Safety Regulation Group

Civil Aviation Authority

CAA PAPER 2003/3

Effects of Interference from Cellular Telephones on Aircraft Avionic Equipment

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List of Effective Pages

Contents

Executive Summary

This report covers activities that respond to CAA Safety Intervention Task 01/10: *Sponsor research to identify the susceptibility to interference from commonly used transmitting devices of vulnerable avionic equipment.*

Tests that exposed a set of aircraft avionic equipment to simulated cellphone transmissions revealed various adverse effects on the equipment performance. Although the equipment demonstrated a satisfactory margin above the original certification criteria for interference susceptibility, that margin was not sufficient to protect against potential cellphone interference under worst-case conditions.

In October 2002, a set of avionic equipment was tested under controlled conditions in a test chamber for susceptibility to cellphone interference. General aviation avionic equipment, representative of earlier analogue and digital technologies, was used. The equipment, comprising a VHF communication transceiver, a VOR/ILS navigation receiver and associated indicators, together with a gyro-stabilised remote reading compass system, was assembled to create an integrated system.

The tests covered the cellphone transmission frequencies of 412 (Tetra), 940 (GSM) and 1719MHz, including simultaneous exposure to 940 and 1719MHz. The applied interference field strengths were up to 50 volts/metre for a single frequency, and 35 volts/metre for dual frequencies.

The following anomalies were seen at interference levels above 30 volts/metre, a level that can be produced by a cellphone operating at maximum power and located 30cms from the victim equipment or its wiring harness.

- Compass froze or overshot actual magnetic bearing.
- Instability of indicators.
- Digital VOR navigation bearing display errors up to 5 degrees.
- VOR navigation To/From indicator reversal.
- VOR and ILS course deviation indicator errors with and without a failure flag.
- Reduced sensitivity of the ILS Localiser receiver.
- Background noise on audio outputs.

Most anomalies were observed at 1719MHz.

The project was managed by UK CAA and assisted with loaned equipment and personnel from Vodafone PLC, CSE Aviation (Oxford), and BAE SYSTEMS (Woodford).

Recommendations

The results of the tests endorse current policy that restricts the use of cellphones in aircraft. Recommendations are made that would further reduce interference risks, and to continue the studies to determine interference effects in aircraft from cellphones and other transmitting devices.

The CAA will remind operators about the specific risk from cellphone usage on the flight deck, and recommend that confirmation be obtained from passengers at check-in that cellphones in their luggage have been switched off.

As part of its ongoing study of the problem, CAA will consider tests to be performed on aircraft to assess further the effects on avionic equipment exposed to cellphone interference.

1 Background

1.1 Between March 1996 and December 2002, the number of aircraft safety-related incidents that cited cellphones as a factor, as reported to the UK CAA in accordance with the UK Mandatory Occurrence Reporting legislation, totalled 35.

1.2 The reports linked interference with effects including:

- False warnings of unsafe conditions (e.g. baggage compartment smoke alarms);
- Distraction[1] of the flight crew from their normal duties;
- Interrupted communications due to noise in the flight crew headphones;
- Increased work load for the flight crew and the possibility of invoking emergency drills;
- Reduced crew confidence in protection systems which may then be ignored during a genuine warning;
- Malfunctioning of multiple systems essential to safe flight.

1.3 Similarly, NASA report, *Personal Electronic Devices and their Interference with Aircraft Systems*, June 2001, recorded and analysed 118 PED related incidents, reported under the voluntary Aviation Safety Reporting System. Cellphones were cited in 25 as having a strong correlation with the event with 16 being classified as associated with a critical anomaly.

1.4 The total number of reported events of cellphone interference is relatively low considering the number of aircraft flights involved. The difficulties experienced in trying to reproduce the events have led many (including pilots) to question whether a genuine problem exists. However, the potential adverse impact on flight safety and the need to keep that risk to tolerable levels have led to restrictions on the use of cellphones in aircraft.

1.5 Following on from tests[2] conducted by CAA to determine the levels of interference that cellphones could generate in an aircraft, CAA established Safety Intervention task 01/10: *Sponsor research to identify the susceptibility to interference from commonly used transmitting devices of vulnerable avionic equipment.* In response a second phase of tests has now been completed and these tests are the subject of this report.

1.6 Cellphone operation and interference propagation are further discussed in Annex 2.

2 Test Strategy

2.1 The goal of the second phase of tests was to determine the levels of cellphone interference needed to adversely affect aircraft equipment and to relate those levels to actual cellphone capability. Test results are tabulated in Annex 1.

2.2 The strategy of this second phase involved exposing aircraft avionic equipment, installed on a rack assembly inside a screened test chamber, to increasing levels of interference from simulated cellphone transmissions. The objectives were to identify any anomalies, caused by the equivalent of an intentional cellphone transmission, such as misleading indications, false warnings of unsafe conditions, degraded performance, and audio noise, then to note the level of interference causing each observed anomaly.

1. Crew distraction is a factor in altitude busts and runway incursions.
2. CAA report 9/40:23-90-02; 2nd May 2000.

2.3 The tests did not address possible interference effects from low-level radiation resulting from electronic processing within a cellphone in its receive mode of operation, i.e. the non-intentional transmission. Only the problem of the intentional transmission was considered.

3 Choice of Avionic equipment

3.1 To obtain maximum yield from the test programme, several items of avionic equipment were selected to create a system representative of equipment currently in use but designed and qualified to the earlier, less-demanding standards (RTCA DO-138 and DO-160). Although airline equipment would be the preferred choice, practical considerations of equipment availability, its size, power requirements, and complexity of the system interface, restricted the choice to general aviation equipment. However, as an advantage, the test programme was able to cover, simultaneously, VHF communications, VOR Navigation, Localiser and Glide Slope equipment, together with a gyro- stabilised remote reading magnetic compass. The specific models of equipment tested were not known to have a history of interference susceptibility as recorded in incident occurrence reports.

3.2 The avionic equipment was assembled on a test rack and connected to create an integrated system in accordance with the manufacturer's installation instructions using aircraft standard components and wiring. Antenna connections were brought out to bulkhead connectors on the rack and terminated. A 28VDC power supply was provided, and heavy gauge bonding straps were attached connecting the rack to the test chamber ground plane.

