ELECTROMAGNETIC INTERFERENCE FROM PORTABLE ELECTRONIC DEVICES

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Operators of commercial aircraft have reported numerous cases of portable electronic devices affecting aircraft systems during flight. These devices, including laptop and palmtop computers, audio players/ recorders, electronic games, cell phones, compact disc players, electronic toys and laser pointers, have been suspected of causing such anomalous events as autopilot disconnects, erratic flight deck indications, aircraft turning off course, and uncommanded turns. Boeing has recommended that devices suspected of causing these anomalies be turned off during critical stages of flight (take-off and landing). The company also recommends prohibiting the use of devices that intentionally transmit electromagnetic signals, such as cell phones, during all phases of flight. In addition, the U.S. Federal Aviation Administration issued Federal Aviation Regulation 91.21, to make operators responsible for governing the use of portable electronic devices on their aircraft.

CATEGORIES OF PORTABLE ELECTRONIC DEVICES

PEDs are classed as either *intentional or non intentional* transmitters of electromagnetic signals.

Those that intentionally transmit signals outside the device must do so in order to accomplish their functions. Examples are :

- Cellphones
- Remote control toys
- Two-way pagers
- Two-way radios

Non-intentionally transmitting PEDs do not need to transmit electromagnetic signals outside the device to accomplish their functions, but, like any electrical or electrical device, they will emit some level of radiation. Depending on the characteristics of this radiation, interference with the operation of other electronic devices can occur. For example operating an AM radio close to a fluorescent light will cause audible "static" in the reception of the radio signal. Examples of non-intentional transmitters are :

- Audio players and recorders
- Compact-disc players
- Electronic games and toys
- Laptop computers
- Laser pointers
- Palmtop computers

Electromagnetic interference (EMI) from a passenger-carried portable electronic device (PED) on commercial aircraft has been reported as being responsible for anomalous events during flight. The operation of PEDs produces uncontrolled electromagnetic emissions that could interfere with aircraft systems.

Aircraft systems are tested to rigorous electromagnetic standards to establish and provide control of the electromagnetic characteristics and compatibility of these systems. However, PEDs are not subject to these same equipment qualification and certification processes. Though many cases of EMI have been reported over the years, with PEDs suspected as the cause, it has proven almost impossible to duplicate these events. Boeing has participated in several related activities, and has revised its all-model service letter for concurrence with the U.S. Federal Aviation Administration (FAA) advisory circular (AC) on the use of cell phones while aircraft are on the ground. However, operators and their flight crews are ultimately responsible for deciding whether to allow the use of PEDS.

Operators can increase their ability to make proper decisions regarding the use of PEDs by becoming aware of the most current information in the following areas :

1. Testing and analysis of PEDs and aircraft systems.

2. Resulting regulations and recommendations.

3. Operator actions for investigating and preventing PED events.

4. Ongoing related activities at Boeing.

TESTING AND ANALYSIS OF PEDS AND AIRCRAFT SYSTEMS

Boeing has conducted several tests and investigations to better understand the effects of PED use on aircraft systems. These include analysis of operator reports, investigation of specific instances of suspected PED interference, ground and aircraft tests of in-seat power, and cell phone tests and analysis.

Analysis of operator reports.

Boeing has received many reports related to PEDs from operators. The majority of these reports were inquiries about PEDs in general. The remaining reports involved aircraft anomalies and can be grouped into one of three categories of PED events:

1. Events where PED interference was suspected (an aircraft anomaly occurred when a PED was being operated);

2. Events with an apparent correlation between PED operation and the aircraft anomaly (the problem disappeared when the PED was turned off, either immediately or shortly thereafter); and

3. Events showing a strong correlation between PED operation and the aircraft anomaly (the problem disappeared when the PED was turned off, returned when PED use resumed and disappeared when the PED was turned off again).

Of the reports involving aircraft anomalies, only a few showed a strong correlation between the aircraft reaction and the suspected PED.

Investigation of specific instances of suspected PED interference.

Some sample cases are included here to illustrate the variety of potential PED events.

1995, 737 aircraft.

A passenger laptop computer was reported to cause autopilot disconnects during cruise. Boeing purchased the computer from the passenger and performed a laboratory emission scan from 150 kHz to 1 GHz. The emissions exceeded the Boeing emission standard limits for aircraft equipment at various frequency ranges up to 300 MHz. Boeing participated with the operator on two flight tests with the actual PED, using the same aircraft and flight conditions, in an attempt to duplicate the problem. Using even these extensive measures to re-create the reported event, Boeing was unable to confirm the reported interference between the PED and the aircraft system.

