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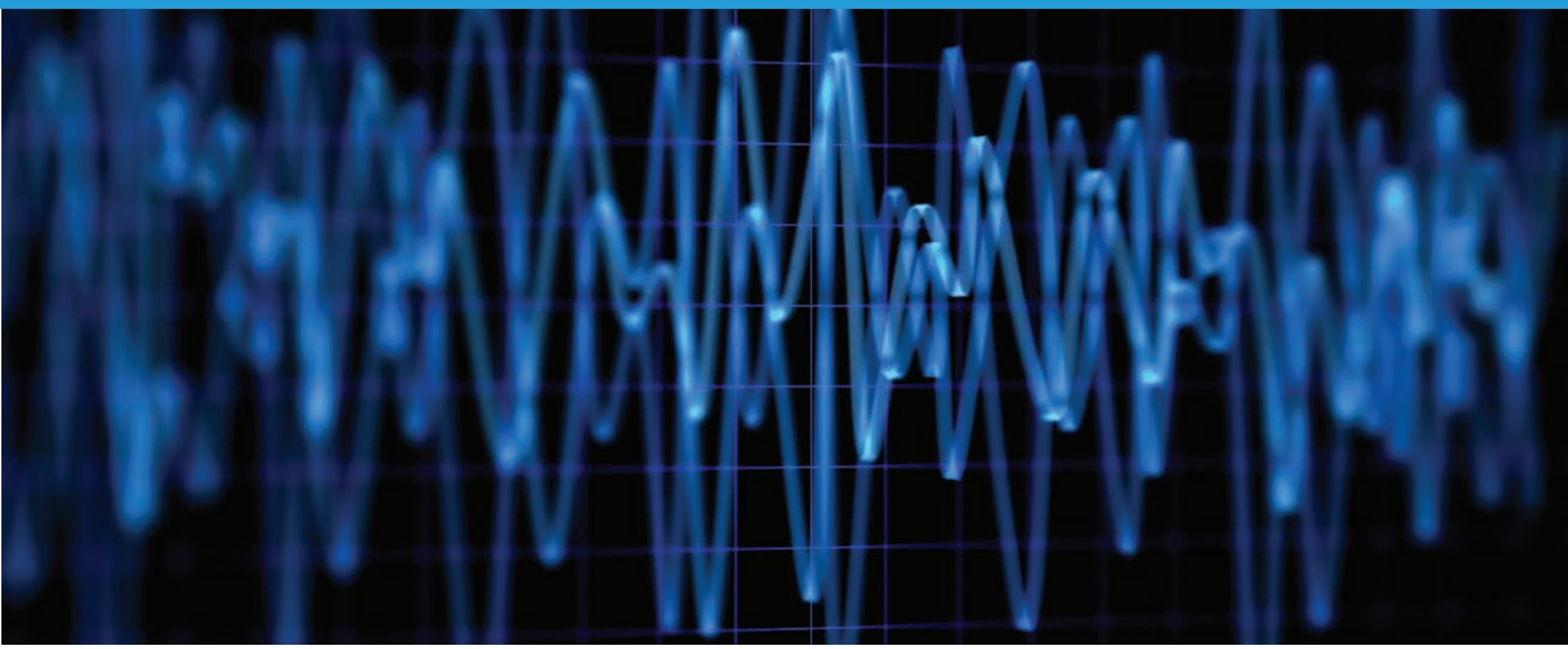
Doc 9718

Handbook on Radio Frequency Spectrum Requirements for Civil Aviation

Volume II — Frequency assignment planning criteria for aeronautical radio communication and navigation systems

Second Edition, 2022



Approved by and published under the authority of the Secretary General

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No.	Date	Entered by

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FOREWORD

Background and purpose

Volume II of the *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation* presents frequency assignment planning criteria for aeronautical radio communication and navigation systems.

This material was developed in response to requests from the ICAO Regions to provide updated frequency assignment planning criteria that can be implemented on a global basis to ensure that aeronautical radio communication and navigation systems are protected from harmful interference on a uniform basis. The frequency assignment planning criteria were developed by the ICAO Aeronautical Communications Panel and the ICAO Frequency Spectrum Management Panel in cooperation with the ICAO Regional Offices.

Status of the Handbook (Volume II)

This volume contains detailed frequency assignment planning criteria for very high frequency (VHF) air-ground communication systems (voice and data) operating in the frequency band 117.975–137 MHz, instrument landing systems (ILS) (localizer and glide path), VHF omnidirectional range (VOR), distance measuring equipment (DME), ground-based augmentation systems (GBAS) and VHF data broadcast (VDB), supplementing the relevant Standards and Recommended Practices (SARPs) in Annex 10 — *Aeronautical Telecommunications*, in particular Volume V — *Aeronautical Radio Frequency Spectrum Utilization*, and provides guidance for the application of these SARPs. In addition, it also provides the relevant background that led to the development of the detailed frequency assignment planning criteria.

In developing the frequency assignment planning criteria, careful attention was given to the material already available and used in the ICAO Regions and published through the relevant Regional Air Navigation Plans.

Implementation of frequency assignment planning criteria

The material contained in this volume is general in nature and should be applicable in all ICAO Regions. However, implementation in the Regions has to take place through relevant decisions by the Regional Planning and Implementation Groups (PIRGs), which are responsible for amending and updating provisions of the Regional Air Navigation Plans. Specific regional requirements on the use of radio frequencies have been accommodated as much as practicable. Future specific regional requirements can be implemented through relevant regional air navigation agreements and/or incorporated in future revisions to this Handbook.

It should be noted that the coordination of frequency assignments as well as the development of the regional frequency assignment plans fall within the remit of the ICAO Regional Offices and that these Offices should be consulted when amendments to these plans are being considered by ICAO Contracting States.

Note.— In some Regions, for administrative and practical purposes, different coordination mechanisms may be implemented.

Global Plan

The frequency assignment planning criteria as contained herein support the development of globally harmonized frequency assignment plans as elements of the Global Air Navigation Plan (GANP), and the application of these criteria ensures the protection of frequency assignments on a globally harmonized and uniform basis.

Organization of this Handbook (Volume II)

Chapter 1 provides general principles and other material to be used in compatibility analyses of aeronautical radio communication and navigation systems. This material forms the technical basis for the frequency assignment planning criteria and can also be used when assessing compatibility of new systems planned to operate in frequency bands already used for aeronautical purposes.

Chapter 2 contains the background that was used when developing frequency assignment planning criteria for VHF air-ground communication systems (voice and data). This chapter gives due account to regional differences in using the VHF band while maintaining the basic principles for the protection of radio frequencies from harmful interference on the basis of globally accepted principles.

Chapters 3, 4, 5 and 6 contain the principles and guidance material for frequency assignment planning for ILS, VOR, DME and GBAS VDB, respectively.

CONTENTS

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GLOSSARY

Altitude. The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).

Designated operational coverage (DOC). The combination of the designated operational range and the designated operational height (for example, 200 NM/FL500 is the DOC for an aid with a designated operational range of 200 NM and a designated operational height of 50 000 ft.

Designated operational range or height (DOR or DOH). The range or height to which an aid is needed operationally in order to provide a particular service and within which the facility is afforded frequency protection.

Note 1.— The designated value for range or height is determined in accordance with the criteria for the deployment of the aid in question.

Note 2.— The designated value for range or height forms the basis for the technical planning of aids.

DME/N. Distance measuring equipment, primarily serving operational needs of en-route or TMA navigation, where the “N” stands for narrow spectrum characteristics.

DME/P. The distance measuring element of the MLS, where the “P” stands for precise distance measurement. The spectrum characteristics are those of DME/N.

Elevation. The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.

Flight level (FL). A surface of constant atmosphere pressure which is related to a specific pressure datum, 1 013.2 hectopascals (hPa), and is separated from other such surfaces by specific pressure intervals.

Height. The vertical distance of a level, a point or an object considered as a point, measured from a specified datum.

Regional frequency allotment tables. The regional frequency allotment tables are contained in the supplement referenced in this Handbook (Volume II) and published separately. This supplement can be downloaded from the website of the Frequency Spectrum Management Panel at http://www.icao.int/safety/fsmp/documents/doc9718.

ICAO Regional Offices are encouraged to reference these frequency allotment tables in the Regional Air Navigation Plans when implementing the frequency assignment planning criteria, as contained in this Handbook (Volume II), as part of the Regional Air Navigation Plans.

ABBREVIATIONS AND ACRONYMS

ACC	Area control centre
ACR	Adjacent channel rejection
AM(R)S	Aeronautical mobile (route) service
AOC	Aeronautical operational control
AS	Aerodrome surface
ATIS	Automatic terminal information service
D/U	Desired to undesired
DOC	Designated operational coverage
dB	Decibel
dBi	Decibels relative to an isotropic radiator
dBm	Decibels relative to 1 milliWatt
dbW	Decibels relative to 1 Watt
DME	Distance measuring equipment
DSB-AM	Double-Sideband Amplitude Modulation
EIRP	Equivalent isotropically radiated power
EUR	European
FIR	Flight information region
FMG	Frequency Management Group
GP	Glide path
GBAS	Ground-based augmentation system
ILS	Instrument landing system
ITU	International Telecommunication Union
MSL	Mean sea level
RF	Radio frequency
RPDS	Reference path data selector
RSDS	Reference station data selector
SAR	Search and rescue
SARPs	Standards and Recommended Practices
UHF	Ultra high frequency
VDB	VHF data broadcast (used with GBAS)
VDL	VHF digital link
VHF	Very high frequency
VOLMET	Meteorological information for aircraft in flight
VOR	VHF omnidirectional radio range
WRC-12	World Radiocommunication Conference — 2012

Chapter 1

GENERAL METHODOLOGY FOR COMPATIBILITY ANALYSIS

1.1 INTRODUCTION

1.1.1 This chapter describes a general methodology that can be used in the analysis of interference between similar and dissimilar radio systems and provides the procedures for calculating the distance and frequency separation required to prevent harmful interference to systems used by aviation for communication and (radio) navigation purposes.

1.1.2 For a more detailed analysis, taking into account the aeronautical compatibility requirements, the method as described in Recommendation ITU-R SM.337 — *Frequency and distance separations* of the International Telecommunication Union (ITU) may be used in some cases. Also relevant are the provisions of ITU Recommendation ITU-R SM.1535 — *The protection of safety services from unwanted emissions*.

1.1.3 The material in this Handbook (Volume II) can be used only for assessing compatibility between aeronautical radio communication and navigation systems with the conditions as specified in the various chapters.

Note.— Material that can be used for assessing compatibility between non-aeronautical and aeronautical systems is in Doc 9718, Volume I, Chapter 9 and Attachment G.

1.1.4 The frequency assignment planning criteria in this Handbook are only valid for the assumptions as specified. When system implementation is different from these assumptions, a more detailed compatibility analysis is required, taking into account actual system characteristics and radio wave propagation model(s).

1.1.5 Details on the allocation of frequency bands by the ITU are in Doc 9718, Volume I.

1.1.6 The material in this Handbook presents frequency assignment planning criteria for use by States and the Regional Offices when coordinating frequency assignments. Regions or States may supplement this material or use different frequency assignment planning criteria to meet regional requirements.

1.1.7 Frequency assignment planning for aeronautical radio communication and navigation systems is based on the need to provide protection from harmful interference throughout the designated operational coverage.

Note.— This concept excludes the need to provide protection for communication or navigation systems outside the designated operational coverage (DOC) as promulgated by States.

1.2 COMPATIBILITY MODEL

1.2.1 Compatibility assessment

The electromagnetic compatibility of radio equipment should be calculated using the following method:

Step 1: determine the desired signal level (and spectral distribution) at the desired (victim) receiver input;

Step 2: determine the maximum undesired (interfering) signal level (and spectral distribution, including noise) at the desired (victim) receiver input, taking into account the total (desired) receiving system performance requirements as per Annex 10;

Step 3: determine the interactive effects (e.g. the desired to undesired (D/U) ratio) among the desired and undesired signals for various frequency separations, while meeting the total (desired) receiving system performance requirements as per Annex 10. These effects can be determined through actual measurements or through analysis;

Step 4: determine from the data obtained in Step 3, the degree of frequency and/or distance separation required to provide the required level of service, while ensuring that any interference received by the victim receiver is not harmful; and

Step 5: determine, for establishing frequency/distance separation requirements, the appropriate propagation model.

Note.— In all cases, the co-frequency protection requirements have to be assessed, preferably through measurements. The procedures described in Recommendation ITU-R SM.337 would allow, under specific conditions, development of the frequency/distance separation when the interfering signal is not co-frequency with the desired signal while meeting the total system performance requirements.

1.2.2 Protection of the desired signal

1.2.2.1 Protection of the desired signal can be considered along two principles.

1.2.2.1.1 The first principle calculates the actual field strength of both the desired and the undesired signal at the receiver antenna, taking into account the distance to the (desired) transmitter. On the basis of the established D/U ratio, the maximum signal level of the undesired (interfering) signal determines, in turn, the maximum level of the interfering signal, before the interference becomes harmful as shown in formula (4) in 1.2.5. This principle is illustrated in Figure 1-1:

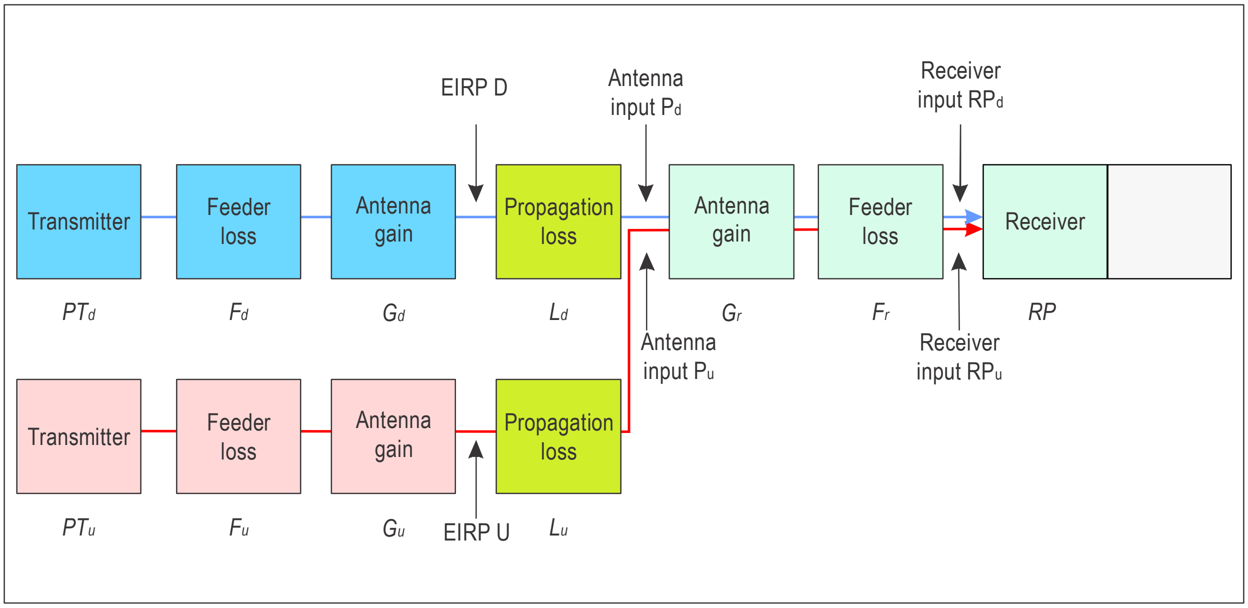

Figure 1-1. Schematic diagram of the complete scenario to be analysed

where:

F_d: feeder loss for the desired transmitter (dB);

F_r: feeder loss of the receiver (dB);

F_u: feeder loss for the undesired transmitter (dB);

G_d: gain of the antenna of the desired transmitter (dBi);

G_r: gain of the receiver antenna (dBi);

G_u: gain of the antenna of the undesired transmitter (dBi);

L_d: transmission loss for the desired signal (dB);

L_u: transmission loss for the undesired signal (dB);

PT_d: output power of the desired transmitter (dBm);

PT_u: output power of the undesired transmitter (dBm);

P_d: power of the desired signal at the antenna of the receiver (dBm);

P_u: power of the undesired signal at the antenna of the receiver (dBm);

RP: power of the signal at the input of the receiver;

RP_d: power of the desired signal at the input of the receiver (dBm); and

RP_u: power of the undesired signal at the input of the receiver (dBm).

1.2.2.1.2 The second principle uses the minimum field strength at the receiver antenna (signal-in-space) as is specified by ICAO for all communication and navigation systems. This minimum field strength has to be ensured throughout the DOC of the facility. Similar to the first principle described in 1.2.2.1.1, on the basis of the established D/U ratio, the maximum signal level of the undesired (interfering) signal can be determined, before the interference becomes harmful. This approach is more appropriate to establish protection throughout the DOC compared to the method in 1.2.2.1.1. This principle is shown in Figure 1-2.

Note.— States are responsible for ensuring that the minimum required field strength, as specified in Annex 10, is maintained throughout the DOC.

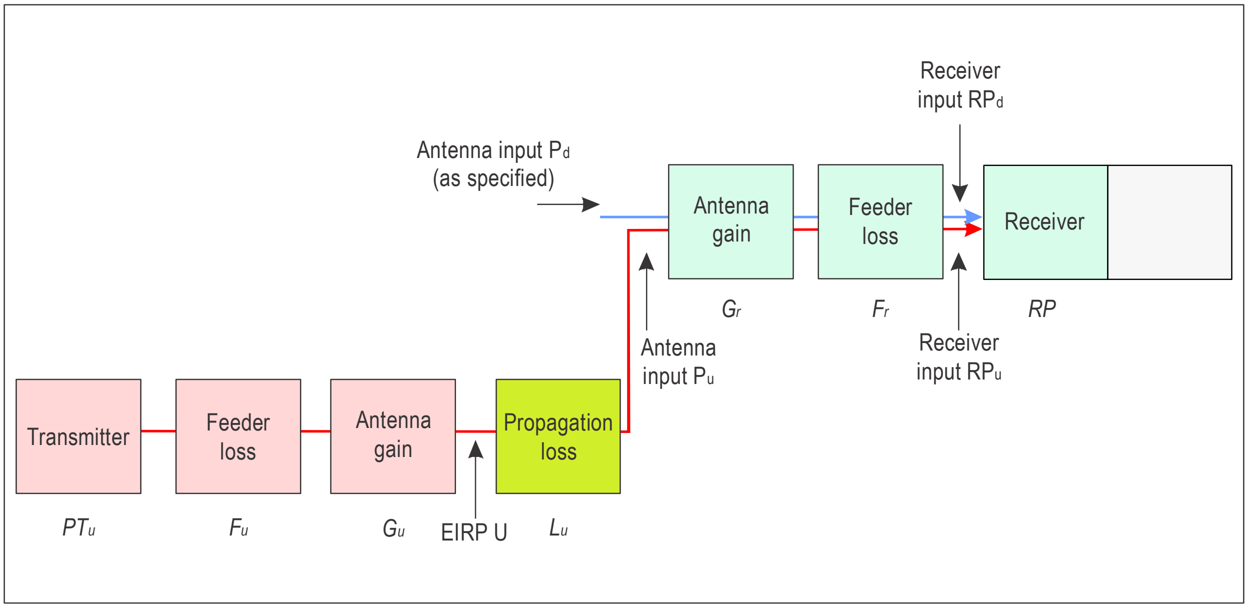

Figure 1-2. Schematic diagram of the minimum signal scenario

1.2.2.1.3 In cases where the interactions between the desired and the undesired signal have not been properly established (e.g. through actual measurements), protection of the desired (aeronautical) signal should be based on ensuring that the undesired signal is well below (6–10 dB) the noise floor of the aeronautical receiver.