3.3 From an interference susceptibility viewpoint, the assembly was representative of the manner in which the equipment would be installed in an aircraft.

3.4 All the equipment operated at 28VDC. No other supplies were required for the equipment under test.

3.5 Details of the avionic equipment may be found in Annex 3. Photographs of the test arrangements are included in Annex 8.

4 Test Equipment and Procedures

4.1 With the aid of cellphone signal generators, power amplifiers, monitoring equipment, and avionic test equipment, signals were injected into each receiver in turn and the assembly was exposed to interference up to a maximum level of 50 volts/metre.

4.2 The avionic test equipment was used to provide signals that exercised the aircraft equipment. The aircraft equipment was monitored for performance of intended functions. The tests did not require the VHF transmitter to operate.

4.3 The interference frequencies and modulations of interest were those used by cellphones in the Tetra 400, GSM 900 and 1800MHz bands. Tests at 2.3GHz were not attempted. The effects due to exposure to simultaneous transmissions in both the 900 and 1800MHz bands were explored.

4.4 Annex 4 provides details of the test equipment used.

5 Limitations of the Tests

5.1 To keep the number of tests within practical limits, only interference frequencies of 412MHz (Tetra), 940MHz (GSM) and 1719MHz were used, each with a maximum field strength of 50 volts/metre. The tests for simultaneous exposure to 940 and 1719MHz were performed with maximum combined field strength up to 35 volts/metre due to test equipment limitations.

5.2 Similarly, only one representative receiving frequency in each aviation band, for VHF communications, VOR navigation, ILS Localiser and Glideslope approach, was tested.

5.3 Due to non-availability of a Tetra modulator, the tests at 412MHz were made using GSM modulation, this being considered as reasonably equivalent.

5.4 The effects monitored were those evident at the external interface with the equipment. Other performance characteristics related to the internal functioning of the equipment were not monitored.

5.5 The equipment selected for these tests represented a very small sample of avionic equipment in general use. Whilst the results provided an indication of the types of problem that can arise, assumptions about their applicability to other equipment should be made with due caution.

6 Observations and Conclusions

6.1 The tests revealed various adverse effects on the equipment performance from simulated cellphone interference. Although the equipment demonstrated a satisfactory margin above the original certification criteria for interference susceptibility, that margin was not sufficient to protect against potential cellphone interference under worst case conditions.

6.2 As recorded on the worksheets reproduced in Annex 1, the following anomalies were seen at interference levels above 30 volts/metre, a level that can be produced by a cellphone operating at maximum power and located 30cms from the victim equipment or its wiring harness.

- Compass froze or overshot actual magnetic bearing.
- Instability of indicators.
- Digital VOR navigation bearing display errors up to 5 degrees.
- VOR navigation To/From indicator reversal.
- VOR and ILS course deviation indicator errors with and without a failure flag.
- Reduced sensitivity of the ILS Localiser receiver.
- Background noise on audio outputs.

6.3 Most anomalies were observed at 1719MHz.

6.4 For the general case, and depending on the other aids available to the flight crew, the consequences of the observed anomalies could include crew distraction, confusion, and loss of confidence in the equipment. The degraded navigation precision could result in an inability to meet required navigation performance with potential adverse effects on aircraft separation and terrain clearance.

7 Recommendations

7.1 For safety reasons and to keep the risks from cellphone interference to tolerable levels, the Regulatory Authorities should continue to restrict the use of cellphones by passengers in aircraft as detailed in Leaflet 29 published by the European Joint Aviation Authorities.

7.2 Aircraft operators should alert their flight crews to the specific risk from active cellphones on the flight deck, and introduce procedures to ensure they are switched off. Similarly, the general aviation community should be alerted to the interference risk in small aircraft.

7.3 The Regulatory Authorities should request airport operators and airlines to consider additional measures to further minimise the risks from cellphones when passengers inadvertently fail to switch them off, including;

a) Seeking confirmation from passengers at check-in that cellphones in luggage have been switched off; and

b) Displaying reminder notices in airport departure lounges and at aircraft boarding points.

7.4 EUROCAE[1] and RTCA, should amend the minimum equipment qualification levels for radio frequency susceptibility, as defined in EUROCAE ED-14D and RTCA DO-160D, Section 20, with the objective of providing an increased margin against potential interference from cellphones and other transmitting devices used on-board the aircraft. Particular attention should be given to minimum susceptibility requirements for equipment intended for installation on the flight deck.

7.5 Recognising that cellphone technology continues to evolve, and that other communication devices are becoming available for general use, the Regulatory Authorities should continue research to ensure the interference risk in aircraft from such devices is properly understood and mitigated.

1. EUROCAE Working Groups 14 and 58 are currently active for this purpose.

Annex 1 Results and Observations of Tests

Test No.	Band	Test Conditions.
1	None	Standard Performance without interference.
Date: 31 October 2002		

Item	System	Parameter	Observations
1.1	Magnetic Gyro-Compass	Slaving speed and sense on HSI	3 degrees per minute left and right
1.2	Slaving Indicator	Left – Right sense	OK
1.3	VOR	Signal strength to hide flags on HSI and CDI	113 MHz; clears at –111dBm
1.4	VOR	To/From accuracy on HSI and CDI	To/From OK
1.5	VOR	Bearing accuracy on CDI and HSI and Navigation receiver display	At 10dBs above flag threshold, indicated bearing in degrees at cardinals: CDI 000 090 180 270 HSI 002 092 182 272 NAV Rx 000 089 180 270
1.6	VOR	Course sensitivity and sense on HSI and CDI	10 degrees for Full Scale Deflection each way each instrument
1.7	Localiser	Signal strength to hide flags on HSI and CDI	109.1 MHz; clears at –111dBm
1.8	Localiser	Lateral sensitivity and sense on HSI and CDI	109.1 MHz; 0.155 DDM Right CDI 4.5 dots HSI 4.9 dots 0.155 DDM Left CDI 4.7 dots HSI 4.7 dots
1.9	Nav Audio	Quality	Good
1.10	Glide Slope	Signal strength to hide flags on HSI and CDI	109.1 MHz; clears at –91dBm
1.11	Glide Slope	Vertical sensitivity and sense on HSI and CDI	331.4 MHz; 0.175 DDM Up CDI 2.2 dots HSI 1.9 dots 0.175 DDM Down CDI 1.8 dots HSI 1.7 dots
1.12	VHF Receiver	Signal strength to lift squelch	127.0 MHz; 1.5 microvollts
1.13	VHF Audio	Quality and signal/level	Good with 1.2 microvolts for 6dB s/n.

