 kHz sub-carrier at a rate of 30 Hz and its phase is independent on the bearing angle between the receiver and VOR station. This signal is referred to as the reference signal. The second part is also modulated at 30 Hz. The phase of this second signal is adjusted such that the difference in phase relative to the reference signal corresponds to the compass bearing of the receiver to the VOR station.

The aircraft's VOR receiver demodulates the VOR signal comparing the phase difference between the two 30 Hz signals. This phase difference can then be used to determine the aircraft's compass bearing to the VOR station. An aircraft's position can be determined by observing multiple VOR stations and the compass bearing relative to the VOR stations.

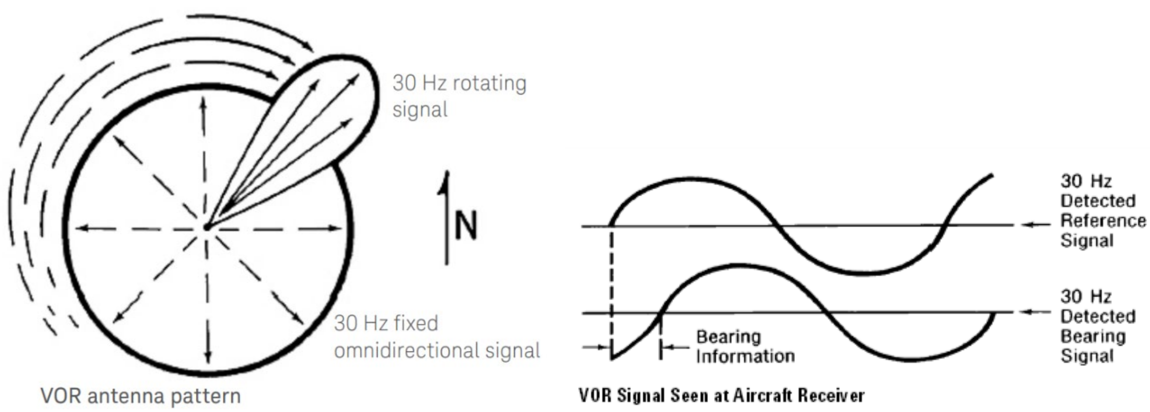

Figure 3. VOR antenna pattern and VOR signal seen at aircraft receiver

In practice, the 30 Hz reference signal is placed on a subcarrier of 9960 Hz using frequency modulation. The peak deviation is set to 480 Hz. This modulated subcarrier is then amplitude modulated onto the VOR carrier in the 108 to 118 MHz range. This makes the reference signal essentially an FM/AM multiplex signal. The variable phase signal is placed directly on the RF VOR carrier. The modulation and phasing of this signal are produced by a special antenna array which produces a cardioid-shaped antenna pattern which rotates at a 30 Hz rate. This special antenna produces a signal at the aircraft receiver which, in effect, is a 30 Hz amplitude modulated signal with a phase proportional to the bearing of the transmitter.

ILS radio navigation signal

The Instrument Landing System (ILS) radio navigation system provides a method of positioning an aircraft vertically and horizontally with respect to a runway during landing. These systems are especially important during situations where visibility to the runway may be impaired due to climate conditions.

A ground-based ILS system emits 4 directional beams arranged around the ideal flight path leading to the runway. One pair of beams, called “Localizer” (LOC), form a left/right pair. The left beam is modulated at 90 Hz, and the right at 150 Hz; however, both are on the same RF carrier frequency. They combine in the aircraft’s antenna/receiver, and the relative strength on the two beams tells the pilot if the plane is left or right from ideal. Likewise, another pairs of beams, called “Glideslope” (GS), form an up/down pair, and tell the pilot if the plane is coming in high or low vs ideal.

The LOC and GS signals are used to orient the aircraft horizontally and vertically, respective to the runway. There are also a set of beacons: the outer marker, middle marker, and inner marker, which provide visual and audible cockpit alerts to the pilot indicating the distance to the runway’s edge.

Localizer signal

The localizer signal is used to provide information to the pilot to align the aircraft horizontally with respect to the centerline of the runway. This system operates on carriers from 108 MHz to 112 MHz. The localizer system in an aircraft determines left, right, or on-center orientation of the craft with respect to the runway utilizing two directionally radiated fields that are each amplitude modulated at rates of 90 Hz and 150 Hz, illustrated in Figure 4. In addition to the two localizer signal amplitude modulations, an audio Voice/Identification signal is placed on top of the localizer carrier. This identification signal uses the baseband frequencies from 350 Hz to 2500 Hz.

