Agilent 8644A-2

Air Navigation Receiver Testing with the Agilent 8644A

Application Note

This application note describes the synthesized internal audio source used in the Agilent Technologies 8645A, 8665A, and 8644A/007 signal generators. This flexible source can be used as a modulation source, as an audio function generator, or to extend the frequency range of the signal generator down to 0.1 Hz with complete AM, FM, øM and pulse modulation. In addition to general purpose modulation signals, this note describes how the audio source is used in conjunction with the signal generator to create VOR and ILS air navigation waveforms.

Courtesy Lockheed

Agilent Technologies

Innovating the HP Way

Modulation/Audio Source

The heart of the audio source is a single integrated circuit that uses digital synthesis to "calculate" the proper output and contains a 12 bit D/A converter to generate the analog waveforms. To the user, the audio generator appears as two sources summed together with four other internal sources used for subcarrier modulation only (Figure 1).

The six audio sources are configured as Audio 1, Audio 2, AM subcarrier, FM subcarrier, øM subcarrier, and Pulse subcarrier (see Figure 1). Limitations only allow four sources to be used sumultaneously, however, each can have independent frequency, amplitude, relative phase, and waveform. Most functions are controlled with the special function menu from the front panel or can be programmed with mnemonics through GPIB.

Frequency Specifications/Control

Each source has a freqency range of 0.1 Hz to 400 kHz. The audio output circuitry has a 400 kHz bandwidth which will affect complex signals with frequency components above 400 kHz. Square waves and sawtooths should be limited to 50 kHz. The audio freqency of Audio 1 is controlled with the front panel Audio Freq key.
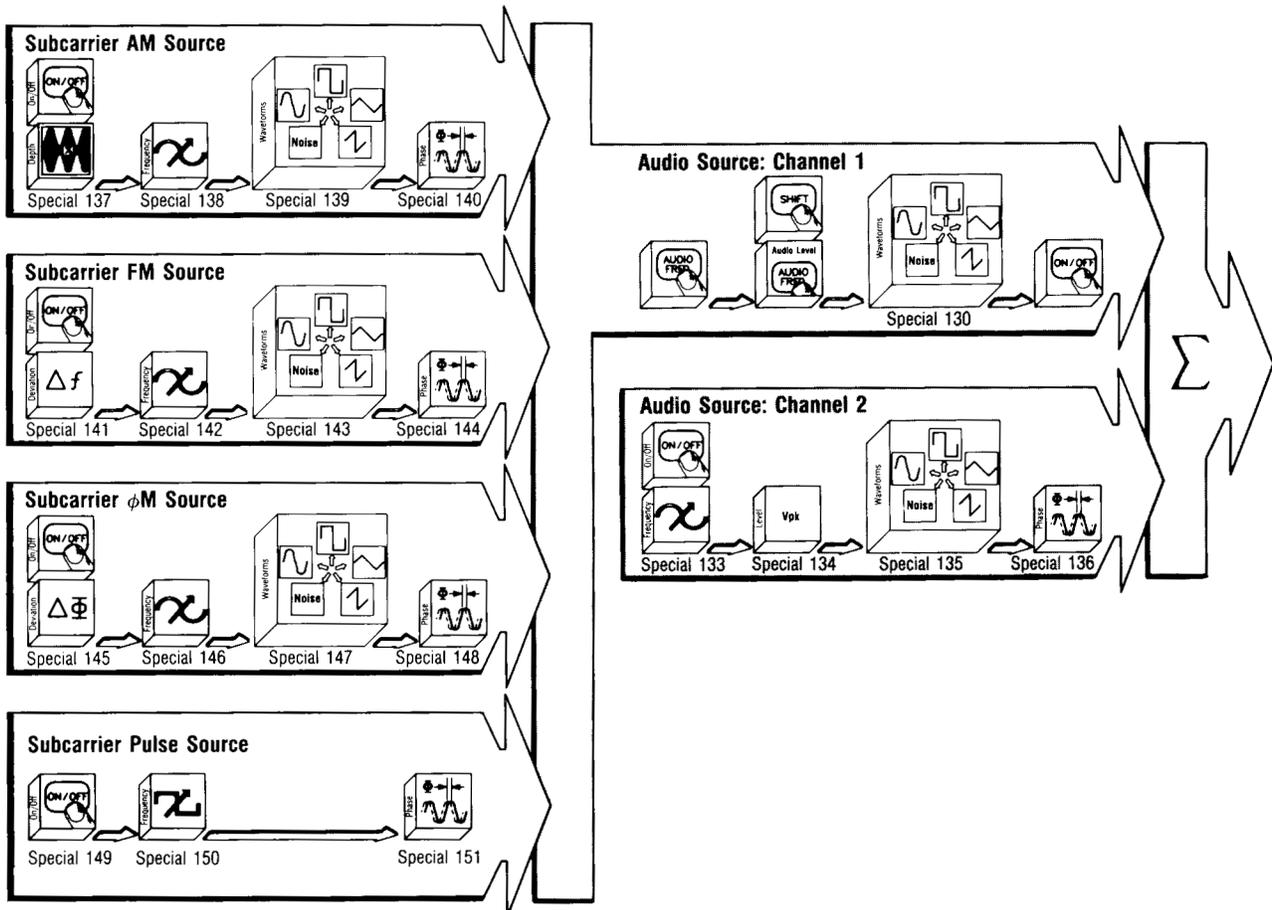

