Aircraft Installation & Operational Aspects of the
Aeronautical
Mobile Airport Communications System (AeroMACS)

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Abstract—The purpose of this paper is to present the results of an analysis done at Honeywell on the electromagnetic compatibility issues of installing an AeroMACS (Aeronautical Mobile Airport Communications System) Radio on aircraft equipped with other on-board Communications, Navigation and Surveillance (CNS) radios. This paper describes a typical aircraft radio frequency interference environment, analyzes the effect of the AeroMACS transmitter on other onboard receivers and the effect of other onboard transmitters on the AeroMACS receiver and summarizes the isolation requirements for installing AeroMACS radios on Aircraft.

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1. INTRODUCTION

The AeroMACS technology is based on the IEEE 802.16-2009 WiMAX standard, primarily developed to address the projected higher bandwidth requirements of aircraft/ground ATM data communication when aircraft are operating in the terminal area while on the airport surface. AeroMACS will use the frequency band 5091 to 5150 MHz with channel bandwidth assignments of 5 MHz.

The AeroMACS radio will be operational only on ground when the aircraft speed is below 50 knots.

The RF interference environment applicable to the AeroMACS Radio comprises of onboard RF transmitters whose RF emissions may have an impact on the design and performance of the AeroMACS radio receiving function, and other onboard RF receivers whose performance may be affected by RF emissions from the AeroMACS Radio.

Section 2 of the report provides a description of the functions, uses and other characteristics of Communications, Navigation and Surveillance RF transmitters and receivers that are installed on air transport, business and general aviation aircraft.

Section 3 of the report also summarizes the key AeroMACS profile specifications and the assumptions made in the interference analysis.

Section 4 of the report provides a high level analysis of the required isolation between the AeroMACS radio and other onboard radio transmitters and receivers to prevent mutual interference.

Section 5 summarizes the results of the analysis and provides conclusions and recommendations derived from the analysis.

2. AIRCRAFT RADIO FREQUENCY INTERFERENCE ENVIRONMENT

Radio transmitters and receivers installed on air transport, business and general aviation aircraft are grouped into three different functional categories according to the services provided. The three functional categories are: communications radios, navigation radios and surveillance radios. Each of these sets of radios provides a set of services that are required for safe operation of the aircraft in different phases of flight and/or different air spaces.
Radios that require transmission of RF signals to provide the required service generate out-of-band emissions which affect the performance of the functions of other onboard RF receivers. Therefore whenever a new RF system that includes an RF transmitter and/or receiver is added to an aircraft installation, it is important to evaluate the impact that the new RF transmitter will have on the performance of the other onboard RF receivers and the impact that other onboard RF transmitters will have on the new RF receiver.

The following Figure 1 provides an idea about various radios that may be installed to provide each of the functional categories of services described below.

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**Safety Communication Radios**

Radios that are installed for use by the flight crew for safety communications are referred to in this paper as “safety services or cockpit communications radios”. These radios provide the means for air/ground voice or data link communications between the flight crew and Air Traffic Control (ATC) facilities as well as Airline Operational Control (AOC) or airline/aircraft operators dispatch centers. They also provide the means for air-to-air emergency voice communications between aircraft. Cockpit communications radios operate in frequency bands that are allocated for aeronautical safety communications only and which cannot be used for commercial purposes. Cockpit communications radios currently in use are VHF COM and HF COM. Radios planned for future use in European air space are the L-band Digital Aircraft Communications System (LDACS).

**Cabin Services Communication Radios**

Communications radios that provide communications services to passengers (and to the flight crew for non-safety communications) are referred to in this report as “cabin services or cabin communications radios”. Cabin communications services include air/ground telephone call, e-mail, text messaging and internet connectivity via the traditional ground telecommunications networks. These radios operate in frequency bands allocated for commercial use, not necessarily limited to aeronautical services. Radios currently in use that fall in this category are the UHF radios that provide the Go-Go service.

Some of the cabin radios may also provide for safety communications by supporting services over multiple parallel air/ground communications links that share some of the communications resources, giving priority to safety services. Thus, one could refer to these as “as cockpit and cabin communications radios”. Radios currently in use that fall in this category are Inmarsat Satcom and Iridium Satcom.

