REPORT ITU-R M.2121

Guidelines for AM(R)S sharing studies in the 960-1 164 MHz band

(2007)

1 Introduction

Current aviation communication bands are severely congested and further pressured by the introduction of new aviation applications and security requirements. In addition, recent experience has shown that evolving technology for navigation and surveillance may necessitate allocations that are more encompassing than simply aeronautical radionavigation service (ARNS).

Based on available studies, two distinct categories of AM(R)S spectrum are required. The first – for surface applications at airports including data links – is distinguished by a high data throughput, however only moderate transmission distances and it is expected that single frequency resources can be shared at multiple geographic locations. The second category, like the current very high frequency (VHF) AM(R)S, will require longer propagation distances (e.g. out to radio line-of-sight), moderate bandwidth, and a number of distinct channels to allow for sector-to-sector assignments. This report deals with the latter category, and initial estimates of potential spectrum requirements have been determined taking into account evolving aeronautical applications, and integration of a new system on an aircraft. For the 960-1 164 MHz band, that estimate is that approximately 60 MHz will be required.

The 960-1 164 MHz band is allocated to ARNS in all Regions on a primary basis. Even though overall in the band 960-1 164 MHz the usage is generally high, in the sub-bands 960-977 and 1 143-1 164 MHz usage by International Civil Aviation Organization (ICAO) Standard systems is relatively low. The band 960-1 164 MHz is also occupied by different systems that are either operated on a nationally coordinated or on a non-interference basis.

Compatibility with existing or planned aeronautical systems operating in accordance with international aeronautical standards will be ensured by ICAO. In some countries in Region 1, the frequency band 960-1 164 MHz is also used by systems in aeronautical radionavigation service for which no ICAO Standards and Recommended Practices (SARPs) have been developed. Studies regarding compatibility between AM(R)S and these systems need to be undertaken in the ITU-R.

This document presents status on ongoing studies within national administrations, ICAO and ITU-R aimed at:

a) defining the assumptions and key characteristics for an aeronautical future communication system (FCS) operating in the considered AM(R)S spectrum allocation in the band 960-1 164 MHz.

b) considering the topic of the FCS compatibility with services (as defined in the ITU-R radio regulations) operating in the adjacent bands below 960 and above 1 164 MHz.

c) supporting the WRC CPM draft resolution text aiming at adding an AM(R)S allocation in the band 960-1 164 MHz, without constraining in any way the operations and the development of systems operating under ARNS in accordance with ICAO standards and recommended practices.

2 Current use of the band

The 960-1 215 MHz band is an ARNS band that is reserved and protected for aeronautical navigation services. This band is already used by many civil aeronautical systems: DME, SSR, GNSS signals etc. There is also the universal access transceiver (UAT) datalink system that will operate in the future on the 978 MHz frequency. Other systems also operate within this band on a nationally-coordinated basis.

Distance measuring equipment (DME)

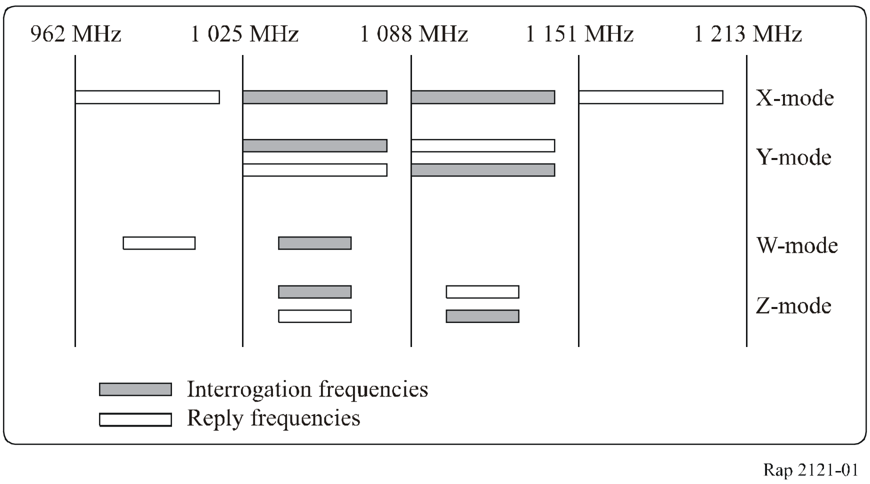
The DME system is an ICAO standardized pulse-ranging system for aircrafts. It allows for the determination of the slant range between an aircraft and known ground locations. A DME ground station may be combined with a collocated VOR, ILS or MLS system to form a single facility. When this is done, the DME frequency is paired with the VOR, ILS or MLS frequency according to ICAO provisions.

The DME onboard interrogator obtains a distance measurement by transmitting pulse pairs and waiting for pulse pairs replies from the ground beacon. Each pulse pair is returned by the transponder after a fixed delay. Based on the measured propagation delay, the aircraft interrogator equipment calculates the distance (slant range) from the transponder to its current location. Pulses have a half-amplitude duration of 3.5 µs and pulse pair spacing depends on the mode. There are four DME modes (X, Y, W and Z) but currently modes W and Z are not used.

