The European Organisation for Civil Aviation Equipment
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AIRCRAFT DESIGN AND CERTIFICATION FOR PORTABLE ELECTRONIC DEVICE (PED) TOLERANCE

ED-239

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FOREWORD

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EXECUTIVE SUMMARY

The United States FAA requested that RTCA, Inc. form a special committee SC-202 to present an up-to-date evaluation of the use of portable electronic devices (PEDs) on board civil aircraft with emphasis on intentional transmitters such as mobile phones, wireless radio frequency (RF) network devices, and other wireless-enabled devices such as personal digital assistants (PDAs). Most recently, SC-234 was formed to revise the requirements of this document to be consistent with existing high intensity radiated field (HIRF) requirements and incorporate industry lessons learned in addition to creating a new industry guidance and best practices document for determining aircraft PED tolerance through a safety risk assessment process, superseding RTCA DO-294C.

Special committees SC-202 and SC-234 included representatives from consumer electronic device manufacturers, avionics manufacturers, aircraft manufacturers, airlines, aircraft operators, pilot and flight attendant associations, regulatory agencies, and related industry associations. The committee worked closely with other industry groups such as the Consumer Electronics Association. This work was coordinated with the European Organisation for Civil Aviation Equipment (EUROCAE) Working Groups 58 and 99.

This report addresses the specific SC-202 Terms of Reference Phase 2, SC-234 Terms of Reference to revise DO-307, and incorporates DO-307 Change 1 to address aircraft design and certification to tolerate operation of PEDs. Previous RTCA reports on aircraft interference from PEDs have emphasized risk assessments and then recommended restrictions on the use of PEDs on aircraft. This report departs from the earlier RTCA reports, and is directed to aircraft design recommendations that lead to aircraft tolerance to both intentional RF transmissions and spurious RF emissions from PEDs.

There are two aspects to the aircraft design recommendations in this report. One aspect defines aircraft system and equipment RF susceptibility qualification recommendations that provide tolerance to RF from intentionally transmitting PEDs. This is commonly referred to as protection from PED back door coupling. The recommendations closely follow existing practices for aircraft system high intensity radiated field (HIRF) protection. Acceptable test approaches for verifying the aircraft system RF susceptibility qualification are defined.

The second aspect defines acceptable interference path loss between aircraft radio receivers and PEDs that emit spurious RF. This is commonly referred to as protection from PED front door coupling. Extensive analysis of measured PED spurious emissions was performed so that the interference path loss targets are based on statistics of actual PED emissions rather than regulatory specifications. Interference path loss test methods are defined.

This report also defines recommended approaches for demonstrating compliance with aircraft design certification regulations.

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CHAPTER 1

INTRODUCTION

Since the end of the 1950s, aircraft operators, aircraft manufacturers, and regulatory authorities have been concerned with the potential for interference with aircraft electrical and electronic systems by portable electronic devices carried on board by passengers and crewmembers. RTCA established five committees: 1) RTCA SC-88 was the earliest, publishing their study and recommendations in RTCA DO-119 in 1963 [Ref 1], 2) RTCA SC-156 published RTCA DO-199 in 1988 [Ref 3], 3) RTCA SC-177 published RTCA DO-233 in 1996 [Ref 4]. 4) RTCA SC-202 published RTCA DO-294C and DO-307 along with Change 1 to DO-307, and 5) the most recent, RTCA SC-234 publishing Rev A to DO-307 and an accompanying users guide.

One recurring recommendation in these reports is that portable electronic devices should not be used on board aircraft during critical phases of flight. However, research shows that passengers and crewmembers continue to operate portable electronic devices, either intentionally or inadvertently, even during takeoff and landing [Ref 5, 6]. Another recurring recommendation is that the regulatory authorities for consumer electronic devices, such as the US Federal Communications Commission (FCC), develop new standards that would limit the harmful emissions from consumer portable electronic devices. However, the consumer electronic device emissions standards have not changed to incorporate the RTCA recommendations. FCC has participated in several of the PED committees and SC-202 recommended changes to their emissions standards; however, these changes have not been adopted.

At the same time, systems have been developed to facilitate the use of portable electronic devices on board aircraft. For example, wireless RF networks have been installed and certified on aircraft that allow passengers and crewmembers to use laptops and other devices for internet and e-mail access through the wireless network. Picocells are being developed for installation on aircraft to allow passengers and crewmembers to use their personal mobile phones in flight, under the control of the picocells. In-seat power supplies are commonplace on aircraft, to allow passengers to power and use their PEDs during flight.

Given these issues, FAA requested that RTCA address the concept of aircraft design and certification so that the aircraft could tolerate use of portable electronic devices, so that adverse interference to the aircraft is unlikely. FAA requested that RTCA Special Committee 202 accept a task during the SC-202 phase 2 activity to address aircraft design and certification that would mitigate the risks from portable electronic devices. Accordingly, SC-202 designated working group 5 to develop aircraft design and certification recommendations for portable electronic device tolerance.

When implemented into an aircraft design, these design and certification recommendations would ensure that an aircraft is designed for PED tolerance, which would significantly reduce the potential for PED interference during all phases of flight. This approach considers transmitting and non-transmitting portable electronic devices and is not restricted to any specific portable electronic device technology, network implementation or intended device function. This focus on aircraft design and certification may reduce the operating restrictions on use of portable electronic devices by providing an aircraft whose systems have demonstrated proper functioning when exposed to the RF emissions and transmissions of PEDs. This may also minimize the need for aircraft operators to perform an allowance process based on specific types of portable electronic devices, as described in RTCA DO-294C [Ref 2] and Advisory Circular (AC) No. 91.21-1C [Ref 7], if they operate aircraft that have been designed for portable electronic device tolerance.

1.1 SCOPE

This document defines design guidance and certification recommendations for aircraft tolerance to interference from portable electronic devices. The aircraft design guidance and certification recommendations address all portable electronic devices, including transmitting portable electronic devices.

The document recommends specific interference path loss targets for aircraft to mitigate the effects of PED spurious emissions on aircraft radio receivers. The document recommends specific RF immunity requirements for aircraft systems that are exposed to PED intentional RF transmissions. For aircraft that successfully meet the recommendations in this report, aircraft operators will have high assurance that the PEDs will not interfere with aircraft systems even in critical phases of flight.

The recommendations are independent of class of aircraft; they can be applied to small and large airplanes, and small and large rotorcraft.

This document does not recommend mandatory certification requirements for PED interference tolerance. It does provide standard requirements for interference path loss and aircraft system immunity that can be used to demonstrate PED tolerance as part of aircraft certification.

1.2 TERMS OF REFERENCE

This document satisfies RTCA SC-202 committee terms of reference for Phase 2, Longer- Term PED Technology Assessment, Task 2, which states:

"Define and recommend specific guidance for aircraft design and certification that can mitigate risks identified for portable electronic devices, if determined practical by the special committee."

Revision A satisfies EUROCAE WG-99 and RTCA SC-234 committee terms of reference which state: *Revise specific requirements in DO-307 to be consistent with the existing high intensity radiated fields (HIRF) requirements and to incorporate industry lessons learned.*

CHAPTER 2

BACKGROUND

Portable electronic devices that may be carried by passengers and crewmembers on board aircraft are ubiquitous. These PEDs are becoming smaller, have powerful computing capability, and incorporate many features and functions. For example, at this time laptop computers have clock speeds on the order of a few gigahertz and incorporate multiple wireless RF transceivers. In another example, mobile phones may operate in multiple frequency bands, with multiple communication protocols, and incorporate features such as planners, calendars, and cameras. Many PED users are not aware if their devices are operating, or if the integrated radio transmitters are active.

Existing aviation regulations, such as the FAA regulation 14 CFR 91.21 [Ref 8], make it the responsibility of the aircraft operator to control passenger and crewmember use of portable electronic devices. However, the RTCA SC-234 committee and EUROCAE WG-99 were tasked to update aircraft design and certification recommendations that would mitigate the risks associated with the use of PEDs on board aircraft.

All PEDs radiate some level of unintentional RF emissions or spurious unwanted signals. These spurious RF emissions result from the internal electrical operation of the devices. In addition, many portable electronic devices intentionally transmit RF energy as useful signals for voice or data transmission. If a PED couples through wires to an aircraft power source or an aircraft data network, the coupled device also reproduces spurious conducted RF emissions that can propagate through the aircraft power or data wiring. FIGURE 2-1 illustrates the different types of PED RF emissions. In practice, for PEDs that are directly connected to aircraft power or data systems via wires, the wiring interface is subject to design and certification requirements that consider conducted spurious emissions. Therefore, the wired aspect of PED emissions is not addressed in detail in this document.

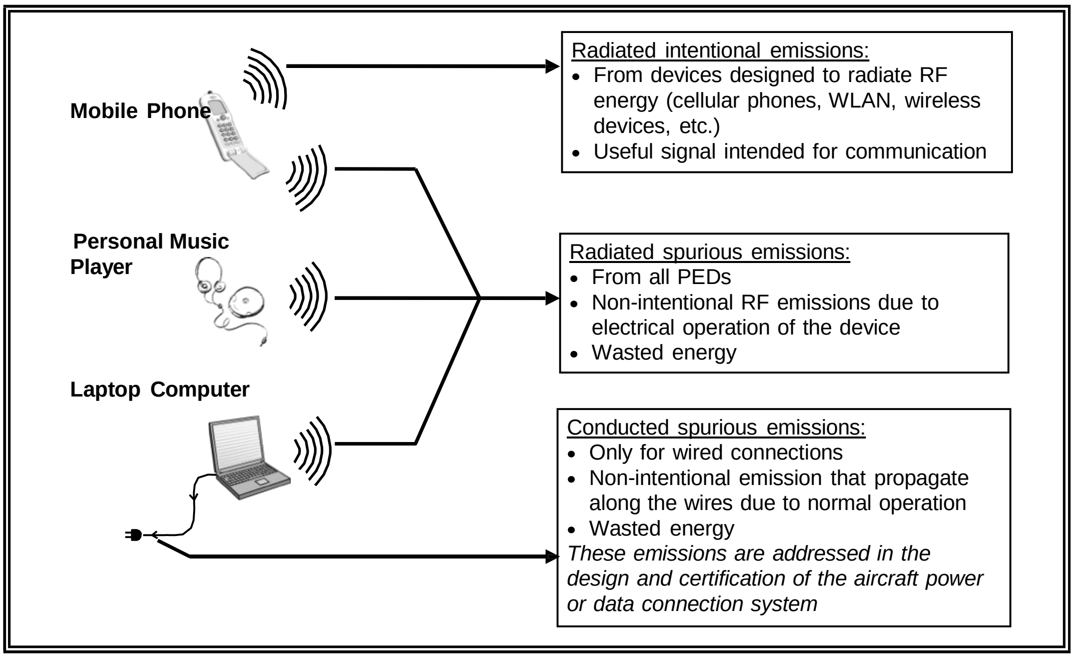

FIGURE 2-1: PED EMISSION TYPES

Any aircraft design and certification recommendations must consider the effects of both intentionally transmitting PEDs (T-PEDs), as well as unintentional RF emissions from all PEDs.

There are four conditions that contribute to potential portable electronic device interference to aircraft electrical and electronic systems. All four conditions must occur for interference to aircraft systems:

a. The portable electronic device must have RF emissions that occur at a frequency where the aircraft system may be susceptible.

b. The aircraft system must be sensitive to the portable electronic device emissions at the particular frequencies of the emissions.

c. The emissions of the portable electronic device must have RF emission of a high enough field strength to exceed the appropriate susceptibility level when measured at the appropriate point.

d. There must be a path for the RF emissions to be radiated or conducted to the potentially susceptible aircraft system.

A comprehensive discussion of PED and T-PED failure modes and potential impacts can be found in RTCA DO-294C Chapter 3 and Appendix 3. DO-294C concludes that, while failures contain some risk of interference, the risk is low for spurious emissions resulting in front-door coupling. Consequently, a separate consideration of PED failure modes is not considered necessary.

Other details will determine the potential effects PED emissions may have on aircraft electrical and electronic systems, and the consequences of these effects. These details include the PED emissions modulation characteristics, and the safety consequences of aircraft system failures and malfunctions.

The aircraft certification regulations do not control the portable electronic device RF emissions. Therefore the approach to aircraft design and certification for PED tolerance must focus on either controlling the path for RF emissions from the PED to the aircraft systems, or controlling the aircraft system sensitivity or immunity to the PED emissions.

2.1 PREVIOUS STUDIES

RTCA, Inc. has previously established four working groups to study this issue and make recommendations. The earliest was RTCA Special Committee 88, which completed its work in 1963. Their study showed a link between local oscillator leakage from transistorized FM radio receivers that could be received by localizer and VOR radio receivers. Their findings and recommendations were published in RTCA DO-119 [Ref 1]. RTCA Special Committee 156 published RTCA DO-199 [Ref 3], which considered the interference path loss between PEDs and aircraft receivers. Special Committee 177 published RTCA DO-233 [Ref 4], which developed the risks from PED spurious emissions and documented measured PED emissions. Finally, RTCA Special Committee 202 published their Phase 1 recommendations in RTCA DO-294C [Ref 2] and their Phase 2 recommendations in RTCA DO-307 [Ref TBD] along with Change 1 to DO-307 [Ref TBD). DO-294C emphasizes the process that aircraft operators should use to show whether PED use is acceptable. That report also provides RF characteristics of transmitting portable electronic devices, and describes the interference thresholds of aircraft radio receivers. DO-307 defined design guidance and certification recommendations for aircraft tolerance to interference from all portable electronic devices. EUROCAE Working Group 58 has also prepared reports on PED interference. EUROCAE ED-118 [Ref 9] characterized the envelopes of PED spurious emissions and envelopes of transmitting PED emissions. EUROCAE WG-58 has worked closely with RTCA SC-202 for aircraft design and certification recommendations, and has published EUROCAE ED-130A [Ref 10] with recommendations in Annex 4 similar to those in this report for equipment qualification levels.

The most significant difference for RTCA DO-307 and ED-130A is that this report and ED-130A focus on the aircraft design and certification for PED tolerance. The earlier reports emphasize operating limits on the use of PEDs on board aircraft, and did not consider aircraft requirements for PED tolerance.

2.2 COUPLING PATHS

RF signals traveling from one point to another can be conducted on wires and radiated through space. Conducted emissions from a PED can occur only if the PED is directly connected to the aircraft via wiring or structure. Radiated emissions from a PED may couple to aircraft systems through apertures in aircraft equipment, induce currents on aircraft wires, or be received by antennas providing a direct path into the aircraft radio receivers. EUROCAE ED-118 [Ref 9] introduced nomenclature for classifying PED-to-avionics coupling paths. This nomenclature will be used for the interference path loss (IPL) discussions that follow in the remainder of this report. The letters in the nomenclature refer to the source of the interference and the potential coupling issue.

The term ‘coupling path’ is used to describe how the emissions propagate and are received by the systems. For radiated spurious and intentional emissions from PEDs, there are two types of coupling paths.

Back door coupling: RF energy radiates from the PED and couples directly into the aircraft electrical and electronic equipment or into the wiring that connects to this equipment. Back door coupling can affect any aircraft electrical and electronic equipment. Back door coupling also includes directly conducted RF energy from the PED, where there is a direct wired connection from the PED to aircraft power, data, or control system. This conducted back door coupling can occur with in-seat power supplies or aircraft wired local area networks.

Front door coupling: RF energy radiates from the PED and couples directly into the aircraft radio receiver antennas. Front door coupling applies only to aircraft radio receivers.

When the coupling paths are combined with the types of PED emissions, eight classes of PED interference have been defined in RTCA DO-294C and EUROCAE ED-118. ED-118 and DO-294C have concluded that three of these classes of PED interference should be addressed when assessing the use of PEDs on aircraft. TABLE 2-1 summarizes the EUROCAE ED-118 classes of PED interference. These classes of potential PED interference are discussed in more detail in the following sections.

TABLE 2-1: POTENTIAL PED INTERFERENCE CLASSES (ADAPTED FROM ED-118)

PED emission type	Coupling path	Nomenclature	Coupling type	Conclusions from previous studies
Intentional **R**adiated emissions (useful signals)	Coupling through radio **A**ntennas	IRA	Front door	Interference is unlikely in any case
	Direct coupling to equipment **U**nits	IRU	Back door	Must be considered
	Coupling to equipment input and **C**ables	IRC	Back door	Must be considered
Non intentional **R**adiated emissions (spurious emissions)	Coupling through radio **A**ntennas	NIRA	Front door	Must be considered
	Direct coupling to equipment **U**nits	NIRU	Back door	Interference is unlikely in any case
	Coupling to equipment input and **C**ables	NIRC	Back door	Interference is unlikely in any case

Conducted spurious emissions	Coupling to **E**quipment **I**nputs	CEI	Back door	Already considered as part of aircraft equipment installation certification
	Cross **T**alk (cable to cable coupling)	CCT	Back door	Already considered as part of aircraft equipment installation certification

2.2.1 Front Door Coupling of Spurious Radiated Emissions (NIRA)

In the operational band of the receivers, the spurious emissions from PEDs received by the aircraft radio receiver antennas can potentially interfere with aircraft radio receivers for two reasons:

a. Aircraft radio receivers are designed to detect very low amplitude signals within their tuned frequency bandwidth, and therefore are also sensitive to very low amplitude interfering signals in these bands.

b. The spurious emissions from PEDs can occur within the tuned frequency bandwidth of the aircraft radio receivers.

FIGURE 2-2 illustrates the potential interference. Spurious emissions with noise-like characteristics increase the noise floor of the affected aircraft radio receivers, distorting low-level desired signals until they are no longer usable. This effectively increases the level of the desired signal necessary for proper communication or guidance, decreasing the maximum operating range for the aircraft radio system. Spurious emissions from PEDs with continuous (CW-like) characteristics can also be received by the aircraft radio receivers and detected as a valid signal, resulting in erroneous responses aircraft system receivers.

Previous analysis in DO-233 [Ref 4] and the interference assessment process described in Section 6 of DO-294C [Ref 2] indicate that low level spurious emissions at frequencies outside the IF bandwidth of the victim receiver will not cause meaningful interference.

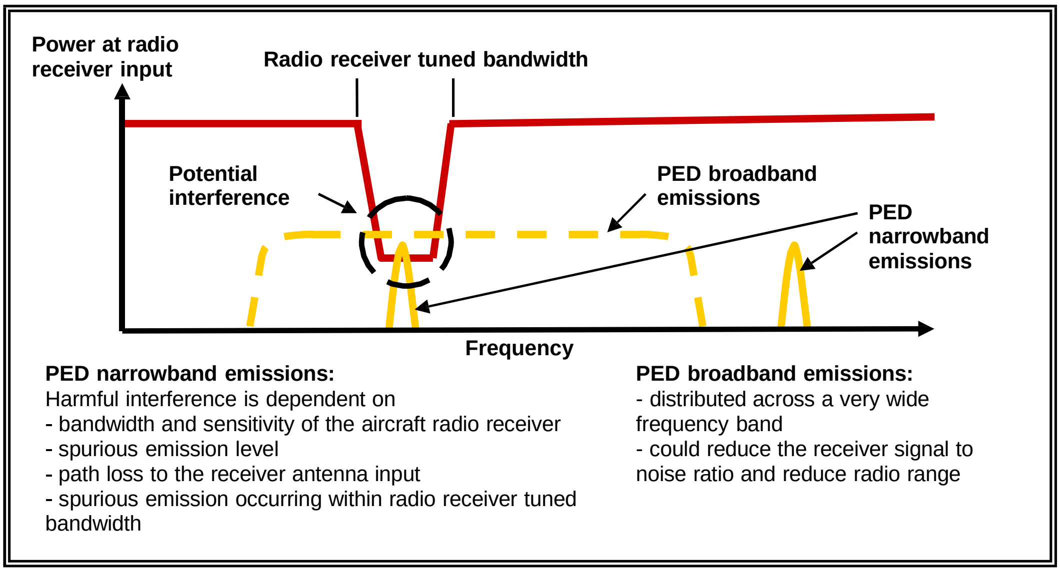

FIGURE 2-2: FRONT DOOR COUPLING OF SPURIOUS RADIATED EMISSIONS (NIRA)

Various studies and aircraft incidents indicate that NIRA interference should be addressed when establishing aircraft tolerance to PED emissions. Broadband (i.e., noise- like) spurious emissions are likely to be a more significant threat than narrowband (i.e., CW-like) emissions, as previous analyses in DO-199 [Ref 3] and DO-233 [Ref 4] have indicated that narrowband emissions require a worst-case combination of condition to affect victim receivers.

2.2.2 Front Door Coupling of Intentional Radiated Emissions (IRA)

The intentional emissions from T-PEDs occur in either licensed frequency bands (such as bands allocated to mobile telephony), in strictly limited and specifically unlicensed bands (such as the FCC Unlicensed National Information Infrastructure bands), or in extremely wide bands with extremely limited power constraints (such as ultra wideband systems). In all cases, these bands are allocated by the international and national telecommunication authorities. Aircraft radio communication, navigation and surveillance frequency bands are internationally harmonized through treaties, and national telecommunication regulatory authorities ensure that no other RF service is assigned within these bands.

