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Ultrawideband Electromagnetic Interference to Aircraft Radios

Results of Limited Functional Testing With United Airlines and Eagles Wings Incorporated, in Victorville, California

Jay J. Ely
Langley Research Center, Hampton, Virginia

Timothy W. Shaver
United Airlines, Indianapolis, Indiana

Gerald L. Fuller
Eagles Wings Incorporated, Mariposa, California

October 2002

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National Aeronautics and
Space Administration

Langley Research Center
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Abstract

On February 14, 2002, the FCC adopted a FIRST REPORT AND ORDER, released it on April 22, 2002, and on May 16, 2002 published in the Federal Register a Final Rule, permitting marketing and operation of new products incorporating UWB technology. Wireless product developers are working to rapidly bring this versatile, powerful and expectedly inexpensive technology into numerous consumer wireless devices. Past studies addressing the potential for passenger-carried portable electronic devices (PEDs) to interfere with aircraft electronic systems suggest that UWB transmitters may pose a significant threat to aircraft communication and navigation radio receivers. NASA, United Airlines and Eagles Wings Incorporated have performed preliminary testing that clearly shows the potential for handheld UWB transmitters to cause cockpit failure indications for the air traffic control radio beacon system (ATCRBS), blanking of aircraft on the traffic alert and collision avoidance system (TCAS) displays, and cause erratic motion and failure of instrument landing system (ILS) localizer and glideslope pointers on the pilot horizontal situation and attitude director displays. This report provides details of the preliminary testing and recommends further assessment of aircraft systems for susceptibility to UWB electromagnetic interference.

1 Background

Ultrawideband (UWB) technology is typically characterized by the radiation and detection of base-band pulse signals, having a duration of less than 1 nanosecond. A periodic sequence of these pulses can be shown in the frequency domain to appear as narrow-band signals at frequency spacing that is the inverse of the pulse repetition interval. Highly broadband antennas are required to transfer enough frequency content through the transmission medium to preserve the required degree of pulse shape characteristics. The first patent for a UWB-type communication system was issued to Gerald Ross, in 1973 [1], however the technology was referred to as *baseband* at that time. According to Dr. Robert Fontana, President of Multispectral Solutions Inc., most UWB technology development prior to 1994 was performed under classified U. S. government programs [2]. Fontana provides an excellent history of UWB, with many downloadable references at the Multispectral Solutions website: http://www.multispectral.com/history.html.

In 1994, Thomas McEwan was issued a patent for an "Ultra-Wideband RADAR Motion Sensor" [3], and was credited with specifying numerous commercial applications for the technology in a Popular Science magazine article entitled "RADAR on a Chip, 101 Uses In Your Life" (June 1995), [4]. Because UWB technology is inherently a pulse modulated radio transmission scheme, blending of digital communications and radar sensor applications is greatly simplified. Some safety-related UWB applications address situational awareness needs in automobiles, like backup-warning systems, intelligent cruise control and collision avoidance. Some security-related UWB applications include sensors that can see into (and even through) boxes, bags, crates and walls, allowing detection of unauthorized equipment or intruders. UWB ground penetrating radars have been demonstrated to provide extensive information about buried pipes, weapons and facilities for military, geological, archeological and architectural applications. UWB systems can be implemented with very inexpensive and compact electronic components. Perhaps these characteristics hold the greatest promise for driving a revolution in new applications for consumer products. Designers and developers of wireless technology are promoting UWB technology for addressing the needs of high data rates, interoperability and location awareness that will be required for emerging wireless applications.

2 Status of UWB Regulation

On February 14, 2002, the FCC adopted a FIRST REPORT AND ORDER, released it on April 22, 2002, and on May 16, 2002 published in the Federal Register a Final Rule, permitting marketing and operation of new products incorporating UWB technology [5]. Years of effort have been invested by the FCC, the National Telecommunications and Information Administration (NTIA), universities and industry to develop a technical rationale for setting limits on allowable UWB signal levels. The FCC Final Rule provides detailed requirements for allowable UWB radiated emission levels. These levels are based primarily on FCC Part 15.209 spurious radiated emission limits [6]. Additional limitations are specified depending upon the stated application: imaging systems, vehicular radar systems, indoor UWB systems, and handheld UWB systems. The technical requirements for handheld UWB systems, as addressed in FCC Final Rule Part 15.519, are of primary concern when considering UWB technology applications within PEDs, particularly as a threat to aircraft radios. Handheld UWB system emission limit levels are specifically provided as effective isotropic radiated power (EIRP) from 960 MHz to above 10.6 GHz. Below 960 MHz, the standard FCC Part 15.209 limits apply. By assuming an isotropic radiation pattern, the field intensity levels specified in FCC Part 15.209 can be converted to EIRP levels at frequencies below 960 MHz. The final composite limits, from 100MHz to 10.7GHz are shown in Figure 1. While UWB operation is stated to be restricted to the 3.1-10.6 GHz frequency band in the FCC Final Rule, relatively high limits are also allowed for operation below 960MHz.

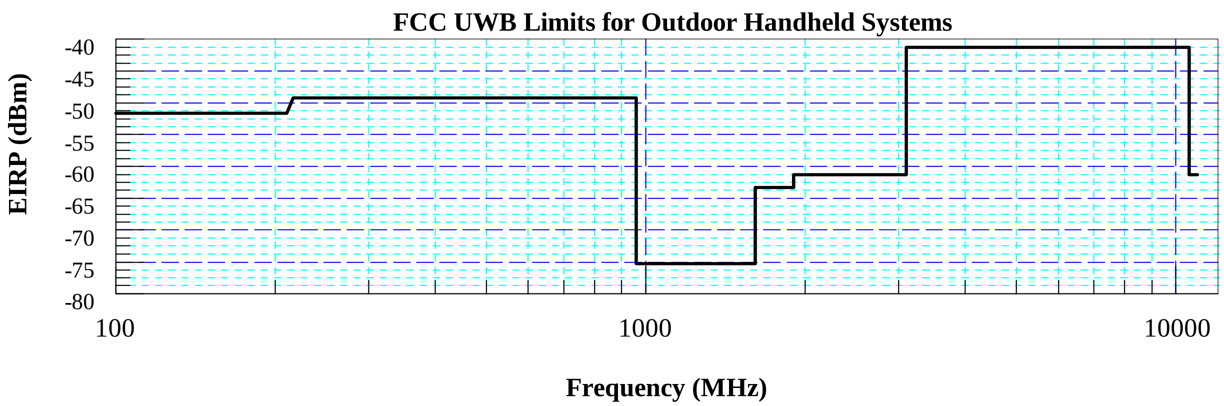

Figure 1: Composite graph of EIRP allowed by the FCC Final UWB Rule, Part 15.519, dated May 16, 2002.

The FCC FIRST REPORT AND ORDER states that the adopted standards "may be overprotective and could unnecessarily constrain the development of UWB technology", and reveals the intention to issue a further rulemaking to "explore more flexible technical standards and to address the operation of additional types of UWB operations and technology". These statements appear to indicate that a relaxation of UWB radiated emission limits is planned for the near future. On July 12, 2002, the FCC issued an additional Order, permitting the continued operation of UWB ground penetrating radars (GPRs) and wall imaging systems that do not comply with the FCC FIRST REPORT AND ORDER [7]. The July 12 Order applies to GPR's and wall imaging systems that had previously been operating without FCC licenses, authorized under FCC experimental rules under FCC Part 5 or by waivers. The July 12 Order cites that several public safety benefits result from the continued operation of existing GPRs and wall imaging systems currently in use, and that the FCC is not aware of any reports of harmful interference resulting from the long-term use of these systems in the past.

3 Why is UWB EMI a Concern For Aircraft Radios?

Spurious radiated emission data from typical PED's is available within the RTCA/DO-199 and /DO-233 publications. (See DO-190 Vol. 2 Section 4.0, and DO-233 Appendix A, [8], [9].) The RTCA publications contain numerous charts, clearly showing that typical PEDs radiate spurious signal amplitudes that are thousands of time less, at most frequencies, than the FCC 15.209 limits require. In fact, the DO-233 analysis concluded that PEDs meeting FCC 15.209 limits could *exceed* interference limits for aircraft VOR and Localizer radios by a factor of over 1000 times, even after their emissions are attenuated by traveling from the passenger cabin to aircraft radio receivers. However, as noted by the DO-233 authors, the probability of a typical device radiating at the FCC limit, on a particular aircraft radio channel is extremely low. UWB transmitters, on the other hand, emit equal-amplitude, narrow band signals at frequency spacing that is the inverse of the pulse repetition interval. When using pulse-position modulation and different clock frequencies, UWB transmitters emit narrow-band signals simultaneously at *any* frequency, even in safety-critical aircraft bands. There is clearly a very big difference between typical consumer devices, that radiate spurious signals nearly always far below FCC 15.209 limits, and UWB devices, that may be intentionally designed to radiate at or near FCC 15.209 limits.