Test No. **2**	Band **900MHz**	**Test Conditions.** Interference at 940 MHz with GSM Modulation on and off. Conical log spiral antenna. Initial injection of 50 volts/metre reducing when adverse effects observed to determine threshold. Standard performance may be assumed unless adverse effects are noted. Nav inputs normally set at 10dB above flag thresholds.
Date 31 October 2002		

Item	System	Parameter	Observations
2.1	Magnetic Gyro-Compass	Slaving speed and sense on HSI	Standard speed and sense but heading card froze with onset of interference. Effect seen at different field strength levels at different times. Lowest interference field strength to cause the effect was 40 volts/metre. Heading flag correctly remained in view when card froze.
2.2	Slaving Indicator	Left – Right sense	Sense OK but noticeable shift in deviation with interference onset together with some instability of needle. Effect observable at 30 volts/metre.
2.3	VOR	Signal strength to hide flags on HSI and CDI	Standard
2.4	VOR	To/From accuracy on HSI and CDI	Standard
2.5	VOR	Bearing accuracy on CDI and HSI and Navigation receiver display	Small kick on CDI with RF interference on/off but returned to standard. HSI standard. For Navigation receiver display, at 000 no effect, but at 180 degrees bearing dropped to 178 at 50 volts/metre and 179 at 40 volts/metre.
2.6	VOR	Course sensitivity and sense on HSI and CDI	Standard
2.7	Localiser	Signal strength to hide flags on HSI and CDI	Standard.
2.8	Localiser	Lateral sensitivity and sense on HSI and CDI	Slight shimmer on deviation needle of CDI and kick on TO/FROM flag otherwise standard.
2.9	Nav Audio	Quality	Good
2.10	Glide Slope	Signal strength to hide flags on HSI and CDI	Standard

Item	System	Parameter	Observations
2.11	Glide Slope	Vertical sensitivity and sense on HSI and CDI	Slight kick on HSI deviation bar with interference on/off. No effect with modulation on/off. Otherwise standard.
2.12	VHF Receiver	Signal strength to lift squelch	Standard
2.13	VHF Audio	Quality and signal to noise ratio	Standard

Test No. **3**	Band **1800**	**Test Conditions.** Interference at 1719 MHz with GSM Modulation on and off. Octave Horn antenna with vertical polarisation. Initial injection of 50 volts/metre reducing when adverse effects observed to determine threshold. Standard performance may be assumed unless adverse effects are noted. Nav inputs normally set at 10dB above flag thresholds.
Date 31 October 2002		

Item	System	Parameter	Observations
3.1	Magnetic Gyro-Compass	Slaving speed and sense on HSI	Standard
3.2	Slaving Indicator	Left – Right sense	Instability of needle with both interference power on/off and modulation on/off.
3.3	VOR	Signal strength to hide flags on HSI and CDI	Standard
3.4	VOR	To/From accuracy on HSI and CDI	To/From flags on CDI and HSI toggled to give reverse indication at 33 volts/metre with RF carrier only (GSM modulation off).
3.5	VOR	Bearing accuracy on CDI and HSI and Navigation receiver display	Deviation bars on CDI and HSI went Full Scale Deflection with fail flag in view at 35 volts/metre and above with carrier only. At 50 volts/metre with a modulated carrier, the same incorrect deviation occurred but the fail flag was retracted so incorrectly indicating proper operation. With 1kHZ AM at 80%, at 50 volts/metre., to/from toggled, the CDI and HSI fail flags appeared with variable deviation bar movement, more severe on the HSI including Full Scale Deviation. System recovered after removal of interference. With a 10dB increase in VOR input signal, the effect was not observed. Navigation receiver display: One degree change in bearing at 270 degrees with GSM modulation on at 50 volts/metre, but 5 degrees change with no GSM modulation. Less effect at 40 volts/metre. With a 10dB increase in VOR input signal, the effect was not observed.
3.6	VOR	Course sensitivity and sense on HSI and CDI	Standard

Item	System	Parameter	Observations
3.7	Localiser	Signal strength to hide flags on HSI and CDI	At 50 volts/metre, 109.1 MHz flag cleared at –95 dBm (previously –111dBm). At 40 volts/metre, flag cleared at –103 dBm
3.8	Localiser	Lateral sensitivity and sense on HSI and CDI	Standard performance but Loc input needed to be set at +16dB above the standard flag threshold.
3.9	Nav Audio	Quality	Generally good with slight increase in background noise with GSM modulation on.
3.10	Glide Slope	Signal strength to hide flags on HSI and CDI	Standard
3.11	Glide Slope	Vertical sensitivity and sense on HSI and CDI	Standard
3.12	VHF Receiver	Signal strength to lift squelch	Standard
3.13	VHF Audio	Quality and signal /noise level	Standard

Test No.	Band	Test Conditions.
4	**900 & 1800 Combined**	Interference at 940 & 1719 MHz with GSM Modulation on and off. Octave Horn antenna with vertical polarisation. Initial injection of 25 volts/metre each frequency (producing an indicated combined field strength of 35 volts/metre) volts/metre. Field strengths higher than 35 volts/metre could not be achieved due to test equipment limitations. Standard performance may be assumed unless adverse effects are noted. Nav inputs normally set at 10dB above flag thresholds.
Date 31 October 2002		