1996/1997,767 aircraft.
Over a period of eight months Boeing received five reports on interference with various navigation equipment (uncommanded rolls, displays blanking, flight management computer [FMC]/autopilot/ standby altimeter inoperative, and autopilot disconnects) caused by passenger operation of a popular hand-held electronic game device. In one of these cases, the flight crew confirmed the interference by turning the unit on and off to observe the correlation.

The same unit was used on another flight and on a different aircraft, but the event could not be duplicated. Boeing purchased two of the actual suspect units through the airline and tested them in the laboratory, along with three off-the-shelf units. It was determined that these suspect units had emission profiles similar to the off-the-shelf units and that the levels from these devices were below aircraft equipment emission limits.

1998, 747 aircraft.
A passenger's palmtop computer was reported to cause the aircraft to initiate a shallow bank turn. One minute after turning the PED off, the aircraft returned to "on course". When the unit was brought to the flight deck, the flight crew noticed a strong correlation by turning the unit back on and watching the anomaly return, then turning the unit off and watching the anomaly stop. Boeing was not able to purchase the actual PED, but contacted the PED manufacturer and purchased the same model. Boeing laboratory emission testing revealed that the unit exceeded Boeing aircraft equipment emission levels by up to 37dB by demonstrating energy levels in the frequency range of 150 to 7OO kHz. In the Boeing navigation laboratory the unit was placed next to the FMCS, control display unit, and integrated display unit, but the reported anomaly could not be duplicated.

As a result of these and other investigations, Boeing has not been able to find a definite correlation between PEDs and the associated reported aircraft anomalies. For future considerations and investigations, other factors are becoming significant. Qualification levels related to high-intensity radiated fields (HIRF) for new aircraft equipment are higher than almost any level of emissions from passenger PEDS. The size of many PEDs is shrinking and, as a result, these units require less power to operate. Though this can increase the margin between aircraft system susceptibility test levels and PED emissions, some PEDs are now operating in new frequency bands and are combining multiple functions, making it more difficult to distinguish between intentionally and non-intentionally transmitting PEDs (see Definitions).

Consequently, some aircraft systems that have not been reported as being susceptible to PEDS, such as the global positioning system, weather radar, and radio altimeter, may pick up energy from newer PEDs that operate in the high-frequency bands and whose harmonics or other noise may fall within one of these aircraft systems' operating bands.

Ground and aircraft tests of in-seat power.
Operators have asked Boeing to install and certify in-seat power outlets for passenger use of laptop computers. Boeing and the FAA have three related electromagnetics concerns :

1 . Whether installing the outlets will increase the use of laptop computers and a corresponding number of potential PED events;

2. Whether the power cord will introduce additional radiated emission effects; and

3. Whether laptop connections will corrupt aircraft power by conducting emissions into the aircraft power system.

Boeing certifies the in-seat power system but does not certify or control the power cords and what is connected to them. The in-seat power system is qualified to the same standards as any other aircraft system. Sufficient attenuation is required within the power supply to ensure that the conducted emissions from laptop computers are not fed into the aircraft power system. In addition to the laboratory tests performed by the supplier, Boeing is required to conduct aircraft tests where the system is fully loaded with laptop computers.

Boeing has tested in-seat power on eight aircraft: two 737s, one 747, two 767s, and three 777s. The number of laptops operating simultaneously in each test ranged from 32 to 245. Included with the laptops were a mixture of compact-disc players and electronic games.

Boeing found no aircraft susceptibility in these eight tests, though some emissions were found to be extremely noisy in the laboratory (up to 40 dB over the aircraft equipment emission limit). The noise levels were above the aircraft equipment emission levels from 150 kHz to 500 MHz. Even though these computers did not cause any aircraft system anomalies, Boeing has observed aircraft antenna receiver susceptibility from "noisy" systems with levels significantly lower than those recorded by the laptop computers used in the tests.

Cell phone tests and analysis.

Boeing conducted a laboratory and aircraft test with 16 cell phones typical of those carried by passengers, to determine the emission characteristics of these intentionally transmitting PEDS. The laboratory results indicated that the phones not only produce emissions at the operating frequency, but also produce other emissions that fall within aircraft communication/navigation frequency bands (automatic direction finder, high frequency, very high frequency [VHF] omni range/ locator, and VHF communications and instrument landing system [ILS]). Emissions at the operating frequency were as high as 60 dB over the aircraft equipment emission limits, but the other emissions were generally within aircraft equipment emission limits. One concern about these other emissions from cell phones is that they may interfere with the operation of an aircraft communication or navigation system if the levels are high enough.

Boeing also performed an aircraft test on the ground with the same 16 phones. The aircraft was placed in a flight mode and the flight deck instruments, control surfaces, and communication navigation systems were monitored. No susceptibility was observed.