1.2.3 Determination of the desired signal at the victim receiver antenna

1.2.3.1 Figure 1-3 illustrates the scenario to be analysed.

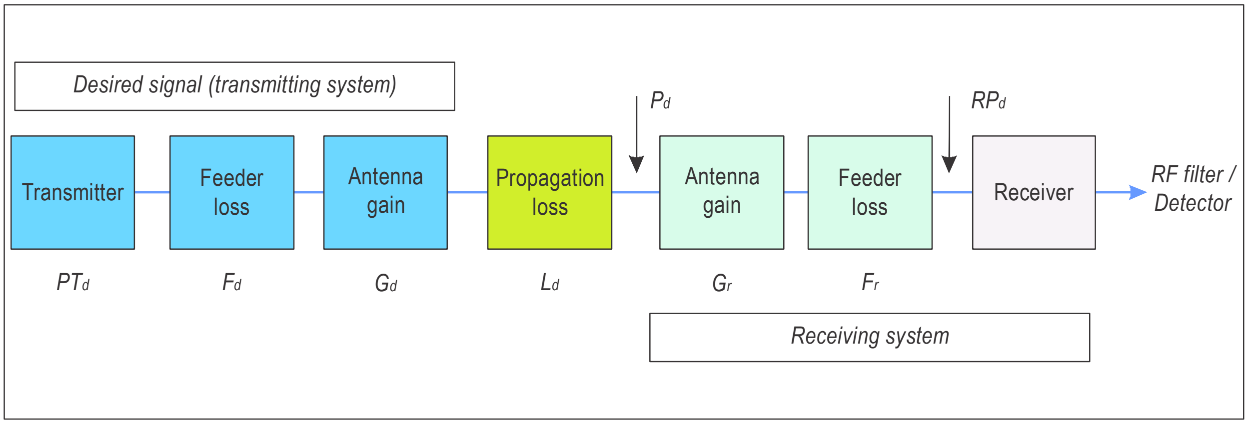

Figure 1-3. Schematic diagram of the desired signal path to the receiving antenna

1.2.3.2 The received power at the antenna of the receiver can be calculated by summing the transmitter power, antenna gains and feeder losses as shown in formula (1):

$$P_d = PT_d - F_d + G_d - L_d \tag{1}$$

where:

PT_d: output power of the desired transmitter (dBm);

F_d: feeder loss for the desired transmitter (dB);

G_d: gain of the antenna of the desired transmitter (dBi);

L_d: transmission loss for the desired signal (dB); and

P_d: power of the desired signal at the antenna of the receiver (dBm).

The transmission loss L_d is calculated in accordance with the appropriate propagation model as developed by the ITU. See 1.3 on using the relevant propagation model to calculate the path loss.

When the minimum desired signal level at the receiver antenna is specified (e.g. in Annex 10, typically in the format of μV/m) and used in compatibility calculations, the scenario as shown in Figure 1-4 applies. In this case, P_d at the antenna of the receiver is the minimum required field strength as specified in the relevant provisions of Annex 10.

This modifies formula (1) into formula (2):

$$P_d = \text{xx dBm} \tag{2}$$

(xx is the minimum field strength as specified by ICAO; for the conversion from μV/m to dBm, see Appendix A).

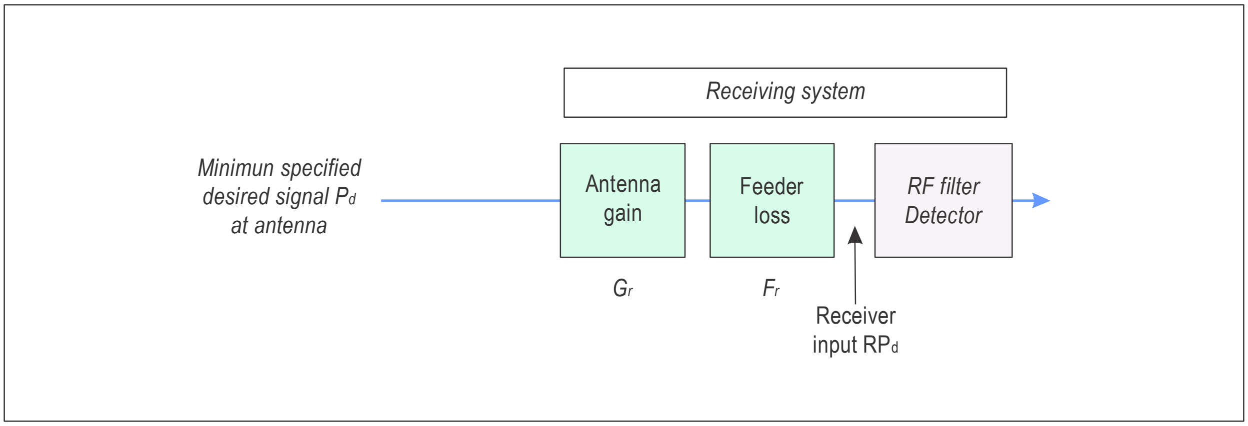

Figure 1-4. Desired signal path when minimum field strength is specified

1.2.4 Calculation of the undesired signal at the victim receiver antenna

Figure 1-5 illustrates the undesired signal path to be analysed.

Note.— The need for calculating the signal level of the undesired signal applies to both principles as identified in 1.2.2.1.1 and 1.2.2.1.2.

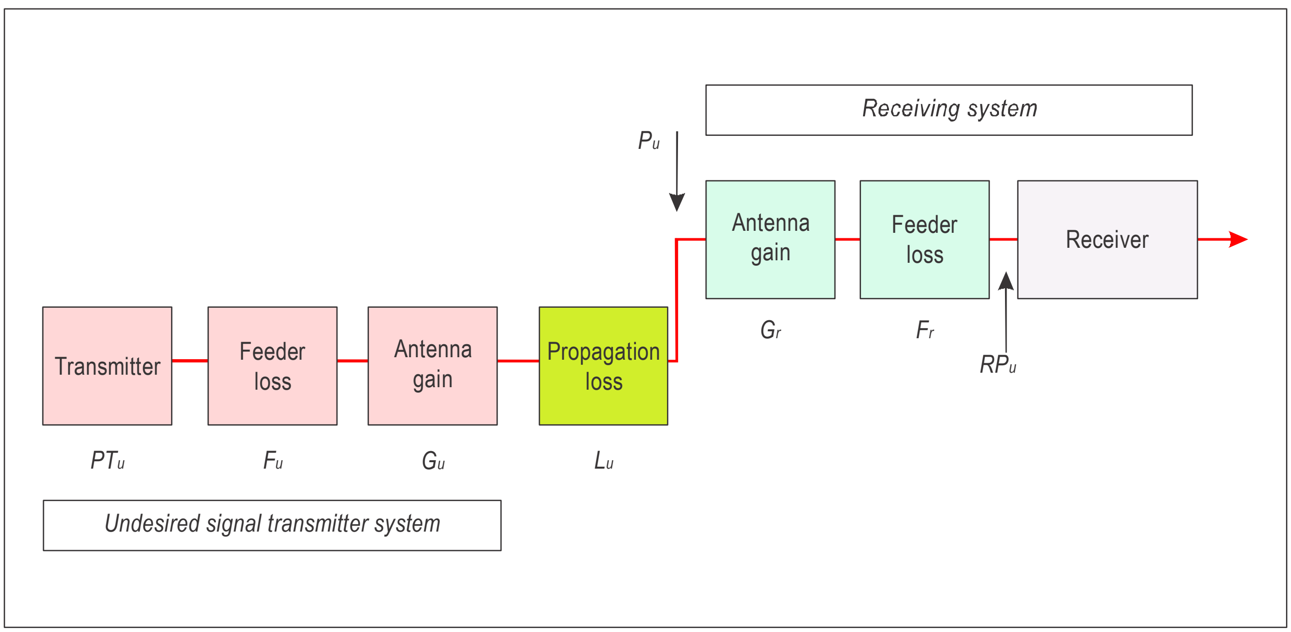

Figure 1-5. Schematic diagram of the undesired signal path

The received power at the input of the receiver antenna can be calculated by summing the various transmitter power, antenna gains and feeder losses as indicated in formula (3):

$$P_u = PT_u - F_u + G_u - L_u \quad (3)$$

where:

F_u: feeder loss for the undesired transmitter (dB);

G_u: gain of the antenna of the undesired transmitter (dBi);

L_u: transmission loss for the undesired signal (dB);

PT_u: output power of the undesired transmitter (dBm); and

P_u: power of the undesired signal at an isotropic equivalent receiver antenna (dBm).

The transmission loss is calculated in accordance with the appropriate propagation model developed by the ITU. See 1.3 on propagation modelling and using the propagation model to calculate the path loss.

1.2.5 D/U ratio

After having calculated the values (or used the relevant ICAO standard value) for the desired signal and the undesired signals at the receiver antenna, these signal levels, in order to protect the desired signal from harmful interference from the undesired signal, need to comply with formula (4):

$$P_d - P_u = D/U \quad (4)$$

where:

P_u: power of the undesired signal at the receiver (dBm);

P_d: power of the desired signal at the receiver (dBm); and

D/U: protection ratio (dB) as required by Annex 10 or established through measurements.

Note.— If the compatibility analysis is for determining compatibility between an aeronautical system and a non-aeronautical system, then a safety margin in the order of 6–10 dB should be added to the required D/U ratio.

1.2.6 The effect of the adjacent channel rejection

When the frequencies are offset (i.e. the frequency of the desired signal differs from that of the undesired signal), the adjacent channel characteristics of the desired receiver will attenuate the desired signal before it is processed in the receiver. The factor with which these signals are attenuated is the adjacent channel rejection (ACR). The ACR is either the ACR as specified by ICAO (typically for intra-system compatibility) or the ACR obtained by measurements (typically for inter-system compatibility).

The power (P_u) at the antenna, as calculated using formula (3) and considering the ACR, becomes for adjacent frequencies:

$$P_u = PT_u - F_u + G_u - L_u - ACR \quad (5)$$

1.2.7 D/U ratio at the receiver input

For both the desired signal and the undesired signal at the receiver antenna, gain (G_r) and receiver feeder losses (F_r) are the same. Therefore, the D/U ratio at the receiver antenna is the same as the D/U ratio at the receiver input.

1.2.8 Interference immunity performance for digital systems

Receiving function — interference immunity performance. The standard measurement technique for digital systems provides that the desired signal field strength be doubled, and that the undesired signal be applied in increasing levels until the channel performance, i.e. the specified error rate, degrades to a value equal to the value found at the specified receiver sensitivity.

1.3 PROPAGATION MODELLING

1.3.1 Introduction

1.3.1.1 The ITU has developed a number of propagation models, some of which are applicable to the study of the frequency assignment planning criteria for aeronautical systems and the protection of those systems from harmful interference from other radio systems that are either sharing the frequency band or operating in an adjacent frequency band.

1.3.1.2 The common propagation models used in aeronautical spectrum studies are described in 1.3.2 to 1.3.4.

1.3.2 Free-space propagation model

1.3.2.1 The free-space propagation model as defined in ITU Recommendation ITU-R P.525 — *Calculation of free-space attenuation*, assumes an ideal propagation path where the transmitter and receiver antennas are considered isotropic antennas located in a perfectly dielectric, homogeneous, isotropic and unlimited environment with no obstructions. The free-space attenuation or transmission loss can be calculated using formula (6):

$$L_{bf} = 20 \log (4\pi d/\lambda) \tag{6}$$

where:

L_{bf}: free-space basic transmission loss (dB);

d: distance; and

λ: wavelength.

Note that d and λ are expressed using the same unit of measurement.

The same formula can be rewritten using the frequency instead of the wavelength:

$$L_{bf} = 32.4 + 20 \log f + 20 \log d \tag{7}$$

where:

f: frequency (MHz); and

d: distance (km);

or

$$L_{bf} = 37.8 + 20 \log f + 20 \log d \qquad (8)$$

where:

f: frequency (MHz); and

d: distance (NM).

1.3.2.2 It should be noted that the propagation of radio waves in the very high frequency (VHF) and ultra-high frequency (UHF) frequency bands is subject to a number of additional conditions compared to the free-space transmission loss. Refraction and ducting, as described below, can extend the range over which this propagation model is applicable.

Note.— The radio refractive index is central to all theories of radio wave propagation through the lower atmosphere. The atmosphere causes a downward curvature of horizontally launched radio waves, which is normally about one quarter of that of the earth. This applies in particular to radio waves propagating in the first kilometre (3 000 ft) above ground. When the propagation path includes trajectories higher than one kilometre, the bending of the radio wave is reduced.

1.3.2.2.1 **Refraction** — Gradual changes in the refractive index of the (standard) atmosphere with altitude causes the bending of radio waves slightly towards (or in some cases away from) the earth. The effect is that radio waves can propagate beyond the physical horizon and can be received up to a distance that is commonly referred to as the radio horizon, as shown in Figure 1-6. Along this path, no (significant) losses other than the free-space propagation loss between the transmitter and the receiver have to be considered. Variations in the refractive index of the atmosphere, however, cause the radio horizon to vary as well. The bending effect of refraction is corrected in radio propagation by calculating the distance to the radio horizon using a 4/3 earth radius. The 4/3 earth radius approximation has been derived based on a standard atmosphere at sea level and is therefore not universally applicable. However, it is widely used and provides a good approximation of the effect of radio path propagation globally.

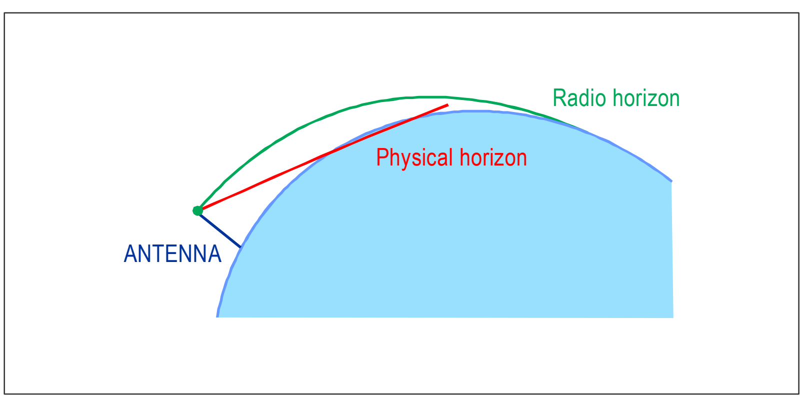

Figure 1-6. Radio horizon versus physical horizon

1.3.2.2.2 **Ducting** — The change in refractive index is normally gradual, but under certain atmospheric conditions a layer of warm air may be trapped above cooler air, often over the surface of water. The result is that the refractive index will decrease far more rapidly with height than is usual. The rapid reduction in refractive index (and therefore dielectric constant) may cause complete bending down, as illustrated in Figure 1-7. The unusual atmospheric condition traps the radio waves in a duct. Extreme bending of the radio waves between the top of the atmospheric duct and reflection of the radio waves from the surface of the earth may propagate the radio waves over extreme long distances (e.g. more than 500 NM). Other phenomena such as sand storms may also cause ducting of radio waves.

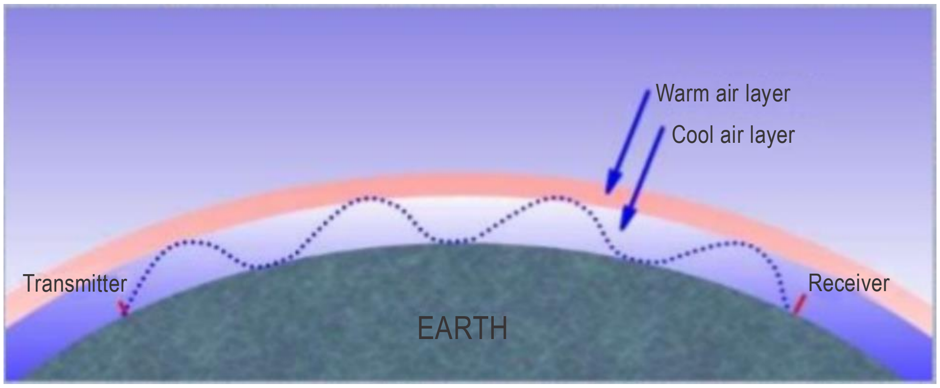

Figure 1-7. Propagation through ducting

1.3.2.2.3 **Sporadic E-layer** — The sporadic E (Es) layer is a layer in the ionospheric E region with a dense electron density and thin altitudinal thickness at altitudes of around 100 km above the earth. Sporadic E propagation bounces signals off smaller "clouds", or “patches”, of an unusually high density of accumulation of metallic ions in the lower E region in the earth’s ionosphere. This occasionally allows for long-distance communication at VHF frequencies not usually well-suited to such communication. Sporadic E-layer propagation has been observed in both the northern hemisphere and southern hemisphere.

1.3.2.2.3.1 These patches can cause anomalous propagation of VHF radio waves by reflecting radio waves that normally penetrate through the ionosphere. Figure 1-7 illustrates anomalous long-distance propagation of VHF radio waves by the Es layer. Signal levels were often observed to propagate over long distances (800–2 000 km) and may be the source of potentially harmful interference. UHF and higher frequencies are not reflected by the Es layer.