Item	System	Parameter	Observations
4.1	Magnetic Gyro-Compass	Slaving speed and sense on HSI	Standard but with slight hesitancy of card movement when modulations switched on or off.
4.2	Slaving Indicator	Left – Right sense	Standard.
4.3	VOR	Signal strength to hide flags on HSI and CDI	Standard.
4.4	VOR	To/From accuracy on HSI and CDI	Standard.
4.5	VOR	Bearing accuracy on CDI and HSI and Navigation receiver display	Standard except one degree of instability on 090 and 270 of navigation receiver display.
4.6	VOR	Course sensitivity and sense on HSI and CDI	Standard.
4.7	Localiser	Signal strength to hide flags on HSI and CDI	Standard.
4.8	Localiser	Lateral sensitivity and sense on HSI and CDI	Standard.
4.9	Nav Audio	Quality	Standard.
4.10	Glide Slope	Signal strength to hide flags on HSI and CDI	Standard.
4.11	Glide Slope	Vertical sensitivity and sense on HSI and CDI	Standard.
4.12	VHF Receiver	Signal strength to lift squelch	Standard.
4.13	VHF Audio	Quality and signal /noise level	Standard.

Test No.	Band	Test Conditions.
5	**Tetra Band**	Interference at 412 MHz with GSM Modulation on and off. (Tetra modulation generator not available). Conical log spiral antenna with 200W amplifier. Initial injection of 50 volts/metre reducing when adverse effects observed to determine threshold. Standard performance may be assumed unless adverse effects are noted. Nav inputs normally set at 10dB above flag thresholds.
Date 31 October 2002		

Item	System	Parameter	Observations
5.1	Magnetic Gyro-Compass	Slaving speed and sense on HSI	At 50 volts/metre, on decreasing heading, the compass card overshot the actual magnetic bearing by 35 degrees and remained in error even when RF carrier switched off. A similar test for increasing heading caused the card to slow almost to a stop when the RF carrier was switched on, and with the fail flag retracted from view. The bearing card remained in error even when the RF carrier was switched off yet responded to physical movements of the mounting tray on which the gyro and flux detector were mounted. The effect was observed at 35 volts/metre. At 32 volts/metre, the card continued to rotate in the increasing heading direction but undershot the correct heading by 20 degrees. At 30 volts/metre, no effects observed.
5.2	Slaving Indicator	Left – Right sense	Significant kicks when RF carrier switched on or off, or when modulation switched on and off.
5.3	VOR	Signal strength to hide flags on HSI and CDI	Standard.
5.4	VOR	To/From accuracy on HSI and CDI	Standard.
5.5	VOR	Bearing accuracy on CDI and HSI and Navigation receiver display	With VOR signal at 20dB above flag threshold, bearing pointer had slight kick at 000 degrees, 0.5 degree change at 090 on both CDI and HSI, 0.8 at 180, and 0.5 at 270 degrees. Navigation receiver displayed bearing changes of 1 degree at 000 and 090, 2 degrees at 180 and 270.
5.6	VOR	Course sensitivity and sense on HSI and CDI	Standard.
5.7	Localiser	Signal strength to hide flags on HSI and CDI	Standard.

Item	System	Parameter	Observations
5.8	Localiser	Lateral sensitivity and sense on HSI and CDI	Standard.
5.9	Nav Audio	Quality	Standard
5.10	Glide Slope	Signal strength to hide flags on HSI and CDI	Standard.
5.11	Glide Slope	Vertical sensitivity and sense on HSI and CDI	Standard.
5.12	VHF Receiver	Signal strength to lift squelch	Standard.
5.13	VHF Audio	Quality and signal /noise level	Standard.

Annex 2 Cellphone Operation and Interference Susceptibility

1 Operational Regulations

1.1 The use of portable electronic devices (PEDs) on board aircraft by flight crew, cabin crew and passengers presents a source of uncontrolled electro-magnetic radiation with the risk of adverse interference effects to aircraft systems.

1.2 Given that a civil aircraft flying at high altitude and high speed in busy airspace is in an obviously hazardous environment, and given that many of the onboard systems are safety devices intended to reduce the risks of that environment to tolerable levels, then anything that degrades the effectiveness of those systems will increase the exposure of the aircraft to the hazards. Consequently, the aircraft operator needs to take measures that will reduce the risks to acceptable limits.

1.3 To safeguard operations, the Joint Aviation Authorities regulation JAR-OPS 1.110 requires an operator "..... to take all reasonable measures to ensure that no person does use, on board an aeroplane, a portable electronic device that can adversely affect the performance of the aeroplane's systems and equipment".

1.4 JAA Leaflet 29, *Guidance Concerning The Use of Portable Electronic Devices on Board Aircraft*, explains the policy. The following text is based on extracts from Leaflet 29.

2 Cellphones

2.1 Cellphones are both non-intentional and intentional transmitting PEDs, operating on spot channel frequencies in the bands of approximately 415 MHz, 900 MHz or 1800 MHz. (Some regions of the world use slightly different bands). Most use digital modulation but analogue types are still in use. Their maximum transmitted power is in the range of typically 1 to 2 watts although higher power units may be in use in some regions. The actual power transmitted at a particular time is controlled by the cellular network and may vary from 20mW to maximum rated power of the cellphone depending on quality of the link between the cellphone and the network. Even in standby mode when an actual call is not in progress, a cellphone transmits periodically to register and re-register with the cellular network and to maintain contact with a base station.

2.2 An aircraft on the ground at an airport is likely to be in close proximity to a base station resulting in a strong link between that station and an onboard cellphone. Under these circumstances the network would set the cellphone output power to a low level, sufficient to maintain the link. The interference risk would, as a result, be low. As the aircraft increases its distance from the base station, the output power setting of the cellphone is increased, eventually to its maximum rating. The risk of interference is then at its greatest.

3 Interference Levels

3.1 For an intentional transmitter such as a cellphone, an obvious risk is recognised even though the cellphone is not transmitting in the aeronautical frequency band. Applying fundamental principles, the maximum field strength E in volts per metre of the transmission at a distance D from a cellphone transmitting P Watts of radio frequency power in a free, unobstructed space, can be estimated using the equation;

$$E = 7\sqrt{P} \text{ divided by the distance D}$$

3.2 Thus, for a 2-watt cellphone, the maximum field strength in free space at one metre distance is approximately 10 volts per metre, and at 100 metres distance, approximately 100 millivolts per metre. At close range, as would apply to cellphone usage on the flight deck, the field strength can be 33 volts per metre at a distance of 30cms.