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**Fig-1 Typical Aircraft Antenna Farm**

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**Navigation and Guidance Radios**

In addition to communications radios, air transport, business and general aviation aircraft are equipped with radio navigation sensors that are used to receive the radio signals emitted by various different types of navigation aids. Navigation radios or receivers current in use are GPS, VOR, Marker Beacon and Automatic Direction Finding (ADF) receivers and Distance Measuring Equipment (DME) and Radio Altimeter radios.

Air transport, business and general aviation aircraft are also equipped with radio navigation sensors that are used to provide guidance to the autopilot/flight control system during approaches and landing under poor visibility conditions. Approach and landing guidance radios currently are the Instrument Landing System (ILS) consisting of a Localizer receiver and a Glide Slop receiver and GPS Landing System (GLS) which uses a VHF Data Broadcast (VDB) receiver to get the landing waypoints and Differential GPS corrections.

**Surveillance Radios**

Air transport, business and general aviation aircraft are also equipped with surveillance radios that are used to collect and provide information about the traffic and weather hazards around the aircraft. Surveillance radios currently in use are the Mode-S Transponder, Traffic Collision Avoidance System (TCAS), Automatic Dependence Surveillance-Broadcast (ADS-B), Universal Access Transceiver (UAT) and Weather Radar.

Table 1 below lists various radios installed in a typical aircraft environment and their operating frequencies.
3. AeroMACS General Characteristics

AeroMACS General Characteristics

The AeroMACS radio characteristics that are relevant to the interference environment analysis are explained in the following paragraphs.

AeroMACS Profile

The spectrum allocated to AeroMACS consists of the 5091 to 5150 MHz band with channel assignments of 5 MHz bandwidth and channel center frequencies starting from 5095 MHz, incrementing by 5 MHz for every channel, covering the entire spectrum in 11 channel grids. In the uplink, the channel bandwidth of 5MHz is subdivided into 17 sub-channels and the sub-channels are further divided into 24 subcarriers with a bandwidth of 10.94 KHz allocated to every subcarrier. In the Downlink, a channel consists of 15 sub-channels. Each of these sub-channels contains 28 subcarriers, where each subcarrier has a bandwidth of 10.94 KHz. Hence the 5 MHz channel bandwidth consists of 512 subcarriers both in the Uplink and the Downlink.

The physical layer and channel access method used by AeroMACS is Orthogonal Frequency Division Multiple Access (OFDMA). Table 2 summarizes the OFDMA parameters with Partial Usage Sub Channelization (PUSC) used in AeroMACS.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Uplink values</th>
<th>Downlink values</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Channel Bandwidth</td>
<td>MHZ</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Sampling factor</td>
<td></td>
<td>1.12</td>
<td>1.12</td>
</tr>
<tr>
<td>Sampling Frequency</td>
<td>MHZ</td>
<td>5.6</td>
<td>5.6</td>
</tr>
<tr>
<td>FFT Size (NFFT)</td>
<td></td>
<td>512</td>
<td>512</td>
</tr>
<tr>
<td>FFT Used</td>
<td></td>
<td>408</td>
<td>420</td>
</tr>
<tr>
<td>FFT Data</td>
<td></td>
<td>272</td>
<td>360</td>
</tr>
<tr>
<td>FFT Pilot</td>
<td></td>
<td>136</td>
<td>60</td>
</tr>
<tr>
<td>FFT NULL</td>
<td></td>
<td>104</td>
<td>92</td>
</tr>
<tr>
<td>Sub Carriers per Sub Channel</td>
<td>24</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>No. of Clusters</td>
<td></td>
<td>n/a</td>
<td>30</td>
</tr>
<tr>
<td>No. of Tiles</td>
<td></td>
<td>102</td>
<td>n/a</td>
</tr>
<tr>
<td>No. of Sub-Channels</td>
<td></td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Sub-Carrier Frequency Spacing</td>
<td></td>
<td>10.94</td>
<td>10.94</td>
</tr>
<tr>
<td>Useful Symbol Time (Tb = 1/fs)</td>
<td>µs</td>
<td>91.4</td>
<td>91.4</td>
</tr>
<tr>
<td>CP or Guard Time (Tg = Tb/8)</td>
<td>µs</td>
<td>11.4</td>
<td>11.4</td>
</tr>
<tr>
<td>OFDMA Symbol Duration (Ts = Tb+Tg)</td>
<td>µs</td>
<td>102.9</td>
<td>102.9</td>
</tr>
<tr>
<td>Frame Duration</td>
<td>ms</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Number of OFDMA symbols in 5ms frame</td>
<td></td>
<td>48</td>
<td>48</td>
</tr>
</tbody>
</table>