The antenna arrays are arranged such that the 90 Hz is stronger than the 150 Hz signal on the left side of the runway. Correspondingly, on the right side of the runway the 150 Hz is stronger than the 90 Hz signal. There is a section of equal amplitude located in the center that is approximately 5° wide.

The left and right orientation of the aircraft is determined in a relatively straightforward manner by demodulating the received localizer signals and comparing the difference in the recovered amplitudes of the 90 Hz and 150 Hz tones. The difference in depth of modulation (DDM) is defined as the difference in the percentage of modulation depth of the stronger signal less the percentage modulation depth of the weaker signal, divided by 100.

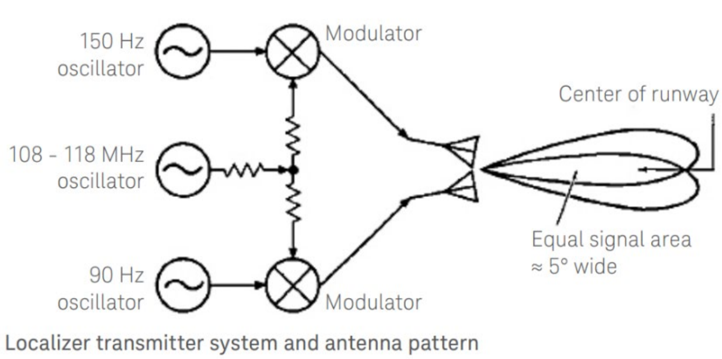

Figure 4. ILS Localizer Transmitter system block diagram and corresponding antenna pattern

Glide slope (GS) signal

The glide slope signal is comprised of two signals that are used to provide position information of the aircraft's vertical situation relative to the glide path for the runway. The glide slope signals utilize the same amplitude modulation scheme and an antenna arrangement that is similar to the localizer system, depicted in Figure 5. The difference between the two systems is that the glide slope system uses carrier frequencies ranging 329.9 MHz to 335 MHz. Additionally, no identification information is encoded on the glide slope carrier.

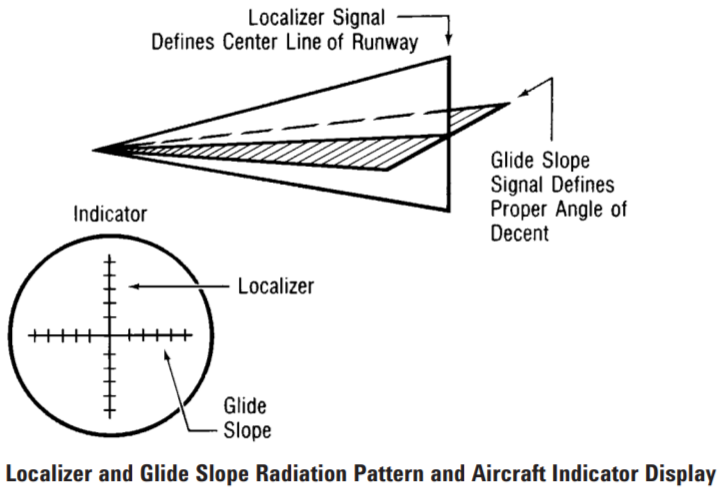

Figure 5. Localizer and glide slope radiation patter and aircraft indicator display

Marker beacon signal

In addition to the localizer and glide slope signals in the ILS system, which provide horizontal and vertical location information to the pilot to align with the runway, there is a set of three marker beacons. These three marker beacons are positioned at specific distances from the edge of the runway. As the aircraft crosses over the marker beacon the receiver in the craft provides visual and audible queues to the pilot. The pulsing of the visual annunciators on the aircraft panel is achieved by pulsing on and off of the beacon transmitters. In addition to visual indication an audible tone can be heard in the cockpit during times of receiver transit over the beacon. This audible tone is achieved by amplitude modulation, at a depth of 95%, of the marker beacon carrier.