Figure 1. Audio Source Block Diagram

Amplitude Specifications/Control

The Agilent Technologies 8644A has a maximum peak output voltage of 2 volts and the 8645A and 8665A have a peak output of 1 volt. The default setting for Audio 1 is the maximum output voltage and must be reduced before using Audio 2 or subcarrier AM. To calculate the peak voltage of the combination of sources use the formula:

Peak Voltage = Audio 1 + (Audio 1 x depth AM) + Audio 2

This cannot exceed the maximum allowed for the signal generator. To control the level of Audio 1 use the front panel Audio Level key. Audio 2 amplitude and AM depth are controlled with the special functions shown in Figure 1.

Relative Phase Control

All audio sources have a phase adjustment which sets phase relative to the phase of Audio 1. All phases can be set ±180 degrees with 0.1 degrees resolution. The zero phase reference for the different types of waveforms are shown in Figure 2.

Waveforms

Except for the pulse subcarrier which is square wave only, all source waveforms are set independently and can be either sine, square, triangle, sawtooth, or white Gaussian noise.
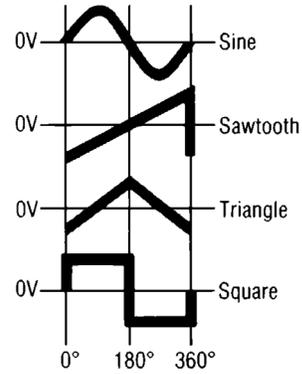

Figure 2. Relative Phase of Audio Waveforms

Air Navigation Waveforms

The Agilent 8644A with Option 007 synthesized audio source and Option 009 specified avionics performance, is an ideal signal generator for VOR (VHF omnirange) and ILS (Instrument Landing System) receiver testing. The remainder of this application note explains these navigation systems and how the 8644A can be used to create the proper test signals.

VOR Navigation System Basics (VHF Omni Range)

The purpose of the VOR system is to provide directional information for aircraft in flight. VOR transmitter stations are strategically located to provide complete coverage for air traffic. Each station radiates a carrier in the 108 to 118 MHz band, which is modulated in a way that provides aircraft bearing information relative to the transmitter location. The modulation is made up of two distinct parts: a 30 Hz reference signal, and a 30 Hz variable phase signal. The reference signal is modulated onto the carrier so that its phase is independent of the bearing at the point of reception. The variable phase signal is modulated so that its phase differs from that of the reference signal by an angle equal to the compass bearing from the point of reception to the VOR station.