Table – 2 AeroMACS Profile

Modulation and Error Correction Coding

Each of the AeroMACs OFDM carriers may use QPSK or 16QAM modulation for both the Uplink and Downlink, while 64QAM support is mandatory for the Downlink, but optional for the Uplink.

Table 3 contains the various modulation/coding schemes supported by AeroMACS.

<table>
<thead>
<tr>
<th>Modulation</th>
<th>DL</th>
<th>UL</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK, 16QAM, 64 QAM</td>
<td>QPSK, 16QAM</td>
<td></td>
</tr>
<tr>
<td>Code rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CC</td>
<td>1/2, 2/3, 3/4, 5/6</td>
<td>1/2, 2/3, 5/6</td>
</tr>
<tr>
<td>CTC</td>
<td>1/2, 2/3, 3/4, 5/6</td>
<td>1/2, 2/3, 5/6</td>
</tr>
<tr>
<td>Repetition</td>
<td>X2, X4, X6</td>
<td>X2, X4, X6</td>
</tr>
</tbody>
</table>

Table – 3 AeroMACS modulation schemes
Depending upon the range (distance between BS and MS) and SNR (Signal to Noise Ratio), the appropriate modulation scheme would be chosen to achieve the maximum bandwidth with optimal power utilization.

**OFDMA Frame Structure**

Both the Uplink and Downlink of AeroMACS operate in OFDMA mode. AeroMACS supports only the TDD (Time Division Duplex) option for its operation. The TDD frame structure is given below in Figure 2.

Transmissions happen as bursts as per the allocated slots where a slot consists of a sub-channel allocated for the duration of 3 OFDMA symbols for the Uplink and 2 symbols for the downlink. In the Uplink, a slot is one subchannel long in the frequency domain and 3 symbols long in the time domain. Each subchannel is subdivided into 6 tiles, where each tile contains 4 subcarriers. On the other hand, a slot in the Downlink is one subchannel long in the frequency domain and 2 symbols long in the time domain. In this case, a subchannel consists of 2 clusters that each contain 12 subcarriers. Titles and clusters are permuted or renumbered such that the sequence of subcarriers that make up a sub-channel are spread out across the spectrum in random fashion.

**AeroMACS Transmitter Characteristics**

The maximum power allowed at the BS antenna output for downlink transmission is 33dBm and at the MS antenna output for uplink transmission is 30dBm. The spectral mask for the transmitted power density is shown in Figure 3 below.

**Fundamental Emissions**

The above Figure 3 provides the spectral mask requirements of a single channel of bandwidth equal to 5 MHz. The 0 dBm reference level is the highest average power of the fundamental emission within the 5 MHz assigned channel measured with a resolution bandwidth of 50 KHz.

**Calculation for Tx Power**

Assumptions:
- subcarrier allocation that is based on mini-subchannel PUSC mode.
- 1 Tile allocated per frame for the MS which corresponds to a data rate of 1.5 Kbits/sec approximately.
- The same Tile (same set of subcarriers) allocated for multiple frames continuously over a considerable period of time
- Aircraft is at the edge of the cell. Hence it uses maximum power for its communication

Calculations
- Average Maximum Tx Power per MS = 30 dBm
- Average Maximum Signal power per subcarrier = 24 dBm
- Average Maximum Tx power per 50 KHz measurement Bandwidth = 30 dBm (all 4 subcarriers fall within measurement band)

**Out-of-band and spurious emissions**

As per the spectral mask definition, all out-of-band emissions including spurious noise from the AeroMACS transmitter into channels that are 7.5 MHz away or more from the AeroMACS assigned channel should be contained below -50dBr.