All the marker beacons operate at a carrier frequency of 75 MHz and are transmitted by an antenna that is arranged such that the energy is emitted in a fan shaped pattern vertically. The outer marker is located at a distance of 5 miles from the edge of the runway. The outer marker amplitude modulation uses a tone at 400 Hz. The middle marker beacon is located approximately 3,500 feet from the edge of the runway. The middle marker beacon is modulated using a tone at 1300 Hz. The inner marker is located at the runway edge and is modulated with a tone at 3 kHz.

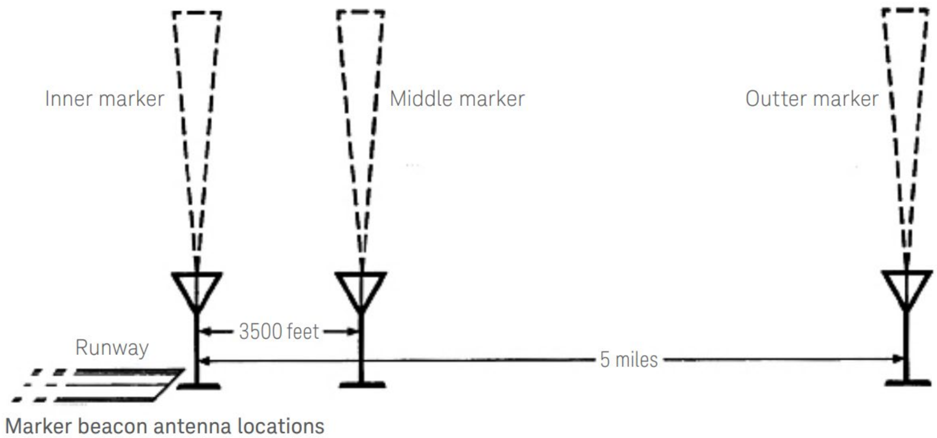

Figure 6. Marker Beacon locations and orientation

Radio Navigation Signal Generation

PathWave Signal Generation for Avionics support four types of avionics signal generation: VOR, ILS Localizer, ILS Glideslope and Marker Beacon signals. Its user-friendly interface lets you configure signal parameters, calculate the resulting waveforms, and play the signals on M9484C VXG or N5186A MXG vector signal generators.

Generating VOR test signals

The VOR signal is a composite signal consisting of a reference signal and a variable phase component which provides bearing information, both modulated on the VOR carrier.

The VOR carrier frequencies range from 108.00 MHz to 117.95 MHz and are selectable by changing the Carrier Frequency Index, listed in the Table 1. You can configurate the VOR signal to be one of the four modes:

- NORM: consisting of the VOR carrier with the reference signal component and the variable phase component
- VAR: consisting of the VOR carrier and the variable phase tone
- Sub-carrier: consisting of only the sub-carrier
- Sub-carrier+FM: consisting of the sub-carrier modulated with the reference tone

VOR Bearing Angle and Direction is adjustable to define the variation in phase for VOR systems. You can also adjust other signal parameters:

- REF/VAR Freq: adjusting the modulation frequency (default 30 Hz).
- Subcarrier Freq: adjusting the sub-carrier frequency (default 9960 Hz).
- VAR Depth: adjusting AM depth of the variable phase tone.

- REF Deviation: adjusting the FM deviation (default 480 Hz) that the reference tone causes on the subcarrier.
- Subcarrier Depth: adjusting the subcarrier AM depth as it modulates the VOR carrier.
- COM/ID Type: selecting Tone or Code to be played. You can change the relative frequency and AM depth of the COM/ID.

