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RF Attenuation Tests Phoenix, Arizona

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Abstract

A field test program was undertaken at Deer Valley Airport in November 2005 to establish the potential radio frequency attenuation achievable using RF shielding material on the windows of an aircraft. The results will assist in the evaluation and mitigation of potential interference between airborne mobile phone networks and co-channel ground based networks.

Revision History

Date	Description	Rev
2005-11-30	First version of the document	PA1
2005-12-1	Revision of doc to include I Walter comments	PA2
2005-12-1	Doc tidy up by J Walsh	PA3
2005-12-3	Doc tidy up by J Walsh	PA4

References

Reference	Description
18/3000-AB	AIRCRAFT ATTENUATION TEST PROGRAM

Contents

Abbreviations

BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CEPT	Committee for European Postal and Telecommunications
CEPT SE 7	CEPT spectrum engineering working group 7
CTIA	Cellular Telecommunications Industry Association
dBm	Decibel relative to 1 milliwatt
EIRP	Effective Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
Eurocae	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Authority
FCC	Federal Communications Commission
ft	feet
GSM	Global System for Communicaitons
kHz	Kilohertz
Km	Kilometre
MHz	Megahertz
NPRM	Notice of Proposal for Rulemaking
PCS	Personal Communications System
RF	Radio Frequency
RTCA	Radio Technical Commission for Aeronautics
TDMA	Time Division Multpile Access
USA	United States of America
W	Watt
WCDMA	Wideband CDMA
3GPP	3rd Generation Partnership Program
3GPP Geran	3GPP Technical Standards working group

1 Executive Summary

A test program was undertaken in Phoenix in November 2005 to examine the effects of shielding the windows of a typical business jet aircraft on the overall attenuation of radio frequency signals to and from the aircraft cabin of a typical business jet. Shielding the windows of an aircraft is one mechanism of mitigating leakage that could potentially interfere with ground based mobile networks.

The testing will assist in determining whether an architecture, that includes shielding the aircraft windows, consisting of an airborne BTS and supported mobiles operating at minimum power, will avoid interfering with ground based mobile systems.

The results of the tests indicate that in the order 20 dB of additional attenuation to that of an unshielded aircraft can be achieved across the frequency range 470 MHz – 2.4 GHz. This frequency range would include most mobile technologies used by ground based networks.

This additional attenuation should be adequate to avoid interference from an airborne GSM system to any ground based CDMA/GSM systems operating in the Cellular (800MHz) or PCS(1900 MHz) bands.

The exact parameters to determine interference are still the subject of investigation in Europe in particular by CEPT SE7 with regard to GSM and UMTS systems. However there appears sufficient margin (approx. 10 dB) to speculate that shielding will suffice in alleviating any concerns regarding the BTS and supported mobiles aboard when operational above 10,000ft.

If an unsupported GSM mobile is switched on or a supported mobile looses contact with the BTS aboard between 10,000ft and 30,000ft then such mobiles can potentially ‘see’ a ground network. However with shielding such mobiles will be unable to access the ground network. Above 30,000 ft an unsupported GSM mobile would be unable to ‘see’ a ground network and would not make an access attempt. Further testing and analysis is required to assess the impact of unsupported GSM mobiles below 10,000ft.

Further investigation is required for CDMA mobiles which are not currently supported by the Honeywell architecture. It should be noted that CDMA mobiles have higher minimum receiver sensitivity than GSM mobiles and thus could potentially ‘see’ ground networks at higher altitudes. Further analysis is required to determine at what altitude a ground based CDMA network could be accessed by CDMA mobiles with the aircraft windows shielded.

In conclusion, shielding the windows of an aircraft offers a technically suitable solution to address concerns regarding potential interference to ground based CDMA and GSM networks from an airborne GSM network operating at minimum power levels above 10,000ft. Further testing and analysis is required to assess the impact of shielding on minimizing the potential interference from unsupported mobiles.

2 Introduction

This document outlines the tests performed and results obtained in a test program undertaken by Honeywell and Altobridge in Phoenix in November 2005. The primary objective of the program was to establish the radio frequency attenuation achievable by shielding the windows of a typical business jet aircraft. Shielding the windows of an aircraft is one method of reducing the potential co-channel interference to ground based mobile phone networks from supported and unsupported mobile phones as well as base stations (BTS) located aboard an aircraft. Supported mobiles are those communicating with the BTS aboard the aircraft whereas unsupported mobiles are those aboard an aircraft but not capable or authorized to communicate with the BTS aboard.

2.1 Background

A number of regulatory bodies and industry organizations are examining the use of mobile phone technologies aboard aircraft at present from inter alia, a technical perspective. These include the FCC, FAA, RTCA and CTIA in the USA as well as CEPT, ETSI and EUROCAE in Europe.

To date much of the effort has concentrated on potential interference to aeronautical communications and navigation systems from transmitting portable electronic devices carried aboard by passengers. This effort has resulted in the publication of two documents namely RTCA DO-294 and Eurocae ED-118 that outline a process for the evaluation of potential interference from such devices. Work is continuing within these bodies on streamlining the evaluation process.

In addition the FCC are evaluating the responses to a Notice of Proposed Rulemaking, NPRM (FCC 04-288) on the possibility of lifting the current ban on the use of 800 MHz for airborne services and introducing additional rules to regulate airborne use of other mobile bands.