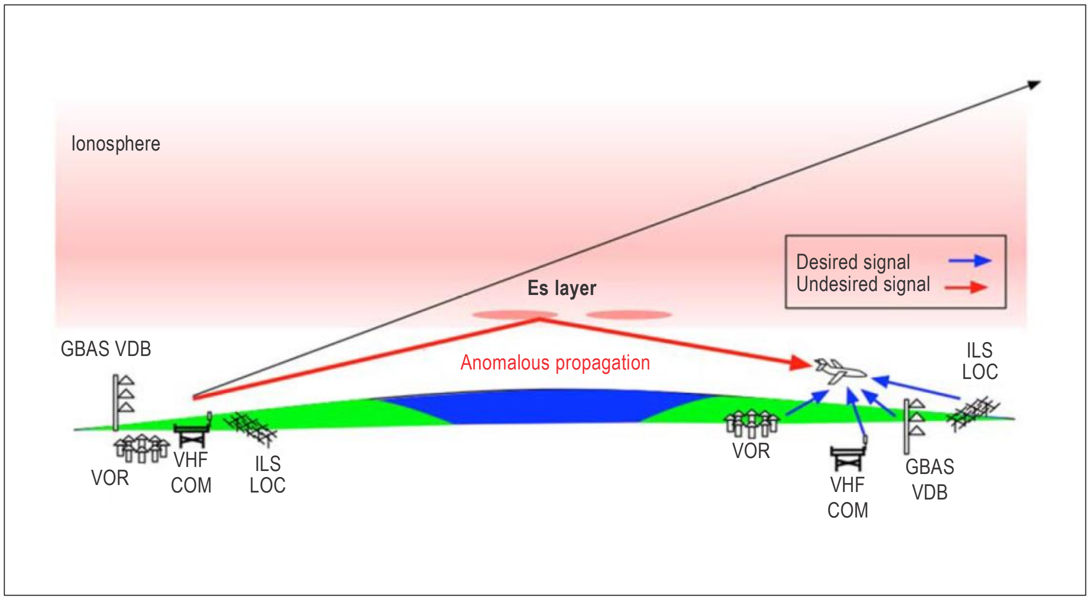

Figure 1-7A.[1] Propagation of VHF radio waves by the sporadic E-layer (Es layer)

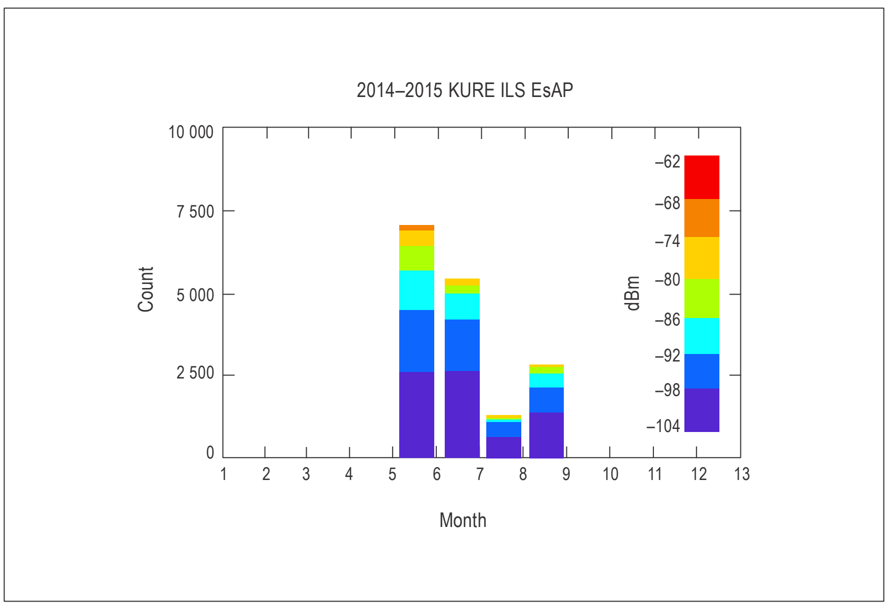

Figure 1-7B.[1] Sporadic E-layer propagation – seasonal variations observed in Japan

1. Sakai, J., Hosokawa, K., Tomizawa, I., & Saito, S. (2019). A statistical study of anomalous VHF propagation due to the sporadic-E layer in the air-navigation band. Radio Science, 54, 426–439. https://doi.org/10.1029/2018RS006781

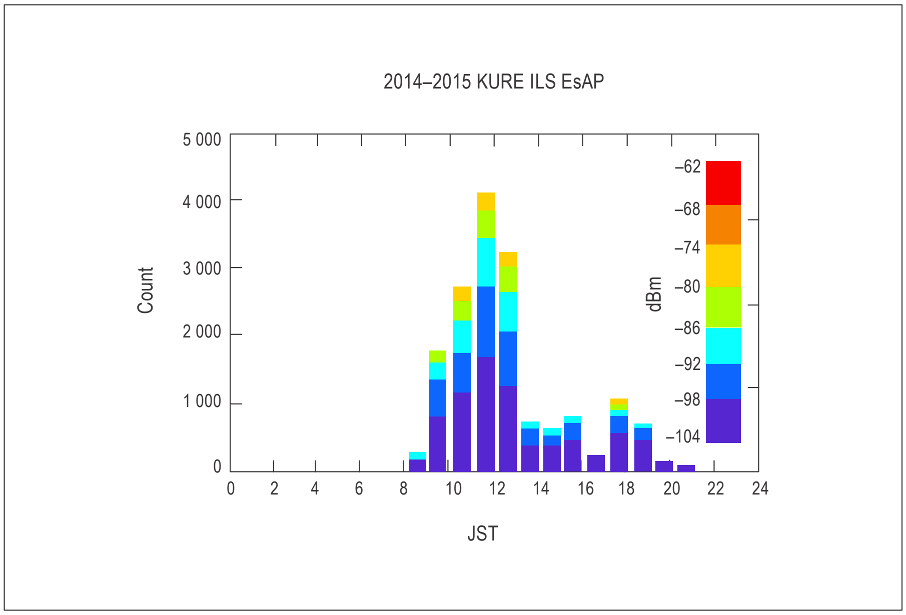

Figure 1-7C.[1] Sporadic E-layer propagation – daily variations observed in Japan

1.3.2.2.3.2 Sporadic E-layer propagation typically shows seasonal variations, with peaks at the summer solstice and smaller peaks at the winter solstice. Daily variations show larger peaks at noon and a secondary peak in the evening.

1.3.2.3 In aeronautical frequency assignment planning, neither variations in the refractive index of the atmosphere (which causes variations in the distance to the radio horizon and effectively modifies the 4/3 factor), nor the effect of ducting are taken into account. In cases where these phenomena cause serious problems, consideration can be given to accommodating different criteria.

1.3.2.4 In the aeronautical standard propagation model, free-space propagation conditions are assumed when the transmitter and the receiver are within the distance to the radio horizon (line-of-(radio) sight).

1.3.2.5 The distance to the radio horizon (4/3 earth radius) can be calculated using equation (9):

$$d_{RH} = 1.23(\sqrt{h_{TX}}) \quad (9)$$

where:

d_{RH}: the distance of the station to the radio horizon (NM); and

h_{Tx}: the height of the transmitter above the earth's surface (ft).

Note.— The same formula can be used to calculate the radio horizon of the receiver by substituting the height of the transmitter with the height of the receiver.

1.3.2.6 In applying formula (9) to both the transmitter and the receiver (e.g. between an airborne transmitter and an airborne receiver), formula (10) can be used for the calculation of the distance to the radio horizon between the transmitter and receiver:

$$d_{RH} = 1.23\left(\sqrt{h_{TX}} + \sqrt{h_{RX}}\right) \quad (10)$$

where:

d_{RH}: the radio horizon separation distance between the transmitter and receiver (NM);

h_{Tx}: the height of the transmitter above the earth's surface (ft); and

h_{Rx}: the height of the receiver above the earth's surface (ft).

1.3.3 Aeronautical propagation curves

1.3.3.1 ITU Recommendation ITU-R P.528-5 — *A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF and SHF bands* contains a method for predicting the transmission loss in the frequency range 125–15 500 MHz[2] for aeronautical and satellite services. The transmission losses presented in these curves are valid for ground-air and air-air radio links. The only data needed to predict the transmission loss are the distance between antennas, the heights of the transmitter and receiver antennas above mean sea level (MSL), the frequency and the time percentage[3] for which the transmission loss is to be determined. Recommendation ITU-R P.528-5 can be downloaded from the ITU website at https://www.itu.int/rec/R-REC-P.528-5-202109-I/en.

1.3.3.2 A description of the development and the application of the curves is in Annex 1 to Recommendation ITU-R P.528-5. The curves are based on data obtained mainly for a continental temperate climate. The curves give the basic transmission loss between ideal loss-free isotropic antennas.

1.3.3.3 These propagation curves are based on empirical data and include actual transmission losses for different time percentage availability. Within the radio horizon and at short distances, these curves are fairly consistent with free-space transmission path losses. Within the region "near" the radio horizon, the transmission loss was calculated using geometric optics to account for interference between the direct ray and a ray reflected from the surface of the earth as well as the increased effect of the ground where the diffraction starts to manifest itself. In general, the transmission losses calculated using Recommendation ITU-R P.528-5 are larger than free-space loss at and beyond the radio line-of-sight.

1.3.3.4 Aeronautical frequency assignment planning is normally based on the curves for 5 per cent of the time for assessing the level of the interfering signal and taking into account the protection of the minimum required field strength of the desired signal from harmful interference.

1.3.3.5 Figure 1-8 provides an example of ITU-R propagation curves for the frequency 108 MHz, a receiving antenna height of 45 000 ft and a transmitter (interferer) antenna height of 20 ft. The curves presented are valid for 5 per cent, 50 per cent and 95 per cent of the time.

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2. An extension of the frequency range for Recommendation ITU-R P.528-5 to include the band 108–124 MHz is in progress. This revision is expected to include material relevant to horizontally polarized radio signals.

3. For example, for the time percentage curve of 5 per cent, the actual transmission loss will be less than the plotted value for 5 per cent of the time.

1.3.3.6 Software for implementing the propagation curves in Recommendation ITU-R P.528-5 can be downloaded at https://github.com/NTIA/p528-gui/releases. This software can be used to generate the propagation curves with the graphical user interface (GUI) and can export the curves in .csv format. This software was developed by the National Telecommunications and Information Administration (NTIA) Institute for Telecommunication Sciences (ITS), based in the United States of America.

1.3.3.7 When using the ITU propagation curves, a determination of the radio horizon in frequency assignment planning is no longer necessary since the curves themselves take this into account.

1.3.3.8 The application of these curves in frequency assignment planning for aeronautical radio navigation systems is described in section 1.5.

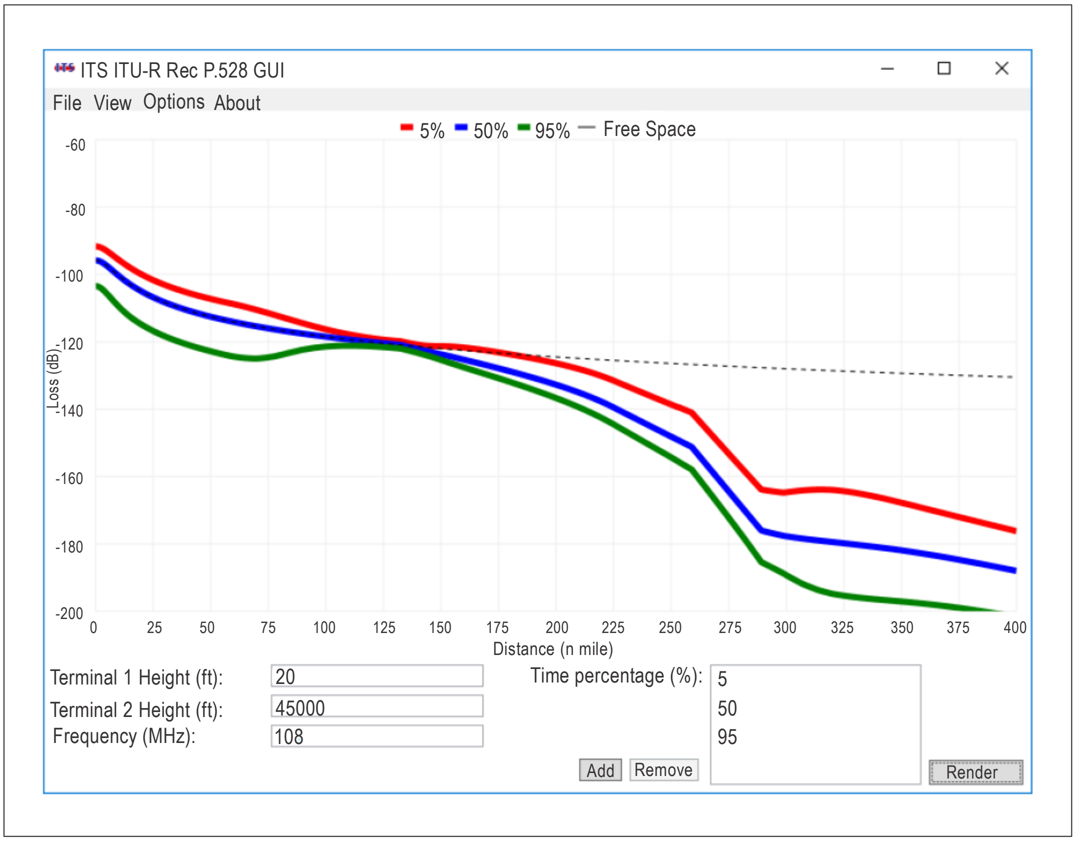

Figure 1-8. ITU-R aeronautical propagation curves for a VOR: receiving antenna height of 45 000 ft and transmitter (interferer) antenna height of 20 ft for 5 per cent, 50 per cent and 95 per cent of the time

1.3.3.9 At about 100 NM, the curve starts to display increased transmission loss (compared to the free-space transmission loss) while still within the radio line-of-sight distance. This is caused by the increased effect of the ground where the effect of the reflected signal starts to manifest itself. At this range, the aircraft is about 4 degrees above the horizontal plane through the transmitter site.

1.3.3.9.1 From the radio line-of-sight distance of 260 NM, a sharp (almost linear) increase in transmission loss is observed. The propagation mode here is propagation by diffraction.

1.3.3.9.2 The propagation curves present the transmission loss for the slant range between the two terminals while keeping Terminal 2 (the aircraft) at a constant altitude. However, at short distances between the two terminals, the aircraft may operate at a lower altitude, which may result in a lower transmission loss. Therefore, an adjustment of the predicted transmission loss at short distances may be appropriate. Figure 1-8A presents the transmission losses at a short distance between the terminals for different altitudes of the aircraft (Terminal 2).

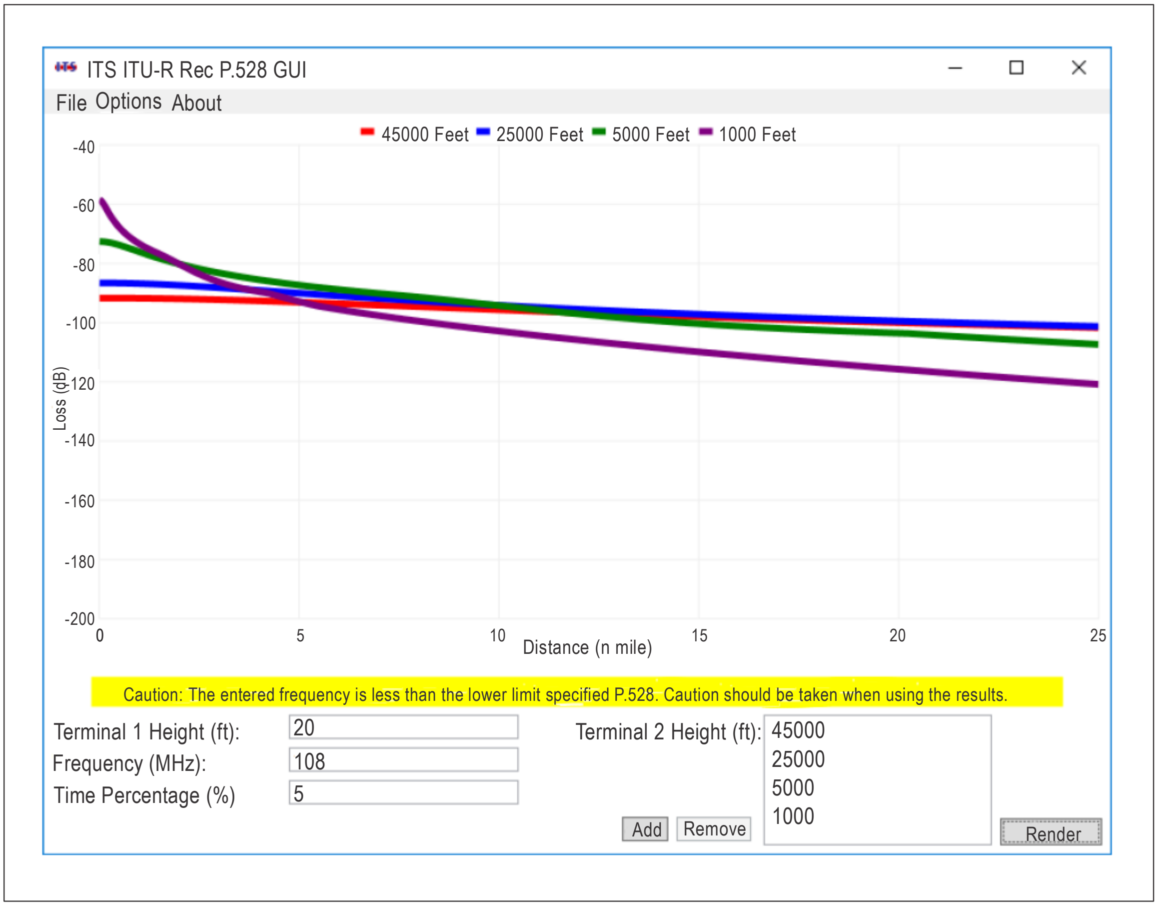

Figure 1-8A. Transmission loss for different altitudes at a short distance between Terminals 1 and 2

1.3.3.9.3 The software developed by the NTIA ITS can be used to estimate the transmission loss for antenna heights (for the undesired Terminal 1 and the desired Terminal 2) down to 5 ft. The transmission loss is calculated taking into account the slant range between the terminals (ground and aircraft).

1.3.3.9.4 Within the range 108–118 MHz, the curves show a small increase in transmission loss with the higher frequency. For example, at 108 MHz and 50 per cent of the time, a transmission loss of 150 dB is achieved at a distance of 256 NM, while the same transmission loss at 118 MHz is achieved at a distance of 155 NM. Or, at a distance of 250 NM, the transmission loss for 108 MHz is 148.17 dB, and for 118 MHz, transmission loss is 148.46 dB (curves for 50 per cent of the time). These differences do not significantly affect the results for calculating the minimum separation distance between a desired and an undesired facility. It is recommended to use the lower frequency of the band 108–117.975 MHz.

1.3.3.9.5 For the frequency range 960–1215 MHz (DME), these values are as follows (50 per cent of the time):

a) transmission loss is 140 dB for 960 MHz at 130 NM and for 1 215 MHz at 103 NM; and

b) transmission loss at 130 NM is for 960 MHz at 140 dB and for 1 215 MHz at 142 dB.

If, in this case, the propagation curve for 960 MHz is used for all DME facilities, this results in a small overprotection of facilities operating close to 1 215 MHz.

1.3.3.9.6 The lower boundary of Recommendation ITU-R P.528-5 is 125 MHz, while that of the GUI provided by the NTIA ITS is 100 MHz.

1.3.4 Calculation of basic transmission loss when both the undesired transmitter and desired receiver are on the ground

1.3.4.1 In certain situations, both the undesired transmitter and the desired (victim) receiver can be located on the ground (e.g. the aircraft is on the surface of the airport and may interfere with a ground receiver station, or a ground transmitter may interfere with an aircraft receiver). In this case, applying free-space transmission loss will result in unrealistic, low transmission losses. More realistic models that may be applied in these cases are either the two-ray (or flat earth) model or the Egli model.

1.3.4.2 *Two-ray or flat earth model*

To calculate the received power taking into account the effect of the ground, the two-ray ground reflection model or flat earth model can be applied using formula (11), which gives a more accurate prediction of the received power compared to the free-space model:

$$P_u = eirp_U + G_R - L_R - L_{pol} - 40\log d + 20\log H_T + 20\log H_R \qquad (11)$$

where:

P_U: received power (dBm) at the receiver input;

$eirp_U$: equivalent isotropically radiated power (EIRP) (dBm) of the undesired (interfering) transmitter, including antenna gain and cable losses;

d: distance (m) between the (undesired) transmitter and (desired) receiver;

H_T: transmitter antenna height (m);

H_R: receiver antenna height (m);

G_R: receiver antenna gain (dB);

L_R: receiver cable losses (dB); and

L_{pol}: polarization discrimination (dB) (assumed to be 10 dB if the direction of polarization differs by 90°).

Note.— This formula is an approximation of transmission loss at low angles and over a short distance (e.g. on the surface of an airport).

1.3.4.3 *Egli model*

The Egli model can be used to predict transmission losses taking into account the effect of the terrain, when both the transmitting and the receiving antennas are located relatively close to the ground. The Egli model offers a more accurate prediction of path loss compared to the free-space model. The Egli model is based on measured path losses as converted into the following mathematical model. It provides an alternative generic method to predict transmission losses when the antennas are close to the ground and includes an empirical frequency-dependent correction for frequencies greater than 30 MHz.

The received power from an undesired (interfering) transmitter can be calculated using formula (12):

$$P_u = eirp_U + G_R - L_R - L_{pol} - 40\log d + 20\log H_T + 20\log H_R + 20\log 40 - 20\log f \quad (12)$$

where:

P_U: received power (dBm) at the receiver input;

$eirp_U$: EIRP of the undesired (interfering) transmitter, including antenna gain and cable losses;

d: distance (m) between the (undesired) antenna and (desired) receiver;

H_T: transmitter antenna height (m);

H_R: receiver antenna height (m);

G_R: receiver antenna gain (dB);

L_R: receiver cable losses (dB);

L_{pol}: polarization discrimination (dB) (assumed to be 10 dB if the direction of polarization differs by 90°); and

f: frequency (MHz).