Table 1. VOR Carrier Frequency Index

Freq. Index	VOR Carrier Freq. (MHz)	Freq. Index	VOR Carrier Freq. (MHz)	Freq. Index	VOR Carrier Freq. (MHz)	Freq. Index	VOR Carrier Freq. (MHz)	Freq. Index	VOR Carrier Freq. (MHz)
1	108.00	33	111.20	65	113.20	97	114.80	129	116.40
2	108.05	34	111.25	66	113.25	98	114.85	130	116.45
3	108.20	35	111.40	67	113.30	99	114.90	131	116.50
4	108.25	36	111.45	68	113.35	100	114.95	132	116.55
5	108.40	37	111.60	69	113.40	101	115.00	133	116.60
6	108.45	38	111.65	70	113.45	102	115.05	134	116.65
7	108.60	39	111.80	71	113.50	103	115.10	135	116.70
8	108.65	40	111.85	72	113.55	104	115.15	136	116.75
9	108.80	41	112.00	73	113.60	105	115.20	137	116.80
10	108.85	42	112.05	74	113.65	106	115.25	138	116.85
11	109.00	43	112.10	75	113.70	107	115.30	139	116.90
12	109.05	44	112.15	76	113.75	108	115.35	140	116.95
13	109.20	45	112.20	77	113.80	109	115.40	141	117.00
14	109.25	46	112.25	78	113.85	110	115.45	142	117.05
15	109.40	47	112.30	79	113.90	111	115.50	143	117.10
16	109.45	48	112.35	80	113.95	112	115.55	144	117.15
17	109.60	49	112.40	81	114.00	113	115.60	145	117.20
18	109.65	50	112.45	82	114.05	114	115.65	146	117.25
19	109.80	51	112.50	83	114.10	115	115.70	147	117.30
20	109.85	52	112.55	84	114.15	116	115.75	148	117.35
21	110.00	53	112.60	85	114.20	117	115.80	149	117.40
22	110.05	54	112.65	86	114.25	118	115.85	150	117.45
23	110.20	55	112.70	87	114.30	119	115.90	151	117.50
24	110.25	56	112.75	88	114.35	120	115.95	152	117.55
25	110.40	57	112.80	89	114.40	121	116.00	153	117.60
26	110.45	58	112.85	90	114.45	122	116.05	154	117.65
27	110.60	59	112.90	91	114.50	123	116.10	155	117.70
28	110.65	60	112.95	92	114.55	124	116.15	156	117.75
29	110.80	61	113.00	93	114.60	125	116.20	157	117.80
30	110.85	62	113.05	94	114.65	126	116.25	158	117.85
31	111.00	63	113.10	95	114.70	127	116.30	159	117.90
32	111.05	64	113.15	96	114.75	128	116.35	160	117.95

