



Report ITU-R M.2318-0
(11/2014)

**Consideration of the aeronautical
mobile (route), aeronautical mobile,
and aeronautical radionavigation
services allocations to accommodate
wireless avionics intra-communication**

M Series
**Mobile, radiodetermination, amateur
and related satellite services**

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REPORT ITU-R M.2318-0

Consideration of the aeronautical mobile (route), aeronautical mobile, and aeronautical radionavigation services allocations to accommodate wireless avionics intra-communication

(2014)

Summary

This Report contains an initial assessment of frequency bands between 960 MHz and 15.7 GHz considered under 2015 World Radiocommunication Conference (WRC-15) agenda item 1.17 and a summary of detailed studies undertaken for some of these frequency bands. Frequency bands below 960 MHz were not considered feasible because the necessary physical antenna sizes in this frequency range are incompatible to wireless avionics intra-communication (WAIC) implementation requirements.

The criteria applied for initial assessment of the frequency bands are defined and summarized in § 4.

In accordance with Resolution **423 (WRC-12)** the assessment considers all aeronautical mobile, aeronautical mobile (route) and aeronautical radionavigation service allocations in the frequency range 960 MHz-15.7 GHz. The results of these assessments are contained in § 5 of this Report.

Out of the frequency bands assessed the frequency bands 2 700-2 900 MHz, 4 200-4 400 MHz and 5 350-5 460 MHz were considered for further detailed sharing studies mainly because of their bandwidth and the preferred frequency range below 6 GHz. The other frequency bands are not taken into further considerations.

In the frequency bands 2 700-2 900 MHz and 5 350-5 460 MHz WAIC systems were found to be incompatible with incumbent systems. Details on the studies on the frequency bands 2 700-2 900 MHz and 5 350-5 460 MHz are contained in Annexes 2-5 of this Report.

Studies contained in Report ITU-R M.2319 show compatibility between WAIC systems and incumbent systems in the frequency band 4 200-4 400 MHz.

The conclusion of this Report is that with reference to the bands studied in detail the frequency band 4 200-4 400 MHz is the only option below 15.7 GHz for satisfying WRC-15 agenda item 1.17, provided suitable measures for outside applications such as the use of directional antennas and reduced transmit power are undertaken.

1 Scope

At the 2012 World Radiocommunication Conference (WRC-12), a new agenda item on WAIC was approved for the 2015 World Radiocommunication Conference (WRC-15). Agenda item 1.17 of the WRC-15 sought to consider spectrum requirements and regulatory actions for WAIC systems. The agenda item read:

*to consider possible spectrum requirements and regulatory actions, including appropriate aeronautical allocations, to support wireless avionics intra-communications (WAIC), in accordance with Resolution **423 (WRC-12)**;*

To address WRC-15 agenda item 1.17, this Report considered the frequency bands initially provided in Resolution **423 (WRC-12)**, and highlights their technical and operational aspects which may affect compatibility with the proposed WAIC systems.

2 Proposal

In order to address WRC-15 agenda item 1.17 this Report provides a brief description of radio frequency bands currently utilized by aviation and considers known operational and technical factors used to motivate the selection of potential candidate frequency bands for WAIC allocation(s). In accordance with Resolution **423 (WRC-12)** frequency bands currently allocated to the aeronautical mobile service (AMS), aeronautical mobile (route) service (AM(R)S), and aeronautical radionavigation service (ARNS) below 15.7 GHz are considered. Based on the results of the initial assessment, studies have been conducted for selected frequency bands. The results of these studies are summarized and conclusions are drawn.

3 Review of existing aeronautical spectrum below 15.7 GHz

In order to determine appropriate radio frequency bands for WAIC applications, *invites ITU-R 1* of Resolution ITU-R **423 (WRC-12)** invites:

“to conduct, in time for WRC-15, the necessary studies to determine the spectrum requirements needed to support WAIC systems”.

In *invites ITU-R 3*, it is detailed that the ITU-R should first consider frequency bands within existing worldwide AMS, AM(R)S and ARNS allocations below 15.7 GHz. Should the spectrum requirements for WAIC systems not be met in this range, then additional frequency bands above 15.7 GHz can be considered.

Spectrum planning for WAIC systems design involves considering regulatory and technical requirements that assure the safety of aircraft and the flying public, spectrum availability, system compatibility, protection criteria of existing systems and the bandwidth required for new services. As WAIC systems will require a certain level of availability, reliability and integrity, these communications links must be located in spectrum whose characteristics are well controlled, in order to enable the levels of performance and reliability required by international aviation.

Section 4 introduces criteria which were used in the following initial assessment of the frequency bands regarding their suitability to accommodate WAIC systems.

Section 5 contains the initial assessments for all aeronautical frequency bands below 15.7 GHz. These assessments are also summarized in a table in Annex 1 which provides also an overview of the degree of fulfilment of the selected criteria.

Section 6 provides the conclusions of the initial assessment and a summary of the results of the performed sharing and compatibility studies. Study results for the frequency bands 2 700-2 900 MHz and 5 350-5 460 MHz can be found in Annexes 4 and 5, respectively. The study for the frequency band 4 200-4 400 MHz is contained in Report ITU-R M.2319.

4 Criteria for considering aeronautical frequency bands for wireless avionics intra-communication systems

Based on the requirements set out in Resolution 423 (WRC-12), the WAIC characteristics contained in Report ITU-R M.2283 and the operational requirements of civil aircraft, the criteria in the following sections are intended to assist in focusing sharing studies.