For an Average Maximum Transmit Power of 30 dBm/50KHz, the out-of-band emissions should be contained below -20dBm/50KHz or -67 dBm/Hz.

**Adjacent Band emission mask**

Figure 4 provides details about emissions into the frequency bands that are adjacent to the AeroMACS band.

The emission mask at the MLS band edge (5091 MHz) is defined as -40dBm which corresponds to an average Tx Power of -10dBm/50KHz. Since any onboard MLS receiver is not expected to be operational at the same time as the onboard AeroMACS radio, as AeroMACS is operational
only after landing, there should be no impact to the aircraft operations due to interference from AeroMACS to the onboard MLS receiver.

The emissions mask at 5150 MHz is -50 dBm which translates to an average Tx power of -20dBm/50KHz. This is well below the required FCC mask and there are no onboard receivers operating in this frequency range.

**AeroMACS Receiver**

**Sensitivity and Susceptibility to Co-channel Interference**

The cumulative noise level at the AeroMACS receiver operating channel comprises of components from thermal noise, receiver noise figure and other implementation losses including imperfections in H/W. The receiver sensitivity is given by the formula,

\[
RxSen(dBm) = N(dBm) + SNR + NF + IL \quad (Eq. 1)
\]

\[
N(dBm) = -174 + 10\log(Fs N_{used}/N_{FFT}) \quad (Eq. 2)
\]

where,

- **N (dBm)** is the Thermal Noise floor in a bandwidth equal to that occupied by the number of used subcarriers
- **SNR** is the minimum required Signal-to-Noise Ratio
- **NF** is the Receiver Noise Figure
- **IL** is the Receiver Implementation Loss

SNR corresponds to the value required for an ideal receiver to achieve a Bit Error Rate (BER) of 10^-6 in Additive White Gaussian Noise (AWGN). SNR value varies with respect to the type modulation and coding schemes used by the system. Figure 5 below represents the Receiver Sensitivity level considering all noise components as provided in the equations above.

![Fig-5 – Receiver Sensitivity and Noise Levels](image)

The interference broadband noise emissions from other sources add up to the noise floor of the AeroMACS receiver and degrade its sensitivity level as explained in the figure above. Practically, when the interfering noise power is less than 1/10th of the Receiver Noise (Thermal Noise + Noise Figure), the impact to the overall receiver sensitivity value is negligible. The Receiver Noise Figure for AeroMACS is defined as 7 dB. Hence our analysis assumes the maximum allowed co-channel interference noise power density is -177 dBm/Hz.

**Susceptibility to Out-of-Band Interference**

Currently there is no specification available for AeroMACS that defines the maximum tolerable level of out-of-band interference that results in no degradation of the AeroMACS receiver performance. It is assumed that the AeroMACS Minimum Operational Performance Standards (MOPS) will specify a level such as -7 dBm (typical for other COM avionics). It is assumed that additional front end filtering will need to be added to COTS WiMAX technology if it cannot meet this specification.

4. ANALYSIS OF INTERFERENCE ENVIRONMENT ON AEROMACS DESIGN AND PERFORMANCE

AeroMACS will be operational only on the ground after the aircraft lands, as it is used only for communications on the airport surface. Hence for the purpose of the mutual interference analysis, only the radios which are operational on the ground are considered. Table 4 lists all onboard radios and their operational status on the ground.

The interference margin \( M(f_E) \) available when one considers the interference signal level produced by the AeroMACS transmitter fundamental (main signal) emission or out-of-band emission at the input of another onboard receiver or by another onboard transmitter at the input to the AeroMACS receiver is defined by the following equation

\[
M(f_E) = PT(f_E) - LCT(f_E) - GT(f_E) - L(f_E) - GR(f_E) - LP(f_E) - LCR(f_E) - SR(f_E)
\]

\[
= PT(f_E) - A(f_E) - SR(f_E) \quad (Eq. 3)
\]