3.3 In the confines of a metallic aircraft fuselage, complex propagation paths arise due to reflections from the metallic structure that can lead to signal cancellation or re-inforcement at different locations in the aircraft. Although the free space equation does not give reliable results under these conditions, tests performed by CAA in February 2000 have shown that the field strength of the interfering cellphone transmission, at maximum power, will exceed by a significant margin the levels used in susceptibility tests for avionic equipment qualified to earlier standards. Similarly, these tests have shown that interference levels would vary by relatively small changes of location of a cellphone and that persons obstructing the transmission path reduce the interference.

4 Aircraft Equipment Qualification Tests

4.1 An internationally agreed aviation standard exists for qualifying aircraft equipment for approval with respect to the extremes of its operating environment including exposure to interference. The standard is known in Europe as EUROCAE ED-14 and in the USA as RTCA DO-160.

4.2 To qualify for approval, equipment to be installed in aircraft has to demonstrate that it is not susceptible to prescribed levels of radiated interference irrespective of the source, and that it will not radiate unacceptable interference. The levels were originally set to ensure equipment could co-exist in the aircraft without mutual interference. For example, for an equipment susceptibility test prior to 1985, the maximum field strength of radiated interference was set at only 100 millivolts per metre with an upper test limit frequency of 1215MHz. The risk of an uncontrolled interference source within the aircraft was not addressed by earlier standards. Recognising the inadequacy of the earlier standards, the tests have become progressively more severe primarily to protect against external threats such as broadcast transmitters, radars, and satellite uplinks.

4.3 For critical equipment, the susceptibility tests now involve field strengths of 200 volts per metre or more with an upper frequency test limit of 18GHz. However, even the latest standards permit a low level of immunity for some equipment. Many aircraft, including newly manufactured aircraft, still have systems and equipment qualified to earlier standards.

4.4 With reference to the earlier standards for equipment approved prior to December 1989, it can be seen that, no qualification tests were required for susceptibility at cellphone frequencies of 1800 MHz (or 1900MHz as used in the USA). Later versions of the standards permitted increased interference susceptibility for equipment installed in a partially protected environment assuming that the interference source was external to the aircraft. For example, a qualification test level of 5 volts/metre was permitted for equipment installed in a well-protected avionics bay. Few aircraft can claim such a level of protection when the interference source is inside the aircraft.

Annex 3 Description of Avionic Equipment

The following paragraphs provide a description of the avionic equipment used for the tests.

1 Gyro-stabilised Magnetic Compass System

1.1 The system comprises an Earth's magnetic flux sensor, directional gyro, slaving controller, horizontal situation indicator, and a shockmount.

1.2 A magnetic flux sensor senses the direction of the earth's magnetic field and, in conjunction with the directional gyro, transmits a gyro-stabilised magnetic heading to the horizontal situation indicator along with a drive signal for the heading failure flag in that unit. The gyro unit contains an internal power supply that provides excitation voltages for the magnetic flux sensor transmitter, and positive and negative DC voltages for the horizontal situation indicator and slaving controller.

1.3 The slaving controller has switches for selecting the slaved or free-gyro mode of operation, and corrector circuitry that compensates for local magnetic disturbances on the magnetic flux sensor.

1.4 When power is first applied to the system, the heading display of the horizontal situation indicator will automatically fast slave to align with the heading transmitted by the magnetic flux sensor. The system will then revert to the normal slaving mode and slave at a constant rate of 3 degrees per minute to keep the system aligned with the earth's magnetic field.

1.5 When the system is selected to the free gyro mode, the heading signal from the gyro is the only input to the heading display. While in the free gyro mode, changes in the displayed heading may be commanded by means of toggle switches on the slaving controller.

1.6 In addition to the gyro-stabilised aircraft magnetic heading, the horizontal situation indicator displays information sent from the navigation receiver for VOR and localizer course deviation, glide slope deviation, a To-From indication, together with manual controls for course and heading datum selections. In addition, warning flags are provided to indicate unusable VOR/Localizer information (NAV Flag) or situations rendering the heading display unusable (HDG Flag). The glide slope pointer will retract from view when the glide slope signal is unusable.

1.7 The equipment design uses analogue technology with output signals from synchro and resolver devices together with low level DC signals to the deviation indicators and To-From pointer.

1.8 The compass system equipment was qualified in accordance with FAA Technical Standard Order TSO-C6c and approved in 1975. It satisfied the environmental conditions of RTCA DO-138[1], Section 13, Class A, that sets a field strength for radiated interference susceptibility of 100 millivolts up to 1215 MHz. Tests were not required above this frequency limit.

1. RTCA DO-138, June 1968.

2 Communications Transceiver

2.1 The transceiver is an airborne VHF communications transceiver designed to be mounted in aircraft instrument panels. The transceiver incorporates solid-state circuit design with a gas discharge type frequency display. The operating frequency range covers the aviation communications band from 118.00 MHz to 136.975 MHz in 25 KHz increments.

2.2 A stabilised master oscillator is used to digitally synthesise the 760 channels for the transmitter and the 11.4 MHz offset local oscillator signal for the receiver.

2.3 A microprocessor is used to general the digital code for the synthesiser, control the display, and to store the last used frequencies in non-volatile memory contained within the microprocessor. The microprocessor primary clock frequency is 12.5 kHz.

2.4 The receiver is an AGC controlled, single conversion superheterodyne type using dual gate field effect transistors for the RF amplifier and mixer to achieve the required sensitivity and overload capacity. A four pole, varactor tuned preselector suppresses the image and spurious frequencies. The intermediate frequency amplifier is a two-stage integrated circuit design each with AGC applied. A 16 KHz wide crystal filter determines the selectivity for the receiver.

2.5 Automatic noise squelch quietens the receiver when there is no incoming signal, with a backup carrier operated squelch for noisy environments. An audio filter is provided to suppress audio heterodynes at or above 4 KHz. An audio amplifier drives earphones or an external audio power amplifier.

