Wireless Avionics Intra-Communications (WAIC)

Agenda Item 1.17 Update and Status on implementing of a regulatory framework for WAIC

Presentation for ICAO Regional Meeting

Lima, Peru

March, 2012

Outline

- **What is WAIC**
- **Why is WAIC Important**
- **Overall Regulatory Process**
  - ITU-R
    - Status of Documents
    - Priority Frequency Bands for Study
  - ICAO, RTCA, EUROCAE
  - Certification of Aircraft
- **Technical Effort**
  - WAIC Technical Characteristics
  - Preliminary Sharing Study Results

What is Wireless Avionics Intra-Communications (WAIC)

- **WAIC is:**
  - Radiocommunication between two or more points on a single aircraft.
  - Integrated wireless and/or installed components to the aircraft.
  - Part of a closed, exclusive network required for operation of the aircraft.
  - Only for safety-related applications.
  - Based on short range radio technology (< 100m).
  - Low maximum transmit power levels of 10mW for low rate and 50mW for high rate applications
  - Mostly internal - within fuselage/cabin.
- **WAIC does not:**
  - Provide off-board air-to-ground, air-to-satellite, or air-to-air service.
  - Provide communications for passengers or in-flight entertainment.

WAIC and Next Generation of Aircraft

- Aircraft and the RF environment in which they operate are evolving.
- In striving to utilize wireless capabilities, aircraft are on the verge of important technological and design transformations.
- WAIC represents the aviation industry's effort to realize the benefits of wireless technologies for the future generation of aircraft for safety-related functions.
- Goal is to add operational efficiencies and reduce the overall weight of systems; and include the ability to obtain more data from the aircraft systems and surfaces during all phases of flight.
- The objective is to enhance efficiency and reliability while maintaining or improving current required levels of safety.
- The intent is to NOT mandate equipage changes or to require additional costs to airlines.

