Carrier frequency

4.2.12 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.

Output power

4.2.13 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 4 m (13 ft) for Category II and III) and at the same time recording the power into the antenna system. Subsequently, the power should be reduced by 3 dB and the resulting threshold field strength again recorded.

Tone frequency

4.2.14 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.

Modulation depth (90/150 Hz)

4.2.15 Modulation depth is probably one of the most difficult quantities to measure to the required accuracy, and only high precision instruments should be used. The technique used to measure the modulation depths should preferably be one which analyses the waveform with both modulating tones present. If the measurement can only be made with one tone present, care should be taken to ensure that:

a) the individual tone amplitude is not affected by the removal or the addition of the other tone;

b) the modulator remains linear with both tones present; and

c) the harmonic content of the tone is as low as possible.

Modulation depth (1 020 Hz)

4.2.16 Measurement of the modulation depth of the 1 020 Hz identification tone can be carried out by wave analyser comparison between the modulation depth of the 90 Hz tone and the 1 020 Hz tone or by portable test equipment, which can measure it directly. The wave analyser is tuned to 90 Hz and the scale amplitude is noted. The wave analyser is then tuned to 1 020 Hz and the modulation depth of the 1 020 Hz is adjusted to the appropriate proportion of the 90 Hz reading.

Harmonic content of the 90 and 150 Hz tones

4.2.17 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. For future checks a distortion factor meter may be used, however, this can indicate a higher value of distortion than that contributed by the harmonics themselves.

90/150 Hz phasing

4.2.18 Measurement of the relative phase between the 90 and 150 Hz 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.

4.2.19 When such equipment is not available, a check that the 90/150 Hz phase is within the required tolerance can be made on the combined waveform using the following oscilloscope technique:

a) with the modulation balance adjusted for the zero DDM tone condition, adjust the oscilloscope time-base to give a locked display of the combined tones, such that four adjacent positive peaks of the waveform are simultaneously visible — two of a larger, equal or nearly equal amplitude, and two of a smaller, equal or nearly equal amplitude;

b) measure, as accurately as possible, the amplitudes of the two largest peaks; and

c) divide the lesser amplitude by the larger amplitude (for a ratio less than or equal to unity). The 90/150 Hz phasing is within tolerance if the ratio is greater than 0.903 for Category I and II localizers or greater than 0.951 for Category III localizers. (Note that any distortion of the tones will degrade the accuracy of the result.)

4.2.20 To measure the phase between the 90 Hz or 150 Hz tones of the two transmitters of a two-frequency system, connect the modulation signal from each transmitter to a separate oscilloscope channel. Configure the oscilloscope to display both channels simultaneously, such that the waveform for the transmitter that leads the other in time crosses the zero amplitude line at a convenient reference point on the horizontal axis. Measure the difference in time between the two waveforms at the point at which they each cross the zero amplitude line, and convert that time to degrees-of-phase for comparison with the tolerance.

ILS carrier frequency and phase modulation

4.2.21 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 centring errors in ILS receivers due to slope detection by a ripple in the intermediate frequency (IF) filter pass-band.

4.2.22 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.

4.2.23 The audio filters used in the modulation meter should have a bandwidth at least as wide as the tone filters used in ILS receivers. This is necessary to ensure that undesired FM and/or AM on frequencies other than 90 Hz and 150 Hz, which could affect an ILS receiver, will be measured by the modulation meter. For standardizing these measurements, the recommended filter characteristics are given in the table below.

Recommended filter characteristics for FM/PM measurement

Frequency (Hz)	*90 Hz band-pass filter attenuation dB*	*150 Hz band-pass filter attenuation dB*
45	10	16
85	0.5	(no spec.)
90	0	14
95	0.5	(no spec.)
142	(no spec.)	0.5
150	14	0
158	(no spec.)	0.5
300	16	10

Monitoring system operation

4.2.24 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 change-over(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.

Monitor course alignment alarm

4.2.25 The purpose of this check is to ensure that the monitor executive action occurs for a course alignment shift of the distances specified in Table I-4-4 (90 and 150 Hz side). One of the following methods may be used:

a) The alignment of the ILS localizer course line 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 course alignment should be verified to be in accordance with Table I-4-4. This test should, where possible, be carried out at the time of the course alignment check.

b) The measurement of course alignment alarm may be carried out by the application of a precision ILS signal generator to the monitor input.

