

## RECOMMENDATION ITU-R SM.1535-0\*, \*\*

**The protection of safety services from unwanted emissions**

(2001)

**Scope**

This Recommendation serves as a basis for mitigation techniques to protect safety services by minimizing harmful interference from unwanted emissions.

**Keywords**

Safety system, unwanted emissions, mitigation, aeronautical services

The ITU Radiocommunication Assembly,

*considering*

- a) that, in some cases, safety services and services employing high-power transmitters have been allocated to adjacent or nearby frequency bands;
- b) that, in making these allocations, practical transmitter and receiver compatibility may not have been considered;
- c) that No. 1.59 of the Radio Regulations (RR) defines a safety service as any radiocommunication service used permanently or temporarily for the safeguarding of human life and property;
- d) that some radiocommunication services, such as those safety services concerned with safety of life or property, are based on the reception of emissions with a higher probability of integrity and availability than is generally required for other radio services;
- e) that RR No. 1.169 defines harmful interference as interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with the RR;
- f) that RR No. 4.10 recognizes the requirement of radionavigation and other safety services for special measures to ensure their freedom from harmful interference;
- g) that it is important to avoid harmful interference to safety services because of the potential for loss of life and property;
- h) that several footnotes of the RR draw attention to the need for greater availability and priority for safety services in certain bands (e.g. Nos. 5.353A, 5.357A, 5.362A). High-power emissions and emissions from spaceborne or airborne stations can be particularly harmful;
- j) that there are various operational practices and mitigation techniques that can be used by safety services to minimize the impact of interference from other services;
- k) that there are various operational practices and mitigation techniques that can be used to avoid causing harmful interference to the safety services;

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\* This Recommendation should be brought to the attention of Radiocommunication Study Groups 4, 5, 6 and 7.

\*\* Radiocommunication Study Group 1 made editorial amendments to this Recommendation in the years 2018 and 2019 in accordance with Resolution ITU-R 1.

- l) that for spurious domain emissions, general limits specified in RR Appendix 3 may not protect to the desired extent the safety services from interference;
- m) that Recommendation 66 (Rev.WRC-2000) called for ITU-R to “study those frequency bands and instances where, for technical or operational reasons, more stringent spurious emission limits than the general limits in Appendix 3 may be required to protect safety services and passive services such as radio astronomy, and the impact on all concerned services of implementing or not implementing such limits”;
- n) that Recommendation 66 (Rev.WRC-2000) called for ITU-R to “study those frequency bands and instances where, for technical or operational reasons, out-of-band limits may be required to protect safety services and passive services such as radio astronomy, and the impact on all concerned services of implementing or not implementing such limits”;
- o) that suitable measures can be taken to avoid the potential of harmful interference to safety services;
- p) that mobility of aircraft and the large viewing area to which aircraft are exposed, together with variability and uncertainty of the occurrence of harmful interference to safety-of-life aeronautical services may make it necessary to use statistical techniques in conjunction with other techniques to assess harmful interference;
- q) that statistical techniques have been successfully employed in other arenas such as manufacturing quality control and reliability analysis;
- r) that the term “harmful interference” must be construed in the light of the nature of the operations and the safety environment,

*recognizing*

that the RR contain definitions and terminology related to safety services (e.g. Nos. 1.28-1.31, 1.32, 1.33, 1.36, 1.43, 1.44, 1.46, and 1.47: services; Nos. 4.10 and 1.59: general; Nos. 1.166, 1.167, 1.168 and 1.169: interference),

*noting*

- a) that explanations of why safety services may need special attention with respect to interference from out-of-band or spurious emissions are presented in Annex 1;
- b) that safety services can only be defined in terms of safety requirements which seek to show that the system reaches a specified integrity level under all operational conditions of use. In the case of protection requirements it is necessary to demonstrate that a safety system's integrity is not compromised;
- c) that information on the history of compatibility between safety services and other services is likely to be useful,

*recommends*

- 1** that the following measures may be taken to avoid the potential of harmful interference to safety services:
  - 1.1** consultation and exchange of technical and operational information between the relevant parties;
  - 1.2** cooperation on the selection and implementation of the most suitable measures between operators of safety systems and other systems; and
  - 1.3** appropriate spectrum management techniques including unwanted emission limits;

- 2 that the mitigation techniques and measures described in Annex 2 may be used by transmitting systems to avoid harmful interference generated by unwanted emissions, bearing in mind the constraints placed on system design;
- 3 that the mitigation techniques and measures described in Annex 3 may be used by safety services to reduce or avoid the impact of interference from other services where they do not degrade the performance of safety service equipment;
- 4 that where it is determined to be necessary, more stringent spurious emission limits than the general limits in RR Appendix 3 be used in the frequency bands in Annex 4; special cases may be resolved by using applicable ITU-R Recommendations;
- 5 that the frequency bands listed in Annex 4 are to be considered as those safety service bands where, for technical or operational reasons, out-of-band limits may be used by other services to protect safety services;
- 6 that the level of harmful interference for safety-of-life systems should be determined on a case-by-case basis in the form of a safety analysis. This analysis would assess the use being made of the safety system and demonstrate that the specified integrity level is still maintained under all operational conditions;
- 7 that the determination of quantitative threshold levels of harmful interference of the various aeronautical mobile services may include the examination of the operation and the appropriate safety criteria as described in Annexes 5 and 6.