Importance of WAIC to Airlines

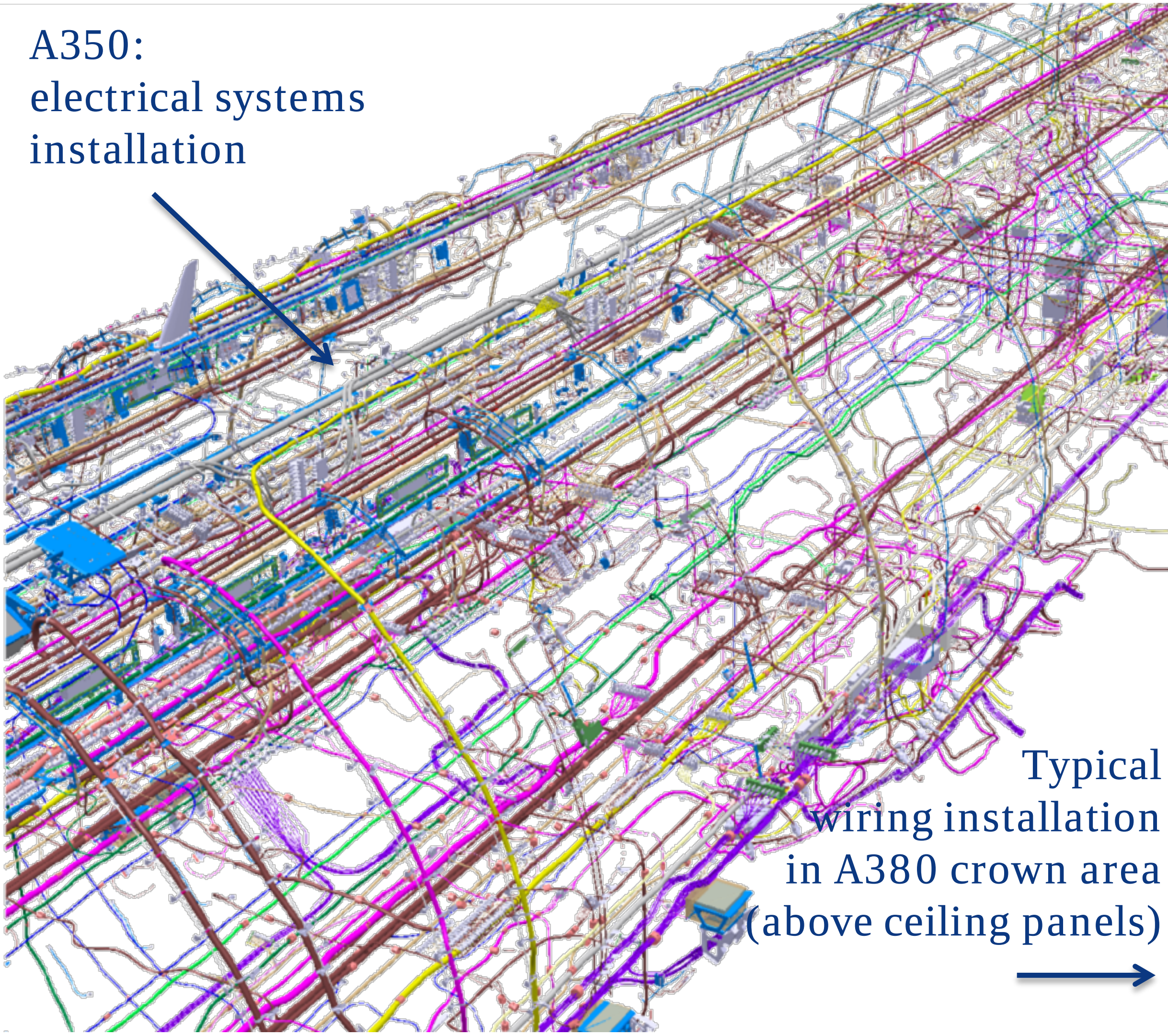
- **Safety Improvements:**
  - Provide dissimilar redundancy
  - Fewer wires means a reduction in connector pin failures, lower risk of cracked insulation & broken conductors.
  - Mesh networking could provide redundancy in emergencies.
- **Environmental Benefits:**
  - Reduced wiring and associated aircraft weight enables less fuel burn.
- **Increased Reliability**
  - Reduce amount of aging wiring
  - Simplify and reduce life-cycle cost of airplane wiring
  - Ability to obtain more data from aircraft systems and surfaces
  - Add new sensors and controls without additional wire routing
- **Provide operational efficiencies and associated cost savings.**
  - To monitor systems and surfaces that currently cannot be monitored without taking the aircraft out of service.

Examples of Potential WAIC Applications

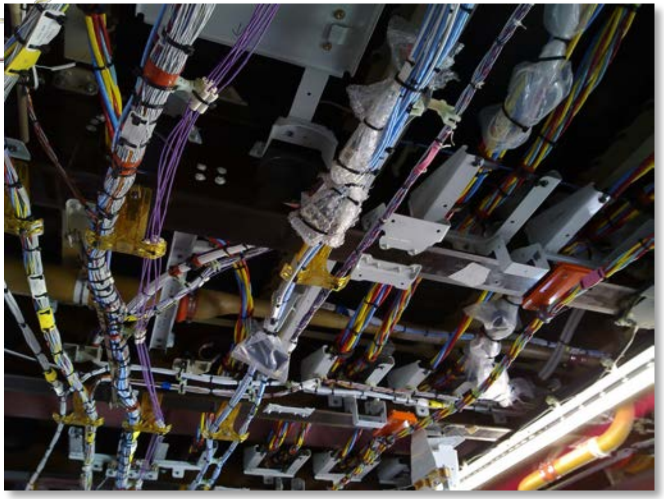
- **Low Data Rate, Interior Applications (LI):**
  - **Sensors**: Cabin Pressure - Smoke Detection - Fuel Tank/Line – Proximity Temperature - EMI Incident Detection - Structural Health Monitoring - Humidity/Corrosion Detection
  - **Controls**: Emergency Lighting - Cabin Functions
- **Low Data Rate, Outside Applications (LO):**
  - **Sensors**: Ice Detection - Landing Gear Position Feedback - Brake Temperature - Tire Pressure - Wheel Speed - Steering Feedback - Flight Controls Position Feedback - Door Sensors Engine Sensors - Structural Sensors
- **High Data Rate, Interior Applications (HI):**
  - **Sensors:** Air Data - Engine Prognostic - Flight Deck/Cabin Crew Images/Video
  - **Comm.:** Avionics Communications Bus - FADEC Aircraft Interface - Flight Deck/Cabin Crew Audio / Video (safety-related)
- **High Data Rate, Outside Applications (HO):**
  - **Sensors**: Structural Health Monitoring
  - **Controls**: Active Vibration Control

