NIGERIA CIVIL AVIATION AUTHORITY

# ADVISORY

CIRCULAR

AC: NCAA-AC-ANS(AET)004
JANUARY 2026

# GUIDANCE ON TESTING AND CHECKING OF RADIO NAVIGATION AIDS

Date: 26/02/26

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NIGERIA CIVIL AVIATION AUTHORITY
(NCAA)

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# GUIDANCE ON TESTING AND CHECKING OF RADIO NAVIGATION AIDS

## GROUND-BASED TESTING OF RADIO NAVIGATION SYSTEMS

## 1.0 PURPOSE

*This Advisory Circular (AC) is intended to provide general guidance on the extent of testing and inspection normally carried out to ensure that radio navigation systems meet the provision in Nigerian CARs Part 14.*

## 2.0 REFERENCES

2.1 Civil Aviation Act 2022 section 67 (a)
2.2 Nigeria Civil Aviation Regulation .14.7.1.7 (a) (1- 5)

## 3.0 GENERAL

3.1 This chapter is intended to provide general guidance on the extent of testing required to be carried out to ensure that radio navigation systems meet the requirements of Nigeria CARs Part 14.7

## 4.0 GROUND VERSUS FLIGHT TESTING/ INSPECTION

4.1 Ground tests are carried out by trained personnel using appropriate test equipment at the facility or at a remote point on the ground from the site. Flight tests are those carried out in the air by trained personnel using suitably equipped aircraft.
4.2 Ground testing usually provide a quick means of evaluating facility performance, while Flight tests are required to examine the signals-in-space as received by the aircraft.

4.3 Ground testing is normally carried out more frequently and can be used as indicators to determine when flight inspection is required

## 5.0 CATEGORIES AND PRIORITIES OF GROUND TEST/ INSPECTION

5.1 The period between test/inspections of a new facility should be short during the early months of operation and may be extended as satisfactory performance is gained.
5.2 *Site proving:* Tests carried out at proposed sites for the ground element of radio navigation aids to prove suitability.
5.3 *Initial proof of performance:* A complete inspection of the facility after installation and prior to commissioning to determine whether the equipment meets the Standards and specifications.
*5.4 Periodic:* Regular or routine inspections carried out on a facility to determine whether the equipment continues to meet the Standards and specifications.
5.5 *Special:* Tests after a failure of the facility or other circumstances that indicate special testing is required. Special tests will often result in appropriate maintenance work to restore the facility and in a special flight inspection, if required.

## 6.0 NOTIFICATION OF CHANGE OF STATUS

6.1 Notification of a change of the facility status is to be done through appropriate Aeronautical Information Publications.

6.2 Day-to-day changes in the status of facilities are to be promptly and efficiently reported. A change in the status of a commissioned facility as a direct result of ground or flight inspection procedures, and resulting in a "usable" ("unrestricted", "limited", or "restricted") or "unusable" designation, should be reported immediately by air traffic control (ATC) personnel to enable the prompt issue of a NOTAM.

6.3 A facility having an "unusab1e" status is normally withdrawn from service and can operate only on test basis or for troubleshooting purposes.

6.4 Particular attention should be given to periodic or corrective maintenance procedures that involve false guidance signals being temporarily radiated. These conditions should be coordinated with ATC and promulgated to users by NOTAM.

## 7.0 GROUND TEST EQUIPMENT REQUIREMENTS

The selection and utilization of special ground equipment used to determine the validity of navigation information should minimize the uncertainty of the measurement being performed. This equipment should be periodically calibrated to ensure traceability of measurements to appropriate standards.

## 8.0 COORDINATION BETWEEN GROUND AND FLIGHT TESTING/ INSPECTION

8.1 Comparison of the results obtained during successive tests on the ground and in the air can determine the extent of degradation in the performance of the equipment as monitored on the ground. These results can also be used to determine the choice of the periodicity of the flight test/inspection.

8.2 Flight test/inspection may involve a coordinated effort with ground specialists who may make adjustments, or participate in the flight test/inspection. An effective two - way communications should be established between ground and air. An additional VHF transceiver is often installed in the flight inspection aircraft and a portable unit is employed at the facility to provide these communications without interfering with the air traffic control channel.

## 9.0 DOCUMENTATION CONTROL

9.1 Retention of data is required in order to permit trend analysis of the ground and airborne flight inspection test results. Such analysis will assist in the identification of fault conditions or substandard performance before development of any safety hazard. Examples of items that might be identified in this way are: a decreasing mean time between outages (MTBO); a slow drift in one or more radiated parameters; or a specific component that may appear to have a high failure rate.

## 10.0 GROUND INSPECTION PERIODICITY

10.1 Many factors influence the choice of appropriate intervals for ground tests. These include the reliability and stability of operation of the equipment, the extent of ground monitoring, the degree of correlation between ground and flight measurements, changes in the operating environment, manufacturer recommendations, and the quality of maintenance. The complete programme of ground inspections should be considered when determining test intervals.

## 11.0 VERY HIGH FREQUENCY OMNIDIRECTIONAL RADIO RANGE (VOR)

### 11.1 General

11.1.1 This part provides guidance on the ground check/test requirements applicable to both conventional (CVOR) and Doppler (DVOR).