Note.— This formula is an approximation of transmission loss at low angles and over a short distance (e.g. on the surface of an airport).

1.4 GENERIC MODEL FOR CALCULATING GEOGRAPHICAL SEPARATION DISTANCES BETWEEN A DESIRED AND AN UNDESIRED FACILITY

1.4.1 The generic model establishes the minimum geographical separation distance between a desired and an undesired facility on the basis of the protection of the minimum field strength (as specified in Annex 10) that is required throughout the DOC of the desired facility. This model is described in paragraph 1.2.2.1.2. The undesired facility should be separated by a distance that protects the desired facility from harmful interference, taking into account the EIRP of the undesired facility, the selectivity of the desired (aircraft) receiver and the transmission loss along the radio path. This generic model is used for calculating minimum separation distances between ILS, VOR, VHF digital link (VDL) Mode 4 and GBAS VDB systems operating in the frequency bands 108–117.975 MHz and 328.6–335.4 MHz (glide path) as well as for DME/UHF tactical air navigation aid (TACAN) systems operating in the frequency band 960–1215 MHz.

1.4.1.1 For the determination of the minimum distance between the location of an undesired radio navigation (transmitting) station and the location of the desired (aircraft) receiver, this model uses the ITU Radiocommunication Sector (ITU-R) propagation curves for aeronautical communication and radio navigation services as per Recommendation ITU-R P.528-5. These curves are described in section 1.3.3 of this Chapter. After the minimum required transmission loss between the desired and the undesired station has been determined, the corresponding separation distance can be derived from these curves.

1.4.1.2 The use of this model results in more conservative separation distances between facilities compared to models that are in use in the European and North Atlantic (EUR/NAT) and North American (NAM) Regions. Those models result in more efficient frequency assignment planning. In due course, when more detailed information is available on overall frequency assignment planning, the generic model should be updated.

1.4.2 The geometry used in the generic model is shown in Figure 1-9.

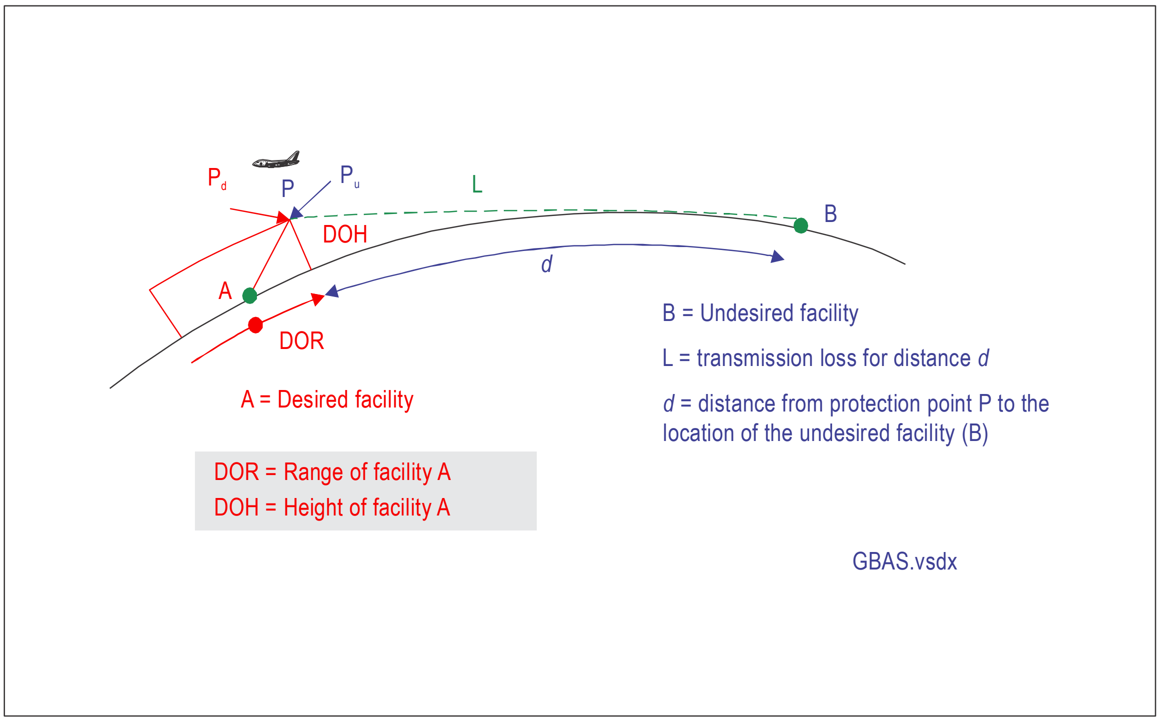

Figure 1-9. Generic model for establishing minimum separation distance

1.4.2.1 The principle in this model is that, through frequency assignment planning, the maximum signal level from an undesired facility (P_u in Figure 1-9) does not cause harmful interference to the minimum signal (P_d in Figure 1-9) *throughout the DOC of the desired facility*. This is achieved by separating the undesired facility by a distance from the DOC of the desired facility that ensures that the signal level (P_u) from the undesired facility at the protection point is [D/U] dB below the minimum signal level of the desired facility (P_d) at any location within the DOC of the desired facility. The D/U ratio is the protection ratio that needs to be applied and that can have a negative value when adjacent frequencies and channels are considered.

Note 1.— This model takes into account the protection of the desired signal-in-space. It assumes that there is an ideal loss-free isotropic antenna at the aircraft.

Note 2.— The minimum signal level of the desired facility is specified in Annex 10.

1.4.2.2 The steps for calculating the minimum separation distance between the desired facility A and the undesired facility B in Figure 1-9 are provided below.

a) Determine the minimum power P_d of the desired signal (facility A) at the location of the (receiving) aircraft (signal-in-space). This can be calculated using the following formula:

$$P_d = E - 20logf - 107.2 \quad (13)$$

where:

P_d: the isotropically received power at the antenna output (dB(W));

E: the minimum (desired) field strength (dB(μV/m)) as specified in Annex 10; and

f: the frequency (MHz).

Note.— E = 20 log FS where FS is the field strength in μV/m.

b) Determine the maximum power P_u of the undesired signal (facility B) at the location of the aircraft. This can be calculated using the following formula:

$$P_u = P_d - D/U \quad (14)$$

where:

P_u: the maximum allowed level of the undesired (interfering) signal (dBW);

P_d: the minimum level of the desired signal (dBW) as calculated in 1.4.2.2 a) above; and

D/U: the protection ratio of the desired signal versus the undesired signal (dB).

c) Determine the minimum required transmission loss from the location of the undesired transmitter to the edge of the DOC of the desired facility using the following formula:

$$P_u = Tx - L \quad (15)$$

where:

P_u: the maximum allowed level of the unwanted signal (dBW);

Tx: the EIRP of the undesired transmitter (dBW); and

L: the minimum total transmission loss (dB) from the undesired facility to the edge of coverage of the desired facility:

$$L = Tx - P_d + D/U \quad (16)$$

Note.— The location of the aircraft as in 1.4.2.2 a) and b) is at the edge of the DOC of the desired facility.

d) Once the minimum required transmission loss has been determined, the minimum separation distance between the location of the undesired transmitter and the (desired) aircraft can be established from the aeronautical propagation curves as per Recommendation ITU-R P.528-5.

A subset of the propagation curves is displayed in Figures 1-10 to 1-12 in section 1.5.

1.4.3 The minimum distance between the location of the desired facility and the location of the undesired facility is established by adding the designated operational range (DOR) of the desired station to the separation distance established in 1.4.2.2 d). When the DOR of the desired facility is described by a polygon, it is necessary to ensure that, for each point on the boundary of the polygon, the minimum separation distance between the undesired facility and the aircraft receiver, as obtained in 1.4.2.2 d), is met.

1.4.4 The generic method does not take into consideration the on-board antenna characteristics. The ITU-R propagation curves give the basic transmission loss between ideal loss-free isotropic antennas. In specific cases, the antenna characteristics can be taken into account. This can be accommodated by adding a margin to the minimum required D/U ratio. This also applies if the on-board transmission line loss for the desired and the undesired signal is not the same. The addition of such margins results in the definition of the minimum required D/U ratio for the signals-in-space.

1.4.5 Examples of compatibility calculations are provided in Chapter 3 (ILS), Chapter 4 (VOR), Chapter 5 (DME) and Chapter 6 (GBAS VDB).

1.5 UTILIZATION OF THE ITU-R AERONAUTICAL PROPAGATION CURVES

1.5.1 For the assessment of interference between aeronautical radio navigation systems in the band 108–117.987 MHz, ICAO uses Recommendation ITU-R P.528-5. For the interference assessment, the curves for 5 per cent of the time are used to analyse the effect of the undesired signal.

1.5.2 Propagation curves, based on Recommendation ITU-R P.528-5,[4] can be calculated using the GUI software, which can be downloaded at https://github.com/NTIA/p528-gui/releases. A subset of these curves is presented in Figure 1-10 (for the frequency 108 MHz, VOR), Figures 1-11A and 1-11B (108 MHz and 328 MHz, localizer and glide path) and Figure 1-12 (for the frequency 960 MHz, DME/TACAN) below.

1.5.2.1 The curves in Figure 1-10 can be used to assess the transmission loss for VOR systems operating at 108 MHz. These curves apply to the undesired (potentially interfering) signal, 5 per cent of the time, an antenna height of the (undesired) transmitter of 15 ft and a height of the (desired) aircraft receiver of 45 000 ft.

4. Currently, Recommendation ITU-R P.528-5 provides propagation curves only for radio signals with vertical polarization. An amendment to this Recommendation is being developed that includes propagation curves for radio signals with horizontal polarization. When this amendment is introduced, an adjustment to the calculations presented (and in Chapters 3, 4, 5 and 6) may be necessary.

Figure 1-10. ITU Propagation curves for the frequency 108 MHz (5 per cent availability)

Note.— The blue dots in Figure 1-10 indicate the distance to the radio horizon with a 4/3 earth radius. These curves show that the transmission loss at the line-of-sight distance (which is almost similar to the radio horizon that can be calculated with a 4/3 earth radius) is significantly larger compared to the free-space transmission loss.

1.5.2.1.1 Using the curves for 5 per cent of the time means that the actual transmission loss is less than that shown with the curve for transmission for 5 per cent of the time. For the remaining 95 per cent of the time, the actual transmission loss is larger than that shown with the curves.

1.5.2.1.2 Additional curves can be generated using the GUI software described in 1.3.3.

1.5.2.2 The curves in Figures 1-11A and 1-11B can be used to assess the transmission loss for the ILS localizer at 108 MHz and the ILS glide path at 328 MHz. These curves apply to the undesired (potentially interfering) signal, 5 per cent of the time, an antenna height of the (undesired) localizer transmitter of 6 ft and a height of the (desired) aircraft receiver of 6 250 ft. For the glide path, the antenna height is 10 ft, and the height of the aircraft receiver is 2 500 ft.

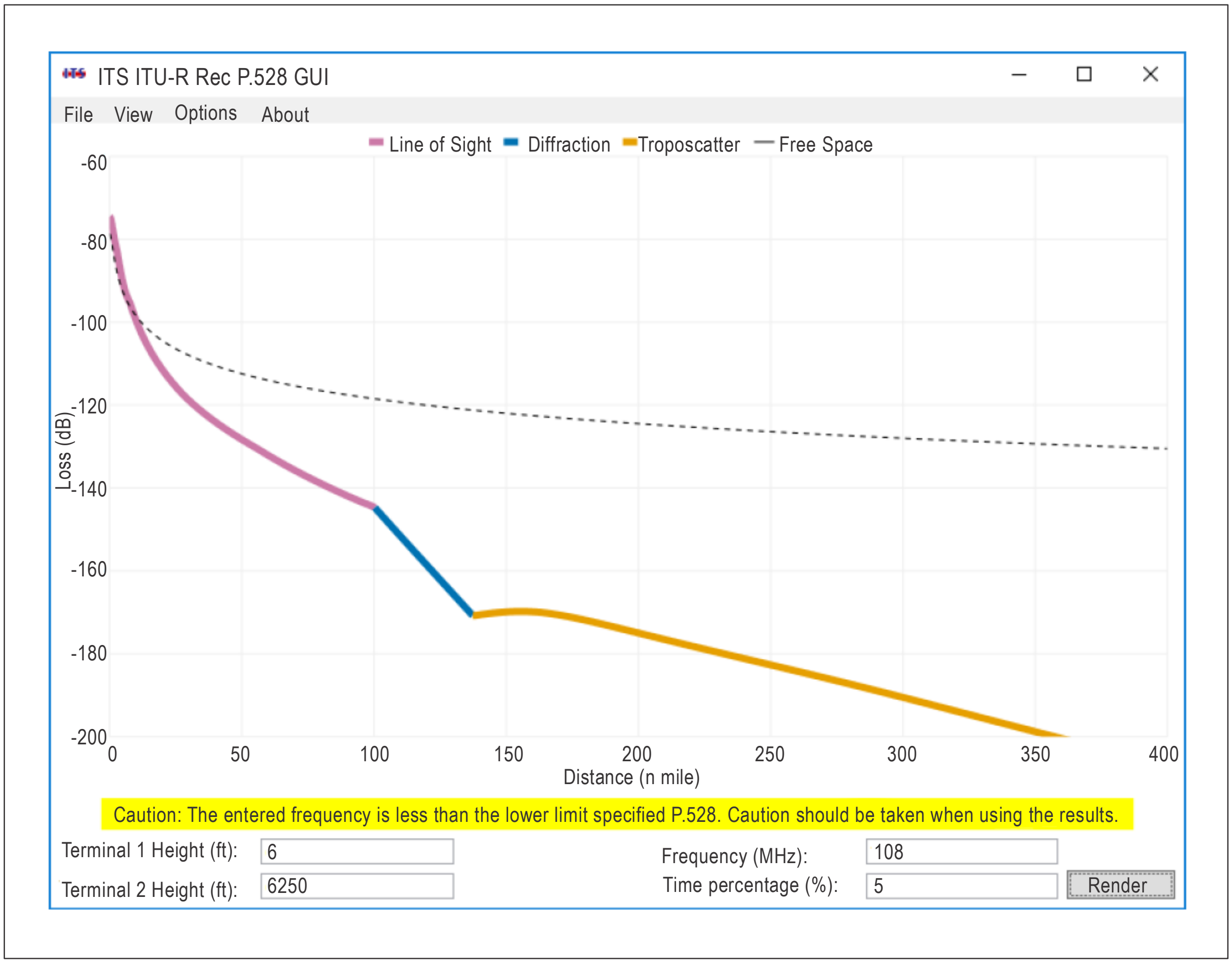

Figure 1-11A. ITU propagation curves for the frequency 108 MHz at 6 250 ft and 5 per cent of time

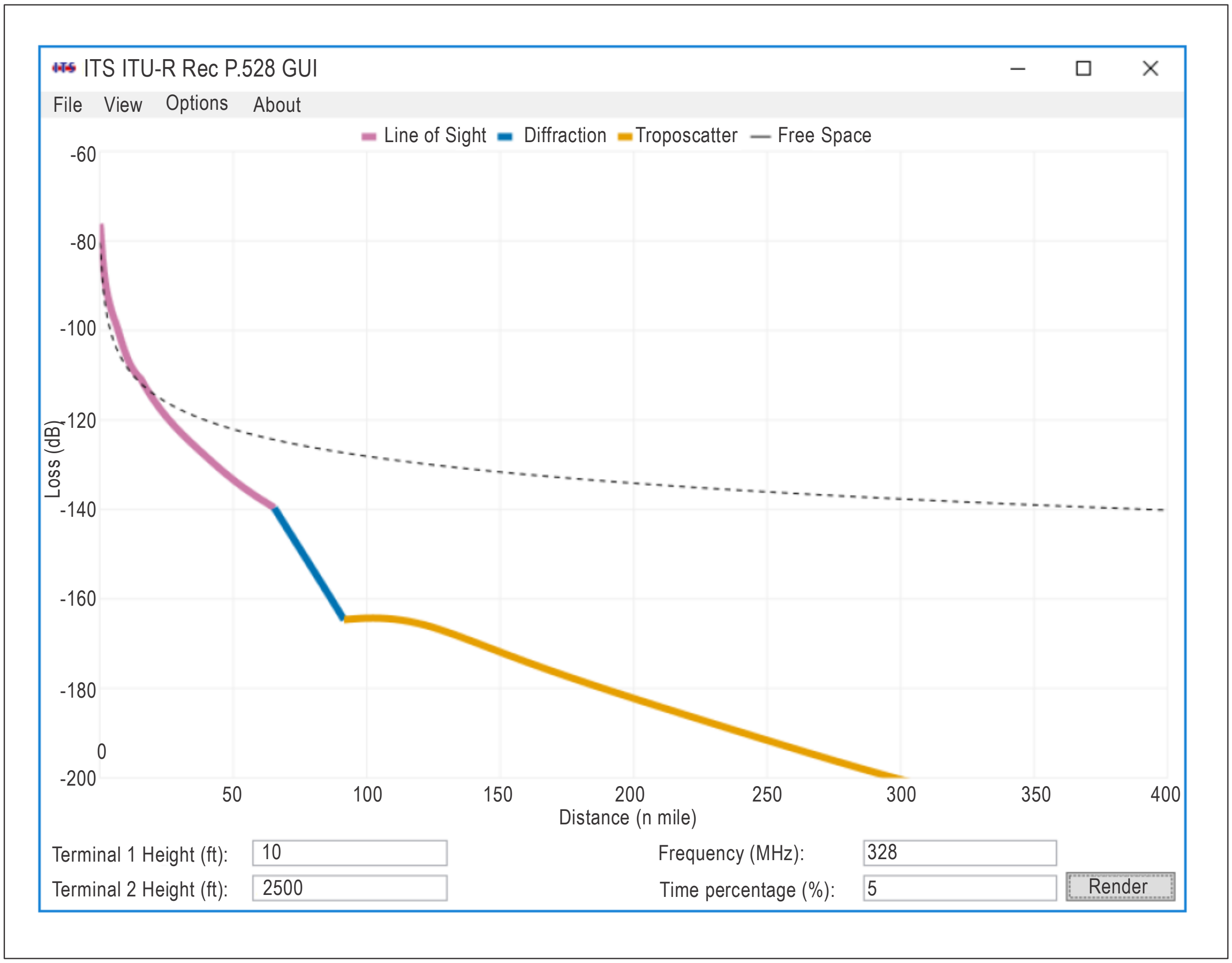

Figure 1-11B. ITU propagation curves for the frequency 328 MHz at 2 500 ft and 5 per cent of time

1.5.2.3 The curves in Figure 1-12 can be used to assess the transmission loss for DME/TACAN systems operating at 960 MHz. These curves apply to the undesired (potentially interfering) signal, 5 per cent of the time, an antenna height of the (undesired) transmitter of 20 ft and a height of the aircraft receiver of between 2 000 ft and 60 000 ft. Additional curves can be generated using the GUI software described in 1.3.3.