Therefore, T-PEDs do not intentionally transmit in the frequency bands currently used for aircraft radio communication, navigation and surveillance. The aircraft communication, navigation and surveillance radio receivers are protected against interference for transmitters outside their operational frequency band, as illustrated in FIGURE 2-3. The separation of operational frequencies, use of Minimum Operational Performance Standards (MOPS) that provide out-of-band interference protection for aviation receivers, and the observation that IRA IPL tends to be higher than NIRA IPL, all combine to minimize impact of IRA. Therefore, the potential for front-door interference from intentional radiated emissions to the antenna is negligible, and does not need to be separately addressed for ensuring aircraft PED tolerance.

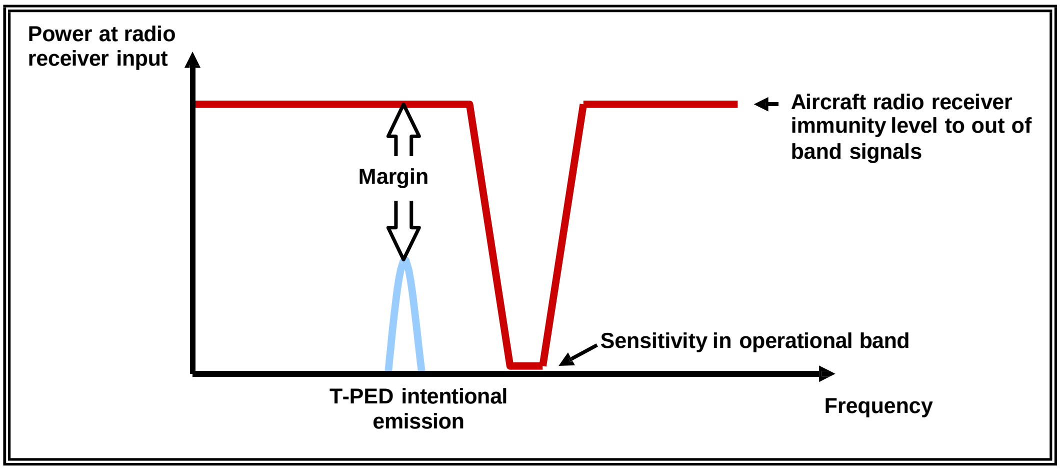

FIGURE 2-3: FRONT DOOR COUPLING OF INTENTIONAL RADIATED EMISSIONS (IRA)

2.2.3 Back Door Coupling of Intentional Radiated Emissions (IRU, IRC)

Intentional RF emissions from transmitting PEDs have the potential to interfere with aircraft electrical and electronic systems by means of coupling to cables or directly into the aircraft system equipment. The potential for interference depends on the strength of the PED transmitted signal, and the aircraft system susceptibility at the specific frequency of the PED transmission. FIGURE 2-4 illustrates the interference scenario for back door coupling.

Aircraft electrical and electronic systems are protected against the effects of electromagnetic interference, particularly against high intensity radiated fields (HIRF), and both the direct and indirect effects of lightning. The system tolerance to RF fields depends on the system criticality and its location in the aircraft. The system RF test average field strengths range from 1 V/m to 300 V/m. The aircraft system HIRF and lightning protection provide some immunity to back door effects of PEDs.

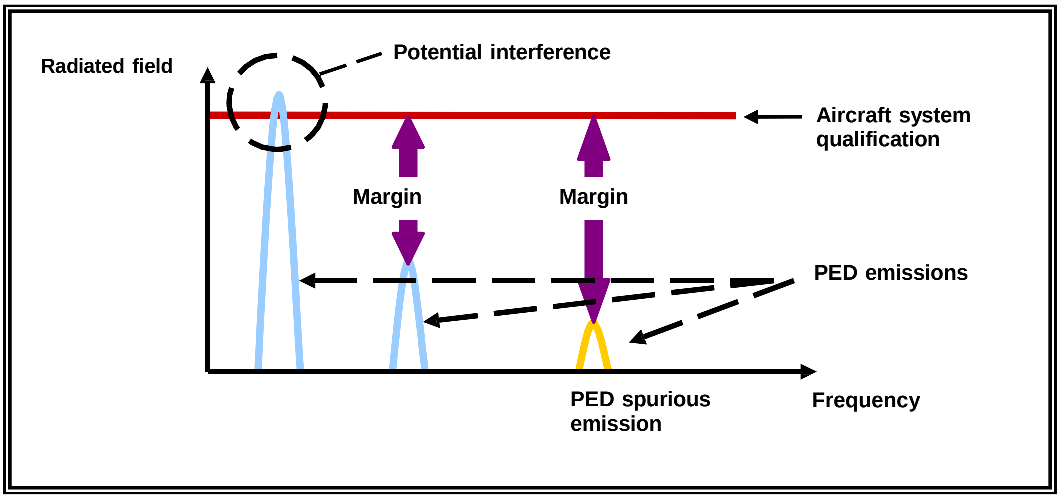

FIGURE 2-4: BACK DOOR COUPLING OF RADIATED EMISSIONS (IRU, NIRU, IRC, NIRC)

For frequencies below approximately 400MHz, RF coupling onto the system interconnecting wiring provides the dominant path from the PED to the aircraft system. Therefore in this frequency range, the amplitude of spurious PED emissions coupled onto the wiring can be directly compared to the amplitude of the functional signal amplitudes of the aircraft electrical and electronic systems. Above approximately 400 MHz, coupling occurs primarily through the interconnecting wiring within roughly a wavelength’s distance from the connector on the aircraft electrical or electronic equipment, or through physical openings directly into the electrical or electronic equipment.

Close to the PED source, transmitting PEDs can generate electric field strengths on the order of tens of volts per meter, so there is a significant potential for transmitting PED signals to interfere with aircraft electrical and electronic systems. This back door interference from intentional PED transmissions (IRU and IRC) should definitely be considered when evaluating aircraft PED tolerance.

2.2.4 Back Door Coupling of Spurious Radiated Emissions (NIRU, NIRC)

Spurious PED emissions produce very low amplitude radiated fields of, typically less than 0.1 V/m at a distance of one meter from the PED. The spurious emissions from a cellular telephone are typically more than a thousand times lower than the intentional transmitted signal generated by the telephone to establish the communication. Therefore back door interference from spurious PED radiated RF emissions (NIRU, NIRC) is unlikely, and does not need to be addressed for aircraft PED tolerance.

2.2.5 Interference from Conducted Emissions (CEI and CCT)

Interference from conducted spurious signals from a PED physically connected to aircraft power or data wiring was considered unlikely because:

a. The aircraft power and data networks intended for PED connections must be isolated from aircraft power and data networks required for aircraft safety.

b. These power and data networks incorporate EMI filters to limit spurious emissions from PEDs that may be conducted onto the power and data networks.

The conducted spurious emissions must be addressed as a part of the design and certification of the installed aircraft power or data system that allow PED connection. Tolerance of CEI and CCT classes of PED interference is specifically considered during the design and certification of the aircraft PED power supplies and data networks, therefore, these classes of PED interference are not addressed in this document.

CHAPTER 3

AIRCRAFT SYSTEM TOLERANCE TO INTENTIONALLY TRANSMITTING PEDS (BACK DOOR COUPLING COMPLIANCE)

Approved and unapproved use of T-PEDs on passenger airplanes is widespread. NASA Aviation Safety Reporting System (ASRS) reports [Ref 6] and recent research by Carnegie-Mellon University [Ref 5] indicate that operation of T-PEDs during transport airplane operation is common. Transmitting PEDs are widespread among passengers and crewmembers, take many forms and have many functions. In many cases the transmitting radio is embedded in a PED so that the operation of the radio transmitter is not apparent to the PED user. These transmitting PEDs operate in many frequency bands and with a wide range of transmitted RF power. Common transmitting PEDs and their transmitted RF power are listed in DO-294C (Appendix 3) [Ref 2].

Spectrum management regulations make it unlikely that transmitting PEDs will interfere with aircraft radio receivers through front door coupling. However, transmitting PEDs do have the potential for interference with other aircraft systems through back door coupling. The risks associated with aircraft system interference from transmitting PEDs is dependent on:

a. The frequency radiated by the T-PED

b. The power radiated by the T-PED

c. The path loss between the T-PED and potentially susceptible aircraft systems

d. The sensitivity of the aircraft system to the T- PED transmission

e. The consequences of interference to specific aircraft systems

There are several options for reducing the risk of transmitting PEDs interfering with aircraft systems. One option is to control the path loss from the transmitting PEDs inside the aircraft to the aircraft systems. However, transmitting PEDs may be located and operated in the aircraft cabin, cockpit or flight deck, or cargo or baggage compartments. In these locations, the transmitting PED may be very close to the aircraft systems and wiring. This results in very low path loss, and increasing the path loss by using shielding materials is generally considered impractical due to manufacturing and continued airworthiness issues.

Another option is to decrease the RF power that transmitting PEDs radiate, by changing consumer electronics RF power limits. However, aircraft manufacturers have no control over PED standards, particularly with variations in the national standards for consumer RF transmitter electronic devices.

A third option is to increase the RF immunity of aircraft systems. If adequate aircraft system RF immunity is provided, then the aircraft system installations are tolerant of transmitting PEDs. This is an aspect that aircraft manufacturers and aviation regulatory authorities can directly control. This approach is similar to the one already used for aircraft system HIRF protection.

Therefore, this section describes the process to determine appropriate aircraft system RF immunity and provides recommended aircraft system RF immunity requirements that will result in tolerance to transmitting PEDs. Using these system RF immunity requirements, aircraft systems and equipment can be designed to make the risks associated with transmitting PEDs very unlikely. This section addresses direct coupling to equipment units (IRU) and coupling to equipment input and cables (IRC) described in TABLE 2-1, above.

The aircraft RF environment produced by transmitting PEDs differs from the aircraft RF environment associated with HIRF. The major differences are:

a. Transmitting PEDs may operate very close to aircraft systems and wiring, within the aircraft cockpit, cabin, and baggage areas while HIRF transmitters operate some distance outside the aircraft. Low transmit power from PEDs compared to HIRF transmit power mitigates this difference.

b. Aircraft typically fly through the maximum HIRF RF levels in a few seconds, while the transmitting PEDs operate within the aircraft for a large portion of the flight. The test procedures used to qualify aircraft systems for HIRF expose the aircraft systems for durations that are long enough to mitigate this difference.

c. HIRF transmitters are typically very high power transmitters in specific geographic locations outside the aircraft, while transmitting PEDs may be operated in many locations within the aircraft, including the cabin, cockpit, and baggage or cargo compartments. Selection of test levels for demonstrating transmitting PED tolerance can mitigate this difference.

3.1 AIRCRAFT SYSTEMS THAT SHOULD BE CONSIDERED

Any locations within the aircraft where transmitting PEDs can be operated must be considered. These locations should include but are not restricted to the passenger cabin, the cockpit and flight deck, cargo bays, baggage compartments, crew rest areas, lavatories, and galleys.

The aircraft systems and equipment that require the certification applicant to demonstrate tolerance to transmitting PEDs should be identified. These include systems and equipment that have been identified as performing functions with failure condition categories of major, hazardous or catastrophic through the safety assessment activities, such as 14 CFR 25.1309 and EASA CS 25.1309 compliance, as well as required aircraft cockpit voice recorders and flight data recorders.

3.2 EVALUATION OF TRANSMITTING PED FIELD STRENGTH

The RF field strength that the aircraft electrical and electronic systems are exposed to de pends on the power transmitted by the PED, the gain of the PED transmit antenna, and the separation distance between the transmitting PED and the aircraft electrical and electronic systems.

The RF power density generated by a transmitting PED can be calculated using far field assumptions:

$$P_d = \frac{P_t\, G}{4\,\pi r^2}$$

where:

P_t	Power transmitted
G	Maximum gain of PED transmit antenna
r	Distance from PED transmit antenna

However, for most given standards, usually either the maximum effective radiated power (ERP) or the effective isotropic radiated power (EIRP) are specified, the latter being related to the electric field strength and distance from the antenna in the far field as:

$$E = \frac{1}{r}\sqrt{\frac{EIRP\,\eta}{4\,\pi}}$$

where:

E	Electric field strength
η	Impedance of free space (120π ohms)
r	Distance from PED transmit antenna

For near field conditions, the Maxwell equations need to be solved, since the fields depend on the type and shape of the source. However, this rigorous approach is highly dependent on the boundary conditions, which may take almost arbitrary values in real life circumstances, which means that the above far-field approximation can still be used even for distances smaller than one wavelength. The approach used in this document is discussed in section 3.3 below.

More in-depth discussion, in regard to both field strength and signal parameters (such as modulation characteristics) is included in DO-294C [Ref 2], ED-118 [Ref 9], and ED-130A [Ref 10].

3.3 AIRCRAFT SYSTEM RF IMMUNITY REQUIREMENTS FOR T-PED TOLERANCE

For the equipment and systems identified in Section 3.1, TABLE 3-1 provides recommended minimum aircraft system RF radiated susceptibility test levels for demonstrating T-PED tolerance, using RF susceptibility test procedures and categories defined in EUROCAE ED-14 / RTCA DO-160 [Ref 11] (Section 20).

These levels were developed as a result of the review of information provided in Appendix B of DO-294C. As denoted within that document, it is possible for higher peak field strengths to be present as a result of close proximity of a T-PED. However, due to the test methods employed within standard test documents, such DO-160 / ED-14, where the entire EUT and at least one half wavelength of wiring must be exposed to the required radiated field, the overall coupled energy resulting is orders of magnitude greater than that which would be coupled by the T-PED antennas, which are physically small compared to the EUT wiring. Therefore, a compromise was accepted within the committee to default to standard test methods and levels.

3.4 METHODS TO VERIFY AIRCRAFT SYSTEM PED TOLERANCE

As in most areas of showing compliance to defined requirements, there are multiple methods of achieving the goal of verifying aircraft system PED tolerance.

The first step to demonstrate PED tolerance would be the identification of the systems and equipment as defined in Section 3.1. After the systems and equipment have been so identified, the applicant must verify that the equipment is qualified to the requirements in Table 3-1 or the aircraft has been certified for HIRF. If the equipment has been previously qualified to the immunity requirements in the table, then the qualification can be submitted in a compliance report to the FAA or other appropriate aircraft certification authority as a means of showing compliance to the back door coupling requirements for transmitting PEDs.

The FAA and EASA aircraft HIRF regulations and the EASA/JAA HIRF special conditions include RF susceptibility requirements for systems and equipment that are classified with major, hazardous or catastrophic failure conditions. Aircraft that meet the FAA or EASA HIRF regulations or EASA/JAA HIRF special conditions for all appropriate systems described in Table 3-1 are considered PED tolerant for back door effects. No further analysis or testing is required when PED tolerance for back door effects is met through aircraft HIRF certification for the FAA or EASA HIRF regulations or EASA/JAA special conditions. Table 3-1 includes requirements for cockpit voice recorders and flight data recorders, in addition to the systems with major, hazardous or catastrophic failure conditions.

Aircraft that only meet the FAA HIRF special conditions have RF susceptibility requirements only for systems classified with catastrophic failure conditions, and do not address systems and equipment with major and hazardous failure conditions. These aircraft do not demonstrate PED tolerance for back door effects. Other actions must be taken to demonstrate aircraft PED tolerance for back door effects. Additional guidance is provided in ED-130A / DO-363, section 3.6.1.

One method of adapting the ED-14 / DO-160 test methods would be that the applicant could pre-calibrate the required field strength within a shielded room, using the calibration technique adapted from ED-14 / DO-160 (Section 20.5 and Figure 20-10). The forward power levels required to produce the field strength (Category R or Category W) should be recorded and the test equipment transferred to the aircraft and tests conducted on the required aircraft systems using the recorded forward power. However, RF fields are extremely hazardous at high power levels, and this type of test method may require special licenses from telecommunication authorities such as the FCC.

It is possible to verify the equipment tolerance using a combination of the methods defined above. For example, there may be situations where some equipment has been previously qualified to TABLE 3-1 requirements, either by test or analysis. However, some equipment may require additional laboratory and/or on-aircraft testing. The verification will need to be documented and submitted to the appropriate aircraft certification authorities for approval.

TABLE 3-1: AIRCRAFT SYSTEM RF RADIATED SUSCEPTIBILITY TEST RECOMMENDATIONS

System functional failure condition classification	Distance between T-PED and system LRU ≥ 20 cm	Distance between T-PED and system LRU < 20 cm
Catastrophic	ED-14D/DO-160D, change 1 or later issues Section 20 Category XR	ED-14D/DO-160D, change 1 or later issues Section 20 Category XW limited to 8 GHz
Hazardous	ED-14D/DO-160D, change 1 Section 20 Category XR	ED-14D/DO-160D, change 1 Section 20 Category XR
Major	ED-14D/DO-160D, change 1 Section 20 Category XT	ED-14D/DO-160D, change 1 Section 20 Category XT
Cockpit voice recorders and flight data recorders	ED-14D/DO-160D, change 1 Section 20 Category XT	ED-14D/DO-160D, change 1 Section 20 Category XT
Minor and no safety effect and not required by regulation	No requirement	No requirement

NOTES:

1. *ED-14D/DO-160D, change 1 Section 20 uses two category characters. Conducted susceptibility test levels are designated with the first character, and radiated susceptibility test levels are designated with the second character. The 'X' as the first character in this table means that conducted susceptibility tests are not required to be performed for PED tolerance.*
2. *ED-14D/DO-160D, change 1 or later revisions are acceptable.*

However, if the examination of the equipment qualification environments reveals that the levels are not sufficient, then additional tests or analysis must be performed on these systems to the requirements defined in TABLE 3-1.

The RF radiated susceptibility requirement for the cockpit voice recorders and flight data recorders is for the recorders themselves and not the overall recorder systems. The cockpit voice recorder and flight data recorder equipment should continue to record the necessary parameters required by cockpit voice recorder and flight data recorder operational and airworthiness regulations when subjected to the RF susceptibility test categories shown in TABLE 3-1. Sensors and other equipment connected to the required cockpit voice recorders and flight data recorders are not required to be tested to categories XT. The performance of the cockpit voice recorders and flight data recorders with these sensors and other equipment, as installed in the aircraft, are checked periodically based on the required maintenance tasks, where any T-PED or HIRF effects must be resolved. They are subject to the RF radiated susceptibility requirements based on their hazard classifications of minor, major, hazardous, or catastrophic, as appropriate.

Analysis may also be used to show compliance. In some cases, such as for electromechanical devices like lights and valves, showing immunity to the effects of radiated energy produced by T-PEDs is relatively straightforward. This is due to the fact that these devices are inherently immune to relatively low levels of RF energy. However, analysis may be used for more complex electrical/electronic devices, but the analysis approach must be validated, and should be reviewed and approved by the appropriate aircraft certification authorities.

If testing is required, the standard requirements of qualification testing, such as approved test procedures, pass/fail requirements, test article conformity, and test witnessing must be followed. There are generally two test methods that can be used to perform this testing.

The first method is to bring the systems or equipment to a RF test facility and perform the standard RF susceptibility tests in accordance to the requirements in TABLE 3-1.

The second method is to perform the tests on the systems while installed on the applicable aircraft. This type of testing is outlined within ED-130A / DO-363 section 6. The procedures within these documents provide general guidelines, such as system identification, transmit antenna locations, and field strengths relative to T-PED output to be used in conducting the test. Since this report provides test levels in TABLE 3-1, then the aircraft tests may adapt the ED-14 / DO-160 test methods for the on-aircraft tests.

Successful tests of the systems or equipment using either of these two methods demonstrate that the aircraft is T-PED tolerant.

CHAPTER 4

AIRCRAFT TOLERANCE TO PED SPURIOUS EMISSIONS (FRONT DOOR COUPLING COMPLIANCE)

4.1 RISK ASSESSMENT OF PED USAGE

The risk to aircraft, crewmembers and passengers associated with PED spurious RF emissions have been investigated in RTCA DO-199 [Ref 3] and RTCA DO-233 [Ref 4]. The likelihood of PED spurious RF emissions resulting in adverse aircraft safety effects depends on the following factors:

a. Passengers and crewmembers bring PEDs on board.

b. PEDs are turned on.

c. Aggregate PED spurious RF emissions as measured at the victim receiver exceed a frequency-dependent tolerable limit.

d. PEDs are in aircraft locations with minimum interference path loss.

e. Aggregate PED spurious RF emissions that exceed a frequency-dependent tolerable limit are on the same tuned frequency as the aircraft radio receiver in use.

f. The aircraft radio receiver is operating in its most sensitive range or mode.

g. PED spurious RF emissions have characteristics that cause adverse effects in the aircraft radio receivers.

h. The flight crew does not detect aircraft system effects caused by PED spurious RF emissions.

While any one of these factors may be expected, the combination of all these factors is needed to result in significant adverse effects to the aircraft. The actual combination of these independent factors is improbable, which explains why there are so few documented problems with PEDs in air travel today.

There are several options for reducing the risk that PED spurious RF emissions will interfere with aircraft radio receivers.

