

Specification for

General requirements for equipment for use in aircraft —

Part 4: Electrical equipment —

Section 2: Electromagnetic interference
at radio and audio frequencies

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Foreword

This British Standard is part of a composite standard in the Aerospace Series of British Standards specifying general requirements for equipment in aircraft. An introduction to the complete standard is given in BS 3G 100-0.

This 1979 revision replaces the October 1973 version of 3G 100-4.2.

A major revision of BS 2G 100-2:1962 was undertaken in 1965 and the document was published as BS 2G 100-2.2:1967. This revision included, for the first time, requirements for the use of peak measuring equipment and also requirements to check the susceptibility of sensitive avionic equipment to r.f. signals and noise both conducted along power supply wiring and radiated. This revision ensured that some degree of correlation could be demonstrated between the British Standard and the various US military specifications and standards and also RTCA DO 138 which were taken into account in the discussions leading up to the revision. The standard was updated in 1973 and published as 3G 100-4.2:1973.

This current revision takes account of the considerable experience which has been gained in laboratories and test houses in recent years and also the results of surveys which have been made to determine the electromagnetic environment in a wide range of aircraft. In addition, due account has been taken of the requirements in current USA specifications MIL-STD-461A and MIL-STD-462, RTCA DO 160 and EUROCAE Publication ED 14.

The main changes in this revision include better definition of test conditions, particularly where circuit loading is concerned, revised levels for susceptibility tests including requirements for modulated signals, and separate requirements, which are generally more onerous, for military aircraft.

It has to be emphasized that although compliance with this standard will provide considerable improvement in the operational performance of the aircraft and its equipment from the interference standpoint it does not guarantee overall electromagnetic compatibility.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 23 and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Scope

This Section of British Standard 3G 100 states the limits and methods of measurement of the electromagnetic interference which may be produced by aircraft electric, electronic and radio equipment; it also specifies the susceptibility of equipment to such interference. Tests are specified for assessing the compliance of equipment with the requirements. This section should be read in conjunction with British Standard 3G 100-0.

The individual specification for the equipment will state the particular requirements of this standard which are to be applied.

This standard does not include spike and transient phenomena the limits of which are specified in British Standard 3G 100-3.

The requirements of this standard relate to individual items of equipment, subsystems, or systems, including interconnecting wiring, as tested in a test laboratory under defined conditions.

2 References

This standard makes reference to the following standards publications:

3G 100, *General requirements for equipment for use in aircraft*.

3G 100-0, *Introduction*.

3G 100-3, *Characteristics of aircraft electrical power supplies*.

BS 727, *Specification for radio-interference measuring apparatus for the frequency range 0.015 MHz to 1 000 MHz*.

3 Definitions

For the purposes of this British Standard the following definitions apply:

3.1

interference

any electrical or electromagnetic disturbance, phenomenon, signal or emission which causes, or is likely to cause, undesired response, malfunctioning or degradation of performance of electrical and electronic equipment

3.2

narrow band interference¹⁾

a type of interference which manifests itself at a discrete frequency. Narrow band interference generally arises from the harmonics produced by equipment generating continuous oscillations. Impulsive interference which would normally be regarded as broad band can manifest itself as narrow band provided that the generation of impulses is fairly regular and that the pulse repetition frequency is comparable with or greater than the bandwidth of the measuring equipment. Narrow band interference can be identified because it is sharply tunable and will normally give equal values on average, quasi-peak and peak measuring equipment. Thus, for example, the interference from a static inverter having a fundamental switching frequency of 400 Hz would be treated as broad band when measured at frequencies greater than 150 kHz using a receiver having a 10 kHz bandwidth but would be treated as narrow band when measured at frequencies less than 150 kHz using a receiver having 200 Hz bandwidth

3.3

broad band interference¹⁾

interference which generates a spectrum of radio noise wide in relation to the bandwidth of the measuring set, and may include a pulse-modulated carrier wave. The measured values of such interference will in general differ depending on the type of voltmeter employed, i.e. average, quasi-peak or peak

3.4

conducted interference

interference reaching the point of measurement through a conductor

3.5

radiated interference

interference reaching the point of measurement by any means except by a direct connection to a conductor

3.6

aerial voltage

the voltage which exists at the terminals of an aerial connected to a measuring set having an input impedance of 50 Ω

¹⁾ Not all equipment will generate both narrow band and broad band interference.