4.1 Regulatory requirements

Resolution 423 (WRC-12) invites the ITU-R to consider only existing AMS, AM(R)S and ARNS allocations in frequency bands below 15.7 GHz.

4.2 Wireless avionics intra-communication requirements

4.2.1 Ability to install wireless avionics intra-communication systems on aircraft

The installation and environmental conditions identified in Report ITU-R M.2283 specifies an optimum frequency range for WAIC transceivers. Due to aircraft weight limitations and the locations of WAIC sensors, a large portion of the transceivers will be small form-factor sensors. To maintain an acceptable level of antenna size and efficiency, this limits WAIC to frequencies above 1 GHz. In addition, the available power to WAIC components favour different frequency ranges; low power sensors are better suited to frequencies below 6 GHz to minimize path loss and absorption, while applications where energy is less critical will be able to operate across the available range.

4.2.2 Size of the frequency band / available bandwidth

Considering the estimated spectrum demand for WAIC systems of 145 MHz and following the objective to minimize the number of non-contiguous frequency bands required, smaller frequency bands will limit implementation options.

4.2.3 Existing aeronautical mobile (route) service allocation

Frequency bands with an existing AM(R)S allocation are preferable to reduce potential regulatory changes.

4.2.4 Level of global harmonization

The frequency bands utilized for WAIC systems must be globally harmonized. Commercial aircraft fly in or over every country in the world. Hence, to ensure a harmonized regulatory status, it is essential to have a global spectrum allocation.

4.2.5 Current systems in the frequency band

Frequency bands with multiple existing aeronautical and non-aeronautical services and their respective operating

4.2.6 System control and location

An incumbent system, whose transceivers are installed on and controlled by the aircraft, will provide options for WAIC systems to optimize transmissions with that incumbent system installed on the same aircraft. Furthermore, it will allow for transceiver coordination (e.g. maximizing isolation between WAIC and incumbent system's antennas) that cannot be achieved with ground based or mobile transceivers.

4.2.7 Other (non-technical) regulatory obstacles

Additional operational or regulatory factors not covered by the above which could prevent the global use of a particular frequency band for WAIC systems

5 Aeronautical radio frequency bands

Based on the initial review, an evaluation summary table has been prepared in Annex 1. Depending on the degree of fulfilment of the selected criteria a value has been dedicated to each criterion.

5.1 Frequencies below 960 MHz

As described in § 4.2.1, the study of WAIC is limited to frequencies above approximately 1 GHz because of limited available aircraft space, aircraft weight restrictions and power source requirements.

5.2 The frequency band 960-1 164 MHz

5.2.1 Current allocations and systems in the frequency band

The frequency band 960-1 164 MHz is primarily used for aeronautical radionavigation. It supports a number of critical civil and government aviation systems, including distance measuring equipment (DME), secondary surveillance radar (SSR), airborne collision avoidance system (ACAS), 1 090 MHz Extended Squitter, universal access transceiver (UAT) and L-band digital aeronautical communication system (LDACS).

5.2.2 Initial assessment of the frequency band

Due to the importance for aeronautical navigation and the intensive use of this frequency band by several navigation applications, the possible integration of WAIC systems requires extensive compatibility studies. Although the frequency band already includes an AM(R)S allocation, the planned introduction of other new aviation systems (both on board aircraft and on the ground) in this frequency band increases the complexity of the interference scenario and makes the frequency band too difficult to share with incumbent and planned systems. Therefore, this frequency band is not taken into further considerations.

5.3 The frequency band 1 164-1 215 MHz

5.3.1 Current allocations and systems in the frequency band

The frequency band 1 164-1 215 MHz is allocated to the ARNS for worldwide operation and development of airborne electronic aids to air navigation and directly associated ground-based facilities. Additionally, the radio navigation satellite service (RNSS) and global navigation satellite systems (GNSS) use this frequency band.

5.3.2 Initial assessment of the frequency band

Because of the numerous and highly sensitive incumbent systems operating both on and off the aircraft, this frequency band would present significant technical challenges to implement a compatible WAIC system. Therefore, this frequency band is not taken into further considerations.

5.4 The frequency band 1 300-1 350 MHz

5.4.1 Current allocations and systems in the frequency band

The frequency band 1 300-1 350 MHz is primarily used for ground-based surveillance radars and long-range detection of aircraft. It is also used to associate airborne transponders for en-route and terminal surveillance tasks.

5.4.2 Initial assessment of the frequency band

The incumbent radar systems are characterized by high transmit power and low receiver threshold levels. Furthermore, they are located near airports which places significant receiver protection and emission limitation requirements on any system attempting to share the frequency band. This frequency band is also of small size. Therefore, this frequency band is not taken into further considerations.

5.5 The frequency band 1 559-1 610 MHz

5.5.1 Current allocations and systems in the frequency band

The frequency band 1 559-1 610 MHz is allocated to ARNS, RNSS, and fixed service (FS) and is utilized by GNSS systems.

The RNSS (space-to-Earth) allocation in this frequency band is the main allocation available for GNSS, and plays an essential role in navigation operations. GNSS is foreseen to provide the basis for most civil aviation radionavigation requirements in the future.