In parallel CEPT working group SE7 are undertaking studies on the issue of compatibility of airborne GSM networks with ground based GSM and WCDMA networks. This effort is supported by other bodies such as ETSI and the 3GPP Geran working group. Among industry bodies who have undertaken field tests and are continuing their programs in providing measurement data are Qualcomm, Onair, Ericsson and Aeromobile.

2.1.1 Interference Scenarios

The potential interference scenarios from an airborne network to the ground network are:

1. Supported mobile phones interfering with the signal received at a ground based BTS from ground based mobile phones
2. Unsupported mobiles interfering with the signals received at a ground based BTS from ground based mobile phones
3. A BTS aboard interfering with the signal received from a ground based BTS at ground based mobiles.

The potential interference scenarios from a ground network to an airborne network are:

1. Mobile phones transmitting to a ground based BTS interfering with the signal received at an airborne BTS from a supported mobile
2. A ground based BTS transmitting to ground based mobile phones interfering with the signal received by a supported mobile aboard an aircraft.

The document is not intended to provide a detailed analysis of these scenarios. This is the subject of studies being undertaken by CEPT WG SE7 at present. However it is reasonable to deduce from the studies to date that the scenarios that present most difficulty from a mitigation perspective are where an airborne mobile is located close to an aircraft window.

2.1.2 Mitigation Mechanisms

In order to minimize potential interference between co-channel airborne and ground networks a number of mechanisms can be employed to vary the parameters that would determine the presence of interference. The two basic parameters that can be varied are the power levels of the potential interference sources and the path loss between the potential interference sources and the potentially interfered with network.

Power levels that can be radiated by the supported mobile phones and BTS aboard the aircraft can be controlled down to 0 dBm for GSM. Therefore supported mobiles offer up to 30 dB additional isolation in comparison to unsupported mobiles when it comes to potential inference. Of course this is only the case if adequate coverage is provided aboard the aircraft. Otherwise a supported mobile would initiate a scan and behave similar to an unsupported mobile phone.

The architecture advocated by some proponents of pico-cell technology involves the use of a unit that essentially generates controlled noise aboard an aircraft. By introducing enough noise in the frequency bands potentially used by unsupported mobile phones, an inadequate signal to noise ratio exists for the unsupported mobile to instigate communication with a ground based BTS. Thus no interference would ensue to ground networks.

An alternative is to shield the windows of an aircraft with some rf shielding material. This would have the effect of increasing the path loss between the ground network and supported mobiles, unsupported mobiles and the BTS aboard the aircraft. If adequate shielding can be achieved then no interference would ensue to the ground network.

Previous tests on the attenuation of radio frequency signals by an aircraft fuselage have the yielded a variety of results and the aircraft attenuation factor is the subject of much debate within the fora previously mentioned. However one conclusion that can be drawn is that most of the leakage from an aircraft is via the windows. No published results appear to exist on the effect on aircraft attenuation if adequate shielding of the windows was employed. For this reason Honeywell and Altobridge have undertaken the test program contained herein.

3 Test Program

3.1 Objective

The objective of the test program was to determine the amount of additional isolation than can be achieved across various mobile technology frequency bands in an aircraft by adequately shielding the windows of the aircraft.

In order to achieve the objective it was decided to carry out a practical field test program using a typical business jet aircraft and readily available shielding material. While the shielding material used may not prove suitable for use in an aeronautical environment it would provide insight into determining the characteristics of a suitable screening material if this mitigation method were to be further pursued.

3.2 Aircraft

The aircraft used for the test program was a Cessna Citation Sovereign. The aircraft is shown in Figure 1. The cabin is shown in Figure 2. Relevant dimensions for the testing program are given in Table 1. A representative template of the aircraft used for displaying the results in the analysis and indicating the position of the transmitting antenna for the tests is shown in Figure 3.

Figure 1. Cessna Citation Sovereign

Figure 2. Cabin of Cessna Citation Sovereign

Wingspan	19.24m
Overall height	6.2m
Overall length	19.37m
Cabin height	1.73m
Cabin width	1.70m
Cabin length	9.07m
Window height above ground	2.0m (approx.)

Table 1. Dimensions of aircraft

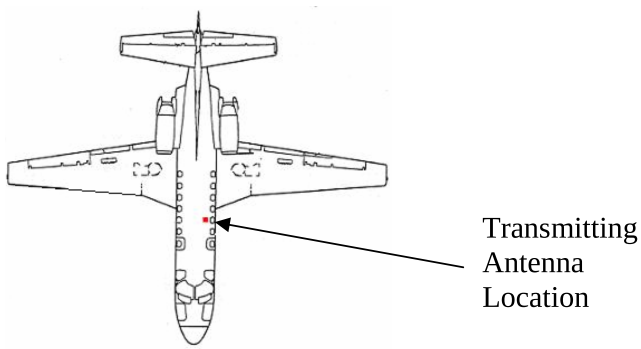


Figure 3. Aircraft template and Transmitter Location within aircraft

3.3 Shielding

The material used to shield the aircraft was a standard off the shelf material known as ‘Phantom fabric’. The material is specified to give 45dB attenuation up to 1 GHz. This was considered adequate to allow determination of the aircraft fuselage attenuation limit provided the windows were adequately shielded. Preliminary examination of the material showed an adequate response at higher frequencies as shown in Figure 4. For the test program involving the shielding of the aircraft, the shielding material was fixed to every window on both sides of the cabin as shown in Figure 5. Further information is contained in Appendix A.

