application
note

Instrument Landing System (ILS) and Distance Measuring Equipment (DME) Ground Receiver and Monitor Alarm Testing

Ensuring the safe guidance and exact positioning of air traffic is dependent upon regular and accurate testing of the ILS and DME monitor alarms that provide early indication of faults or changes in the operating characteristics. This application note discusses both these systems and describes how the 2030 series avionics signal generators may be used to maintain their operational integrity.

Instrument Landing System - ILS

Instrument Landing Systems (ILS) are installed at major airports throughout the world. The system ensures the safe approach of aircraft in congested airspace and is essential for continuous operation in low visibility and adverse weather conditions. The system is comprised of two parts - the Localizer that controls the horizontal alignment and the Glideslope that controls the angle of approach.

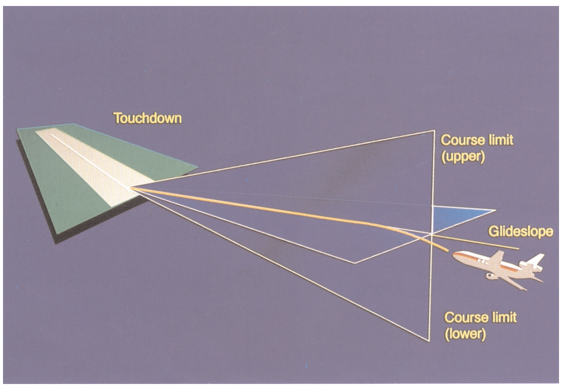

Figure 1 - Glideslope course width alarm limits

In order that the integrity of the radiated beams are maintained in operation, the ILS includes comprehensive monitors that alert operations staff when changes in the beam characteristics exceed predetermined limits. Changes can be caused by:

- transmitter faults or drift
- antenna damage
- interfering signals
- environmental disturbances
- multi-path effects

For example, a vehicle parked or moving in the vicinity of the antenna system can cause a temporary disturbance of the transmitted beam. In order to ensure the accurate guidance of air traffic approaching the airport it is essential that the monitor alarm levels are periodically checked, and re-aligned if necessary. The type and complexity of ILS monitor systems varies depending upon the regulations set by the local civil aviation authorities, the category of operation and the system manufacturer. The system typically includes integral monitors that form part of the system antenna installation, and near and far field RF monitors that operate from separate antenna placed at strategic points in the radiated beam. The performance of the ILS system is designated as Category I, II and III, with the tightest limits being set on the Category III systems (there are sub-categories for these systems which depend upon other systems being present).

ILS Category	*Localizer DDM limit*	*μA Deflection*	*IFR Avionics Signal Generator DDM accuracy at DDM limit*
Cat I	0.015	14.5	± 0.00060
Cat II	0.011	10.6	± 0.00052
Cat III	0.009	8.7	± 0.00048

Independent monitors are provided for the localizer and glideslope and each typically provides alarms for; Displacement Sensitivity, Course Sector Difference Depth of Modulation (DDM), Course Line DDM, Clearance, Sum Depth of Modulation (SDM), Identity Keying and RF Field Level.

ILS Waveform Generation

The 2030 series avionics signal generators include the capability of generating very accurate ILS signals. A large LCD panel and soft key controlled operator interface, together with special firmware, present the operator with easy to use test facilities. ILS parameters are presented in terms familiar to the avionics engineer such as SDM and DDM. These parameters can be quickly set to the monitor alarm settings using the keyboard and adjusted with the rotary control or increment keys. The extensive non-volatile memory facilities for storage of the signal generator parameters and alarm parameters enable semi-automatic testing of the monitor system, providing repeatable results and significantly speed up the test routine. A PC based software support package is also available to aid report generation and the storage of ILS system parameters.

ILS Monitor Alarm Testing

In order to test or calibrate the monitor system an accurate RF ILS signal must be applied to the monitor's receiver. The monitors are not placed directly on the approach path so they receive signals that typically have non-zero DDM's and different modulation depths compared to that seen by an approaching aircraft. The installation is normally checked by flight tests and once the system integrity has been verified the monitor signal levels are noted and used as reference values for each monitor point.

As each monitor point is expected to receive this signal, the alarms are set so that the operators are alerted if the signal deviates from this reference value. The monitors can be tested by replacing the off air signals with the 2030 avionics signal generator whose parameters can be adjusted to simulate the required off air signal and then deviated from it so that the alarms are tripped. As these parameters are adjusted from the expected signal the metering circuits, indicators and alarm circuits can be verified.