2.6 The transmitter delivers a minimum 10 watts to a 50-Ohm antenna.

2.7 The power supply employs a ringing choke regulator plus two series regulators to produce various voltages.

2.8 The transmitter was qualified in accordance with FAA Technical Standard Order TSO-C37b (RTCA DO-157 Class 4) and the receiver with TSO– C39b (RTCA DO-156 Class C & D). The receiver design was upgraded to meet the European FM immunity requirements in 1994 at which time it was declared compliant with the environmental conditions of RTCA DO-160[1], Section 20, Class A, that sets a field strength for radiated interference susceptibility of 100 millivolts up to 1215 MHz. Tests were not required above this frequency limit.

3 Navigation Receiver and VOR/Localiser Converter

3.1 The navigation receiver is a 200-channel, superheterodyne, single conversion receiver operating in the band 108 to 118 MHz. It uses band switching for the RF front end and an intermediate frequency of 21.4 MHz. A double balanced active mixer formed by 4 junction field effect transistors is used. The RF amplifier and mixer have high dynamic range and an intermodulation performance to meet the European requirements for FM broadcast interference immunity.

3.2 Two monolithic, 6 pole filters are employed after the mixer to provide the required selectivity. The detected output provides a composite navigation signal for the VOR (9960 Hz with 30Hz FM) or Localizer (90 and 150Hz tones) converter, and for audio identification. The detected audio is amplified to provide a 100mW audio output.

1. RTCA DO-160, February 1975

3.3 The converter filters the VOR composite output signal to recover the 30Hz reference and 30Hz variable components needed to derive the VOR bearing for the horizontal situation indicator.

3.4 The external resolver of the horizontal situation indicator provides course selection.

3.5 For an ILS Localizer channel, the output is filtered to recover the localiser 90Hz and 150Hz tones that are then rectified, buffered and sent to drive the deviation bar of the horizontal situation indicator.

3.6 The navigation receiver and converter were qualified in accordance with FAA Technical Standard Order TSO-C36c (Localiser) (RTCA DO-131 Class D), and TSO–C40A (VOR) (RTCA DO-153, Category A & B). The receiver design was upgraded to meet the European FM immunity requirements in 1994 at which time it was declared compliant with the environmental conditions of RTCA DO-160, Class A, that sets a field strength for radiated interference susceptibility of 100 millivolts up to 1215 MHz. Tests were not required above this frequency limit.

4 Glide Slope Receiver

4.1 The Glide Slope receiver is an AGC controlled 40-channel superheterodyne receiver and converter. The receiver section accepts signals in the range of 329.15 to 335.00 MHz, amplifies and mixes them with the output of a varactor-controlled oscillator to produce an intermediate frequency of 33 kHz. The signal is then fed to a bandpass filter and amplified by an intermediate frequency amplifier. Detected output is fed to a converter containing 90 and 150 Hz tone amplifiers, precision detectors, and deviation and flag drivers for the external indicator.

4.2 The glide slope receiver/converter was qualified in accordance with FAA Technical Standard Order TSO-C34c (RTCA DO-132, Category II, Class D). In 1994, it was declared compliant with the environmental conditions of RTCA DO-160, Class A, that sets a field strength for radiated interference susceptibility of 100 millivolts up to 1215 MHz. Tests were not required above this frequency limit.

5 Course Deviation Indicator

5.1 The course deviation indicator is an analogue device containing VOR/Localiser signal converters with VOR/Localiser and glide slope deviation indicators and warning flags. The VOR/Localiser converters obtain their information from the composite signal provided by the external navigation receiver. The glide slope information is obtained from the external glide slope receiver/converter.

5.2 The course deviation indicator was qualified in accordance with FAA Technical Standard Order TSO-C36c (Localiser) (RTCA DO-131 Class C); TSO– C40A (VOR) (RTCA DO-114); and TSO-C34c (Glide Slope) (RTCA DO-132, Class D, Cat II). In January 1977, the unit was declared compliant with the environmental conditions of RTCA DO-138, Class A, that sets a field strength for radiated interference susceptibility of 100 millivolts up to 1215 MHz. Tests were not required above this frequency limit.

Annex 4 Test Equipment Details

Description	Model
Cellphone Simulators (2)	Hewlett Packard ESG D3000A
Power Amplifier (25W 0.8-4.2GHz)	Amplifier Research 25SIG4A
Power Amplifier (120W 941MHz)	Aerial Facilities Ltd 12-006804
Power Amplifier (200W 220-400MHz)	Amplifier Research 200HA
Octave Horn Antenna (1-2 GHz)	EMCO 3161-0
Conical Log Spiral Antenna (200MHz-1GHz)	EMCO 3101
Calibrated Field Probe System (400-1000MHz)	Amplifier Research FM-2004/FP2000
Calibrated Field Probe System (1800MHz)	EMCO 7120/7130
Calibrated Field Probe System (100kHz-3000MHz)	Wandel & Goltermann EMR300
VHF Communications Signal Generator	Marconi 2955B
VOR/ILS Signal Generators	IFR Inc. NAV750B and NAV402AP
Video Camera (fibre-optic)	Baxall GTEM
Video Camera	Fujitsu TCS-330P
Video Monitors (2)	JVC/CCTV
Digital Camera	Kodak DC265

Annex 5 References

Joint Aviation Requirement, JAR OPS 1.110: *Portable Electronic Devices*.

Joint Aviation Requirement, JAR OPS 1.285 *Passenger Briefing.*

Joint Aviation Authorities, Leaflet 29; *Guidance Concerning the Use of Portable Electronic Devices on Board Aircraft*; October 2001.

Federal Aviation Administration, Advisory Circular AC 91.21-1A; *Use of Portable Electronic Devices Aboard Aircraft*; October 2000.

UK Civil Aviation Authority: *Interference Levels In Aircraft at Radio Frequencies used by Portable Telephones*; report 9/40:23-90-02, May 2nd, 2000.

RTCA Inc: *Portable Electronic Devices carried on board Aircraft;* document DO-233, August 20th, 1996.