## ANNEX 1

### **Protection of safety services**

Safety services are radiocommunications services used for safeguarding human life and property. For example, all aeronautical operational and air traffic control and many maritime communications are fundamentally safety of life. The systems, including radionavigation systems and radionavigation satellite systems, used for safety of life often depend on the ability to detect a weak or distant signal where interference can critically affect reception. This means special protection may be required for safety services as stated in RR No. 4.10, because of the criticality of protecting life and property. The necessity for safety systems to detect weak signals makes it important that these systems operate in an environment free from harmful interference. The international radio regulatory authorities recognize that special protection is required for the safety services. In view of the importance of safety systems and their vulnerability to interference, RR Article 31 specifically prohibits any emission causing harmful interference to distress and safety communications on any of the discrete frequencies identified at RR Appendices 13 and 15. Furthermore, in addition to the general spurious emission limits specified in the RR, specific standards or applicable ITU-R Recommendations are required to protect some safety services. Some examples are

Recommendations ITU-R M.218, ITU-R M.441, ITU-R M.589, ITU-R M.690, ITU-R M.1088, ITU-R M.1233, ITU-R M.1234, ITU-R M.1313, ITU-R M.1317, ITU-R M.1318, ITU-R M.1343, ITU-R M.1371, ITU-R M.1460, ITU-R M.1461, ITU-R M.1463, ITU-R M.1464, ITU-R M.1478, ITU-R S.1342, ITU-R SM.1009 and ITU-R SM.1051.

## **1 Aeronautical systems**

For international civil aviation, specific safety standards are specified in International Civil Aviation Organization's (ICAO) Standards and Recommended Practices, Annex 10 to the Convention on International Civil Aviation. ICAO states "The Radio Regulations also have a major concern with the prevention of interference of all kinds, whether between services or regions, between assignments, or from other sources of radiation such as industrial or medical equipment. Particular attention is accorded to services where there is a predominant safety-of-life function, as in aeronautical services."

In the design of aeronautical communications, navigation, and surveillance (CNS) systems, the attributes of spectrum efficiency and robustness of system operation (e.g. adequate link margin, resistance to interference, minimal failure modes) often will be in conflict. When this is the case, it should be recognized that robustness of system design must be given priority due to the safety-critical nature of aeronautical CNS systems.

## **2 Space-based distress alerting and location systems**

Distress and safety systems operating in space stations with sensitive receivers are particularly vulnerable to interference from terrestrial and space-based emitters. Systems such as Cospas-Sarsat utilize low altitude Earth orbit satellites which have fields of view of millions of square kilometres and geostationary Earth orbit satellites which view approximately 1/3 of the Earth's surface. These satellites receive distress signals from low-power satellite emergency position-indicating radio beacons (EPIRBs) and are vulnerable to interference. Interference to Cospas-Sarsat in the band 406-406.1 MHz has been shown to originate from equipment in adjacent and near-adjacent bands as well as from transmitters with broadband modulation characteristics operating at frequencies as much as 20 MHz away from 406 MHz. The out-of-band and spurious emissions from high-power systems that use pulse and digital modulation techniques can be at levels that completely mask reception of EPIRB transmissions.

### **2.1 Cospas-Sarsat protection requirements**

ITU has approved Recommendations that:

- identify protection requirements for Cospas-Sarsat search and rescue processors operating in the 406-406.1 MHz frequency band; and
- provide guidance for detecting and eliminating harmful interference in the 406-406.1 MHz frequency band.

Specifically, Recommendation ITU-R M.1478 – Protection criteria for Cospas-Sarsat search and rescue processors in the band 406-406.1 MHz – establishes the maximum acceptable broadband signal spectral power flux-density threshold level at the input to the satellite antenna as  $-198.6 \text{ dB(W/(m}^2 \cdot \text{Hz))}$ . This Recommendation also establishes that narrow-band spurious emissions should not exceed  $-185.8 \text{ dB(W/m}^2)$  at the input to the Sarsat antenna. Recommendation ITU-R SM.1051 provides information on principles of EPIRB detection and location, the processing of 406 MHz interfering signals, harmful interference levels, and procedures for locating/eliminating harmful interference.