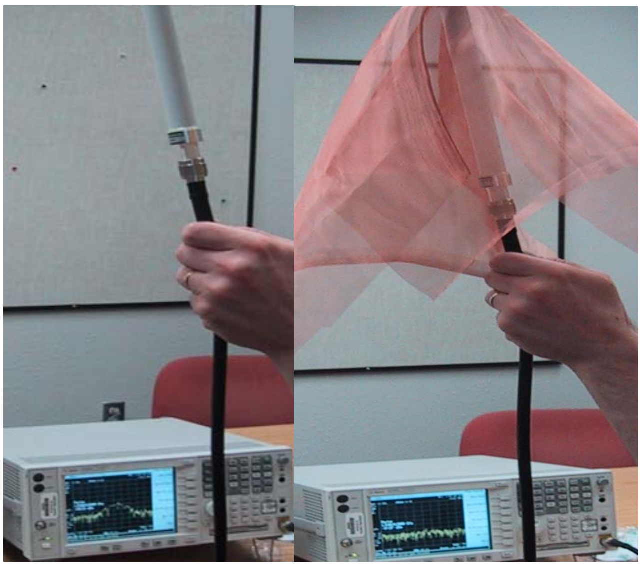


Figure 4. Preliminary examination of shielding material

Figure 5. Shielding material fixed to aircraft

3.4 Frequency Bands

The mobile technologies considered by the FCC NPRM include Part 22 Cellular Services operating in the 800MHz band, Part 24 Personnel Communications Services operating in the 1900 MHz, Part 90 Specialised Mobile Radio Services operating from 2 MHz to 2.1 GHz band and Part 27 Wireless Communications Services ranging in frequency from 700 MHz to 2.3 GHz.

In order to establish a representation of the potential attenuation achievable across the bands under consideration, the test program was confined to four frequency bands, the 470 MHz mobile band, the ISM 900 MHz and 2.4 GHz bands and the PCS 1900 MHz band.

3.5 Test Methodology

The proposed test program for this phase of testing is contained in Doc 18/3000-AB ‘Aircraft Attenuation Test Program’. Due to time and aircraft availability the proposed testing was not fully completed. However enough data was ascertained to enable some general conclusions on the use of shielding to be made. The number, type and method of measurements recorded were determined by the equipment used and time available.

The baseline measurements referred to below were carried out in a relatively clutter free environment. The remaining tests were carried out close to the aircraft hanger. This increased the potential for error due to reflections from the hanger building and other nearby buildings. However the data obtained close to the hanger correlated sufficiently well with the baseline measurements to justify the conclusions made herein.

The baseline tests that established the path loss between the signal source and measurement points for the test frequencies without an aircraft present resulted in measurement values approximately 10 dB lower than equivalent free space path loss values.

The transmitter antenna was set up at the worst-case location from a leakage perspective for the aircraft tests. This is considered as the window as shown in Figure 6. A signal generator was used to generate a continuous wave at a specified frequency and power level. Power measurements were made at a specified distance from the transmitter around the aircraft as shown in Figure 7. The measurements were made using a spectrum analyser. A typical spectrum plot presented by the analyser is shown in Figure 8. The analyser parameters remained constant for each measurement and for each frequency.

Figure 6. Transmitter location

Figure 7. Measurement location

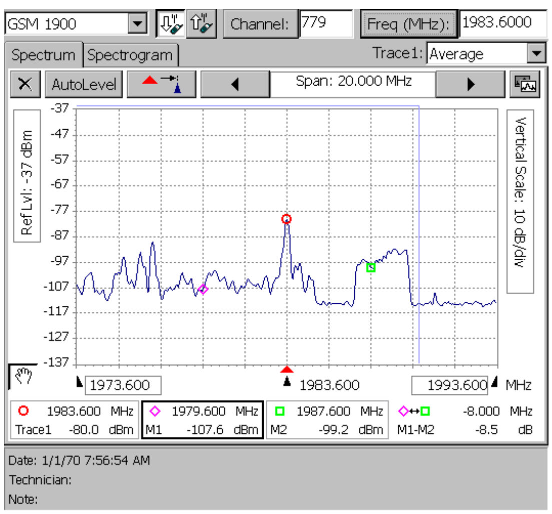


Figure 8. Typical spectrum plot

3.5.1 Egress testing

An on-board signal generator was fitted within the aircraft. This equipment was used as the transmit signal source for the 415MHz, 915MHz & 2.4GHz test frequencies. The test program recorded a set of received signal data sets recorded using the spectrum analyser to establish the power levels of the 415MHz, 915MHz & 2.4GHz signals “leaking” from the aircraft.

Each data set detailed the received signal level powers, as recorded on the spectrum analyser, at fixed radii locations around the aircraft. The measurements were made at a distance of 45 ft from the transmitting antenna.

Signal measurements were recorded with and without the window shielding material.

3.5.2 Ingress testing

For the PCS 1900MHz tests, the spectrum analyser was located within the aircraft. This equipment was used to record a set of received signal data sets from an existing commercial cellular Base Station Site penetrating into the aircraft.

Each data set detailed the received signal level powers, as recorded on the spectrum analyser, at locations inside and outside the cabin near each window.

Signal measurements were recorded with and without the window shielding material.

