Keysight Technologies

VOR and ILS Radio Navigation Receiver Test Using Option 302 for Keysight Signal Sources

Application Note

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Introduction

The Keysight X-series (EXG and MXG) analog and vector signal generators with Option 302, avionics license, are ideal signal generators for VHF Omnidirectional ranging (VOR) and instrument landing system (ILS) radio navigation receiver test solutions from Keysight. This application note describes the signals used by VOR and ILS transmitters and how the X-series signal generators can be used to create the proper signals to provide a test solution for ILS and VOR radio receiver test.

Abstract

This application note describes the Avionics License Option 302 that is available in the Keysight Technologies N5171B EXG, N5172B EXG, N5181B MXG, and N5182B MXG signal generators. These performance signal sources can be used to generate AM, FM, ØM, and pulse modulated signals across 9 kHz to 6 GHz, option dependent. In addition to general purpose modulation format capabilities, these signal generators can be used to generate VOR and ILS radio navigation waveforms. This application note provides a brief overview of the VOR and ILS radio navigation signals, as well as using the Keysight EXG and MXG series signal generators to generate VOR and ILS waveforms.

Overview

Overview of VOR and ILS radio navigation signals

The VOR system in an aircraft provides directional information while in flight by interpreting the specially coded information transmitted by VOR stations located on the ground. VOR stations transmit over the 108 to 118 MHz frequency spectrum [1].

The VOR signal transmitted by the station is modulated using two distinct parts. The first part of the VOR signal is amplitude modulated onto a 9.960 kHz sub-carrier at a rate of 30 Hz [2] and in such a way that its phase is not dependent on the bearing angle between the receiver and VOR station [1]. This signal is referred to as the reference signal. The second signal 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 [1].

The aircraft's VOR receiver demodulates the transmitted VOR signal comparing the phase difference between the two transmitted 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. Position location utilizing the VOR system can be used to provide confirmation of the location information reported by GPS systems.

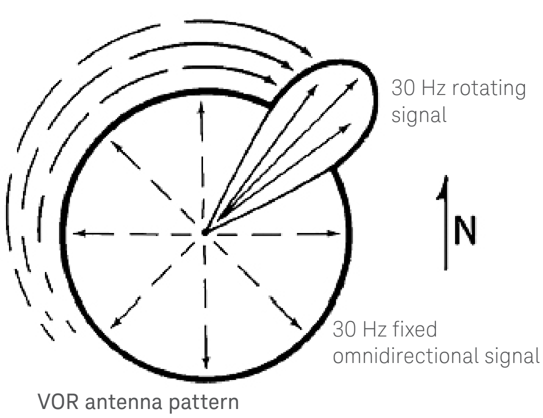


Figure 1. VOR antenna pattern

Brief overview of the ILS radio navigation signal

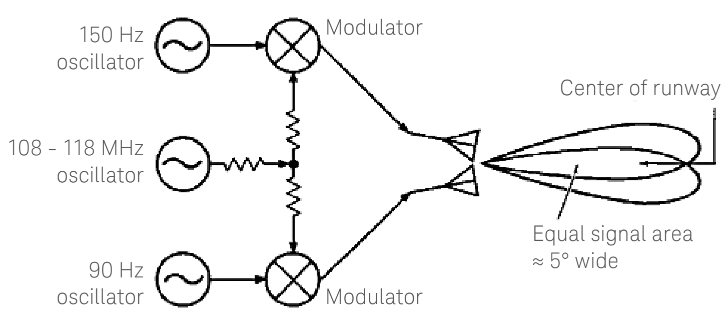
ILS radio navigation provides a method of positioning an aircraft vertically and horizontally with respect to a runway during landing. These systems are especially important during situations where visibility to the runway may be impaired due to climate conditions. A variety of signals and systems are utilized as part of the ILS system to provide the three dimensional spatial orientation required. These signals are the localizer and glide slope signals that are used to orient the craft 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 and glide slope signals

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 118 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 2 [1]. 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 [1].

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 [1].

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 [1].



