Graphical Representation of the Effects of Antenna Locations on Path Loss Data

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Abstract

The use of portable wireless technology has increased dramatically over the past few years. This increased use has caused a heightened concern for electromagnetic interference from wireless-enabled technologies, such as laptop computers and cellular phones to aircraft communication and navigation radios. Researchers at NASA Langley Research Center, United Airlines and Eagles Wings Incorporated, have tested and collected interference path loss data on a United Airlines out-of-service B737 aircraft near Victorville, CA. This paper summarizes the results found from the measured data sets as well as includes graphical representations of the interference path loss data on a B737 plane with different system antennas.

1. Introduction

Although all airlines prohibit the use of portable transmitters on-board airliners, it is not uncommon to see today's passengers with cell phones and wireless-enabled laptop computers while traveling. These portable transmitters are prohibited because of the possibility of electromagnetic interference (EMI) with the communication and navigation radios, via their antennas, placed at different locations on the aircraft fuselage. Interference path loss (IPL) data for four types of Boeing 737-200 aircraft systems are considered in this report, including the Traffic alert and Collision Avoidance System (TCAS) (antenna located on the fuselage top centerline above window #2), the VHF communication system (with the system#1 antenna located directly above the over-wing emergency exit), the Instrument Landing System (ILS) Glideslope (GS) system (antenna located in the nose of the airplane), and the ILS Localizer (LOC) and VHF Omniranging (VOR) systems (antennas located near the tail of the plane). This IPL data was obtained from reports delivered under NASA Contract L-16099.

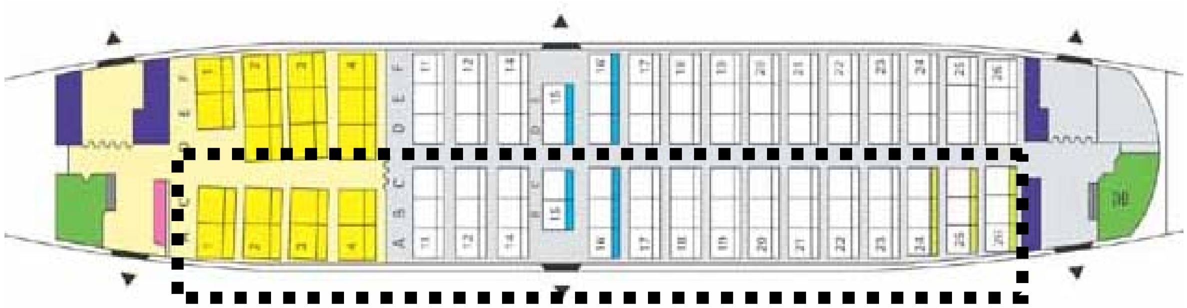
IPL data was taken by radiating a low powered continuous wave (CW) test signal, frequency-synchronized to the spectrum analyzer sweep and fed to the test transmitting antenna via a double shielded RF cable. The spectrum analyzer, laptop computer controller, signal generators, RF amplifiers and preamplifiers were located inside the aircraft. The spectrum analyzer input cable was connected to the aircraft radio receiver rack cable in the avionics equipment bay. To perform an IPL measurement, the team measured the radio frequency (RF) power loss between the calibrated signal source and a spectrum analyzer, via the entire length of test cables plus the aircraft cable, plus the free space loss between the reference antenna and the aircraft antenna.

$$\alpha_{GSE/AC/FS(dB)} = [P_{Xmt}(dBm)-P_{Meas}(dBm)]_{GSE/AC/FS\ System\ Loss}$$

The IPL is the power difference between the CW test source radiated power level and the power level received at the point of entry into the aircraft radio receiver. Two types of data were collected: fixed location data at windows, seats, and aisles, and sweep data along the seams of doors, cockpit windows, hatches, and emergency exits. All data was taken in both horizontal and vertical polarization (Fuller [1]).