The method of ILS waveform generation ensures that accurate SDM and DDM performance is achieved. This is described in a separate application note.

The use of 2030 series avionics signal generators in the checking of alarms results in a reduction in the number of routine flight tests that are performed and gives an early indication of faults or changes in the alarm system.

Distance Measuring Equipment - DME

The DME system has two physically separated sub-systems, an airborne interrogator and a ground transponder.

The system provides the aircraft with distance information from a ground station. The distance between the aircraft and the station is the slant range distance (i.e. line of sight) and not the horizontal distance.

Paired pulses, at a specific spacing, are sent out from the aircraft (interrogator) and are received at the ground station. The ground station (transponder) then transmits paired pulses back to the aircraft at the same pulse spacing, but on a different frequency. The time required for the round trip for this signal exchange is measured in the airborne DME unit and is translated into distance (nautical miles) from the aircraft to the ground station. A correction factor is applied during the translation to cater for the ground station processing delay.

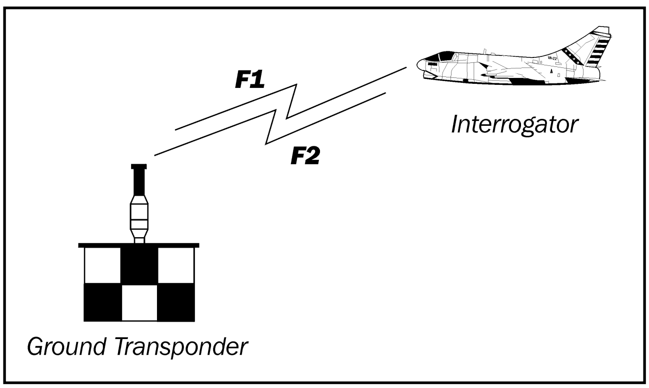

Figure 2 - Distance Measuring Principle

Two types of DME are used, DME/N for en-route and terminal applications, and precision DME/P used on airfield approach.

2030 series avionics signal generator with DME capability

As stated previously, the interrogation signals use pairs of pulses that have a defined spacing. The DME option provides the capability of generating Gaussian shaped RF pulses. Variable control of pulse width, rise and fall times, pulse pair spacing and repetition rate are available giving complete flexibility when defining the required pulse profile. The Gaussian shaped pulses can be generated over the DME range 960 to 1215 MHz with identical amplitude and shape, and level accuracy of 0.5 dB over the range -110 to +10 dBm.

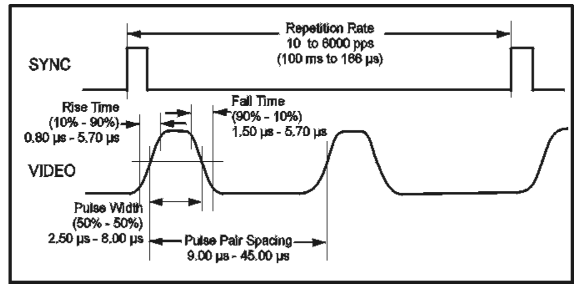

Figure 3 - Pulses definition in the 2030 signal generator

To be compatible with the ICAO standards recommended in Annex 10, DME ground equipment has to conform to the Eurocae ED57 Minimum Operational Performance Specification (MOPS). This ensures that accurate guidance information is provided and maintained. As with ILS, alarm monitoring is used. The following describes how the 2030 series avionics signal generators, fitted with the DME option, can be used to perform a number of receiver tests and monitor alarm checks.

Receiver and Sensitivity Tests

The receiver sensitivity is measured at the DME ground station cabinet antenna input connector.

The sensitivity is specified to be at least equal to the figures quoted below (derived from ICAO Annex 10).

Equipment Type	*Signal Level, (dBm)*	*Reply efficiency (%)*
DME/N en-route	-91	70
DME/N terminal	-81	70

The pulse shape of the interrogation test signal has to conform to the DME standard characteristics in duration, rise/fall times and spectrum while performing the tests. The sensitivity must not vary by more than 1 dB for a reply rate between 0 and 2400 pp/s. For high capacity transponders, it must not vary by more than 3 dB between 2400 pp/s and 3600 pp/s. The threshold sensitivity must not change by more than 3 dB for an interrogation frequency drift to ±100 kHz from the assigned channel frequency and for the maximum receiver frequency drift.