By demodulating the transmitted VOR signal, an aircraft receiver can compare the phases of these two 30 Hz signals to determine the compass bearing to the VOR station. By tuning to two or more VOR stations and recording each bearing angle, pilots can determine their exact location on an air chart by triangulation.

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.

30 Hz Rotating Signal

N

30 Hz Fixed Omnidirectional Signal
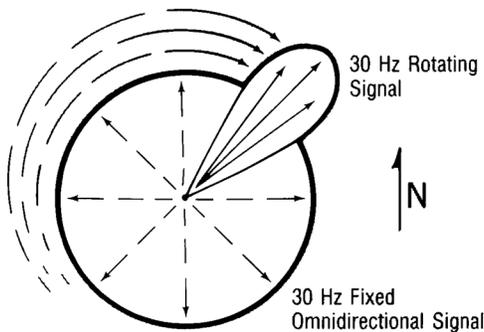
VOR Antenna Pattern

Generating VOR Test Signals with the Agilent 8644A

To test a VOR receiver with the 8644A, a composite VOR signal is generated with the audio source and AM modulated onto an RF carrier at the proper frequency and amplitude. To configure the signal generator for VOR, execute Special Function 220 (VOR Setup) which configures the signal generator for a VOR signal of 0 degrees "To" the station at a carrier frequency of 108 MHz. To set different bearings use Special Function 144 (Audio FM phase) to enter the radial and use Special Function 136 (Audio 2 phase) to change bearing "To" or "From". Set the Audio 2 phase to 0 degrees for "From" setting or to 180 degrees for "To" settings.

To alter the carrier frequency, simply enter the desired frequency using the front panel keys. If other parameters of the modulation signal need adjusted, simply adjust the special shown in Table 1.

Table 1. Executing Special 220 (VOR Setup) is similar to individually entering the following list of commands:

1) Instrument Preset

Audio Source 1–Sets the 9960 Hz carrier
2) Audio freq 9960 Hz
3) Audio level 1 Volt

Audio FM–Modulates the subcarrier with variable 30 signal
4) Special 141, 480 Hz
5) Special 142, 30 Hz
6) Special 143, 0 degrees, this sets variable bearing radial 0.0 to 359.9 degrees.

Audio Source 2–Sets the 30 Hz reference signal
7) Special 133, 30 Hz
8) Special 134, 1 Volt
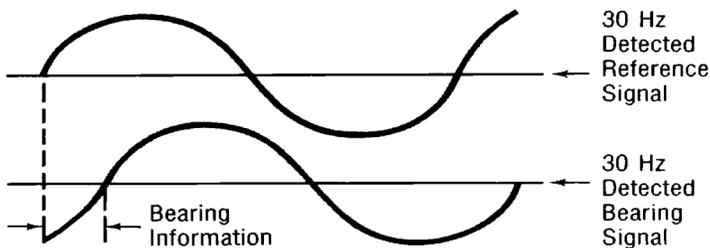9) Special 136, 0 degrees for "from" bearings, 180 degrees for "to" bearings

Carrier Modulation–Set maximum depth of modulation
10) AM 60%, internal

Carrier Frequency
11) RF frequency 108 MHz

30 Hz Detected Reference Signal

30 Hz Detected Bearing Signal

Bearing Information

VOR Signal Seen at Aircraft Receiver

ILS System Basics (Instrument Landing System)

To assist aircraft in landing during periods of poor weather, the ILS or Instrument Landing System was developed. This system is composed of several separate signals, each of which is designed to provide the pilot with specific information relating to the position of the aircraft relative to the runway. These signals are: the Localizer, Glide Slope, Outer Marker, Middle Marker, and the Inner Marker.
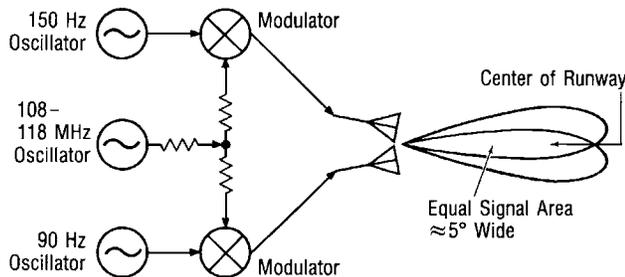
Localizer