- One option is to decrease the sensitivity of aircraft radio receivers. However, decreasing aircraft radio receiver sensitivity will lead to a decrease in radio range and performance. This option would have detrimental effects on the function the aircraft radio receivers are intended to perform.
- A second option is to decrease the spurious RF emissions that PEDs radiate, through more stringent consumer electronics RF emission standards. However, aircraft manufacturers have no control over PED RF emissions, particularly with variations in the national standards for RF emissions from consumer electronic devices. Also, this option does not address PEDs that are produced to earlier standards.
- A third option is to control the path loss from the PEDs inside the aircraft to the aircraft radio receiver. Aircraft can be designed and tested to achieve adequate path loss from the PED, through the aircraft radio receiver antenna, to the radio receiver. If adequate path loss is provided, then the aircraft radio receiver installations will be tolerant to PED spurious emissions. This is the only aspect that aircraft manufacturers and aviation regulatory authorities can directly control.

Since the third option is the most viable from the industry standpoint, this section describes the process to determine appropriate aircraft interference path loss for aircraft radio receiver installations and provides recommended PED interference path loss targets that will result in tolerance to PED spurious RF emissions. Using these interference path loss targets, aircraft can be designed to minimize the risks associated with PED spurious RF emissions. This section addresses front door coupling of spurious radiated emissions (NIRA) described in section 2, FIGURE 2-2.

4.2 PED EMISSIONS ANALYSIS

In order to assess the nature of the threat posed by PED emissions, an effort was mounted to acquire emissions measurements from a variety of devices. Fortunately, many measurement campaigns have been conducted over the years as awareness of the PED threat has become more prominent, and thus data is available for collection, collation, and analysis.

A request for data sharing resulted in several organizations providing PED emissions data. The contributors included:

a. NASA
b. Cessna Aircraft
c. The Boeing Company
d. The FAA

Numeric electromagnetic emissions data were collected from a total of over 150 unique PEDs. Graphical data for another 148 PEDs were also reviewed for some frequency bands due to the lack of numerical data. The PEDs were loosely categorized into device classes. TABLE 4-1 shows the device classes used and the total number of devices in each class. The device classes were:

a. 2-Way Radio – FRS (family radio service) type radios – sometimes referred to as “walkie-talkie” or “handy-talkie” radios
b. CMRS – Commercial Mobile Radio Services, the FCC nomenclature for mobile phones or “cell phones”
c. Computer – includes laptop computers and personal digital assistants (PDAs) without wireless capability
d. WLAN – wireless local area networks using the 802.11 family of technologies
e. WPAN – wireless personal area networks using the Bluetooth or 802.15 family of technologies

TABLE 4-1: COUNT AND CLASS OF PORTABLE ELECTRONIC DEVICES USED IN EMISSIONS MEASUREMENTS

Device Class	Count of Devices
All	157
2-Way Radio	10
CMRS	87
Computer	20
WLAN	23
WPAN	17

The data was collected by different organizations, at different times, with different objectives, with several measurement techniques. Many of the measurements were taken in accordance with EUROCAE ED-14 / RTCA DO-160 Section 21 [Ref 11] techniques. Other measurements were performed using reverberation chamber techniques, or using modified EUROCAE ED-14 / RTCA DO-160 Section 21 techniques described in RTCA DO-233 [Ref 4].

The trend in technology for new PEDs use smaller electronic components that use lower power and lower signals and therefore the emissions are not considered to be increasing. The spurious emissions analyzed at the initial revision of this document are still considered acceptable. As a result of this the assumptions from the previous version of DO-307 for spurious emissions are still valid.

4.2.1 RTCA DO-160 / EUROCAE ED-14 Methods

As previously noted, many of the data were obtained using EUROCAE ED-14 / RTCA DO-160 measurement methods.

Generally, EUROCAE ED-14 / RTCA DO-160 calls for the use of a semi-anechoic chamber, equipped with RF absorber on the walls and ceiling, but with metallic benches (for grounding purposes). In addition, EUROCAE ED-14 / RTCA DO-160 specifies numerous metrics such as measurement distance, equipment grounding, bench configuration, and similar requirements.

Resolution bandwidths for each measurement spectrum are specified in Paragraph 21.5 of EUROCAE ED-14 / RTCA DO-160. For convenience, the bandwidth specification is repeated in TABLE 4-2 for reference as to the standards when this study was conducted.

TABLE 4-2: RESOLUTION BANDWIDTH SETTINGS FROM RTCA DO-160 / EUROCAE ED-14 SECTION 21

Frequency Band	Resolution Bandwidth (RBW)
0.15-30 MHz	1 kHz
30-400 MHz	10 kHz
400-1000 MHz	100 kHz
1000-6000 MHz	1 MHz

4.2.2 Reverberation Chamber Methods

Some data was taken using reverberation chambers for these measurements. Reverberation chambers have the advantage of effectively capturing the peak emissions of a given device without requiring multiple measurements to determine in which direction the peak emissions emanate. Additionally, reverberation chambers effectively capture the maximum of both field polarizations, again reducing the effort required to make measurements. Reverberation chambers do require mode stirring, and care must be taken that proper mode stirring methods are employed.

4.2.3 RTCA DO-233 Methods

For some data collection, other measurement methods were used based on the processes defined in DO-233. The primary differences between the ED-14 / DO-160 and DO-233 methods are elimination of the conductive surface on which the PED rests, and the height of the bench is reduced to 80 cm from 1 m.

4.2.4 Narrowed Resolution Bandwidth Methods

For some measurements, NASA engineers used different resolution bandwidths (RBW) than typical in certain frequency ranges, as shown in TABLE 4-3. The objective of using a smaller resolution bandwidth is to improve the measurement by reducing the noise floor of the spectrum analyzer used to perform the measurements. A RBW of 10 kHz will have a measurement noise floor that is 20 dB below the measurement noise floor experienced with a 1 MHz RBW. Therefore, by reducing the RBW, the spectrum analyzer may more accurately characterize lower emission levels of the PED unit under test.

TABLE 4-3 - RESOLUTION BANDWIDTH USED BY NASA DURING DATA COLLECTION

Frequency Band	Resolution Bandwidth (RBW)
105-140 MHz	10 kHz
325-340 MHz	10 kHz
960-1250 MHz	100 kHz
1565-1585 MHz	10 kHz
5020-5100 MHz	30 kHz

4.3 HARMONIZING THE DATA

In order to obtain useful statistics from the disparate data sources, the data needed to be manipulated in the following ways:

Measurement Bandwidth Correction: Noise-like emissions data obtained using narrow resolution bandwidth methods were adjusted using the standard correction factor

$$CF = 10\log\left(\frac{BW_{New}}{BW_{Old}}\right)$$

Where BW_{New} refers to the new corrected bandwidth, BW_{Old} refers to the original bandwidth. Thus, data originally taken using a 30 kHz bandwidth, but being compared to data taken with a 1 MHz bandwidth would be corrected by

$$CF = 10\log\left(\frac{1\ MHz}{30\ kHz}\right) = 15\ dB\ increase$$

Note that narrow bandwidth measurements typically should be adjusted to the wider bandwidth measurements rather than the other way around. This is due to the increased likelihood that the wider bandwidth signals have a significant contribution from noise.

Semi-Anechoic vs. Reverberation Chamber Measurements: EUROCAE ED-14 / RTCA DO-160 measurement techniques will yield horizontal and vertical polarizations for each frequency data point, while measurements taken in a reverberation chamber will only yield a single measurement. Of the various ways to consider combining the two values together (average, maximum, and RMS), the maximum of the two values is equivalent to the corresponding values obtained in a reverberation chamber. Consequently, the data was harmonized by taking the maximum value of the two measurements representing orthogonal polarizations.

4.4 PED EMISSIONS DATA EVALUATION METHOD

The data was further scrubbed for the following issues which might skew the results:

- **Distribution Analysis:** When examining data distributions, it is common to use a *normal* or *Gaussian* distribution if the data sufficiently matches (which most large data sets do). Examination of the data distribution showed, however, that it was severely noise-bound on the lower end, meaning that a heavy skew towards higher values was present. Under conditions like this, a normal distribution is not an appropriate method of analysis.

  A decision was made to approach the statistical analysis of the data set by using the Wilks percentile estimator. The various mathematical approaches considered, and details of the mathematics selected for use can be found in Appendix A.

- **Noise-Bound Data:** Performing a visual review of various data sets, it became apparent that some of the data collections consisted primarily of noise. That is, the data did not reflect what the PED is actually emitting; it was simply the measurement instrumentation noise floor instead. The data was reviewed by the committee; the noise-bound data was annotated as such and removed from statistical consideration.

- **Data Variety:** Due to the diverse sources of data, a concern arose that all PEDs would not contribute an equivalent number of data points to the statistical analysis. Examples of ways that a single device could contribute more data points than the others might include spectrum analyzers configured with very narrow sweep bands, the same device being tested more than once, or reduced RBW methods.

The data was reviewed by the committee and the committee determined that an acceptable variety of device data was included. Counting the emissions data in each frequency band of interest from each PED allowed the committee to assess the relative contributions of each device. While variations in the quantity of data were observed, the committee's opinion was that the data was sufficiently diverse to prevent a single device or small subset of devices from skewing the results of the data significantly. Consequently all data were used for statistical analysis.

General Considerations: Generally, the emissions measurements were focused upon the aviation bands. Approaches to analysis included:

a. Analyzing an entire avionics band as a single unit

b. Separating the data by type of PED.

The method selected to analyze the data consisted of the following:

a. Scrub the data for noise-bound or PED-bound distortions

b. Compute the statistical distribution for each receiver band.

4.5 PED RF EMISSIONS STATISTICS

After scrubbing the data to remove known distortions, a statistical analysis was performed on the RF emissions for each PED. The mathematical process and statistical results are described in Appendix A. The statistical analysis reports the estimated peak emissions of an ensemble of PED and T-PED devices at each of several percentile values. Thus, the values in TABLE 4-4 are considered percentile of the peak emission value. The peak emissions have been appropriately adjusted as discussed in section 4.3 to correspond to the measurement procedure of ED-14 / DO-160, change 1, Section 21. The limits of ED-14 / DO-160, change 1 (Section 21) are provided for comparison.

TABLE 4-4: SYNOPSIS OF PED RF EMISSIONS STATISTICS PER APPENDIX A

Frequency Band (MHz)	Single PED Emissions (dBµV/m)					ED-14 / DO-160Dch1 Section 21 Limits (dBµV/m)	
	80th Percentile	90th Percentile	95th Percentile	99th Percentile	99.9th Percentile	Cat M	Cat H
105-140	16	20	24	30	37	35	25
325-340	18	22	26	42	68	53	38
960-1250	32	37	41	50	59	50	46
1565-1585	16	21	25	40	47	53	49
4200-4400	57*					71	71
5030-5090	26	27	32	42	57	72	57

* This value is considered to be the test equipment noise floor, and was based upon the observed maximums of graphical RF emission data plots measurements of measured from 148 PEDs. Due to the limited sample population of PED tabulated RF emission data sets in this frequency range, the analysis of the graphical data plots this was deemed to be the more appropriate analysis method.

When used in conjunction with the aggregate receiver susceptibility thresholds from DO-294C (Table 6-2), the percentile values in TABLE 4-4 must be adjusted in the following ways:

- First, because the aggregate thresholds from DO-294C (TABLE 6-2) are referenced to power and not generated field, the values of TABLE 4-4 should be adjusted by the 105 dB factor as shown in FIGURE 4-1.
- Second, because the aggregate thresholds from DO-294C (TABLE 6-2) are related to the time-average emission power spectral density, the peak values of the power must be reduced to estimate the *average* effective radiated power of a typical device. Previous FAA work on emissions suggests that a value of between 10 dB and 15 dB is an appropriate conversion factor, provided that the specific emitter does not operate at an extremely low duty factor. If a very low duty factor is present (as in many RFID devices) a larger peak – to – average correction of

  $$10\log_{10}(TransmitTime/TotalTime)$$

  should be used. A conversion using the conservative 10 dB factor is used in developing the recommendations in this document.
- Third, because the aggregate thresholds of DO-294C (TABLE 6-2) are given in terms of power spectral density, the adjusted average power statistics must be adjusted by the resolution or measurement bandwidth. This adjustment is similar to that discussed in section 4.3 above. The adjustment is based on the resolution bandwidth of the appropriate ED-14 / DO-160, change 1, Section 21 measurement process and varies with the affected frequency band. The effect of these three adjustments is shown in TABLE 4-5.

For the time average of a sine wave in the far field:

$$W_{av} = \frac{1}{2}\left(E_{pk} * H_{pk}\right) = \frac{1}{2}\left(\frac{E_{pk}^2}{120\pi}\right)$$

Where:

E_{pk} Peak electric field in volts per meter
H_{pk} Peak magnetic field in amperes per meter
W_{av} Average radiated power density in watts per square meter

For isotropic radiation:

$$P = 4\pi r^2 W_{av} = \frac{4\pi r^2}{2}\left(\frac{E_{pk}^2}{120\pi}\right) = \frac{r^2 E_{pk}^2}{60}$$

Where:

P Radiated power in watts
r Radius of sphere in meters

With r = 1 m,

$$E_{rms} = \frac{E_{pk}}{\sqrt{2}} = \sqrt{30P}$$

For 0 dBm

$$E_{rms} = \sqrt{30(10^{-3})} = -15.23\ \mathrm{dBv/m} = 105\ \mathrm{dB\mu v/m}$$

Therefore, the equation to convert the measured PED emissions to dBm becomes:

$$E_{dB} = P_{dBm} + 105\ \mathrm{dB}$$

Where:

P_{dBm} Measured spurious emissions effective isotropic radiated power in dBm
E_{dB} Measured spurious emissions electric field strength in $\mathrm{dB\mu V/m}$

FIGURE 4-1: DERIVATION OF CONVERSION FACTOR FROM ELECTRIC FIELD (DB µV/M) TO POWER (DBM) UNITS

TABLE 4-5: SYNOPSIS OF PED RF EMISSIONS STATISTICS CONVERTED TO TIME-AVERAGED EIRPSD

Frequency Band (MHz)		ED-14 / DO-160D ch1 RBW (kHz)	Time-averaged Single PED EIRPSD (dBm/Hz)				
Min	Max		80th	90th	95th	99th	99.9th
105	140	10	-139	-135	-131	-125	-118
325	340	10	-137	-133	-129	-113	-87
960	1250	1000	-143	-138	-134	-125	-116
1565	1585	1000	-159	-154	-150	-135	-128
5030	5090	1000	-149	-148	-143	-133	-118

4.6 MULTIPLE EQUIPMENT FACTOR FOR FRONT DOOR EFFECTS

Because the aggregate thresholds of DO-294C (Table 6-2) are the aggregate interference power from all PED sources, and the statistics summarized in the various portions of TABLE 4-4 are for individual PEDs, the values of Table 4-5 must be adjusted to account for the effect of multiple PEDs. This multiple equipment factor (MEF) is the MEF associated with the front door coupling.

The front door MEF is a multiplying factor that accounts for the cumulative effects on the interference level of many PED devices. Front door MEF is computed relative to the minimum measured IPL on representative aircraft. For example, for large aircraft (e.g. B737), NASA measurements in the aircraft cabin [Refs 12, 13, 14, and 15] indicate that the effect of approximately 100 PEDs at the passengers' seats is an increase in the noise level at the localizer receiver of approximately 12 dB, or a linear multiplier of 16. Using equivalent NASA measurements on large (B737), medium (Gulfstream II) and small (Cessna Citation II) aircraft. TABLE 4-6 gives the recommended MEF for various size aircraft, based upon number of passenger seats.

NOTE: *The information in TABLE 4-6 specifically applies to front door MEF. A different MEF value may be associated with back door coupling.*

4.7 INTERFERENCE PATH LOSS TARGETS

The amount of energy lost traveling from the PED inside the aircraft to the aircraft radio receiver is the interference path loss (IPL). Using the PEDs RF emissions statistics in TABLE 4-5 and the receiver interference threshold in TABLE 4-7, calculation of the IPL required to ensure that the receiver tolerates PED emissions is possible. This section calculates a target IPL for various classes of aircraft.

TABLE 4-6 - RECOMMENDED FRONT DOOR MEF

Aircraft Radio System	Front Door MEF (dB)		
	Small aircraft – less than 10 passengers	Medium aircraft – from 10 to 19 passengers	Large aircraft – more than 19 passengers
ADF	n/a [1]	n/a [1]	n/a [1]
HF Voice	n/a [1]	n/a [1]	n/a [1]
HF Data Link	n/a [1]	n/a [1]	n/a [1]
Marker Beacon	4 [2]	6 [2]	12 [2]
VHF Data Broadcast	4	6	14
VHF Omni-Range (VOR)	4	6	14
VHF Voice Comm.	3	2	13
VDL Mode 2	3	6	14
VDL Mode 3	3	6	14
VDL Mode 4	3	6	14
Distance Measuring Equipment (DME)	7	9	10 [2]
Universal Access Transceiver (UAT)	7	9	10 [2]
Mode A/C Transponder Receiver	9	5	10
Mode S Transponder Receiver	9	5	10
TCAS Interrogator Receiver	6	7	10
GNSS L5/E5	6	6 [2]	10[2]
AMS(R)S SATCOM	7	6 [2]	10 [2]
GNSS L1	7	6	10 [2]
Radio Altimeter	n/a[1]	n/a[1]	n/a [1]
Microwave Landing System (MLS)	5 [3]	6 [3]	7 [3]
Weather Radar	n/a[1]	n/a[1]	n/a[1]

1. n/a = not applicable. The risk of interference in these bands has been determined to be minimal for reasons discussed in Section 4.7.2
2. Value extrapolated from nearby frequency bands.
3. Engineering estimate.

TABLE 4-7: TARGET IPL BY RECEIVER

Receiver	Operational Frequency Range (MHz)	DO-294C Receiver Aggregate Susceptibility Threshold PSD (dBm/Hz)	Single PED 95th Percentile EIRPSD (dBm/Hz)	Single PED 99th Percentile EIRPSD (dBm/Hz)	Emission Percentile Applied for System	Target IPL for Specified Emissions Percentile (dB)		
						Small aircraft – less than 10 passengers	Medium aircraft – from 10 to 19 passengers	Large aircraft – more than 19 passengers
ADF	0.190-1.750	n/a	n/a	n/a	95%	n/a	n/a	n/a
HF Voice	2-30	n/a	n/a	n/a	95%	n/a	n/a	n/a
HF Datalink	2-30	n/a	n/a	n/a	95%	n/a	n/a	n/a
Marker Beacon	75	-113	n/a	n/a	n/a	n/a	n/a	n/a
ILS Localizer (Cat I)	108-112	-151	-131	-125	95%	24	26	34
ILS Localizer (Cat II & III))	108-112	-151	-131	-125	99%	30	32	40
VHF Data Broad-cast	108-112	-162	-131	-125	95%	35	37	45
VHF Omni-Range (VOR)	108-118	-147	-131	-125	95%	20	22	30
VHF Voice Comm.	118-137	-152	-131	-125	95%	24	23	34
VDL Mode 2	118-137	-159	-131	-125	95%	31	34	42
VDL Mode 3	118-137	-159	-131	-125	95%	31	34	42
VDL Mode 4	118-137	Not defined	-131	-125	95%	Not defined	Not	Not defined
ILS Glide Slope (Cat I)	329-335	-142	-129	-113	95%	19	21	27
ILS Glide Slope (Cat II &III))	329-335	-142	-129	-113	99%	35	37	43
Distance Measuring Equipment	962-1213	-156	-134	-125	95%	29	31	32
Universal Access Transceiver (UAT)	982	-181	-134	-125	95%	54	56	57
Mode A/C Trans-ponder Receiver	1030	-160	-134	-125	95%	35	31	36

TABLE 4-7: TARGET IPL BY RECEIVER (CONTINUED)

Receiver	Operational Frequency Range (MHz)	DO-294C Receiver Aggregate Susceptibility Threshold PSD (dBm/Hz)	Single PED 95th Percentile EIRPSD (dBm/Hz)	Single PED 99th Percentile EIRPSD (dBm/Hz)	Emission Percentile Applied for System	Target IPL for Specified Emissions Percentile (dB)		
						Small aircraft – less than 10 passengers	Medium aircraft – from 10 to 19 passengers	Large aircraft – more than 19 passengers
Mode S Transponder Receiver	1030	-162	-134	-125	95%	37	33	38
TCAS Interrogator Receiver	1090	-163	-134	-125	95%	35	36	39
ADS-B Receiver	1090	-175	-134	-125	95%	47	48	51
GNSS L5/E5	1164-1215	-180	-134	-125	95%	52	52	56
AMS(R)S SATCOM	1530-1559	-187	-150	-135	95%	44	43	47
GNSS L1	1559-1610	-183	-150	-135	95%	40	39	43
Radio Altimeter	4200-4400	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Microwave Landing System (MLS) Cat I	5030-5090	-174	-143	-133	95%	36	37	38
Microwave Landing System (MLS) Cat II & III	5030-5090	-174	-143	-133	99%	46	47	48
Weather Radar	5350-5470	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Weather Radar	9300-9500	n/a	n/a	n/a	n/a	n/a	n/a	n/a
n/a = not applicable. Reasons for the n/a designation vary with radio function, and are described in the text.								