Figure 9. Typical outside PCS antenna location for ingress tests

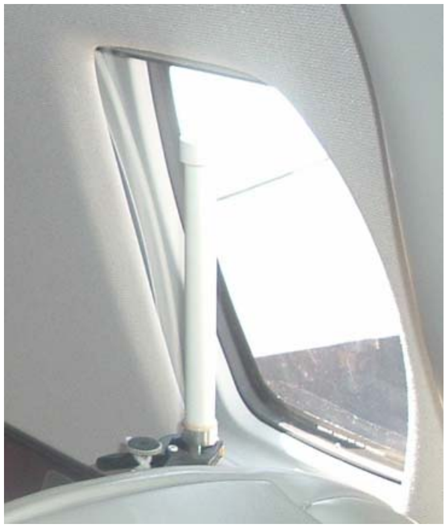


Figure 10. Typical inside PCS antenna location for ingress testing

3.6 Baseline Measurements

A series of baseline measurements were carried out prior to the main test program. A set of measurements was carried out at 450MHz, 915MHz, and 2.4GHz in the absence of aircraft. These levels were used to give an indication of the expected path loss between the transmitter and the receiver. The measurements were repeated with the aircraft present. These measurements were carried out in an area of the airport as free from clutter such as buildings, hangers, etc as possible.

The signal generator was set to the test frequencies of each of the associated bands. An external antenna was connected and mounted at a height of 2m above ground level. The spectrum analyser was set to receive the test frequencies of each of the associated bands. An external antenna was connected and mounted at an approximate height of 2m above ground level. The test configuration is detailed in Figure 11 and Figure 12.

Received signal levels were recorded for each of the frequency bands at a distance of 60 ft. along 30^0 radials from the signal source.

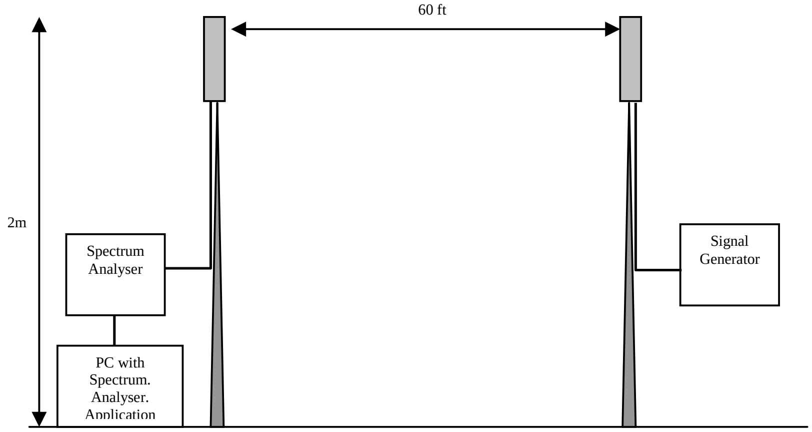


Figure 11. Baseline measurement test configuration

Figure 12. Transmitter and Receiver set-up for baseline tests

3.7 Test Sequence

Tests for the unshielded aircraft were carried out first. These were followed by the same tests for the shielded aircraft.

The full sequence of tests is given in Table 1.

Test Number	Frequency MHz	Measurement Location	Shielded
1	467	At 45ft distance along 5^o radials	No
2	915	At 45ft distance along 5^o radials	No
3	2435	At 45ft distance along 5^o radials	No
4	1938	Outside at each window	No
5	1938	Inside at each window	No
6	467	At 45ft distance along 5^o radials	Yes
7	915	At 45ft distance along 5^o radials	Yes
8	2435	At 45ft distance along 5^o radials	Yes
9	1938	At 45ft distance along 5^o radials	Yes

Table 2. Test Sequence

3.8 Transmit Power Levels

The signal generator rf power output was set to -20 dBm for all frequency bands for the baseline tests and unshielded aircraft tests. The antenna gains associated with each test were 0dB for the 470 MHz band (estimated as the antenna was operating out of band), 3dBi for the 915 MHz band and 7/8 dBi for the 2.4 GHz band. For the aircraft shielded tests, the transmitter power was increased to -10 dBm. Each antenna is specified as having an omni-directional gain pattern in the horizontal plane a fact that was verified in the baseline testing.

3.9 Equipment

The signal generator used for the tests was an Agilent A4438B. The spectrum analyser used for the baseline tests was an Agilent E4440. The spectrum analyser used for the main testing was a Tektronix NetTek Analyser YBT250.

Further details are given in Appendix B. The relevant antenna details are given in section 3.8.

4 Results and Analysis

A general analysis of the measurements is given herein.

4.1 Baseline tests

The results of the baseline testing, for the various test frequencies, are presented is this section. The results also form reference values used in the analysis of the main sets of measurements made as part of the program.

The aircraft runs along the 270^o – 90^o radial. The nose is at 90^o. The transmitter on the aircraft is at the middle of the plot.

4.1.1 470 MHz

The results of the 470 MHz baseline tests are shown in figure 13. The inside plot represents recorded measurements around the transmitter source with no aircraft present while the outside plot represents ‘leaked’ signal from an unshielded aircraft[1]. There was effectively 0 dB attenuation measured for the test transmitter located at the window with the receiver located along the 0^o radial. This confirms the worst case location for leakage. There was noticeable attenuation at the front, back and far side of the aircraft.