Localizer transmitter system and antenna pattern

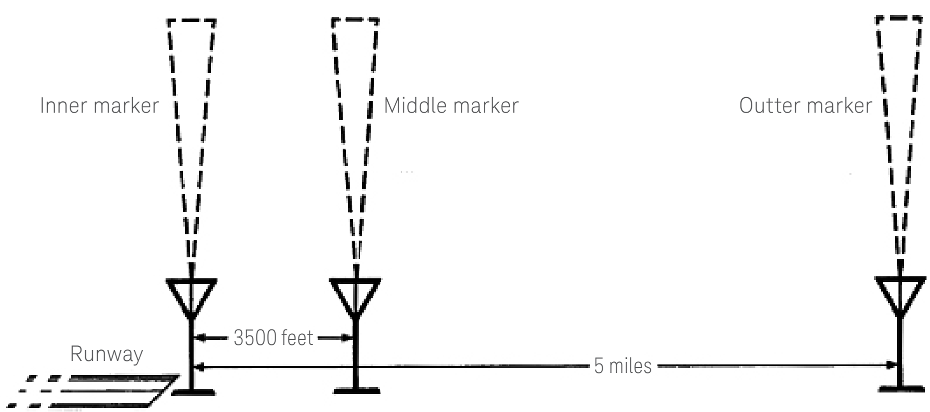
Figure 2. ILS Localizer Transmitter system block diagram and corresponding antenna pattern

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 Fig. 2. The difference between the two systems is that the glide slope system uses carrier frequencies in the band ranging 329.9 MHz to 335 MHz. Additionally, no identification information is encoded on the glide slope carrier [1].

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% [1], 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 [1]. 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 [1]. The inner marker is located at the runway edge and is modulated with a tone at 3 kHz.



Marker beacon antenna locations

Figure 3. Marker Beacon locations and orientation

Radio Navigation Signal Generation using N5171B/72B EXG and N5181B/82B MXG

When Option 302 is enabled on the Keysight N5171B/72B EXG and N5181B/82B MXG signal generators the Auxiliary Function key is used to access the avionics menu and settings that are used in the generation of the aviation radio navigation test signals.

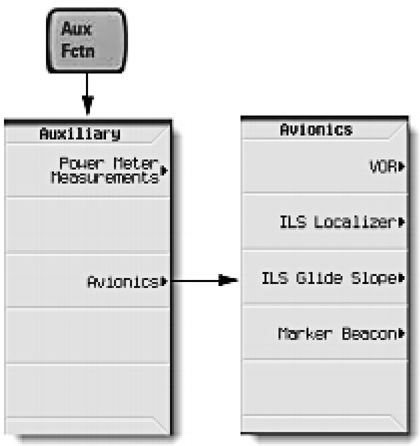


Figure 4. Auxiliary Function key menu and Avionics signal generation selection menu (Option 302) display.

Generating VOR Test Signals

The Keysight N5171B/72B and N5181B/82B can be used to generate VOR test signals. The VOR signal is a composite signal consisting of a reference signal that is frequency modulated on to the VOR sub-carrier frequency and a variable phase component which provides bearing information. The variable phase signal is amplitude modulated at a rate of 30 Hz onto the primary VOR carrier frequency. The variation in phase, corresponding to the bearing angle setting, is achieved by adjusting the relative phase between the amplitude modulated portion of the carrier and the reference signal that is modulated onto the sub-carrier.