3.7 impulse bandwidth

for an interference measuring set this is the area under its predetector amplitude versus frequency response curve divided by the maximum value of the curve. It is thus the bandwidth of an imaginary rectangular frequency response having the same area and maximum value

the bandwidth is given by the following formula:

$$\frac{1}{A_0} \int_0^\infty A(f).df$$

where

A_0 is the maximum value of the amplitude versus frequency response curve

$A(f)$ is the amplitude at any frequency f .

when measuring a broad band emission, the voltmeter reading of the measuring set is divided by the impulse bandwidth to give a measure of the spectral intensity expressed in μV or μA per kHz for the type of circuits encountered in measuring sets this is equivalent to 1.05 times the 6 dB bandwidth

3.8 susceptibility

the characteristic which causes an equipment to malfunction or exhibit an undesirable response when its case or any external lead, circuit or accessory, excepting aerials, is subjected to the specified radio frequency voltage or field

NOTE The term "immunity", which in general is the inverse of susceptibility, may replace the term susceptibility in future revisions of this British Standard.

3.9 power line

a line conveying power to or from the test sample. It does not include lines intended to carry information or instruction or, for example, leads from power supplies derived from within a group of associated equipment and which do not feed loads other than those within that group of equipment

4 Measurement

4.1 Measuring equipment. All limits of broad band interference are quoted in this standard in terms of unit bandwidth, i.e. $\mu\text{V}/\text{kHz}$, and are peak values. In general, the measuring equipment to be used shall comply with the requirements of section two of BS 727:1967. It is recognized that peak measuring receivers with alternative bandwidths can be used but it shall be established by the test authority that a valid bandwidth correction can be applied.

Measurements of clearly identifiable narrow band interference, i.e. oscillator harmonics, can be made using equipment complying with section one, two or three of BS 727:1967. When measuring narrow band interference as defined in 3.2, the receiver shall be tuned to maximum response. In cases where the nature of the interference is not clearly established, the peak measuring receiver shall be used.

All voltages measured shall be referred to 50 Ω . If the input impedance of the measuring set differs from this value, a suitable matching network shall be used and the appropriate correction factor applied.

As the impulse bandwidth of measuring sets normally differs from 1 kHz, an appropriate linear correction factor shall be applied, based upon the actual bandwidth at the test frequency.

4.2 Screened room. Measurements of radiated field strength at the levels required by this standard shall be made in a screened enclosure because of the high levels of extraneous interference from electrical equipment and broadcasting stations. All supply and load leads passing through the screen shall be adequately filtered.

NOTE To reduce standing wave patterns and cavity resonance effects in the screened room, damping materials should be installed wherever possible. It is recommended that the screened room should be not less than 3 m high $\times$ 3 m wide $\times$ 4.5 m long.

4.3 Ground plane. A rectangular ground plane shall be provided in the screened room having an area not less than 1.5 m² with its smaller side not less than 0.7 m. The ground plane shall be bonded to the screened room at points not more than 1 m apart and at its extremities. The line stabilizing networks and the test specimen shall be bonded to the ground plane.

The test sample shall be mounted on the ground plane in a manner similar to that of the installation in the aircraft. For example, antivibration mountings, if used in the aircraft, shall be used in the test.

4.4 Stabilizing network. In order to provide a power supply of a defined impedance, across which all r.f. voltages shall be measured, line impedance stabilizing networks shall be inserted in the power supply lines. Figure 1 and Figure 2 show the impedance characteristics and circuit diagram of a typical unit.