### 11.2 GROUND TESTING

11.2.1 The following paragraphs contain information and guidance for establishment of an orderly maintenance programme for VOR facilities. A maintenance programme consists of standardized:

a) periodic performance tests to determine if the facility is operating in accordance with established criteria;

b) equipment adjustment procedures;

c) periodic formal facilities inspections;

d) logistic support procedures; and

e) equipment modification as required.

## 11.3 Ground test procedures

11.3.1 The VOR should be inspected in accordance with the manufacturer's recommended procedures. The following procedures provide guidance for testing of VOR specific parameters as specified in Nig.CARs.14.7.1.

11.4 ***Rotation***

Correct rotation should be confirmed. This can be performed during the measurement of a ground error curve to determine antenna pattern accuracy.

11.5 ***Sensing***

Correct sensing should be verified by checking a radial other than $O^0$ or $180^0$.

11.6 ***Frequency***

Using the frequency counter determines the transmitter carrier frequency in accordance with procedures in the equipment instruction book. If the frequency is out of tolerance, adjust it in accordance with the equipment instruction book.

11.7 **Pattern *accuracy***

11.7.1 A ground check is a means for determining course alignment errors. The actual courses produced by the VOR are compared (using monitor circuits) with simulated courses produced by a VOR test generator. Data recorded during the ground check are used to prepare a ground check error curve. It is desirable to maintain the ground check error curve (maximum positive error to maximum negative error) within approximately $2.0^{\mathbf{0}}$**.** If the facility cannot provide this level of performance, a broader value should be considered. The stability of the error curve spread is considered more important to the facility performance analysis than the magnitude of the error spread.

11.7.2 Example of procedure for conducting a ground check for a conventional VOR:

(a) Place a field detector into the $O^o$ positioner bracket and feed signals to the monitor in the normal manner.

(b) Rotate the azimuth selector of the monitor for an "on course" indication (reference and
variable signals in phase).

(c) Substitute signals from the test generator. This can be accomplished by temporarily switching the field detector and test generator cables.

d) Without changing monitor adjustments, rotate the test generator dial until an "on
course" is again established. Read and record test generator dial reading. The difference between the dial reading of the test generator and the location of the field detector is the amount of course error at that location.

e) Repeat steps a) through d) for all bracket locations.

Plot a ground check error curve (amount of error versus azimuth) on rectangular Co-ordinate graph paper.

**11.8 Establishment of reference curve at commissioning.**

11.8.1 It is desirable to prepare a reference ground check error curve immediately following the commissioning flight inspection. This curve is no different from that described above except that it is an average of three separate ground checks conducted on the same day, if possible. The reference error curve serves as a standard for comparing subsequent ground checks. The reference error curve is updated whenever courses are realigned during a flight inspection.

11. 9 ***Coverage***

11.9.1 The coverage of the facility is established at the commissioning flight inspection.

11. 10 ***Modulation***

11.10.1 The preferred method is the use of a modulation meter. If a modulation meter is not available, an oscilloscope may be used instead.

11.11 9. *960* ***Hz deviation***

11.11.1 The deviation in a CVOR may be measured at the output of the FM modulation stage or by direct measurement of the radiated signal using a modulation analyser.

11.12 *9 960* ***Hz modulation depth of the radio frequency carrier***

11.12.1 The CVOR 9 960 Hz modulation depth of the carrier frequency can be measured by directly using a modulation meter, modulation analyser, or an oscilloscope.

11. 13 In the oscilloscope method, a portion of the RF carrier (modulated by one frequency at a time) is coupled to the oscilloscope synchronized at the modulating frequency. An amplitude modulated waveform is produced from which the high ***(Emax)*** and low ***(Emin)*** points are measured.

11.14 The modulation of the carrier for a DVOR is achieved in space by the combination of the reference signal and the switched 9 960 Hz variable signal. The modulation depth should be checked using a signal derived from a field monitor. A tuned modulation analyser is required due to the lower signal strength available.

11. 15 ***30 Hz modulation depth of the radio frequency carrier***

11.15.1 The CVOR variable signal modulation level (space modulation) is a function of the ratio of sideband energy to carrier energy radiated. The procedure in the equipment instruction book should be followed for adjusting the variable signal modulation level because different means (i.e. antenna systems) are employed in producing the rotating figure-of-eight radiation pattern.

11.16 A procedure for adjusting the variable signal level that can be adapted to most VOR facilities is as follows:

a) Stop rotation of the figure-of-eight pattern.

b) Measure and record the relative field intensity (using monitor field intensity meter indications) at the two maximum field intensity points ($180^{O}$apart) in the figure-of-eight radiation pattern. One of these points will be in-phase (Max) and the other out-of-phase (Min) with the carrier RF energy.

c) Compute the modulation percentage by substituting the Max and Min quantities obtained by applying b) above.

d) Vary sideband power until the desired modulation level is attained.

11.17 Accuracy will require corrected field intensity readings obtained from a calibration curve (transmitter power output versus field detector meter indication) either furnished with the equipment or prepared by field maintenance personnel. The final setting of the 30 Hz variable signal level (course width) is determined by flight inspection.

11.18 DVOR carrier modulation depth by the 30 Hz can be measured directly using a modulation meter, modulation analyser, or an oscilloscope. All other modulation should be inhibited unless the characteristics of the modulation analyser allow individual separation of the modulating signals.