5.5.2 Initial assessment of the frequency band

Received RNSS signal levels are low power and GNSS systems require extreme care and careful design to ensure that they can deliver the required performance on a continuous basis. The stringent technical requirements of GNSS make co-frequency use of this frequency band highly restrictive. In addition this frequency band is of small size. Therefore, this frequency band is not taken into further considerations.

5.6 The frequency band 1 610-1 626.5 MHz

5.6.1 Current allocations and systems in the frequency band

The frequency band 1 610-1 626.5 MHz is reserved on a worldwide basis for the use and development of airborne electronic aids to air navigation and any directly associated ground-based or satellite-borne facilities. This frequency band is constrained by sharing with the radio astronomy allocation, which has primary status. Additionally, RR Footnote 5.149 limits airborne use.

5.6.2 Initial assessment of the frequency band

Due to the requirement for a harmonized world-wide allocation for WAIC systems, this frequency band is prohibitive for WAIC systems due to the fact there are many Administration-specific footnote allocations in this frequency band. In addition this frequency band is of small size. Therefore, this frequency band is not taken into further considerations.

5.7 The frequency band 2 700-2 900 MHz

5.7.1 Current allocations and systems in the frequency band

Use of the frequency band 2 700-2 900 MHz by the ARNS is restricted to ground-based radars and to associated airborne transponders that transmit only when actuated by radars operating in the same frequency band. Ground-based meteorological radars have primary status (via footnote) in this frequency band. In Canada, the maritime radionavigation service also has primary status.

The frequency band is particularly used for primary surveillance radars (providing a surveillance range of up to 200 NM) and meteorological radars (providing an observation and detection weather range of up to 150 NM and altitude range of up to 20,000 meters), which are often placed in or near airports.

5.7.2 Initial assessment of the frequency band

The high transmit power and low receiver threshold levels associated with the incumbent radar systems in the frequency band 2 700-2 900 MHz and their proximity to aircraft at airports places significant receiver protection and emission limitation requirements on any system attempting to share the frequency band. However, mainly because the attractive implementation properties for WAIC systems in this frequency range this frequency band was selected for further considerations.

Corresponding studies were performed and can be found in Annex 4. It is concluded in Annex 4 that the frequency band 2 700-2 900 MHz is not an appropriate candidate frequency band for implementation of outside or inside WAIC systems.

5.8 The frequency band 4 200-4 400 MHz

5.8.1 Current allocations and systems in the frequency band

Use of the frequency band 4 200-4 400 MHz by the ARNS is reserved exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground. Radio altimeters provide the primary means of altitude detection for all critical phases of flight, especially the final stages of landing.

The standard frequency and time signal-satellite service is also authorized to use the frequency range 4 200-4 204 MHz for space-to-Earth transmissions.

5.8.2 Initial assessment of the frequency band

Due to the limited number and location of incumbent systems, the globally harmonized allocation and the fact that any WAIC use on an aircraft will require ICAO and aircraft standardization groups involvement and ultimately aircraft certification ensuring safe operation of all critical systems, this frequency band was selected for further considerations. Corresponding studies were performed and can be found in Report ITU-R M.2319.

It is concluded in that report that WAIC systems located inside the aircraft can share the frequency band 4 200 4 400 MHz with the aeronautical radionavigation service, the Earth exploration-satellite service (EESS) (passive) and the fixed service. Studies also show that WAIC systems located outside the aircraft using measures such as directional antennas and reduced transmit power can also share the frequency band 4 200-4 400 MHz with the aeronautical radionavigation service, the EESS (passive) and the fixed service

Examination has been done to quantify the order of magnitude of interference from WAIC systems into the FSS and no harmful interference is expected. Based on the WAIC power level, it was agreed an adjacent band study would not be required because the separation distance between WAIC systems and VSATs is in the range of 50 m to 100 m.

5.9 The frequency range 5 000-5 250 MHz

5.9.1 Current allocations and systems in the frequency range

The frequency bands 5 000-5 010 MHz and 5 010-5 030 MHz are allocated to the AMS(R)S, ARNS, and RNSS. The frequency band 5 030-5 091 MHz is allocated to the AM(R)S. The frequency band 5 091-5 150 MHz is allocated to the AMS and restricted via footnote to systems operating in the AN(R)S and in accordance with international aeronautical standards, limited to surface applications at airports and to aeronautical telemetry transmissions from aircraft stations. Both frequency bands 5 030-5 091 MHz and 5 091-5 150 MHz are also allocated to the ARNS and AMS(R)S. Furthermore, the frequency band 5 091-5 150 MHz is allocated to the FSS via a footnote. The frequency band 5 150-5 250 MHz is allocated to the ARNS, FSS, MS (except aeronautical mobile) and the AMS limited to aeronautical telemetry. These provisions for aeronautical telemetry are limited to parts of ITU Region 1 and Brazil.

5.9.2 Initial assessment of the frequency band(s)

Due to the large number of incumbent systems, the numerous technical protection requirements and compatibility issues, and the potential regulatory changes foreseen in portions of this frequency range, it is unlikely that WAIC systems can make use of these frequency bands without causing interference to incumbent systems or being interfered by them. Therefore, this frequency range is not taken into further considerations.

5.10 The frequency band 5 350-5 460 MHz

5.10.1 Current allocations and systems in the frequency range

The frequency band 5 350-5 460 MHz is allocated to the ARNS, EESS (active), space research service (SRS) (active), and the radio location service (RLS). The allocation to the ARNS is limited to airborne radars. This allocation is also used for airborne weather and ground mapping observations. The EESS (active), the SRS (active) and the RLS allocations are subject to the condition that systems operating under these allocations shall not cause harmful interference to ARNS systems.