where,
Table - 4 Radios Operational on Ground

<table>
<thead>
<tr>
<th>Onboard CNS Radios</th>
<th>Frequency Band (MHz)</th>
<th>Operational on Ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADF</td>
<td>0.19-1.6</td>
<td></td>
</tr>
<tr>
<td>HF COM</td>
<td>2-30</td>
<td></td>
</tr>
<tr>
<td>Marker Beacon</td>
<td>74.5-74.5</td>
<td></td>
</tr>
<tr>
<td>ILS Localizer</td>
<td>108-112</td>
<td></td>
</tr>
<tr>
<td>VOR</td>
<td>108-118</td>
<td></td>
</tr>
<tr>
<td>VDB</td>
<td>108-118</td>
<td></td>
</tr>
<tr>
<td>UHF COM</td>
<td>118.127</td>
<td>✓</td>
</tr>
<tr>
<td>ILS Glide Slope</td>
<td>328.6-328.75</td>
<td>✓</td>
</tr>
<tr>
<td>L-DACS2</td>
<td>390.5-3975</td>
<td>✓</td>
</tr>
<tr>
<td>UAT</td>
<td>977-979</td>
<td>✓</td>
</tr>
<tr>
<td>L-DACS1 Rx</td>
<td>986-1009.5</td>
<td>✓</td>
</tr>
<tr>
<td>Mode S XDR Rx</td>
<td>1027-1033</td>
<td>✓</td>
</tr>
<tr>
<td>TCAS Tx</td>
<td>1027-1033</td>
<td>✓</td>
</tr>
<tr>
<td>L-DACS1 Tx</td>
<td>1048.5-1071.5</td>
<td>✓</td>
</tr>
<tr>
<td>Mode S XDR Tx</td>
<td>1097-1099.3</td>
<td>✓</td>
</tr>
<tr>
<td>TCAS Rx</td>
<td>1087-1093.3</td>
<td>✓</td>
</tr>
<tr>
<td>DME (low band) Rx</td>
<td>960-1150</td>
<td>✓</td>
</tr>
<tr>
<td>DME (high band) Rx</td>
<td>1160-1215</td>
<td>✓</td>
</tr>
<tr>
<td>DME Tx</td>
<td>1031-1160</td>
<td>✓</td>
</tr>
<tr>
<td>GPS L5/Galileo E5a</td>
<td>1169-1169</td>
<td>✓</td>
</tr>
<tr>
<td>Colico E6b</td>
<td>1107-1217</td>
<td>✓</td>
</tr>
<tr>
<td>GPS L2C</td>
<td>1217-1237</td>
<td>✓</td>
</tr>
<tr>
<td>Inmarsat Satcom Rx</td>
<td>1520-1530</td>
<td>✓</td>
</tr>
<tr>
<td>GPS &amp; Galileo L1</td>
<td>1555-1555</td>
<td>✓</td>
</tr>
<tr>
<td>Iridium Satcom</td>
<td>1510-1525.5</td>
<td>✓</td>
</tr>
<tr>
<td>Inmarsat Satcom Tx</td>
<td>1626.5-1660.5</td>
<td>✓</td>
</tr>
<tr>
<td>Radio Altimeter</td>
<td>4200-4400</td>
<td>✓</td>
</tr>
<tr>
<td>MLS</td>
<td>5030-5091</td>
<td>✓</td>
</tr>
<tr>
<td>Weather Radar</td>
<td>3000-3500</td>
<td>✓</td>
</tr>
</tbody>
</table>
AeroMACS antenna locations. Ultimately, the achieved isolation and interference margin must be confirmed by measurement on each aircraft type to be equipped with an AeroMACS Radio.

**AeroMACS Transmitter Emissions Effect on RF Receivers**

The modes of interference from AeroMACS Transmissions to other on-board Receivers considered for the purpose of analysis are,

- Interference from the AeroMACS Fundamental emission on a channel within 5091-5150 MHz which produces spurious responses in other on-board receivers.

- Interference from AeroMACS out-of-band spurious, harmonic and broadband noise emissions which fall within the receive band of other on-board receivers.

Tables 5 and 6 below provide the calculated minimum required isolation $A(f_E)$ between the AeroMACS and other potential onboard victim receivers to avoid interference from the fundamental and broadband noise emissions of the AeroMACS Transmitter respectively.