11.19 ***30 Hz modulation frequency***

11.19.1 Measure the 30 Hz modulation frequency using the frequency counter.

11.20 ***9*** *960 Hz* ***subcarrier frequency***

11.20.1 Measure the 9960 **Hz** subcarrier frequency using the frequency counter.

11.21 ***CVOR AM modulation*** *of 9960 Hz* ***subcarrier***

11.21.1 Observe the 9960 Hz subcarrier using an oscilloscope at the output of the FM modulator or after detection from a field monitor. Use the method described above to determine the AM modulation of the subcarrier with all other modulation off.

11.22 ***DVOR AM modulation*** of 9***960*** *Hz* ***subcarrier***

11.22.1 Observe the composite signal with an oscilloscope connected to a test receiver or monitor and all other modulation off. Determine the percentage of amplitude modulation using the method described above.

11.23 ***Sideband level of the harmonics of the*** *9960* ***Hz component***

11.23.1 The level of the 9960Hz harmonics can be determined by using a spectrum analyser and observing the radiated signal of the VOR from a field monitor probe.
CVOR measurements can also be made at the antenna feed point of the reference signal.

***11.24 Voice channel***

11.24.1 ***Peak modulation*** of ***voice channel.*** Connect an audio generator set to the nominal line level to the audio input of the VOR. Measure the peak modulation using a modulation meter or the oscilloscope method described above.

11.25 ***Audio frequency characteristics.*** Select a frequency of 1000Hz using an audio generator and establish a reference modulation level. Maintain the same output level from the audio generator and vary the audio frequency between 300Hz and 3000Hz noting the modulation characteristics over the range.

11.26 ***Speech effect on normal navigation function.***
Operate the VOR in normal mode with all navigation modulation present. Apply the normal audio programme and observe the station monitor for any effect on the navigation performance.

***11.27 Identification***
11.27.1 ***Speed.*** Observe the identification signal envelope using an oscilloscope. The code transmission speed can be established by measuring the period of a “dot”.

11.28 ***Repetition.*** The repetition rate can be established by counting the repetition of the code cycle over a fixed period or by measuring the time required for the completion of several cycles.

11.29 ***Tone.*** The identification tone can be measured directly using a frequency counter.

11.30 ***Modulation depth.*** Measure the modulation depth using a modulation meter or the oscilloscope method with the identification tone continuously on and no other modulation present.

11.31 ***Monitoring***
11.31.1 Two methods are available to test the monitor performance. The first method is the simulation of the monitor input signal by the use of test equipment; and the second method is the adjustment of the transmitter to provide the required test signals. The use of discrete test equipment is the preferred method. Additional monitors may be provided in different equipment types. The manufacturer’s test procedures should be followed in such cases.

11.32 ***Bearing.*** Generate a VOR signal that equates to the monitored radial. Vary the phase of the variable signal relative to the reference signal to generate a positive and negative bearing alarm. Record the phase difference.

11.33 ***Modulation.*** Apply a standard monitor input signal and vary the modulation of the 9960 Hz and the 30Hz signals to cause alarm conditions for either or both of the navigation tones.

11.34 ***Polarization***

11.34.1 This parameter is normally measured by flight inspection, but may be measured on the ground if suitable equipment is available.

11.35 ***Spurious modulation***
11.35.1 Spurious (unwanted) modulation should be as low as possible (0.5 per cent or less) to prevent possible course errors. This modulation level may be determined by comparing AC voltage indications required to produce a known modulation level (only one modulation frequency applied) with the AC voltage indications, while audio input level controls (1020 Hz, 10 kHz, and voice) are adjusted to zero. The modulation output meter may be used for these readings. Record the modulation value obtained.

11.36 ***Site infringement***
11.36.1 The site surrounding the VOR should be inspected at each maintenance visit for infringements of the clear area surrounding the facility.

11.37 **Test equipment**
11.37.1 The following is a suggested list of test equipment for use in maintaining VOR facilities:

a) oscilloscope - a bandwidth of 400MHz is recommended;

b) audio oscillator;

c) VOR test generator;

d) frequency counter;

e) modulation analyser or modulation meter;

f) wattmeter, voltage standing wave ratio indicator or through-line wattmeter;

g) probe detector, VHF;

h) spectrum analyser.

## 12.0 DISTANCE MEASURING EQUIPMENT (DME)

### 12.1 General
12.1.1 This chapter provides guidance ground testing requirements applicable to the standard distance measuring equipment (DME), as specified in Nig.CARs14.7. The basic radar principles, upon which the DME functions, are such that the accuracy of the distance indications is essentially independent of the ground equipment-radiated field pattern. Consequently, the determination of correct ground equipment

performance can largely be made with the ground monitoring and maintenance equipment in accordance with the procedures outlined in the manuals of the individual DME transponder manufacturers. While ground checks are important in ensuring the quality of a DME system, it is good practice to confirm these results by flight inspection.

12.2 **Ground Testing**
12.2,1 The frequency with which such tests should be performed should be based on experience with each type of equipment and the quality of maintenance. The procedures and test equipment to be employed in ground testing a DME transponder vary according to the commercial product involved. The appropriate manufacturer's technical manuals should be used as guidance.

12.3 **Ground test procedures**
12.3.1 The DME should be checked in accordance with the test procedures proposed in the manufacturer's equipment instruction book.

12.4 ***Transmitter frequency stability.*** Use the frequency counter to measure the transmitter frequency.

12.5 ***Pulse spectrum.*** Use the spectrum analyser to measure the spectrum of the output pulse Check and correct the modulation level (pedestal and Gaussian pulse) and adjust the transmitter stages if provided. Note the output power and pulse shape during adjustments.