Need for WAIC - Complexity of electrical wiring in modern aircraft

A350:
electrical systems
installation



Typical
wiring installation
in A380 crown area
(above ceiling panels)



Need for WAIC - Complexity of electrical wiring in modern aircraft

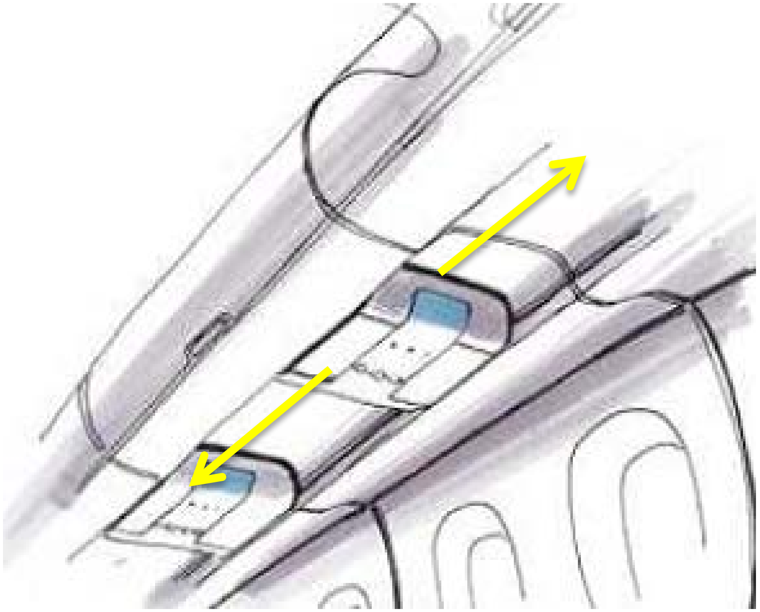
- **Electrical wiring:**
  some statistics for the example of the A380-800
  - Total wire count: ~100 000
  - Total wire length: 470 km
  - Total weight of wires: 5 700 kg
  - About 30% of additional weight to fix the harness to the structure

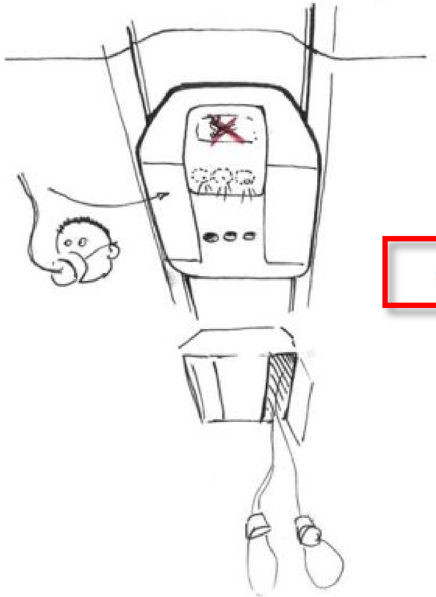
<u>About 30% of electrical wires are potential candidates for a wireless substitute!</u>