4.7.1 Aircraft Receiver Interference Thresholds

Aircraft receiver interference thresholds are defined as the levels in which the receiver performance is affected by noise-like interference present at the front end of the receiver. This interference can be characterized in many different forms, however for the case of T-PED / PED the aggregate interference threshold in terms of power spectral density (PSD) is being used in the determination of the required path loss. This value is defined in units of dBm/Hz. The value is an *aggregate* value, in that it reflects the threshold of the acceptable level of interference from all PED devices.

RTCA DO-294C [Ref 2] provides an excellent reference for the description of the various characteristics of aircraft receiver interference. The computation of required IPL, uses the aggregate interference threshold values provided in RTCA DO-294C TABLE 6-2. All receivers in TABLE 4-7 with failure conditions that are catastrophic, hazardous, or major must be addressed.

4.7.2 Target IPL Calculations

Target IPL calculations have been performed for the receivers listed in RTCA DO-294C TABLE 6-2. The process of calculating receiver specific target IPL is described below.

1) The single PED emission statistics were converted to effective isotropic radiated power spectral density (EIRPSD) using the process described in section 4.5. The appropriate values are listed in TABLE 4-5.
2) Common aviation practice was used to choose an appropriate PED threat level. The 95th percentile is commonly used for error bounds for aviation navigation systems. Thus, the 95th percentile of the measured PED RF emissions from TABLE 4-4 was used for most aircraft radio receivers. The 99th percentile value was used for radio receivers supporting category II and III instrument landing systems, except for GPS-based category II and III landing systems.
3) The 95th percentile was retained for the GPS-based Category II and III landings for the following reasons:
    - The primary concern is the integrity of the course deviation and vertical deviation information presented to the flightcrew while close to the ground. This has the highest hazard classification for the system.
    - There are additional differential corrections and integrity messages via a ground based VHF digital data link to the aircraft in the VHF navigation radio band.
    - Both the GPS signal and the data over the VHF link are digitally encoded, and therefore any PED interference is considered to cause a loss of information rather than corruption of the GPS and or the VHF data to a degree that would provide credible course and vertical deviation indication to the pilot.
    - The loss of the GPS signal during category II and III is considered to be less severe and therefore IPL based on the use of 95th percentile emissions is considered acceptable.
4) For the ILS systems, the previous revision of this document had IPL values based on the coverage limit and decision height (DH). The radio receivers are required to meet both of these IPL requirements and therefore at this revision, TABLE 4-7 only includes IPL for the DH, which is the worst case (lower IPL) of the two.
5) Selection of the 95th percentile or 99th percentile from the single PED emissions statistics of Table 4-5 *does not* mean that the aggregate interference value will exceed the threshold 5% or 1% of the time. In fact, selection of these single PED levels is significantly more conservative due to the effect of the Central Limit Theorem of statistics.

6) The target IPL, IPL_{TARGET}, in decibels, was computed based on the following relationship:

$$IPL_{TARGET} = (Emissions + MEF) - Rcvr\_threshold\_level$$

where *Emissions* is emissions level in dBm/Hz for the appropriate frequency band and percentile level, selected from Table 4-5; *MEF* is the front door multiple equipment factor in decibels for the appropriate frequency band and aircraft size, selected from Table 4-6; and *Rcvr_threshold_level* is the appropriate aggregate receiver threshold level in dBm/Hz for the appropriate radio function, selected from Table 6-2 of DO-294C, and repeated in TABLE 4-7.

TABLE 4-7 gives the target IPL computed by this method for the important aeronautical radio bands. Each aircraft receiver will have its own target IPL, due to the differing interference thresholds inherent to each receiver and the variation of PED spurious emissions in different frequency bands. TABLE 4-7 shows the calculated target IPL and the input values for the calculations.

Systems not affected:

- No target IPL is applicable for ADF, HF voice, and HF data link radios, which operate at frequencies below 30 MHz, because the physics of PED emissions in these frequencies ranges preclude meaningful emissions at these frequencies. Since PEDs are physically small, they cannot radiate frequencies with wavelengths significantly larger than the dimensions of the PED. For example, the wavelength of the upper frequency range of the HF voice transmitter (30 MHz) is 10 meters, resulting in a quarter wavelength of 2.5 meters and one-tenth wavelength (where radiators begin to act as transmission lines) of 1 meter, which is much larger than the typical PED.
- No target IPL is applicable for the Marker Beacon function because the statistical emissions reported in TABLE 4-5 are already significantly lower than the aggregate receiver interference threshold. Thus, the Marker Beacon function is not affected by PED-induced spurious emissions.
- No target IPL is applicable for the 4 GHz radio altimeter, the 5 GHz weather radar, or the 9 GHz weather radar systems. Each of these systems uses a very directional antenna, limiting the coupling between the PED emission and the receiver. Furthermore, PED-induced increases in the receiver noise floor only affect receiver outputs at the far limits of coverage where the impact of such effects has minimal operational impact. Critical operations of such systems, e.g., wind shear detection or decision height determination only occur at close ranges where the received signal level is sufficient to overcome PED-induced increases in the noise floor.

4.8 AIRCRAFT IPL MEASUREMENTS

Aircraft interference path loss measurements should be used to verify that the actual aircraft IPL meets or exceeds the target IPL defined in DO-294C (TABLE 6-2) and repeated in TABLE 4-7. The baseline aircraft IPL measurement method is defined in Appendix B.

Determine the worst-case IPL values for each area of the aircraft separately. If these worst-case IPL values for flight deck/cockpit, crew rest and cargo areas can be demonstrated to be independent of the cabin IPL, and these areas are not accessible for the passengers in flight, then different MEF values can be applied. The cabin IPL should meet or exceed the applicable target IPL of TABLE 4-7 for the aircraft size. For cockpit/flight deck, crew rest and cargo areas the target IPL can be used from the next lower cabin size, e.g. medium instead of large aircraft.

4.9 AIRCRAFT CHANGES THAT AFFECT IPL

Changes to aircraft structure that affect the coupling paths could have significant impact on IPL values. Examples include: changes to aircraft doors, cargo doors, windows, door/window seals, antenna/receiver location, or installation of a new receiver system. These changes require a new IPL assessment, either through analysis or test, as outlined in section 5.4.

The IPL measurement assumes a furnished aircraft. New IPL measurement is not required if it can be shown that furnishing changes either increase the IPL or do not significantly impact the IPL value. Minor repositioning or change in the number of seats is not expected to affect the IPL value significantly. Major changes (such as creating large sections with no furnishing, especially areas close to doorways/exits or to windows nearest to aircraft antennas) can lead to an undesirable reduction of the IPL value.

CHAPTER 5

CERTIFICATION ASPECTS OF AIRCRAFT PED TOLERANCE

5.1 RELEVANT AIRWORTHINESS REGULATIONS AND GUIDANCE

Intentional transmissions and spurious RF emissions from PEDs are known RF environmental conditions. In-service experience has shown that PED intentional and spurious emissions have the potential for RF interference with aircraft systems. Existing operating regulations such as 14 CFR 91.21 regulate the use of PEDs on board aircraft.

The specific regulations which currently address the use of PEDs on aircraft are found in the operational rules, namely § 91.21 and § 121.306. These regulations require that the operator of the aircraft determine that the PED will not cause interference with the navigation or communication system of the aircraft on which it is used. These regulations are outdated because they do not address interference to equipment other than navigation and communications on the aircraft needed for safe operation. In addition, with the proliferation of PEDs on the airplane and subsequent unintentional transmission of RF energy, it is very difficult for an operator to adequately address the safety concerns of PED operation without forbidding their operation during taxi, takeoff and landing phases of flight.

The use of PEDs might be acceptable depending on the outcome of an assessment of the potential for interference with specific aircraft systems namely those whose functional failure effects are classified as major, hazardous or catastrophic, and flight data recorders and cockpit voice recorders. AC 91.21-1C [Ref 7] can be used for showing compliance with § 91.21. RTCA DO-363/ED-130A [Ref 16, 10] can be used to comply with the requirements in the advisory circular for either transmitting PEDs or non-transmitting PEDS. If an operational assessment in accordance with 14 CFR §91.21 is made, then the use of PEDs should be restricted during taxi, takeoff and landing (including initial climb and final descent) phases of flight.

An aircraft certification applicant may choose to design or modify the aircraft for tolerance to PED intentional transmissions and spurious RF emissions to assist the operator in controlling PED use for compliance with § 91.21.

Although the current 14 CFR parts 23, 25, 27 and 29 currently do not specifically address PEDs, there are certain regulations that may be considered relevant when an applicant elects to demonstrate that an aircraft is PED tolerant. These are 14 CFR §§ 23.1309(b), 25.1309(a), 27.1309(a) and 29.1309(a). These regulations require that critical environmental conditions and foreseeable operating conditions be considered in ensuring that equipment, systems and installations perform their intended functions. However, since there is no specific discussion for PED tolerance in these regulations, PED tolerance is not at this time a mandatory aircraft design requirement.

If the applicant wishes to use a design approach to the certification of a PED tolerant aircraft, then the guidance provided in this document should be used. The aircraft evaluation can cover spurious RF emissions (front door coupling) or intentional transmission (back door coupling), either separately, as a partial assessment, or at the same time. It is not the intent of this guidance to suggest that the applicant must demonstrate that both intentional and spurious RF emissions requirements described in sections 3 and 4 are met. Compliance with either requirement is sufficient for a partial demonstration of a PED tolerant aircraft.

If the aircraft system RF susceptibility limits identified in section 3 are met to mitigate the intentional transmissions, but the interferences path loss (IPL) limits of section 4 cannot be met to mitigate spurious emissions, tolerance to transmitting PED intentional transmissions is demonstrated but tolerance to PED spurious emissions is not. Because protection against the effects of the intentional transmission tolerance was shown, this data can now be used to support an aircraft operator’s application to operate T-PEDs and other PEDs during non-critical phases of flight in accordance with § 91.21.

Conversely, if the IPL limits of section 4 were met but not the section 3 limits for RF emissions, then the T-PED could not be used on the airplane. However, the certification data to support an aircraft operator's application to permit other non-intentionally transmitting PED use during all phases of flight can still be provided.

In order to demonstrate complete PED tolerance (both T-PED and PED) for all phases of flight, the appropriate limits specified within section 3 and 4 must all be met:

a. the aircraft system RF susceptibility limits, or aircraft certification basis, as identified in section 3 are met in order to mitigate the intentional emissions; and

b. the IPL limits of section 4 were met, mitigating PED spurious emission effects on the aircraft system receivers function and performance.

In terms of mitigating RF interference, this demonstration and supporting certification data could support an aircraft operator's application to permit all PED use during all phases of flight. Other operational requirements might still impose restrictions on PED use during various phases of flight, such as the need to prevent loose article hazards and the need for passenger attention during safety briefings.

In summary, an applicant may use either the PED tolerance design approach described in this document, or use operational allowance process described in AC 91.21-1C with appropriate guidance using RTCA DO-363/ED-130A to ensure safe operation of PEDs on aircraft.

In either approach, the effect on the following must be evaluated:

- All systems having functional failure conditions of major, hazardous or catastrophic.
- Flight data recorders and cockpit voice recorders.

Using the design approach to certification, the aircraft can be independently evaluated for spurious or intentional PED RF emissions. If the aircraft meets the requirements for spurious and intentional emissions, then PED operation may be allowed during any phase of flight (with respect to electromagnetic interference issues.) Those aircraft that only meet the requirements for intentional emissions or that have been evaluated only in accordance with DO-363/ED-130A guidance in regards to backdoor tolerance, should prohibit use during landing.

Other operational considerations may still require limits on use of PEDs in certain flight conditions, such as control of loose objects in the aircraft during takeoff and landing.

5.2 DOCUMENTING A PED-TOLERANT DESIGN

To ensure the operational safety of the aircraft, it is critical that the PED tolerant features of the airplane not be compromised by subsequent modifications. Because there are no specific PED design rules in the federal code of regulations, it is possible that changes may be made to the aircraft without obvious impact to the PED tolerant features. Some examples might be the changing of aperture seals or movement of antennas. Any change to the aircraft should be evaluated by an EMI specialist in order to assess their impact on the PED tolerant design. With this in mind, the following guidance is provided to ensure the integrity of a PED tolerant design.

Operators may use techniques and methods in this document to demonstrate that the operator's aircraft are PED tolerant. As no aircraft alterations are being performed, references in following sections to establishing ICAs do not apply.

NOTE: *Various approaches are available to the applicant in regards to documentation of the airplane's PED tolerance. The following is one, but not the only, method that can be used to ensure that proper documentation is available to the operator for use in showing compliance to the operational rules.*

Upon completion of the necessary testing, a detailed test or compliance report providing all the information outlined in the previous sections should be submitted to, and approved or accepted by, the appropriate aircraft certification authorities for aircraft design. Consistent with § 91.21 and § 121.306, operators are not required to submit PED approval data to regulatory agencies.

In addition, the appropriate sections within the maintenance manual should be revised, noting the aircraft PED tolerance level for back door and front door tolerance as appropriate.

Any continued airworthiness instructions required to maintain this level of tolerance should be specified. Since anyone who modifies an aircraft must comply with the aircraft instructions for continuing airworthiness (ICA), this notation will ensure that any change to the aircraft will address effects on prior PED tolerance. This is supported by FAA Order 8110.54, which places the burden for ICA on the person approving the change. Anyone modifying a product has an obligation to review and provide, as needed, additions or changes to the aircraft basic ICA to cover their modification/repair. (See Section 5.7 for more information on instructions for continued airworthiness.)

The design approval holder should also notify the operator via Service Letter, combined with appropriate instructions, denoting the PED tolerant allowances along with any special considerations such as references to maintenance manual and AFM supplement information.

For aircraft not HIRF certified, the documentation provided to the aircraft operator should describe the aircraft systems with catastrophic functional failure conditions, flight data recorder and cockpit voice recorders, or aircraft radio systems that were tested or an analysis performed, to show front door and/or backdoor PED tolerance. The documentation should contain information on any changes to the aircraft, if any that were necessary in order to achieve front door and/or backdoor PED tolerance. Information should include any interiors configuration items that were determined to be a key factor in front door or back door compliance, for example cabin windows that were blocked out (window insert) or blocked by monuments.

Finally, the Aircraft Flight Manual/Supplement (AFM/S) should provide appropriate instructions regarding any operational limitations on the use of the PEDs and the PED tolerance allowances of the aircraft; this will ensure that the flight crew is aware of the aircraft PED tolerance limitations. Supplements can be applied to all or limited numbers of a model and changed or updated if the specifics of the PED tolerance change.

5.3 APPLICATION TO NEW AIRCRAFT TYPE CERTIFICATION

Applicants for a new type certificate should consider showing aircraft tolerance to both intentional RF transmissions and spurious RF emissions using the guidance described in sections 3 and 4 for PED intentional and spurious emissions. The applicant can also certificate the aircraft separately or in combination for intentional transmissions or spurious RF emissions and document the appropriate PED tolerance in the ICA and AFM/S as discussed in section 5.2.

In demonstrating tolerance to PED spurious and intentional emissions, the applicant should accomplish the following steps:

Intentional Transmissions (back door coupling)

a. Identify the aircraft systems to be assessed for PED intentional emissions tolerance.

b. Establish RF test level per system functional failure condition classification or aircraft certification level (section 3).

c. Demonstrate that the identified aircraft system equipment performs its intended function when subjected to the RF test level requirements identified in step b., above.

d. Submit appropriate evidence, such as the aircraft system equipment test report, to the appropriate aircraft certification authorities to demonstrate the aircraft PED intentional emissions tolerance.

Spurious RF Emissions (front door coupling)

a. Identify the aircraft radio receiver systems that must be assessed for PED spurious emissions tolerance.

b. Demonstrate the actual aircraft IPL satisfies the target IPL requirements in section 4 for the aircraft radio receiver systems identified in step a.

c. Submit appropriate evidence such as the aircraft radio receiver list and IPL test report to the appropriate aircraft certification authorities to demonstrate the aircraft PED spurious emissions tolerance.

5.4 MODIFICATIONS TO PREVIOUSLY CERTIFIED PED TOLERANT AIRCRAFT

This section addresses the certification of design changes on previously PED tolerant certificated aircraft. This includes installation of new or modified equipment managed through Form 337 modification and through supplemental or amended type certification/approval. If aircraft PED tolerance is to be maintained after the introduction of design changes, it will be necessary for the applicant to show that the PED tolerance as described in section 5.2 has not changed. Failure to retain PED tolerance will potentially impact the aircraft operator's means of showing compliance with § 91.21 and § 121.306.

If the aircraft had previously been determined to be PED tolerant by an aircraft manufacturer, that manufacturer should be queried for any relevant PED tolerant documentation such as a service letter providing PED tolerance information.

If new equipment installed on a PED tolerant aircraft has functional failure conditions classified as major, hazardous or catastrophic, or is a flight data recorder or cockpit voice recorder, then the new equipment should be qualified according to the guidance in section 3. This is required to maintain aircraft tolerance to transmitting PEDs (back door coupling).

If the new equipment described above includes radio receivers or new antenna installations for the radio receivers, then the guidance in section 4 should be followed to demonstrate that the aircraft tolerance to spurious PED emissions is maintained (front door coupling).

- Changes to aircraft doors, windows and other apertures, interior furnishings or antenna/receiver locations can affect the spurious emissions tolerance. Therefore, if the PED spurious emissions (front door) tolerance is to be maintained, the applicant should submit data to the appropriate aircraft certification authorities showing the results of analyses and/or testing used to verify the aircraft changes have not adversely affected the IPL needed for PEDs spurious emission tolerance.
- Should the applicant be unable to maintain compliance with the original spurious emission IPL limits, the restriction usually applied to the use of PEDs would need to be applied, restricting any PED use to non-critical phases of flight only.
- The certification requirements for the PED tolerance aspects of any design change certification should be discussed with the certificating authority at an early stage. The acceptance of a design change from a certification applicant is predicated upon the availability of the necessary original aircraft and equipment design data on which to base the PED tolerance assessment process.

If the tolerance to PED intentional and spurious emissions is not demonstrated for the newly installed equipment, then the aircraft is no longer PED tolerant. In this case, the aircraft operator should follow the guidance for PED use in AC 91.21-1C and RTCA DO-363/EUROCAE ED-130A.

5.5 MODIFICATIONS TO AIRCRAFT NOT PREVIOUSLY CERTIFIED PED TOLERANT

If an applicant desires to make a previously non-PED tolerant aircraft PED tolerant, then the method to achieve PED tolerance is identical to the method used for any new airplane design as described in section 5.3. Otherwise the applicant should follow the guidance in AC 91.21-1C and DO-363/ED-130A [Ref 16, 10] to obtain an operational allowance for the new equipment under § 91.21 for an operator's specific aircraft.

The certification requirements for the PED tolerance aspects of any design change should be discussed with the certificating authority at an early stage. The certification applicant that desires to demonstrate that an aircraft is PED tolerant may need to acquire original aircraft and equipment design data on which to base the PED tolerance assessment as described in this document.

5.6 APPLICATION TO DIFFERENT CLASSES OF AIRCRAFT

The guidance provided in this document can be applied to the certification of any aircraft type as identified by the airworthiness regulation categories. These include 14 CFR part 23 for normal, utility, aerobatic and commuter airplanes, part 25 for large airplanes, part 27 for small rotorcraft, and part 29 for large rotorcraft. The design criteria for spurious emissions may prove challenging for smaller aircraft or aircraft with short distances between PED users and aircraft radio receivers.

For any aircraft being considered for PED tolerance certification, the requirements of 14 CFR §§ 23.1309, 25.1309, 27.1309 and 29.1309of the relevant aircraft type certification basis should be applied.

5.7 INSTRUCTIONS FOR CONTINUED AIRWORTHINESS

Regulations in 14 CFR parts 23.1529, 25.1529, 27.1529 and 29.1529 require that instructions for continued airworthiness (ICA) be developed for all aircraft. In addition, FAA Order 8110.54 requires that all design approval holders furnish acceptable ICA to product owners per 14 CFR § 21.50(b). The ICA must be made available to any other persons required to comply with the ICA. Any TC/STC applicant seeking certification for a PED tolerant aircraft must develop the appropriate material to ensure that the declared PED tolerance can be maintained throughout the life of the aircraft. Modifications to aircraft that are PED tolerant may also require updates to the aircraft ICA.

For aircraft certified as HIRF compliant with 14 CFR 23.1308, 25.1317, 27.1317, 29.2317, or that are certified to FAA/EASA/JAA HIRF special conditions, as part of the original type certificate (TC), then no further ICA for maintaining back door PED tolerance are required.

In addition, for any aircraft that complies with the front door PED tolerance requirements of DO-307 Section 4, no further ICA are required to maintain front door PED tolerance.