The final FCC rule explicitly states that "the operation of UWB devices is not permitted onboard aircraft, ships, or satellites…". This statement indicates that the FCC has documented EMI concerns for UWB operation on board these vehicles. The FCC rule provides no guidance on how UWB devices can be restricted from operating in these vehicles, who is responsible for enforcing the restrictions, and what the penalties are.

4 Limited Functional Testing of UWB EMI on United Airlines Airplanes

4.1 NASA/Eagles Wings/United Airlines/Eclypse Test Project

To determine the threat power at the connector of a particular aircraft radio receiver, due to the spurious radiated emissions from a PED, losses due to propagation, antenna loss and cable loss occurring between the PED and the aircraft radio connector must be known. These losses can be identified as "interference path loss" (IPL). Since the RTCA/DO-199 & DO-233 studies, significant additional work has been performed by Eagles Wings Incorporated (EWI), Delta Airlines and NASA to better understand and quantify IPL. Previous analyses note that there are significant deficiencies in available data to allow estimation of the probability that a particular passenger location will have an IPL below a particular threshold [10]. A need was identified to extend the available IPL database on typical commercial transport aircraft. Such measurements are labor-intensive, and require exclusive access to airplane interior locations, exterior antenna systems, and avionics bay connections.

EWI submitted a proposal to NASA to work with United Airlines in resolving several technical issues related to IPL measurement data, including aircraft-to-aircraft repeatability, the type of test antenna, and IPL measurements at all passenger cabin seat locations. The proposal was supplemented with an evaluation of IPL mitigation techniques (ie. door/window exit seam shielding, and conductive window films), and assessment of aircraft RF cable and antenna health using new-technology instrumentation tools. NASA issued a Purchase Order (L-16099) to work with EWI, United Airlines, and Eclypse on these goals. United Airlines was able to provide a limited number of flight-ready airplanes at an aviation storage facility in Victorville, California, including fuel, engineering and mechanic support for this purpose. Measurements were performed during three one-week visits to the Southern California Aviation facility, in Victorville, California.

Under the NASA/EWI contract, IPL measurements were performed on 6 B737-200 airplanes at all windows and door exits, for the VOR/Localizer, VHF-1 comm., Glideslope, TCAS, and GPS radio antenna systems, and on 4 B747-400 airplanes at selected windows and door exit locations, for the Localizer, VHF-1 comm., Glideslope, TCAS, GPS and Satcom radio antenna systems. (VOR and ILS localizer share an antenna and RF pathway on the B737-200.) Duplicate sets of path loss data were obtained on multiple, identical aircraft, to establish repeatability of the measurement process and to identify any differences related to subtle aircraft configuration changes. (See aircraft pictured in Figure 2.) IPL measurements were also performed using an alternate, electrically small biconical antenna for the VHF band. Comparison of biconical antenna data to standard dipole data will provide insight into measurement variability and to identify advantages and disadvantages due to antenna type. Additional interference path loss measurements were performed at numerous seat locations, to quantify the degree to which interference path loss varies as the transmitting source moves away from a window. The additional seat location data may be useful for assessing the additive threat due to multiple transmitters. The NASA/EWI contract also included an evaluation of a new-technology Standing Wave Reflectometer, manufactured by Eclypse Inc., for measuring voltage differences on RF transmission lines due to an applied signal of linearly-varying frequency. The Standing Wave Refelectometer easily connects to an aircraft RF system without antenna removal, and provides distinctly different output indications due to antenna or aircraft wiring faults.

Figure 2: Airplanes provided for PED EMI assessment by United Airlines.

Although UWB testing was not a part of the NASA/EWI statement of work, all parties were interested in performing a preliminary test. After the contractually-required testing was completed, the EWI/United Airlines/NASA team worked together to see if an UWB transmitter could affect operational aircraft radio systems. United airlines provided engineering and mechanic support, as well as fueled and operational airplanes. EWI provided engineering support and NASA provided engineering support as well as UWB sources and instrumentation.

4.2 UWB Laboratory Signal Sources

As part of the FAA/NASA Interagency Agreement, four UWB sources were purchased in November, 2001, for the purpose of studying UWB signal characteristics using standard EMC instrumentation, and to assess future instrumentation requirements needed to quantify UWB signals as EMI threats. The UWB sources are shown in Figure 3. Each UWB source has an internal 9V battery, and has a jack for external power using a 9VDC source. There is also a jack for switching on/off UWB pulses by using an external TTL clock signal. If an external TTL clock signal is not available, the unit has an internal 10MHz TTL clock that can be used by placing the CLOCK EXT/INT switch in the INT position.

When operated, the UWB sources emit extremely short duration electrical pulses from their output jack. The manufacturer provided data specifications for the electrical pulses as follows:

Output Voltage (peak to peak)=	6.7 ± 0.3 V.
Risetime=	259 ± 5 picoseconds
Fall Time=	116 ± 7 picoseconds
Pulse Width (RMS)=	239 ± 10 picoseconds

Because the UWB source output pulses are of such short duration, they contain frequency components that span several GHz. Figure 4 shows a close-up spectrum analyzer display of the UWB source output in the frequency domain, measured at NASA LaRC.

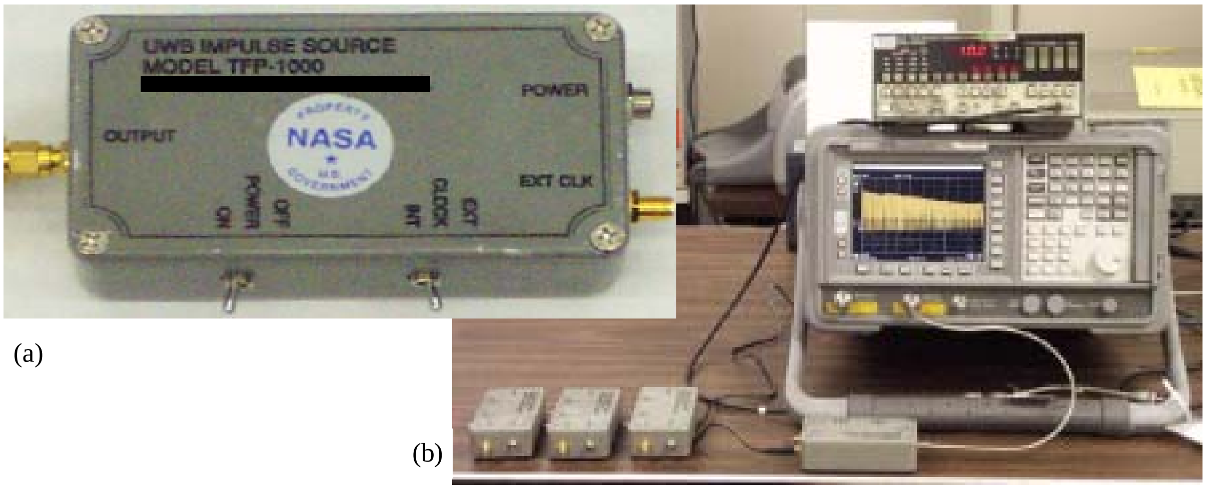

Figure 3: a) Laboratory UWB Signal Source. b) Set of 4 UWB Signal sources being tested for RF spectrum characteristics. Function Generator used for external clocking is also shown.

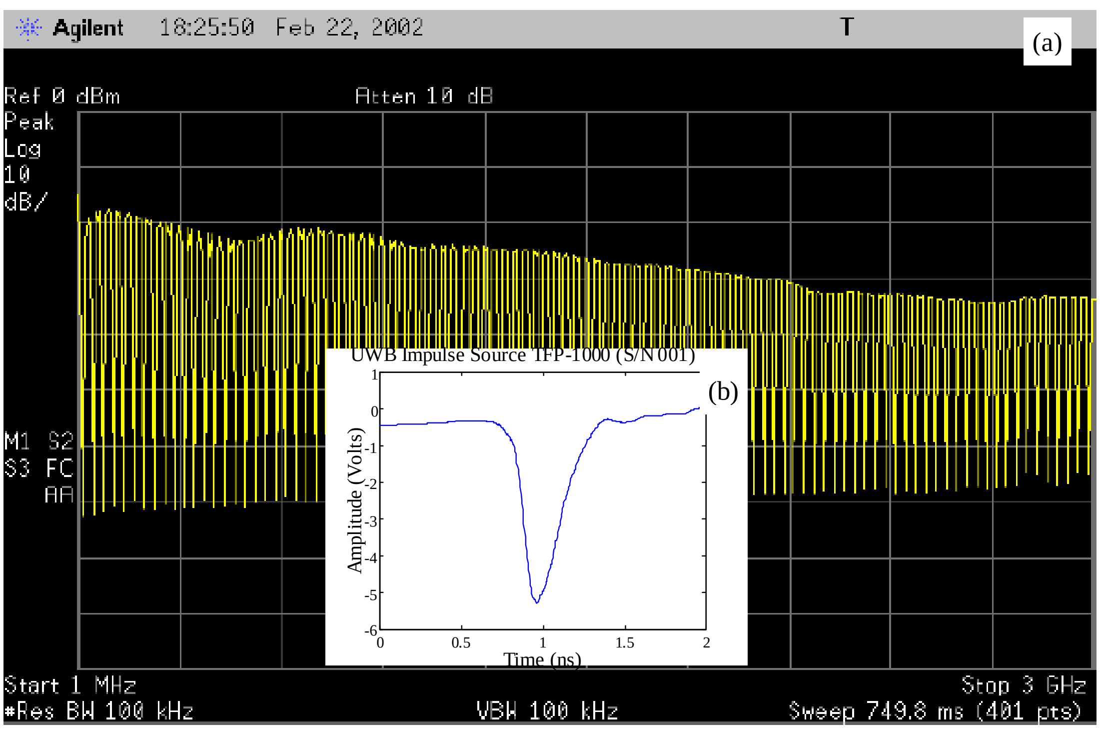

Figure 4: a) Spectrum Analyzer display of UWB source output, from 1 MHz to 3 GHz. b) Manufacturer data showing typical UWB pulse shape in the time domain.