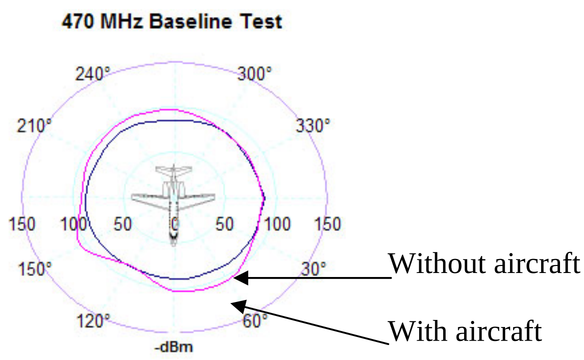


Figure 13. 470 MHz Baseline measurements

The mean measured value at 60 ft was -88 dBm. This is 14 dB below an equivalent free space loss based value of -74 dBm. The average attenuation with the transmitting antenna located at the window was measured as 7 dB with a standard deviation of 7 dB. The sample set is small consisting of 12 recorded readings and the results are considered indicative only.

4.1.2 900 MHz

The results of the 900 MHz baseline tests are shown in figure 14. There was effectively 0 dB attenuation measured for the test transmitter located at the window with the receiver located along the 0^o radial. This confirms the worst case location for leakage. There was noticeable attenuation at the front, back

[1] The x axis represents negative values of the recorded measurements

and far side of the aircraft.

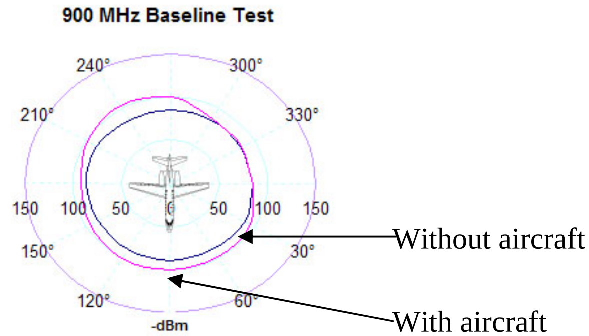


Figure 14. 900 MHz Baseline measurements

The mean measured value at 60 ft was -87 dBm. This is 9 dB below an equivalent free space loss value of -78 dBm. The average attenuation with the transmitting antenna located at the window was measured as 8 dB with a standard deviation of 6 dB. The sample set is small consisting of 12 recorded readings and the results are considered indicative only.

4.1.3 2435 MHz

The results of the 2435 MHz baseline tests are shown below. Some attenuation (in the order of 3-5 dB) was measured for the test transmitter located at the window at this frequency with the receiver located along the 0^o degree radial. This confirms the worst case location for leakage. There was noticeable attenuation at the front, back and far side of the aircraft.

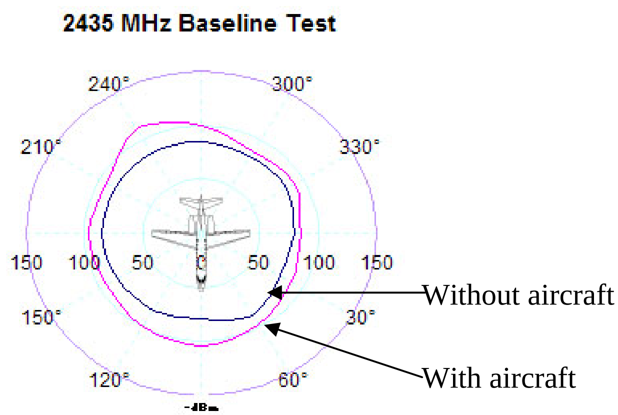


Figure 15. 2435 MHz Baseline measurements

The mean measured value at 60 ft was -86 dBm. This was 8 dB below an equivalent free space loss based value of -78 dBm. The average attenuation with the transmitting antenna located at the window was measured as 7 dB with a standard deviation of 7 dB. The sample set is small consisting of 12 recorded readings and the results are considered indicative only.

4.2 Aircraft Attenuation

The plots contained in this section represent the amount of additional attenuation in comparison to the worst case (assumed 0 dB for all frequency bands) location (window) for leakage from the aircraft. It should be noted that the higher the attenuation the less will be the leakage.

4.2.1 470 MHz Band

The results of the relative attenuation achieved through shielding the aircraft windows for the 470 MHz band are shown at Figure 16.

The aircraft runs along the 270^{o} – 90^{o} radial. The nose is at 90^{o}. The transmitter on the aircraft is at the middle of the plot.

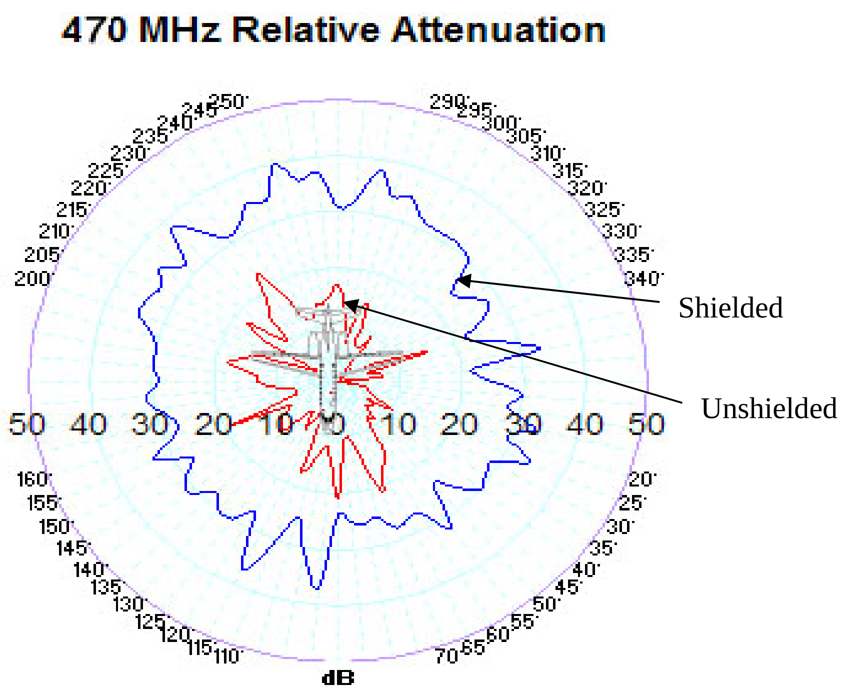


Figure 16. Relative attenuation Shielded Vs Unshielded 470 MHz

The mean attenuation around the aircraft was measured as 10.5 dB for the transmitter location chosen for the unshielded aircraft. The standard deviation was 5 dB. The mean attenuation around the aircraft was measured as 30 dB for the transmitter location chosen for the shielded aircraft. The standard deviation was 4 dB.