5.10.2 Initial assessment of the frequency band

This frequency band is used by numerous incumbent systems with protection criteria that most likely make sharing difficult. Nevertheless due to the size of the frequency band and the favourable implementations properties in this frequency range this frequency band was selected for further considerations. Corresponding studies were performed and can be found in Annex 5.

It is concluded in Annex 5 that the frequency band 5 350-5 460 MHz is not an appropriate candidate frequency band for implementation of outside or inside WAIC systems.

5.11 The frequency band 8 750-8 850 MHz

5.11.1 Current allocations and systems in the frequency band

The frequency band 8 750-8 850 MHz is allocated to the ARNS and RLS. In Algeria, Germany, Bahrain, Belgium, China, Egypt, the United Arab Emirates, France, Greece, Indonesia, Iran (Islamic Republic of), Libya, the Netherlands, Qatar, Sudan and South Sudan, the frequency band 8 825-8 850 MHz is also allocated to the maritime radionavigation service on a primary basis for use by shore-based radars only. The use of the frequency band by the ARNS is limited to airborne Doppler navigation aids.

5.11.2 Initial assessment of the frequency band

Compatibility with systems operating in the ARNS and RLS might be difficult to implement, as both services operate in the same collocated airspace. Sharing between airborne Doppler radars, e.g., on board helicopters and WAIC systems on board aircraft is considered particularly difficult due to the possibility of very short separation distances between these vehicles in practical airport scenarios. Therefore, this frequency band is not taken into further considerations.

5.12 The frequency band 9 000-9 200 MHz

5.12.1 Current allocations and systems in the frequency band

The frequency band 9 000-9 200 MHz is allocated to the ARNS and RLS. The ARNS is restricted to ground-based radars and associated airborne transponders that transmit only when actuated by radars operating in the same frequency band. In Algeria, Germany, Bahrain, Belgium, China, Egypt, the United Arab Emirates, France, Greece, Indonesia, Iran (Islamic Republic of), Libya, the Netherlands,

Qatar, Sudan and South Sudan, this frequency band is also used on a primary basis for shore-based radar systems in the maritime radionavigation service. Stations operating in the radiolocation service shall not cause harmful interference to, nor claim protection from aeronautical radionavigation systems utilizing this frequency band or radar systems in the maritime radionavigation service. Systems that use this frequency band include primary surveillance radar, precision approach radar and airport surface detection equipment (ASDE).

5.12.2 Initial assessment of the frequency band

The high transmit power and low receiver threshold levels associated with radar systems in the frequency band 9 000-9 200 MHz and their proximity to aircraft at airports places significant receiver protection and emission limitation requirements on any system attempting to share the frequency band. Therefore, this frequency band is not taken into further considerations.

5.13 The frequency band 13.25-13.4 GHz

5.13.1 Current allocations and systems in the frequency band

The frequency band 13.25-13.4 GHz is allocated to the ARNS, EESS, and SRS (active). Aviation's use of this frequency band is limited to Doppler navigation aids and ground mapping radars. In Bangladesh, India and Pakistan, this frequency band is also allocated to the FS on a primary basis. The EESS (active) and SRS (active) operating in this frequency band shall not cause harmful interference to, or constrain the use and development of aeronautical radionavigation service systems. Furthermore, this band is foreseen by some Administrations for the use by airborne sense and avoid radars.

5.13.2 Initial assessment of the frequency band

The high transmit power and low receiver threshold levels associated with in particular airborne sense and avoid radar systems in the frequency band 13.25-13.4 GHz places significant receiver protection and emission limitation requirements on any system attempting to share the frequency band. Therefore, this frequency band is not taken into further considerations.

5.14 Review of the frequency range 15.4-15.7 GHz

5.14.1 Current allocations and use of the frequency band

The frequency range 15.4-15.7 GHz contains allocations for the ARNS, RLS, and FSS. The frequency band 15.4-15.7 GHz is used by aviation for ground-based primary surveillance radar systems including precision approach radar and ASDE. The main purpose of these systems is to provide surveillance to support precision approach to aircraft and to detect traffic at airports.

A part of this frequency band is also a supplementary frequency band for the main FSS feeder link operation at 19 GHz and 29 GHz. The RLS allocation is to provide remote environmental sensing.

5.14.2 Initial assessment of the frequency band

The high transmit power and low receiver threshold levels associated with the radar systems operated in this frequency band and their proximity to aircraft at airports places significant receiver protection and emission limitation requirements on any system attempting to share this frequency band. Therefore, this frequency range is not taken into further considerations.

6 Conclusion

Based on the results of the initial assessment in a first step the following frequency bands have been selected for a more detailed analysis:

- 2 700-2 900 MHz
- 4 200-4 400 MHz
- 5 350-5 460 MHz.

The studies on the frequency bands 2 700–2 900 MHz and 5 350–5 460 MHz conclude that sharing between WAIC systems and in particular ground based radar systems in these frequency bands is not feasible.

With reference to the frequency bands studied in detail the frequency band 4 200-4 400 MHz is the only option below 15.7 GHz for satisfying WRC-15 agenda item 1.17. This is due to the low number of different applications and their specific characteristics enabling shared use of the frequency band.