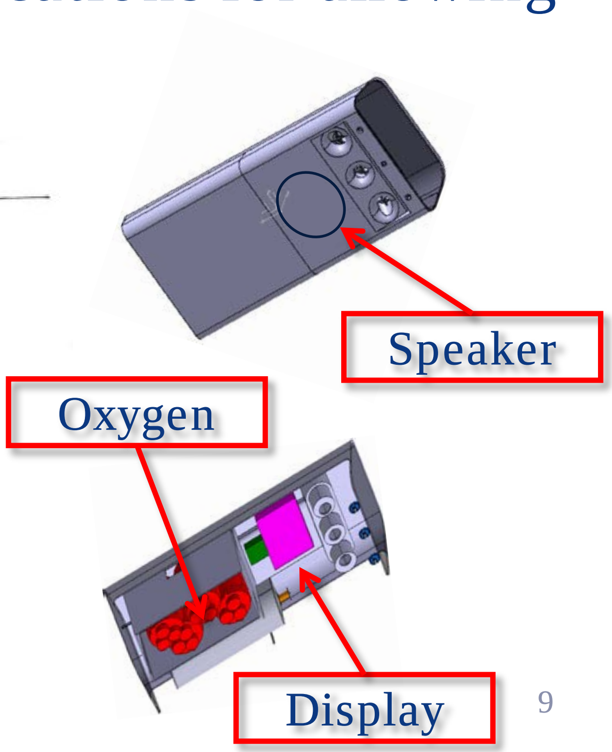
Need for WAIC - Reconfigurability

Example: Wireless Supply Unit

- Release of oxygen masks and trigger of oxygen flow
- Passenger Address Function (audio announcement)
- Display providing safety information to the passenger
- Needs to feature flexible installation locations for allowing fast reconfiguration of seat layout