### Table – 5 Victim Receiver Isolation from AeroMACS Transmitter Fundamental Emission

<table>
<thead>
<tr>
<th>Victim Receiver</th>
<th>Frequency Band (MHz)</th>
<th>AeroMACS Fundamental Emission Level (dBi)</th>
<th>Victim Receiver Susceptibility to Interference</th>
<th>Minimum Required Isolation $A(f_E)$ with 0 dB Margin (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHF COM</td>
<td>118-137</td>
<td>-67</td>
<td>-171</td>
<td>104</td>
</tr>
<tr>
<td>L-DACS2</td>
<td>960.5-975</td>
<td>-67</td>
<td>-180</td>
<td>113</td>
</tr>
<tr>
<td>L-DACS1</td>
<td>985.5-1000.5</td>
<td>-67</td>
<td>-180</td>
<td>113</td>
</tr>
<tr>
<td>Mode S XPD</td>
<td>1027-1033</td>
<td>-67</td>
<td>-175</td>
<td>106</td>
</tr>
<tr>
<td>TCAS</td>
<td>1087-1093</td>
<td>-67</td>
<td>-175</td>
<td>106</td>
</tr>
<tr>
<td>GPS L5/Galileo E5</td>
<td>1166-1186</td>
<td>-67</td>
<td>-185</td>
<td>118</td>
</tr>
<tr>
<td>Galileo E5</td>
<td>1187-1217</td>
<td>-67</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>GPS L2C</td>
<td>1217-1237</td>
<td>-67</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Inmarsat Satcom</td>
<td>1529-1550</td>
<td>-67</td>
<td>-185</td>
<td>116</td>
</tr>
<tr>
<td>GPS L1</td>
<td>1556-1595</td>
<td>-67</td>
<td>-185</td>
<td>116</td>
</tr>
<tr>
<td>Iridium Satcom</td>
<td>1610-1625.5</td>
<td>-67</td>
<td>-177</td>
<td>110</td>
</tr>
</tbody>
</table>

Note 1: Only the receivers that are active on ground are considered.
Note 2, 3: The values correspond to emissions and susceptibility to interference in the frequency range 5091 – 5150 MHz.

### Table – 6 Victim Receiver Isolation from AeroMACS Transmitter Broad Band Noise Emission

Onboard RF Transmitters Emissions Effect on AeroMACS Receiver Performance

The AeroMACS receiver performance will be affected by the fundamental and out-of-band emissions from other onboard RF transmitters which fall within the AeroMACS receiving band. The out-of-band emissions include any discrete spurious emissions, emissions on harmonics of the main signal center or carrier frequency and broadband noise emissions within the 5091-5150 MHz band.

Tables 7 and 8 below capture the analysis done on

- Interference from the Fundamental emission from other on-board transmitters which produce a spurious response in the AeroMACS receiver (e.g. cross-modulation, in-band aliasing, etc)

- Interference due to out-of-band spurious, harmonic and broadband noise emissions from other on-board transmitters which fall within the AeroMACS 5091-5150 MHz receive band respectively.
AeroMACS Minimum Isolation Requirement

Table 9 summarizes the minimum required AeroMACS transmitter and receiver isolation calculated from Tables 5, 6, 7 and 8.

One major observation from the analysis, as listed in Table 9 is that the minimum isolation required between the AeroMACS Radio and other onboard radios ranges from 108 to 118 dB. And in most cases, with a couple of exceptions, the required isolation is driven by the out-of-band broadband noise and spurious emissions from the AeroMACS transmitter. The isolation is the amount of attenuation that must be provided between the antenna port of the AeroMACS radio and the antenna port of the onboard victim receiver or interfering transmitter. It is equal to the sum of the antenna gains of the transmitting and receiving system minus the propagation, cable and antenna polarization coupling losses.

The isolation level of 108 to 118 dB is very difficult to achieve across all onboard radios only by spacing the AeroMACS antenna away from all other on board Rx Antennas. Hence it is expected that additional filtering will be needed to attenuate the broadband and spurious emissions from the AeroMACS Transmitter below 2 GHz range by a factor of at least 50 dB.