## ANNEX 2

### **Mitigation techniques and measures that may be used at the transmitter**

Several possible mitigation techniques have been described in ITU-R Recommendations, such as Recommendation ITU-R SM.328, which may have direct relevance to the categories listed below:

#### **1 Practical hardware and system measures to be considered at an early stage in the design of systems in order to reduce interference from unwanted emissions**

- Transmitter architecture.
- Design of the output power amplifier to avoid spectral regrowth of the signal into adjacent channels, or intermodulation.
- Use of components that operate with linear characteristics to the extent possible.
- Analysis and/or simulations to determine that ageing of transmitter components will not produce interference to distress and safety systems during the operational life of the transmitter.
- Design of the modulation process to avoid unwanted emissions.
- Antenna patterns.
- Power control.

#### **2 Traffic loading management**

Traffic loading management is the modification or reduction of potential interference source emissions during situations (time or scenarios) where harmful interference could result if no such reduction occurred. It is felt, in many cases, that the likely traffic considerations to determine whether the potential for interference could occur would need to be included in the overall compatibility assessment. Also felt, as a general comment, traffic loading management of the potential interference source for the purpose of protecting a safety service is not thought to be workable due to the high level of integrity required for such protection.

### 3 Band utilization

- One way to avoid co-channel harmful interference is to make optimum use of frequency reuse.
- Geographic and frequency separations are standard methods of precluding harmful interference.
- Safety services are more easily protected from harmful interference due to unwanted emissions when they are allocated frequency bands for their exclusive use.
- Space-based distress alerting and location systems have sensitive receivers and the following considerations should be addressed when planning new systems or upgrading old systems:
  - Proposed protection bandwidths must account for Doppler shifts due to relative motion between the transmitter and receiving space station. This is especially important when the transmitter is also located in space.
  - Special consideration must be given to the impact of out-of-band and spurious emissions from systems employing pulse, spread spectrum, and other broadband modulation techniques. These types of systems can cause interference when the transmitter frequency is relatively near in frequency to the safety system carrier frequency.
- Desensitization of amplifiers can occur when both the safety and non-safety systems are located in close spatial proximity. A potential for burnout of low noise amplifiers also exists where, e.g. orbital geometries are such that the safety and non-safety systems are in close proximity.
- Applicable ITU-R Recommendations identifying harmful interference levels to safety systems should be used as aids to establish proper frequency separation between safety and non-safety systems.

### 4 Guard channels

Channel 16 in the marine band has been protected in the past by providing vacant channels either side of the distress and safety calling and working channels. For example, in the past channels 15 and 17 were not used in order to avoid interference to channel 16. RR Appendix 18 includes protection for channel 16 by footnotes encouraging the use of low-power operation and on-board communications on channels 15, 75, 76 and 17. The use of guardbands in allocations adjacent to safety services can help to mitigate interference.

### 5 Monitoring

Reports of interference can be used to determine the type of interference or service received to determine whether the problem is to be resolved by local or international monitoring stations.

Monitoring of spectrum by mobile monitoring teams and electromagnetic compatibility (EMC) laboratories can be used to supplement the fixed monitoring facilities.

## **6 Transmit inhibit**

Operating procedures may be established whereby the transmitter is inhibited when the radiation mainbeam is in the field of view of a safety service system.

# **ANNEX 3**

## **Mitigation techniques and measures that may be used by safety services to minimize harmful interference from other services**

Mitigation techniques vary for different services and systems. Not all of the techniques listed below are suitable in all cases. For example, some communications and surveillance systems used by civil aviation have frequency diversity and signal processing. However, other techniques such as tailoring the antenna pattern or beam-tilting may limit the performance of some aeronautical safety systems and would not be appropriate.

### **1 Receiver architecture**

Improved RF selectivity will reduce unwanted signals outside of the tuned bandwidth. Double superheterodyne design will give both good image and adjacent channel rejection performance.

### **2 Site-shielding**

Mesh fences and suitable use of local topography can provide attenuation to interfering signals.

### **3 Operational measures**

The use of correct operational procedures, where appropriate, can help minimize the sources of interference.

### **4 Error correction and interleaving**

The use of error correction coding and interleaving techniques may improve the performance of digital systems in the presence of unwanted signals.

### **5 Frequency diversity**

Where a number of frequencies are available for use at any time, two or more frequencies may be transmitted simultaneously. Signals can be either combined at the receiver or the strongest signal is selected. It should be noted that this technique is, however, spectrally inefficient.

## **6 Space diversity**

Weak signals are enhanced by the use of antennas separated in space with their outputs combined at the receiver.

## **7 Beam down-tilt**

Not only can the interfering signal be reduced by as much as 3 dB (even co-channel) but also penetration can be increased. Antenna techniques such as null fill have been used to provide a better quality service.

## **8 Antenna pattern**

Corner reflectors and other directional antennas can be used to tailor the service area of interest and minimize interference from outside the service area.