The Localizer operates at a carrier frequency from 108 to 112 MHz. This signal provides the pilot with information which indicates whether the aircraft is to the left of, to the right of, or in-line with the runway. The Localizer does this by radiating a directional field pattern directly down the center of the runway. The Localizer's carrier is amplitude modulated by two tones: 90 Hz and 150 Hz.

Each of the resulting modulated carriers is sent to a separate directional antenna system. This antenna array is arranged so that the 90 Hz signal is stronger than the 150 Hz signal on the left side of the runway, and the 150 Hz signal is stronger than the 90 Hz signal on the right side of the runway. This equal zone is designed to be approximately 5 degrees wide. This system allows for relatively simple AM demodulators to be built which can recover the 90 Hz and 150 Hz tones and then compare their levels to provide the "localizing" information. The difference in depth of modulation (DDM), is used to provide the pilot with "on course" information. DDM is defined to be the percentage modulation depth of the larger signal minus the percent modulation depth of the smaller signal, divided by 100. In addition to the actual localizer signal, an audio Voice/Identity signal is also placed on the localizer carrier. The baseband frequencies from 350 Hz to 2500 Hz are allocated for this purpose.

Glide Slope

The Glide Slope operates with a carrier frequency in the 329.9–335 MHz band and provides signals which indicate whether the aircraft is above, below, or on the glide path. The Glide Slope provides the same type of information as the Localizer, but for a vertical reference as opposed to a horizontal reference (Figure 3). In fact the same modulation and antenna techniques are used, including the use of 90 and 150 Hz modulation tones. The only exception is that no Voice/Ident signal is used with the glide slope signal.

Localizer Transmitter System and Antenna Pattern

Localizer/Glideslope Test Signals

Testing a localizer or glideslope receiver with the Agilent 8644A Option 007 uses the audio source to simultaneously generate the 90 Hz and 150 Hz test signals. These signal are AM modulated onto the RF carrier at the proper amplitude and frequency. To configure the signal generator for a localizer waveform, execute Special Function 221 (Localizer Setup) for a 0 ddrn output at 108.1 MHz. To select different ddm settings, use the formula given in Table 2.

Table 2. Executing Special Function 221 (Localizer Setup) is equivalent to the following commands:

1) Instrument Preset

Audio Source 1–Sets the 150 Hz signal
2) Audio freq 150 Hz
3) Audio level 1 V (see below)

Audio Source 2–Sets the 90 Hz signal
4) Special 133, 90 Hz
5) Special 134, 1 Volt (see below)

Carrier Modulation–Set maximum depth of modulation
6) AM 40% for localizer

Carrier Frequency
7) RF Frequency 108.1 MHz

Executing Special Function 222 (Glideslope Setup) is similar to the preceding setup except AM is set to 80% and RF frequency is set to 334.7 MHz.

Setting both the Audio Level and Special 134 to 1 volt generates localizer and glideslope signals with 0 ddm between the 90 and 150 Hz tones. To test other ddrn settings, these voltages must be adjusted according to the formula and examples shown in Table 3 and Table 4.
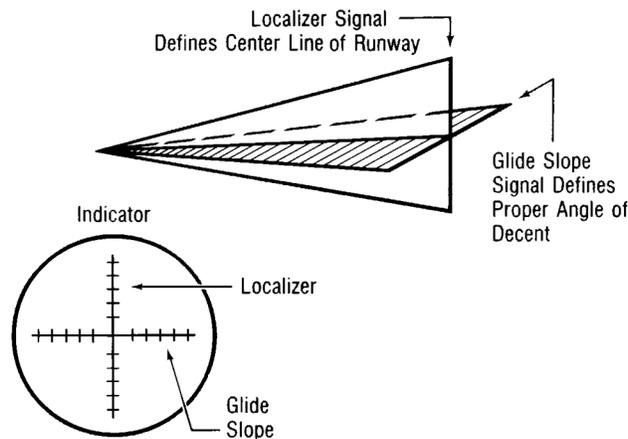
Table 3. Localizer