4.3 UWB Testing on 3/22/2002, B737-200

All objectives under NASA/EWI contract L-16099 were complete by 3/21/2002, allowing several hours for UWB EMI assessment with a fully operational aircraft. The UWB signal source was operated using its internal 9V battery and 10MHz internal clock, and connected to an antenna tuned for the frequency band of the aircraft radio system being evaluated. A list of test equipment is provided in Table 1. Spectrum Analyzer and antennas were verified to be within calibration schedule limits. UWB EMI assessment was performed on the VHF Omni-Ranging (VOR), instrument landing system (ILS) Localizer, ILS Glideslope, traffic collision avoidance system (TCAS), air traffic control radio beacon system (ATC), and VHF Comm. aircraft radio systems as described herein.

Item Description	**Manufacturer**	**Model# and Serial/ID #**
Airplane	Boeing	737-200, UAL Nose #1989 Boeing SN 21751
UWB Signal Source		TFP-1000, S/N 101
Spectrum Analyzer	Agilent	E4407B, NIMS# 1636813
3 Ft Cable	Pasternack	3 ft. Low Loss
Antenna, Dual Ridge Horn "DRH" (1-18GHz)	A H Systems	SAS-200/571, SN 164
Antenna, Reference Dipole Set (28-1000MHz)	ETS	3121C, NIMS# 2098522
Hand Held VHF Radio (aircraft frequency band)	ICOM	-
Digital Video Camera	Sony	DCR-TRV900, NIMS# 1613199
Aircraft Radio Recievers:		
VHF Comm	Collins	622-5218-005
VOR/ILS (Localizer and Glideslope)	Collins	622-3257-008
ATC	Collins	622-7878-201
TCAS	Collins	622-8971-022
Aircraft Radio Antennas:		
VHF Comm	Sensor Systems	S65-8262-2
VOR/ILS Localizer	Dorne&Margolin	DMN23-1/C
ILS Glideslope	Sensor Systems	522-0700-023
ATC	Sensor Systems	DMNI50-2-1
TCAS (Upper)	Collins	622-8973-001

Table 1: Equipment List for 3/22/2002 UWB EMI Testing

4.3.1 VHF Voice Communications

Test Procedure

A conversation was initiated and maintained between the aircraft VHF radio and handheld VHF radio. The handheld VHF radio was operated from an automobile located about 30 ft away from the nose of the aircraft, at both 118.02 MHz and 119.90 MHz. The UWB signal source was internally clocked (10MHz), battery powered, and connected to the ETS 3121C dipole antenna (60-140MHz balun, with element length set to 54.0cm), which was placed 1 meter away from the aircraft VHF-1 upper antenna (vertical polarization). Using the test-setup in Figure 5, the UWB signal amplitude was measured to be -23 dBm at 119.9 MHz, and less than -80dBm at 118.0 MHz. See Figure 6.

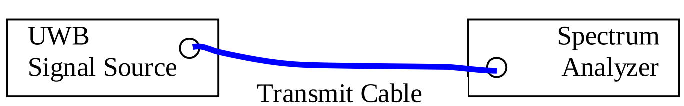

Figure 5: Test arrangement for measuring UWB source output level.

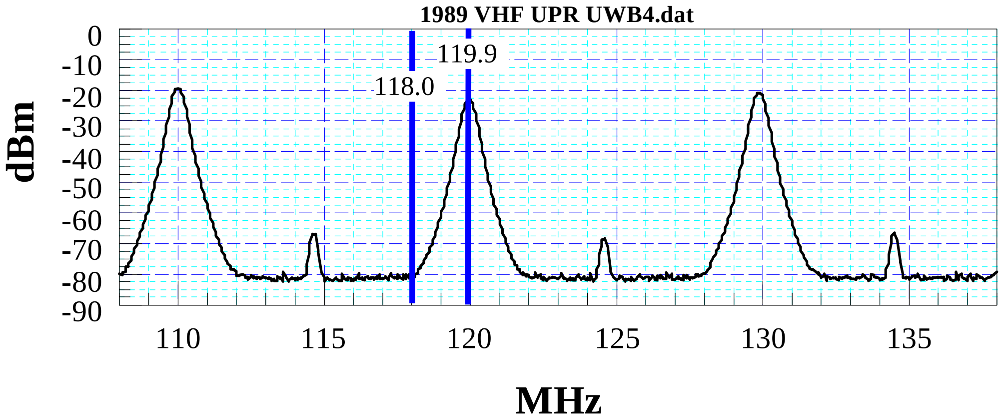

Figure 6: UWB signal source output in the aircraft VHF communications frequency band, using 10MHz internal clock. Measured using spectrum analyzer peak detector, with 300kHz resolution bandwidth.

Observations

No discernable effect in audio quality was observed during the conversation.

4.3.2 ILS Localizer

Test Procedure

The local ILS Localizer beacon could not be acquired by the aircraft at the test location. The UWB signal source was internally clocked (10MHz), battery powered, and connected to the ETS 3121C dipole antenna (60-140MHz balun, with element length set to 64.6cm), which was placed 1 meter away from the aircraft VOR/Localizer tail antenna (horizontal polarization).

Observations

Cockpit instruments did not display any ILS Localizer information. No UWB effects were observed.

4.3.3 VOR

Test Procedure

The local VOR beacon was acquired by the aircraft at the test location. The UWB signal source was internally clocked (10MHz), battery powered, and connected to the ETS 3121C dipole antenna (60-140MHz balun, with element length set to 64.6cm), which was placed 1 meter away from the aircraft VOR/Localizer tail antenna (horizontal polarization).

Observations

Cockpit instruments displayed appropriate navigation information for local beacon. No UWB effects were observed.

4.3.4 ILS Glideslope

Test Procedure

The local ILS Glideslope beacon was marginally acquired by the aircraft at the test location. The UWB signal source was internally clocked (10MHz), battery powered, and connected to the ETS 3121C dipole antenna (140-400MHz balun, with element length set to 21.2cm), which was placed 1 meter away from the aircraft Glideslope nose antenna (horizontal polarization).

Observations

Cockpit instruments displayed appropriate navigation information for local beacon. No UWB effects were observed.

4.3.5 ATC and TCAS

Test Procedure

The local ATC interrogator and TCAS transponders on aircraft in the local airspace were acquired by the test aircraft. The UWB signal source was internally clocked (10MHz), battery powered, and connected to the AH Systems dual ridge horn (DRH) antenna. Because interference was observed with the horn antenna placed 1 meter away from the aircraft TCAS upper antenna, the test procedure was expanded to include locations inside the passenger cabin with the aircraft doors closed.

Observations

The "ATC Fail" indicator lamp on the cockpit display panel illuminated, and airplane targets disappeared from the TCAS display when the UWB signal source was turned ON. Video was recorded of the EMI situation. This failure was observed with the UWB source transmitting from the following locations:

- Outside the aircraft, ~1.5m from the aircraft upper TCAS antenna, port side. (DRH Pol. = Vert.)
- At all first class window locations (windows #1 to 6), port side. (DRH Pol. = Vert.) All aircraft doors closed.
- At the 3rd window location in Coach class (window #9), port side. (DRH Pol. = Vert.) All aircraft doors closed.

To quantify the level of local TCAS signals relative to UWB signals required to upset aircraft TCAS operation, the instrumentation setup described in Figure 7 was used to acquire data shown in Figure 8. To measure the output power directly from the UWB source, the test setup shown in Figure 5 was used. In Figure 8, the black diamonds show spectrum analyzer data, collected after about 20 seconds in "Max Hold" mode, with the UWB source turned OFF. This data was intended to show the amplitude of ambient TCAS signals (from other airplanes and ground interrogators), as seen from the TCAS antenna mounted on the top of the airplane. However, the spectrum is dominated by signals centered about 1090 MHz, which were likely to be the test aircraft's own ATCRBS Mode S reply transmissions.