The receiver bandwidth must be such that for interrogation signals with a rise time between 0.8 and 3 μs the sensitivity figures are met. When the carrier frequency of interrogation signals is more than 900 kHz from the nominal channel frequency at the cabinet input, these signals must not trigger the transponder. Input signals at the receiver image frequency and all other spurious within the 960 MHz to 1215 MHz band have to be attenuated by at least 75 dB.

Monitor characteristics

For monitoring purposes, the transponder is interrogated by test signals that simulate the air-to-ground interrogation. The monitor then checks the pulses emitted by the transponder. In case of faulty parameters, alarms are triggered to allow standby equipment switching. The alarms must be triggered if the time between pulses deviates from the nominal value by more than 0.4 ± 0.1 μs for DME/N. They also need to be triggered if the designated carrier varies by more than ± 0.0002% from its nominal value.

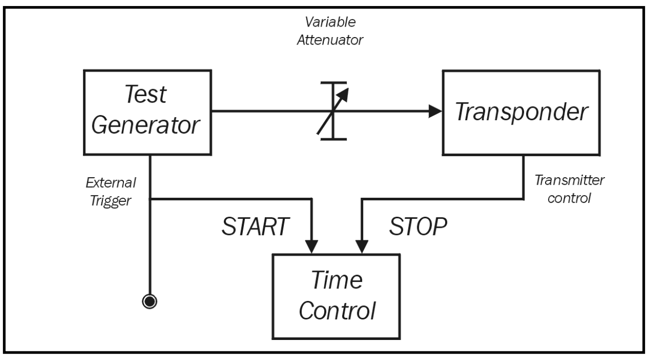

Figure 4 - Typical test setup

Summary

In addition to the 2030 series, the avionics option is also available on the 2040 (low noise) and 2050 (digital and vector) series of signal generators.

The 2030 series signal generators are used extensively for checking airfield ILS monitor systems to make sure the automatic alarm systems are working correctly. It is also used to check the calibrated receivers that are installed on flight inspection aircraft that perform tests of ILS installations. Manufacturers and aircraft workshops use the 2030 series to check the performance of aircraft ILS, VOR and VHF radios. In manufacturing the excellent accuracy of the RF output signal ensures that the 2030 series signal generators meet even the most demanding applications. When fitted with the DME option, interrogator signals can be simulated for the testing of transponder receivers.

The 2040 series signal generators provide very low noise signals that can test the selectivity of aircraft receivers in the presence of other signals. The low phase noise of the 2040 series ensures the test results are not influenced by limitations in the signal generator noise, particularly at offset frequencies of between 6 kHz and 30 kHz. As the aviation frequency bands become more crowded the performance level required of both the navigation receivers (ILS, VOR) and the radio systems become more critical, making it essential that adjacent channel rejection and blocking tests are performed.

The 2050 series signal generators are capable of generating signals conforming to the VDL standards with low levels of adjacent channel power, extending the application of the generator to digital avionics receivers.

Model Number	**Versions**
2030, 2040, 2050	10 kHz to 1.35 GHz Signal Generator
2031, 2041, 2042	10 kHz to 2.7 GHz Signal Generator
2032, 2042, 2052	10 kHz to 5.4 GHz Signal Generator
Option 001	Second Internal Modulation Oscillator
Option 006	Avionics (must be ordered with Option 001)
Option 010*	DME (requires option 001 & 006)
NAV 750C	2030 fitted with Option 1 and 6 only
Other Options	
Option 002	Pulse Modulation
Option 008	RF Profile and complex sweep
Option 009*	Internal Pulse
Option 012	Electronic Attenuator
Option 112	Ext. mod 2 Input 600

* Only available on 2030 series.

Specification

The following specifications are in addition to the overall specification for the 2030/40/50 series signal generators.

Avionics Specification - Option 1 & 6

ILS MODE

Tone Frequencies
90 Hz, 150 Hz nominal. The tone frequency may be changed by varying the ILS repetition rate of 30 Hz in 0.1 Hz steps. Tone frequencies maintain 3:1 and 5:1 relationships with the ILS rate.