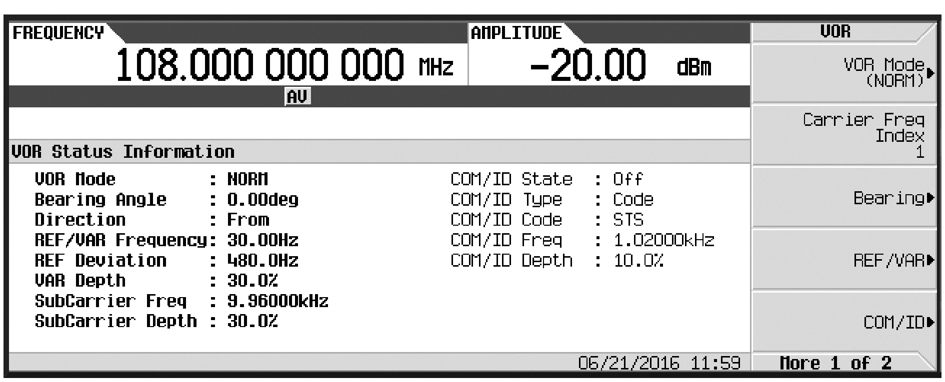


Figure 5. User interface for controlling VOR test signal generation parameters

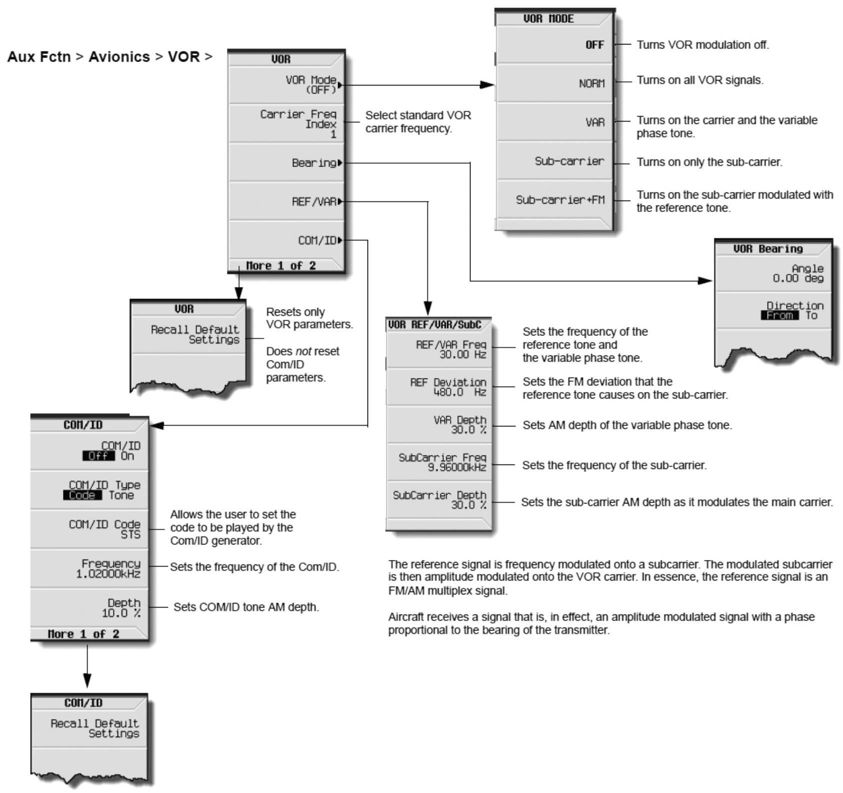


Figure 6. VOR signal generation menus allow access to functions to give complete control over the test signal generation parameters

The VOR signal generation function has soft key menus, Figure 6 , that allows the user to have full control over the VOR test signal generation as well as setting only certain parts of the VOR test signal to be created. The VOR carrier frequencies range from 108.00 MHz to 117.95 MHz and are selectable by changing the carrier frequency index in the VOR signal generation function menu. Table 1 lists the VOR carriers by carrier frequency index setting.

Table 1. VOR carrier frequency by Carrier Frequency Index setting of the VOR signal generation function

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

Generating ILS-LOC and ILS-GS Test Signals

The Keysight N5171B/72B and N5181B/82B can be used to generate localizer or glide slope ILS test signals to generate the 90 Hz and 150 Hz modulation tones. These tones are modulated on to the ILS carrier for the localizer signal. The available localizer frequencies by frequency index are shown below in Table 2. Similarly, the glide slope carrier can be set to one of the standard carriers by carrier frequency index, listed in Table 3. The signal generator can be set to generate the localizer or glide slope signals by selecting the respective “ILS Localizer” or “ILS Glide Slope” soft keys in the Auxiliary function key’s Avionics menu.