## **9 Signal processing (radar)**

Recommendation ITU-R M.1372 – Efficient use of the radio spectrum by radar stations in the radiodetermination service, provides some of the methods that can be used to enhance spectrum efficiency of radar systems operating in radiodetermination bands. Several receiver post-detection interference suppression techniques currently used in radionavigation, radiolocation and meteorological radars are addressed along with system performance trade-offs (limitations) associated with the interference suppression techniques.

## **10 RF filtering**

Notch filtering has successfully been used in the past to protect hyperbolic navigation systems such as Loran from harmful interference. This type of filtering can easily be used to attenuate large power signals nearby the wanted signal. Other types of filtering, such as band pass filtering etc., could also be usefully employed, where only a few channels or bands are of interest. These techniques can be applied to both transmitters and receivers.

## **11 Time division multiple access (TDMA)/ frequency division multiple access (FDMA) systems**

Time and frequency multiplexing systems can offer greater immunity to some types of interference than asynchronous and large bandwidth systems.

## **12 Digitally coded squelch (DCS)/continuous tone control signalling system (CTCSS)**

A receiver using this technique is only activated when traffic is intended for that particular unit.



### 13 Monitoring

The Cospas-Sarsat system has the ability to locate many types of interfering signals. This capability has been implemented at numerous ground stations and the information is routinely reported to administrations and ITU. An example of spectrum monitoring procedures is given in Recommendation ITU-R SM.1051.

### 14 Traffic loading management

Traffic loading management can be accomplished in different ways. One way is to set up a priority and pre-emption scheme. In other words, when all available communications channels are in use by non-safety messages, messages with a higher priority will pre-empt the lower priority messages. This technique can be used within the network of a satellite system carrying non-safety mobile-satellite service communications and safety communications of the aeronautical mobile-satellite (R) service (AMS(R)S) and the global maritime distress and safety system (GMDSS). A trunking system that carries safety communications may use priority and pre-emption when a control channel is employed.

### 15 Adaptive power control

A mobile transmitter's power may be automatically adjusted. This technique has practical limitations.

## ANNEX 4

### Relevant frequency bands for safety services

This Annex lists frequency bands that have been identified as being used for safety services. Some other bands under the control of national administrations may be in use for safety services, but these may not be included in the list.

| Frequency band  | Brief description of safety use  |
|-----------------|--|
| 70-130 kHz      | Hyperbolic phase comparison  |
| 90-110 kHz      | Hyperbolic time difference LORAN-C                                     |
| 190-535 kHz     | Non-directional beacons, NAVTEX  |
| 275-335 kHz     | Digital global navigation satellite system (DGNSS),<br>hyperbolic RANA |
| 1 625-1 635 kHz | Hyperbolic phase comparison TORAN                                      |
| 1 800-1 810 kHz | Hyperbolic phase comparison TORAN                                      |
| 2 160-2 170 kHz | Hyperbolic phase comparison TORAN                                      |

| <b>Frequency band</b>                   | <b>Brief description of safety use</b>   |
|---|--|
| 2.1-28 MHz<br>(various bands)           | Aeronautical mobile (R) and (OR) service and GMDSS communications in accordance with RR Article 5  |
| 74.8-75.2 MHz                           | Instrument landing system (ILS) marker beacon  |
| 108-118 MHz                             | Radionavigation aids – VHF omnidirectional range, ILS localizer, terrestrial augmentation for the radionavigation-satellite service (RNSS)   |
| 118-137 MHz                             | Aeronautical safety communications   |
| 121.45-121.55 MHz                       | Distress beacons: Cospas-Sarsat and aeronautical emergency location  |
| 156-162 MHz                             | GMDSS maritime communications, automatic identification system   |
| 242.95-243.05 MHz                       | Distress beacons: Cospas-Sarsat and aeronautical emergency location  |
| 225-328.6 MHz                           | Air-to-ground and ground-to-air safety communications  |
| 328.6-335.4 MHz                         | ILS glide slope  |
| 335.4-400 MHz                           | Air-to-ground and ground-to-air safety communications  |
| 406.00-406.10 MHz                       | Distress beacon Cospas-Sarsat (Earth-to-space), GMDSS  |
| 960-1 215 MHz                           | Aeronautical radionavigation aids – distance measuring equipment, tactical air navigation, radar beacons, secondary surveillance radar, airborne collision avoidance system, radionavigation satellite systems |
| 1 215-1 400 MHz                         | Aeronautical radar   |
| 1 215-1 260 MHz                         | Radionavigation satellite systems  |
| 1 525-1 559 MHz (space-to-Earth)        | Mobile satellite distress and safety communications (GMDSS and AMS(R)S)  |
| 1 544-1 545 MHz (space-to-Earth)        | EPIRB GMDSS  |
| 1 559-1 610 MHz                         | Radionavigation satellite systems, terrestrial and satellite-based augmentations for satellite navigation systems  |
| 1 626.5-1 660.5 MHz<br>(Earth-to-space) | Mobile satellite distress and safety communications (GMDSS and AMS(R)S)  |
| 1 645.5-1 646.5 MHz<br>(Earth-to-space) | EPIRB GMDSS  |
| 2 700-3 300 MHz                         | Radar (shipborne, land-based, aeronautical and weather, RACON, and airborne transponders)  |
| 4 200-4 400 MHz                         | Airborne radio altimeter   |