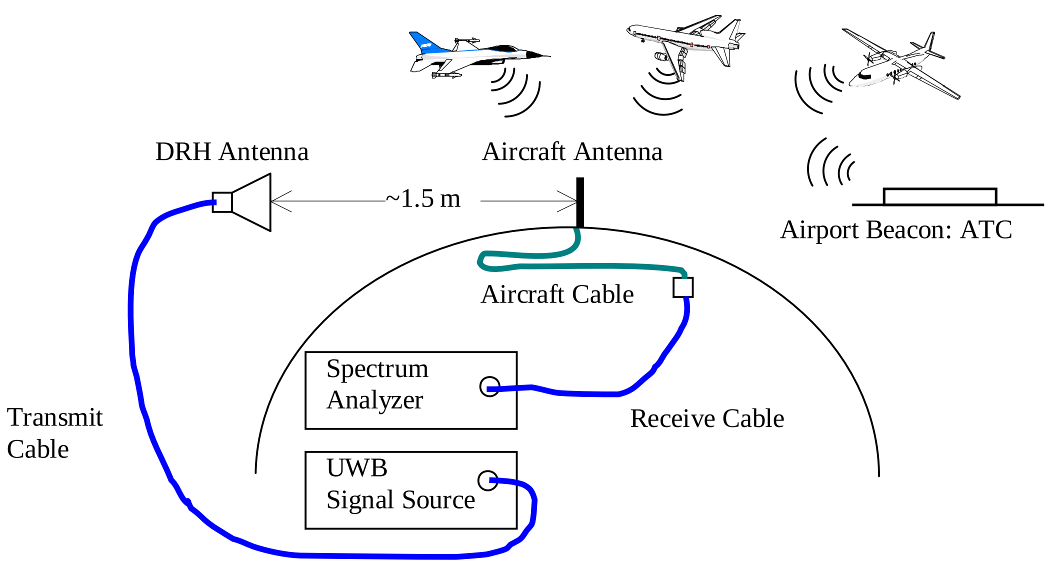

Figure 7: Schematic of test setup used to measure relative amplitudes of UWB and surrounding ATC/TCAS signals.

A few seconds after this spectrum analyzer trace was recorded, the UWB source was turned ON, and the trace was recorded again to obtain the red triangles. (Note that during the 13 seconds before the second trace was recorded, several more ambient signals were observed by the spectrum analyzer. These can be readily identified as they follow the envelope of the other ambient signals, and should be disregarded.) The green diamonds show the signal amplitudes directly out of the UWB source, as measured using the Figure 5 test setup. This chart reveals a ~20dB free-space /antenna/cable loss for the UWB source, when transmitting ~1.5 m away from the TCAS upper antenna, versus being connected directly into the spectrum analyzer. To accurately compare ambient TCAS and ATCRBS interrogator signals with the UWB source-transmitted signal at the TCAS receiver, it will be necessary to deactivate the aircraft ATCRBS transponder in subsequent tests.

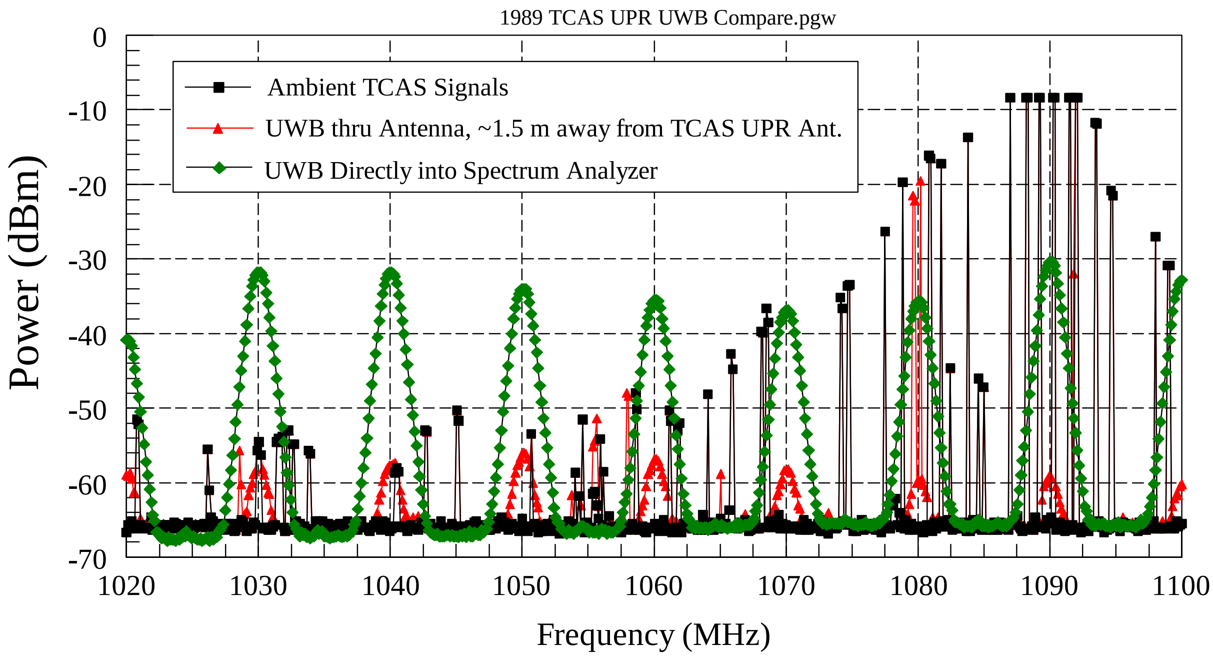

Figure 8: Spectrum analyzer data showing ambient TCAS/ATC signals with UWB source signals. Measured using spectrum analyzer peak detector, with 1 MHz resolution bandwidth.

This test conclusively demonstrated serious air traffic control system failures due to a battery-operated UWB transmitter being operated on-board the aircraft. The output power directly from the source was measured to be -30dBm (as shown in Figure 8). Adding a DRH antenna gain of 10 dB, the UWB source transmitted an equivalent isotropic radiated power (EIRP) of –20dBm. Additional ATC/TCAS testing was performed on 4/12/2002 and 5/8/2002, and is reported in Sections 4.4 and 4.5.

4.4 UWB Testing on 4/12/2002, B747-400

All objectives under NASA/EWI contract L-16099 were complete by noon, 4/12/2002, allowing about two hours for UWB EMI assessment with a fully operational aircraft. The test team was prepared with additional test capabilities compared to the previous visit. An external UWB source power supply and HP 8116A Pulse Function Generator were provided by NASA to externally clock the UWB signal source, and a portable VOR/ILS Ramp Test Set (TIC Tester) was provided by United Airlines to allow transmission of ILS reference signals. A list of test equipment is provided in Table 2. The HP 8116A Pulse Function Generator was set to output 1 microsecond pulses at the desired pulse repetition frequency, and allowed external modulation of the UWB clock pulse by connecting a modulating signal to its "Control-Input" jack. When selecting the "FM" modulation mode, the HP 8116A essentially provided a dithered mode of pulse spacing to the UWB source clock input (by deviating the pulse repetition frequency of the output clock pulses). When selecting the "AM" modulation mode, the HP 8116A essentially provided an On-Off-Keying mode of pulse control to the UWB source clock input (depending upon whether the audio voltage output exceeded the TTL "1" level at the time of pulse generation). A MicroCassette player audio signal was connected to the HP 8116A control-input jack, while playing back a 30-minute segment of voice audio (recorded from the Weather Channel). The Spectrum Analyzer, pulse function generator, TIC Tester and antennas were verified to be within calibration schedule limits. UWB EMI assessment was performed on the ILS Localizer, ILS Glideslope, traffic collision avoidance system (TCAS), air traffic control radio beacon system (ATC), GPS, SATCOM aircraft radio systems as described herein.