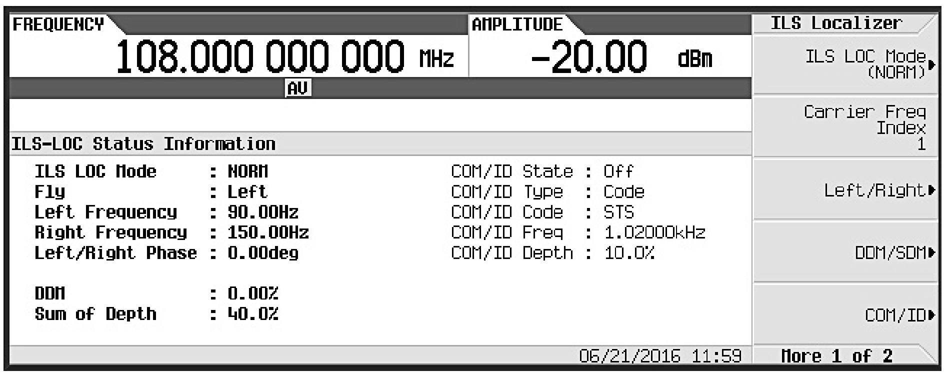


Figure 7. ILS Localizer user interface

Table 2. Localizer carriers by index selection available under Avionics > ILS Localizer > Carrier Freq Index

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

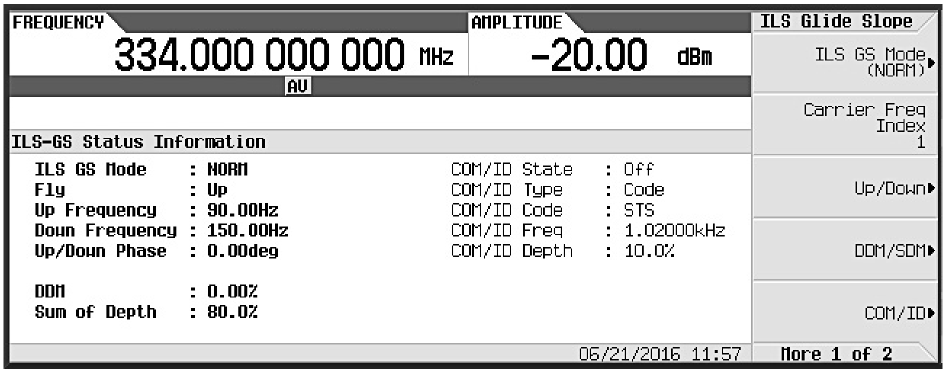


Figure 8. ILS Glide Slope user interface

Table 3. Glide Slope carriers by index selection available under Avionics > ILS Glide Slope > Carrier Freq Index