A summary of the initial evaluation, the results of the conducted sharing and compatibility studies are included in:

- Annex 1: Provides the initial evaluation of the suitability of the frequency bands discussed above in § 5 in tabular format.
- Annex 2: Methodology for analysis of the impact of aeronautical radionavigation, meteorological and radiolocation radars onto Wireless Avionics Intra-Communication systems
- Annex 3: Wireless Avionics Intra-Communication and radar characteristics used in the studies of the impact of aeronautical radionavigation, meteorological and radiolocation radars onto Wireless Avionics Intra-Communication systems
- Annex 4: Estimation of potential impact of radar systems in the frequency band 2 700-2 900 MHz onto Wireless Avionics Intra-Communication systems operating co-frequency
- Annex 5: Estimation of potential impact of radar systems in the frequency band 5 350-5 460 MHz onto Wireless Avionics Intra-Communication systems operating co-frequency

Annex 1

Summary of the initial assessment of frequency bands for wireless avionics intra-communication

Frequency band or frequency range	Installation Capability	Size of the frequency band(s)	AM(R)S	Level of harmonization	Current systems in the frequency band	System control and installation	Other Obstacles
8.3 kHz-960 MHz	+	+	+	+	+	+	+
960-1 164 MHz	+++	+++	+++	+++	++	++	+
1 164-1 215 MHz	+++	++	+	+++	++	++	++
1 300-1 350 MHz	+++	++	+	+++	+++	+	++
1 559-1 610 MHz	+++	++	+	++	++	++	+
1 610-1 626.5 MHz	+++	+	+	++	+	++	+
2 700-2 900 MHz	+++	+++	+	+++	+++	+	++
4 200-4 400 MHz	+++	+++	+	+++	+++	++	+++
5 000-5 010 MHz	+++	+	+	+++	+	++	+
5 010-5 030 MHz	+++	+	+	+++	+	++	+
5 030-5 091 MHz	+++	++	+++	+++	++	++	++
5 091-5 150 MHz	+++	++	+++	+++	++	++	++
5 150-5 250 MHz	+++	++	+	++	+	++	+
5 350-5 460 MHz	+++	+++	+	+++	+++	++	+++
8 750-8 850 MHz	++	++	+	+++	++	++	++
9 000-9 200 MHz	++	+++	+	+++	+++	+	+++
13.25-13.4 GHz	++	+++	+	++	++	++	++
15.4-15.43 GHz	++	+	+	+++	++	+	++
15.43-15.63 GHz	++	+++	+	+++	++	++	++
15.63-15.7 GHz	++	++	+	+++	+++	++	+++

The criteria described in § 4 of this document are further contracted into factors that can be used to help narrow the list of potential frequency bands for detailed study.

1 Capability to install wireless avionics intra communication systems on aircraft

- +++ Spectrum between 960 MHz and 6 GHz
- ++ Spectrum above 6 GHz
- + Spectrum below 960 MHz.

2 Size of frequency band

- +++ Bandwidth > 100 MHz
- ++ Bandwidth > 50 MHz ≤ 100 MHz
- + Bandwidth ≤ 50 MHz.

3 Existing aeronautical mobile (R) service allocation

- +++ AM(R)S allocation
- ++ AM(R)S allocation with restriction
- + No AM(R)S allocation.

4 Level of global harmonization

- +++ Fully harmonized on global level
- ++ Includes allocations with regional/national deviations
- + Aeronautical allocations on regional/national basis.

5 Current use of the frequency band

- +++ Priority of aeronautical use and low number of non- aeronautical allocations
- ++ High number of non- aeronautical allocations on primary basis
- + Restrictions to aeronautical mobile use.

6 System control and installation

- +++ All potentially affected elements of incumbent systems are installed on board the same aircraft as the WAIC system is installed on and are under the aircraft's control
- ++ Some elements of the incumbent systems are installed on board the same aircraft as the WAIC system is installed on and are under the aircraft's control
- + None of the elements of the incumbent systems is under the control of the aircraft on which the WAIC system is installed.

7 Other non-technical obstacles

- +++ Minimal non-technical obstacles (expected)
- ++ Obstacles limited to aeronautical community
- + High level of resistance from other implemented or planned services or applications.

Annex 2

Methodology for analysis of the impact of aeronautical radionavigation, meteorological and radiolocation radars onto Wireless Avionics Intra-Communication systems

A-2.1 Acceptable interference power level at the input of a Wireless Avionics Intra-Communications receiver

The acceptable interference power level at the input of a WAIC receiver is calculated as follows:

$$I_{acc} = P_{WAIC\ trans} + G_{WAIC\ trans} + G_{WAIC\ rec} + 20\lg\left(\frac{\lambda}{4\pi R_{WAIC}}\right) + (I/S)_{acc} \quad (A-2.1)$$

where:

I_{acc} : acceptable interference power level at the input of the WAIC receiver in dBW

$P_{WAIC\ trans}$: max. transmit power level of external WAIC transmitters in dBW

$G_{WAIC\ trans}$, $G_{WAIC\ rec}$: transmit and receive antenna gains of WAIC systems in dBi

λ : carrier wavelength in m

R_{WAIC} : maximum distance between WAIC transmit and receive antennas in m and

$(I/S)_{acc}$: respective protection criterion of a low or high rate WAIC system in dB.

A-2.2 Minimum required separation distance

For assessing the interference impact caused by radar systems onto a WAIC system receiver operating co-frequency, the minimum required separation distance between both systems is calculated according to equation (A-2.2).