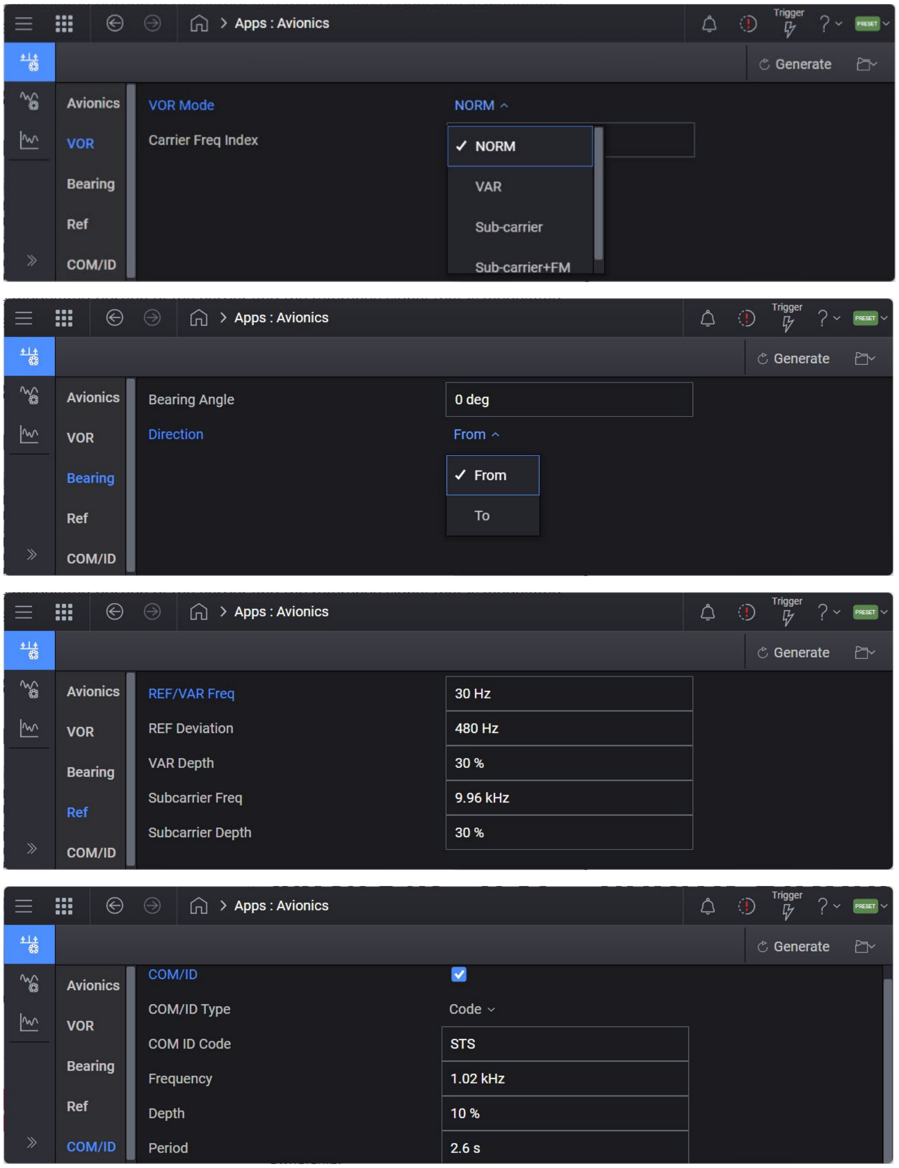

Figure 7. User interface for controlling VOR test signal generation parameters

Figure 8. VOR signal viewed using a N9040B UXA signal analyzer in the N9092EM0E Avionics measurement application

Generating ILS-LOC and ILS-GS test signals

A ground-based ILS system emits 4 directional beams arranged around the ideal flight path leading to the runway, a left/right pair as LOC signal, and an up/down pair as GS signal.

The LOC carrier frequencies are assigned between 108.1 MHz 111.95 MHz, while GS carrier frequencies are between 329.15 MHz and 335.0 MHz. The 90 Hz and 150 Hz modulation tones are modulated on to the LOC carrier or the GS carrier. The available LOC frequencies by frequency index are shown below in Table 2. Similarly, the GS carrier can be set to one of the standard carriers by carrier frequency index, listed in Table 3.

You can adjust the modulation frequency and phase. You can also turn off the signal from a direction, for example, by selecting Suppress Right to turn off the right signal, or, Suppress Up to turn off the up signal.

Difference in Depth of Modulation (DDM) of the 2 base tones can be translated into the deviations from the ideal landing path. The value of DDM uA is calculated as DDM*967.75 and the value of DDM percentage is calculated as DDM*100. You can configure DDM, SDM (sum of depth of modulation), and the setting of Fly which sets DDM polarity.

Table 2. ILS-LOC Carrier Frequency Index

Freq. Index	LOC Carrier Freq. (MHz)	Freq. Index	LOC Carrier Freq. (MHz)	Freq. Index	LOC Carrier Freq. (MHz)	Freq. Index	LOC Carrier Freq. (MHz)	Freq. Index	LOC Carrier Freq. (MHz)
1	108.10	9	108.90	17	109.70	25	110.50	33	111.30
2	108.15	10	108.95	18	109.75	26	110.55	34	111.35
3	108.30	11	109.10	19	109.90	27	110.70	35	111.50
4	108.35	12	109.15	20	109.95	28	110.75	36	111.55
5	108.50	13	109.30	21	110.10	29	110.90	37	111.70
6	108.55	14	109.35	22	110.15	30	110.95	38	111.75
7	108.70	15	109.50	23	110.30	31	111.10	39	111.90
8	108.75	16	109.55	24	110.35	32	111.15	40	111.95

Table 3. ILS-GS Carrier Frequency Index

Freq. Index	GS Carrier Freq. (MHz)	Freq. Index	GS Carrier Freq. (MHz)	Freq. Index	GS Carrier Freq. (MHz)	Freq. Index	GS Carrier Freq. (MHz)	Freq. Index	GS Carrier Freq. (MHz)
1	334.70	9	329.30	17	333.20	25	329.60	33	332.30
2	334.55	10	329.15	18	333.05	26	329.45	34	332.15
3	334.10	11	331.40	19	333.80	27	330.20	35	332.90
4	333.95	12	331.25	20	333.65	28	330.05	36	332.75
5	329.90	13	332.00	21	334.40	29	330.80	37	333.50
6	329.75	14	331.85	22	334.25	30	330.65	38	333.35
7	330.50	15	332.60	23	335.00	31	331.70	39	331.10
8	330.35	16	332.45	24	334.85	32	331.55	40	330.95