DME frequencies are spaced in 1 MHz increments throughout the 962 to 1 213 MHz band. Interrogation frequencies are contained within the band 1 025 to 1 150 MHz, and reply frequencies from the beacon are on paired channels located either 63 MHz below or above the corresponding interrogation frequency. Figure 1 depicts the standard DME/TACAN channel plan. Note that secondary surveillance radar (SSR) and ACAS operate on the frequencies 1 030 and 1 090 MHz, so DME channels lying near those frequencies, and the corresponding ground reply frequencies are not used. Note this frequency plan is also valid for the TACAN system that is described below.

FIGURE 1

Standard DME/TACAN Channel Plan



Secondary surveillance radars (SSR)

ATC secondary surveillance systems (SSR) Mode A, Mode C, and Mode S are cooperative radars that operate by interrogating transponders onboard suitably equipped aircrafts.

Ground stations interrogate on a frequency of 1 030 MHz and aircraft respond on 1 090 MHz. Because of the aircraft active response, SSRs typically operate at much lower power levels, a few hundreds of watts, compared to primary radars, several thousand of watts. Mode S equipped SSRs interrogate aircraft individually using differential phase shift keying (DPSK).

The airborne collision avoidance system (ACAS) interrogates SSR transponders onboard nearby aircraft on 1030 MHz. Then, this system processes replies transmitted at 1090 MHz to provide the collision avoidance function.

Universal access transceiver (UAT)

The ICAO standard UAT system supports automatic dependent surveillance – broadcast (ADS-B) data transmission as well as ground uplink services such as traffic information service – broadcast (TIS-B) and flight information service – broadcast (FIS-B).

UAT employs TDMA technique on a single wideband channel of 1 MHz at a frequency of transmission of 978 MHz. Transmissions from individual aircrafts are composed of a single short burst, of duration 276 µs (basic message) or 420 µs (long message), that is transmitted each second. Ground uplink transmissions occur also once per second and lasts 4452 µs. The modulation employed is a binary continuous phase frequency shift keying (CPFSK) at a 1.042 Mbit/s rate and modulation index is not less than 0.6.

1 090 extended squitter (1090ES)

1 090 MHz extended squitter transmissions from Mode S transponders or other non-transponder devices are used to broadcast information relating to position of aircraft, aerodrome surface vehicles, fixed obstacles and/or other related information. The broadcast can be received by airborne or ground based receivers and can contain ADS-B and/or TIS-B messages.

GNSS

Global Navigation Satellite System (GNSS) signals will be transmitted in the coming years within the 1 164-1 215 MHz RNSS frequency band that is included in the 960-1 215 MHz ARNS band. Examples include the Galileo E5 signal, that is composed of both the Galileo E5a signal transmitted at 1 176.45 MHz and the Galileo E5b signal broadcast at 1 207.14 MHz, the GPS L5 signal also transmitted at 1 176.45 MHz, and GLONASS also transmitting an L5 signal at several nominal frequencies in the band 1 197,648 - 1 213,875 MHz. These signals are expected to be used by Civil Aviation for Safety-of-Life applications. ICAO is undertaking standardization of those signals and preliminary susceptibility levels have been proposed. DME operations are protected from GNSS by Resolution 609 (WRC-03) procedures and agreements.

National systems (NS)

One example of a nationally-coordinated system operating in portions of the 960-1 215 MHz band is an advanced radio system that provides information distribution, position location and identification capabilities in an integrated form. This system is not ARNS, therefore it operates under constraints that are set on national basis to avoid interference with existing air traffic control equipment that operate within the same frequency band.

Non ICAO-standard ARNS systems

The Tactical Air Navigation (TACAN) system was designed primarily for military use. A TACAN transponder consists of a DME transponder and an associated bearing antenna. This antenna rotates or scans, enabling an aircraft to estimate its bearing with respect to the transponder. Ranging information is also estimated by the airborne TACAN receiver thanks to the DME transponder. This system operates on the same frequencies and with the same channel separations than those of DME.

In addition, in a number of countries the band 960-1 164 MHz is used by other non ICAO-standard systems operating in the aeronautical radionavigation service. These systems are used to support navigation (e.g., radio systems of short range navigation (RSBN)) and air traffic control functions

2.1 Interference scenarios to consider

To perform the compatibility analysis, one can use the classic "*source-path-receiver*" methodology. This requires collecting information on the following three elements:

– *Potential interference sources* (location, antenna characteristics, transmitted power, operating frequency, waveform type etc.). In our study, the potential interference source is the FCS.

– *Interference-victim receiver encounter scenario* (distance between interference and victim receiver antenna, victim receiver antenna characteristics etc.).

– *Receiver performance in presence of interference* (susceptibility values depending on the interference type).

Once that information is available, link analyses can be performed. There are multiple potential outcomes of these analyses, e.g. the maximum allowable unwanted emissions by a potential interference source or the minimum separation distances between the interference source and the victim receiver.