The network shown in Figure 2 shall be used at frequencies between 0.15 MHz and 150 MHz. In the frequency range 0.05 MHz to 0.15 MHz, an additional capacitor of at least 8 μF shall be connected between the supply terminal and ground. This capacitor has negligible effect on the performance of the network at frequencies above 0.15 MHz and need not be disconnected during tests at the higher frequencies.

The insertion loss of the capacitors C_1 and C_2 (0.05 μF) cannot be neglected in the frequency range 0.05 MHz to 0.15 MHz and shall be measured. The resulting correction factor shall be applied when making measurements.

4.5 Current probe. The current probe to be used in determining compliance with the requirements of this standard shall typically comply with the following requirements.

Frequency range	10 kHz to 100 MHz
Transfer impedance $\geq 3 \Omega$	between 1 MHz and 100 MHz
$\geq 1 \Omega$	at 100 kHz
$\geq 0.5 \Omega$	at 50 kHz

The probe shall be capable of handling 350 A d.c. or power frequency current without saturation and the insertion impedance on the primary circuit shall not exceed 1 Ω when the secondary is loaded by 50 Ω .

5 Measuring techniques and control of interference

5.1 Disposition of equipment. The equipment under test shall be installed on a ground plane in general accordance with the arrangements shown in Figure 3, Figure 8 and Figure 9 (see 5.2.1 and 5.3.1). It is recognized that these arrangements cannot be rigidly adhered to for all types of equipment but the arrangement used shall be agreed in a test plan.

NOTE Every effort should be made to keep the test layout as compact as possible.

The electrical power supply to be used for testing should comply as far as possible with the requirements of BS 3G 100-3, particularly in respect of power factor, harmonic content and ripple. Power shall be supplied to the test equipment through isolating or stabilizing networks and the length of lead between them shall be kept as short as practicable, the preferred length being 60 cm. All stabilizing networks shall be terminated by 50 Ω non-reactive resistors when not in use for measurement.

The equipment under test shall be mounted on the ground plane in a manner similar to that of the installation in the aircraft, (including bonding), e.g. antivibration mountings, if used in the aircraft, shall also be used in the test. Interconnecting cables between units under test shall be separated from the ground plane by not less than 5 cm.

NOTE These cables should be of the type and length to be used in the aircraft, or as recommended by the equipment manufacturer. If the length is not known, it should be taken to be 2 m. Where the cables are too long to be readily accommodated in the test arrangement, they should be coiled and placed 5 cm above the ground plane. The plane of the coil should be parallel to the ground plane.

5.2 Measurement of conducted interference

5.2.1 General. It is considered that the most satisfactory technique for the assessment of electromagnetic interference from aircraft electrical equipment is the measurement of r.f. voltage across a defined impedance. Therefore, the preferred limits and test method in this standard refer to r.f. voltage measured via line impedance stabilizing networks connected in the lines to the equipment under test.

The equipment shall, where possible, be installed in general accordance with the arrangement shown in Figure 3. Line impedance stabilizing networks shall be inserted in all power lines and shall be inserted in output power lines where practicable.

It is recognized that there will be types of equipment and circumstances in which stabilizing networks cannot be used, e.g. when the insertion of such an impedance in a control or signal line prevents the equipment under test from functioning correctly or when it is impossible to break the conductors. In these situations, alternative test methods are available, i.e. the use of the capacitive probe to measure the r.f. voltage on the line or the use of current transformers to measure the r.f. current in the line. These measurements shall be made with an installation which is as near to the final arrangement as possible since it is not practicable to define the impedance conditions under which the measurement is to be made. In particular, it is not possible to specify a constant r.f. impedance which is sufficiently low at all frequencies to ensure maximum current transfer for all items of equipment. There are items of equipment for which the installation of a large capacitor (10 μF) would seriously disturb the normal operation. The limits which are specified for the r.f. current are, as far as possible, compatible with the r.f. voltage limits and have been derived from these limits by taking realistic mean values for the circuit impedance throughout the frequency range.