This represents an order of 20 dB additional attenuation achievable by shielding the windows of the aircraft at 470 MHz.

This is a conservative value as it includes the attenuation more due to the aircraft fuselage as opposed to the unshielded windows as evidenced by the measurements taken along some radials, for example those along 225^{o} to 240 ^{o}. If the 90^{o} arc 315 ^{o} to 45 ^{o} about the worst case leakage from the transmitter location chosen is considered then the additional attenuation offered by shielding is 22 dB.

4.2.2 900 MHz Band

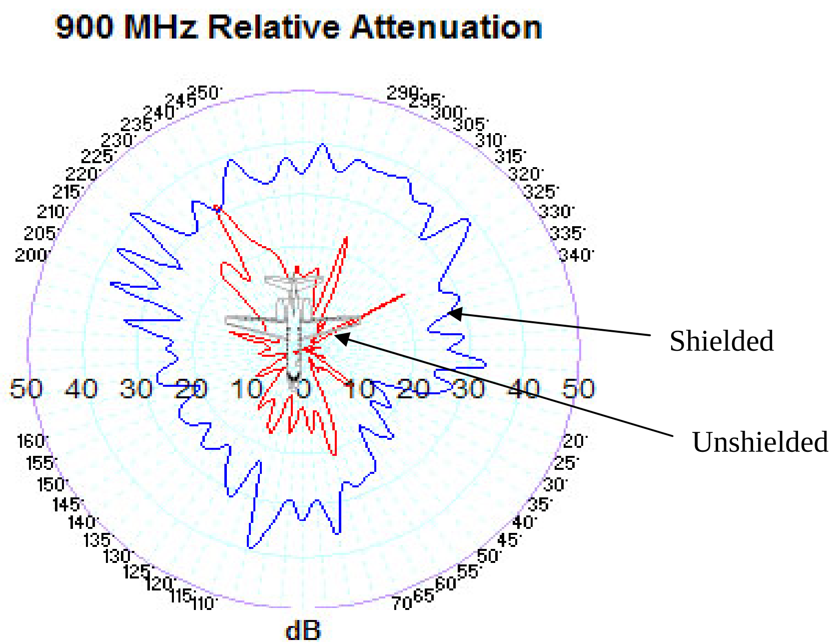


Figure 17. Relative attenuation Shielded Vs Unshielded 470 MHz

The mean attenuation around the aircraft was measured as 8.5 dB for the transmitter location chosen for the unshielded aircraft. The standard deviation was 7 dB. The mean attenuation around the aircraft was measured as 28 dB for the transmitter location chosen for the shielded aircraft. The standard deviation was 6 dB.

This represents an order of 20 dB additional attenuation achievable by shielding the windows of the aircraft at 900 MHz.

This is a conservative value as it includes the attenuation more due to the aircraft fuselage as opposed to the unshielded windows as evidenced by the measurements taken along some radials, for example those along 225^{o} to 250 ^{o}. If the 90^{o} arc 315 ^{o} to 45 ^{o} about the worst case leakage from the transmitter location chosen is considered then the additional attenuation offered by shielding is 22 dB.

4.2.3 1900 MHz Band

The window positions denoted 1 to 7 correspond to the windows of the aircraft from front to back on the door side. The window positions denoted 0,1' to 7' correspond to the windows of the aircraft at the far side of the aircraft from front to back. The measurements taken above the wings (5-7 and 5' to 7') appear weak in comparison to the corresponding signal levels measured inside the aircraft. This could be due to reflections off the aircraft wing. Therefore the measurements were analysed both including and excluding these locations.

		Unshielded	Shielded
Window Position	**Outside(dBm)**	**Inside(dBm)**	**Inside(dBm)**
1	-76	-88	-102
2	-79	-78	-103
3	-75	-76	-108
4	-77	-77	-105
5	-85	-74	-108
6	-84	-78	-104
7	-84	-80	-104
0	-77	-83	-100
1'	-76	-80	-102
2'	-80	-77	-98
3'	-84	-78	-103
4'	-76	-76	-102
5'	-81	-74	-104
6'	-79	-80	-104
7'	-84	-77	-105

Table 3. Results of Ingress Tests at 1900 MHz

The mean attenuation for the locations chosen including the wing measurements was -1.4 dB for the unshielded aircraft. The mean attenuation for the shielded aircraft was 24 dB. This represents an order of 25 dB of additional attenuation achievable by shielding the aircraft at 1900MHz.

The mean attenuation for the locations chosen excluding the wing measurements was 1.4 dB for the unshielded aircraft. The mean attenuation for the shielded aircraft was 23 dB. This represents an order of 22 dB of additional attenuation achievable by shielding the aircraft at 1900MHz.