NOTE: *HIRF certification does not imply that an aircraft meets the front door PED RF spurious emissions tolerance requirements in section 4 of this document.*

For all other aircraft, as a minimum, the instructions for continued airworthiness should include:

a. All maintenance necessary to ensure that all required aircraft equipment continues to meet the RF susceptibility qualification standards appropriate to the declared PED tolerance. To retain PED tolerance certification, any required aircraft equipment introduced or replaced, which perform functions classified with catastrophic failure modes by the applicant, must meet the levels identified in section 3 of this document.

b. All maintenance necessary to ensure the integrity of the aircraft IPL limits. Maintenance tasks may be needed to ensure that the aircraft windows and doors, any other aircraft apertures and interior features that were chosen to obtain the IPL identified in section 4 of this document are not compromised; preventing degradation of the IPL for the duration of the aircraft's life.

c. The minimum inspection and maintenance tasks for aircraft PED tolerance protection measures, maintenance of aircraft structure shielding and aircraft electrical wiring installation protection should be included in the aircraft instructions for continued airworthiness.

CHAPTER 6

REFERENCES

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CHAPTER 7

MEMBERSHIP

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Portable Electronic Devices (PEDs)

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Alex	Wilson	The Boeing Company
Ben	Wong	United Airlines, Inc.
Naruto	Yonemoto	Electronic Navigation Research Institute (ENRI)
Dan	Zanette	Electronics Test Centre

APPENDIX A

STATISTICAL ANALYSIS OF SPURIOUS EMISSIONS FROM PORTABLE ELECTRONIC DEVICES

APPENDIX A

STATISTICAL ANALYSIS OF SPURIOUS EMISSIONS FROM PORTABLE ELECTRONIC DEVICES

A.1 INTRODUCTION

This appendix was prepared by Fabien Mangeant and Madjid Mahmoudi, EADS Innovation Works.

A database of measured spurious emissions for many portable electronic devices was created so that the RF emission statistics from a large number of PEDs could be analyzed. This database contains RF emissions data from typical PEDs brought by passengers on aircraft.

The goal is to define an index that will monitor the risk. The α-quantile was chosen:

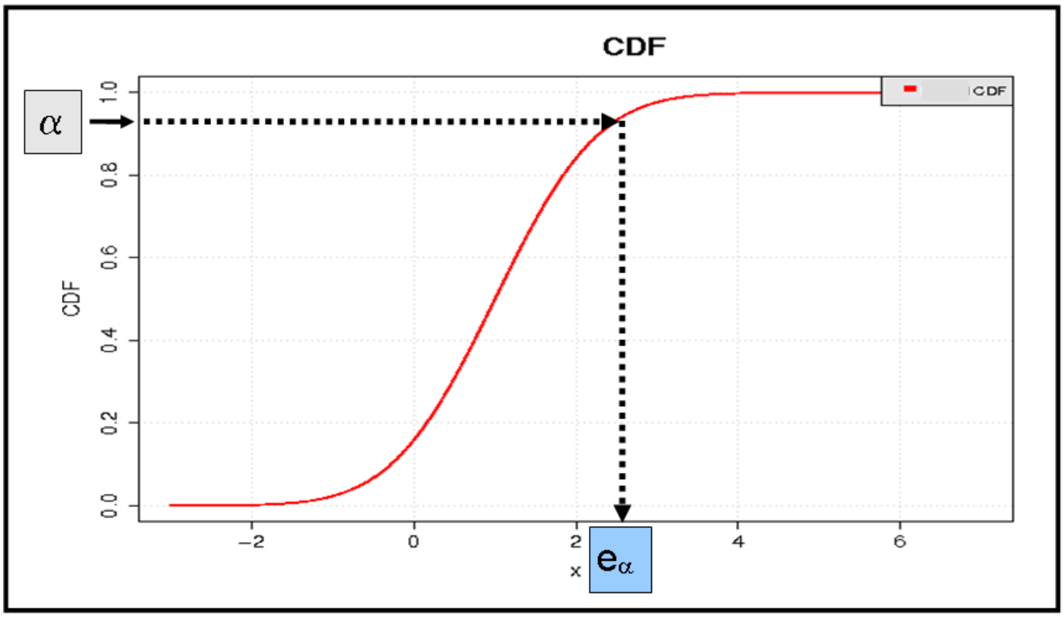

FIGURE A-1: DEFINITION OF AN α-QUANTILE

For our purpose, we will use two calculation methods for the α-quantile, without any assumption on the distribution law. In addition, we introduce the notion of confidence β intervals on this α-quantile. These estimators are used to analyze the global threat due to PEDs carried by passengers aboard aircraft.

The objectives are as follows:

a. To show the different methods and the underlying hypothesis to evaluate percentiles with a given level of confidence

b. To show the results obtained on different frequency bands for different sets of data from the RTCA database

To provide tools to analyze these results and compare them with other standard limits.

A.2 SOURCE OF DATA

The RF emissions data were provided by RTCA committee members Boeing, Cessna and NASA. Emissions data from various devices were provided, such as laptops, GSM mobile phones and CDMA mobile phones. From this initial data, we have defined different sets of data as listed in TABLE A-1. Measurements made in the frequency band (1565-1585 MHz) could be used to extrapolate to the GNSS frequency band (1559-1610 MHz).

TABLE A-1: PED FREQUENCIES USED

Set Number	No. of PEDs	Frequency Band	No. of Frequencies
1	92	105-140 MHz	600
2	104	325-340 MHz	600
4	97	960-1250 MHz	600
5	105	1565-1585 MHz	600
6	not enough data	4200-4400 MHz	600
7	98	5030-5090 MHz	600

A.3 PRESENTATION OF THE METHODS

In this section, we present the method used to perform the statistical analysis. We also show two different ways to deal with the RF emissions data. The RTCA SC-202 committee selected the α-quantile as the most relevant output to analyze the RF emissions. We present the techniques to compute the α-quantile without any assumption on the distribution law.

A.3.1 Notation

B	Frequency Band
Δf	Bandwidth
P+1	Number of frequencies in the frequency band B=f_1, $f_1 + \Delta f$, ..., f_1 + P $*\Delta f$
$I_j = [f_1 + (j - 1) * \Delta f, f_1 + j * \Delta f]$	j_{th} frequency sub band
N	Number of PED emission measurements
N_{sample}	Size of the sample to estimate the α-quantile
$E \rightarrow L(\underline{\theta})$	Statistical law of the emissions

A.3.2 Definition Of The α-Quantile e_α

In our study, we evaluate an estimator of the α-quantile defined by:

$$P(E \leq e_\alpha) = \alpha$$

Different estimators can be defined: Empirical percentile; Wilks percentile; or approximated Wilks quantile. Further details about these different estimators are given in section A.5 of this appendix. In the rest of the appendix, for robustness and accuracy reasons, we have chosen to use the Wilks percentile.

The estimation of this α-quantile is based on the N_{sample} values of emission admissible in the statistical population. Two methods (method A, method B) were proposed to define the size N_{sample} from the data set.

The steps of method A are:

a. Build the sample of the Nsample for the α–quantile from the measurements data set corresponding to the N PEDs, for each frequency band I*j*. Following the previous notation, we obtain P samples $s_1^N, \cdots, s_P^N$ of size $N_{sample} = N$.

b. Estimate the α-quantile for each sample s_j^N with a given level of confidence β.

c. Draw the curve of α-quantile versus frequency.

The steps of method B are:

a. Build one global sample S_{NxP} corresponding to the gathering of N x P measurements on the frequency band $[f_1; f_1 + P * \Delta f]$. This corresponds to a sample of size $N_{sample} = N$ x P.

b. Estimate the α-quantile of the sample S^{NxP} with a given level of confidence β.

c. Draw the curve of α-quantile versus frequency.

With the method A, the α-quantile will vary for each frequency bandwidth on the frequency band B. This assumes that the peaks at one frequency are a characteristic of the population.

The method B assumes that all the aleatory features are not determined by the frequency by frequency behavior but that the emittive behavior over one frequency band. It cannot be separated frequency by frequency.

Method A is more adequate if the peaks are “deterministic” behaviors of the PED population on-board an aircraft.

Method B is more representative if all the emissions to be considered due to the PEDs in an aircraft behave randomly in the frequency band of interest. In addition, the use of this method allows us to calculate a higher percentile.

In this appendix, we present the result of the statistical analysis using method B.

A.4 ANALYSIS RESULTS

FIGURES A-2 through A-11 show the PED RF emissions raw data and the calculated percentiles.