Need for WAIC - Dissimilar Redundancy

Example: Redundant communication paths

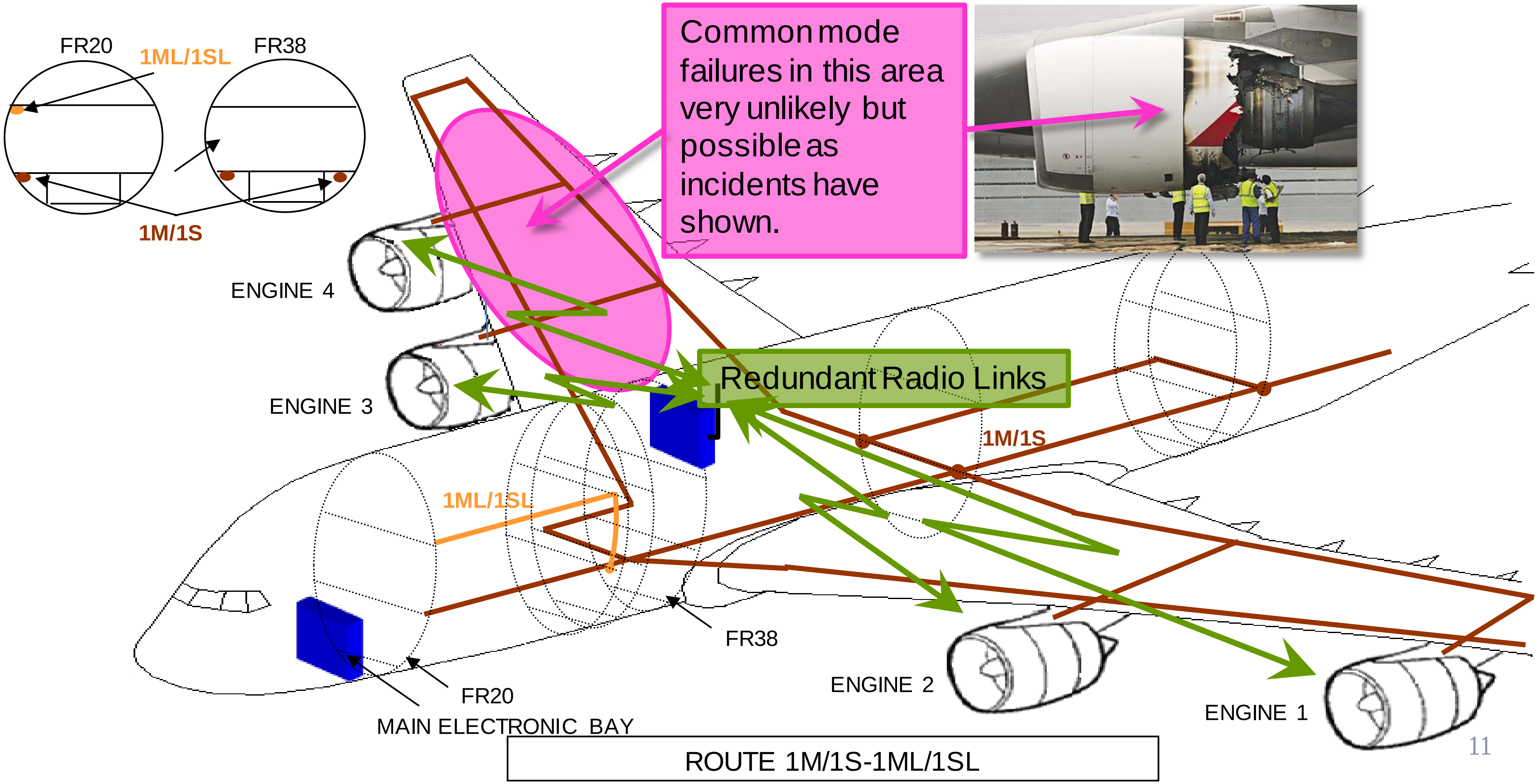
- Aircraft wiring typically features dual or triple redundancy.
- Redundant wiring routes in different areas within the aircraft structure mitigate risk of single points of failure
- Wiring routes are segregated to the farthest possible extend allowed by the aircraft geometry

A wireless connection provides a dissimilar redundancy if wires are disconnected.

Need for WAIC - Dissimilar Redundancy

Example: Redundant communication paths (cont'd)

- Route segregation, combined with redundant radio links, provides dissimilar redundancy and mitigates risk of single points of failure



Regulatory Process and Update

- **The safety of the aircraft is the #1 priority!**
- **The ITU is only the first of many regulatory processes.**
  - The first sharing studies will be submitted in May 2013.
- **Updating ICAO, regional spectrum organizations, and industry organizations as information is developed.**
- **ICAO SARPS likely in any aeronautical frequency band in which WAIC is deployed.**
- **RTCA and EUROCAE must also get involved.**
  - EUROCAE process has started and Boeing is working on starting the RTCA process.
- **Ultimately, the aircraft certification organization at FAA, etc. must support the safe installation of WAIC on any aircraft.**

Status of ITU Documents

- **CPM Document has only background info.**
- **Aviation Band Analysis Document**
  - Resolution requires ITU-R to first consider AMS, AM(R)S and ARNS bands below 15.7 GHz, and if spectrum requirements cannot be met, in bands above 15.7 GHz.
  - "Consider" does not mean a detailed technical analysis.
  - The band(s) of "least resistance" is a valid consideration, and probably the most important consideration.
  - Based upon factors in the document, the bands:
    - 2700-2900 MHz, 4200-4400 MHz, 5350-5470 MHz, and portions of 15.4-15.7 GHz will first be studied.

First – the safety of the aircraft cannot be compromised

Status of ITU Documents (cont.)