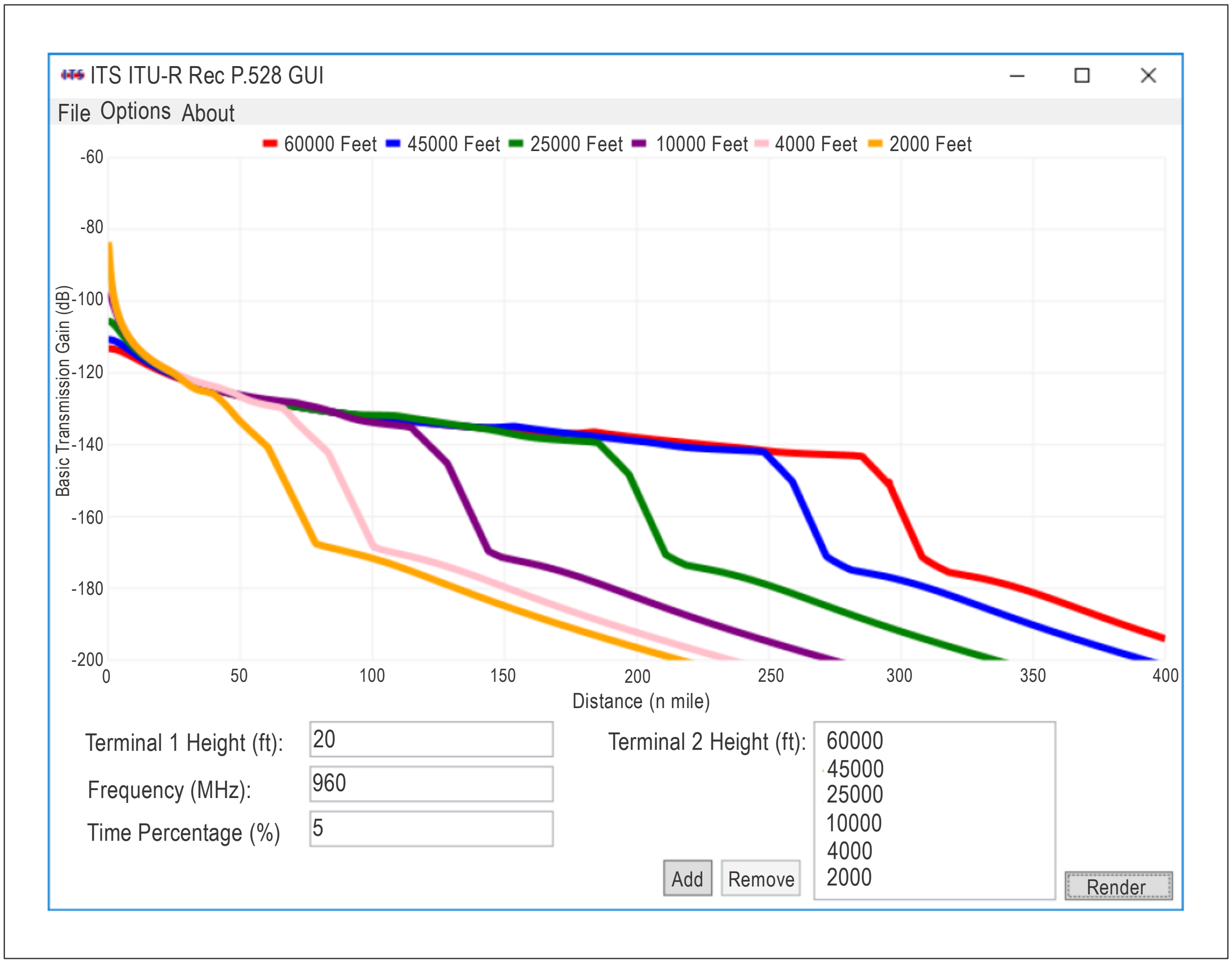

Figure 1-12. ITU propagation curves for the frequency 960 MHz

1.5.3 Use of the ITU propagation curves

1.5.3.1 The ITU propagation curves are used to establish the minimum required geographical separation distance between a desired radio navigation facility and an undesired (potentially interfering) facility operating on the same or adjacent frequencies.

1.5.3.2 The steps to establish the minimum separation distance are provided below.

a) Determine the minimum field strength (*E*) (dB(µV/m)) of the desired facility. For a localizer, *E* = 32dB µV/m.

b) Determine the minimum desired power (P_d) at the aircraft receiver (assuming there is a lossless isotropic aircraft antenna) using formula (13):

$$P_d = E - 20logf - 107.2$$

where:

P_d: dBW; and

f: 110 MHz.

For a localizer, $P_d = -116$ dBW.

c) Determine the maximum undesired power (P_u) using formula (14):

$$P_u = P_d - D/U$$

where:

P_u: maximum undesired power (dBW); and

D/U: the required desired to undesired signal ratio (dB).

For a co-frequency localizer, D/U = 36 dB, and $P_u = -116 - 36 = -152$ dBW.

d) Determine the transmission loss (*L*) (dB) that is required to achieve the maximum P_u at the aircraft receiver using formula (16):

$$L = Tx - P_d + D/U$$

where:

L: transmission loss (dB); and

Tx: the EIRP of the undesired facility.

For an undesired localizer with a *Tx* EIRP of 17 dBW, $L = 17 - (-116) + 36 = 169$ dB.

e) To determine the distance at which the minimum required transmission loss for the undesired signal is achieved, refer to Figure 1-11A, which depicts the propagation curve for 108 MHz with the terminal height (aircraft) h1 of 6 250 ft and the terminal height (ground station) h2 of 6 ft. This is the distance from the edge of the coverage of the desired localizer to the location of the undesired localizer. The minimum separation distance between the location of the desired and the undesired localizer facilities for a DOR of 25 NM is therefore 151 NM (126 NM plus 25 NM) in cases where the direction of the localizer is not known.

Note.— This exercise needs to be repeated if the undesired localizer in the example above becomes the desired localizer, and the desired localizer is the undesired localizer. The minimum required separation distance is the larger of the two values.

1.5.4 The application of these curves can be considered as the worst-case scenario. More sophisticated propagation models, such as the IF-77 model or programme, can be used for a more detailed compatibility analysis.

1.5.5 SITE ELEVATION

1.5.5.1 The site elevation[5] of the radio navigation facility is a factor that may need to be considered in cases where the elevation of the site of the desired and undesired facility is different. The main effect of the site elevation is an increase in the distance to the radio horizon, or, when the ITU-R aeronautical propagation curves are used, the use of a propagation curve corresponding to the site elevation of the undesired facility and/or the elevation of the upper boundary of the DOC for the desired facility.

Note.— If the upper level of the DOC of the desired facility is referenced to MSL (for example, as flight level), the actual site elevation of the desired facility must be ignored.

1.5.5.2 The ITU-R aeronautical propagation curves in Recommendation ITU-R P.528-5 are based on a spherical earth where the site of the undesired facility is at MSL and the maximum height of the DOC of the desired facility is referenced to MSL.

1.5.5.3 In the ICAO COM lists for radio navigation systems, the site elevation is not included and therefore is not normally taken into consideration in (international) frequency assignment planning and coordination. In these cases, the compatibility calculations assume that all facilities operate at a height referenced to MSL.

1.5.5.4 The geometry to calculate the effect of the site elevation is shown in Figure 1-13.

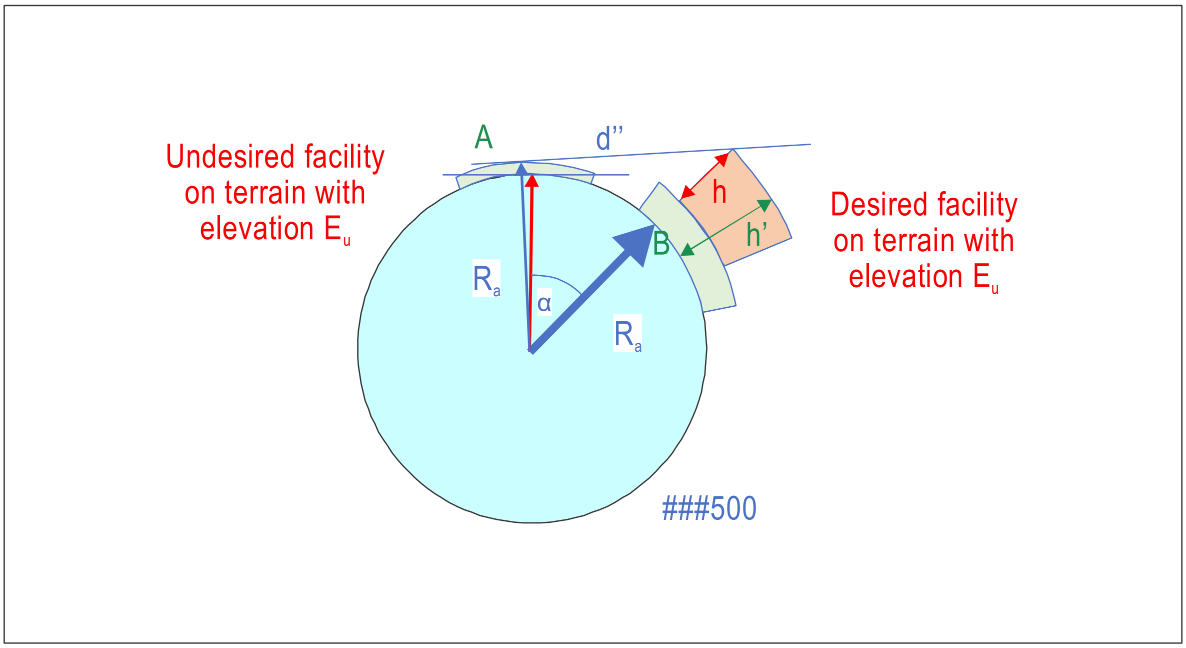

Figure 1-13. Effect of site elevation

5. The site elevation is the height of the ground station site referenced to MSL.

1.5.5.4.1 The distance (*d"*) to the radio horizon can be calculated using formula (17):

$$d'' = \sqrt{(R_a + E_d + h)^2 - (R_a + E_u)^2} \quad (17)$$

which gives formula (18):

$$d'' \approx 1.23\sqrt{E_D - E_u + h} \quad (18)$$

where *d"* is in NM and E_D, E_u and *h* are in ft.

Note.— If the upper boundary of the DOC of the desired facility is referenced to MSL, E_D is zero.

1.5.5.5 In cases where the site elevations of navigation facilities differ by 1 000 ft or more, the separation distance must be increased as follows in order to protect the facility with the higher elevation:

a) for a VOR with an operational height of 45 000 ft, add 3 NM per 1 000 ft site elevation difference;

b) for a VOR with an operational height of 10 000 ft, add 4 NM per 1 000 ft site elevation difference; and

c) for a VOR with an operational height of 5 000 ft, add 7 NM per 1 000 ft site elevation difference.

Alternatively, when using the actual ITU-R propagation curves, the selection of the curve should be increased with the height difference between the navigation facilities.

1.5.5.6 *Effect of the antenna height above ground*

1.5.5.6.1 The height of the antenna above the local terrain will affect the propagation curves in that a higher antenna would generally result in the transmission losses being reduced.

1.5.5.6.2 The following typical antenna heights are normally used in the compatibility assessment of frequency assignments:

a) localizer: 6 ft;

b) glide path: 10 ft;

c) VOR: 20 ft (counterpoise: diameter of 52 ft, 12 ft above ground; antenna at 4 ft above counterpoise);

d) GBAS: 45 ft; and

e) DME: 20 ft.

1.5.5.6.3 When States deploy facilities with different antenna heights, ICAO should be informed accordingly to adjust interference calculations, as required.

1.5.6 Transmitter power degradation

1.5.6.1 Typically, in aeronautical frequency assignment planning, the effect of power degradation of the desired transmitter that may occur before the system is shut down (3 dB) is not taken into consideration. This is because frequency assignment planning is based on the minimum field strength of the desired signal that has been specified for the relevant facility in Annex 10. This minimum field strength should also be maintained during periods of power degradation before the system is shut down. States should ensure these minimum values when implementing navigation or communications facilities.

1.5.6.2 When frequency planning within a Region or State is based on a methodology that uses the radiated power of the desired transmitter, the addition of a 3 dB-factor to the D/U ratios used in the compatibility assessment may be necessary.

1.5.7 The application of this generic methodology for frequency assignment planning is further described in Chapter 2 for GBAS VDB systems versus VHF communications systems, Chapter 3 for ILS, Chapter 4 for VOR systems, Chapter 5 for DME/TACAN systems and Chapter 6 for GBAS VDB systems.

Chapter 2

AERONAUTICAL VHF AIR-GROUND RADIO COMMUNICATION SYSTEMS OPERATING IN THE BAND 117.975–137 MHz

2.1 INTRODUCTION

2.1.1 The frequency band 108–137 MHz is allocated by the ITU to the aeronautical mobile (route) service (AM(R)S) and is used for air-ground voice and for air-ground and air-air data link communications. The use of this band is regulated by the ITU through the ITU Radio Regulations and relevant ITU-R Recommendations and Reports. Details on these Regulations can be found in Volume I of this Handbook. Specific provisions pertaining to the aeronautical use of this band are contained in the relevant ICAO Standards and Recommended Practices (SARPs) in Annex 10, Volumes III and V. This chapter contains technical and operational material on the assignment and use of frequencies in the band 117.975–137 MHz. Material on the use of the band 108–117.975 MHz by the AM(R)S (GBAS VDB and VDL Mode 4) may be found in section 2.11 and Chapters 3, 4 and 6.

Note.— The use of the allocation to the AM(R)S in the band 108–117.975 MHz by the AM(R)S is subject to the conditions as contained in ITU Resolution 413 (WRC-12).

2.1.2 ICAO documents relevant to frequency assignment planning in the band 117.975–137 MHz are:

a) Annex 10, Volume III (*Communication Systems*),

   1) Part I (*Digital Data Communication Systems*) — Chapter 6 — VHF Air-Ground Digital Link (VDL);

   2) Part II (*Voice Communication Systems*) — Chapter 2 — Aeronautical Mobile Service;

b) Annex 10, Volume V, Chapter 4 — Utilization of frequencies above 30 MHz; and

c) ICAO Regional Air Navigation Plans and relevant ICAO regional air navigation agreements.

2.2 INTERFERENCE MODEL

2.2.1 General

2.2.1.1 Aeronautical communication systems can be subject to interference caused by transmissions from other (nearby) aircraft and from ground stations. These interfering transmissions can be generated on the desired (operational) frequency (co-frequency interference) or on frequencies adjacent to the desired frequency (adjacent frequency interference). The general methodology (as described in Chapter 1) that is used to establish separation distances between co-frequency and adjacent frequency assignments for air-ground communication systems is illustrated in Figures 2-1 and 2-2.

2.2.1.2 The protection of communications from harmful interference requires that, in general, when receiving a signal from a desired radio frequency (RF) source, the receiver will not simultaneously receive a signal from another (undesired) RF source that can cause harmful interference to the proper reception and processing of the desired signal. To achieve this, the frequency assignment planning process has to ensure that the undesired RF source is separated in distance (if both sources operate on the same frequency) from the (desired) receiver or, when operating on adjacent frequencies, is sufficiently separated in frequency and distance. There needs to be sufficient distance separation (or frequency/distance separation) to bring the undesired signal level to a value below which the interference, if any, is no longer harmful and the total receiving system performance requirements are met.

2.2.2 Interference model for aeronautical frequency assignment planning

2.2.2.1 The model used for establishing (co-frequency) separation distances in aeronautical frequency assignment planning for systems used in the band 117.975–137 MHz for VHF air-ground communications is based on the general methodology in Chapter 1 and illustrated in Figures 2-1 and 2-2. This model assesses interference at the antenna input (signals-in-space). Specifications for aeronautical systems as established by ICAO also refer to signals-in-space.

2.2.2.2 RF emissions that are co-frequency (or adjacent frequency) to the actual operating frequency of ground station **A** and aircraft station **a** in Figure 2-1 (e.g. emissions from aircraft station **b** or ground station **B**) may interfere with communications within the DOC of the desired station or service (area **A** in Figure 2-1). Frequency assignment planning for both ground stations **A** and **B** in Figure 2-1 needs to ensure that no harmful interference is caused between any stations operating within the DOC of ground station **A** and of ground station **B**. This is achieved by ensuring sufficient geographical separation between the ground stations.

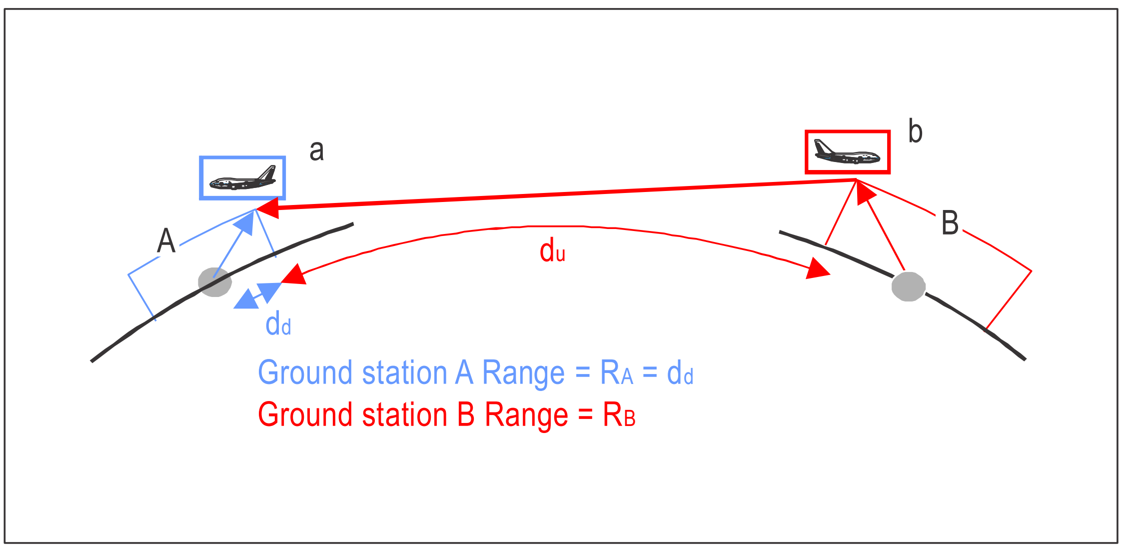

Figure 2-1. Model for establishing separation distances

2.2.2.3 For air-ground communications, the protection of the desired aircraft receiver (which is communicating with a ground station) from harmful interference caused by transmissions from another aircraft (operating on the same or an adjacent frequency) is normally the most constraining factor in ensuring that these frequencies are free from harmful interference. This model is illustrated in Figure 2-1; the schematic diagram of this model is in Figure 2-2.

2.2.2.4 In Figure 2-1, aircraft station **a**, which is receiving signals from the (desired) ground station **A**, can be interfered by transmissions from aircraft station **b** (or any other undesired RF source). The separation distance between aircraft station **a** and aircraft station **b** needs to ensure that the level of (undesired) signals received by aircraft station **a** from aircraft station **b** are sufficiently below the level of the signals received by aircraft station **a** from ground station **A** to prevent harmful interference. The signal ratio necessary to protect the desired signal from harmful interference from the undesired signal is the protection ratio (D/U).

*Note.— If ground station **B** (or both ground stations **A** and **B**) is an aeronautical broadcast station (e.g. meteorological information for aircraft in flight (VOLMET)), a different geometry from that shown in Figure 2-1 applies. This is further described in 2.7.2.4 and 2.7.2.5.*

2.2.2.5 The signal level of the desired and the undesired signal at the aircraft antenna can be calculated with the method as illustrated in Figure 2-2.

The level of the desired and of the undesired signal at the (desired) antenna input can be calculated using formulas (19) and (20) and as shown in Chapter 1, 1.2.3 (formula (1)) and 1.2.4 (formula (3)).

The level of the desired signal at the antenna input is:

$$P_d = PT_d - F_d + G_d - L_d \quad (19)$$

The level of the undesired signal at the antenna input is:

$$P_u = PT_u - F_u + G_u - L_u \quad (20)$$

Formula (4) in Chapter 1, 1.2.5 shows that $\mathrm{P_d} - \mathrm{P_u} = \frac{\mathrm{D}}{\mathrm{U}}$

Note.— For both the desired signal and the undesired signal, the antenna gain and the feeder losses of the receiving station are the same when the frequency of both signals is the same (co-frequency) or when both transmitters operate on the (first) adjacent frequency (25 kHz). The ratio of the desired to the undesired signal at the antenna is therefore the same as at the receiver input.