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

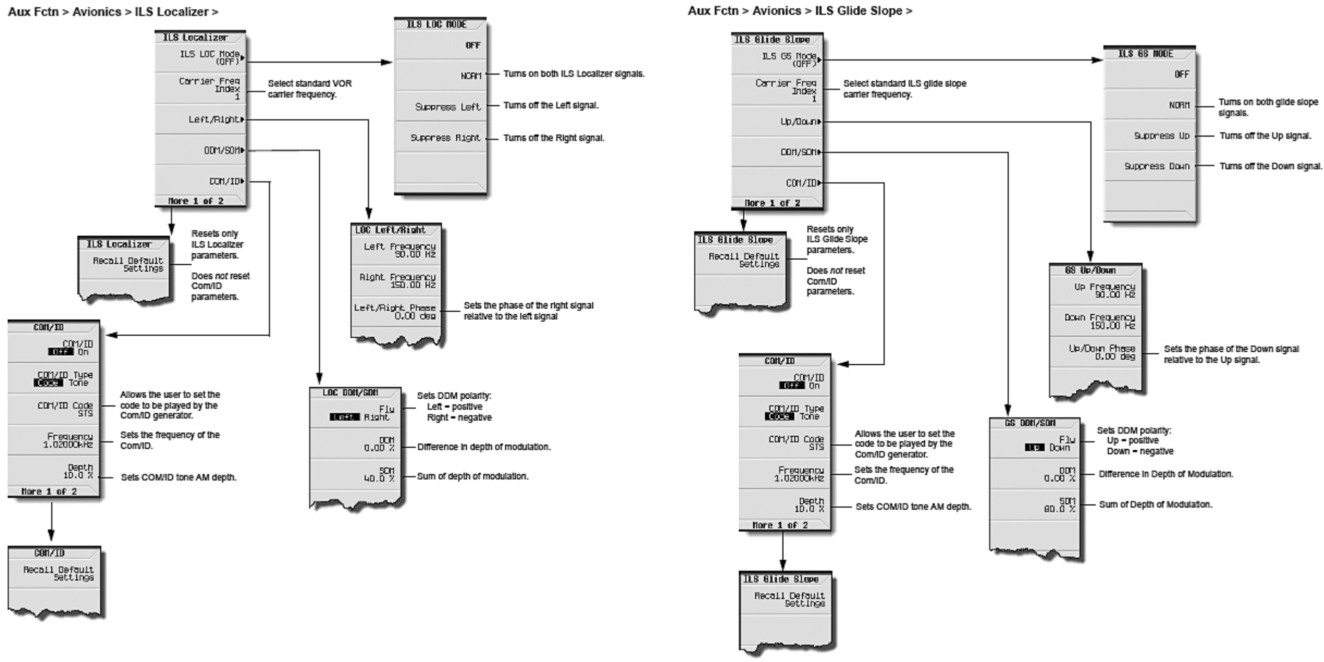


Figure 9. Localizer (a) and Glide Slope (b) soft keys for control of localizer test signal generation

The localizer and glide slope signal generation functions have soft key menus, Figure 9(a) and (b) respectively, which enable control over the ILS test signals generated.

Generating Marker Beacon Test Signals

The Keysight N5171B/72B and N5181B/82B can be used to generate non-pulsed marker beacon test signals. Marker beacon test signals can be generated by selecting the “Marker Beacon” soft-key from the avionics auxiliary function menu.

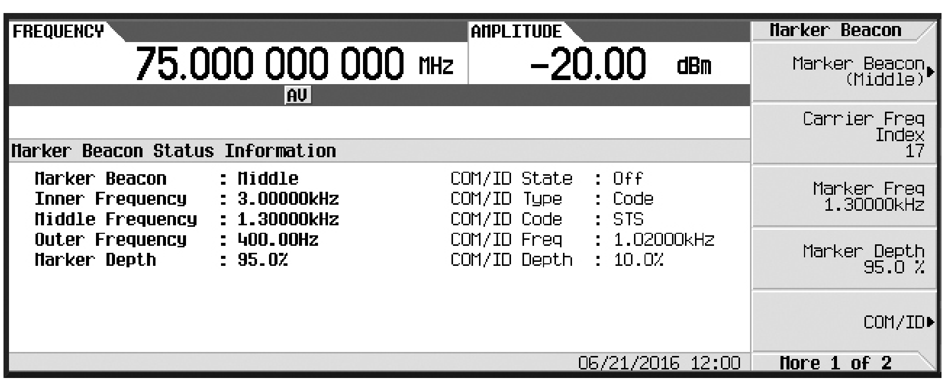


Figure 10. Marker Beacon user interface

When the marker beacon signal type is selected, the marker beacon interface is displayed. The left column of the marker beacon status information indicates the currently active marker beacon, the currently set AM rates for each marker beacon as well as the modulation depth. The right column of the status information display indicates information pertaining to the generation of the COM/ID signal that is amplitude modulated on the carrier in addition to the marker tone's amplitude modulation. This includes the state of the COM/ID signal, 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.