2700-2900 MHz:

- Considered a candidate to study first:
  - Worldwide allocation to the ARNS
  - Used for ground-based radars at low duty cycles
  - Aircraft or WAIC systems might be able to implement mitigation factors (not yet defined) to avoiding harmful interference.

4200-4400 MHz:

- Considered a candidate to study first:
  - Worldwide allocation to the ARNS and more specifically to only one system (radio altimeters onboard aircraft) with minor exceptions in a few countries)
  - Radio altimeters and WAIC systems are located on the same aircraft; therefore aircraft manufacturers have full operational control over both WAIC and radio altimeter systems. Therefore, operational mitigation efforts can be used.

Status of ITU Documents (cont.)

5350-5460 MHz:

- Considered a candidate to study first:
  - Worldwide allocation to the ARNS
  - Used for ground-based radars at high power levels but low duty cycles
  - Aircraft or WAIC systems might be able to implement mitigation factors (not yet defined) to avoiding harmful interference.
- **The bands above can provide most of the bandwidth to satisfy a considerable part of WAIC spectrum requirements.**
- **Access to only a portion of a band is acceptable.**
- **Sharing studies have started and will be submitted to various Administrations. Inputs can be expected for the upcoming ITU-R Working Party 5B meeting in May 2013.**

Agenda Item 1.17 – Resolution 423

resolves

that WRC-15 consider, based on the results of ITU-R studies, possible regulatory actions, including appropriate aeronautical allocations, to support the implementation of WAIC systems, while taking into account spectrum requirements for WAIC and protection requirements for systems operating in accordance with existing allocations,

invites ITU-R

1 to conduct, in time for WRC-15, the necessary studies to determine the spectrum requirements needed to support WAIC systems;

2 to conduct sharing and compatibility studies, based on the results of *invites ITU-R* 1, to determine appropriate frequency bands and regulatory actions;

3 when conducting studies in accordance with *invites ITU-R* 2, to consider:

- i) frequency bands within existing worldwide aeronautical mobile service, aeronautical mobile (R) service and aeronautical radionavigation service allocations;
- ii) additional frequency bands above 15.7 GHz for aeronautical services if spectrum requirements cannot be met in frequency bands studied under *invites ITU-R* 3i),

Early Technical Effort

- **A lot of technical information about WAIC can be found in ITU-R Report 2197 (2010)**
  - Limited to a single aircraft scenario
  - Locations, number of nodes, and data rates
    - LI/LO < 10 kbits/s inside/outside the aircraft
    - HI/HO ≥ 10 kbits/s inside/outside the aircraft
  - Reference architecture concept
  - Generally, power requirements depend upon frequency range and available bandwidth.

Updated Technical Information

- **November 2012, WAIC Technical Characteristics Document approved to Preliminary Draft New Report.**
  - Intent is to approve at WP5B the document for Study Group 5 approval in November 2013.

- **Document Contains:**
  - Technical Characteristics grouped by “key” characteristics
  - System architecture
  - Aircraft shielding analysis
  - Bandwidth and data rate requirements
  - Other information necessary to conduct compatibility studies

Update of Technical Information

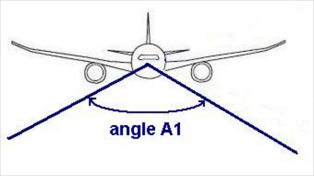
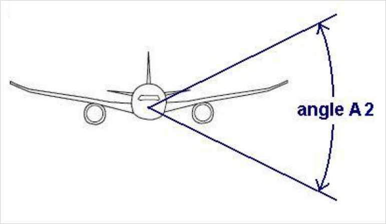
- **Location and data rate groupings remain constant**
  - Definitions of LI, LO, HI, HO (inside/outside and 10 kbits/s) remain unchanged
  - There are no simultaneously active links in any given frequency or channel -- The number of transmitters on any single channel will be one. (i.e. – is no transmit power aggregation)
  - Overall network architecture is same and additional detail is provided.