This equation employs the acceptable interference power level defined in § A-2.1.1. Equation (A-2.2) assumes free-space propagation between WAIC system receiver and the incumbent system's transmitter.

$$R = 10^{\left(\frac{P_{eff\ int} + G_{int} + G_{WAIC\ rec} + 20\lg\left(\frac{\lambda}{4\pi}\right) - I_{acc}}{20} \right)} \quad (A-2.2)$$

where:

R : protection distance in m

$P_{eff\ int}$: effective interference power in dBW

G_{int} : interfering transmitter antenna gain in dBi

$G_{WAIC\ rec}$: WAIC receiver antenna gain in dBi

λ : carrier wavelength in m

I_{acc} : acceptable power of interference at input of external WAIC receiver in dBW.

The effective interference power level $P_{eff\ int}$ takes the type of interference (pulsed/continuous) and the ratio between WAIC system signal bandwidth and the bandwidth of the interference signal into account (see equations (A-2.3) and (A-2.4)):

$$\text{If } \Delta F_{WAIC} \leq \Delta F_I \text{ then } P_{eff\ int} = P_{int} + 10\lg(Q) + 10\lg(\Delta F_{WAIC}/\Delta F_I) - L \quad (A2.3)$$

$$\text{if } \Delta F_{WAIC} > \Delta F_I \text{ then } P_{eff\ int} = P_{int} + 10\lg(Q) - L \quad (A2.4)$$

where:

- $Q = t/T$: pulse duty factor
 t : pulse width in s
 T : pulse repetition period in s
 L : feeder loss in dB ($L=0$ due to the fact that the power is calculated at the antenna)
 P_{int} : radar transmit power into the radar antenna in dBW
 ΔF_1 : radar's -3 dB emission bandwidth in MHz.

Two scenarios were considered for assessment of the protection distances:

- interference into the WAIC system receiver is caused by the interfering system's transmitter through antenna main lobe coupling and co-frequency operation with the WAIC system;
- interference into the WAIC system receiver is caused by the interfering system's transmitter through antenna side lobe coupling and co-frequency operation with the WAIC system.

Annex 3

Wireless Avionics Intra-Communications and radar characteristics used in the studies of the impact of aeronautical radionavigation, meteorological and radiolocation radars onto Wireless Avionics Intra-Communication systems

A-3.1 Technical characteristics of Wireless Avionics Intra-Communication systems

A summary of technical characteristics of WAIC systems according to Report ITU-R M.2283 is provided in Table A-3.1. The protection criteria for WAIC systems is defined by way of interference-to-signal ratio (I/S) at the input of a WAIC system receiver. The I/S ratio shall not exceed -9 dB (for low data rate systems) and -14 dB (for high data rate systems).

TABLE A-3.1

Technical characteristics of wireless avionics intra-communication systems

	Low data rate systems (LR)	High data rate systems (HR)	Unit
Antenna gain (Rx and Tx)	0	0	dBi
Maximum Tx power	10	50	mW
3 dB emission bandwidth	2.6	16.6	MHz
Required S/N	9	14	dB
Protection criterion $(I/S)_{\text{acc}}$	-9	-14	dB
Maximum distance between WAIC receiver and transmitter	15	15	m

A-3.2 Technical characteristics of radiodetermination radars used in the compatibility studies

Recommendation ITU-R M.1464-1 contains characteristics of radiodetermination radars operating in the frequency band 2 700-2 900 MHz. Table A-3.2 provides characteristics of radars that were used for analysis of compatibility with WAIC systems.

TABLE A-3.2
**Characteristics of radiodetermination radars in the frequency
 band 2 700-2 900 MHz used for studies**

	Radar A	Radar B	Radar C	Radar F	Radar G	Radar I	Radar K	Unit
Antenna main beam gain	33.5	33.5	34	33.5	45.7	33.5	40	dBi
Antenna side lobe levels	–	7.3	9.5	7.5	20	26	–	dBi
Feeder loss	0							dB
Output power	61.5	61.2	44.0	48.5	57.0	47.8	60.0	dBW
Pulse width	0.6	1.03	89	20	4.7	40	100	µs
Pulse repetition rate, Hz	1 040	1 172	1 050	1 100	452	1 100	300	Hz
Pulse repetition period	962	853	952	909	2 212	909	3 333	µs
Q (duty cycle)	0.000624	0.001207	0.09345	0.022	0.002124	0.044	0.03	-
RF emission bandwidth	6	0.6	1.9	2	0.6	2.5	100	MHz

Recommendation ITU-R M.1849 contains characteristics of meteorological radars operating in the band 2 700-2 900 MHz. Table A-3.3 provides characteristics of the meteorological radar that were used for analysis of compatibility with WAIC systems.

Table A-3.3
**Characteristics of meteorological radar in the frequency
 band 2 700-2 900 MHz used for studies**

	Radar 2	Unit
Antenna main beam gain	38	dBi
Antenna side lobe levels	15	dBi
Feeder loss	0	dB
Output power	56	dBW
Pulse width	1	µs
Pulse repetition rate	539	Hz
RF emission bandwidth	1.5	MHz

Recommendation ITU-R M.1638 contains characteristics of radiodetermination, aeronautical radionavigation and meteorological radars operating in the band 5 350-5 460 MHz. Table A-3.4 provides characteristics of radars that were used for analysis of compatibility with WAIC systems.