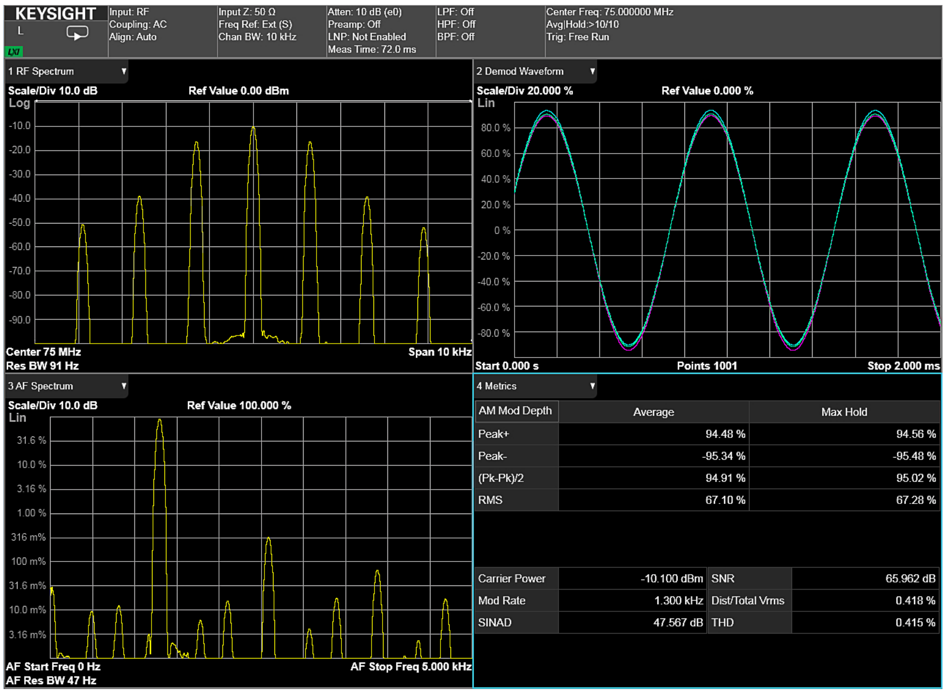


Figure 11. Middle marker beacon signal viewed using a N9040B UXA signal analyzer in the N9063C analog demodulation measurement application

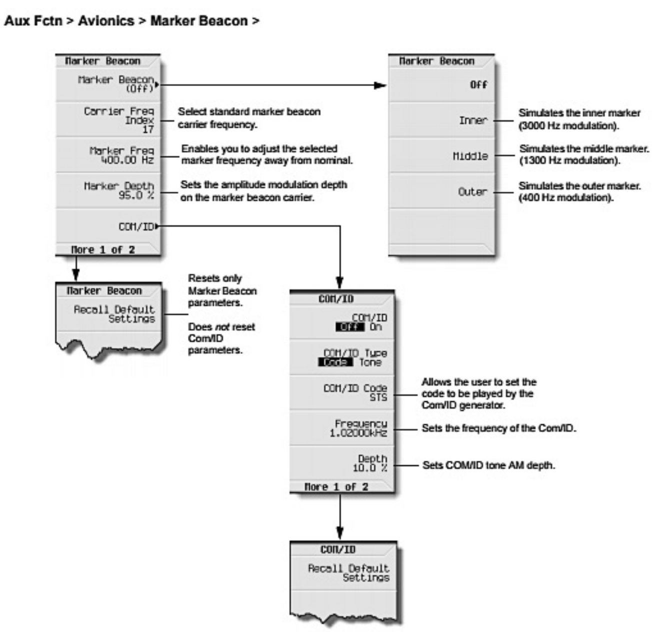


Figure 12. Marker Beacon Soft-key displays

The marker beacon soft-key menus, shown in Figure 12, allow for control over the marker beacon signal. The marker beacon modulation can be turned on for the three pre-set marker modulations or completely off. In addition, one of 33 pre-set carriers, listed in Table 4, can be selected. The marker beacon soft-key menu can also be used to adjust modulation rate and depth for the selected marker away from the nominal rate and depth.

Table 4. Available marker beacon carrier frequencies by frequency index

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

References

[1] Keysight Technologies, “Air Navigation Receiver Testing with the Keysight 8644A,” Santa Rosa, 2000.

[2] N. T. Larsen, D. F. Vecchia and G. R. Sugar, “VOR Calibration Services,” National Bureau of Standards, Technical Note 1069, April 1985.

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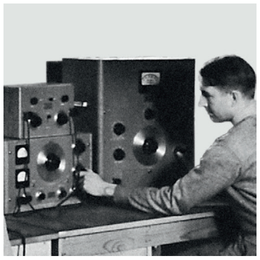
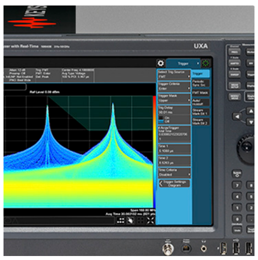


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