12.6 ***Pulse shape.*** Use the oscilloscope to measure the shape of the output pulse.

12.7 ***Pulse spacing***. Use the oscilloscope to measure the spacing of the output pulse.

12.8 ***Peak power output***. Use the peak power meter and the calibrated load, or the variable attenuator when available, to measure the peak power output of the transmitter.

12.9 ***Peak variation***. Measure the power drop of the output pulse using the oscilloscope. The variation in power level at the peak of any pair should not deviate from the average peak power by more than +or-1 dB.

**12.10 *Transmitter pulse repetition frequency (PRF).***

12.10.1 The DME is set to a variable duty cycle or, if provided, to a constant duty cycle at commissioning. Measure the transponder reply pulse rate using the frequency counter,
following the procedure of the equipment instruction book. If the system is set to variable duty cycle, the measured reply pulse rate depends on the manufacturer's design, which will be described in the detailed technical characteristics of the equipment. In any case, it should not be less than 700 pulse pairs per second (pps), or more than 1 350 + *or - 90* pps in the absence of interrogations.

12.11 ***Receiver frequency stability***. Use the frequency counter to measure the receiver frequency in accordance with the procedure in the equipment instruction book. The accuracy of the receiver frequency depends on the accuracy of the transmitter frequency, and if provided with crystals, from their tolerances. Note that the transmitter frequency is always separated from the receiver frequency by + *or* -63 MHz**.** The sign depends on operating channel mode.

12.12 ***Receiver sensitivity***. Use the calibrated built-in or external DME test equipment to measure the on-channel sensitivity to 70 per cent reply efficiency at an interrogation rate of 30 to 40 pulse pairs per second. The receiver sensitivity can be set at commissioning to different values depending on the required output power. Use the procedures and settings of the test equipment as described in the instruction book.

12.13 ***Receiver sensitivity variation with load***. Use the calibrated built-in or external DME test equipment to measure the on-channel sensitivity to 70 per cent reply efficiency at an interrogation rate from O to 90 per cent of the maximum transponder transmission rate (depends on the requirements).

12.14 ***Receiver bandwidth.*** Use the calibrated built-in or external DME test equipment to measure the receiver sensitivity, as described in the paragraph "receiver Sensitivity", except:

a) with an incoming frequency drift of + *or* -l00 kHz from the centre frequency. Check the loss in sensitivity; and/or

b) with an incoming frequency drift of + *or* -900 kHz from the centre frequency and with a level of 80 dB above receiver threshold. Check the interrogation pulse rejection.

12.15 ***Decoder***. Use the calibrated built-in or external DME test equipment to measure the receiver sensitivity as previously described, except:

a) with a shift of 0.4 µs in the pulse spacing of the interrogation signal. Check that there is no change in sensitivity;

b) with a shift between 0.5 µs and 2 µs in the pulse spacing of the interrogation signal. Check that the loss in sensitivity is less than 1 dB; and

c) with a shift of more than 2 µs in the pulse spacing of the interrogation signal. Check the interrogation pulse rejection.

12.16 ***Time delay***. Use the calibrated built-in or external DME test equipment and the oscilloscope to measure the time between the first pulse of the interrogation to the first pulse of the reply using the 50 per cent point of the leading edge. Follow the settings of the test equipment and the procedures of the manufacturer's instruction book to make sure that the measurement is made precisely. The nominal transponder time delay is:

X-Mode: 50 µs
Y-Mode: 56 µs

Operational requirements at commissioning may justify setting the time delay to another value. It is recommended that the time delay variation be checked with different interrogation levels (from the receiver sensitivity threshold to 80 dB above the threshold) to verify that the slant distance accuracy is not dependent upon the level. Follow the procedure of the instruction book.

12.17 ***Identification.*** The identification signal consists of a series of paired pulses transmitted at a repetition rate of 1350 pps. The identification keying is pre-settable for associated or independent facilities. Use the frequency counter and a stopwatch to measure the time of the dots, the dashes, the spacing between dots and/or dashes and the spacing between consecutive letters or numerals. Check the total period of transmission of one identification code group. Check the repetition time between the code groups.

12.18 ***The automatic monitor control***. Check and verify, using the milliwatt meter, the oscilloscope and the frequency counter that the monitor RF pulse peak output signal is correct (reference calibrated level: 0dBm). Follow the test procedures of the instruction book. Use the calibrated built-in or external DME test equipment and the oscilloscope, and the test procedures in the equipment instruction book, to confirm the parameter alarm circuits operate within the tolerances. Check the indications and automatic functions for changing over to the standby transponder, or switching off the transponder, if any alarm occurs.

12. 19 ***Test equipment***

The following is a suggested list of test equipment for use in maintaining DME facilities:

a) oscilloscope, with adequate time base;

b) UHF peak power meter;

c) UHF milliwatt meter;

d) UHF load, suitable for at least 1.3 GHz and 1.3 kWp;

e) UHF frequency counter;

f) UHF directional coupler with calibrated outputs;

g) calibrated attenuator, 20 Wp, 10dB;

h) calibrated attenuator, 20 Wp, 20dB;

i) UHF spectrum analyser;

j) Built-in or external DME test equipment (supplied from manufacturer);

k) Recommended: variable UHF attenuator with calibration chart.

12.20 ***Positioning***

The increased accuracy requirements of the DME system require a reference system with accuracy better than 20 m (65 ft). A three-dimensional reference system suitable for calibration of the ILS will be adequate for DME calibration.