4.2.4 2.4 GHz Band

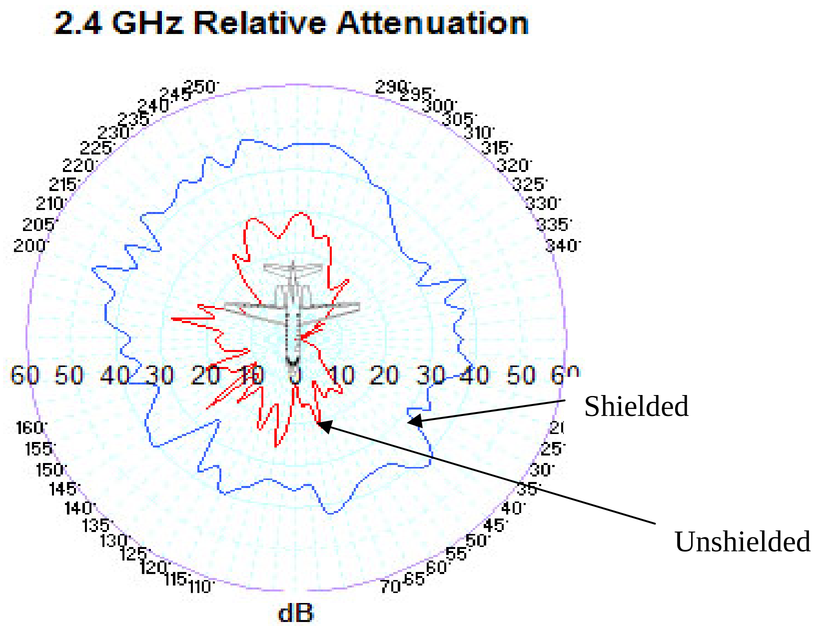


Figure 18. Relative attenuation Shielded Vs Unshielded 2435 MHz

The mean attenuation around the aircraft was measured as 15 dB for the transmitter location chosen for the unshielded aircraft. The standard deviation was 8 dB. The mean attenuation around the aircraft was measured as 38 dB for the transmitter location chosen for the shielded aircraft. The standard deviation was 6 dB.

This represents an order of 23 dB additional attenuation achievable by shielding the windows of the aircraft at 2435 MHz.

This is a conservative value as it includes the attenuation more due to the aircraft fuselage as opposed to the unshielded windows as evidenced by the measurements taken along some radials, for example those along 225^{o} to 250 ^{o}. If the 90^{o} arc 315 ^{o} to 45 ^{o} about the worst case leakage from the transmitter location chosen is considered then the additional attenuation offered by shielding is 30 dB.

5 Conclusions

5.1 Baseline tests

There is effectively 0 dBs of attenuation in the frequency bands 470 MHz, 900 MHz and 1900 MHz bands with the transmitter located at the aircraft window.

There is some attenuation (in the order of 3-5 dB) at the 2.4 MHz band with the transmitter placed at the aircraft window.

5.2 Shielded/Unshielded tests

Shielding the aircraft gives an average additional attenuation of 20 dB approx. for the worst-case leakage (window) at 470 MHz.

Shielding the aircraft gives an average additional attenuation of 20 dB approx. for the worst-case leakage (window) at 900 MHz.

Shielding the aircraft gives an additional attenuation of 22 dB approx. for the worst-case leakage (window) at 1900 MHz.

Shielding the aircraft gives an average additional attenuation of 23 dB approx. for the worst-case leakage (window) at 2435 MHz.

5.3 Shielding Material

The shielding material is specified to give 45 dB approx. of attenuation up to 1 GHz. The results obtained when the shielding material was fixed to the aircraft indicate that the aircraft fuselage becomes the limiting factor for leakage from the aircraft.

5.4 Overall Conclusion

Shielding the windows of an aircraft potentially offers an additional isolation factor of at least 20 dB when considering interference from an airborne mobiles operating in the 470MHz, 900 MHz, 1900MHz and 2.4 GHz to ground based networks.

An architecture comprising of a PCS band GSM BTS aboard an aircraft operating at minimum power controlling supported mobiles also operating a minimum power in an aircraft flying above 10,000 ft with the windows shielded would appear to offer a negligible threat of interference to ground based CDMA or GSM networks. Potential interference to ground networks from unsupported mobiles which exists even in the absence of an on board network would be substantially decreased with window shielding.

The following is included for illustrative purposes only to support the above conclusion.

In a link budget analysis presented by Qualcomm at the 9th plenary of RTCA 202 January 05, the maximum allowable eirp from a single GSM (1900 MHz) mobile unit operating on an aircraft at 3,000m was determined as -6.3 dBm so as not to desensitize a ground based CDMA BTS by more than 1 dB. This was based on an aircraft attenuation factor of 0 dB. By including an additional aircraft attenuation factor of 20 dB achievable through shielding the windows, the effect of a GSM mobile operating at 0 dBm (under the control of an on board BTS) on a ground based CDMA network would become negligible. Seven mobiles operating simultaneously will have no increased impact due to the TDMA nature of GSM.

In a link budget analysis taken from a draft of a report being prepared by CEPT SE7 (to be completed by February 06) a screening margin of 13.34 dB is required to prevent a successful access from a GSM mobile operating at maximum power at an altitude of 10,000 ft to a ground based network. This figure is based on an aircraft attenuation factor of 5 dB. The margin represents the difference between the minimum sensitivity of the ground based GSM BTS and the signal received from a mobile operating at full power aboard an aircraft. Extrapolating these values would appear to suggest that any mobile operating at 0 dBm at an altitude of 10,000 ft would have a negligible impact on a ground based GSM network. Shielding the aircraft would serve to add an additional safety margin of at least 20 dB.