TABLE A-3.4

Characteristics of radars in the frequency band 5 350-5 460 MHz used for studies

	Radar A	Radar B	Radar D	Radar F	Radar J	Unit
Antenna main beam gain	39	37.5	34	40	45	dBi
Antenna side lobe levels	-26	-20	-31	-25	-20	dBi
Feeder loss	0					dB
Output power	54	48	23	54	34	dBW
Pulse width	2	6	20	2	0.1	µs
Pulse repetition rate	1 200	200	1 440	1 180	100 000	Hz
Pulse repetition period	833	5 000	694	847	10	µs
Q (duty cycle)	0.0024	0.0012	0.0288	0.00236	0.01	–
RF emission bandwidth	0.5	0.6	1	0.6	10	MHz

TABLE A-3.4 (continued)

Characteristics of radars in the frequency band 5 350-5 460 MHz used for studies

	Radar I	Radar M	Radar N	Radar O	Radar Q	Radar S	Unit
Antenna main beam gain	54	47	45.9	42	30	40	dBi
Antenna side lobe levels	-20	-20	-22	-22	-25	-25	dBi
Feeder loss	0						dB
Output power	64	61	60	52	55	26	dBW
Pulse width	5	1	1	100	1	1	µs
Pulse repetition rate	640	640	1 280	320	750	1 500	Hz
Pulse repetition period	1 562.5	1 562.5	781.3	3 125	1 333.3	666.7	µs
Q (duty cycle)	0.0032	0.0006	0.0013	0.032	0.0008	0.0015	–
RF emission bandwidth	0.5	0.9	0.9	8.33	1.2	4	MHz

Annex 4

Estimation of potential impact of radar systems in the frequency band 2 700-2 900 MHz onto wireless avionics intra-communication systems operating co-frequency

A-4.1 Selected radar characteristics for studies

Due its lower transmitter power into antenna, pulse repetition rate (minimum value is taken) and pulse width (maximum value is taken), the radar type 2 is chosen to be the most favourable case for the sharing studies based on radars detailed in the Recommendation ITU-R M.1849.

Miscellaneous radars extracted from the Recommendation ITU-R M.1464 are also considered.

Characteristics are provided in the Annex 3 of this Report.

A-4.2 Technical characteristics of wireless avionics intra-communication systems and acceptable interference power level at the input of a wireless avionics intra-communication receiver

Characteristics of WAIC systems used in this study are based on Report ITU-R M.2283 also summarized in the Annex 3 of this Report.

Calculated values of acceptable interference power levels at the input of WAIC low rate and high rate WAIC receivers are presented in Table A-4.1.

TABLE A-4.1

Acceptable interference power levels at the input of low and high rate wireless avionics intra-communication receivers

Frequency	Low rate WAIC	High rate WAIC
2 800 MHz	-93.9 dBW	-91.9 dBW

A-4.3 Radiodetermination radar impact assessment on the operation of outside wireless avionic intra-communication systems

The methodology applied for calculating the minimum required separation distances to protect outside WAIC systems operating co-frequency with radiodetermination radars in the frequency band 2 700-2 900 MHz is provided in Annex 2 of this Report. The resulting minimum separation distances are provided in Table A-4.2.

TABLE A-4.2

**Minimum separation distances to protect outside wireless avionics
intra-communication systems from radiodetermination radar
in the frequency band 2 700-2 900 MHz**

Radar	Required separation distance (km)			
	Main lobe coupling		Side lobe coupling	
	Low rate WAIC	High rate WAIC	Low rate WAIC	High rate WAIC
2	493	392	35	28
A	389	470	–	–
B	798	635	39	31
C	$> R^*$	814	61	48
F	785	624	39	31
G	$> R^*$	$> R^*$	138	110
I	$> R^*$	817	433	345
K	$> R^*$	$> R^*$	–	–

* R is the maximum line-of-sight (LOS) distance for two aircraft at an altitude of 12 km. The LOS distance accounting for refraction in this case is equal to 900 km.

Analysis of the results presented in Table A-4.2 shows that in case of main lobe coupling protection distances for external WAIC systems would have to be larger than 493 km for the radar type 2 and larger than 900 km for radar types C, G, I and K.

For the case of side lobe coupling required separation distances are considerably lower than for the main lobe coupling case, but are in the best case still in the order of several kilometres.

These distances are considered too large to assure compatibility between outside WAIC systems and radiodetermination radars in the frequency band 2 700-2 900 MHz for practical operational scenarios.

A-4.4 Radiodetermination radar impact assessment on the operation of inside wireless avionic intra-communications systems

The methodology applied for calculating the minimum required separation distances to protect inside WAIC systems operating co-frequency with radiodetermination radars in the frequency band 2 700-2 900 MHz is provided in Annex 2 of this Report.

An additional attenuation value of 30 dB due to the fuselage has been applied considering transmitters installed in the lower lobe of aircraft fuselage in accordance with Report ITU-R M.2283.

The resulting minimum separation distances are provided in Table A-4.3.

TABLE A-4.3

**Minimum separation distances to protect inside wireless avionics
intra-communication systems from radiodetermination radars
in the frequency band 2 700-2 900 MHz**

Radar	Required separation distance (km)			
	Main lobe interference		Side lobe interference	
	Low rate WAIC	High rate WAIC	Low rate WAIC	High rate WAIC
2	15	12	1.1	0.9
A	12	15	–	–
B	25	20	1	1
C	32	26	2	1
F	25	20	1	1
G	84	67	4	4
I	33	26	14	11
K	37	75	–	–

Analysis of the results presented in Table A-4.3 shows that in case of main lobe coupling minimum separation distances for internal WAIC systems would remain larger than 15 km for the radar type 2 and larger than 84 km for the radar type G.