Table 10 provides the minimum isolation required when the out-of-band AeroMACS emissions are 50 dB lower than allowed by the FCC emissions mask.
5. SUMMARY

This paper has described the RF environment that the AeroMACS Radio will have to deal with on typical air transport, business and general aviation aircraft.

Some of the observations from this analysis are,

- AeroMACS spurious and broadband emissions that are merely compliant with the emissions mask defined in the AeroMACS Profile [2] will produce interference levels requiring more than 110 dB of isolation between the AeroMACS transmitter and other onboard receivers such as GNSS receivers, COM and Surveillance radio receivers. It is highly difficult to achieve that much isolation between the AeroMACS antenna and other Rx antennas on the aircraft. Hence additional reduction of 50-70 dB in the AeroMACS emissions below 2 GHz is recommended.

- Another important observation is that the minimum isolation required between AeroMACS receiver and L- Band transmitters like Mode S, transponders and TCAS are also very high at 113 dB and 114 dB respectively. It is very difficult to achieve such isolation at the aircraft only by spacing AeroMACS antenna away from the Mode S and TCAS antennas. Hence TCAS and Mode S transmissions may have some impact on AeroMACS radio performance. Since, the interference is due to the broadband emissions that fall within the operating range of the AeroMACS receiver, it is impossible to evade such interference from these two systems using any filtering mechanisms. However since the Mode S and TCAS transmissions are of short duration and their duty cycle is very low (less than 1%),the fraction of the time that AeroMACS reception will be interfered with will also be low.

It is also understood that the airborne AeroMACS radio needs to be designed to deal with RF interference from distant ground transmitters and to distant ground receivers as well as other satellite systems operating across various RF bands. However, the levels of interference from the ground transmitters/to the ground receivers are range dependent and generally not as high as those from/to onboard RF systems. Similarly, the RF levels of interfering signals from/to other satellite systems are also much lower than those from/to onboard RF systems. The AeroMACS RF emissions and susceptibility to RF interference dealt with in this report are emissions radiated via the AeroMACS antenna and susceptibility to RF interference received via the AeroMACS antenna. The AeroMACS radio will also have to be certified for compliance with RF radiated and conducted emissions out of the radio enclosure(s) and cabling connected to the unit, and for compliance with RF susceptibility to radiated and conducted interference coupled via the cabling connected to the AeroMACS radio per applicable industry standards [30, 31].
6. REFERENCES

**BIOGRAPHIES**

**Alfonso Malaga** is an Aerospace Engineering Fellow in the Honeywell Aerospace Advanced Technology organization. He has over 30 years of experience in the development of avionics Communications, Navigation and Surveillance radios and the technology associated with them.

He holds an M.S.E.E. and Ph.D. in Electrical Engineering from the University of Massachusetts, and a B.S.E.E. from Fairleigh Dickinson University in New Jersey.

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Previously, Mr. Roy was Director of Programs at Flextronics Corporation managing several major telecommunications OEM accounts, such as Alcatel-Lucent, Motorola, Tekelec, Adtran, ADC, etc. In this role, Mr. Roy was responsible for business development, outsourcing, and globalization of hardware design activities supporting large volume contract electronic manufacturing. Mr. Roy’s prior experiences include various positions at ARINC Aviation Systems Division and AT&T Bell Laboratories. Mr. Roy has extensive experience in aeronautical standards development at ICAO, RTCA and AEEC. Currently, he is a co-chair of RTCA Special Committee 223, developing AeroMACS standards. Previously, He led the VDL SARPs change control group under ICAO AMCP and participated in SATCOM, HFDL, and ATN Panels. At RTCA, Mr. Roy participated at SC-172, SC-189, and SC-202 and contributed to VDL, ATN, FANS/ATS and PED MASPs and MOPS developments.

Mr. Roy taught data communication networks, protocols, and air-traffic management systems at various seminars hosted by NASA, FAA, Eurocontrol, Brazilian civil aviation authorities, IATA, Rockwell-Collins, Teledyne Controls, and others. Mr. Roy holds an MBA degree from University of Maryland-College Park and an MSEE degree from Louisiana State University.

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