Telephones installed and certified on the aircraft by Boeing or operators are not actually cell phones, but part of an airborne certified satellite system. These phones are electromagnetically compatible with the aircraft systems because their emissions are controlled. In contrast, the emissions from passengers' cell phones are not known or controlled in the same way as permanently installed equipment.

RESULTING REGULATIONS AND RECOMMENDATIONS

All electrical and electronic aircraft systems are qualified to meet stringent requirements for electromagnetic susceptibility. They are tested to well-established limits during various modes of operation and with setup configurations that represent the aircraft installation in terms of electromagnetic protection. Sufficient margins exist between the qualification susceptibility test level and the expected aircraft environment noise levels.

Compliance with these requirements provides a high level of confidence that the aircraft systems will function as intended in the electromagnetic environment of the aircraft. However, susceptibility can occur in the aircraft if an uncontrolled source of electromagnetic energy radiates emission levels above the susceptibility level to which the aircraft system was tested or if the aircraft system protection has been degraded. In addition, aircraft systems with a receiving antenna component have an exception from the susceptibility requirements.

The radio frequency (RF) radiated susceptibility test is performed on the system over a full frequency spectrum, but not in the designed operating frequency band of the antenna. No value is gained from performing the RF radiated susceptibility test in the operating band of the antenna because it is designed to respond to signals in this band.

PEDs can radiate non-intentional noise within the aircraft antenna's operating frequency band, and this can create EMI.

Because the basic function of an antenna-based system is to seek and find low-level electromagnetic signals and to respond to signals in a certain frequency band, the probability of interference to these systems is more likely than interference to systems not connected to an antenna receiver.

As a result of these conclusions, recommendations and regulations regarding PED-related anomalies have been established by several agencies, including the U.S. Radio Technical Commission for Aeronautics (RTCA), the FAA, the U.S. Federal Communications Commission (FCC), and Boeing.

RTCA.

The RTCA has focused its attention on aircraft system susceptibility with the highest probability of EMI from a PED - namely, aircraft antenna receiver systems. (RTCA Document DO-199, 'Potential Interference to Aircraft Electronic Equipment from Devices Carried Aboard,' lists the eight conditions that are required for an aircraft antenna receiver system to experience interference from a PED.)

The RTCA concluded that the probability of a PED interfering with an aircraft receiver system is very low. In the case of an ILS localizer antenna, the probability of PED interference was calculated as one in one million. Based on the total number of flights per year (determined in 1988), the expected ILS localizer receiver disruption is once in any twoyear period.

The first national committee that investigated interference by passenger-carried PEDs was created in the early 1960s. Its activities were initiated by a report that a passenger-operated portable FM broadcast receiver caused an aircraft navigation system to indicate that the aircraft was off course by more than 100. The aircraft was actually on course and, when the portable receiver was turned off, the malfunction ceased. A final report from this committee, RTCA DO-119, was issued in 1963 and resulted in the revision of the FAA Federal Aviation Regulations (FAR) by establishing a new rule (FAR 91.19, now 91.21), which states that the responsibility for ensuring that PEDs will not cause interference with aircraft navigation or communication systems remained with the operator of the aircraft.

In the early 1980s, media attention focused on inflight portable computer use and variations in airline policies. Some computer trade publications suggested that their readers avoid particular operators who restricted the use of portable computers. As a result, one operator requested that a special committee be formed to "generate a Minimum Operational Performance Standards document against which manufacturers (of computers and other portable electronic devices) marketing their products for airborne use, could test and label them as meeting this standard in a manner similar to the Underwriters Laboratories Inc. sign of approval." In 1988 a final report was released (RTCA DO-199) that recommended the following :

- Acceptable limits of radiation and associated test methods for PEDs should be established.
- The FCC should specify a new classification for PEDs that may be operated on board aircraft.
- The FAA should initiate a regulatory project to revise FAR 91.19, providing guidance for acceptable methods of compliance and to develop methods to enhance public awareness.
- Standardized reporting of suspected interference by PEDs should be implemented.

In 1992, the U.S. Government requested that the RTCA resolve out-standing questions on PEDs to ensure air safety, specifying that unnecessary restrictions should not be placed on untested PEDS, and to gain an understanding of multiple effects and those from intentional radiators such as remote control devices and cell phones. For various reasons, intentional radiators were not evaluated. In 1996, the committee issued its report, RTCA DO-233. The recommendations are as follows:

1. The FAA should modify FAR 91.21 (previously 91.19), Portable Electronic Devices, so that
   a. The use of any PED is prohibited on aircraft during any critical phase of flight.
   b. The use of any PED having the capability to intentionally transmit electromagnetic energy is prohibited in an aircraft at all times unless testing has been conducted to ascertain its safe use.

2. PED testing efforts should be continued and should include existing and new technology devices such as satellite communications, embedded communications devices, and twoway pagers.