It is not always practicable to use stabilizing networks in testing equipment for which many lines are involved. In such cases the current shall be measured using the current probe on all branches of multiple conductors which are to be installed in cable forms. The net r.f. current in each branch shall comply with the relevant limits.

5.2.2 *Conducted interference on power lines.*

Measurements of the r.f. voltage shall be made on power supply lines within the frequency range 0.05 MHz to 150 MHz using line impedance stabilizing networks, the impedance frequency characteristic and a circuit diagram of which are shown in Figure 1 and Figure 2, in a test circuit similar to that shown in Figure 3. The r.f. voltage limits shown in Figure 4 for broad band interference and in Figure 5 for narrow band interference shall apply but with both curves extended to 150 MHz.

In those few instances where it is not possible to install stabilizing networks, either the r.f. voltage shall be measured using a capacitive probe or the r.f. current shall be measured using a current probe. In the case of voltage the limits of Figure 4 and Figure 5, extended to 150 MHz as above, shall apply, and in the case of the r.f. current limits of Figure 6 and Figure 7 shall apply.

5.2.3 *Conducted interference on all lines other than power lines.* The measuring technique described in 5.2.1 shall apply also to control and signal lines, etc., where practicable and the results shall be assessed by comparison with the appropriate limits. Control and signal lines shall be terminated with their correct load, except that when this is not possible they shall be terminated with an r.f. impedance which is equivalent, as near as practicable, to the aircraft installation. Where this is not possible, a suitable network shall be used to simulate such impedances, consisting of 1 000 pF in series with 50 Ω and this network shall be used in cases where, for example, transducers are joined by long leads to the equipment under test.

In the case of subsidiary power lines or switch and contactor lines feeding loads which are either grounded or have capacitive suppression to ground, the line impedance stabilizing network forms an appropriate load. The bonding arrangements shall also simulate, as far as practicable, the aircraft installation. The measurement of r.f. voltage remains the preferred method but it is accepted that in certain cases it will not be possible to install line impedance stabilizing networks and in these cases either the r.f. voltage shall be measured using a capacitive probe or the r.f. current shall be measured using a current probe. In the case of voltage, the limits of Figure 4 and Figure 5 shall apply, and in the case of the r.f. current the limits of Figure 6 and Figure 7 shall apply. Equipment which is tested as a complete system comprising several units joined by multiple connecting lines shall be tested by installing the current probe on all branches of the cable form which is to be installed in the aircraft. The limits of Figure 6 and Figure 7 shall apply to the net r.f. current.

5.3 Measurement of radiated interference

5.3.1 *General.* In this subclause 5.3 the methods of measurement of the field strength radiated from sources of interference are described.

Measurement of radiated field strength at the levels required by this standard shall be made in a screened enclosure because of the high levels of extraneous interference from electrical equipment and broadcasting stations. Results of field strength measurements made in reflecting enclosures are not necessarily related to the equivalent results in free space and hence the quotation of limits in microvolts per meter cannot be rigidly defended. Nevertheless, for convenience in operation and to follow international practice, this method has been adopted. The methods of matching the aerial to the interference measuring set are not defined and the responsibility for ensuring that correction factors appropriate to the aerial tuning unit are used rests with the test establishment.

The equipment shall be installed in general accordance with the arrangement shown in Figure 8 and Figure 9.

5.3.2 *Aerials.* The limits of radiated interference imposed by this standard are quoted in decibels relative to 1 $\mu\text{V}/\text{m}$ and thus, theoretically, any aerial can be used provided that it has adequate sensitivity and that the appropriate correction factors are applied. The preferred aerials are:

- a) a 1 m vertical rod in the frequency range 10 kHz to 30 MHz;
- b) a biconical aerial used in both horizontal and vertical polarizations for the frequency range 30 MHz to 200 MHz;

- c) A log-conical aerial from 200 MHz to 1 000 MHz.