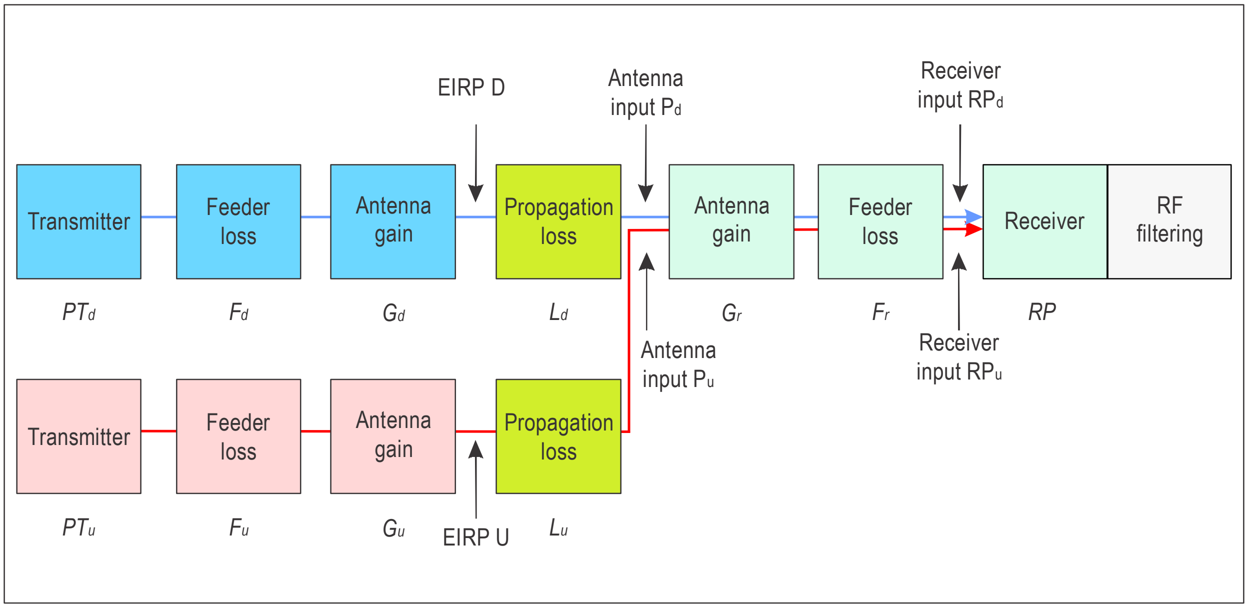

Figure 2-2. Desired signal and undesired signal path to desired (victim) receiver

In formula (19), L_d is the free-space propagation loss for the designated operational range (DOR) of the desired facility (**A** in Figure 2-1) and can be calculated as shown in Chapter 1, 1.3.2 (formula (8)):

$$L_d = 37.8 + 20\log f + 20\log d_{DOR}$$

In formula (20), L_u is the free-space propagation loss for the separation distance between the undesired RF source (aircraft station **b** in Figure 2-1) and the desired receiver (aircraft station **a** in Figure 2-1) and can be calculated using formula (8):

$$L_u = 37.8 + 20\log f + 20\log d_{SEPDIST}$$

The formula below is established using the formulas for L_d and L_u and formula (4):

$$\frac{D}{U} = P_d - P_u = e.i.r.p\,D - \ L_d - (e.i.r.p\,U - L_u) = e.i.r.p.D - e.i.r.p\,U - 20\log d_{DOR} + 20\log d_{SEPDIST}$$

From this formula, the minimum free-space separation distance between the desired receiver and the undesired transmitter ($d_{SEPDIST}$) can be calculated.

2.2.3 Separation distance ratio method

2.2.3.1 If the EIRP of both the desired transmitter (**A** in Figure 2-1) and the undesired RF source (**b** in Figure 2-1) are the same, the (required) D/U can be expressed as the ratio between $\boldsymbol{d_{SEPDIST}}$ and $\boldsymbol{d_{DOR}}$ in the formula above.

For the desired signal at the receiver antenna: $P_d = \ e.i.r.p - L_d$

For the undesired signal at the receiver antenna: $P_u = \ e.i.r.p - L_u$

Note.— Equal EIRP for ground and aircraft transmitters is normally assumed in frequency assignment planning for aeronautical air-ground communication systems. The EIRP includes the transmitter output power and the effect of cable losses and antenna gain. Tables 2-1 and 2-2 in 2.3.2 provide typical values normally used in compatibility analyses.

The D/U signal ratio equals $P_d - P_u$ (formula (4) in Chapter 1); P_d and P_u are expressed in dBm.

$$\frac{D}{U} = e.i.r.p - L_d + G_r - F_r - (e.i.r.p - L_u + G_r - F_r) = L_u - L_d$$

L_d and L_u are respectively the propagation losses along the radio path from the desired transmitter and from the undesired transmitter to the receiver and are based on free-space propagation conditions. L_d (dB) is calculated based on the DOR of the desired facility. The free-space propagation model is documented in Chapter 1, 1.3.2. If the separation between the desired receiver and the undesired transmitter is larger than the radio horizon of each station, the effect of the propagation beyond the radio horizon needs to be considered. The effect of beyond-the-radio horizon propagation is described in Chapter 1, 1.3.3, and Chapter 2, 2.2.5. The free-space propagation loss is calculated using formula (8) in Chapter 1, 1.3.2 as follows:

$$L_d = 37.8 + 20\log f + 20\log d_d$$

and

$$L_u = 37.8 + 20\log f + 20\log d_u$$

which brings

$$\frac{D}{U} = L_u - L_d = 37.8 + 20\log f + 20\log d_u - (37.8 + 20\log f + 20\log d_d) = 20\log d_u - 20\log d_d = 20\log\frac{d_u}{d_d} \quad (21)$$

Formula (21) demonstrates that the D/U signal ratio can be expressed as the ratio between the distance from the receiver to the undesired transmitter and the distance to the desired transmitter under free-space propagation conditions.

For aeronautical VHF air-ground voice communication systems, ICAO SARPs specify that the D/U protection ratio for air-ground voice communication systems is 20 dB (signals-in-space). In areas with frequency congestion, a D/U protection ratio of 14 dB may be used.

Substituting in formula (21) D/U = 20 gives a separation distance ratio (d_u/d_d) of 10. If (in free-space) the distance from the receiver to the undesired transmitter is **10 times** larger than the distance to the desired transmitter (when both the desired and the undesired transmitter radiate with the same EIRP), the signal ratio of the desired signal to the undesired signal is 20 dB.

Substituting in formula (21) D/U = 14 gives a separation distance ratio (d_u/d_d) of 5. If (in free-space) the distance from the receiver to the undesired transmitter is **5 times** larger than the distance to the desired transmitter (when both the desired and the undesired transmitter radiate with the same EIRP), the signal ratio of the desired signal to the undesired signal is 14 dB.

Note.— Free-space propagation conditions only apply when the transmitter and the receiver are within radio line-of-sight of each other (within the radio horizon).The separation distance ratio (d_u/d_d*) assumes equal EIRP of both the desired and the undesired transmitter station. See 2.3.1 for the application of the D/U ratio of 20 dB or of 14 dB.*

2.2.3.2 The interference model described in 2.2.2 and the distance ratio method in 2.2.3 calculate (directly or indirectly) the desired signal level at the receiver antenna (or the receiver input). In these models, when the distance between the desired transmitter and receiver is decreased, the actual signal strength at the receiver increases and, while meeting the required D/U criteria, the distance from the undesired (interfering) transmitter to the receiver may be decreased.

Note.— The minimum signal level method, described in 2.2.4, is based on the protection of the minimum field strength throughout the DOC of the desired service. The frequency assignment planning constraints in this case are more restrictive.

2.2.3.3 Adjacent channel separation distance ratios can also be calculated using the separation distance ratio method. The adjacent channel separation is calculated using formula (21):

$$\frac{D}{U} = L_u - L_d$$

For adjacent channel calculations, taking into account the ACR, this formula can be rewritten into:

$$\frac{D}{U} = (L'_u + ACR) - L_d$$

$$\boldsymbol{\frac{D}{U} = L_u - L_d = (L'_u + \mathrm{ACR}) - L_d = (20\log d'_u + \mathrm{ACR}) - 20\log d_d}$$

$$\boldsymbol{\frac{D}{U} - \mathrm{ACR} = 20\log d'_u - 20\log d_d = 20\log\frac{d'_u}{d_d}};$$

$$\frac{d'_u}{d_d} = 10^{(\frac{D}{U} - \mathrm{ACR})/20}$$

Note.— d'_u *is the distance from the undesired transmitter to the receiver.*

The D/U ratio to be used (normally 20 dB) depends on the regionally agreed frequency assignment planning criteria.

2.2.3.4 The minimum geographical separation distance between facilities operating on the first adjacent channel (either 25 kHz or 8.33 kHz) is normally less than 3 NM. This has led to the conclusion that adjacent channels interference, which in most cases is transient in nature, should not be considered in frequency assignment planning for VHF air-ground voice communication (VHF communications) systems.

2.2.3.5 In a mixed environment where both 8.33 kHz and 25 kHz channels are being used, adjacent channel criteria apply (see 2.7.4). The method in 2.2.4 is recommended for determining adjacent channel separation.

2.2.3.6 The distance ratio method cannot be used for determining geographical separation distances for area services (e.g. ACC, FIR) or for cases where the transmitter is located well outside the centre of (or even outside) a circular service area.

2.2.4 Minimum signal level method

2.2.4.1 Annex 10, Volume III, specifies minimum field strength levels (signal-in-space) for the air-ground communication systems that can operate in the frequency band 112–137 MHz. Protection of aeronautical VHF air-ground communication systems is typically based on the principle that the minimum desired signal is not subject to harmful interference when the interfering (undesired) signal is 20 dB or more (or 14 dB, as required) below the specified minimum field strength (of the desired signal), in accordance with the provisions in Annex 10. As specified in Annex 10, Volume III, Part II, the minimum field strength for VHF communications systems should be 75 µV/m throughout the DOC, and, as specified in Annex 10, Volume V, the D/U ratio is either 20 dB or, where applicable, 14 dB.

Note.— These field strength levels, together with other relevant data such as typical values for ground and airborne transmitter power, are reproduced in Tables 2-1 and 2-2 (see 2.3.2).

2.2.4.2 When protecting only the minimum specified field strength level (which, from the frequency assignment protection point of view is the safest method), the method used for establishing co-frequency separation distances does not take into account the radiated energy of the desired transmitter but requires that the minimum specified RF signal throughout the DOC area is protected. Generally, this method provides for better protection compared to the distance ratio method described in 2.2.3.

2.2.4.3 The minimum signal level method is described in Chapter 1, 1.2.2.1.2, Figure 1-2 and is illustrated in Figures 2-3 and 2-5. In this method, protection of the desired signal from harmful interference requires that a signal from an undesired source (e.g. aircraft station **b** in Figure 2-3) at the desired receiver is sufficiently below the minimum signal level (75 µV/m) of the desired signal (and NOT the actual (desired) signal level as calculated in 2.2.2 and 2.2.3).

2.2.4.4 This model also applies to calculating separation distances when the desired receiver and the undesired transmitter are operating on adjacent frequencies. Due to the effect of RF selectivity of the desired receiver, the minimum separation distance in this case is less than when they are operating on the same frequency. The undesired (interfering) station can be an aircraft station or a ground station.

2.2.4.5 *Effect of the vertical polar diagram of VHF communications antennas*

2.2.4.5.1 The minimum signal level method assumes that the VHF communications facility radiates, in all directions, just enough power to achieve at the edge of the coverage area the minimum signal level as specified in Annex 10. In the system design for VHF communications systems, it should be ensured that for the ground station the conditions of Annex 10 (which specify the minimum field strength) are met. Since the alternative (or simplified) model does not take into account the actual EIRP of the desired ground station (transmitter), no separation distance ratio criterion, as described in 2.2.2.4, can be developed.

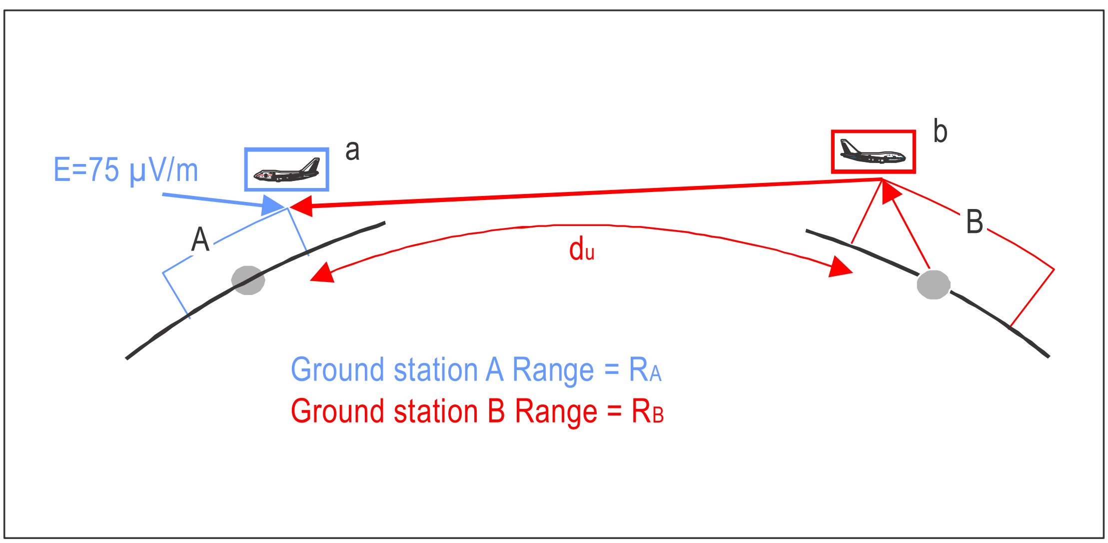

Figure 2-3. Model for establishing separation distances when minimum field strength is specified

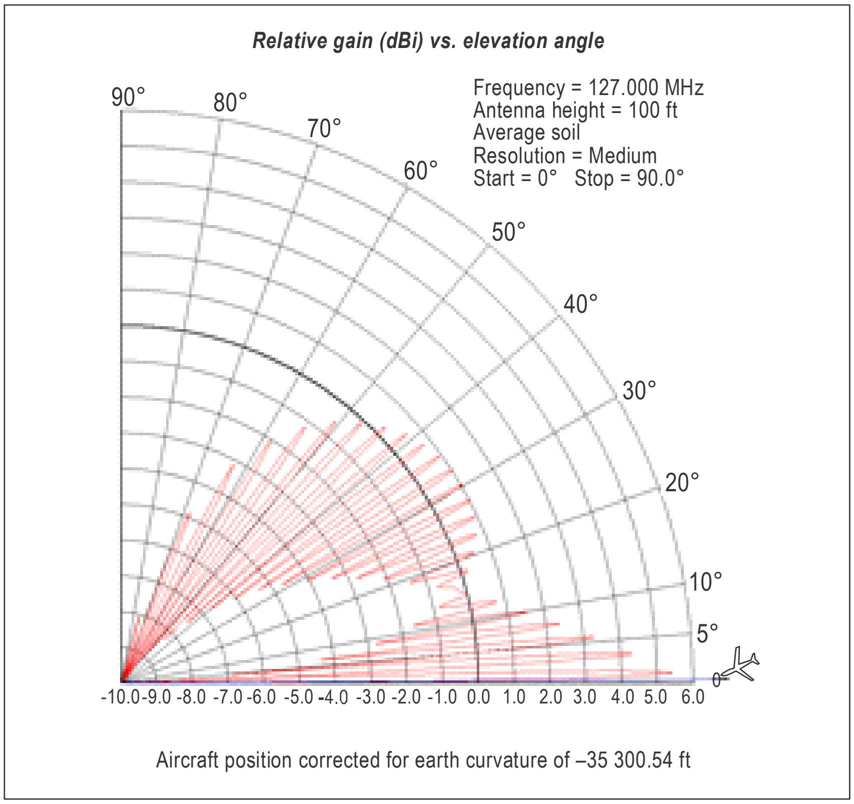

Figure 2-4. Vertical polar diagram of antenna 30 m above ground level

2.2.4.5.2 The minimum signal level method is recommended for use in particular when compatibility with dissimilar systems (e.g. VHF communications voice and VDL) has to be established.

2.2.4.6 The minimum signal level method requires that the signal level of the undesired (interfering) signal be calculated at the antenna of the receiver. The desired signal level is 75 µV/m. The D/U ratio (P_d – P_u (dBm)) is 20 (14) dB. The analysis below describes this method, which is illustrated in the schematic diagram in Figure 2-5.

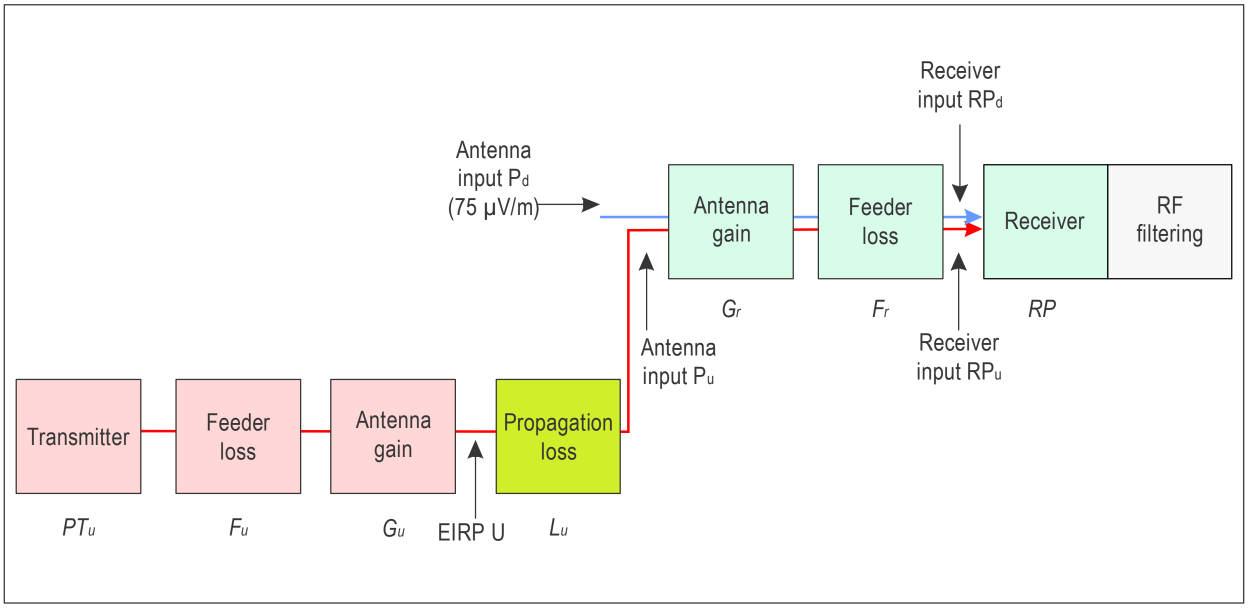

Figure 2-5. Minimum desired signal at antenna and undesired signal path to desired (victim) receiver antenna

2.2.4.7 The (desired) signal level (P_d) at the antenna is 75 µV/m (–82 dBm). The level of the undesired signal (P_u) (aircraft station **b** in Figure 2-3) is calculated using formula (20) in 2.2.2.5.