2. IPL Data Analysis and Visualization

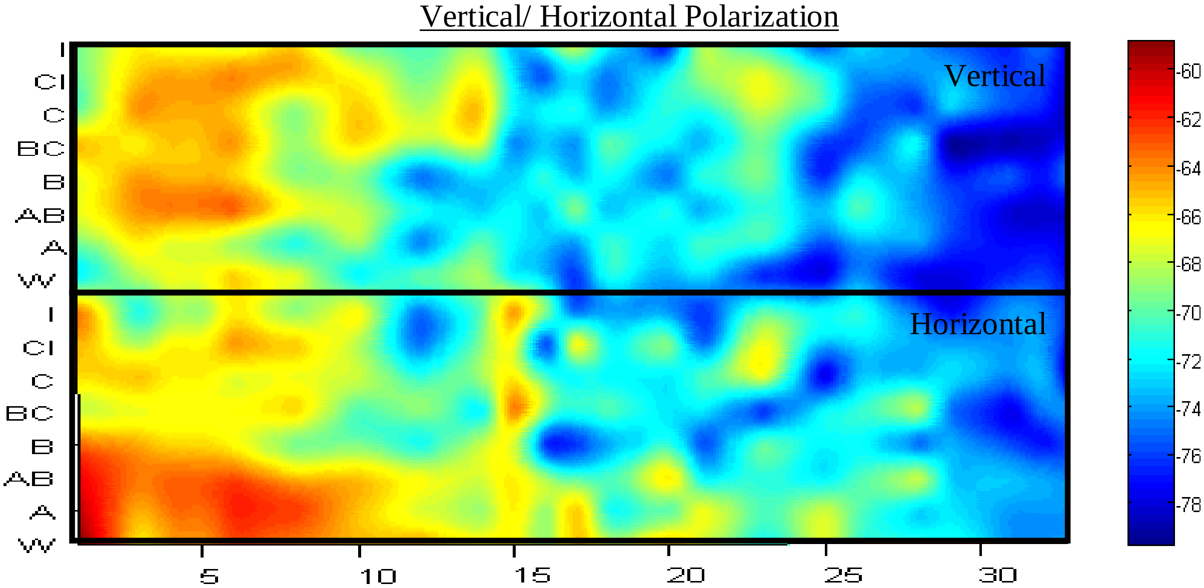
MATLAB was used to graphically represent the hand-taken data. Two assumptions were made during plotting: any missing data was assumed to be an average of surrounding seats and any missing row was an average of the forward and backward rows. These assumptions were made only to make the final representations more readable. Below is a close representation of the B737 tested, the seats measured are boxed in dashed- black:



3. Results

The following graphs were obtained for both horizontal and vertical polarization from the path loss to the top TCAS, nose GS, tail top LOC and VHF-L(1) systems in a United Airlines Nose #1989 B737 airplane. The 3-D models were simulated to show the areas where most path loss was encountered relative to each antenna system. Each graph is accompanied with a color-legend which helps in relating the color on the graph to the dB value of the path loss. The x-axis represents the aircraft window location, and the y-axis represents the aircraft seat designation across each row ("W" for window and "I" for Aisle). In general, the red region represented higher coupling (lower path loss). The dashed line around the graph represents the dashed region in the schematic of B737 above.