Item Description	**Manufacturer**	**Model# and Serial/ID #**
Airplane	Boeing	747-400, UAL Nose #8188 Boeing SN 26877
UWB Signal Source	-	TFP-1000, S/N 101
Spectrum Analyzer	Hewlet Packard	8561E, NIMS# 1257651
Pulse Function Generator	Hewlet Packard	8116A, NIMS# 037346
VOR/ILS Ramp Test Set Cat. III	TIC	T30D
150 Ft Cable	-	RG214 150'#1
3 Ft Cable	Pasternack	3 ft. Low Loss
Antenna, Dual Ridge Horn "DRH" (1-18GHz)	A H Systems	SAS-200/571, SN 164
Antenna, Reference Dipole Set (28-1000MHz)	ETS	3121C, NIMS# 2098522
Antenna, Biconical (30-1000MHz)	Schwarzbeck	UBAA9114/BBVU9135 SN 124
Digital Video Camera	Sony	DCR-TRV900, NIMS# 1613199
MicroCassette Recorder	GE	3-5376A
Aircraft Radio Recievers: VOR/ILS ATC TCAS GPS Sending Unit SATCOM Data Unit SATCOM LNA/Diplexer	 Collins Collins Collins Honeywell Collins Ball Aerospace	 822-0282-120 822-0336-001 622-8971-022 HG2021GC02 622-8848-001 511610-500
Aircraft Radio Antennas: ILS Localizer ILS Glideslope ATC TCAS GPS SATCOM	 Sensor Systems Sensor Systems Dorne&Margolin Collins Adams-Russel Ball Aerospace	 S65-147-7 S41422 DM1601354-001 622-8973-001 ANPC111-2 511611-500

Table 2: Equipment List for 4/12/2002 UWB EMI Testing

4.4.1 ILS Localizer

Test Procedure

The VOR/ILS Ramp Test Set was placed about 20 ft (6 meters) from the nose of the airplane, and the aircraft localizer radio receiver was captured with the 118.10 MHz test set reference signal. The UWB signal source was externally powered and externally clocked with the HP 8116A Pulse Function Generator at 9.99MHz, to place a UWB frequency component at 118.10 MHz, coinciding with the ILS localizer test set channel. The UWB source was connected to a 150 ft length of RG214 coaxial cable, allowing the ETS 3121C dipole antenna (60-140MHz balun, with element length set to 64.6cm) to be placed about 20ft (6 meters) from the aircraft ILS localizer nose antenna (horizontal polarization), next to the VOR/ILS Ramp Test Set. Pictures of the aircraft ILS Localizer antennas and the VOR/ILS Ramp Test Set are shown in Figure 9. Measured output data from the UWB source, when using both FM (dithered) and AM (on-off keying) modulation techniques are plotted in Figure 10.

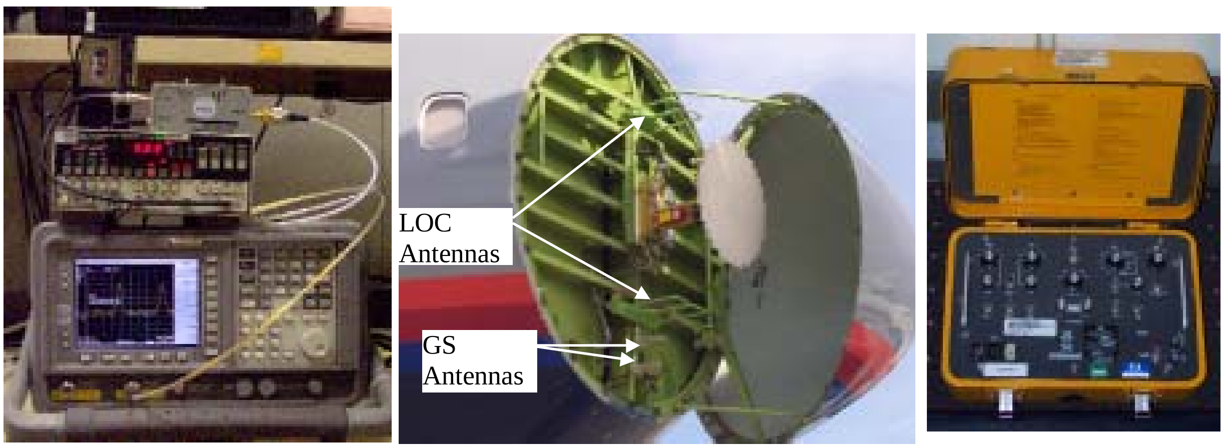

Figure 9: a) UWB source, external clocking instrumentation and spectrum analyzer. b) Nose view of B-747 airplane, with radome open. c) VOR/ILS Ramp Test Set ("TIC" Tester).

Observations

Radiated signals from the UWB transmitter caused uncommanded motion and blanking of the Course Deviation Indicator bar on the aircraft Horizontal Situation Display. Failures occurred only when applying FM to the UWB source clock input (dithered UWB), but not with AM (on-off keying) or no modulation. Because of time limitations, no attempt was made to transmit from the UWB source inside the aircraft, or to determine the minimum UWB transmit level at which the interference would occur. Video was recorded of the cockpit display anomalies due to UWB EMI.

This test conclusively demonstrated serious ILS Localizer navigation failures due to a UWB transmitter being operated near the aircraft. The output power from the source was measured to be -20dBm, as shown in Figure 10. Adding a dipole antenna gain of 3 dB and subtracting the cable loss of 4dB, the UWB source transmitted an equivalent isotropic radiated power (EIRP) of –21dBm. There was no attempt to determine whether –21 dBm was the lowest EIRP at witch the failure would occur. Additional ILS Localizer testing was performed on 5/8/2002, and is reported in Section 4.5.

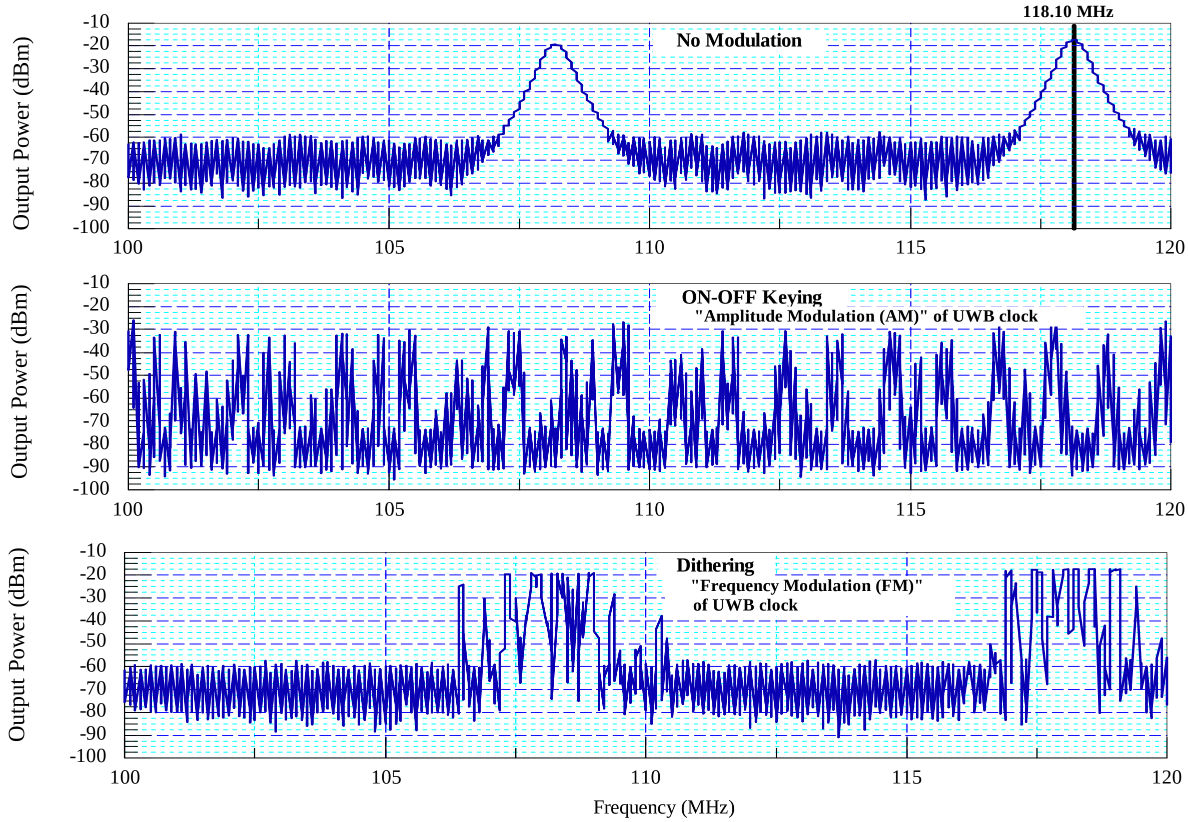

Figure 10: Spectrum analyzer data, comparing UWB frequency spectra in the VOR/LOC band, when applying different modulations to the UWB source clock. The ON-OFF keying (AM) and Dithered (FM) spectra are actually very dynamic, whereas these plots are merely a snapshot in time. Data was measured using the spectrum analyzer peak detector, with a 300 kHz resolution bandwidth.