The use of alternative aerials is not excluded nor is the use of aerial tuning units to enable increased sensitivity or wider bandwidth to be obtained, or to achieve a significant reduction in the size of the aerial while still maintaining the required sensitivity. It is essential that the appropriate correction factors shall be used in order to express the results in the correct units. Examples of aerials which it would be permissible to use are given in Appendix A.

In all tests, the separation distance between the aerial and the nearest face of the equipment under test shall be $1 \text{ m} \pm 5 \text{ cm}$ and the separation distance between the aerial extremities and the screened room surfaces shall be not less than 50 cm.

5.3.3 Control requirements. The equipment under test shall not radiate electric fields in excess of the values shown in Figure 10 and Figure 11 when measurements are made in accordance with 5.1, 5.3.1 and 5.3.2. Full compliance with this standard covers the frequency range from 0.15 MHz to 1 000 MHz; in cases where full compliance is not required, the appropriate limits over a restricted frequency range shall apply.

Equipment under test producing only broad band electrical interference shall be subject to the limits shown in Figure 10 at frequencies up to 400 MHz.

5.4 Determination of susceptibility

5.4.1 General. The audio frequency susceptibility requirements are in two parts; a.f. voltages rather greater than the permissible ripple voltages shall be imposed on to the power supply lines of the equipment under test, and the equipment shall also be subjected to a magnetic field of 20 A/m at 400 Hz.

All radio communication, instrumentation, navigation, data processing and similar electronic equipment shall be capable of normal operation while subject to r.f. voltages superimposed on the power supply leads and to r.f. electric fields. The criterion of acceptability for all equipment shall be based on the performance specification and shall be agreed by the Approval or Procurement Authority. In the case of complex electronic and navigational equipment, it is generally impracticable to call up the full performance specification, and a restricted test in the most susceptible mode of operation shall be selected. The measurements shall be made at the output terminals of the communications or audio system using a suitable output power meter.

NOTE In the case of audio or speech communications it is recommended that the signal to noise ratio under conditions of maximum sensitivity should be not less than 10 dB.

The r.f. voltage and field specified in this subclause 5.4 comprises a general level throughout the required frequency range but an increased level in those frequency ranges where transmissions of substantial power may occur, e.g. the HF, VHF and UHF bands, 2 MHz to 30 MHz, 108 MHz to 150 MHz and 225 MHz to 400 MHz, respectively. Where the frequency ranges overlap the most onerous limit shall apply.

NOTE The harmonic and spurious content of the r.f. power sources should be limited. For guidance, a value of at least 15 dB below the fundamental should be achieved.

Modulation of both conducted and radiated susceptibility r.f. test signals (see 5.4.4 and 5.4.5) is required to establish the immunity of the equipment to r.f. interfering signals from both on-board and external transmitters.

The type and frequency of modulation shall be selected according to the nature of the equipment under test, to ensure that conditions are produced which will establish the maximum susceptibility. In the absence of any specific instructions regarding modulation frequency, then the signal shall be amplitude modulated to a depth of 80 % with a sine wave signal or to a depth of 100 % with a square wave at 400 Hz or 1 000 Hz.

In addition, for military applications, pulse modulation of the test signal over the frequency range from 200 MHz to 10 GHz shall be applied. In the absence of any specific instructions a pulse width of 10 μs and a pulse repetition frequency of 400 Hz or 1 000 Hz shall be used.

NOTE The signal level is equal to the true peak value of the signal divided by $\sqrt{2}$, i.e. as measured by the peak detector of an r.f. measuring set.

5.4.2 Susceptibility to audio frequency voltage on power lines. A typical arrangement of the equipment shall be as shown in Figure 12 and the applied signal shall be 3 V r.m.s. in the frequency range 50 Hz to 15 kHz. The signal shall be applied to the power lines of the equipment under test and only to the control or signal lines, etc., if specifically required by the individual equipment specifications. The signal shall be applied from a circuit having an output impedance not exceeding 1 Ω and the amplitude shall be monitored by a high impedance voltmeter with the test sample disconnected.