EUROCAE: *Environmental Conditions and Test procedures for Airborne Equipment*; document ED-14, February 1975. (ED-14 is technically equivalent RTCA document DO-160).

JAA documents are available from Information Handling Services (IHS). Information on prices, where and how to order, is available on the JAA web site (www.jaa.nl) and on the IHS web sites www.global.ihs.com and www.avdataworks.com

EUROCAE documents may be purchased from EUROCAE, 17 rue Hamelin, 75783 PARIS Cedex 16, France, (Fax: 33 1 45 05 72 30). Web site: www.eurocae.org

FAA documents may be obtained from Department of Transportation, Subsequent Distribution Office SVC-121.23, Ardmore East Business Center, 3341 Q 75th Avenue, Landover, MD 20785, USA. Web site www.faa.gov/aviation.htm

RTCA documents may be obtained from RTCA Inc, 1828 L Street, NW., Suite 805, Washington, DC 20036, USA, (Tel. 1 202 833 9339, Fax. 1 202 833 9434), Web site: www.rtca.org

Annex 6 Abbreviations

AGC	Automatic Gain Control
CAA	Civil Aviation Authority (UK)
CDI	Course Deviation Indicator
CFR	Code of Federal Regulations (USA)
DC	Direct Current
dB	Decibel
dBm	Decibels relative to one millivolt
EMC	Electro-Magnetic Compatibility
EUROCAE	European Organisation for Civil Aircraft Equipment
FAA	Federal Aviation Administration (USA)
FM	Frequency Modulation
GSM	Global System for Mobile Communications
HSI	Horizontal Situation Indicator
ILS	Instrument Landing System
JAA	Joint Aviation Authorities (Europe)
NASA	National Aeronautical and Space Administration (USA)
PED	Portable Electronic Device
RF	Radio Frequency
RTCA	RTCA Inc
VHF	Very High Frequency
VOR	VHF Omni-Range

Annex 7 Test Team Members

Name	Organisation
Daniel Hawkes Project Leader	Civil Aviation Authority Systems Department, Gatwick Airport, West Sussex
Jonathan Hughes Surveyor	Civil Aviation Authority Systems Department, Gatwick Airport, West Sussex
Dave Woodward Head of EMC Laboratories	BAE SYSTEMS Woodford Aerodrome, Cheshire
Gian Sohal Principal Avionics Engineer	BAE SYSTEMS Woodford Aerodrome, Cheshire
David Ineson Senior Engineer	Vodafone Ltd Newbury
Peter Dennis Senior Engineer	Vodafone Ltd Warrington

Annex 8 Photographs

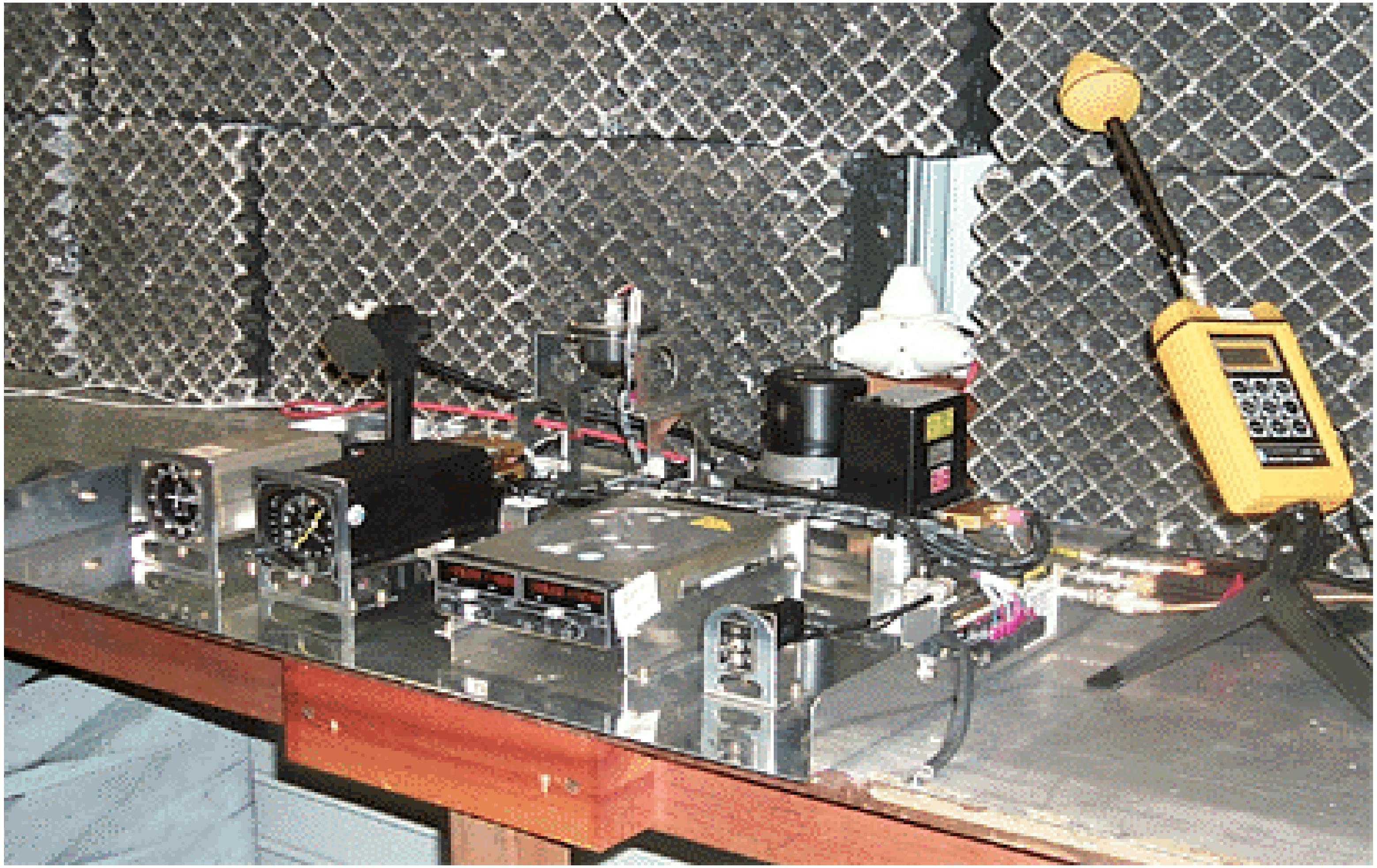

Figure 1 Test Rack Assembly with installed Avionic Equipment and Field Strength Probes