Monitor displacement sensitivity alarm

4.2.26 The purpose of this check is to ensure that the monitor displacement sensitivity alarm action occurs for changes in displacement sensitivity specified in Table I-4-4. One of the following methods may be used:

a) The ILS localizer course width may be adjusted by operating a suitable control (width control) until the monitor system indicates that a wide alarm condition has been reached. When an alarm is indicated, the displacement sensitivity in the far-field should be verified to be in accordance with Table I-4-4. Following this measurement, the width control setting needed to initiate the narrow alarm is selected and displacement sensitivity again measured using the ILS test method as described above.

b) The measurement of displacement sensitivity alarm may be carried out by the application of a precision ILS signal generator to the monitor input.

Monitor power reduction alarm

4.2.27 The purpose of this check is to ensure that the monitor power reduction alarm action occurs for the change in power specified in Table I-4-4. The ILS localizer output power is reduced by operation of a suitable control (transmitter output power) until the monitor system reaches an alarm condition. At this point, the output power should be measured. A calibrated signal generator input into the monitor can also be used for this measurement.

Far-field monitor

4.2.28 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. The far-field monitor indications are normally readily available to the ground maintenance staff to facilitate the assessment of localizer performance. A continuous logging or display of localizer parameters is preferred. In the interpretation of the results, it should be remembered that the indications will be disturbed by aircraft overflying the localizer and far-field monitor as well as other vehicle movements at the airport. Periodically, the correlation between the far-field monitor and the localizer signal-in-space should be established.

Glide path

Path angle

4.2.29 The recommended means of measurement of a glide path angle (θ) is by flight test. However, it may be measured on the ground either at the field monitoring location or at a distance of at least 400 m (1 200 ft) from the transmitting antenna, preferably on the extended centre line of the runway.

4.2.30 The measurement location used will depend on the type of glide path, its monitoring system and the local site conditions. Where there is no field monitoring, or where the signal at the monitor location may be affected by local conditions, e.g. accumulation of snow, change in ground characteristics, etc., then the angle measurements should be made at least 300 m (1 000 ft) in front of the glide path as suggested above. In any case, it is preferable at the time of commissioning to measure the glide path parameters at this location for future reference.

4.2.31 When measurements are made beyond the normal monitoring location, a portable ILS ground checking installation should be used comprising a vehicle or trailer suitably equipped for measuring glide path signals. The facilities should include lifting gear to enable the antenna of the test receiver to be raised to a height of at least 22 m (70 ft). Means should be provided for determining the height of the test antenna above ground level to an accuracy of ±5 cm (±2 inches). The figures obtained as a result of this test may differ from those derived from an in-flight measurement, by an amount which will depend on the siting of the test equipment relative to the transmitter antenna and the type of transmitting equipment used.

Displacement sensitivity

4.2.32 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.

Clearance below path

4.2.33 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 0.3θ 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 0.3θ above the horizontal. However, if it is achieved at an angle above 0.45θ, the DDM value should not be less than 0.22 at least down to 0.45θ.

Carrier frequency

4.2.34 This test is the same as for the localizer (4.2.12).

Output power

4.2.35 This test is the same as for the localizer (4.2.13), except that the threshold power measurements should be made at the zero DDM height.

Tone frequency (90/150 Hz)

4.2.36 This test is the same as for the localizer (4.2.14).

Modulation depth (90/150 Hz)

4.2.37 This test is the same as for the localizer (4.2.15).

Harmonic content of the 90 and 150 Hz tone

4.2.38 This test is the same as for the localizer (4.2.17).

90/150 Hz phasing

4.2.39 This test is the same as for the localizer (4.2.18).

ILS carrier frequency and phase modulation

4.2.40 This test is the same as for the localizer (4.2.21).

Monitor system operation

4.2.41 This test is the same as for the localizer (4.2.24).

Monitor angle alarms

4.2.42 The purpose of this check is to ensure that the monitor executive action occurs for a change in glide path angle specified in Table I-4-5 (90 and 150 Hz side). 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 verified to be in accordance with Table I-4-5. 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.