- **Aircraft Shielding:**
  - Very complex issue: depends on installation location of transmitter and receiver.
  - Fuselage attenuation is a directional property of the aircraft.
  - Statistically, the most common orientation between an aircraft and point on the ground is significantly higher than the average over all of the viewing angles (can exceed 30 dB).
  - Even outside systems experience partial shielding – depending on location.

WAIC Technical Characteristics

	Low data rate systems	High data rate systems	Reference to section	Units
Total net average data rate per aircraft	1.25	30.7	3	Mbps
Total net peak data rate per aircraft	2.3	161.8	3	Mbps
Overall spectrum demand	94*	145*	5.6	MHz
Spectrum demand per aircraft	26**	80**	5.6	MHz
number and location of simultaneously active transmitters	see section 4.5	see section 4.5	4.5	-
Antenna gain (RX and TX)	3	3	-	dBi
Max. transmission power	10	50	-	mW
3-dB emission bandwidth	2.6	20	-	MHz
20-dB emission bandwidth	6	22	-	MHz
40-dB emission bandwidth	12	60	-	MHz
Receiver IF-bandwidth	2.6	20	-	MHz
Thermal noise floor (kBT)	-110	-101	-	dBm
Receiver noise figure	10	10	-	dB
Required signal-to-noise ratio++	9	12+	-	dB
Receiver sensitivity	-91	-79	-	dBm

Aircraft Shielding

Case	Viewing Angle	Configuration	Typical attenuation
1	viewed from A1 	a) transmitters within cabin	25dB
		b) transmitters installed in lower lobe of aircraft fuselage	35dB
2	viewed from A2 	a) transmitters within cabin	10dB
		b) transmitters installed in lower lobe of aircraft fuselage	30dB
3	All angles	Enclosed compartments or aircraft fitted with shielded windows	35dB
4	n/a	Partly shielded external aircraft areas	5dB

Aircraft Component Shielding

WAIC transmit antenna location	Assumed aircraft structural shielding / dB		
	'+/- 60° rel. to yaw axis	+/- 30° rel. to pitch axis	all other angles
flight deck	25	10	35
cabin compartment	25	10	35
avionics compartment	35	35	35
fwd and aft cargo compartment, center tank, bilge	35	30	35
bulk cargo compartment	35	30	35
wing fuel tank	35	35	35
horizontal stabilizer	35	35	35
nacelles	35	35	35

WAIC transmit antenna location	Assumed aircraft structural shielding / dB		
	'+/- 60° rel. to yaw axis	+/- 30° rel. to pitch axis	all other angles
nose (lower shell only)	0	5	0
center (upper shell)	5	0	0
center (lower shell)	0	0	0
tail (upper shell only)	5	0	0
left wing (upper shell only)	5	5	0
right wing (upper shell only)	5	5	0

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Power Levels and Spectrum Requirements

- **EIRP values of all WAIC applications are provided and calculated on a per-compartment or per-aircraft level for internal and external applications.**
  - EIRP per channel and EIRP density values are provided

- **Bandwidth Requirements:**
  - Low data rate systems will require 94 MHz
  - High data rate systems will require 145 MHz

- **These values include multiple aircraft in close proximity.**

Conclusion

- **WAIC technology will benefit the airlines and aerospace industry.**
- **WAIC will not require avionics systems to be retrofitted.**
- **Safety will be enhanced, and not compromised!**
- **ITU, ICAO, CITEL, APT, CEPT, ATU, ASMG, RCC and aviation groups are all being updated.**
- **All groups interested in aviation are welcome to participate.**
- **The ITU effort is the first process that must be started – will only define at a high level the ability for WAIC to use any particular frequency band.**
  - ICAO, RTCA and EUROCAE efforts start in earnest once there regulatory certainty is achieved or a regulatory solution is more clearly defined.

Questions?

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