$P_d = 75\ \mu V/m = -82\ dBm$ (at the receiver antenna)

$P_u = PT_u - F_u + G_u - L_u$ (at the receiver antenna; P_{Ttu} is for most transmitters typical 25 W)

For P_{Tu} = 25 W (44 dBm), F_u = 3 dB and G_u = 0 dB,

$$P_u = 44 - 3 + 0 - L_u = (41 - L_u)dBm$$

$$\frac{D}{U} = 20\ dB = P_d - P_u = -82\ dBm - 41\ dBm + L_u = -123\ dBm + L_u$$

$$L_u = 143\ dB$$

2.2.4.8 In this scenario (D/U = 20 dB), and assuming a typical transmitter power for the undesired aircraft transmitter of 25 W, the minimum separation distance between the desired receiver and the undesired (aircraft) transmitter needs to ensure that the transmission losses over the radio path are 143 dB.

Formula (8) in Chapter 1, 1.3.2, calculates that for a free-space transmission loss of 143 dB (*f* = 127 MHz) a (free-space) distance of 1 428 NM is required. This distance is far greater than double the distance to the radio horizon for aircraft at an altitude of 45 000 ft (2*261 NM), as required by Annex 10. The effect of the radio horizon is described in 2.2.5. Calculations for establishing the minimum separation distance between facilities are in 2.7.

2.2.4.9 If the protection ratio is 14 dB (see 2.3.1), the required free-space transmission loss is calculated as follows:

$$\frac{D}{U} = 14\ dB = P_d - P_u = -82\ dBm - 41\ dBm + L_u = -123\ dBm + L_u$$

$$\boldsymbol{L_u = 137\ dB}$$

Formula (8) in Chapter 1, 1.3.2 calculates that for a free-space transmission loss of 137 dB (*f* = 127 MHz) a (free-space) separation distance of 718 NM is required. This distance is greater than double the distance to the radio horizon for aircraft at a maximum altitude of 45 000 ft. The effect of the radio horizon is described in 2.2.5. Calculations for establishing the minimum separation distance between facilities are in 2.7.

Note.— When applying the minimum signal level method as described in this section, the application of a D/U of 14 dB or 20 dB has no (or a limited) effect on the minimum separation distance with a co-frequency interfering station since, in both cases, the free-space separation distance that is required to ensure protection of the desired signal from harmful interference is more than the sum of the distances to the radio horizon of the respective facilities.

2.2.4.10 As described in 2.2.4.7, the minimum signal level method can also be used to calculate the adjacent channel separation distance as follows:

$P_d = 75\ \mu\text{V/m} = -82\ dBm$ (at the receiver antenna)

$P_u = PT_u - F_u + G_u - (L'_u + ACR)$ (at the receiver antenna)

Where the total transmission loss for the undesired signal $L_u = L'_u + ACR$

(ACR is +60 dB for the first adjacent channel)

For PT_u = 25 W (44 dBm), F_u = 3 dB and G_u = 0 dB,

$$P_u = 44 - 3 + 0 - L'_u - \text{ACR} = 41 - L'_u - \text{ACR}\ (dBm)$$

$$\frac{D}{U} = 20\ dB = P_d - P_u = -82\ dBm - 41\ dBm + L'_u + \text{ACR} = -123 + L'_u + \text{ACR (dB)}$$

$$L'_u = 123 + \frac{D}{U} - ACR$$ (for the values of P_d and P_u above)

If ACR = 60 dB (first adjacent channel rejection), $L_u = 63 + \frac{D}{U}$

$$L'_u = 37.8 + 20\log f + 20\log d_u = 83\ \ (dB)$$

For *f* = 127 MHz and *D/U* = 20 DB, L'_u = 1.4 NM

2.2.4.11 In a mixed environment where both 8.33 kHz and 25 kHz channels are being used, different adjacent channel criteria apply (see 2.7.4).

2.2.5 The effect of the radio horizon

2.2.5.1 The effect of the radio horizon on the (radio) path loss is shown in Figure 2-6.

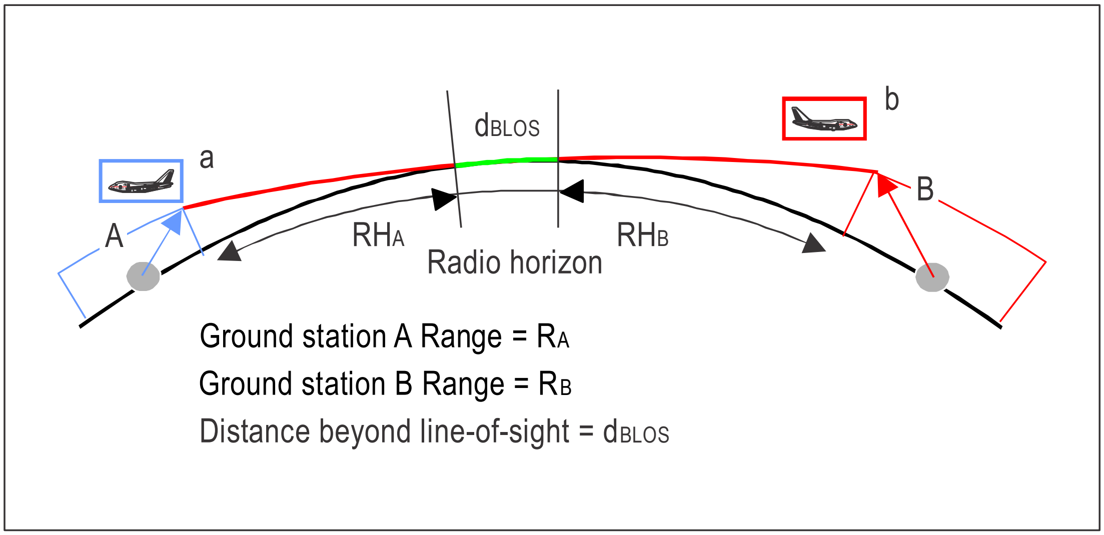

Figure 2-6. Propagation path greater than radio line-of-sight

2.2.5.2 In cases where minimum required free-space separation distance between the receiver and the undesired (interfering) transmitter, as calculated with the methods in 2.2.3 or 2.2.4, is greater than the sum of the distance to the radio horizon of the respective facilities, the calculation of the total minimum separation distance needs to include the conditions applicable to the “over the horizon” propagation. The radio signals over the horizon are attenuated at a much faster rate per nautical mile compared to free-space propagation. This is shown in the ITU propagation curves in Chapter 1. For VHF frequencies, the attenuation beyond the radio horizon is 0.5 dB/NM (see Chapter 1, 1.3.3.1).

2.2.5.3 In the example given in Figure 2-6, the total free-space loss (propagation loss) between aircraft stations **a** and **b** is equal to the sum of the free-space attenuation of the path (RHA + RHB) to which the attenuation d_{BLOS} needs to be added.

2.2.6 Protection based on line-of-sight separation

2.2.6.1 When the minimum required separation between the DOC of facilities operating on the same frequency is larger than the sum of the distance to the radio horizon of each facility (to obtain the required D/U ratio (20 dB or 14 dB)) at the edge of coverage (maximum range and maximum height), the frequency assignment planning criteria for co-frequency assignment planning, as contained in Annex 10, Volume V, 4.1.4, require that the DOC areas for each facility be separated by no less than the sum of the distances to the radio horizon of each facility.

2.2.6.2 This implies that when the separation distance is indeed determined by the sum of the distance to the radio horizon of the respective facilities, the required D/U protection ratio is not met in a small area at the closest points between the two DOC areas. It is, however, recognized that it is highly unlikely that two aircraft will be at the closest point at the edge of each DOC area at the same time. The size of the small area depends on the dimensions of the DOC of the two facilities.

2.2.6.3 In some specific cases, however, as described in 2.7, the effect of propagation beyond the radio horizon has to be considered when establishing geographical separation distances.

Note.— The calculation of minimum separation distances for various air-ground communication services is described in 2.7 and 2.8.

2.3 FREQUENCY ASSIGNMENT PLANNING CRITERIA

Note.— This section describes the frequency assignment planning criteria for VHF air-ground voice communication systems. Frequency assignment planning criteria for the VHF air-ground data link (VDL Mode 2 and VDL Mode 4) are in 2.9.

2.3.1 General planning criteria

2.3.1.1 Provisions concerning the deployment of VHF frequencies and the avoidance of harmful interference are contained in Annex 10, Volume V, Chapter 4, 4.1.4.

2.3.1.2 For co-frequency assignments, the minimum geographical separation between facilities shall be such that the DOC of each facility is separated by a distance not less than:

a) that required to provide a D/U ratio of 20 dB; or

b) the sum of the distance to the radio horizon of the DOC area of each facility.

Alternatively, in areas where the frequency congestion is severe, a protection ratio of 14 dB can be used on the basis of a regional air navigation agreement.

Note 1.— Facilities using a common frequency do not require frequency protection between each other (e.g. extended range facilities).

Note 2.— The distance to the radio horizon is calculated as shown in Chapter 1, 1.3.2, with the formula:

$$d_{RH} = 1.23(\sqrt{h})$$

where:

d_{RH}: the distance of the station to the radio horizon (NM); and

h: the height of the transmitter or receiver above the earth's surface (ft).

2.3.1.2.1 The application of the minimum separation distance based on the sum of the radio horizon distance of each facility assumes that it is highly unlikely that two aircraft will simultaneously be at the closest points between the two facilities and at the maximum altitude of the frequency protected service volume of each facility.

2.3.1.2.2 Details on the calculation of separation distances are in 2.7. Paragraph 2.8 contains separation distances for the uniform DOC for aeronautical services as identified in 2.6.

2.3.1.2.3 The separation distance is calculated for aircraft operating at the maximum range and maximum height of the DOC.

2.3.1.2.4 In cases where broadcast services (VOLMET) are involved, the minimum geographical separation distance required to obtain a protection ratio D/U of 20 dB is established relative to the ground broadcast transmitter.

2.3.1.3 For adjacent frequency assignments, the minimum geographical separation between facilities shall be such that each facility is separated by a distance sufficient to ensure operations free from harmful interference.

Note 1.— The edge of the DOC is at the maximum range and maximum height.

Note 2.— For facilities operating with 25 kHz or 8.33 kHz channel spacing, no geographical separation is required (see 2.7.4).

Note 3.— Protection is based on an ACR of 60 dB with the first assignable 25 kHz or 8.33 kHz channel.

Note 4.— In a mixed environment, where both 25 kHz and 8.33 kHz channel spacings are deployed, the adjacent channel separation as shown in Table 2-6 is to be applied when making frequency assignments.

2.3.2 Typical signal parameters

2.3.2.1 Tables 2-1 and 2-2 contain typical values for ground and airborne transmitter power that can be used in a detailed compatibility assessment.

Table 2-1. Typical values for various parameters for VHF communication systems (transmitter)

Parameter	*DSB-AM*	*DSB-AM*	*VDL-M2*	*VDL-M2*	*VDL-M3*	*VDL-M3*	*VDL-M4*	*VDL-M4*
TRANSMITTER	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*
Output power transmitter (typical ground station output power is 25 W or 50 W (44 dBm or 47 dBm)	44 dBm (25 W)	50 dBm (100 W)	42 dBm (16 W)	44 dBm (25 W)	44 dBm (25 W)	44 dBm (25 W)	42 dBm (15 W)	45 dBm (32 W)
Feeder loss (assumed)	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB
Antenna gain (assumed)	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB
EIRP	41 dBm (12.5 W)	49 dBm (80 W)	39 dBm (8 W)	43 dBm (20 W)	41 dBm (12.5 W)	43 dBm (20 W)	40 dBm (10 W)	44 dBm (25 W)
Adjacent frequency emissions (transmitter) for VDL specified in Annex 10, Volume III, Part I, 6.3.4.								
1st adjacent frequency (16 kHz bandwidth)	Not specified in Annex 10		–18 dBm	–18 dBm	–18 dBm	–18 dBm	–18 dBm	–18 dBm
2nd adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–28 dBm	–28 dBm	–28 dBm	–28 dBm	–28 dBm	–28 dBm
4th adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–38 dBm	–38 dBm	–38 dBm	–38 dBm	–38 dBm	–38 dBm
8th adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–43 dBm	–43 dBm	–43 dBm	–43 dBm	–43 dBm	–43 dBm

Parameter	*DSB-AM*	*DSB-AM*	*VDL-M2*	*VDL-M2*	*VDL-M3*	*VDL-M3*	*VDL-M4*	*VDL-M4*
TRANSMITTER	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*
16th adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–48 dBm	–48 dBm	–48 dBm	–48 dBm	–48 dBm	–48 dBm
32nd adjacent frequency (25 kHz bandwidth)	Not specified in Annex 10		–53 dBm	–53 dBm	–53 dBm	–53 dBm	–53 dBm	–53 dBm

Table 2-2 Typical values for various parameters for VHF communication systems (receiver)

Parameter	*DSB-AM*	*DSB-AM*	*VDL-M2*	*VDL-M2*	*VDL-M3*	*VDL-M3*	*VDL-M4*	*VDL-M4*
RECEIVER	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*	*Airborne*	*Ground*
Minimum signal at receiver antenna Annex 10, Volume III	75 μV/m (–82 dBm) Part II, 2.2.1.2	20 μV/m (–93 dBm) Part II, 2.3.1.2	75 μV/m (–82 dBm) Part I, 6.2.2.	20 μV/m (–93 dBm) Part I, 6.3.2	75 μV/m (–82 dBm) Part I, 6.2.2.	20 μV/m (–93 dBm) Part I, 6.3.2	75 μV/m (–82 dBm) Part I, 6.9.5.1.1.2	35 μV/m (–88 dBm) Part I, 6.9.5.1.1.1
Feeder loss	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB	–3 dB
Antenna gain	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB	0 dB	2 dB
Minimum signal at receiver input	–85 dBm	–94 dBm	–85 dBm	–94 dBm	–85 dBm	–94 dBm	–85 dBm	–89 dBm
Out-of-band immunity performance of receiver as per Annex 10, Volume III, Part I, 6.3.5.3 (VDL) and Volume III, Part II, 2.3.2.8 (DSB-AM).								
1st adjacent channel	–	–	–40 dB	–40 dB	–40 dB	–40 dB	–40 dB	–40 dB
4th adjacent channel	–50 dB	–50 dB	–60 dB	–60 dB	–60 dB	–60 dB	–60 dB	–60 dB

2.3.2.2 Conversion from input power (dBm) to field strength (μV/m and vice versa) was calculated using formula (17):

$$P_r = E - 20\log f - 167.2$$

where:

P_r: is isotropically received power (dB(W));

E: is the electric field strength (dB(μV/m)); and

f: is the frequency in GHz (ITU Recommendation ITU-R P.525-4 refers).

This formula can be rewritten into:

$$10\,log\,P_r = 20\,log\,E - 20\,log\,f - 77.2$$

where:

P_r: is the signal at receiver antenna (in space) in mW;

E: is the field strength at the antenna in μV/m; and

f: is the frequency in MHz;

[dB(μV/m) = 20log(μV/m)]

$10\log P_r$ is expressed in dBm (power relative to 1 milliWatt).

Note.— The typical transmitter power of ground stations can vary from 10 to 100 W.

2.4 ALLOTMENT OF THE FREQUENCY BAND 117.975–137 MHZ

2.4.1 Special frequencies

2.4.1.1 Annex 10, Volume V, Chapter 4 contains a general allotment of the frequency band 117.975–137 MHz. The main subdivisions of this band are the frequency bands allocated to both international and national services and frequency bands solely allocated to national services. Specific allotments to services are to be determined regionally. Appendices B and C contain these regionally agreed allotment plans. In practice, not much consideration is given to the allotments for national/international use (see Figure 2-7).

Note.— Frequency assignments for international use are those that are required as per Regional Air Navigation Plans. These frequencies are identified by "ICAO" in the frequency assignment plan. Other frequencies are for national use and are identified as "NAT" in the frequency assignment plan.

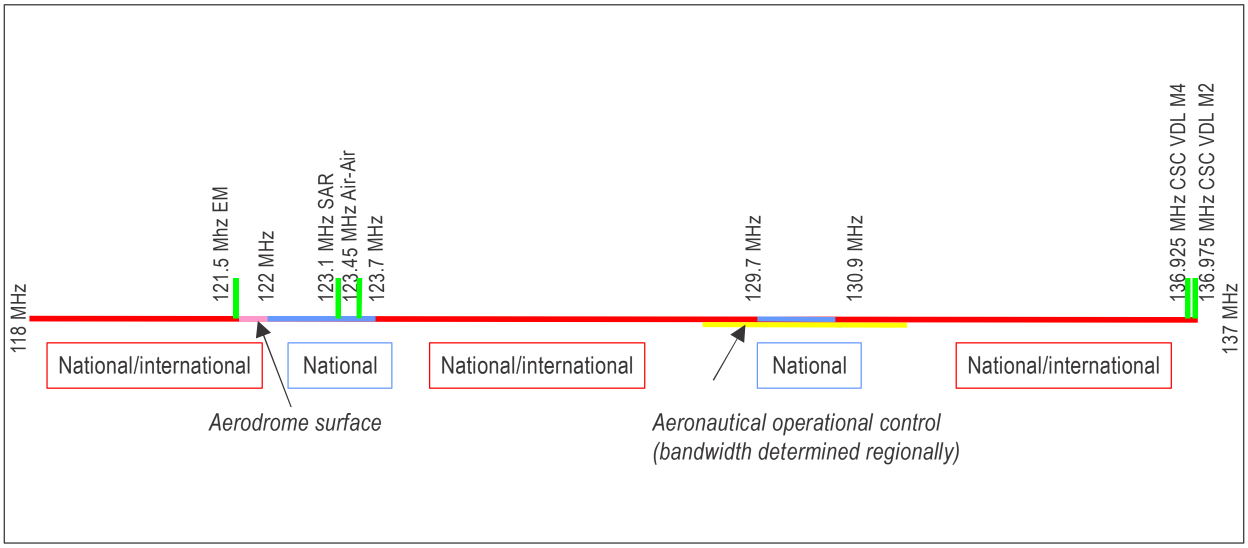

Figure 2-7. Special frequencies and allotments (Annex 10)

2.4.1.2 Annex 10, Volume V includes provisions for the use of specific frequencies, which are shown in Figure 2-7 and Table 2-3:

Table 2-3. Frequency allotment and special frequencies

Frequency (MHz)	*Usage*	*Comments*	*Annex 10, Volume V*
121.500	Aeronautical emergency frequency	Guard band* 121.450–121.550 MHz	4.1.3.1
121.550–122.917	Aerodrome surface communications		–
123.100	Auxiliary frequency (SAR)	Guard band* 123.050–123.150 MHz	4.1.3.4
123.450	Air-to-air communications	Outside range of VHF stations	4.1.3.2
128.825–132.025	Aeronautical operational control	Range to be determined regionally**	4.1.6.1.2 Recommendation
136.925	Common signalling channel	Reserved for VDL Mode 4	4.1.3.3.2
136.975	Common signalling channel	Reserved for VDL Mode 2	4.1.3.3.1
136.500–136.975	Only for frequency assignments with 25 kHz channel spacing		4.1.6.1, Note 1

* The frequencies 121.450 MHz, 121.550 MHz, 123.050 MHz and 123.150 MHz are assignable frequencies.
** Regional allotment plans have determined the actual band for aeronautical operational control communications.

2.4.1.3 Regional allotment plans provide for the use of the frequency band 136–137 MHz by VDL (VDL Mode 2 and VDL Mode 4).

2.4.2 Regional allotment plans

2.4.2.1 In addition to the general allotment plan in Annex 10, all regions have developed more detailed allotment plans through which operational services are allotted to certain frequency bands and are included in relevant ICAO Regional Air Navigation Plans. The prime goal of these allotment plans is to accommodate new frequency assignments in the sub-bands allotted to a particular service. Appendix B and the supplement (published separately) to this Handbook contain a detailed overview of these allotment plans. The supplement can be downloaded at: http://www.icao.int/safety/fsmp/documents/doc9718.