The problem then becomes one of potential interference from unsupported mobiles potentially radiating at maximum power levels.

Again taking a link budget analysis from a draft of a report being prepared by CEPT SE7 (to be completed by February 06), a screening margin of 20.54 dB (based on GSM standard values at 900 MHz) is required in order to prevent a successful access attempt to a ground based GSM network from a GSM mobile aboard an aircraft at 10,000 ft. The equivalent margin for the 1800 MHz band is given as 9.34 dB. This would appear to suggest that unsupported GSM mobiles if switched on above 10,000 ft would be unable to access a ground based GSM BTS provided the windows of the aircraft were shielded.

6 Recommendations

The proposed architecture involving a BTS operating at minimum power and supported mobiles also operating at minimum power with the windows of the aircraft shielded to minimize leakage from the aircraft appears to alleviate any concerns regarding co-channel interference from such a network to ground based networks. The proposed architecture should continue to be examined.

Additional testing and analysis is required to further assess the impact of unsupported mobiles, both CDMA and GSM.

Further screening tests with an aircraft suitable screening material should be undertaken. The original proposed program was not completed due to equipment, time and aircraft availability. Cooperation of aircraft manufacturer should be considered to advance the screening proposal. Other aircraft types should be examined.

Flight testing should be undertaken in cooperation with ground network operators to obtain further data on the path loss from an airborne shielded aircraft as well the impact such a network would have on a ground network.

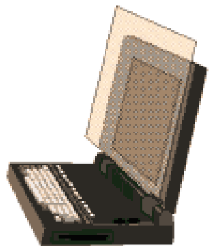
An analysis on any increases in electric field strengths and their impact inside the cabin due to screening the windows should be undertaken.

An application to the FCC for an experimental licence to continue tests using the proposed architecture should be considered.

Appendix A

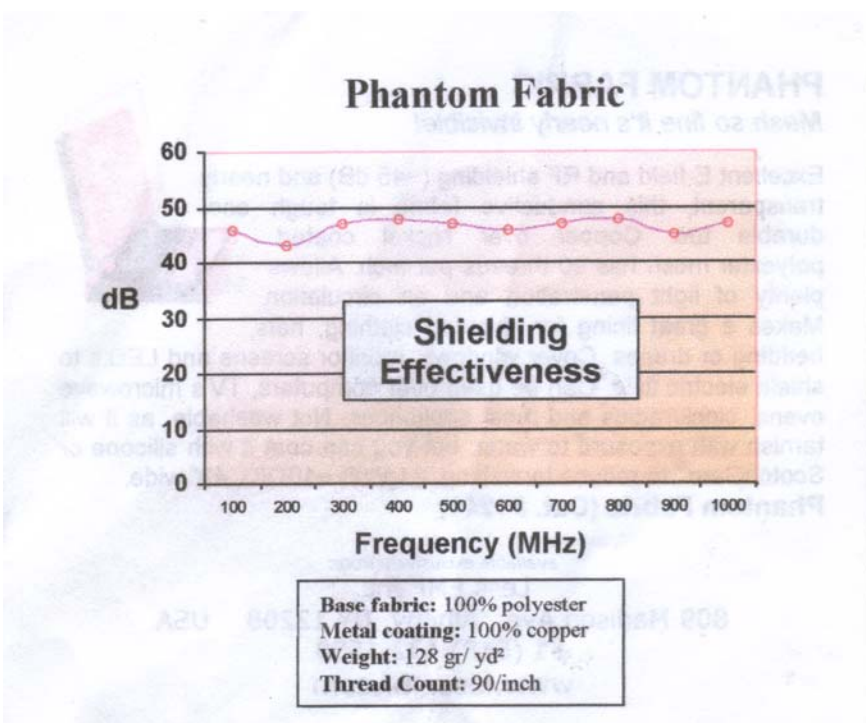
Shielding Material

PHANTOM FABRIC



"Mesh so fine it's nearly invisible!"

Excellent E-field and RF shielding (~45 dB) and nearly transparent, this conductive fabric is tough and durable too. Copper over Nickel coated polyester mesh has 90 threads per inch. Allows plenty of light penetration and air circulation. Makes a great lining for shielded clothing, hats, bedding or drapes. Cover windows, monitor screens and LED's to shield electric field. Can be used over computers, TV's microwave ovens, clock/radios and most appliances. Not washable, as it will tarnish with exposure to water, but you can coat it with silicone or ScotchGard® to reduce tarnishing. 41g/m², ~10 Ohms per square, 43" wide.



Appendix B

Equipment

1. Spectrum Analyser

NetTek® Analyzer
YBT250 Base Station Transmitter and Interference Analyzer

For further information visit:
http://www.tek.com/site/ps/0,,17-15749-INTRO_EN,00.html

2. Signal Generator

Agilent E4437B ESG-DP Series Signal Generator

Frequency range: 250kHz – 4.0GHz

For further Information
http://cp.literature.agilent.com/litweb/pdf/5968-4313E.pdf

3. Spectrum Analyser (used for Baseline tests)

Agilent E4440 PSA Series Spectrum Analyzer

(3Hz – 26.5GHz)

For further Information visit:
http://www.home.agilent.com/USeng/nav/-536885882.536881888/pd.html