## 13.0 INSTRUMENT LANDING SYSTEM (ILS)

### 13.1 General

13.1.1 The purpose of this chapter is to provide guidance on ground inspection requirements applicable to the standard instrument landing system (ILS), as specified in Nig.CARs14.7.1.

### 13.2 **Ground testing**

13.2.1 Adequate monitoring, ground testing and maintenance on a routine and continuing basis should be the normal means of ensuring that the ILS signal-in-space performs within the specified tolerances and that the operational integrity and serviceability of the ILS facility is maintained. Ground testing provide awareness of long-term changes in the operational environment caused by effects such as multipath from on-airport construction activities. In practice, it has been found that certain ILS performance parameters can be determined more accurately and with greater reliability by ground measurements than through flight inspection. If the ground and flight measurements show different results, the reason for the divergence should be investigated.

### 13.3 **Ground performance parameters**

13.3.1 Ground test requirements for localizers, glide paths, and Distance Measuring Equipment (DME).

### 13.4 Ground test procedures

13.4.1 The procedures for conducting the ground testing of the parameters are intended to provide basic guidance in the method of measuring the various parameters. These procedures should not be construed as the only means of accomplishing the intended purpose; individual ANSP might find modified or new methods which better suit their requirements or local situation.

13.4.2 Independence of ground measurements and monitor equipment

In most cases, these measurements will be made using equipment other than the monitors that are a part of the normal installation. This is because a primary value of ground tests is to confirm overall monitor performance, and it is therefore desirable to make corroborative checks on monitor indications using independent equipment. However, especially where large aperture antenna systems are used, it is often not possible to place the monitor sensors in such a position that the phase relationship observed in the far field could be observed at the monitor sensing point. Therefore, it is recommended that these check measurements be made at more realistic positions. Significant differences in the correlation between the check measurements and monitor indications should always be investigated and resolved.

13.4.3 Correlation between field and monitor indications

When checks are made on the monitor indications by means of portable test equipment, the following effects should be taken into account:

a) *Aperture effect:* The extent of the near-field is a function of the aperture of the radiating antenna system.

i) *Localizer:* For apertures up to 30 m (100ft), negligible error due to the near-field effect will be introduced if measurements are made at points beyond a ten-aperture (twenty apertures preferred) distance from the localizer antenna. For larger aperture antennas, a minimum distance of twenty apertures is recommended to obtain readings that are more accurate.

ii) *Glide path:* The equipment is normally adjusted so that the signal phase relationships existing on the runway centre line at threshold or beyond are correct. For this reason, the ILS reference datum represents a good position for glide path measurement. If possible, positions on the extended runway centre line should be used. However, any location is suitable if a good correlation between the measured and far-field conditions is obtained.

*b) Ground constants:* In the near-field region the measurement accuracy may be adversely affected by changes in ground constants. Satisfactory drainage and soil stabilization would help to achieve stability.

*c) Diffracted and reflected energy:* The alignment and displacement sensitivity of the localizer and the glide path may be affected by the presence of diffracted and reflected energy. This should be taken into account when such characteristics are determined for the first time.

13.4.4 Correlation between ground and flight tests

Whenever possible, the correlation between simultaneous or nearly simultaneous ground and airborne measurement results on the same or related parameters should be analysed.

Typically, the necessary conditions for correlation of measurement results include the ready availability of proper ground maintenance test equipment, traceable calibration programmes for ground and airborne test equipment, availability of commissioning and recent test reports, and similar training between ground and airborne personnel on the meaning and value of measurement correlation receivers are used. If measurements do not agree within reasonable tolerances and cannot be resolved, actions such as tightening monitor alarm points, declassifying the facility, or removing it from service should be considered.

## 13.5 Localizer

13.5.1 *Localizer course alignment*

The measurement of localizer course alignment should be carried out in the far-field region of the localizer.

**13.5.2 *Displacement sensitivity***

Displacement sensitivity of the localizer is measured with portable test equipment located at surveyed positions in the far-field where the course structure is known and stable. These test positions are typically on opposite sides of the runway centre line at the edge of the half-course sector. The test equipment reading obtained at each position is recorded, and the displacement sensitivity is calculated in units of DDW metre as the sum of the absolute value of the two DDM values, divided by the linear distance between the two surveyed points.

**13.5.3 *Off-course clearance***

The procedure to be adopted for ground measurement of off-course clearance will vary from station to station depending upon the layout of the airfield.

**13.5.4 *Carrier frequency***

This is usually measured at the transmitter output using a dummy load tap or test point connected to a frequency counter or frequency meter. For a two- frequency system, the carriers are arranged symmetrically about the assigned frequency. Checks on those systems should be made of each frequency and of the difference between the two carriers.

**13.5.5 *Output power***

The power into the antenna system may be measured using a wattmeter, preferably of the through-line type that is capable of indicating direct and reflected power. During installation, it may be convenient to relate this power measurement to field strength at the runway threshold. This can be done by measuring field strength on the course line at the threshold (at a height of 4m (13ft) for Category II and III) and at the same time recording the power into the antenna system. Subsequently, the power should be reduced by 3dB and the resulting threshold field strength again recorded.

**13.5.6 *Tone frequency***

Measurement of tone frequency is made by use of a frequency counter or other suitable type of basic test instrument. Instructions on the method to be employed can be found in the equipment handbook. In cases where signal tones are generated from very stable sources, this measurement of tone frequency may be performed less frequently.