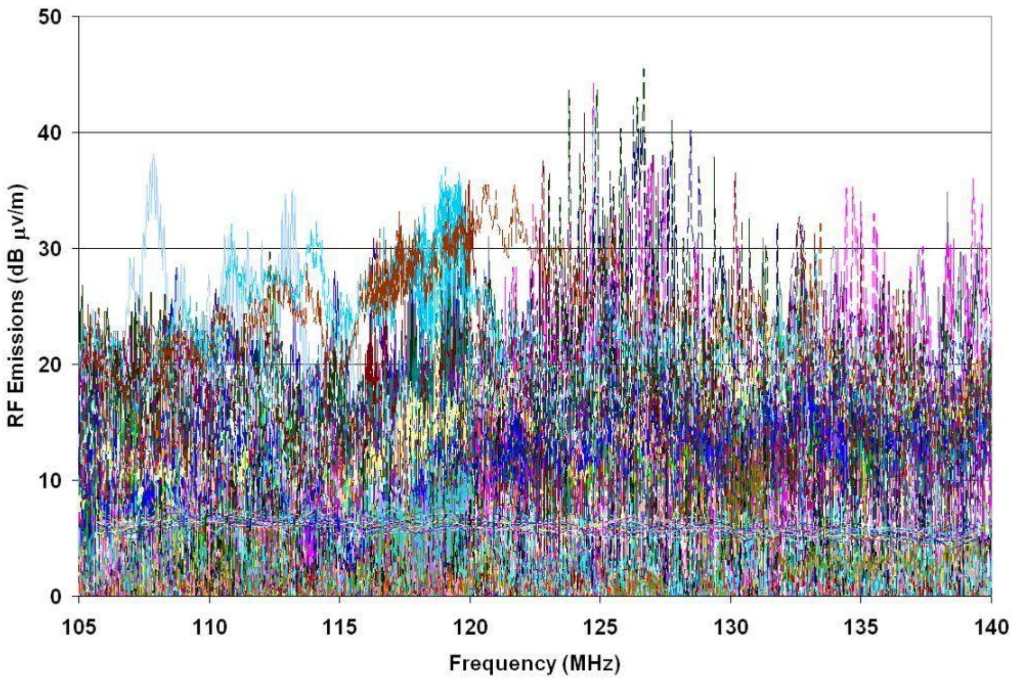

FIGURE A-2 - RAW DATA SET 1

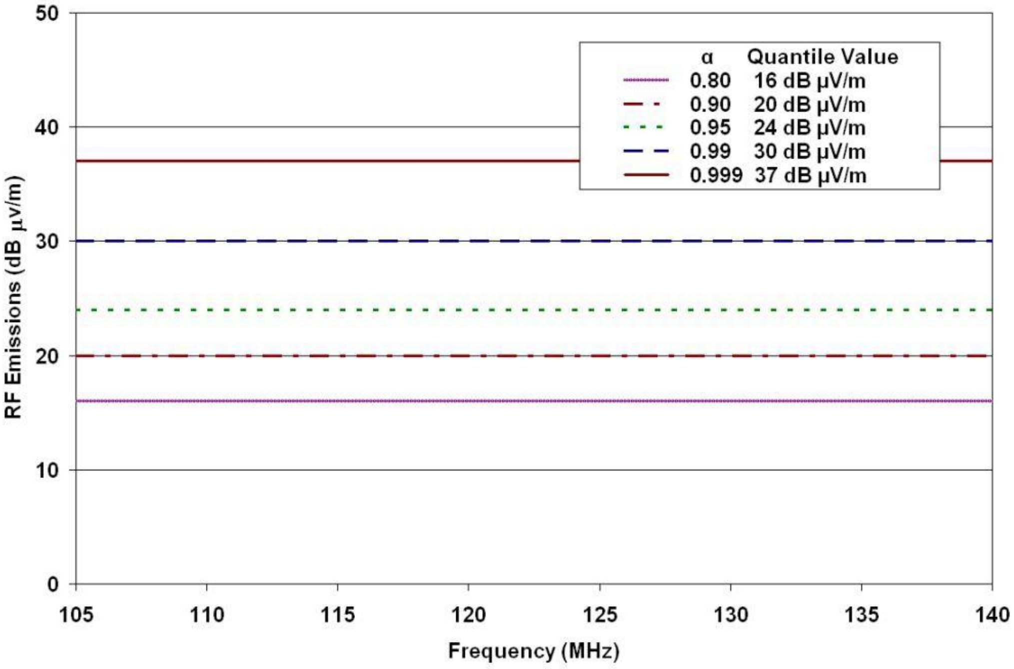

FIGURE A-3 - METHOD B ON SET 1 α-QUANTILE WITH CONFIDENCE β = 0.95

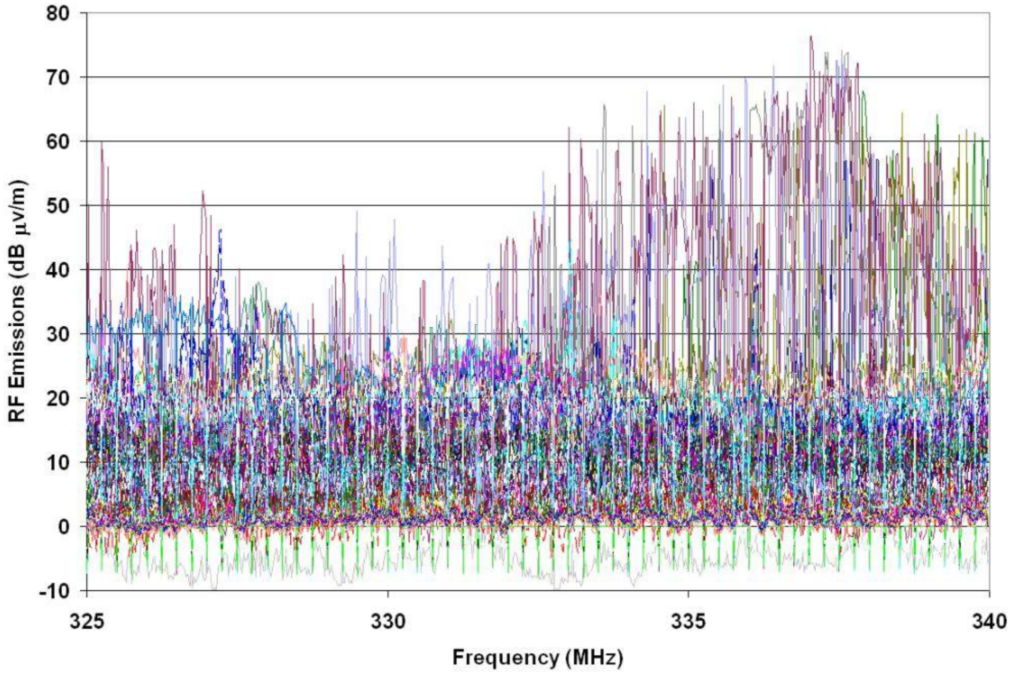

FIGURE A-4: RAW DATA SET 2

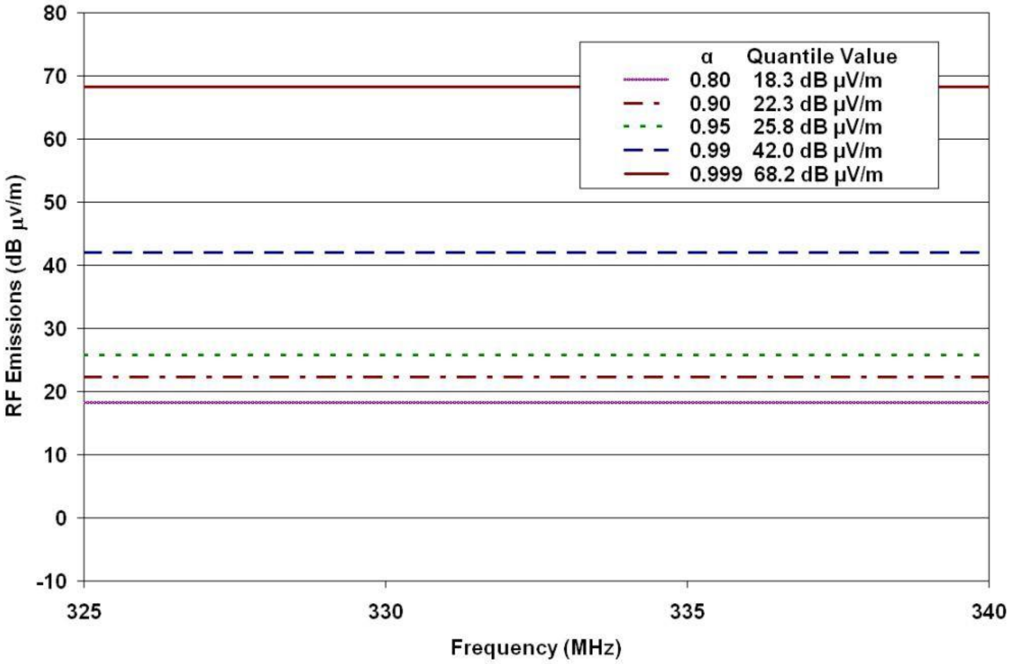

FIGURE A-5: METHOD B ON SET 2 α-QUANTILE WITH CONFIDENCE β = 0.95

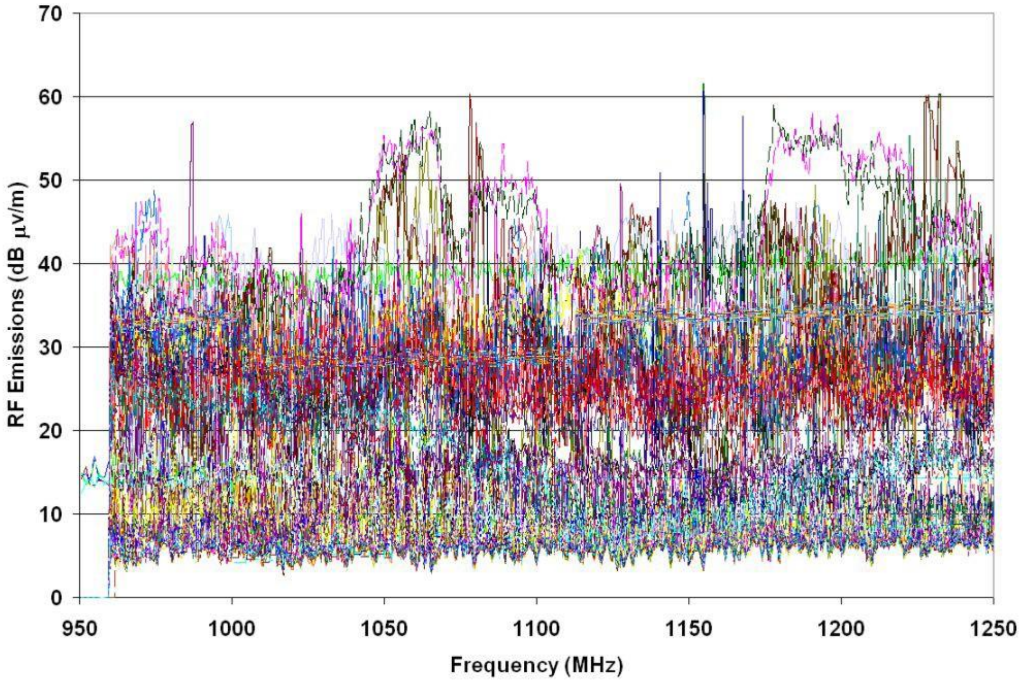

FIGURE A-6: RAW DATA SET 4

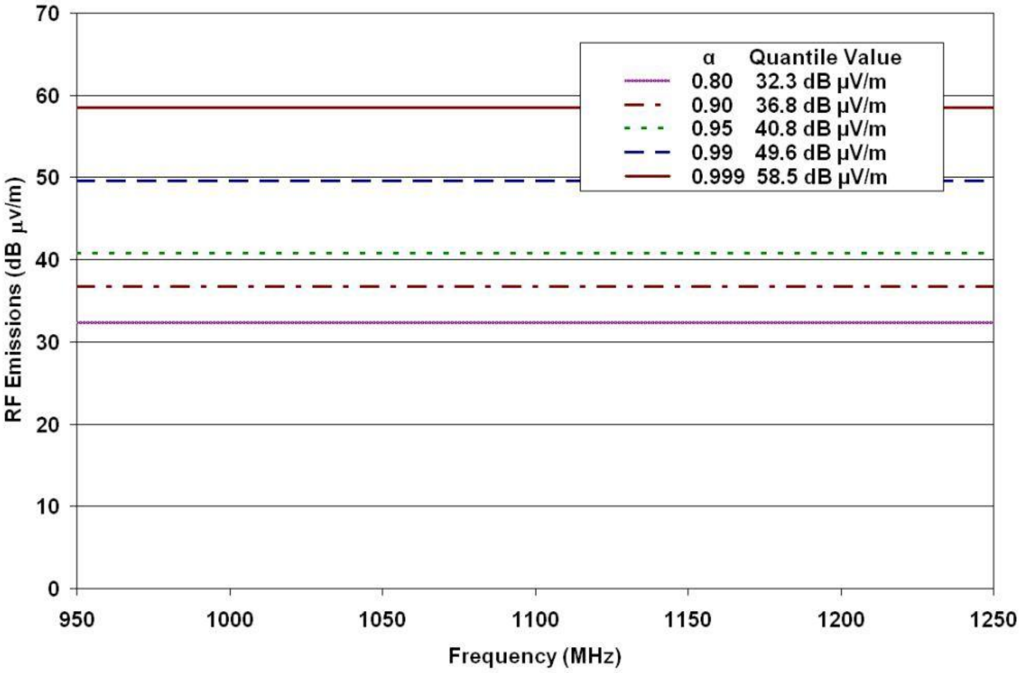

FIGURE A-7: METHOD B ON SET 4 α-QUANTILE WITH CONFIDENCE β = 0.95

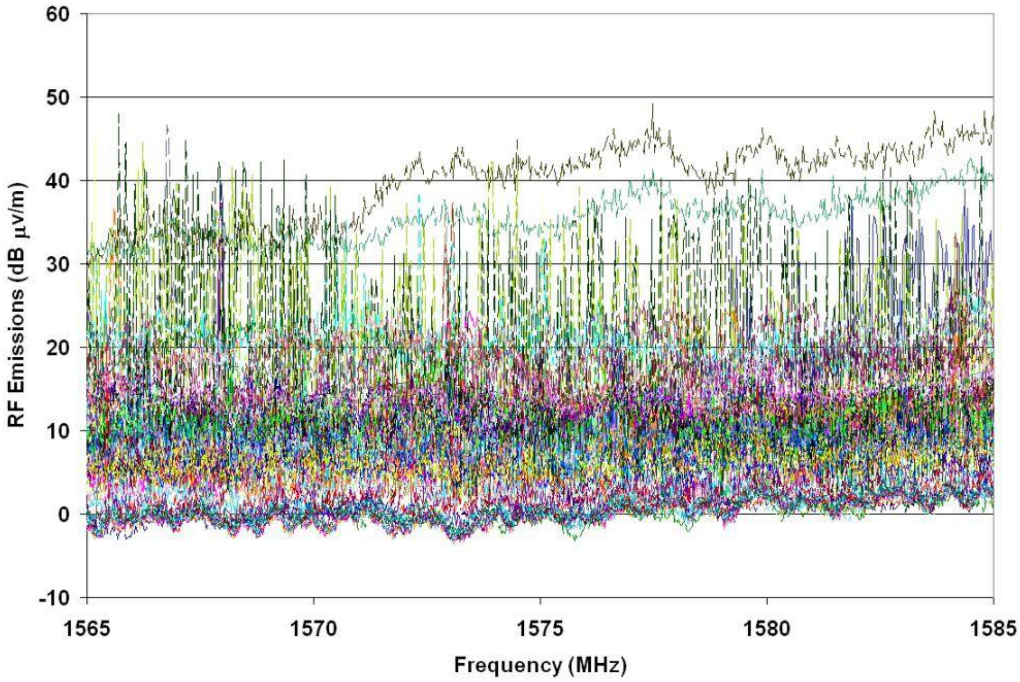

FIGURE A-8: RAW DATA SET 5

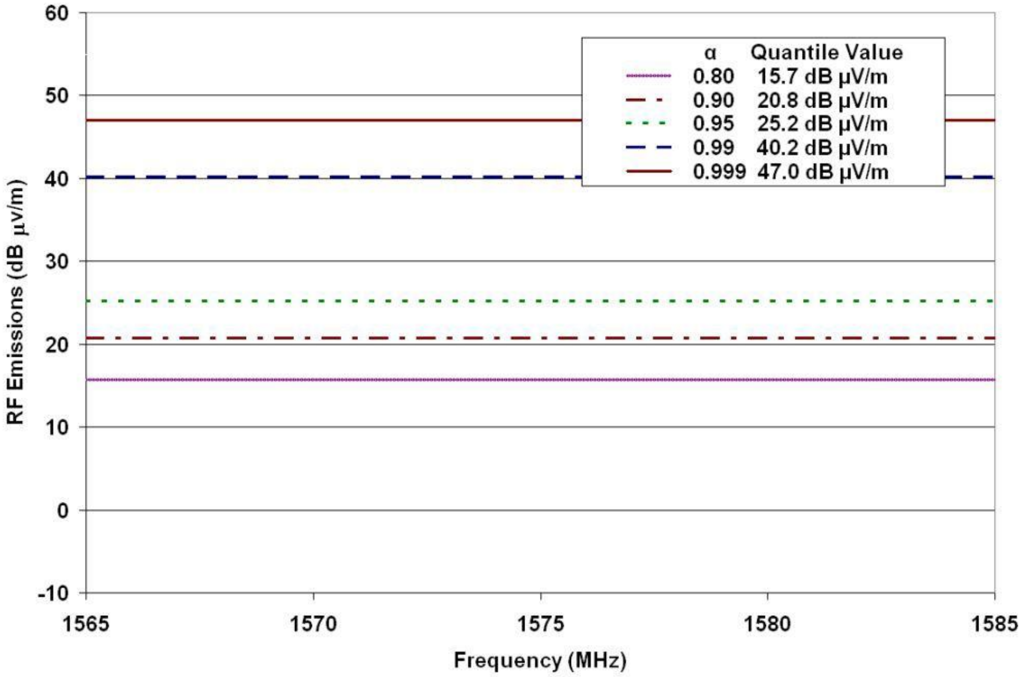

FIGURE A-9: METHOD B ON SET 5 α-QUANTILE WITH CONFIDENCE β = 0.95

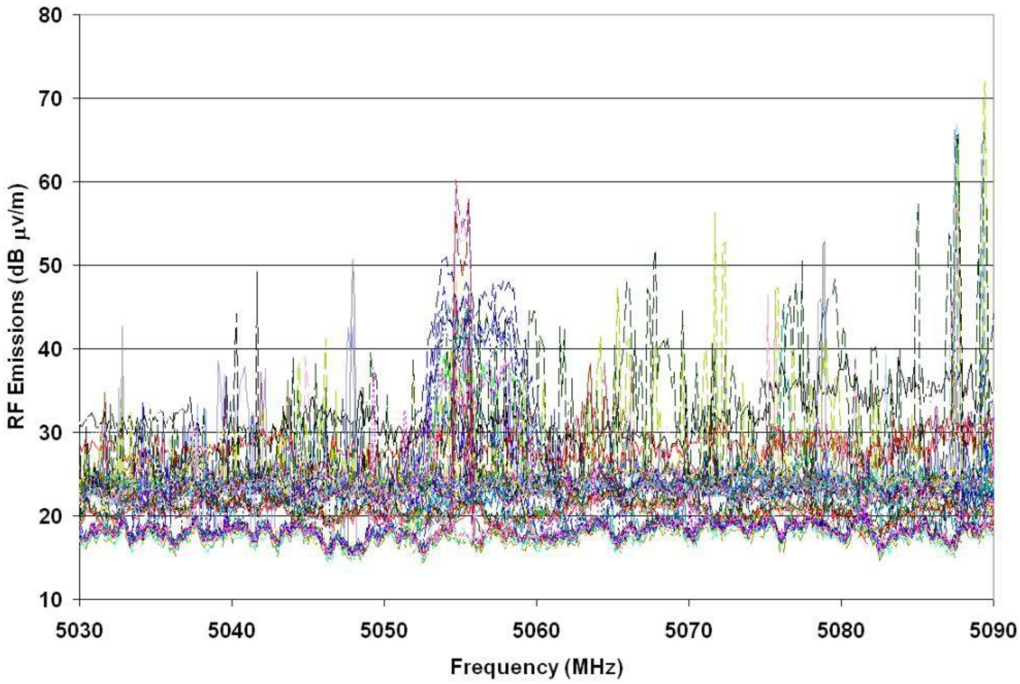

FIGURE A-10: RAW DATA SET 7

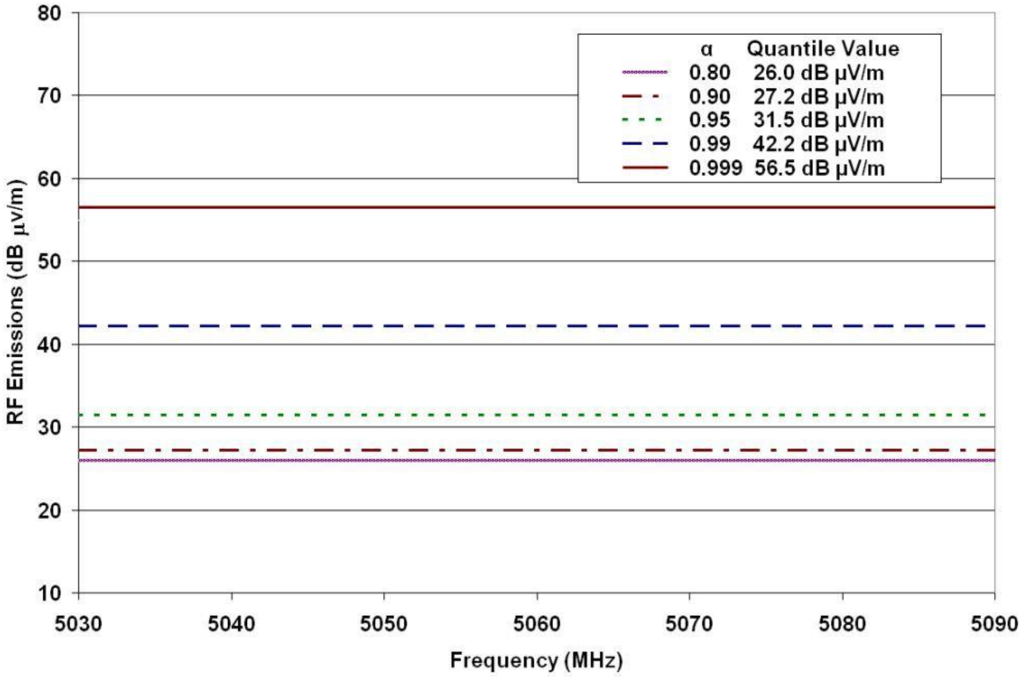

FIGURE A-11: METHOD B ON SET 7 α-QUANTILE WITH CONFIDENCE β = 0.95

A.5 STATISTICAL ESTIMATORS

The purpose of this section is to show the different methods for α-quantile calculation.

A.5.1 Definition of the α-Quantile Estimation

Let us define an n-sample $E_1, ..., E_n$ of random variables following the same statistical law. This law is not explicitly known and its density is $f(e)$. Our goal is to define an estimator of the α-quantile $e\alpha$ defined by:

$$P(E < e_\alpha) = \alpha$$

An estimator is based on a function $\theta_n : R_n \rightarrow R$ to be defined, which must be such that $\hat{E}_{\alpha,n} = \theta\,(E_1, ..., E_n)$ is close to e_α. To quantify this notion of closeness, one classically uses the notion of quadratic risk, which is the sum of the square of the bias and the variance:

$$R^2_{\alpha,n} = \left(E\left[\hat{E}_{\alpha,n}\right] - e_\alpha\right)^2 + Var\left(\left[\hat{E}_{\alpha,n}\right]\right)$$

If we want the estimator to have a confidence β, it can be written:

$$P(\hat{E}_{\alpha,N_{sample}} \geq e_\alpha) \geq \beta$$

Of course, if $\hat{E}_{\alpha,N_{sample}}$ is a sure estimator with confidence β with the sense given above, every estimator $\hat{E}'_{\alpha,\,N_{sample}}$ such that $\hat{E}'_{\alpha,n} \geq \hat{E}_{\alpha,\,N_{sample}}$ is also sure with confidence β.

Our goal is thus to define the smallest sure estimator with confidence β among all estimators. These estimators are based on the rank statistics. It means that we associate to the n-sample $E_1, ..., E_{N_{sample}}$ the following n-sample $E'_1, ..., E'_{N_{sample}}$ such that $E'_1 \leq ... \leq E'_{N_{sample}}$. For example, suppose that three numbers are observed or recorded, resulting in a sample of size $n=3$. If the sample values are:

$$E_1 = 10$$

$$E_2 = 100$$

$$E_3 = 1$$

When you apply the association defined above, you have:

$$E'_1 = 1$$

$$E'_2 = 10$$

$$E'_3 = 100$$

This implies that:

$$E'_1 \leq E'_2 \leq E'_3$$

A.5.2 Estimation of an α-Quantile

A.5.2.1 Empirical Quantile

The classical formula:

$$\hat{E}_{\alpha, N_{sample}} = E_{(\lfloor \alpha, N_{sample} \rfloor + 1)}$$

where $\lfloor x \rfloor$ is the floor function of x.
A more elaborate formula is:

$$\hat{E}_{\alpha,N_{sample}} = t_\beta \frac{\sqrt{\alpha(1-\alpha)}}{\sqrt{N_{sample} + 2f(e_\alpha)}}$$

where $t_\beta = \Phi - 1(\beta)$ and Φ is the cumulative distribution function of the standard reduced normal law $N(0, 1)$. This last formula implies that the density of the law must be known, which is not always the case and particularly in the analysis of real data from PEDs. Moreover, as we are looking for high level of quantiles (α can be greater than 95%), the value of f can be very low, which leads to a problem of estimation.

A.5.2.2 Wilks Formula

The Wilks estimator can be written:

$$\hat{E}_{\alpha,N_{sample}} = E_{(\lfloor \alpha, N_{Sample} \rfloor + r)}$$

So, one has to determine r with a certain margin. An exact formula to determine r is the smallest integer such that:

$$C_\alpha\left(N_{sample,r}\right) \leq 1 - \beta$$

where:

$$C_\alpha\left(N_{sample,r}\right) = \sum_{j=0}^{\lfloor N_{sample}(1-\alpha) \rfloor - r} C_{N_{sample}}^{j} (1-\alpha)^j \alpha^{N_{sample}-j}$$

A simpler formula can be given to asymptotically determine r:

$$r \approx t_\beta \sqrt{\alpha(1-\alpha)N_{sample}}$$

where $t_\beta = \Phi\text{-}1(\beta)$ and Φ is the cumulative distribution function of the standard reduced normal law $N(0, 1)$.

This estimation is the one which was used for the FIGURES A-3, A-5, A-7, and A-9.

A.5.2.3 Validation on a Gaussian Law

This paragraph aims at presenting some results about the use of the empirical quantile and the Wilks estimator of the α-quantile.

We compared the different α-quantile estimators with known values and not from PED data. We wanted to justify the use of the formula showing that it gives the most suitable α-quantile values. We sampled several times (Q times) a sample of size N_{sample} $Y_1, ..., Y_{N_{sample}}$ following a Gaussian law $N(0, 1)$ in order to evaluate the statistics of the different estimators of the α-quantile with confidence β. FIGURES A-12 through A-16 show the comparison of the methods. For Set 3 with $Q = 104$, $N_{sample} = 50$, $\alpha = 0.95$, $\beta = 0.95$, it was impossible to define a Wilks formula and impossible to justify the β-confidence for the empirical quantile unless the law is known.