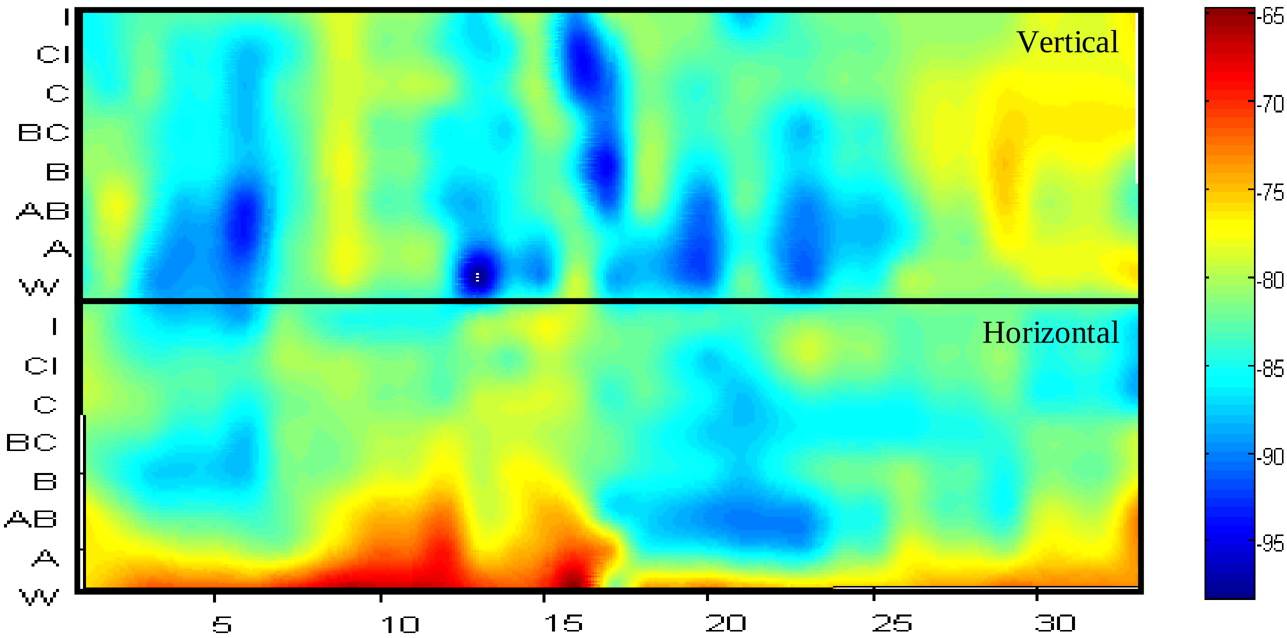
Glide Slope
(Antenna located in the nose of the aircraft)
Vertical/ Horizontal Polarization



LOC

(Antenna located near the tail of the aircraft)