| Frequency band  | Brief description of safety use   |
|-----------------|---|
| 5 000-5 250 MHz | Microwave landing system (MLS), radionavigation satellite systems   |
| 5 350-5 650 MHz | Radar beacons, airborne and weather radar   |
| 8 750-8 850 MHz | Airborne Doppler navigation aids (radar)  |
| 8 900-9 280 MHz | Land-based radar, aeronautical radar  |
| 9 200-9 500 MHz | Radar (shipborne), radar beacons and target enhancers, airborne and land-based weather radar, aeronautical ground-based radar, search and rescue transponders |
| 13.25-13.4 GHz  | Airborne Doppler navigation aids (radar)  |
| 15.4-16.4 GHz   | Airport surface detection equipment, weather radar, aircraft landing system, radar sensing and measurement system   |

## ANNEX 5

### Factors that should be considered when establishing protection criteria for aeronautical safety services

#### 1 Introduction

For the purposes of this Annex, electromagnetic noise or noise is defined as all electromagnetic energy from both intentional and unintentional radiators, except from a desired signal for a specific system of interest.

Existing and proposed protection criteria, sometimes referred to as maximum permissible interfering signals, maximum permitted interfering field strengths, or noise limits, are often stated in the following manner:

$$N (\mu\text{V/m}) \text{ at } 30 \text{ m for the frequency band } 108\text{-}112 \text{ MHz}$$

This type of statement may be insufficient in itself as it fails to consider a number of pertinent factors, some of which will be identified in Section 2.

#### 2 Specific factors

**2.1** The conditions for the field strength measurement of the interfering signal should be stated. Failure to specify the conditions for field strength measurements, such as the receiver bandwidth (e.g. 10 kHz, 100 kHz or 1 MHz, 3 dB, 6 dB, or effective impulse bandwidth), receiver detector characteristics, calibration techniques, type of antenna used, polarization and antenna height above ground, leaves the method of measurement open to interpretation; this could then result in erroneous conclusions and inability to compare with data obtained by other experts.

**2.2** Systematic and random measurement errors result from errors in instruments and their calibrating sources and from errors in test set-up and measurement procedures. Error problems also exist because electromagnetic interference problems are often probabilistic, rather than deterministic, in nature. The method of error analysis in the development of parameter limits becomes important where regulatory aspects must be considered.

**2.3** Interference prediction techniques, noise models and communication system models are currently under development or refinement by a number of administrations, educational institutes, and industrial research organizations. A non-exhaustive list of noise measurement parameters and techniques used includes:

- average voltage ( $V_{avg}$ );
- root-mean-square voltage ( $V_{rms}$ );
- quasi-peak voltage ( $V_{qp}$ ) (both International Special Committee on Radio Interference (CISPR) and American National Standards Institute (ANSI));
- peak voltage ( $V_p$ );
- impulsiveness ratio:  $V_d = 20 \log (V_{rms}/V_{avg})$ ;
- effective antenna noise factor ( $F_a$ );
- mean noise power ( $P_n$ );
- amplitude probability distribution (APD);
- noise amplitude distribution (NAD);
- average crossing rate (ACR).

Some of these parameters are useful principally as means of detecting the presence or absence of unwanted emissions from some area or object. Ideally, the emission or radiation parameter or measurement technique selected should correlate directly to how the noise is degrading the performance of a radio communication or navigation system.

**2.4** A single protection ratio covering all noise sources within a fixed frequency band may not be realistic. Such a protection ratio may fail to take into account the characteristics of the noise (that is, whether the noise is continuous wave, Gaussian, random or impulsive). Noise sources may have to be broken down into groups such as power lines, industrial-scientific-medical apparatus and ignition systems, with protection ratios defined for each of these groups.

**2.5** The time characteristic of the noise is an important consideration. Depending on the grade of service required, a noise source that exceeds the protection criterion only 0.5% of the time may have to be treated differently from a noise source that exceeds this criterion 95% of the time.

**2.6** Protection criteria may be required to take into account variations in radio communication and navigation equipment performance. One approach may include the determination of susceptibility of radio communication and navigation systems to man-made noise and the establishment of parameters and levels that describe the noise that these systems can withstand without degradation in performance.

**2.7** Where the sources of noise are manufactured in quantity, control of their radio frequency emission limits may be affected by statistical sampling tests (e.g. CISPR test method). Such tests may only give guarantees that a certain proportion of the manufactured items conform to a stated limit. A detailed examination of the statistical sampling test may therefore be necessary to establish whether the statistical guarantees are compatible with the particular protection required.