4.4.2 ILS Glideslope

Test Procedure

The VOR/ILS Ramp Test Set was placed about 20 ft (6 meters) from the nose of the airplane, and the aircraft ILS glideslope radio receiver was captured with the 334.70 MHz test set reference signal. The UWB signal source was externally powered and externally clocked with the HP 8116A Pulse Function Generator at 9.72MHz, to place a peak UWB frequency component at 334.6 MHz, coinciding closely to the ILS glideslope test set channel. The UWB source was connected to a 150 ft length of RG214 coaxial cable, allowing the Schwarzbeck biconical antenna (very efficient in Glideslope frequency band) to be placed about 20ft (6 meters) from the aircraft ILS glideslope nose antenna (horizontal polarization). Pictures of the aircraft ILS glideslope antennas and the VOR/ILS Ramp Test Set are shown in Figure 9.

Observations

Radiated signals from the UWB transmitter appeared to sometimes cause intermittent motion and blanking of the glideslope deviation indicator on the aircraft Horizontal Situation Display. However, it was difficult to correlate the display events with UWB transmission. There was no difference when applying FM (dithered UWB), AM (on-off keying) or no modulation to the UWB source clock input. No attempt was made to transmit from the UWB source inside the aircraft, or to move the UWB transmitter closer to the aircraft ILS glideslope antenna. Additional ILS glideslope testing was performed on 5/8/2002, and is reported in Section 4.5.

4.4.3 ATC and TCAS

Test Procedure

The local ATC interrogator and TCAS transponders on aircraft in the local airspace were acquired by the subject aircraft at the test location. Testing was performed with the UWB signal source either internally clocked (10MHz) or externally clocked at various frequencies, powered either externally or by battery, and connected to the AH Systems dual ridge horn (DRH) antenna. External clock frequencies were selected to place UWB frequency components at 1030 MHz and 1090 MHz and to approximate various pulse spacings and time-slot durations used by the ATC and TCAS receivers. It was planned to first observe interference with the horn antenna placed 1 meter away from the aircraft TCAS upper antenna, and to extend the survey to include locations inside the passenger cabin.

Observations

An "ATC Fail" message was observed on the cockpit display panel, and airplane targets disappeared from the TCAS display when the UWB signal source transmitted out the pilot's escape hatch, about 1 meter away from the top TCAS antenna. The view from the pilot's escape hatch is shown in Figure 11. The failure was reproduced when using different UWB clock frequencies when transmitting out the pilot's escape hatch. However, with the UWB source transmitting from inside the cockpit or out the passenger cabin window, no effect was observed to the aircraft ATC/TCAS systems. Table 3 shows the various test configurations and observations. Video was recorded of the cockpit display anomalies due to UWB EMI.

Figure 11: View through the pilot's escape hatch on top of a Boeing 747-400 airplane.

Location	UWB Clock Freq.	UWB Clock Modulation	Observed effect
Cockpit Hatch	20MHz	None	**ATC Fail, TCAS loss of targets**.
Cockpit Hatch	4MHz	None	No effect.
Cockpit Hatch	8MHz	None	**ATC Fail, TCAS loss of targets**.
Window Upr. Starboard #1	20MHz	None	No effect.
Window Upr. Starboard #1	10.2MHz	None, FM, AM	No effect.
Window Upr. Starboard #1	8MHz	None, FM, AM	No effect.
Window Upr. Starboard #1	4MHz	None, FM, AM	No effect.
Window Upr. Starboard #1	500kHz	None, FM, AM	No effect.
Pilot Seat	20MHz	None, FM, AM	No effect.
Pilot Seat	20MHz	None, FM, AM	No effect.
Cockpit Hatch & Other Locations	10MHz (internal)	None	**ATC Fail, TCAS loss of targets**, only when transmitting outside hatch, nowhere else.

Table 3: Test cases for ATC/TCAS on B747 aircraft

This test conclusively demonstrated serious air traffic control system failures due to a UWB transmitter being operated outside the aircraft. The output power from the source was measured to be -30dBm. Adding a DRH antenna gain of 10 dB, the UWB source transmitted an equivalent isotropic radiated power (EIRP) of –20dBm. Additional ATC/TCAS testing was performed on 5/8/2002, and is reported in Section 4.5.

4.4.4 GPS and Satcom

Test Procedure

Acquired GPS satellite navigation UTC & position and Satcom Link Status "OK" on the aircraft system information display. Testing was performed with the UWB signal source either internally clocked (10MHz) or externally clocked at various frequencies, powered either externally or by battery, and connected to the AH Systems dual ridge horn (DRH) antenna. External clock frequencies were selected to place UWB frequency components at 1575.42 MHz and to approximate the GPS C/A code clock rate. It was planned to first observe interference with the horn antenna placed just outside the pilot's escape hatch, about 3 meters away from the aircraft GPS upper antenna and about 2 meters away from the Satcom low-gain antenna, and to extend the survey to include locations inside the passenger cabin. The GPS antenna and the Satcom low-gain antennas can be seen as the small, flat, white patches and the black blade farthest towards the airplane tail, respectively, in Figure 11.

Observations

No effect was observed with the GPS satellite navigation UTC and position and Satcom Link Status "OK" indication on the aircraft system display UWB source. Table 4 shows the various test configurations and observations. The GPS satellite navigation UTC and position and Satcom Link Status indications do not provide much insight into possible signal interference. Given there were only a few minutes available to perform the assessment due to time limitations, it is not surprising that no interference effects were observed.

Location	UWB Clock Freq.	UWB Clock Modulation	Observed effect
Cockpit Hatch & Window Upr. Starboard #16*	10MHz (internal)	None	No effect.
Cockpit Hatch	16.3MHz	None	No effect.
Cockpit Hatch	1.02MHz	None	No effect.
Cockpit Hatch	20MHz	None, FM, AM	No effect.

Table 4: Test cases for GPS and Satcom on B747 aircraft. *Window Upr. Starboard #16 was the location of least interference path loss between the passenger cabin and GPS antenna.

4.5 UWB Testing on 5/8-9/2002, B737-200

From 5/8/2002 to 5/9/2002, approximately 6 hours was allocated for UWB EMI assessment with a fully operational aircraft. The primary goal was to duplicate the ILS Localizer interference found on the B747-400, and to better quantify the UWB interference thresholds found previously for the ILS, TCAS and ATC aircraft systems. A list of test equipment is provided in Table 5. Again, an external power supply and HP 8116A Pulse Function Generator were provided by NASA to externally clock the UWB signal source, and a portable VOR/ILS Ramp Test Set (TIC Tester) was provided by United Airlines to allow transmission of ILS reference signals. The HP 8116A Pulse Function Generator was set to output 1 microsecond pulses at the desired pulse repetition frequency, and allowed external modulation of the UWB clock pulse by connecting a modulating signal to its “Control-Input” jack. When selecting the “FM” modulation mode, the HP 8116A essentially provided a dithered mode of pulse spacing to the UWB source clock input (by deviating the pulse repetition frequency of the output clock pulses). When selecting the “AM” modulation mode, the HP 8116A essentially provided an On-Off-Keying mode of pulse control to the UWB source clock input (depending upon whether the audio voltage output exceeded the TTL “1” level at the time of pulse generation). A MicroCassette player audio signal was connected to the HP 8116A control-input jack, while playing back a 30-minute segment of voice audio (recorded from the Weather Channel). The Spectrum Analyzer, pulse function generator, TIC Tester and antennas were verified to be within calibration schedule limits. UWB EMI assessment was performed on the ILS Localizer, ILS Glideslope, traffic collision avoidance system (TCAS), and air traffic control radio beacon system (ATC) aircraft radio systems as described herein.

Item Description	**Manufacturer**	**Model# and Serial/ID #**
Airplane (ILS Localizer and Glideslope tests)	Boeing	737-200, UAL Nose #1879 Boeing SN 21544
Airplane (ATC and TCAS tests)	Boeing	737-200, UAL Nose # 1994 Boeing SN 22384
UWB Signal Source	-	TFP-1000, S/N 101
Spectrum Analyzer	Hewlet Packard	8561E, NIMS# 1257651
Pulse Function Generator	Hewlet Packard	8116A, NIMS# 037346
VOR/ILS Ramp Test Set Cat. III	TIC	T30D
50 Ft Cable	-	RG214 50’#1
50 Ft Cable	-	RG214 50’#5
3 Ft Cable	Pasternack	3 ft. Low Loss
Antenna, Dual Ridge Horn "DRH" (1-18GHz)	A H Systems	SAS-200/571, SN 164
Antenna, Reference Dipole Set (28-1000MHz)	ETS	3121C, NIMS# 2098522
Antenna, Biconical (30-1000MHz)	Schwarzbeck	UBAA9114/BBVU9135 SN 124
Digital Video Camera	Sony	DCR-TRV900, NIMS# 1613199
MicroCassette Recorder	GE	3-5376A
Aircraft Radio Recievers: VOR/ILS (Localizer and Glideslope) ATC TCAS	 Collins Collins Collins	 622-3257-008 622-7878-201 622-8971-022
Aircraft Radio Antennas: VOR/ILS Localizer ILS Glideslope ATC TCAS (Upper)	 Dorne&Margolin Sensor Systems Sensor Systems Collins	 DMN23-1/C 522-0700-023 DMNI50-2-1 622-8973-001

Table 5: Equipment List for 5/8-9/2002 UWB EMI Testing

4.5.1 ILS Localizer

Test Procedure

The VOR/ILS Ramp Test Set was operated from the cockpit of the airplane (UAL Nose #1879), and the ILS localizer radio receiver was captured with the 108.15 MHz test set reference signal. The UWB signal source was externally powered and externally clocked with the HP 8116A Pulse Function Generator at 9.97MHz, to place a UWB frequency component at 108.15 MHz, coinciding with the ILS localizer test set channel. The UWB source was connected to two 50 ft lengths of RG214 coaxial cable connected inline, allowing the ETS 3121C dipole antenna (60-140MHz balun, with element length set to 64.6cm) to be placed anywhere within the airplane passenger cabin. A picture of the aircraft ILS Localizer antenna is shown in Figure 12.