Frequency Accuracy
As frequency standard

Tone Suppression
Either tone can be suppressed

Additional Modulation
Available for 0% DDM from an internal or external modulation source

SUM OF DEPTH OF MODULATION (SDM)

SDM Range
0 to 99.9% in 0.1% steps representing the arithmetic sum of each tone depth

SDM Selection
By keyboard entry of data and variation by UP/DOWN keys or rotary control

RF Accuracy of SDM
±2% of SDM setting for carrier frequencies up to 400 MHz (from 100 MHz to 400 MHz with Option 12)
At 40% SDM accuracy is ±0.8% depth
At 80% SDM accuracy is ±1.6% depth

DIFFERENCE IN DEPTH OF MODULATION (DDM)

DDM Range
0 to 20% in 0.01% steps
20 to 99.9% in 0.1% steps

DDM Selection
By keyboard entry of depth in %, mA or index and variation by UP/DOWN keys or rotary control

RF Accuracy of DDM
±0.02 of DDM setting ±0.0003 DDM _(0.03% depth)
At 0 DDM (on course) accuracy is ±0.0003 DDM (0.03% depth)
At 0.155 DDM accuracy is ±0.0034 DDM (0.34% depth)

LF Output
Available from the LF Output connector

LF Accuracy of DDM
Equivalent to ±0.0003 DDM ±0.005 of setting
At 0 DDM (on course) accuracy is ±0.0003 DDM

MARKER BEACON MODE
Provides default carrier of 75 MHz, 95% AM depth and a modulation frequency of 400 Hz, 1.3 kHz or _3 kHz corresponding to Outer, Middle and Inner Markers. Carrier frequencies, AM depth and modulation frequency can be adjusted from the default values.

VOR MODE

Selection
By keyboard entry of depth and variable by UP/DOWN keys and rotary control

Bearing Control
Relative phase of 30 Hz tone and subcarrier modulation adjustable from 0° to 359.9° in 0.01° steps by entering VOR bearing. Bearing can be entered as TO or FROM the beacon.

Bearing Accuracy
±0.05°

Additional modulation
Available on 0° bearing from an internal or external modulation source

AM Depth Accuracy
±3% of setting ±0.5% for carrier frequencies up to 400 MHz (from 100 MHz to 400 MHz with Option 12)

Frequency
The VOR repetition frequency of 30 Hz may be varied in 0.1 Hz steps. The subcarrier frequency and deviation maintain a fixed relationship with the VOR repetition rate.

Frequency Accuracy
As frequency standard
9.96 kHz subcarrier

AM Range
0 to 49.9% depth in 0.1% steps

Modulation
Frequency modulated by a 30 Hz tone with settable deviations of 420 Hz, 450 Hz, 480 Hz, 510 Hz and 540 Hz

30 Hz TONE

AM Range
0 to 49.9% depth in 0.1% steps
Arithmetic sum of 30 Hz tone and subcarrier limited to 99.8%

ADF MODE
Provides a default carrier of 190 kHz with 30% AM depth at a 1 kHz rate. Carrier frequency, AM depth and rate, and RF level can be varied from the default values.

SELCAL MODE
Provides a facility for modulating the carrier frequency with sequential calling tones defined by the SELCAL protocol. The entry of two character pairs is permitted that define the SELCAL code generated to open the audio path of aircraft radios. Default tone duration and gap are 1s and 250 ms respectively and can be varied from nominal values.

DME Specification - Option 10

Specifications remain as standard 2030 series with the following additions.

DME MODE

RF OUTPUT

Frequency Range
960 MHz to 1215 MHz

Level Range
-110 dBm to +10 dBm

Absolute Level
Accuracy Standard level error ±0.5 dB

Pulse Pair level Accuracy
±0.5 dB

ON-OFF Ratio
>80 dB

VIDEO OUTPUT

(REAR PANEL BNC)

Pulse Characteristics
Double pulses, Gaussian shaped

Pulse Width
2.50 µs to 8.00 µs, resolution 50 ns

Rise Time
0.80 µs to 5.75 µs, resolution 50 ns

Fall Time
1.50 µs to 5.75 µs, resolution 50 ns

Pulse Pair Spacing
9.00 µs to 45.00 µs, resolution 50 ns

Repetition Rate
10 pp/s to 6000 pp/s

Level
Pseudo TTL (Typically 0 to 4.5 V, 0 to 2.5 V into 50 Ω)

SYNC OUTPUT (REAR PANEL BNC)

Pulse Width
Typically 400 ns

Level
TTL (Typically 0 to 4.5 V, 0 to 2.5 V into 50 Ω)

Rise/Fall Time
Typically 5 ns

EXTERNAL TRIGGER (PULSE INPUT)

Characteristics
Rising-edge, TTL level into 50 Ω
Min. pulse width 2 ns

Trigger to SYNC Delay
Typically 60 ns

Jitter
Typically 25 ns

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Part no. 46891/901
Issue 1