These distances are considered too large to assure compatibility between inside WAIC systems and radiodetermination radars in the frequency band 2 700-2 900 MHz for practical operational scenarios.

A-4.5 Conclusion

Based on the results of the study above, it can be concluded that the frequency band 2 700-2 900 MHz is not an appropriate candidate frequency band for implementation of outside or inside WAIC systems.

Annex 5

Estimation of potential impact of radar systems in the frequency band 5 350-5 460 MHz onto wireless avionics intra-communication systems operating co-frequency

A-5.1 Selected radar characteristics for studies

Miscellaneous radars extracted from in the Recommendation ITU-R M.1638 are considered.

Characteristics are provided in the Annex 3 of this Report.

A-5.2 Technical characteristics of wireless avionics intra-communications systems and acceptable interference power level at the input of a wireless avionics intra-communication receiver

Characteristics of WAIC systems used in this study are based on Report ITU-R M.2283 and described in the Annex 3 of this Report.

Calculated values of acceptable interference power levels at the input of WAIC low rate and high rate WAIC receivers are presented in Table A-5.1.

TABLE A-5.1

Acceptable interference power levels at the input of low and high rate wireless avionics intra communication receivers

Frequency	Low rate WAIC	High rate WAIC
5 370 MHz	-99.6 dBW	-97.7 dBW
5 440 MHz	-99.7 dBW	-97.7 dBW

A-5.3 Radiodetermination radar impact assessment on the operation of outside wireless avionic intra-communications systems

The methodology applied for calculating the minimum required separation distances to protect outside WAIC systems operating co-frequency with radiodetermination radars in the frequency band 5 350-5 460 MHz is provided in Annex 2 of this Report. The resulting minimum separation distances are provided in Table A-5.2.

TABLE A-5.2

**Minimum separation distances to protect outside wireless avionics
intra-communication systems from radiodetermination radars
in the frequency band 5 350-5 460 MHz**

Radar	Required separation distance (km)			
	Main lobe coupling		Side lobe coupling	
	Low rate WAIC	High rate WAIC	Low rate WAIC	High rate WAIC
A	$> R^*$	744	46	37
B	291	234	29	23
D	50	40	1	1
F	$> R^*$	827	58	47
J	182	287	18	29
L	$> R^*$	$> R^*$	$> R^*$	$> R^*$
M	$> R^*$	$> R^*$	262	211
N	$> R^*$	$> R^*$	237	191
O	$> R$	$> R^*$	172	247
Q	193	155	11	9
S	26	26	1	1

* R is the maximum line-of-sight (LOS) distance for two aircraft at an altitude of 12 km. The LOS distance accounting for refraction in this case is equal to 900 km.

Analysis of the results presented in Table A-5.2 shows that in case of main lobe coupling the minimum required separation distances for external WAIC systems would have to be larger than the LOS distance between two aircraft at an altitude of 12 000 m.

In case of side lobe coupling the separation distance is are lower for most radar types (except for Radar L). However, they remain in the order of several tens to hundreds of kilometres for most radars.

These distances are considered too large to assure compatibility between outside WAIC systems and radiodetermination radars in the frequency band 5 350-5 460 MHz for practical operational scenarios.

A-5.4 Radiodetermination radar impact assessment on the operation of inside wireless avionic intra-communication systems

The methodology applied for calculating the minimum required separation distances to protect inside WAIC systems operating co-frequency with radiodetermination radars in the frequency band 5 350-5 460 MHz is provided in Annex 2 of this Report.

An additional attenuation value of 30 dB due to the fuselage has been applied considering transmitters installed in the lower lobe of aircraft fuselage in accordance with Report ITU-R M.2283.

The resulting minimum separation distances are provided in Table A-5.3.

TABLE A-5.3

**Minimum separation distances to protect inside wireless avionics
intra-communication systems from radiodetermination radar
in the frequency band 5 350-5 460 MHz**

Radar	Required separation distance (km)			
	Main lobe coupling		Side lobe coupling	
	Low rate WAIC	High rate WAIC	Low rate WAIC	High rate WAIC
A	29	23	1.5	1.2
B	9	7	0.9	0.7
D	1.6	1.3	0.03	0.03
F	32	26	1.8	1.5
J	6	9	0.6	0.9
L	634	511	63	51
M	83	67	8	7
N	93	75	7	6
O	67	97	5	8
Q	6	9	0.3	0.3
S	0.8	0.8	0.04	0.04

Analysis of the results presented in Table A-5.3 shows that in case of main lobe coupling minimum separation distances for internal WAIC systems would remain from hundreds of meters to more than hundreds of kilometres.

Even in case of side lobe coupling, required minimum separation distances are in the order of several kilometres to several tens of kilometres.

These distances are considered too large to assure compatibility between inside WAIC systems and radiodetermination radars in the frequency band 5 350-5 460 MHz for practical operational scenarios.

A-5.5 Conclusions

Based on the results of the study above, it can be concluded that the frequency band 5 350-5 460 MHz is not an appropriate candidate frequency band for implementation of outside or inside WAIC systems.