Figure 12: a) Aft view of B-737 passenger cabin. b) Tail view of B-737 airplane. The two VOR/ILS Localizer antennas are parallel to one another, and are embedded horizontally within the top edge of the aircraft tail. The corner tip section has been removed in the photograph, to expose the two RF cable connections to the two antennas.

Observations

Two sets of testing were performed. On 5/8/2002, the goal was to repeat the UWB interference situation witnessed on the ILS Localizer during the 4/12/2002 testing. The VOR/ILS Ramp Test Set output attenuation was adjusted such that –4.3 dBm maximum power was delivered to its antenna at 108.15 MHz. The output power from the UWB source was measured to be -20dBm, using the spectrum analyzer (as previously described in Section 4.3.5). Adding a dipole antenna gain of 3 dB and subtracting the cable loss of 4dB (100ft, RG 214 @110 MHz), the UWB source transmitted an equivalent isotropic radiated power (EIRP) of –21dBm. Table 6 shows the various test configurations and observed effects. Test dipole antenna polarization was horizontal in all cases. For test window locations, the dipole antenna was centered in the window, as close to window as possible. In all cases, "LOC Fail" was characterized by erratic motion and retraction of the Course Deviation bar on the HSI, and erratic motion and retraction of the Localizer pointer and extension of the LOC Fail flag on the ADI.

Location	UWB Clock Modulation	Observed effect
6m in front of aircraft nose	FM	**LOC Fail**
Door, Port #2 (aft)	FM	No effect
Window, Port #33 (last one)	FM	**Erratic Course Dev and Loc Pointer motion**
Window, Port #32	FM	**LOC Fail**
Window, Port #32	None	No effect
Window, Port #31	FM	**LOC Fail**
Window, Port #30	FM	**LOC Fail**
Window, Port #29	FM	**LOC Fail**
Window, Port #28	FM	**LOC Fail**
Window, Port #27	FM	**LOC Fail**
Window, Port #26	FM	No effect
Window, Port #25	FM	No effect
Window, Port #24	FM	No effect
Window, Port #23	FM	**LOC Fail**
Window, Port #22	FM	**LOC Fail**
Window, Port #21	FM	**LOC Fail**
Window, Port #20	FM	**LOC Fail**
Window, Port #19	FM	**LOC Fail**
Window, Port #18	FM	**LOC Fail**
Window, Port #17	FM	**LOC Fail**
Window, Port #16	FM	**Erratic Course Dev and Loc Pointer motion**
Window, Port #15	FM	No effect
Window, Port #14	FM	No effect
Window, Port #13	FM	No effect
Window, Port #12	FM	No effect
Window, Port #11	FM	No effect
Window, Port #10	FM	No effect
Window, Port #9	FM	No effect
Window, Port #8	FM	Some LOC Pointer deflection
Window, Port #7	FM	No effect
Window, Port #6	FM	No effect
Window, Port #5	FM	No effect
Window, Port #4	FM	No effect
Window, Port #3	FM	No effect
Window, Port #2	FM	No effect
Window, Port #1	FM	No effect
Window,	FM	No effect

Table 6: Test cases for ILS Localizer on a B737-200 aircraft, with UWB source transmitting at **–21dBm EIRP**

On 5/9/2002, the goal was to quantify the UWB interference thresholds found previously for the ILS Localizer aircraft system. To approximate the FCC UWB limits for Outdoor Handheld Systems (published at http://ftp.fcc.gov/Bureaus/Engineering_Technology/News_Releases/2002/nret0203.ppt, as –41 dBm below 960MHz), a 20 dB attenuator was placed inline at the output of the UWB source. Adding a dipole antenna gain of 3 dB and subtracting the cable loss of 4dB (100ft, RG 215 @110 MHz), the UWB source transmitted an equivalent isotropic radiated power (EIRP) of –41dBm. The VOR/ILS Ramp Test Set output attenuation was adjusted such that -34.5dBm was delivered to its antenna at 108.15 MHz. This was a minimum output power at which the aircraft ILS localizer system provided stable lock for the HSI and ADI Localizer indications. Table 7 shows the various test configurations and observed effects.

Location	UWB Clock Modulation	Observed effect
Window, Port #30	FM	**LOC Fail**
Window, Port #29	FM	**LOC Fail**
Window, Port #28	FM	**LOC Fail**
Window, Port #27	FM	No effect
Window, Port #26	FM	No effect
Window, Port #25	FM	No effect
Window, Port #24	FM	No effect
Window, Port #23	FM	No effect
Window, Port #22	FM	No effect

Table 7: Test cases for ILS Localizer on a B737-200 aircraft, with UWB source transmitting at **–41dBm EIRP**

This test conclusively demonstrated serious ILS Localizer navigation failures due to a UWB transmitter being operated inside the aircraft, transmitting near levels the FCC has approved for marketing and operation of inexpensive handheld UWB devices. A video was recorded of the cockpit display anomalies due to UWB EMI.

4.5.2 ILS Glideslope

Test Procedure

The VOR/ILS Ramp Test Set was operated from the cockpit of the airplane (UAL Nose #1879), and the ILS glideslope radio receiver was captured with the 334.55 MHz test set reference signal. The UWB signal source was externally powered and externally clocked with the HP 8116A Pulse Function Generator at 9.98MHz, to place a UWB frequency component at 334.55 MHz, coinciding with the ILS glideslope test set channel. The VOR/ILS Ramp Test Set output attenuation was adjusted such that –17.2 dBm was delivered to its antenna at 334.55 MHz. The UWB source was connected to a 50 ft length of RG214 coaxial cable, allowing the Schwarzbeck biconical antenna (very efficient in Glideslope frequency band) to be placed near the ILS glideslope nose antenna (horizontal polarization). The output power from the UWB source was measured to be –21 dBm, using the spectrum analyzer (as previously described). Adding a biconical antenna gain of 3 dB and subtracting the cable loss of 2.4 dB (50ft, RG 214 @335 MHz), the UWB source transmitted an equivalent isotropic radiated power (EIRP) of –20.4 dBm. A picture of the aircraft ILS glideslope antenna is shown in Figure 13.

Observations

Radiated signals from the UWB transmitter caused erratic motion and retraction of the GS bar and GS pointer and extension of the GS Fail flag on the HSI and ADI, respectively. There was no difference when applying FM (dithered UWB), AM (on-off keying) or no modulation to the UWB source clock input. These failures were only observed when the UWB source was transmitting from outside the aircraft (in front of the nose), but not when transmitting from within the passenger cabin. A video was recorded of the EMI situation.

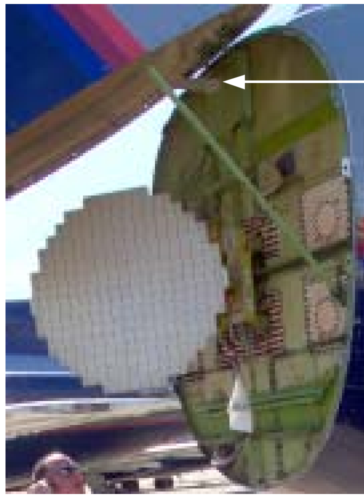

Figure 13: Nose view of B-737 airplane, showing ILS Glideslope antenna.

4.5.3 ATC and TCAS

Test Procedure

The local ATC interrogator and TCAS transponders on aircraft in the local airspace were acquired by the test aircraft (UAL Nose # 1994). The UWB signal source was internally clocked (10MHz), battery powered, and connected to the AH Systems dual ridge horn (DRH) antenna. This test was similar to that performed on 3/22/02, but was supplemented with measurements on the starboard side of the airplane passenger cabin. (The B737-200 aircraft TCAS antenna is installed somewhat toward the port side of the aircraft centerline, thus providing better coupling to the port side passenger cabin windows when compared to the starboard side.) For an additional test, to approximate the threat of a UWB device transmitting at the FCC 15.209 limits, a 20dB attenuator was placed inline at the output of the UWB source.