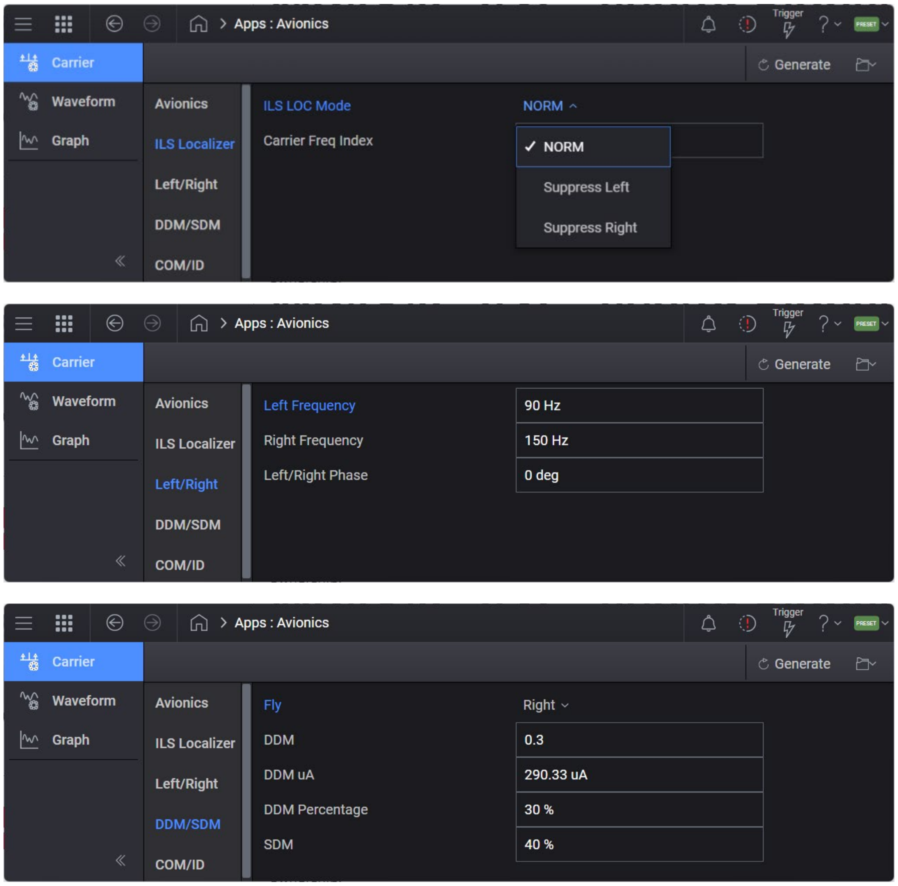

Figure 9. ILS Localizer user interface for controlling ILS-LOC test signal generation parameters

Figure 10. ILS-LOC signal viewed using a N9040B UXA signal analyzer in the N9092EM0E Avionics measurement application