3. A public awareness campaign should be initiated to educate the flying public about PEDs and especially those designed as intentional radiators.

4. More research is needed on the design and feasibility of detection devices.

FAA.

In 1993, the FAA issued AC 91.21 -1, "Use of Portable Electronic Devices Aboard Aircraft." This circular provides guidance to the airlines in establishing compliance with FAR 91.21, which provides recommended procedures for airlines and test criteria for manufacturers. For the use of cell phones, the AC states that the FCC currently prohibits the use and operation of cell phones while airborne.

The reason for this relates primarily to cellular ground base system susceptibility because a cell phone in the air will have greater coverage (transmitting to several cell bases simultaneously on the same frequency) than a cell phone on the ground (transmitting to one cell base). The FAA supports this airborne restriction because of the potential for interference to critical aircraft systems.

Currently, the FAA does not prohibit use of cell phones in aircraft while on the ground if the operator has determined that they will not cause interference with the navigation or communication system of the aircraft on which they are to be used. An example might be use at the gate or during an extended wait on the ground, when specifically authorized by the captain. A cell phone must not be authorized for use while the aircraft is taxiing for departure after leaving the gate. The unit must be turned off and properly stowed; otherwise, a signal from a ground cell could activate it.

FCC.

The U.S. Code of Federal Regulations, Title 47, Part 22, Subpart H, "Cellular Radiotelephone Service," Section 22.925, "Prohibition on airborne operation of cellular telephones," states that cell phones installed in or carried. aboard aircraft must not be operated while such aircraft are airborne (not touching the ground). When any aircraft leaves the ground, all cell phones on board that aircraft must be turned off, and the use of cell phones while airborne is prohibited by FCC rules. The use of cell phones on the ground and in the aircraft is also subject to FAA regulations.

BOEING.

In addition to its active participation on the last two RTCA committees, Boeing released an all-model service letter in 1993 to provide guidance to operators regarding the use of PEDS. The letter included the following statements:

- Use of intentional transmitters should be prohibited at all times.
- Use of non-intentional transmitters should be prohibited during take-off and landing (critical stages of flight).
- Operation of non-intentional transmitters should be allowed for use during non-critical stages of flight unless the operator of the aircraft has determined otherwise.
- Airline procedures should be established for PED termination if problems arise.
- Data should be recorded during a suspected PED-related event.

Boeing has revised its service letter to be in accordance with the FAA AC on the use of cell phones while the aircraft is on the ground.

OPERATOR ACTIONS FOR INVESTIGATING AND PREVENTING PED EVENTS

Because PED interference is often named as the cause of aircraft anomalies, operators should be thorough when confirming a cause-and-effect relationship. Other possibilities should always be considered, including loose cables or other maintenance issues, flight crew activity, and HIRF.

The initial reports that operators submit to Boeing about possible PED interference must contain sufficient detail to allow further investigation, if desired. Follow-up information is difficult to obtain because the passenger and the PED involved in the event are seldom available, details may not have been fully documented, and relevant data may be unknown. To support further investigation, operators should provide the following data :

- Model and make of the PED.
- Identification of peripherals used with the PED.
- Seat location of the PED.
- Operating mode of the PED.
- Name, address, and telephone number of the passenger using the PED.
- Aircraft model and tail number or effectivity number.
- Identification of aircraft system and description of anomaly.
- Frequency and operation mode of the aircraft system, if applicable.
- Length of time between PED shut-off and aircraft system recovery, and confirmation of whether the PED was cycled off and on to confirm the cause-and-effect relationship.
- Flight phase and route.
- Copy of flight data recorder output.
- Results of post-maintenance inspection.

ONGOING RELATED ACTIVITIES AT BOEING

Boeing continues to monitor its fleet through reports submitted by operators and to investigate these reports when possible. The company continues to share its experience and knowledge of PEDs and aircraft with the industry and the public. Boeing is committed to supporting future committee activity and investigations into PED detection devices.

SUMMARY

Passenger-carried PEDs on commercial aircraft will continue to present a source of uncontrolled emissions and as a result may cause interference with aircraft systems.

The potential is great that PEDs will continue to be blamed for some anomalies regardless of whether they are the true cause. As a result, regulatory agencies and operators continue to offer the current policy for PED use on aircraft as the best safety measure.

Most operators enforce this policy, which calls for no PED operation during takeoff and landing, no operation of intentionally transmitting PEDs during any stage of flight, and allowing the use of cell phones at the gate with operator or flight crew approval and with a termination procedure in place in the case of an anomaly. If an operator or flight crew suspects a PED-related event, further investigation can be initiated if key information was recorded at the time of the anomaly. Whenever a PED is suspected as the cause of an aircraft anomaly, the operator should also investigate all other potential causes to validate the cause-and-effect relationship.