Observations

The "ATC Fail" indicator lamp on the cockpit display panel illuminated, and airplane targets disappeared from the TCAS display when the UWB signal source was turned ON, transmitting from the first 3 port-side windows, inside the passenger cabin. The interference effects dissipated when adding the 20 dB attenuator inline, on the output of the UWB source. Interference effects were observed on the starboard side only when the UWB source was transmitting out the starboard door, about 1.5m from the aircraft TCAS antenna. Failure conditions are summarized in Table 8. Video was recorded of the cockpit display anomalies due to UWB EMI.

Location	Added Attenuation	Observed effect
Door, Starboard #1 (front)	none	**ATC Fail, Loss of TCAS targets.**
Window, Starboard #1	none	No effect
Window, Starboard #2	none	No effect
Window, Starboard #3	none	No effect
Window, Port #1	none	**ATC Fail, Loss of TCAS targets.**
Window, Port #2	none	**ATC Fail, Loss of TCAS targets.**
Window, Port #3	none	**ATC Fail, Loss of TCAS targets.**
Window, Port #1	20dB	No effect
Window, Port #2	20dB	No effect
Window, Port #3	20dB	No effect

Table 8: Test cases for ATC/TCAS on a B737-200 aircraft.

4.6 Findings Summary

In summary, NASA, United Airlines and EWI have collaboratively revealed that UWB device emissions can interfere with essential flight navigation radios. This work was performed as a voluntary supplement to general PED EMI research on a non-interference basis. Table 9 provides an outline of the findings.

Date of Test	RF system	Aircraft Type	Signal source Config.	Signal Source Level [dBm]	UWB EMI Source Configuration	UWB EIRP Level [dBm]	Failure Description
3/22/02	ATC & TCAS	B737	Local Beacon & Aircraft	?	Internal 10MHz Clock, Xmit from Port Side door #1, windows 1-6, 9	-20	ATC FAIL ON. Loss of TCAS targets
4/12/02	ATC & TCAS	B747	Local Beacon & Aircraft	?	Internal 10MHz Clock, Xmit from Pilot Escape Hatch	-20	ATC FAIL ON. Loss of TCAS targets
4/12/02	LOC	B747	TIC, Monopole, 118.10 MHz, Aircraft Nose	?	External Clock, FM, Xmit from Aircraft Nose	-21	Erratic motion and blanking of CDI on HSI Display
5/8/02	GS	B737	TIC, Monopole, 334.55 MHz, Cockpit	-17.2	External Clock, Xmit from Aircraft Nose	-20.4	Erratic GS Bar & Pointer, GS Fail Flag on ADI, HSI
5/8/02	LOC	B737	TIC, Monopole, 108.15 MHz, Cockpit	-34.5	External Clock, FM, Xmit from Aft. Passenger Cabin	-41	Erratic motion and retraction of CDI on HSI Display
5/9/02	ATC & TCAS	B737	Local Beacon & Aircraft	?	Internal/External Clock, Xmit from Door #1 both sides, windows 1,2,3 Stbd. side	-20	ATC FAIL ON. Loss of TCAS targets

Table 9: Summary of cockpit display anomalies caused by UWB EMI to aircraft navigation radios.

5 Conclusions

It has been conclusively demonstrated that a handheld, low-power UWB transmitter can interfere with aircraft TCAS, ATC, ILS localizer and ILS glideslope radios. Failure was demonstrated to occur on a B737 aircraft ILS localizer system with UWB EIRP levels as low as –41dBm. Measurements were performed on two types of Boeing passenger jets. It is likely that EMI will occur at lower UWB EIRP levels on smaller regional airplanes, because of better electromagnetic coupling to aircraft antennas from their passenger cabins. Testing was very limited, and not likely to reveal the full degree of aircraft system susceptibilities. Several important aircraft systems were not considered at all, including radar altimeters, microwave landing systems, and DME. If the FCC 15.519 limits are modified, or particular devices exceed the limits, it is more likely that UWB EMI to aircraft ATC/TCAS and other systems will occur.

Testing demonstrated that modulation of the UWB signal greatly influenced the susceptibility threshold of the ILS localizer radio. It is likely that the modulation technique used in this test was not worst-case. A more detailed test, with careful attention to modulation parameters would likely induce failures at lower UWB EIRP levels. The VOR and VHF communication systems were not tested for increased susceptibility to modulated UWB, nor were they tested for susceptibility when receiving communication signals close to their receiver sensitivity limits. It is possible that these systems may have susceptibilities that are as yet undiscovered.

The focus of the NASA/United/EWI testing was directed only towards handheld UWB systems. Other legitimate UWB applications, such as imaging systems, ground penetrating radars, surveillance systems, vehicular radars, and various communications and measurement systems may also pose a threat to air traffic control and aircraft navigation and communication systems. More detailed analysis and testing of UWB device impact upon flight-essential aircraft navigation and communication systems, and air traffic control is strongly recommended, particularly before unlicensed devices are widely available. The additional FCC Order of July 12,2002 [7], permitting the continued operation of UWB GPRs and wall imaging systems that do not comply with the FCC Final Rule, indicates that the FCC will likely continue to loosen UWB transmitter restrictions until harmful interference is proven to occur.

6 Recommendations for Additional Aircraft System UWB EMI Assessment

As yet, there is insufficient information to predict how widespread operation of UWB devices may impact the safety of passenger air travel. The goal for subsequent analysis and testing should be to provide data for establishing well-defined, enforceable regulations that avoid unnecessary restrictions of UWB applications, while guaranteeing that UWB products do not jeopardize passenger safety and security when traveling on board airplanes. Such a task is larger in scope than any government agency, product manufacturer, airline or university can effectively complete alone.

A three-element approach is recommended, including ❶analysis and laboratory testing, ❷field-testing on operational aircraft, and ❸development of regulatory policies based upon authoritative technical merit.

The radio signal structure for all aircraft navigation and communication systems should be studied to determine interfering signal modulation characteristics and levels that are required to impact aircraft radio performance. Analysis of UWB device modulation approaches must be performed to identify the most threatening types, and quantify amplitudes required to threaten aircraft radio system performance. Actual commercial UWB products should be tested for emissions in aviation frequency bands, with particular care to use resolution bandwidths narrow enough to resolve aircraft frequency channels. Closed-loop navigation system testing, incorporating actual flight hardware and trained pilots, should be performed to specifically describe symptoms and anomalies that may be caused by interfering UWB signals, so that flight crews can readily determine whether they are experiencing an EMI situation.

Aircraft field-testing is necessary for pre-screening to reveal likely problem areas, and for validation of analytical studies and laboratory test predictions. Once the UWB signal levels required to impact aircraft radio performance are known, the expected IPL between particular passenger-cabin locations and particular aircraft radios (via their antennas) can be evaluated to determine minimum UWB handheld device emissions required for interference. These predictions should be validated during aircraft field-testing. The tests documented in this report fall into the pre-screening category. Additional pre-screening is recommended before completing analytical studies on several aircraft systems, particularly VHF communications, VOR, and ILS Glideslope. Such prescreening should include minimizing desired signal amplitude available to the aircraft antenna, to optimize the potential for UWB signal interference. Prescreening should also include applying various modulations to the UWB source clock.

Results of all analysis and test should be made publicly available for peer review and verification. Airlines, UWB device manufacturers, airborne radio manufacturers, universities and government (FAA, FCC, NASA, NTIA) should interact and cooperate to generate sound technical data and perform comprehensive analysis to develop regulatory policies with the safety and security of the public in mind.

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6. AUTHOR(S)
Jay J. Ely
Timothy W. Shaver
Gerald L. Fuller

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13. ABSTRACT (*Maximum 200 words*)
On February 14, 2002, the FCC adopted a FIRST REPORT AND ORDER, released it on April 22, 2002, and on May 16, 2002 published in the Federal Register a Final Rule, permitting marketing and operation of new products incorporating UWB technology. Wireless product developers are working to rapidly bring this versatile, powerful and expectedly inexpensive technology into numerous consumer wireless devices. Past studies addressing the potential for passenger-carried portable electronic devices (PEDs) to interfere with aircraft electronic systems suggest that UWB transmitters may pose a significant threat to aircraft communication and navigation radio receivers. NASA, United Airlines and Eagles Wings Incorporated have performed preliminary testing that clearly shows the potential for handheld UWB transmitters to cause cockpit failure indications for the air traffic control radio beacon system (ATCRBS), blanking of aircraft on the traffic alert and collision avoidance system (TCAS) displays, and cause erratic motion and failure of instrument landing system (ILS) localizer and glideslope pointers on the pilot horizontal situation and attitude director displays. This report provides details of the preliminary testing and recommends further assessment of aircraft systems for susceptibility to UWB electromagnetic interference.

14. SUBJECT TERMS
Ultrawideband, UWB, EMI, Electromagnetic, Interference, FCC, Aircraft, Avionics

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