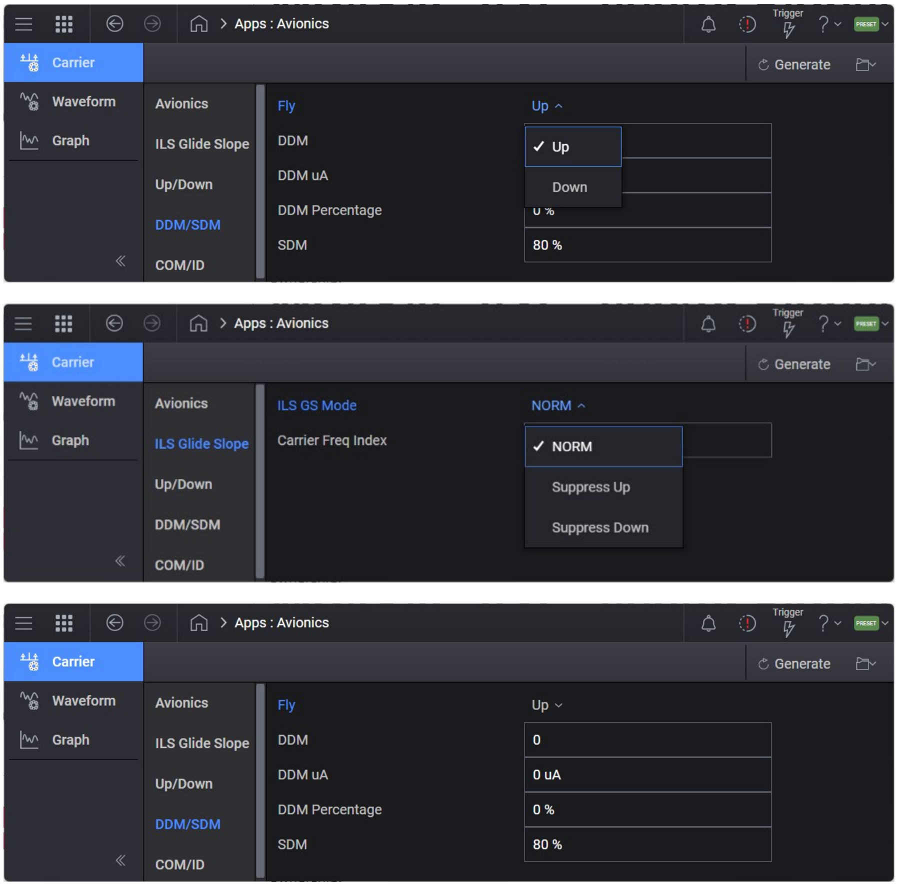

Figure 11. ILS Glide Slope user interface for controlling ILS-GS test signal generation parameters

Figure 12. ILS-GS signal viewed using a N9040B UXA signal analyzer in the N9092EM0E Avionics measurement application

Generating Marker Beacon test signals

A marker beacon is a 75-MHz RF beacon to be emitted upwardly from an antenna installed under the landing approach path to a runway. It is used in conjunction with ILS to provide pilots with information about the lateral distances to the end of the runway (or the runway threshold).

The marker beacon carrier frequency is selectable between 74.6 to 75.4 MHz (spacing 25 kHz). The available carrier frequencies by frequency index are shown below in Table 4.

You can select one of the three types of marker beacons to configure the marker beacon signals:

- Outer marker amplitude modulated by 400 Hz;
- Middle marker amplitude modulated by 1300 Hz;
- Inner marker (closest to runway) amplitude modulated by 3000 Hz.

The Marker Beacon Mode indicates the currently active marker beacon, as shown in Figure 13. You can change the carrier frequency, the default modulation frequency, as well as the modulation depth. When the COM/ID is enabled, the generation of the COM/ID signal is amplitude modulated on the carrier in addition to the marker tone's amplitude modulation. The COM/ID signal settings include the type of signal modulated onto the carrier, the ID code to be generated, the modulation frequencies of the COM/ID tone, and the depth of modulation.

Table 4. Marker Beacon Carrier Frequency Index

Freq. Index	Carrier Freq. (MHz)	Freq. Index	Carrier Freq. (MHz)	Freq. Index	Carrier Freq. (MHz)	Freq. Index	Carrier Freq. (MHz)	Freq. Index	Carrier Freq. (MHz)
1	74.600	8	74.775	15	74.950	22	75.125	29	75.300
2	74.625	9	74.800	16	74.975	23	75.150	30	75.325
3	74.650	10	74.825	17	75.000	24	75.175	31	75.350
4	74.675	11	74.850	18	75.025	25	75.200	32	75.375
5	74.700	12	74.875	19	75.050	26	75.225	33	75.400
6	74.725	13	74.900	20	75.075	27	75.250		
7	74.750	14	74.925	21	75.100	28	75.275		