**13.5.7 *Modulation depth (90/150 Hz)***

The technique used to measure the modulation depths should preferably be one which analyses the waveform with both modulating tones present.

**13.5.8 *Modulation depth (I020 Hz)***

Measurement of the modulation depth of the 1020 Hz identification tone can be carried out by wave analyser comparison between the modulation depth of the 90 Hz tone and the 1020 Hz tone or by portable test equipment, which can measure it directly.

**13.5.9 *Harmonic content of the 90 and I50Hz tones***

This is measured at the transmitter cabinet using a detector feeding a wave analyser from which a value is obtained on a root mean square (RMS) calculation basis.

13.5.10 Measurement of the relative phase between the 90 and150Hz tones can most conveniently be made using one of the commercially available instruments specifically designed for this purpose. Where two frequency carrier systems are used, the relative phase of the 90/150 Hz tones should be checked separately for each system. An additional check of the relative phase of the two 90 Hz and two 150 Hz tones should then be carried out.

**13.5.11 ILS *carrier frequency and phase modulation***
In addition to the desired 90 Hz and 150 Hz AM modulation of the ILS RF carriers, undesired frequency modulation (FM) and/or phase modulation (PM) may exist. This undesired modulation may cause centering errors in ILS receivers due to slope detection by a ripple in the intermediate frequency (IF) filter pass-band.

13.5.12 One method of measuring this undesired FM And/or PM is to use a commercial modulation meter. The RF input to the modulation meter may be taken from any convenient RF carrier sampling point on the ILS transmitter. The modulation meter and its connecting cables should be well screened, since any unwanted pickup of sideband radiation may be interpreted as FM or PM. It is preferable to use a sampling point with a high signal level and place an attenuator directly on the input socket of the modulation meter.

13.5.13 *Monitoring system operation*
This test is essentially a check on the overall executive operation of the monitor systems. The total time periods specified are never-to-be-exceeded limits and are intended to protect aircraft in the final stages of approach against prolonged or repeated periods of localizer guidance outside the monitor limits. For this reason, they include not only the initial period of outside tolerance operation but also the total of any or all periods of out-of-tolerance radiation, which might occur during action-to-restore service, for example, in the course of consecutive monitor functioning and consequent changeover(s) to localizer equipment(s) or elements thereof. The intention is that no guidance outside the monitor limits be radiated after the time periods given, and that no further attempt be made to restore service until a period in the order of 20 seconds has elapsed.

13.5.14 *Monitor course alignment alarm*
The purpose of this check is to ensure that the monitor executive action occurs for a course alignment shift of the distances as specified.

13.5.15 *Monitor displacement sensitivity alarm*
The purpose of this check is to ensure that the monitor displacement sensitivity alarm action occurs for changes in displacement sensitivity.

13.5.16 *Monitor power reduction alarm*
The purpose of this check is to ensure that the monitor power reduction alarm action occurs for the change in power.

13.5.17 *Far-field monitor*
A far-field monitor usually consists of a number of antennas and receivers located at the middle marker-to-threshold region to provide continuous measurement of localizer parameters for ground inspection purposes. It may also function as a monitor of course position, and optionally, of course sensitivity.

### *13.6 Glide path*

13.6.1 *Path angle*
The recommended means of measurement of a glide path angle (e) is by flight test. However, it may be measured on the ground either at the normal monitoring location or at a distance of at least 400 m (1200 ft) from the transmitting antenna, preferably on the extended centre line of the runway.

13.6.2 *Displacement sensitivity*
The recommended means of measurement of displacement sensitivity is by flight test. However, ground measurement of this parameter should be made using the method described for the glide path angle, but test antenna heights should be determined additionally at which 0.0875 DDM occurs below and above the glide path. The heights obtained will enable figures to be derived for the representative standard upper and lower half-sector displacement sensitivities at the position at which the checks are made.

13.6.3 *Clearance below path*
Ground measurement of below path clearance is not normally required for null reference systems. For other systems the measurement may be made as described for the glide path angle. Test antenna heights should be determined and DDM values recorded to enable a curve to be plotted showing DDM between 0.38 and the lower half-sector. From the curve of DDM versus angle plotted, the representative standard clearance below path performance may be obtained. A value of 0.22 DDM should be achieved at an angle not less than 0.30 above the horizontal. However, if it is achieved at an angle above 0.458, the DDM value should not be less than 0.22 at least down to 0.450.

13.6.4 ***Carrier frequency***
This test is the same as for the localizer (13.5.4).

13.6.5 ***Output power***
This test is the same as for the localizer (13.5.5), except that the threshold power measurements should be made at the zero DDM height.

13.6.6 ***Tone frequency (90/150** Hz)*
This test is the same as for the localizer (13.5.6).

13.6.7 ***Modulation depth (90/150** Hz)*
This test is the same as for the localizer (13.5.7).

13.6.8 ***Harmonic content of the 90 and I50 Hz tone***
This test is the same as for the localizer (13.5.9).

13.6.9 ***90/150 Hz phasing***
This test is the same as for the localizer (13.5.10).

13.6.10 ***ILS carrier frequency and phase modulation***
This test is the same as for the localizer (13.5.11).

13.6.11 ***Monitor system operation.***
This test is the same as for the localizer (13.5.13).