**2.8** For the protection of aeronautical safety services it may not be realistic to formulate protection ratios based on field strength measurements made at or near ground level when, in the real world, aircraft fly over noise sources. An examination of available literature has shown that in some cases, noise levels at a given distance measured laterally from a noise source are lower than those measured at the same distance above the noise source. In addition, aircraft in flight could be subjected to noise from many possible sources; although the noise produced by one source may be of little consequence, the effect of many such sources could be significant. It should be noted that aircraft in flight regularly experience unwanted signals that are not detected by ground monitoring.

Considering the mobility of aircraft and the large viewing area to which aircraft are exposed, together with the variability and uncertainty of assessing and controlling harmful interference to safety-of-life services, the impracticability becomes obvious of accurately accounting for all of the signal characteristics of the unwanted signal sources that aircraft may encounter. Nevertheless, these factors must be accommodated if the high reliability of civil air transport is to be maintained. One method of accommodating these factors is by including compensation in the form of a margin added to the protection ratios.

## ANNEX 6

### **General safety criteria from the viewpoint of the aeronautical services**

#### **1 Background**

The ITU definition of harmful interference is contained in RR No. 1.169. The term “harmful interference” must be construed in the light of the nature of the operations and the safety environment. This leads directly to the conclusion that the determination of quantitative threshold levels of harmful interference for the various aeronautical mobile radiocommunication services requires the examination of the appropriate safety criteria.

#### **2 Aeronautical and non-aeronautical sources of harmful interference**

In identifying harmful interference to a particular radio service, it is usually necessary to understand the nature and variations of the interference, which could have serious implications. This would apply particularly to those environments where there is a multitude of potential interfering sources, possibly of more than one type, and where the aggregate harmful interferences at any particular point, therefore, could be expected to vary with time.

An important aspect of the study of harmful interference is the determination of whether or not the criteria for harmful interference from non-aeronautical sources has, or should have, any relationship with the technical planning criteria established in the aeronautical services for co-channel and adjacent channel assignments. Frequency assignment planning criteria adopted internationally within the aeronautical services are based on practical considerations which take into account the operational usage of the particular service. In addition, the planning criteria are based, reasonably enough, on the premise that mutual cooperation and internationally agreed aviation standards and procedures are used by everyone involved. It is a point of fact that the contracting States of ICAO are under certain obligations relative to the adoption of aeronautical standards, recommended practices, and procedures, as set forth in Article 38 of the Convention on International Civil Aviation (Chicago, 1944). Pursuant to these obligations, there is a highly developed international information and registration service which ensures that all aviation facilities and their frequency protected service volumes are formally promulgated and available on charts in accordance with Annex 15 to the Convention on International Civil Aviation; and appropriate information from this service becomes part of aircraft flight deck documentation. Thus, in respect of all technical protection criteria adopted in the international civil aviation community against aeronautical-to-aeronautical harmful interference, there is comprehensive and significant additional protection provided through the organizational structure of international civil aviation, with ICAO at its focal point.

The additional protection indicated in the above paragraph is largely non-existent for non-aeronautical sources of harmful interference to aviation, some of which are only partially regulated by the ITU. Consequently, there is not necessarily an inherent relationship between aeronautical protection criteria and those criteria which may be appropriate to safety services for application to non-aeronautical sources of harmful interference. Each potential non-aeronautical source of harmful interference requires individual consideration in this respect.

The following external sources of man-made emissions and radiations are known to have caused harmful interference to aeronautical services:

- broadcasting, LF/MF AM and VHF FM;
- cable distribution systems;
- power line distribution systems;
- industrial, medical, and scientific equipment;
- local oscillator emission from domestic electronic equipment;
- non-licensed devices;
- satellite uplinks.

It should be observed that some of the above are not under the direct purview of ITU, and therefore, cooperation may be necessary between ITU, ICAO, and other concerned organizations.

### **3 Shared allocations**

A safety service must take considerable precautions to ensure that any radio service sharing the same radio band is constrained sufficiently to leave an adequate margin under all likely circumstances so that the aggregate harmful interference never exceeds the required protection criteria.

The constraints of weight, size and power consumption placed upon airborne equipment have resulted in relatively low-powered transmitters and sensitive receivers, which is consistent with general ITU guidance for efficient and effective use of the radio spectrum. Nonetheless, the above constraints may cause difficulties for the aeronautical community to mitigate against interference when it arises. For instance, the wanted signal at the edge of a VHF communications service volume must be at a certain level to meet ICAO standards and recommended practices. For an aircraft, the wanted field strength could be equalled or exceeded by an unwanted signal source on the ground. Thus caution should be exercised before considering any sharing involving the aeronautical radiocommunication services.