DDM	Audio Level	Aud2 Level (Special 134)
0	1.000 V	1.000 V
0.046	1.115 V	0.885 V
0.093	1.232 V	0.767 V
0.115	1.387 V	0.612 V
0.200	1.500 V	0.500 V
Variable	$20 + 50*ddm$	$20 - 50*ddm$
	20 V	20 V

Note: These settings will deflect the localizer indicator left of the central position by the ddm amount shown. Reversing Audio Level and Special 134 level will deflect the indicator right of center. When using calculated voltages, always round the results down to the nearest millivolt. When setting the voltages, the total can never exceed 2 volts.

Table 4. Glideslope

DOM	Audio Level	Aud2 Level (Special 134)
0	1.000 V	1.000 V
0.045	1.055 V	0.943 V
0.091	1.113 V	0.886 V
0.175	1.218 V	0.781 V
0.400	1.500 V	0.500 V
Variable	$40 + 50*ddm$	$40 - 50*ddm$
	40 V	40 V

Note: These settings will deflect the glideslope indicator up above the central position by the ddm amount shown. Reversing Audio Level and Special 134 level will deflect the indicator down. When using calculates voltages, always round the results down to the nearest millivolt. When setting the voltages, the total can never exceed 2 volts.

Localizer and Glide Slope Radiation Pattern and Aircraft Indicator Display

Markers

The final components of the ILS system are the three marker beacons. The marker beacons provide the pilot with information which indicates the distance of the aircraft relative to the threshold of the runway. All markers operate at a carrier frequency of 75 MHz and are transmitted through vertical antenna arrays which project a fanshaped pattern. The outer marker transmitter amplitude modulates the carrier with a 400 Hz tone. The antenna for the outer marker is located approximately five miles from the runway. The middle marker uses a 1300 Hz tone to amplitude modulate the beacon carrier. The antenna for the middle marker is located 3500 feet from the runway. For a normal landing, the aircraft should be at an altitude of 200 feet by the time the middle marker is reached.

In addition, the pilot should have the ground in sight at this point. The inner marker uses a 3 kHz tone and is located at the threshold to the runway. All marker beacon tones produce an AM depth of 95% in the RF carrier. Marker beacon receivers illuminate different colored lights as the aircraft passes through each marker beacon signal. For additional aid, the tones used to modulate the carrier are pulsed on and off so as to flash the receiver lights.

Marker Beacons

The Agilent 8644A can be used to simulate pulsed or non-pulse marker beacon signals. Special Functions 223, 224, and 225 configure the signal generator for outer marker, middle marker, and inner marker beacon signals respectively.
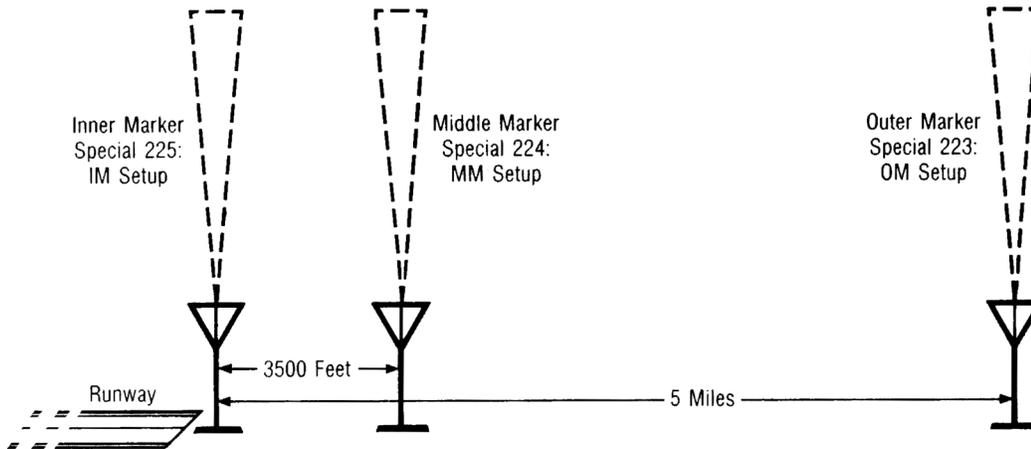
Table 5. Executing these Special Functions is similar to entering the following commands:

Audio Source 1–Sets the tone frequency
1) Audio freq 400 Hz–Outer marker
or 1300 Hz–Middle marker
or 3000 Hz–Inner marker

Audio Pulse–Pulses the marker tone at a 2 Hz rate
2) Special 149, ON (Turn OFF for nonpulse tests)
3) Special 150, 2 Hz

Carrier Frequency
4) RF Frequency 75 MHz

While these avionics waveforms can be simulated with any 8644A with Option 007, Option 009 is available for specified performance and includes software drivers that simplify using the signal generator in automatic test systems. These specifications and a summary of the software drivers are shown next.

Inner Marker
Special 225:
IM Setup

Middle Marker
Special 224:
MM Setup

Outer Marker
Special 223:
OM Setup

Runway

← 3500 Feet →

← 5 Miles →

Marker Beacon Antenna Locations

Description of Software Subroutines Available for Air Navigation Waveforms on the Agilent 8644A

These subroutines are intended to be added to a receiver test program to simplify using the 8644A audio source for complex air navigation waveforms. These subroutines require that parameters be passed to the sub routine and return string variables that can be directly output to the signal generator.

VOR (VHF omnirange) Subroutines
SUB Vor_setup(Direction$,Bearing, Lfsource$,Modulate$)
Direction$
This is an input into the sub routine and must contain either "To" or "From" indicating whether the bearing is to or from the transmitter.

Bearing
This is an input corresponding to the radial in degrees either to or from the transmitter.

Lfsource$
This is a string variable returned from the subroutine that contains the GPIB command string to set up the Low Frequency with correct bearing and direction information. This can be output directly to the signal generator and assumes that the modulation source was in a state similar to an instrument preset before the command is sent.

Modulate$
This is similar the Lfsource$ except that it sets up the correct amplitude modulation for VOR waveforms. This can be output directly to the signal generator and assumes no other modulation is being used before the command is sent.

Example: Call Vor_setup("From",90.0, Output1$,Output2$)
This sets the string variables output 1 and output 2 to the correct GPIB commands to simulate a VOR signal 90 degrees from a VOR transmitter.

SUB Vor_bearing(Direction$,Bearing, Lfsource$)
This is similar to Vor_setup except that it only modifies the bearing angle and assumes that the Vor_setup program has already been run. The variable Lfsource$ can be output directly to the signal generator.

Localizer Subroutines
SUB Loc_setup(Direction$,Ddm,Lfsource$, Modulate$)
Direction$
This is an input into the subroutine and must contain either "Left" or "Right" indicating whether the indicator is left or right of the central position.

Ddm
This is an input that indicates the Difference in Depth of Modulation that the generator will produce to test the receiver.

Lfsource$
Returns the string variables to set the levels for the 90 Hz and 150 Hz tones for localizer waveforms.

Modulate$
Returns the GPIB command to set the proper AM modulation for localizer waveforms.

SUB Loc_offset(Direction$,Ddm,Lfsource$)
This is similar to the Loc-setup subroutine except that is assumes the amplitude modulation has previously been set with the Loc-setup routine.

Glideslope Subroutines
SUB Gs_setup(Direction$,Ddm,Lfsource$, Modulate$)
Direction$
This is an input into the sub routine and must contain either "Up" or "Down" indicating whether the glideslope display is up or down of the central position.