Monitor displacement sensitivity alarm

4.2.43 The purpose of this check is to ensure that the monitor displacement sensitivity alarm action occurs for changes in displacement sensitivity specified in Table I-4-5. One of the following methods may be used:

a) The ILS glide path width is adjusted by operating a suitable control (width control) until the monitor system indicates that a wide or narrow alarm condition has been reached. When an alarm is indicated, the displacement sensitivity in the far-field should be verified to be in accordance with Table I-4-5. Following this measurement, the width control setting needed to initiate the alternate alarm is selected and displacement sensitivity again measured using the test method as described above.

b) The measurement of displacement sensitivity alarm may be carried out by the application of a precision ILS signal generator to the monitor input.

Monitor power reduction alarm

4.2.44 This test is the same as for the localizer (4.2.27).

Marker beacons

Carrier frequency

4.2.45 The carrier frequency should be checked using an accurate frequency counter to ensure that it is within tolerance. Reference should be made to the instructions supplied with the frequency counter which will give the detailed procedures for its use.

RF output power

4.2.46 Since the power output of the beacon transmitter directly affects the coverage obtained, it is important to keep the power output as close as possible to the value recorded at the time of commissioning. On most equipment, a meter is provided to read the reference output voltage (or some other measure of output power) of the transmitter. This indication may be checked by using an independent power output meter. The voltage standing wave radio (VSWR) should also be checked using the formula below based on measurements of forward and reflected powers. Any change in the output level or VSWR from its initial value at commissioning could be due to a change in the power delivered from the transmitter and/or a change in the characteristics of the antenna system. Changes should therefore be investigated, as the performance of the beacon will be affected.

$$\text{SWR} = \frac{1+p}{1-p} \text{ where } p = \sqrt{\frac{\text{Forward power}}{\text{Reflected power}}}$$

Modulation depth

4.2.47 The modulation depth can be measured using a modulation meter (it may be built into the equipment) or by an oscilloscope. Using an oscilloscope, the modulated signal from the beacon is displayed (usually by direct connection to the deflection plates), and the modulation percentage obtained by measuring the maximum and minimum of the modulation envelope. If *Amax* and *Amin* are the maximum and the minimum of the envelope respectively, then

$$\text{Modulation \%} = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} \times 100\%$$

Modulation tone frequency

4.2.48 This test is the same as for the localizer (4.2.14).

Harmonic content of modulating tone

4.2.49 This test is the same as for the localizer (4.2.17).

Keying

4.2.50 An audible indication of keying will usually be available from a test point on the equipment or monitor. The keying can therefore be checked audibly for clear, correct identification. A more exact check can be made by using a suitable oscilloscope.

Monitor system

4.2.51 The monitor system should be checked to ensure it will detect erroneous transmissions from the marker beacon. Some monitors include switching functions that permit out-of-tolerance conditions to be simulated. Detailed procedures can be found in the manufacturer's instructions.

Charts and reports

General

4.2.52 The objective of the collection and analysis of data on the various ILS parameter measurements is to build up a record-of-performance of the equipment in order to determine whether its performance objectives are being achieved. In addition, these records can show performance trends and long-term drifts which, in some cases, will enable preventive maintenance to be carried out prior to an unscheduled service outage. Although the methods used by different authorities to carry out ground inspections and the analysis of results will vary, there are certain general principles to be observed and precautions to be taken.

Equipment failure analysis

4.2.53 It is important that records be kept and an analysis be made on equipment failures and outage times to determine if the reliability objectives appropriate to the category of operation are being achieved in service. Details of the type of data to be collected and the method of analysis can be found in Attachment F to Annex 10, Volume I.

Performance analysis

General

4.2.54 In order that the performance determined from measurements over a long period will be statistically valid, unnecessary adjustments should be minimized. The equipment settings should not be modified if the parameters listed in Tables I-4-4 through I-4-6 are within 50 per cent of the given tolerance.

Analysis of alignment and sensitivity measurement

4.2.55 The localizer and glide path alignment and displacement sensitivity measurements should be analysed to determine the mean and distribution of these parameters. Some States are installing online data-processing systems, which will automatically collect and analyse these parameters and produce the performance statistics. The radiating equipment should then be adjusted so that, on a long-term basis, the mean of the parameter corresponds to the proper nominal value. The distribution should be analysed to determine whether 99.7 per cent of the measurements are contained within the “adjust and maintain” limits of Annex 10, Volume I, 3.1.3.6.1 and 3.1.3.7.3 for localizers, and 3.1.5.1.2.1 and 3.1.5.6.6 through 3.1.5.6.8 for glide paths. If this is not being achieved, then the cause needs to be investigated.