### **4 Aeronautical radiocommunication systems**

Precise details of aeronautical radiocommunication systems are contained in Annex 10 to the Convention on International Civil Aviation. However, Annex 10 does not contain standards for primary radars. Synopses of the systems are given below:

#### **4.1 Non-directional beacons (NDB) (LF/MF)**

Although NDBs may appear similar to VHF omnidirectional radio range (VOR) in concept, there are significant practical differences in their usage. NDBs are more widely implemented than VORs and are frequently used by smaller aircraft, which are, in some cases, not equipped to utilize VORs. NDBs are also frequently used to guide and establish aircraft on flight paths that enable them to acquire more accurate VHF aids (VOR, ILS, etc.) as part of the approach procedure. In this use, they are also known as locators. In addition, the airborne equipment used in association with NDBs is simpler in concept and is less able to cope with interference than more sophisticated airborne equipment. The basic simplicity of the system makes it less able to distinguish between true NDB signals and unwanted emissions near or within the channel passband. In particular, an overhead beacon indication on the aircraft flight deck can be falsely provided under certain conditions by interfering signals.

Interference to NDBs is an important issue in the aviation world, because many NDBs are in radio bands which are shared with other users in some parts of the world, and in addition, these bands are sometimes highly congested. Protection criteria against harmful interference must take these facts into consideration.

## 4.2 HF and VHF digital data interchange and analogue radiotelephony

Air/ground digital data interchange or analogue radiotelephony constitute a direct link between an aircraft in flight and aeronautical stations on the ground. The number of aircraft flying simultaneously in any given airspace and the multiplicity of air routes flown, result in a complex set of rules and procedures to ensure the safety of air operations. While it is true that interference to air/ground radiotelephony communications is relatively easier to detect, in as much as the pilot can hear it and is normally less likely to be misled, than in the case of interference to digital data interchange or to a radionavigation aid, such interference may nonetheless have serious consequences, particularly for aircraft contacting approach control of an airport while flying at positions where the ground clearance is of the order of a few hundred feet. Thus, regardless of adherence to precise phraseology and to other standard operational procedures, cases have arisen where even a slight interference to a single phrase has resulted in catastrophic consequences.

The conversion of the above factors into quantitative protection ratio criteria is a difficult task. On the one hand there is general acceptance of the view that some minimum interference to voice communications could normally be accepted, but on the other hand, it needs to be recognized that under difficult operational circumstances, errors that would normally be accepted can assume great significance, and under these circumstances an interference-free service can be vital.

## 4.3 VOR

The VOR system consists of a ground-based beacon radiating an omnidirectional signal providing directional guidance in the horizontal plane in such a manner that the airborne system provides an accurate indication of the compass bearing from the aircraft to the beacon. The system also provides identification signals and allows for voice transmission. The beacon transmits modulated continuous wave (CW) signals continuously and can serve simultaneously any number of suitably fitted aircraft. The service volume of some *en route* facilities can extend beyond 300 km.

Most VOR-installations provide *en route* service, often in association with distance measuring equipment (DME). In addition, certain low-power VOR-installations are used as holding or approach aids in the vicinity of aerodromes. With respect to the bearing function, interference to VOR can manifest itself as false bearing information to the aircrew and/or automatic flight control system, and this interference would directly impinge on the safety of the flight. The degree of the effect of the interference would depend on its type, strength and duration. In the low-powered VOR cases, even lower levels of interference could be critical to the operation of the aircraft, but fortunately, the service volumes concerned are relatively small. Compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-137 MHz is addressed in Recommendation ITU-R SM.1009.



#### 4.4 VHF emergency frequencies

The RR and Annex 10 to the Convention on International Civil Aviation contain special provisions for the use and protection of the aeronautical mobile emergency frequency 121.5 MHz. Subsequently, the ICAO has agreed on special procedures for monitoring these frequencies while, in addition, the Cospas-Sarsat system provides for essential alerting capabilities. Also, EPIRBs, compulsory in some countries for carriage on board aircraft, operate on these frequencies. It is important that reception of distress and emergency transmissions will not be impaired. These frequencies are also used by other services for communications with the aeronautical services in the event of an emergency.

#### 4.5 ILS (VHF and UHF)

The ILS consists of a localizer (VHF) providing lateral guidance for aircraft to the airport runway, a glide-path (UHF) providing the line of descent in the vertical plane, and one, two, or three marker beacons providing the aircraft with height and distance checks at known points from the runway threshold. One or more locators or other supplementary approach aids such as VOR may be used in conjunction with the ILS to assist in guiding aircraft to the on-course radio beams. Each of the above components of the ILS performs a different function and hence it can be seen that these components do not provide any form of redundancy for each other.