The compatibility scenarios that must be analyzed include those listed below. For each of them, the "source-path-receiver "methodology may be applied.

– *Co-site compatibility*. FCS transmissions from an aircraft will be sensed by aeronautical receivers onboard the same aircraft. Co-site compatibility is likely to be one of the driving compatibilities given the close spatial proximity of equipments and the close frequency proximity of systems.

– *Air-to-ground compatibility.* FCS transmissions from aircraft will be sensed by aeronautical ground stations. In a worst-case approach, minimum separation distances between the aircraft and ground-based stations must be assumed. These minimum distances depend on the current phase of flight of the aircraft.

– *Ground-to-ground compatibility.* Uplink transmissions from FCS ground stations will be sensed by ground stations. One of the outcomes of this item will be the minimum separation distance between the involved ground stations.

– *Ground-to-air compatibility.* Uplink transmissions from FCS ground stations will be sensed by airborne receivers. Same comments than for the air-to-ground compatibility.

– *Air-to-air compatibility.* FCS transmissions from aircraft will be sensed by aeronautical receivers onboard a nearby aircraft. For this case, minimum separation distances are given by applicable ATC standards.

2.2 Analysis

Temporally speaking, one has to distinguish between continuous and bursted-type communication signals, e.g. TDMA structure. Then, from a frequency standpoint, narrow band and wideband signals must be considered separately. Wideband signals are assumed to be signals whose spectrum is flat over the victim receiver passband.

The emissions of the FCS in adjacent bands will consist of out-of-band emissions and spurious emissions such as intermodulation products. Note the FCS cannot generate any harmonics within the 960-1 215 MHz frequency band given the small frequency separation between the involved systems. Assuming the FCS equipment transmit on multiple frequencies, intermodulation products will have to be considered.

Continuous signal

If FCS equipment broadcast continuous signals, then out-of-band emissions will likely result in an increase of wideband background noise in passbands of victim receivers.

Regarding co-channel compatibility, if the spectrum of the FCS is large as compared to the victim receiver passband then continuous wideband susceptibilities may be applicable. In any case dedicated study through simulations or experiments may be required.

Bursted-type signal

If the FCS employs a TDMA structure, victim receivers may consequently receive burst-type interfering signals. For adjacent-band compatibility, out-of-band emissions will likely appear as bursts of background noise within the receiver passband. Typical bursts durations could range from about hundreds of microseconds to a few milliseconds depending on the signal bandwidth and the amount of data to be transmitted.

Moreover, because of the rise and fall times of bursts, time-domain transient peaks are expected within the victim receivers passbands. Those transient peaks must be accounted for as they may be harmful to receivers. For instance they could lead to early RF component saturation.

2.3 Interference reduction

There are multiple ways to reduce the impact of the future aeronautical communication system on other systems. Some possible examples to be considered are listed below:

Signal spectrum design

The spectrum of the signal can be carefully selected so as to limit the occupied bandwidth to the most efficient value as well as to limit the level of the components emitted in the outer parts of the spectrum, i.e. unwanted emissions. To do so, compliance with Recommendation ITU-R SM.329-9 is advised. For instance, nulls of the spectrum may be chosen on the UAT and DME equipment frequencies. An interesting modulation is the binary continuous phase frequency shift keying (CPFSK). This CPFSK modulation reduces the level of side lobes as well as constraining the passband.

Emission filter

The emission filter should also be chosen carefully to limit the amplitudes of spectrum components present in outer parts of the spectrum. Regarding spurious emissions, Recommendation ITU-R SM.329-9 should be applied. State-of-the-art in technology, and economic constraints should also be accounted for when selecting the emission filter.

Signal polarization

The signal polarization may be chosen to include, if possible, polarization losses at the other (victim) systems.

Antenna isolation

The on-board isolation between the FCS and other systems antennas should be carefully studied as it will allow reduction of unwanted emission levels in victim receivers passbands. One typical isolation value is 40 dB for on-board aeronautical systems.

Mutual suppression system

If deemed necessary, the FCS may be connected onboard to a mutual suppression system in order to prevent mutual interference with other systems. However, the operational impact of the disruption of critical data transmission by the FCS, such as ATC data, should be further assessed.

3 AM(R)S/FCS compatibility analysis with respect to in-band systems

a) Compatibility with SSR and its derivatives (Mode S and ACAS) operating at 1 030 and 1 090 MHz

b) Compatibility with DME. As noted in Fig. 1, below 1 030 MHz DME is limited to only ground transmitters, while above that frequency both airborne and ground DME transmitters must be considered.

c) Compatibility with international systems that are outside ICAO standards (e.g. NS or non-ICAO-standard ARNS systems)

d) Compatibility with ADS-B systems such as UAT and 1090 ES.

4 AM(R)S/FCS compatibility analysis with respect to adjacent bands

Within ITU-R compatibility verification should be accomplished with respect to systems operating in adjacent bands. In particular, this would include the mobile communication systems operating in the mobile service below 960 MHz. In addition, FCS compatibility with services and systems operating in the band 1 164-1 215 MHz should be required.