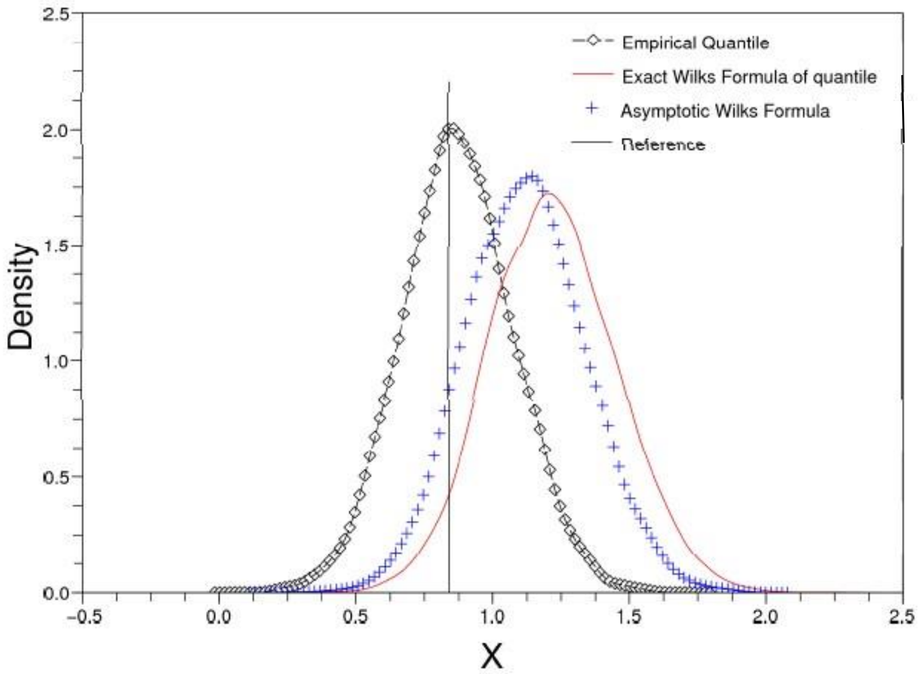

FIGURE A-12: SET 1: Q = 104, N_{SAMPLE} = 50, α= 0.80, β= 0.95

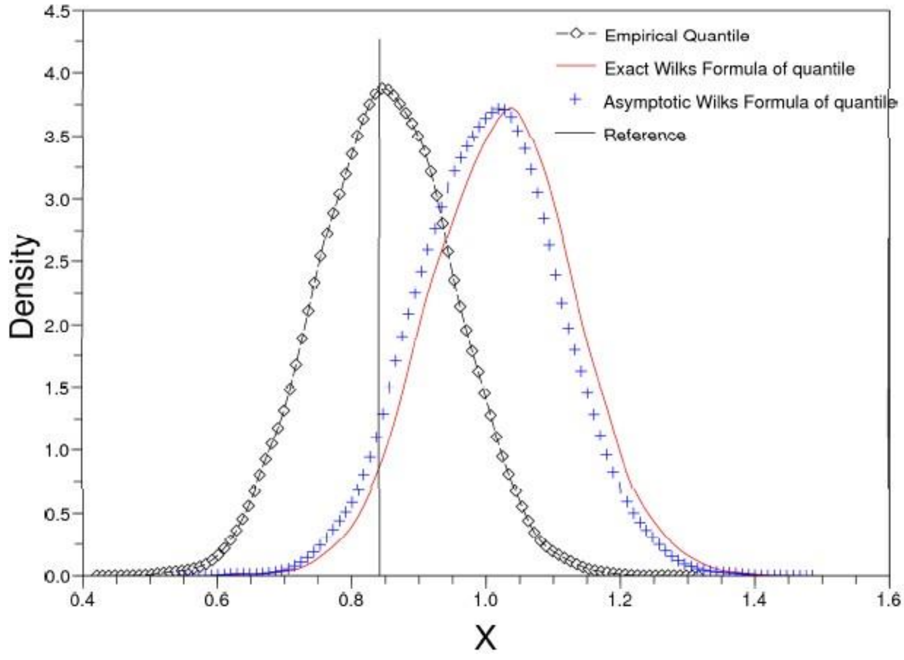

FIGURE A-13: SET 2: Q = 10^4, N_{SAMPLE} = 200, α= 0.80, β = 0.95

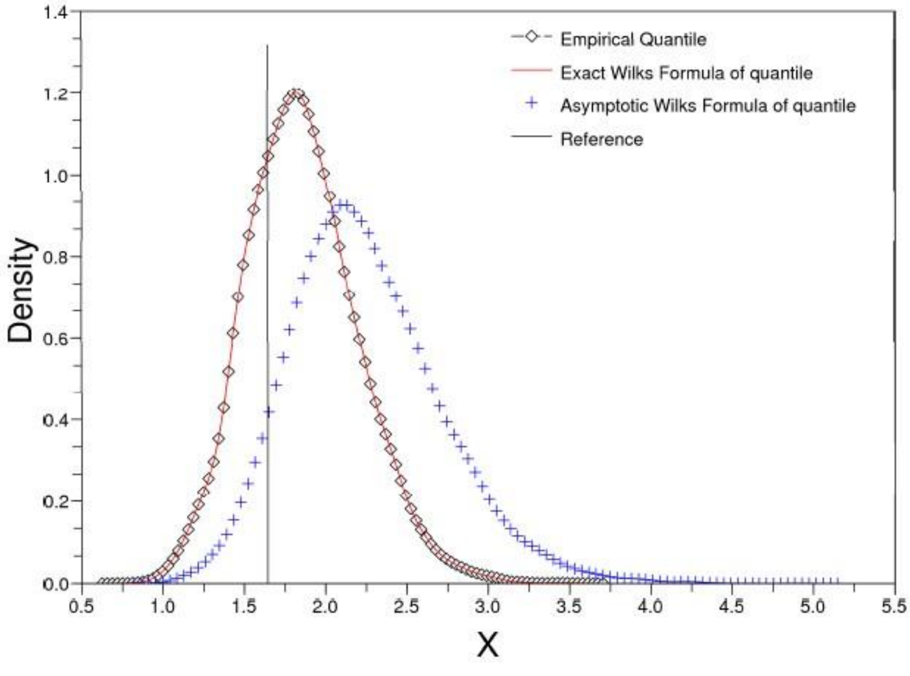

FIGURE A-14 - SET 4: Q = 10^4, N_{SAMPLE} = 50, α = 0.95, β = 0.80

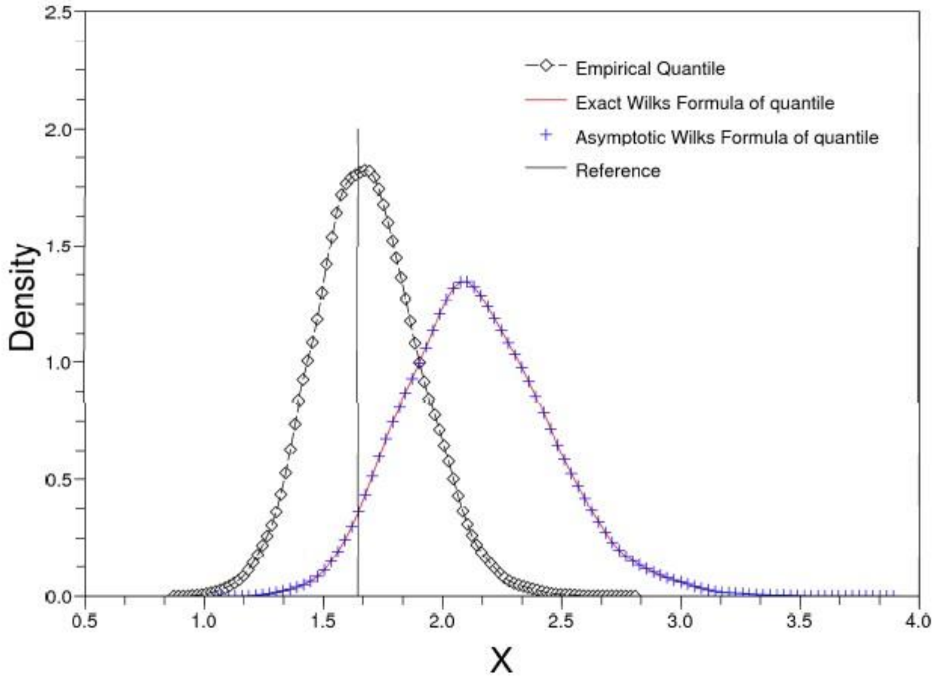

FIGURE A-15: SET 5: Q = 10^4, N_{SAMPLE} = 100, α = 0.95, β = 0.95

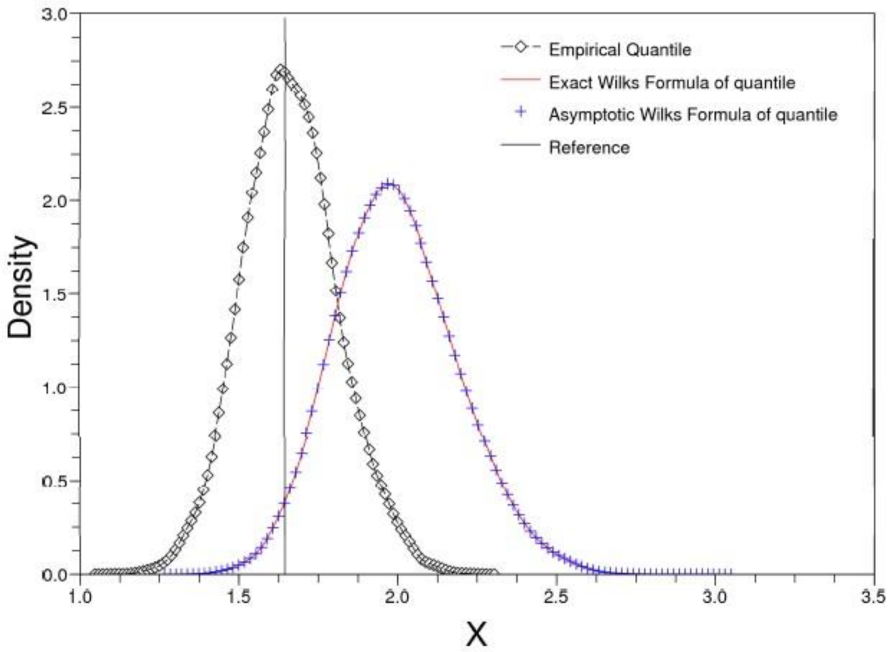

FIGURE A-16: SET 7: Q = 10^4, N_{SAMPLE} = 200, α = 0.95, β = 0.95

A.6 REFERENCES

The computations are performed with the Open Source software Scilab 4.0 (www.scilab.org).

APPENDIX B

RECOMMENDED AIRCRAFT INTERFERENCE PATH LOSS (IPL) MEASUREMENT TECHNIQUE

APPENDIX B

RECOMMENDED AIRCRAFT INTERFERENCE PATH LOSS (IPL) MEASUREMENT TECHNIQUE

B.1 INTERFERENCE PATH LOSS DEFINITION

Interference path loss (IPL) is defined as the ratio of the power measured at the aircraft radio receiver input to the power measured at the output of the transmitter reference antenna terminals, as shown in FIGURE B-1. RTCA DO-294C [Ref 2] and EUROCAE ED-118 [Ref 7] define IPL in the same way. GNSS active antennas have an internal passive antenna followed by an amplifier. For GNSS, IPL is defined for the power measured at the output of the internal passive antenna (Point D shown in FIGURE B-1). Point C is the preferred measurement location. However if a different measurement point is used, the IPL must be decreased to account for the associated cable loss.

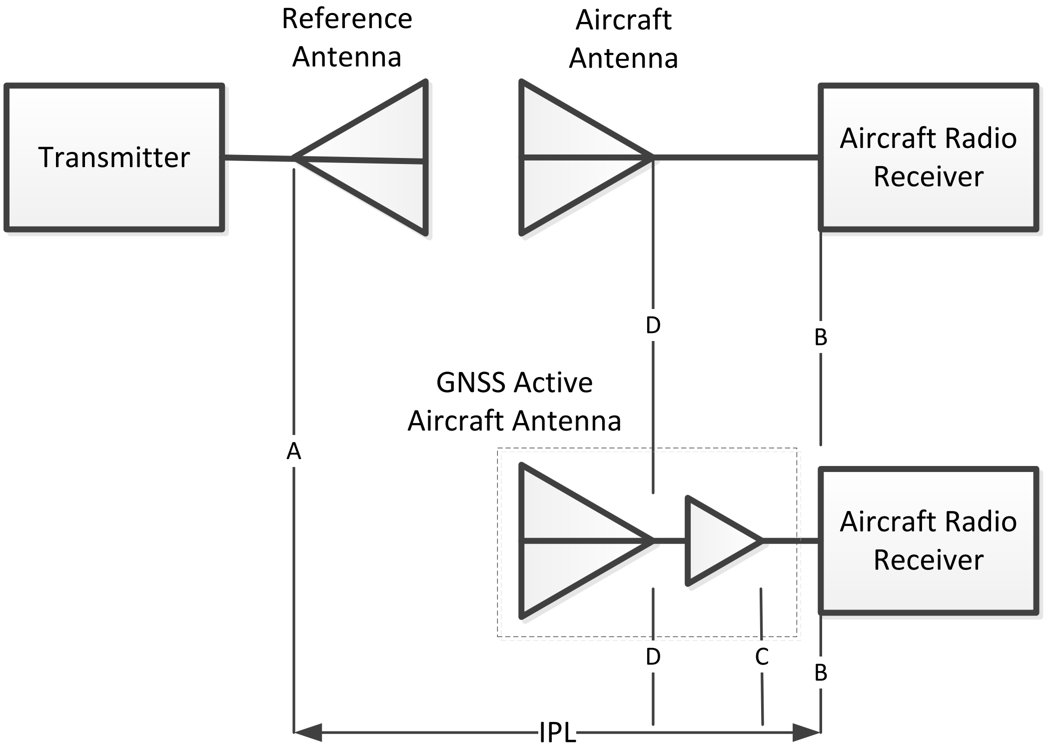

FIGURE B-1: DEFINITION OF INTERFERENCE PATH LOSS

In FIGURE B-1, IPL is defined as the ratio, or the difference in dB, between the power radiated from the reference antenna at Location A to the power received at Location B. For most aircraft radio receivers, interference path loss (IPL) includes aircraft cable loss, since radio receiver susceptibility thresholds are specified at the receiver antenna port, so that:

$$IPL = P_{Tr(A)} - P_{Rec(B)}$$

where:

$P_{Tr\,(A)}$	Power transmitted at Point A, in dBm
$P_{Rec(B)}$	Power received at Point B, in dBm

For aircraft GPS receivers, interference thresholds are specified at the output of a passive GPS antenna. Thus, IPL for GPS should not include antenna cable loss. The test cable should connect directly to the GPS antenna output or very close to it, and so that the spectrum analyzer measures the power at the output of the antenna directly (Location D). Active GPS antennas must be powered during the measurement. A bias-Tee is useful in coupling DC power to the antenna. In addition, the effect of the antenna's internal amplifier gain must be removed. This is achieved by increasing the measured IPL value by an amount equal to the gain value. In this case:

$$IPL_{GPS} = P_{Tr(A)} - P_{Rec(C)} + G_{Amp}$$

where:

$P_{Rec(C)}$	Power received at Point C, in dBm
G_{Amp}	Internal amplifier gain for active GPS antenna, in dB ($G_{Amp} = 0$ for passive antennas)

B.2 EVALUATION OF WORST-CASE IPL

The IPL for a particular radio receiver installation varies rapidly with frequency and position. Therefore it is necessary to measure IPL at a number of positions inside the aircraft over the radio receiver operating frequency range to determine the worst-case IPL value. The worst-case IPL is the lowest measured IPL.

Aircraft door IPL measurements: Specific IPL measurements must be performed at each door of the aircraft.

Aircraft cabin IPL measurements: IPL measurements are not required at each seat locations. However, it is necessary to take measurements at regular intervals (every 50 cm) along a single line inside the aircraft, i.e., in the middle of the aisle for a single aisle aircraft or the aisle closest to the majority of aircraft doors for larger aircraft.

Aircraft interiors and passengers are expected to increase the measured IPL. Because there is no set minimum on the number of passengers and their seating arrangements, their contributions to loading shall not be taken into account. Therefore, measurement should be carried out on a fully furnished aircraft but with no passengers in order to find the typical IPL. Determining the IPL without the aircraft fully furnished will lead to worst-case results.

Aircraft flight deck IPL measurements: As pilots and other crew members allowed into the flight deck are also capable of carrying PEDs, IPL should be measured from the flight deck. The IPL measurements are performed by placing the transmit antenna in several locations within the flight deck.

Aircraft cargo bay IPL measurements: IPL measurements should also be conducted inside the cargo bay. Because of the varying size of the cargo doors, the number of measurements necessary to address the apertures varies with the size of the aircraft. This area should be empty when performing this test, as credit may not be taken for any expected loading given by baggage or cargo.

B.3 MEASUREMENT FREQUENCY BANDS

As discussed in Section 4, IPL measurements at or below 75 MHz are not required.

Note that for GNSS systems, the measurement connection should be made at the antenna port rather than at the aircraft radio receiver as described in B.1 and shown in FIGURE B-1.

IPL should be measured across the operating frequency band for the selected aircraft radio receiver installations in Table 4-7. IPL measurements are not required outside the operating frequency band for aircraft radio receiver installations.

B.4 MEASUREMENT PROCESS

The general IPL measurement set-up is shown in FIGURE B-2. Note that for GNSS systems, the measurement connection should be made at the antenna port rather than at the aircraft radio receiver as shown in the FIGURE B-2.

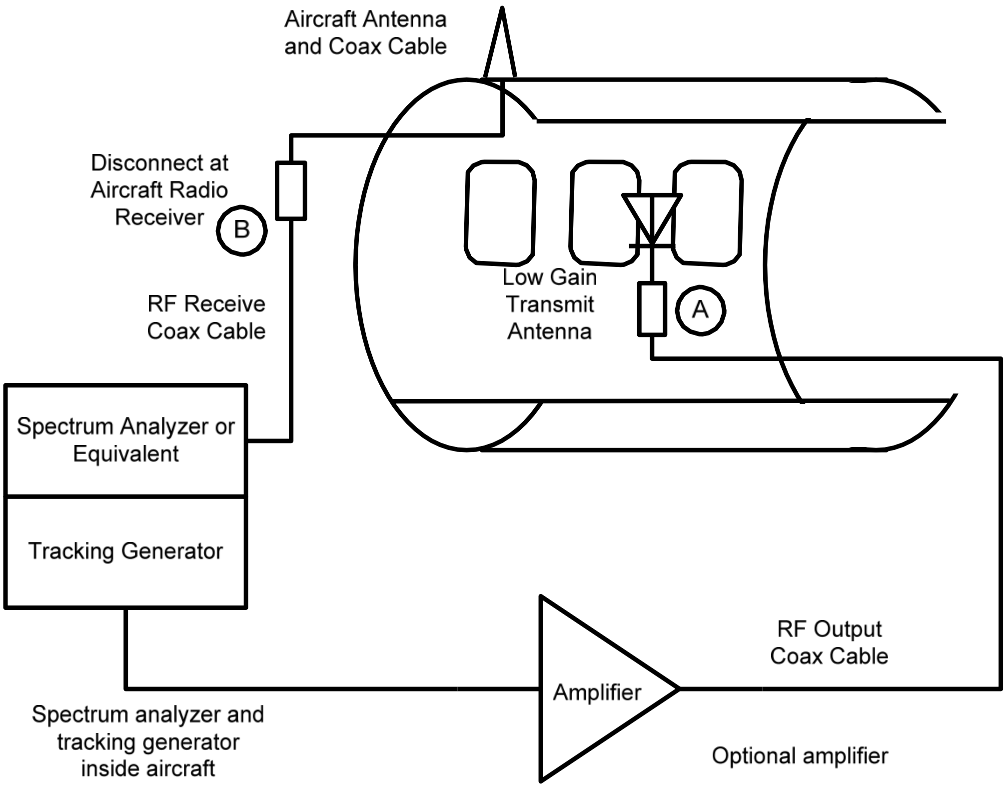

FIGURE B-2: TYPICAL MEASUREMENT SETUP

B.5 SET-UP

Equipment needed:

a. Low gain antenna

b. Spectrum analyzer (SA) with tracking generator or receiver with greater than or equivalent accuracy (e.g., vector network analyzer)

c. HF-switch (optional)

d. Very long, low loss coaxial cables

e. Amplifier (optional).

An omnidirectional or low directivity antenna should be used as a transmitting antenna (reference antenna). Good choices are disc-cones, mono-cones, bi-cones or other dipoles. Assessments of antenna gains or antenna efficiencies are not needed. If the antenna free space VSWR is 2:1 or less, then reflected power does not need to be accounted for. If the antenna VSWR is greater than 2:1, free space reflected power must be accounted for in the calculations.

Demonstrate measurement receiver has sufficient dynamic range and sensitivity to measure the transmitted signal. If necessary a preamplifier may be used.

All stimuli and measurement equipment used in the performance of the tests should be identified by make, model, serial number and the calibration expiration date and/or the valid period of calibration where applicable; all test equipment calibration standards should be traceable to national and/or international standards.

In order to ensure the highest possible repeatability, all test parameters, such as transmit antenna types, polarization angles, coaxial cable loss, equipment part numbers and serial numbers, and test setup photographs, should be thoroughly documented and recorded.

Disconnect the aircraft antenna coax cable from the aircraft radio receiver. Connect the aircraft antenna coax cable to the spectrum analyzer.

The coax cables must be sufficiently long to allow transmitter locations anywhere in the cabin. Depending on the frequency range, the use of low loss cables should be considered.

Instrumentation should be grounded to the aircraft. If the aircraft does not power instrumentation, the aircraft should be ground referenced to the external power source. All doors and exits should be closed (in flight configuration). Cables entering the aircraft from the outside should pass through the smallest possible aperture and disrupt fuselage shielding as little as possible. Outside the aircraft, steps should be taken to shield the cable from re-radiating toward aircraft antennas. Good practices include routing the cables tightly along metal surfaces (for shielding) and in the direction away from the aircraft.

B.6 REFERENCE MEASUREMENTS

Reference measurement for all antenna and receiver cables must be performed initially in order to account for coax cable loss. If the optional amplifier is used, it must be included in the reference measurement. This reference measurement must be repeated whenever cables are unhooked at the instrumentation or amplifier (if used). Typical reference measurement setups are provided in FIGURE B-3 and FIGURE B-4.

Set the spectrum analyzer and tracking generator to sweep the frequency range of interest. Record the value measured.

If the same magnitude of drive signal to the antenna is used during the IPL measurements, this value recorded during the reference measurement will be treated as the radiated power.

If the magnitude of the drive signal is varied during testing, the delta between the test drive signal and the reference measurement drive signal must be accounted for as applicable.

In all cases, if the transmit antenna has a VSWR greater than 2:1 the reflected power must be accounted for. In addition, any differences between the amplifier gain during reference measurement and test must be accounted for.

Care should be taken when hooking an amplifier to the input of a measurement receiver. Most measurement receivers cannot handle high power levels and low level drive signals should be considered in order to avoid damaging the receiver.

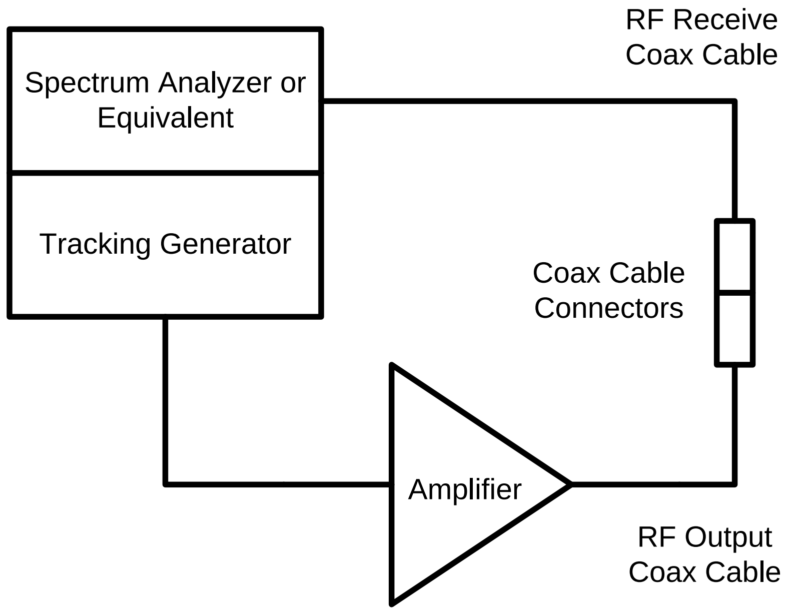

FIGURE B-3: TYPICAL REFERENCE MEASUREMENT SETUP WITH OPTIONAL AMPLIFIER

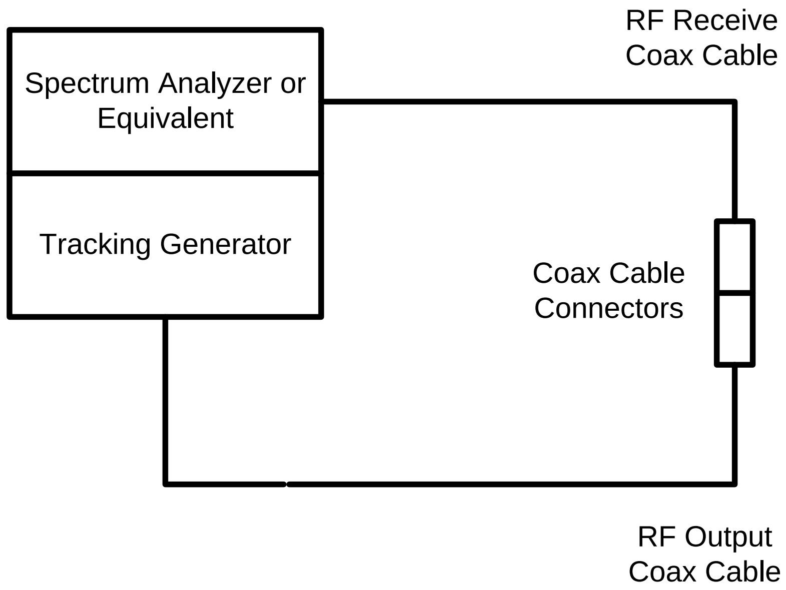

FIGURE B-4: TYPICAL REFERENCE MEASUREMENT SETUP WITHOUT OPTIONAL AMPLIFIER

B.7 MEASUREMENT

In all cases, two orthogonal antenna polarizations must be used. These polarizations are rotated in a plane parallel to the apertures of interest, e.g., the windows in the cabin. These polarizations are treated as independent measurements and no vector analysis is required. Due to size limitations in certain frequency ranges, it may be required to use two separate antennas for the two polarizations. This is allowed as long as the reflection aspect is taken into account.