Ddm
This is an input that indicates the Difference in Depth of Modulation that the generator will produce to test the receiver.

Lfsource$, Modulate$
These are similar to the variables returned in the localizer setup subroutine except they correspond to glideslope waveforms.

SUB GS_offset(Direction$,Ddm,Lfsource$)
This is similar to the Gs_setup sub routine except that is assumes the amplitude modulation has previously been set with the Gs_setup routine.

Marker Beacon Subroutines
SUB Mb_setup(Marker$,Lfsource$, Modulate$)
Marker$
This is an input to the subroutine and is either "0", "M", or "I" for outer, middle, or inner marker.

Lfsource$, Modulate$
These are similar to the string variable returned from the VOR setup routine. These assume that no other modulation has previously been set and can be output directly to the signal generator.

Option 009
Specifications
Option 009 provides specified VOR/ILS performance for the 8644A with Option 007. These specifications are in addition to those for the standard 8644A. This performance cannot be specified with Option 002 (doubled version) or Option 005 (electronic attenuator).

VOR (108 to 118 MHz)

Bearing accuracy	0.1 degrees
Frequency accuracy	Set by timebase
AM accuracy	±5% of setting
FM accuracy	±1.5 Hz
(480 Hz deviation)	
AM distortion	2%

ILS: Localizer/Glide Slope (108 to 112 MHz/329.3 to 335 MHz)

AM accuracy	±5% of setting
AM distortion	2%
DDM resolution	
(Localizer)	0.0004
(Glide Slope)	0.0008
DDM accuracy	
(Localizer)	±0.0006 ±5% of DDM
(Glide Slope)	±0.0012 ± 5% of DDM

Marker Beacon (75 MHz)

AM accuracy (95%)	±5% of setting +1%
AM distortion	5%

Specification Verification

VOR Bearing accuracy is the relative phase accuracy of two 30 Hz signals. One directly AM modulates an RF carrier, the other is first FM modulated onto a 9960 Hz subcarrier which then AM modulates the same RF carrier. Bearing accuracy refers to the relative phase accuracy of the two 30 Hz signals on the RF carrier.

There are two main sources of bearing error in the 8644A implementation. The first is from the audio source which generates the composite signals. A complete investigation of this digital source shows this is always <0.044 degrees and has been verified on calibrated test equipment (Arbiter 1070A). Another source of error is the phase shift in the AM path of the 30 Hz reference signal and the 9960 Hz subcarrier which has the 30 Hz variable signal imposed on it. This AM phase shift is measured with calibrated network analyzers to a test line limit of <15 degrees shift of the 9960 Hz signal. This is equal to 0.05 degrees of phase shift of the 30 Hz signal modulated on the 9960 Hz carrier. Summing together this 0.05 degrees error with the 0.044 degree maximum from the digital source gives a maximum error of <0.1 degrees.

Localizer and glideslope ddrn is the difference in depth of modulation of a 90 Hz and 150 Hz tone AM modulated on a RF carrier. When setting this difference with the 8644A there are three sources of error. First, the audio source which generates these two tones. The digital nature of this audio source guarantees the two tones within one LSB or 2 mV in 1000 mV. For localizer this equates to an uncertainty of 0.0004 ddrn since the modulation sensitivity is 0.4 ddm/2000 mV (40% AM). For glideslope the uncertainty is 0.0008 ddrn because the sensitivity is 80% AM. The second source of error is from the AM flatness between the two tones. This is verified to be <0.005 dB which has an equivalent difference if depth of modulation of 0.00012 for localizer and 0.00023 ddrn for glideslope. AM accuracy is the third contribution to error and is a multiplier on the amount of ddrn selected. This final error is measured with a modulation analyzer (Agilent 8901B). The worst case spec for localizer is 0.0004+0.00012+(AM accuracy*ddm). The guaranteed specification is 0.0006 + 5% of ddrn selected for localizer, 0.0012 + 5% of ddrn selected for glideslope.

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