Figure 2 Front view of Test Rack Assembly

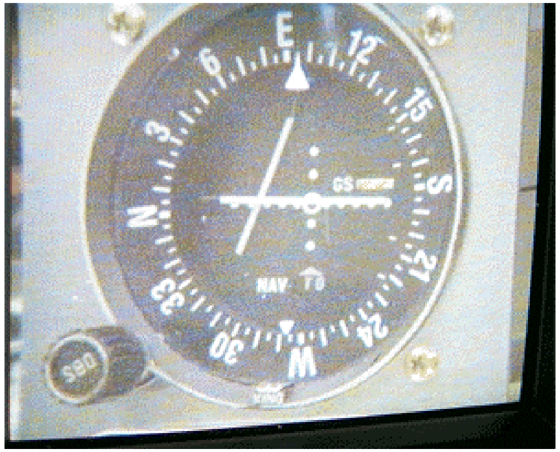

Figure 3 Monitor View of Course Deviation Indicator

Figure 4 Monitor View of Digital Navigation Display

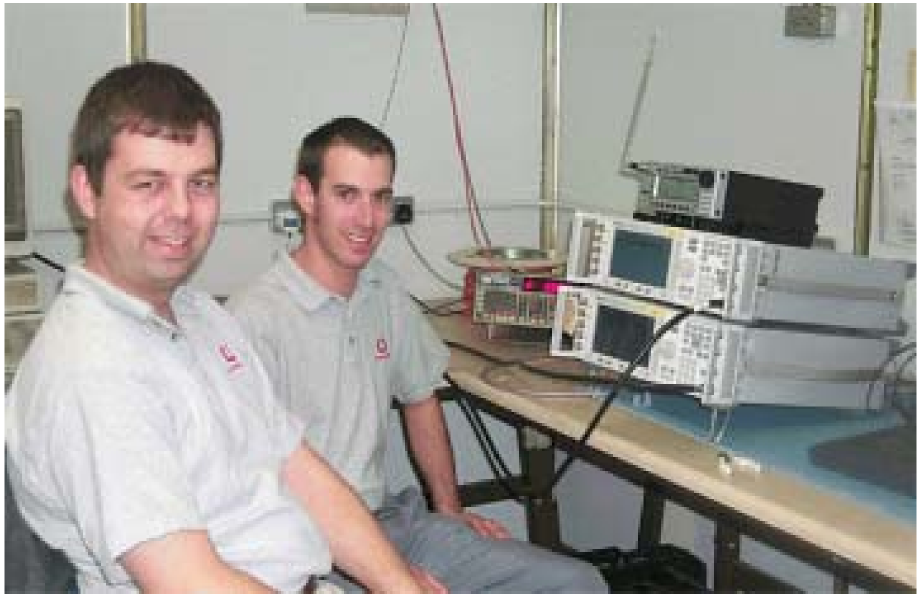

Figure 5 Vodafone Engineers with Cellphone Simulators

Figure 6 CAA and BAE SYSTEMS Engineers

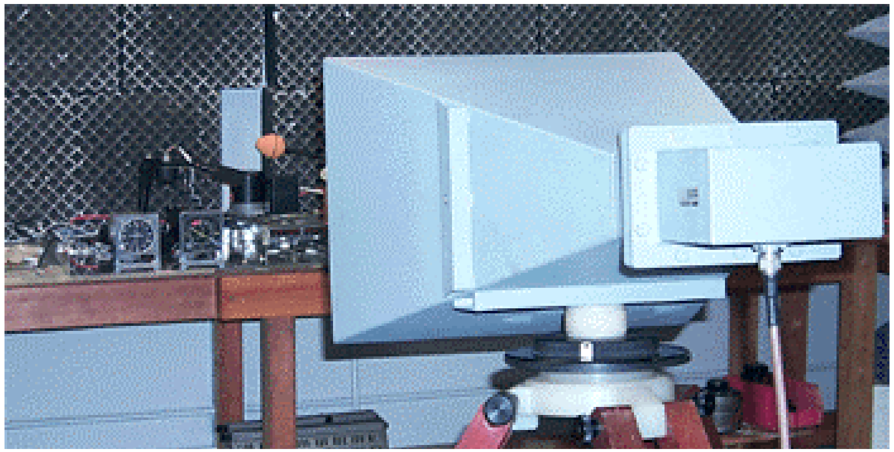

Figure 7 Octave Horn Antenna

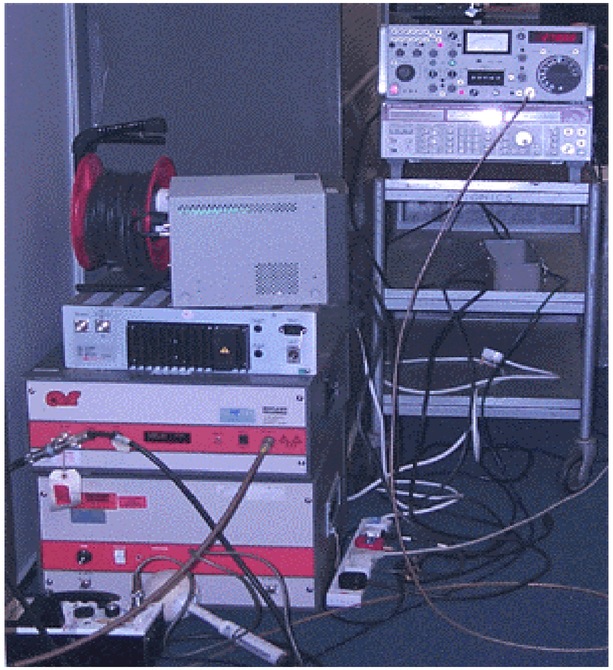

Figure 8 Signal Generators and Power Amplifiers