Typical measurement steps are:

a. Connect the receive coax cable to the aircraft receive antenna at the appropriate point specified in section B.4 above.

b. Set the spectrum analyzer and tracking generator to sweep the frequency range of interest.

c. Perform the IPL measurements at each transmit antenna location. Transmit antenna locations are defined in the following subsections. Use two orthogonal polarizations that are tangential to the planes of windows or apertures. Typically vertical and horizontal polarizations are chosen.

d. Ensure the signal level measured is at least 10 dB above the measurement receiver noise floor. If necessary, adjust the output power of the tracking generator, being sure to record the delta between the test output power and the calibration output power.

e. Record the measured signals

f. For GPS, ensure that signal level does not overload the sensitive active GPS antenna and results in erroneous reading. One approach is to reduce the transmit power by a fixed amount while confirming that the received signal is also reduced by the similar amount. This step should be performed at the strongest coupling location. If necessary, reduce power and repeat the measurement.

Transmit antenna measurement locations are defined as follows.

B.7.1 Aircraft Door IPL Measurements

A diagram depicting typical antenna placement is provided in FIGURE B-5.

a. Place the transmit antenna 0.75 m away from the door, as long as it does not come within 0.75 m of the aircraft sidewall opposite the door.

b. Locate the transmit antenna at the center of the door height and width. If the transmit antenna cannot be placed 0.75 meters from the door for small aircraft, place the transmit antenna in the center of the fuselage, cockpit or baggage compartment, while remaining in line with the door to be measured.

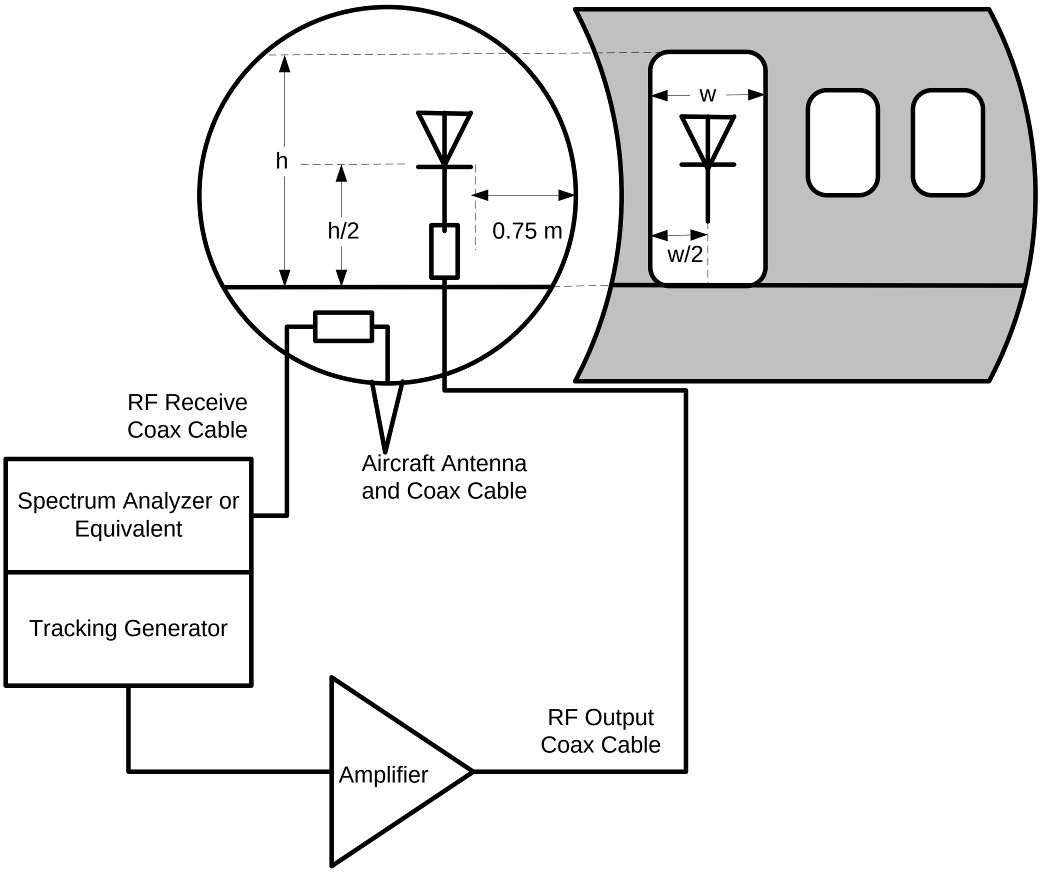

FIGURE B-5: TYPICAL ANTENNA PLACEMENT FOR DOOR LOCATIONS

B.7.2 Aircraft Cabin IPL Measurements

The IPL measurement locations for the aircraft cabin are described below. A typical test setup is provided in FIGURE B-6.

a. Place transmit antenna 50 cm away from the front of the aircraft cabin, at a height equal to the center of cabin windows.

b. For subsequent measurements, place the transmit antenna at 50 cm intervals in a straight line along the center of the aisle. The last location should be within 50 cm of the aft cabin.

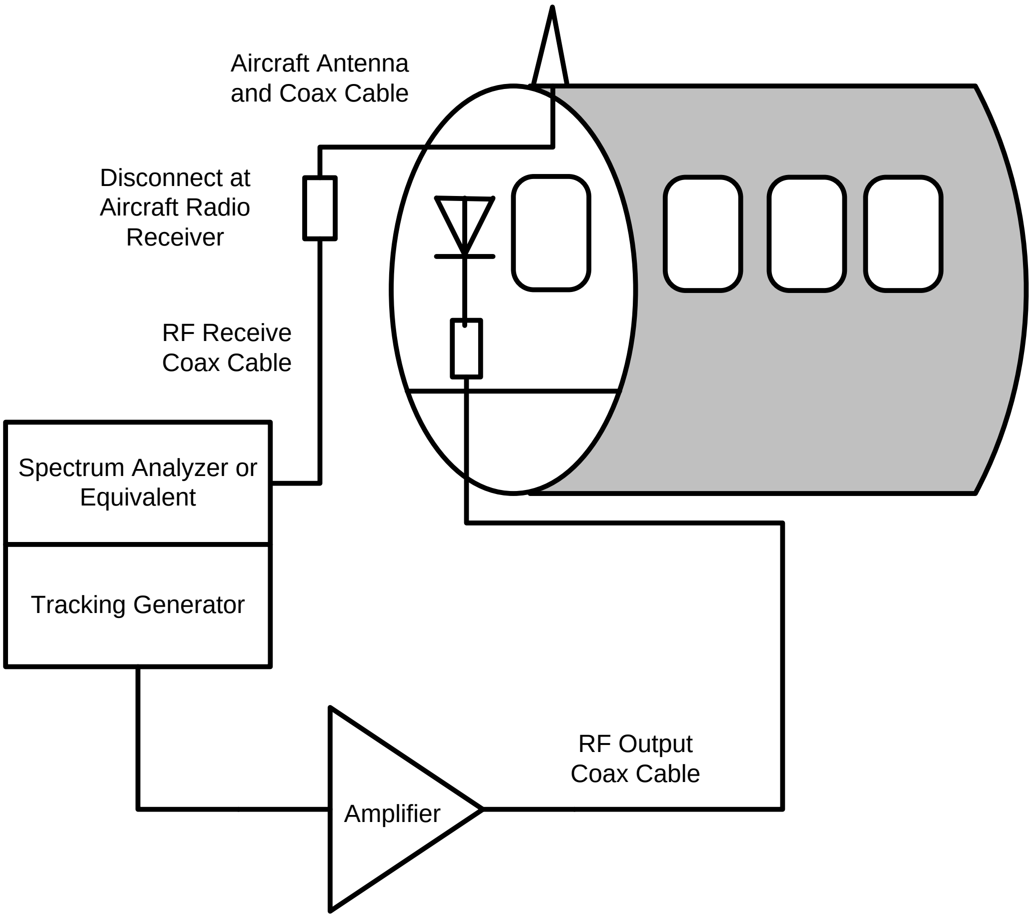

FIGURE B-6: TYPICAL CABIN TEST SETUP

B.7.3 Aircraft Cargo Compartment IPL Measurements

The procedure for antenna placement in an aircraft cargo or baggage compartment is provided below. Typical transmit antenna locations are provided in FIGURE B-7.

a. Select antenna locations that are in straight line 0.75m from plane of the cargo compartment door.

b. Use transmit antenna positions that are 50 cm apart, covering the width of the door plus 150 cm on each side of the door, or until the transmit antenna is within 50 cm of the front or rear of the cargo compartment.

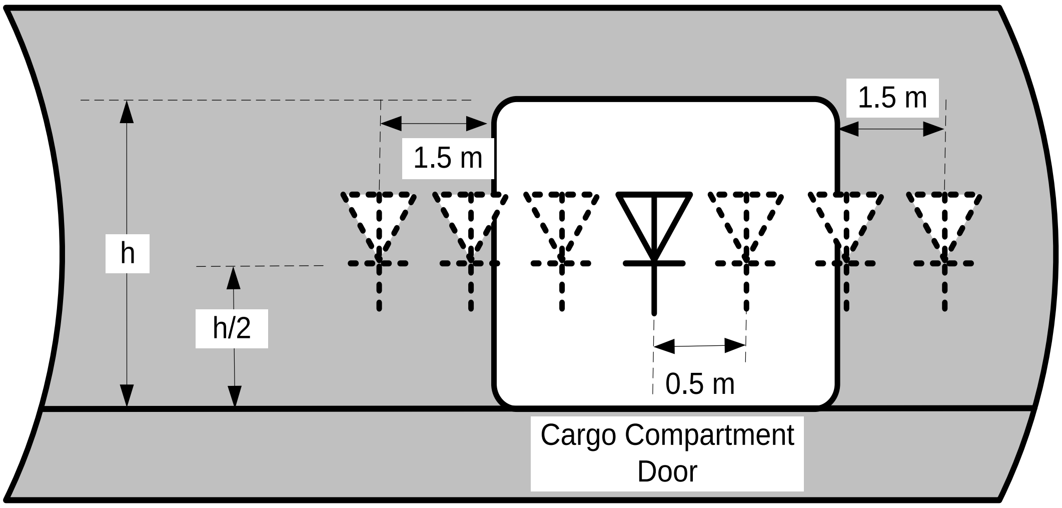

FIGURE B-7: TYPICAL ANTENNA PLACEMENT IN A CARGO COMPARTMENT

B.7.4 Aircraft Flight Deck IPL Measurements

The IPL measurement positions for the aircraft flight deck are described below. A typical test setup is provided in FIGURE B-8.

a. Place the transmit antenna on the pedestal between the pilot and copilot seats at a height equal to the center of the largest cockpit or flight deck window.

b. For subsequent measurements, move the transmit antenna 50 cm aft from the previous location until it is within 50 cm of the flight deck door or passenger cabin.

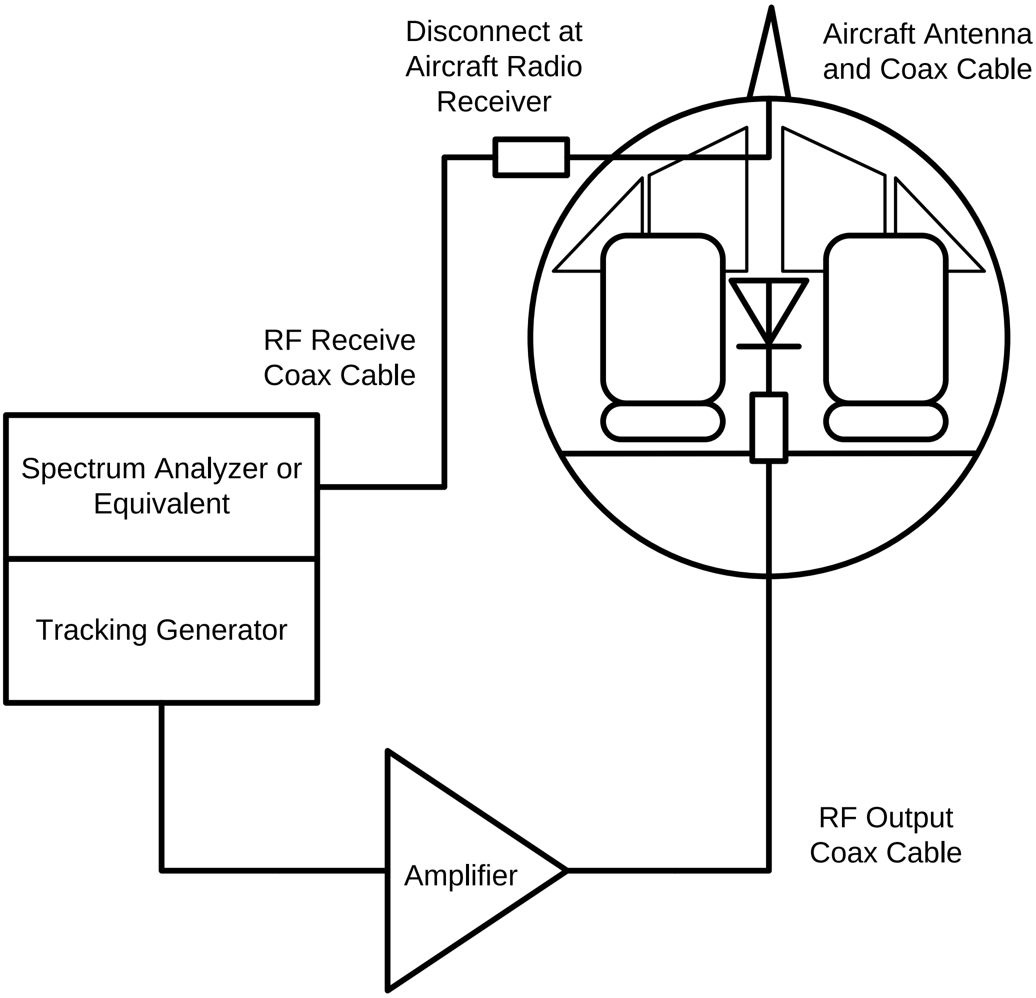

FIGURE B-8: TYPICAL FLIGHT DECK TEST SETUP

B.8 CALCULATION OF IPL

Once all positions have been measured, calculate the aircraft IPL value. The equations shown below are frequency dependent. All values must be recorded at the same frequency in order for the equations to be valid.

The calculation can be performed as follows:

$$\Delta_{CT} = P_{TT} - P_{TC}$$

where:

Δ_{CT}	Power ratio in dB
P_{TT}	Tracking generator power output during test in dBm
P_{TC}	Tracking generator power output during reference measurement in dBm

Once the power ratio is known, the:

$$IPL = P_{MC} + \Delta_{CT} - P_{MT}$$

where:

Δ_{CT}	Power ratio in dB
P_{MT}	Power measured during test in dB
P_{MC}	Power measured during reference measurement in dB

For active GPS antennas, the gain of the built-in amplifier must be removed since the IPL is defined for a passive antenna. The amplifier gain value is required. The IPL for an active GPS antenna is:

$$IPL = P_{MC} + \Delta_{CT} - P_{MT} + G_{Amp}$$

where:

G_{Amp}	Active GPS antenna amplifier gain value in dB.

B.9 CALCULATION OF SINGLE IPL FOR A RADIO RECEIVER

Once the IPL has been measured for a specific aircraft radio receiver, the lowest measured IPL value is considered to be the aircraft IPL for that radio receiver.

For example, IPL was measured with eight reference antenna positions for a specific VHF radio installation. The IPL values were calculated for the eight antenna positions (FIGURE B-9).

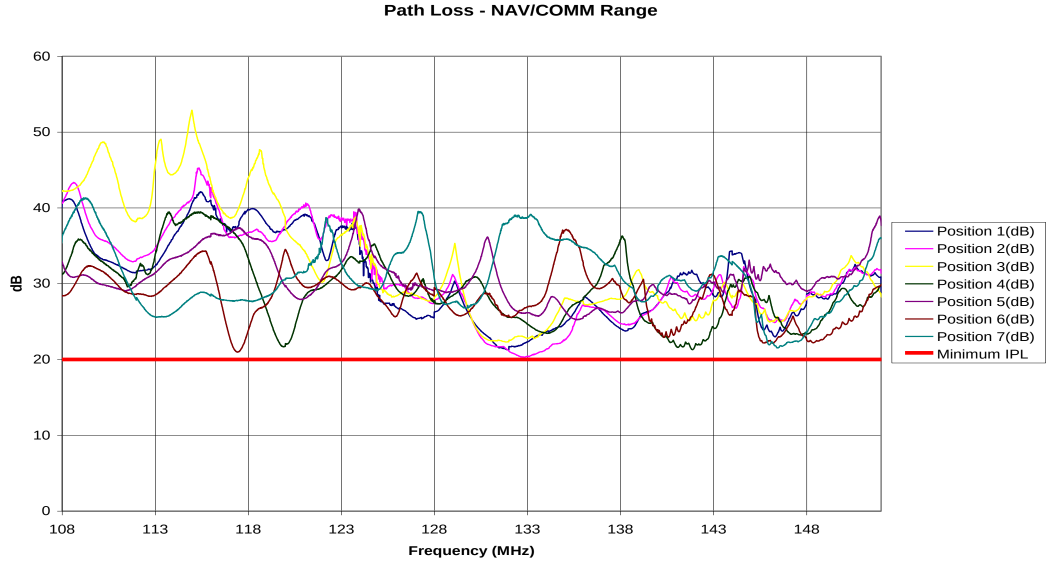

FIGURE B-9: EXAMPLE OF IPL RESULTS FOR EIGHT MEASUREMENTS

In this example, the lowest measured IPL is 20 dB. Therefore, the aircraft IPL for this radio receiver installation would be 20 dB. A comparison can now be made against the relevant target IPL provided in section 4. If the measured aircraft IPL is shown to be higher than the target IPL, then this aircraft radio receiver installation is considered to be PED tolerant.

B.10 OTHER METHODS

There are other methods available to measure the aircraft radio receiver IPL. Examples include frequency stirring, mechanical stirring, field mapping, etc. Since the worst case measurement is the one that is being used to determine IPL, it is possible to speed up the measurement by simply placing the measurement receiver in the Peak Hold mode and slowly move the transmitting equipment down the aisle, ensuring that sweep time is extremely fast compared to the movement of the transmitting antenna. This, as well as the other methods mentioned can involve modeling, analysis, different test procedures or combinations of all three. Analytical models, representative of the aircraft and transfer characteristics of the installation, may be used in conjunction with supporting test data to provide the justification of compliance.

APPENDIX C

ACRONYMS AND ABBREVIATIONS

APPENDIX C

ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
ADF	Automatic Direction Finder
AFM/S	Aircraft Flight Manual/ Supplement
AMSS	Airborne Mobile Satellite Service
AMS(R)S	Airborne Mobile Satellite (Route) Service (protected aeronautical safety communications via satellite)
ASRS	Aviation Safety Reporting System
Cat	Category
CCT	Conducted Spurious Emissions Coupled To Equipment Inputs
CDMA	Code Division Multiple Access
CEI	Conducted Spurious Emissions Cross Talk Coupled From Cable To Cable
CFR	Code Of Federal Regulations
CMRS	Commercial Mobile Radio Service
DC	Direct Current
DH	Decision Height
DME	Distance Measuring Equipment
EASA	European Aviation Safety Agency
EIRP	Effective Isotropic Radiated Power
EMI	Electromagnetic Interference
ERP	Effective Radiated Power
EUROCAE	European Organisation For Civil Aviation Equipment
FAA	Federal Aviation Administration
FCC	Federal Communication Commission
FM	Frequency Modulated
FRS	Family Radio Service
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System For Mobile Communication
HF	High Frequency
HIRF	High Intensity Radiated Fields
ICA	Instructions For Continuing Airworthiness
ILS	Instrument Landing System
IPL	Interference Path Loss
IRA	Intentional Radiated Emissions Coupled Through Equipment Antennas

IRC	Intentional Radiated Emissions Coupled Through Equipment Cables
IRU	Intentional Radiated Emissions Coupled Through Equipment Units
LRU	Line Replaceable Unit
MLS	Microwave Landing System
NASA	National Aeronautics And Space Administration
NIRA	Non-Intentional Radiated Emissions Coupled Through Equipment Antennas
NIRC	Non-Intentional Radiated Emissions Coupled Through Equipment Cables
NIRU	Non-Intentional Radiated Emissions Coupled Through Equipment Units
PDA	Personal Digital Assistant
pdf	Probability Density Function
PED	Portable Electronic Device
PSD	Power Spectral Density
RBW	Resolution Bandwidth
RF	Radio Frequency
RMS	Root Mean Square
RTCA	Formerly Radio Technical Commission For Aeronautics
TCAS	Traffic Alert And Collision Avoidance System
T-PED	Transmitting Portable Electronic Device
UAT	Universal Access Transceiver
VDL	Very High Frequency Digital Link
VHF	Very High Frequency
VOR	Very High Frequency Omni-Range
VSWR	Voltage Standing Wave Ratio
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network

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