In the approach and landing phase of flight, when the aircraft is manoeuvring in close proximity to the ground, it is essential that harmful interference to any of the radio aids in use during this phase of flight be kept at an extremely low level of probability of occurrence. It is particularly relevant to note in this regard that the use of automatic landing systems which utilize ILS guidance signals, is the normal operating procedure for modern large aircraft, regardless of weather conditions. It should be noted that the very high level of protection against harmful interference required to support such operations is only needed within fairly constrained volumes of airspace around the ILS installations, e.g. around aerodromes. This factor may be helpful when considering the practical issues involved in protection against harmful interference.

Due to its critical nature considerable investigation of interference to ILS has been carried out and compatibility between the sound-broadcasting service in the band of about 87-108 MHz and the aeronautical services in the band 108-137 MHz is addressed in Recommendation ITU-R SM.1009.

#### 4.6 DME (UHF)

The DME system utilizes coded digital transmissions providing the aircraft with accurate slant-range distance measurements to ground-based beacon positions. The beacon transmits in response to an interrogation from an aircraft, and although the coded interrogation and reply offers a measure of interference protection, the system can become saturated when many aircraft are within range of a beacon. Under these circumstances, interference could be detrimental to safety.

DMEs are most often used in conjunction with VORs to provide international short-range navigational facilities. However, some DMEs are used in association with ILS, and consequently these circumstances may require special provisions to ensure adequate protection against harmful interference.

It is also important to recognize that DME frequency assignments are paired by international agreement with a VOR or ILS or MLS frequency. Consequently, frequency protection considerations need to be satisfied simultaneously on all of the paired frequencies.

#### 4.7 Global navigation satellite system (GNSS)

The ICAO GNSS Panel is developing the first space-based navigation system for global civil aviation. It is called the GNSS. It is made up of the two satellite constellations, the U.S. global positioning system (GPS) and the Russian Federation global navigation satellite system (GLONASS). Each of the constellations is made up of twenty-four satellites in medium earth orbit. Each satellite transmits one signal in the frequency band 1 559-1 610 MHz. These signals are received directly by aviation receivers on-board aircraft. The signals are then processed to determine the precise location in three-dimensional space.

The signals are adequate for *en route* navigation worldwide. They may also be used for precision approach and landing when augmented by either a space based augmentation system (SBAS) or a ground based augmentation system (GBAS), also being developed by the GNSS Panel. The GBAS augmentation signal uses frequencies in the 108-118 MHz band.

The satellite signals are received at very low levels, therefore they may be susceptible to harmful interference. However, it should be noted that there would be significant processing gain in the demodulation process, as the signals are direct sequence spread spectrum. Thus, special measures may be necessary to protect these receivers from emitters both on-board the aircraft and external to it for aviation uses of GNSS, particularly when used for approach, landing, and taxiing. Special measures to control spurious emissions from ground-based sources are contained in ITU-R Recommendations, e.g. Recommendation ITU-R M.1343. Such measures may have to be applied in order to protect the GNSS from cumulative effects of large numbers of individual emitters.

At the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000), the band 1 164-1 215 MHz was allocated for RNSS (space-to-Earth). It is anticipated that developments in the band of new and existing systems will allow aircraft worldwide to calculate positions with accuracies such that augmentation may not be needed for some precision applications, and the augmentation may be greatly reduced for others. In addition, new signals will increase availability and robustness of the RNSS systems.

#### 4.8 MLS

The MLS provides similar guidance information to a landing aircraft as does ILS. The system provides a single frequency signal in the 5 GHz band giving both azimuth and elevation guidance. MLS has some distinct advantages over ILS as it has been designed to be less susceptible to multipath. Due to this, MLS may allow the use of a landing aid on a runway or at an airport where previously ILS could not be used due to the local multipath environment. MLS may also increase

runway capacity due to the reduced separation required between a landing aircraft and any further ahead in the approach or those aircraft already on the ground. MLS also offers alternatives to the straight line approach path provided by ILS which may provide operational advantages to aircraft operators by allowing curved approaches to a runway.

Similar comments to those made under the ILS section on interference protection also apply. A methodology for determining the coordination distance between MLS operating in the band 5 030-5 091 MHz and feeder links of the mobile-satellite service operating in the band 5 091-5 150 MHz is contained in Recommendation ITU-R S.1342.

#### **4.9 Radars**

Radar for aeronautical purposes can take many forms with widely varying characteristics and operational usages, e.g. long-range air traffic surveillance, radar altimeters, secondary surveillance radar, very short-range aerodrome surface surveillance, airborne weather detection and navigational assistance.

It is not possible to provide a universal interference assessment to cover these variations, and therefore, each case needs to be considered separately. However, it is worthy of note that regardless of the transmission characteristics employed, it is quite normal for the reception requirements of a radar system to be, necessarily, highly sensitive and thus capable of detecting low levels of unwanted signals.

Sophisticated processing techniques can sometimes be used to alleviate some types of interference, but these techniques are not practicable universally, and under some operational conditions are not acceptable.

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