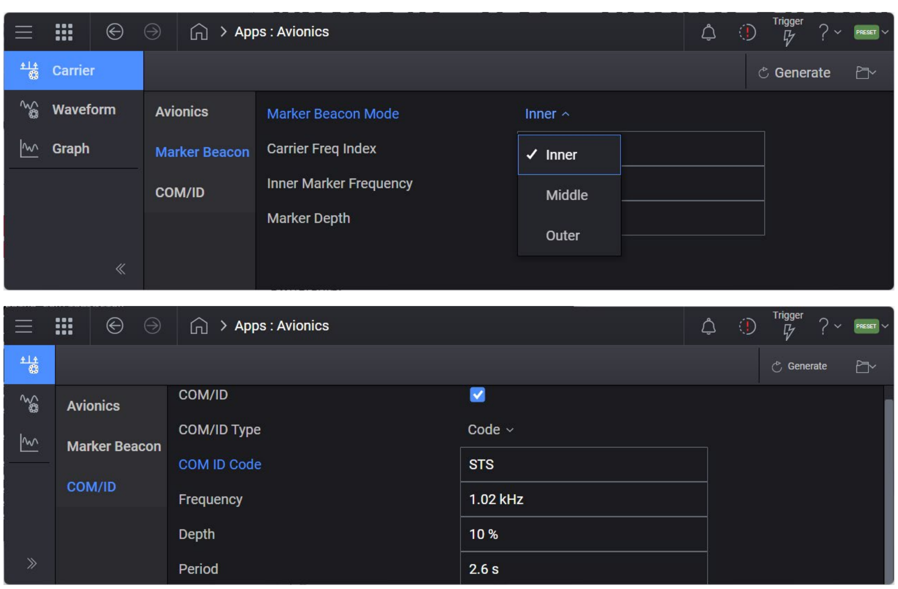

Figure 13. Marker Beacon user interface

Figure 14. Middle marker beacon signal viewed using a N9040B UXA signal analyzer in the N9092EM0E Avionics measurement application

Performance characteristics

Avionics on N5186A MXG (E7641APPC license required)

VOR (108 to 118 MHz)		
Bearing accuracy	± 0.1°	
Frequency accuracy	Same as RF reference source, nominal	
AM accuracy	30% depth	± 5% of setting
AM distortion	2%	
FM accuracy	480 Hz deviation	± 1.7 Hz
ILS: Localizer (108 to 112 MHz) and Glide slope (329 to 335 MHz)		
AM accuracy	40% depth	± 5% of setting
AM distortion	2%	
Difference in depth of modulation (DDM) resolution	Localizer	0.0002
	Glide slope	0.0004
Difference in depth of modulation (DDM) accuracy	Localizer	± 0.0004 ± 5% of DDM [1]
	Glide slope	± 0.0008 ± 5% of DDM [1]
Marker beacon (75 MHz)		
Marker tone AM accuracy	95% depth	± 5% of setting + 1%
Marker tone AM distortion	95% depth	5%

[1] DDM must not be equal to 0.

Ordering Information

Software licensing and configuration

PWSG for Avionics application offers flexible licensing options, including:

- Node-locked: Allows you to use the license on one specified instrument/computer.
- Transportable: Allows you to use the license on one instrument/computer at a time. This license may be transferred to another instrument/computer using Keysight's online tool.
- Floating: Allows you to access the license on networked instruments/computers from a server, one at a time. For concurrent access, multiple licenses may be purchased. Floating support single site, single region and worldwide three different types.
- USB portable: Allows you to move the license from one instrument/computer to another by end-user only with certified USB dongle, purchased separately.
- Subscription (Time-based): License is time limited to a defined period, such as 12, 24 or 36 months

- **PWSG for Avionics requires N7641APPC for M9484C VXG or E7641APPC for N5186A MXG**

Software license type	Software license	KeysightCare subscription
Node-locked perpetual	SW1000-LIC-01	SW1000-SUP-01
Node-locked time-based	SW1000-SUB-01	Included
Transportable perpetual [1]	SW1000-LIC-01	SW1000-SUP-01
Transportable time-based [1]	SW1000-SUB-01	Included

One-month KeysightCare Support and Subscription

Software license	Software license type
SW1000-SUP-01	1-month extension for node-locked perpetual license
SW1000-SUP-01	1-month extension for transportable perpetual license

1. Transportable license is supported on N5186A with firmware version A.16 and above.

Try before you buy!

Download the PathWave Signal Generation and use it free for 30 days to make measurements with your analysis hardware: www.keysight.com/find/n7641appc

Request your free trial license today:

www.keysight.com/find/signalstudio_trial

Hardware configurations

To learn more about compatible hardware and required configurations, please visit:

www.keysight.com/find/SignalStudio_platforms

PC requirements

A PC is required to run PWSG Desktop. www.keysight.com/find/SignalStudio_pc

Websites

www.keysight.com/find/PWSG

PathWave Signal Generation for Avionics: www.keysight.com/find/N7641APPC

PathWave Signal Generation Desktop Software: www.keysight.com/find/PWSG_software

Avionics Test Solutions, Application Notes and Videos: www.keysight.com/find/Avionics

Literatures

PathWave Signal Generation, Brochure, 5989-6448EN

VOR and ILS Radio Navigation Receiver Test Using Option 302 for Keysight Signal Sources, Technical Overview, 5992-1919EN