13.6.12 ***Monitor angle alarms***
The purpose of this check is to ensure that the monitor executive action occurs for a change in glide path angle. Some facilities may require monitor executive limits to be adjusted to closer limits than those specified in the table because of operational requirements. One of the following methods may be used:

a) The alignment of the ILS glide path may be offset by the operation of a control in either the transmitter cabinet or antenna system, as may be appropriate, to the particular installation under examination. At the point where the monitor system indicates that an alarm condition has been reached, measurement of the resulting far-field path alignment should be accomplished. This test should, where possible, be carried out at the time of the path alignment check.

b) The measurement of the path alignment alarm may be carried out by the application of a precision ILS signal generator to the monitor input. The correlation between the resulting alarm indication and the location of the glide path in the far-field should be carried out periodically.

13.6.13 ***Monitor displacement sensitivity alarm***
The purpose of this check is to ensure that the monitor displacement sensitivity alarm action occurs for changes in displacement sensitivity.

13.6.14 ***Monitor power reduction alarm***
This test is the same as for the localizer (13.5.16).

13.6.15 **Test equipment**
The test equipment inherent errors should be at least five times smaller than the tolerances.

13.6.16 **Test equipment list.**
The following recommended list of test equipment, or equivalent, is necessary to make the measurements described in this chapter:

a) a frequency meter covering the 75, 108-112, and 328-336 MHz bands and having an accuracy of at least 0.001 per cent;

b) an audio frequency meter or standard frequency source having an accuracy of at least 0.5 per cent for the modulating frequency measurement;

c) a modulation meter or oscilloscope for modulation percentage measurement;

d) an audio wave analyser or a spectrum analyser for harmonic distortion measurements;

**13.7 Commissioning and categorization**

13.7.1 ***Inspections***.

The basic type of inspection, serving either of these purposes, is a comprehensive inspection designed to obtain complete detailed data relating to facility performance and to establish that the facility, as installed, will meet the operational requirements. This type of inspection is conducted under the following circumstances:

a) *Commissioning:*

i) *Initial.*
Prior to initial commissioning of an ILS;

ii) *Recommissioning.*
After relocation of an antenna or installation of a different type of antenna or of transmitting equipment;

b) *Categorization.* At the time when categorization of an ILS is required.

13.7.2 *Periodic inspections.* These are regularly scheduled flight inspections conducted to determine whether the facility performance continues to meet standards and satisfy its operational requirements. Typically, the transmitters are flown in both normal and alarm conditions, and path structure is evaluated. If the available flight inspection equipment dictates that the structure cannot be measured during every periodic inspection (e.g. theodolite equipment is not available), then the structure should be measured every other periodic inspection as a minimum.

## 14.0 NON-DIRECTIONAL BEACON (NDB)

### 14.1 INTRODUCTION

14.1.1 A non-directional beacon (NDB) (also called a low- or medium-frequency homing beacon) transmits non-directional signals, primarily via ground wave propagation, whereby a pilot can determine the bearing to the ground beacon and "home-in" on it. These facilities operate on frequencies available in portions of the band between 190 and 1750 kHz with keyed identification and optional voice modulation. The airborne receiver installation is usually called an Automatic Direction Finder (ADF).

### 14.2 GROUND TESTING

### 14.2.1 General

The purpose of ground testing is to ensure that the NDB radiates a signal, which meets the requirements of Nig.CARs14.7., on a continuing basis. Since NDB equipment varies greatly, it is not possible to define detailed tests applicable to all types. Therefore, only a high-level description of the tests is provided. Refer to the manufacturer's recommendations for additional tests and detailed procedures for specific equipment.

## 14.3 Ground test procedures

### 14.3.1 Test equipment

14.3.1.1 ***Test equipment list.*** The following test equipment is recommended for NDB ground maintenance:

a) Frequency meter, standard, or counter with an accuracy of at least 0.001 per cent (for carrier frequency);

b) RF thermocouple ammeter (if not part of the equipment), for measuring the antenna current;

c) distortion meter or wave analyser, for audio frequencies distortion;

d) frequency meter or standard frequency source with an accuracy of at least 0.5 per cent (for identification frequency measurement) - this instrument can typically be the same as used in a) above;

e) modulation meter or oscilloscope for modulation percentage measurements; and

f) field intensity meter where ground field strength measurements are to be made or where an airborne field strength installation is to be calibrated. The field intensity meter can also be used to check for the radiation of spurious harmonics from the NDB.

## 15.0 PRECISION APPROACH RADAR (PAR)

## 15.1 INTRODUCTION

15.1.1 Precision approach radar (PAR) is the part of the precision approach radar system that provides the range, azimuth and elevation data when the aircraft is in the final stages of approach. The surveillance radar element (SRE), when installed, provides the orientation information required to direct the aircraft to the correct position and altitude so that the final approach can be instituted.

## 15.2 GROUND TESTING

The operation of the PAR involves an air traffic controller, it is important that this person be satisfied and confident in the operational validity of the equipment performance. Should conflict exist between the technical criteria and operational confidence, prompt action should always be taken to verify the system and resolve questionable factors.

## 15.3 Ground performance

15.3.1 **parameters**

Ground testing of a PAR requires that certain tests be done periodically. The following text presents general performance tests that may be used. These should be modified to conform to the specific manufacturer's recommendations, tolerances, and experience with the specific equipment being maintained.