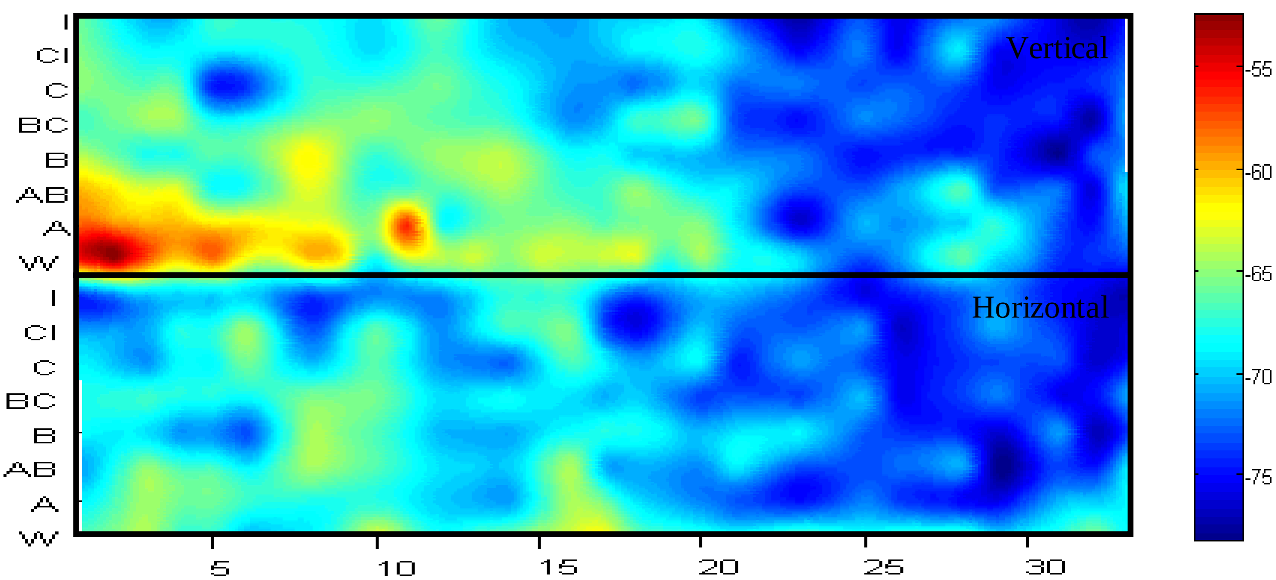
Vertical/ Horizontal Polarization



TCAS

(Antenna located near window 2 above fuselage)

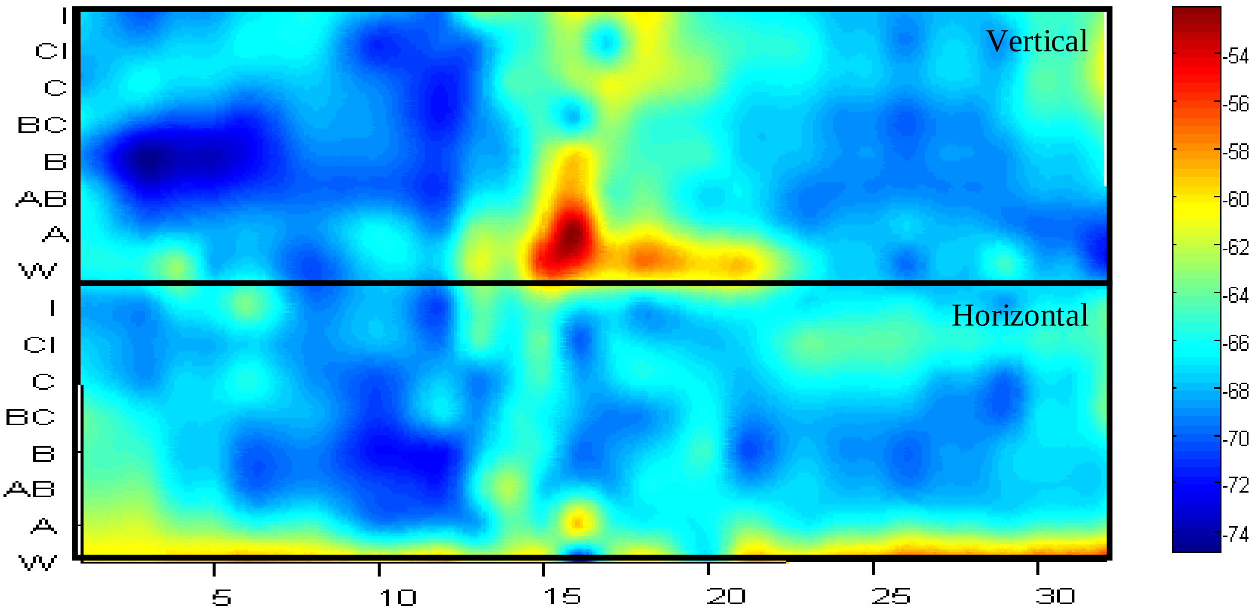
Vertical/ Horizontal Polarization



VHF-1

(Antenna located above exit door near window 16)

Vertical/ Horizontal Polarization



Conclusions

The above graphs represent the path loss data measured on a B737 airplane, United Airlines Nose #1989. The red regions often very accurately indicate the passenger cabin locations nearest the aircraft radio antennas. With this representation, it is also easy to visualize the extent of the path loss between different seat locations. The Localizer data indicates that the best passenger cabin coupling locations are in the front half of the airplane for horizontal polarization. This was not expected.

Reference

[1] Fuller, Gerald. "B737-200 Path Loss Tests: Victorville, California." Mariposa, CA: March 2002, Task 1 report under NASA Contract L-16099