Test equipment

4.2.56 The test equipment inherent errors should be at least five times smaller than the tolerances specified in Tables I-4-4 to I-4-6.

4.2.57 *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;

e) an RF power output meter, preferably of a directional type; and

f) a portable ILS receiver.

4.3 FLIGHT TESTING

General

4.3.1 The purpose of flight testing is to confirm the correctness of essential signal-in-space parameters, determine the operational safety and acceptability of the ILS installation, and periodically correlate signal patterns observed in flight and from the ground. Since flight testing instrumentation varies greatly, only a general description of the test methodology is given below.

4.3.2 Flight tests constitute in-flight evaluation and sampling of the radiated signals in the static operating environment. The signals-in-space are evaluated under the same conditions as they are presented to an aircraft receiving system and after being influenced by factors external to the installation, e.g. site conditions, ground conductivity, terrain irregularities, metallic structures, propagation effects, etc. Because dynamic conditions, such as multipath due to taxiing or overflying aircraft or moving ground vehicles, are continually changing, they cannot be realistically flight-tested. Instead, these effects on the signal-in-space are controlled by the establishment of critical and sensitive areas and by operational controls.

Flight test performance parameters

General

4.3.3 Flight test requirements for localizers, glide paths and ILS marker beacons are listed in Tables I-4-7, I-4-8 and I-4-9. Flight test requirements for DME associated with ILS are listed in Table I-3-3.

Schedules of flight inspection

4.3.4 *Site proving inspection.* This flight inspection is conducted at the option of the responsible authority, and its purpose is to determine the suitability of a proposed site for the permanent installation of an ILS facility. It is sometimes performed with portable localizer or glide path equipment. The inspection is sufficiently extensive to determine the effects that the ground environment will have on the facility performance. The site-proving inspection is not a recurring type inspection.

4.3.5 *Commissioning and categorization 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*:

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

   2) *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.

4.3.6 *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.

4.3.7 *Special flight inspection.* This is a flight inspection required by special circumstances, e.g. major equipment modifications, reported or suspected malfunctions, etc. During special flight inspections it is usually necessary to inspect only those parameters that have or might have an effect on performance; however, in some cases it may be economically advantageous to complete the requirements for a routine or annual inspection. It is impractical to attempt to define all of the purposes for which special inspections will be conducted or the extent of inspection required for each. Special inspections may also be requested as a result of ground checks of the performance, or flight inspection, in which case the nature of the suspected malfunction will guide the inspection requirements.

4.3.8 *Flight inspections following ground maintenance activities.* Certain ground maintenance activities, as well as changes in the ground environment near radiating antenna systems, require a confirming flight inspection. This is because ground measurements cannot duplicate the operational use of the signals in some respects. Although engineering judgement should be used in individual cases to prevent unnecessary costly airborne testing, the following changes typically require a confirming inspection:

a) a change in the operating frequency;

b) significant changes in the multipath environment within the antenna pattern limits;

c) replacement of antenna arrays or antenna elements; and

d) replacement of radio frequency components, such as bridges, phasers, amplifiers, and cabling, when ground measurements prior to and after the changes are not available, or the results do not support restoration without a flight inspection.

Flight test procedures

General

4.3.9 The procedures for conducting the flight inspection of the parameters listed in Tables I-4-7, I-4-8 and I-4-9 are intended to provide basic instruction for positioning the aircraft for proper measurement, analysis of performance data and application of tolerances. These procedures should not be construed as the only means of accomplishing the intended purpose; particular air navigation service providers (ANSPs) might find modified or new methods which better suit their equipment or local situation.

4.3.10 Some requirements in the procedures can be fulfilled concurrently with others, thereby enhancing the efficiency of the flight inspection.

4.3.11 During inspections, certain parameters require the use of aircraft positioning or tracking devices to provide accurate aircraft position relative to the localizer course or glide path for adequate analysis of the performance. The position of the tracking device with respect to the facility being inspected is critical to obtaining good flight inspection results. Further guidance on tracker positioning and use is given in Chapter 1.