## 15.4 Ground test procedures

The ground test procedures described here are in general terms. Detailed test procedures should conform to the manufacturer's equipment manuals and will tend to vary considerably with the equipment being tested.

## *15.5 Procedures*

15.5.1 ***Panel meter readings.*** The equipment is usually provided with front panel meters or computerized readouts that allow regular checking of power supply and other voltages, as well as selected current figures for important circuits. These readings should be recorded and analysed to detect gradual changes in circuit performance and indications of possible future failures. Any out-of-tolerance readings obtained should be investigated and corrected.

15.5.2 ***Transmitter power output.*** Many PAR transmitters have included a power monitor unit that allows direct measurement of average RF power output. As the power is affected by the pulse width and pulse repetition frequency (PRF), these two tests should be carried out at the same time. If a power monitor unit is not part of the equipment, it will be necessary to have a power meter and associated thermistor mount, wave-guide coupler and variable attenuator to make this measurement.

15.5.3 ***Transmitter pulse width.*** The transmitter pulse width is measured using an oscilloscope triggered from the PAR trigger pulse with a calibrated time base of approximately 5µs/cm. The detected pulse output from the transmitter is fed to the vertical input of the oscilloscope and a
suitable vertical sensitivity position selected to produce near full vertical scale deflection. The pulse width is measured between the 50 per cent levels at the leading and trailing edge of the pulse.

15.5.4 ***Transmitter*** PRF. After measuring the pulse width, the oscilloscope time base is switched to a position suitable for measurement of the PRF. For instance, for a PRF of 3 850 pulses per second, 260 µ**s** between pulses, a time base of 50µs/cm would be suitable. The PRF is measured between the 50 per cent levels of two successive pulses.

15.5.5 ***Waveform measurements.*** The waveforms at the various test points indicated on the equipment can be a valuable source of information regarding the equipment

operation. These waveforms should be viewed on the oscilloscope and compared to the expected waveform.
The correct setting for the oscilloscope will vary with the waveform and equipment. Normally, it will be necessary to trigger the oscilloscope from the PAR trigger pulse.

15.5.6 ***Transmitter frequency.*** **A** wave meter used in conjunction with a suitable indicating device, or a digital counter, may be used to measure transmitter frequency. A signal is obtained from the waveguide coupler, passed through the wave meter and after amplification (if necessary) is viewed on an oscilloscope. As the wave meter is tuned through its band, the display signal is viewed to detect minimum signal (some wave meters display maximum signal). As the minimum is reached, the transmitter frequency is read off the wave meter dial, applying any correction necessary. If the transmitter is off-frequency, it will be necessary to replace the local oscillator.

15.5.7 ***Receiver performance.*** The operation of the receiver is usually characterized by two basic checks, noise figure and minimum discernible signal **(MDS).**

a) The noise figure is checked with the aid of a noise source and a noise meter. The noise source is inserted into the receiver at an appropriate point in the waveguide (through a waveguide switch) and the output of the IF amplifier applied to the noise meter. The noise source and meter must be compatible and the calibration of the noise meter carried out as per the manufacturer's instructions.

b) The **MDS** of the receiver system is measured by injecting a known signal level into the receiver through appropriate attenuators and measuring the point at which the IF output pulse disappears into the noise. The attenuation between the signal source and the receiver is increased until the signal at the output of the IF amplifier just disappears. The input signal level could be determined by use of a power meter and the attenuation can be read from the attenuator dial. The resulting input **MDS** level can then be determined.

15.5.8 ***Receiver noise level.*** The voltage level of the noise ("grass") at the output of the IF amplifier is usually specified. This level is set by viewing the IF output on an oscilloscope and adjusting the appropriate controls. If sensitivity time control is provided on the equipment, its
operation in eliminating the noise over the appropriate ranges may be checked at this time.

15.5.9 ***Receiver bandwidth.*** The receiver bandwidth may be checked using the same Set-up as for the local oscillator tuning, provided suitable frequency markers are available on the sweep generator. When the local oscillator has been tuned to provide the correct pulse from the IF amplifier, the marker pulses are superimposed and adjusted until they coincide with the 3 dB points on the IF pulse.

15.5.10 ***Observing the PAR display.*** The daily observation of the PAR display should include a check on the operation of all console controls, adequacy of the presented picture, accurate superimposition of the up and down scan frames, the presence of all range, elevation and azimuth marks.

15.5.11 ***Console high voltage check***. This check is carried out using a vacuum tube voltmeter (VTVM) and a high-voltage probe. Due to the high voltage present (approximately 15 kV), the check should be carefully done by switching off the high voltage before connecting the probe. If the reading of high voltage is not correct, it should be adjusted accordingly.

***Inspection and modifications***

15.5.12 Periodic inspection of the PAR facility should be conducted to ensure that local maintenance staff are complying with directives and providing an adequate level of maintenance. This is also desirable from the point of view of keeping current with field experience with the equipment, so that problems can be investigated and corrected. The repeated requirement for adjustment or repair of some features of the PAR equipment may be an indication that modification is required. The Authority shall approve standard modifications once they have been shown to improve operation or serviceability.

15.5.13 *Ground personnel requirements.* The following personnel are required on the ground:

a) one controller to monitor the radar console;

b) two technicians to carry out the functions required from the theodolite. One is required to track the flight check aircraft with the cross hairs of the instrument and the other to monitor the elevation or azimuth vernier scales and advise the pilot of the aircraft's position in relation to the glide path or the centre line of the runway and record the deviations.