2.4.2.2 Frequency assignments should preferably be made in accordance with the provisions of the regional allotment table. However, if a particular requirement for a frequency assignment cannot be made from within the sub-band that is allotted to the relevant service, other sub-bands can be considered to satisfy the requirement. The regional frequency allotment plans also include provisions for sub-bands for aeronautical operational control (AOC) communications.

2.4.2.3 Regional allotment plans provide the use of the frequency band 136–137 MHz by VDL (VDL Mode 2 and VDL Mode 4). In Europe, the frequency band 136.700–137.000 MHz is reserved for VDL (see Appendices B and C).

2.5 FREQUENCY SEPARATION AND CHANNELLING

2.5.1 Frequency separation between VHF communications channels

2.5.1.1 Annex 10 stipulates that the minimum separation between assignable frequencies in the aeronautical mobile (R) service shall be 8.33 kHz (see Annex 10, Volume V, 4.1.2.2). This provision recognizes that in regions or areas where 25 KHz channel spacing provides an adequate number of frequency assignments to meet national and international requirements, for equipment designed for 25 kHz channel spacing, such equipment will continue to be used and continue to be protected. The introduction of 8.33 kHz channel spacing in regions or areas requires a regional air navigation agreement for the mandatory carriage of equipment designed for 8.33 kHz channel spacing.

2.5.1.2 Currently, 8.33 kHz frequency separation has only been introduced in the EUR region. All other regions have agreed to base frequency assignment planning on 25 kHz frequency separation. This implies that radio equipment designed for 50 kHz or 100 kHz frequency separation, which may be still in operational use, may not always be protected from harmful interference that can be caused by stations operating on adjacent 25 kHz or 8.33 kHz frequencies.

2.5.2 Protection of 25 kHz frequency assignments from 8.33 kHz assignments

In regions that continue operating communication equipment designed for a frequency separation of 25 kHz, frequency assignments are protected from harmful interference from the use of frequencies operating on multiples of 8.33 kHz, both within the same region as well as in adjacent regions (see Annex 10, Volume V, 4.1.2.3, Note and 4.1.6.1, Note 2).

2.5.3 Channelling

Normally, in aviation (e.g. in radiotelephony), the frequency in use is identified by the actual frequency. When using 8.33 kHz frequencies, the frequency identification for 8.33 kHz frequencies is replaced with a channel identification using a number (similar to the identification of a frequency) which is mapped to the actual frequency in use. The channel/frequency identification to be used for identifying frequencies with a channel spacing of 8.33 kHz is as shown in Table 2-4.

Table 2-4. Channelling/frequency pairing for frequencies with 25 kHz and 8.33 kHz separation

Frequency (MHz)	*Frequency separation (kHz)*	*Channel*
118.0000	25	118.000
118.0000	8.33	118.005
118.0083	8.33	118.010
118.0167	8.33	118.015
118.0250	25	118.025
118.0250	8.33	118.030
118.0333	8.33	118.035
118.0417	8.33	118.040
118.0500	25	118.050
118.0500	8.33	118.055
118.0583	8.33	118.060
118.0667	8.33	118.065
118.0750	25	118.075
118.0750	8.33	118.080
118.0833	8.33	118.085
118.0917	8.33	118.090
118.1000	25	118.100
etc.		

2.6 SERVICES AND DESIGNATED OPERATIONAL COVERAGE (DOC)

2.6.1 Services

Frequency assignments are made to implement specific aeronautical services, as follows:

Aerodrome

AS	Aerodrome surface communications
AFIS	Aerodrome flight information service
TWR	Aerodrome control tower

Approach

APP	Approach control service
ATIS	Automatic terminal information service
PAR	Precision approach radar

En-route

ACC	Area control centre
FIS	Flight information service

Other functions

A/A	Air-to-air
A/G	Air-to-ground
AOC	Aeronautical operational control
BC	(ground) broadcast communications
EM	Emergency
GP	VHF En-Route General Purpose
RGA	Regional Guard
SAR	Search and rescue
VOLMET	Meteorological information for aircraft in flight

2.6.2 Coordination of special frequencies

No coordination of frequency assignment planning is necessary for the emergency frequency 121.500 MHz and the SAR frequency 123.100 MHz as these services are available globally at each station where this service is required. The provisions in Annex 10 include a guard band for these frequencies to prevent adjacent channel interference. Also, no specific frequency assignment planning is required for the air-to-air communication channel 123.450 MHz as this channel is to be used only in remote and oceanic areas when the aircraft is out of the coverage of VHF ground stations.

2.6.3 Table of uniform values for DOC

2.6.3.1 Frequencies for aeronautical radio communication services are (normally) implemented to satisfy the operational need for specific services. These services, and their uniform DOC areas, are as in Table 2-5.

Table 2-5. Table of uniform DOC

Service	*Designated operational coverage (DOC)*		*Comments*	*Mode*
	Range (NM)	*Height (ft)*		
Aerodrome				
TWR	25	4 000	Height above ground	A/G
TWR/L	16	3 000	Height above ground; only in EUR	
PAR	25	4 000	Height above ground	A/G
AFIS	25 EUR: 15	4 000 EUR: 3 000	Height above ground	A/G
AS	Limits of aerodrome	Surface		A/G
Approach				
APP–L	50 EUR: 25	12 000 10 000		A/G
APP–I	75 EUR: 40	25 000 EUR: 15 000		A/G
APP–U	150 EUR: 50	45 000 EUR: 25 000		A/G
En-Route				
ACC–L	Area	25 000	Within specified area; maximum recommended range is 155 NM	A/G
ACC-LL	EUR: Area	15 000	Within specified area; maximum recommended range is 120 NM	
ACC-I	Area	25 000 EUR: 35 000	Within specified area; maximum recommended range is 130 NM Within specified area; maximum recommended range is 185 NM	A/G
ACC–U	Area	45 000	Within specified area; maximum recommended range is 200 NM	A/G
FIS-L	Area	25 000	Within specified area; maximum recommended range is 155 NM	A/G
FIS or FIS-U	Area	45 000	Within specified area; maximum	A/G

Service	*Designated operational coverage (DOC)*		*Comments*	*Mode*
	Range (NM)	*Height (ft)*		
		EUR: 23 000	recommended range is 200 NM Within specified area; maximum recommended range is 120 NM	
VOLMET	200	45 000	Maximum recommended range is 200 NM	BC
Other functions				
ATIS	200 EUR: 60	45 000 EUR: 20 000		BC
A/A	200	45 000	Maximum recommended range is 200 NM	A/G
A/G	200	45 000	Maximum recommended range is 200 NM	A/G
AOC	100	250	Not protected; maximum recommended range is 100 NM	A/G
EM	N/A	N/A	No frequency coordination required	A/G
SAR	N/A	N/A	No frequency coordination required	A/G
GP	200	45 000	Maximum recommended range is 200 NM	A/G

Note 1.— Different DOC areas may be specified by States.

Note 2.— DOC for AOC-only provided to enable compatibility assessment when frequencies for AOC are shared with air traffic control (ATC) services; different DOC may be specified.

Note 3.— For area services, no frequency protection is provided outside the specified area.

Note 4.— Unless specified by States, the DOC for A/A and A/G is assumed at 45 000 ft/200 NM.

Note 5.— Mode: A/G: air-ground communications; BC: (ground) broadcast communications.

2.6.3.2 Additional functionality concerning the use of these services in the “Comments” column may be added to the services as follows:

CD: Clearance delivery

CTA: Control area

DF: Direction finding

ER: Extended range

PAR: Precision approach radar

RCAG: Remote controlled air-ground communication

SR: Surveillance radar

These additions do not alter the basic service or the DOC for which the frequency is required and should be included as a remark to the frequency assignment in the global table of frequency assignments. Certain services may not require protection because they are not in operation to provide safety-of-life service (e.g. for gliders, hot air balloons). However, when these services are shared with ATC services, a compatibility analysis is required (see also 2.7.2.5.3).

2.6.3.3 Non-standard DOC (range and height) may be implemented as and when required. Reduced DOC, where operationally acceptable, may alleviate frequency congestion.

2.6.3.4 The use of common frequencies, preferably region-wide, to satisfy requirements for specific non-protected applications such as light aviation, gliding and hot air balloon activities is recommended, as such use increases the efficiency in frequency assignment planning.

2.6.3.5 Frequencies for aeronautical operational control are not protected through frequency planning. These frequencies are normally assigned on the basis of the traffic load that is expected (e.g. within the same area, smaller airlines can share the same frequency for operational control purposes).

2.6.4 Coverage at very low angles from the ground transmitter

2.6.4.1 Due to the vertical polar diagram of the antenna of the ground station, at very low angles the radiation of the transmitted energy is too low to provide coverage over a large area. Also, the distance to the aircraft decreases if the angle of the radio path with the horizontal plane through the ground antenna increases. As an example, for an aircraft operating at 45 000 ft, the distance to the ground transmitter decreases as shown in Table 2-6 (4/3 earth radius).

Table 2-6. Distance as function of angle above horizon

Angle (degree)	*Distance (NM) Height: 45 000 ft*	*Distance (NM) 25 000 ft*	*Distance (NM) 4 000 ft*
0 (radio horizon)	261	195	78
.1	252	186	70
.2	245	178	63
.3	237	171	57
.4	230	164	52
.5	223	158	74
.6	217	152	43
.7	210	146	40
.8	204	140	37
.9	198	135	34
1	192	130	32

The geometry used in these calculations is shown in Figure 2-8.

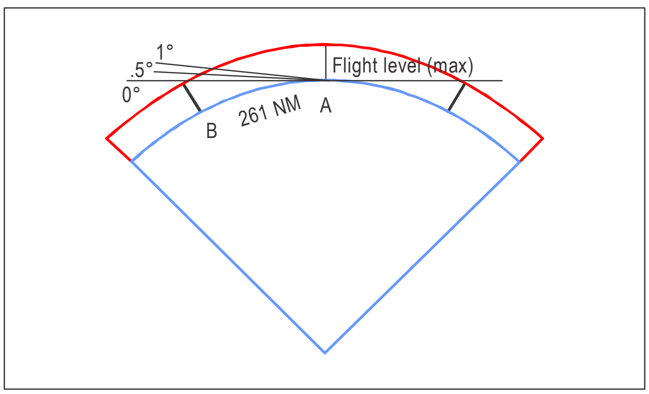

Figure 2-8. Range as function of angle above horizon

2.6.4.2 On the basis of the principles in 2.6.4.1, for certain services no actual maximum DOR has been specified, and the maximum operational range within which frequency protection is provided can be about 80 per cent of the distance to the radio horizon. For some of these services, a maximum operational range has been incorporated in Table 2-5.

2.6.4.3 It is recognized that States may require different values for the DOC from the uniform values in Table 2-5 for certain services.

Note.— Application is to be decided at a regional level.

2.6.5 Interference from FM broadcasting stations

The risk of interference from FM broadcasting stations operating in the band 87–108 MHz is generally not considered for frequency assignments in the band 117.975–137 MHz.

2.6.6 Co-location of facilities

ICAO frequency assignment planning does not include protection against interference that may be caused if facilities are co-located (e.g. interference due to intermodulation products). During the installation of communications systems, the communications service provider needs to take measures to prevent such cases of interference (e.g. by using cavity filters).

2.6.7 Coordination of frequency assignments

2.6.7.1 Frequency coordination must take place with all States that may be affected by a proposal for a new frequency assignment or where the characteristics of an existing assignment are modified. Normally, such coordination is effected through the ICAO Regional Offices which have a central and coordinating role in frequency assignment planning.

2.6.7.2 At the interregional level, bilateral coordination procedures should be agreed between the ICAO Regional Offices involved, while documenting, inter alia, actions with timelines and information required for coordination. Typical information required for such interregional coordination includes operational frequencies, type of operation, the geographical coordinates of the location, the designated operational coverage area and the date of planned implementation.

2.7 CALCULATION OF SEPARATION DISTANCES (METHODOLOGY)

Note.— The material in this section can be used in cases where frequency assignment planning needs to consider systems with only 25 kHz or 8.33 kHz frequency separation to ensure co- and adjacent frequency compatibility. Paragraph 2.7.4 contains material that can be used when there is a need to establish separation distances to ensure compatibility between systems operating with 25 kHz and 8.33 kHz characteristics.

2.7.1 Frequency and/or distance separation

2.7.1.1 Protection of frequency assignments from harmful interference is achieved through frequency and/or distance separation. Normally, the determining factor in frequency assignment planning is the risk of interference between two aircraft operating within different DOC areas at the closest point. As normally the ground station is located well within the DOC area, the ground station is protected when the aircraft (receiver) is protected from harmful interference.

2.7.1.2 The separation distances provided in this section are the minimum distances that need to be maintained between the ground stations that provide the relevant service. The separation distances have been established using the method and provisions in 2.2 and 2.3 and comply with the frequency assignment planning criteria as specified in Annex 10, Volume V. Practical values for the separation of co-frequency facilities are in 2.8.

2.7.2 Co-frequency separation distances

2.7.2.1 *Air-ground communication services*

Protection of co-frequency assignments for air-ground communication services (involving aircraft transmissions) is obtained by ensuring that the D/U ratio is in accordance with the regionally agreed value. The D/U ratio can be either 14 dB or 20 dB (see 2.3).

2.7.2.2 *Circular service areas*

When the separation distance is based on D/U = 20 dB or radio line-of-sight distance:

As described in 2.3 and as per the requirements of Annex 10, the minimum required separation distance from the edge of the DOC of the (desired) ground station to another (undesired) aircraft, operating on the same frequency (and outside the desired DOC), should be no less than the sum of the distance to the radio horizon from each aircraft station. As shown in Figure 2-9, the minimum distance between the DOC of the service areas is equal to:

$$RH_A + RH_B$$

The distance to the radio horizon can be calculated using formulas (9) or (10) in Chapter 1, 1.3.2. In these formulas, the factor $\mathbf{h_{TX}}$ or $\mathbf{h_{RX}}$ is the designated operational height of the respective DOC areas.

As shown in Figure 2-9, when the ground stations (with circular coverage and the ground stations located approximately at the centre of this coverage area) have a DOR of $\mathbf{R_A}$ and $\mathbf{R_B}$ respectively and $\mathbf{RH_A}$ and $\mathbf{RH_B}$ is the distance from the respective aircraft to the radio horizon, the minimum separation distance between the ground stations is:

$$R_A + RH_A + RH_B + R_B.$$

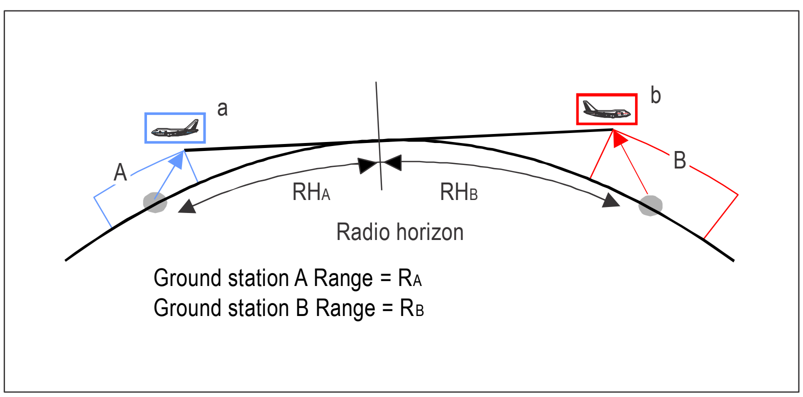

Figure 2-9. Separation based on radio line-of-sight

When the separation distance is based on D/U = 14 dB (1:5 separation distance ratio) or radio line-of-sight:

As described in 2.2.2 and as per the requirements of Annex 10, the minimum required geographical separation distance between the edges of the DOC areas can be calculated with the separation distance ratio method as follows (this method has been implemented in Europe and North America):

To meet the 14 dB protection requirement, the distance between the (desired) aircraft receiver and the (interfering) aircraft transmitter needs to be at least 5 times the distance between the (desired) aircraft receiver and the desired ground station in case all transmitters use the same EIRP (see 2.2.3).

In Figure 2-10, the DOR for ground station **A** is RA and for ground station **B** is RB. Aircraft stations **a** and **b** operate at the closest point and at the edge of the respective DOC areas. If the (minimum) separation distance from aircraft station **a** to aircraft station **b** is at least 5 times the distance from aircraft station **a** to ground station **A** ($5*R_A$), then aircraft station **a** is protected (14 dB) from interference from aircraft station **b**. Vice versa, if the distance from aircraft station **b** to aircraft station **a** is at least 5 times the distance from aircraft station **b** to ground station **B** ($5*R_B$), then aircraft station **b** is protected from interference from aircraft station **a**. The minimum required separation distance between the two DOC areas **A** and **B** is the largest of:

$$(Max)\ [5*R_A \text{ or } 5*R_B]$$

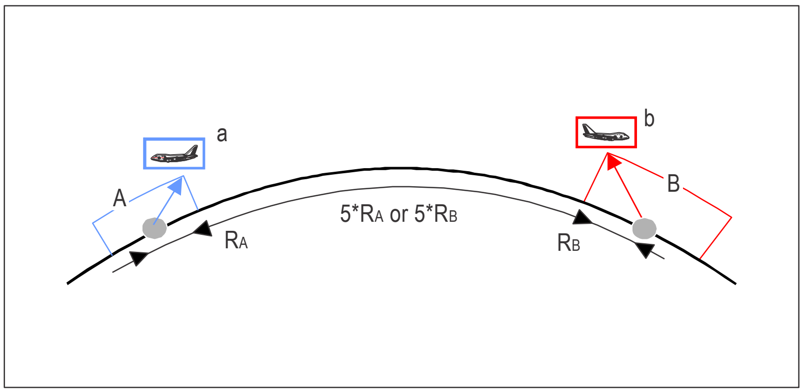

Figure 2-10. Separation distance based on the 5:1 distance ratio

The minimum separation between the ground stations (with circular coverage for **A** and **B** and the ground stations located in the approximate centre of the DOC) is the larger value of:

$$(Max)\ [(R_A + 5R_A + R_B) \text{ or } (R_A + 5R_B + R_B)]$$

In cases where the value (Max) [$5*R_A$ or $5*R_B$] is larger than the sum of the distances to the radio horizon of each facility **($RH_A + RH_B$)** as described in 1.3.3.1 and 2.2.5, the radio line-of-sight criterion should be used. The minimum total required separation distance between closest points at the edges of the respective coverage areas is therefore:

$$(Min)\ \{[RH_A+RH_B] \text{ or } (Max)\ [5R_A \text{ or } 5R_B]\}$$

Note 1.— In both the above cases, the edge of the DOC area is the point where the aircraft can operate at maximum DOR and height. Application of the 5:1 distance ratio assumes that the EIRP of both the desired station and the undesired/interfering station are the same. Where the EIRP of the transmitters is different, adjustments to the 5:1 distance ratio are necessary (see 1.3.4).

Note 2.— The application of the 5:1 distance ratio in frequency assignment planning is not recommended for area services or for services with circular DOC when the ground station is located well outside the centre of the circular service, since in these cases the worst case where the 5:1 distance ratio needs to be met is not always the closest point between the DOC areas being considered. In addition, it should be recognized that the benefits for efficient frequency assignment planning using the 5:1 distance ratio are marginal. Only in areas where frequency congestion is becoming desperate should the use of the 5:1 distance ratio for frequency assignment planning be considered.

*Note 3.— In both the above cases, once protection of the aircraft receiver **a** is secured, the ground station is protected from harmful interference (from aircraft station **b**, since the ground station is well beyond the radio horizon of aircraft station **b**).*

2.7.2.3 *Area services – co-frequency separation distances*

2.7.2.3.1 The minimum separation distance between the DOC of two area services is equal to the sum of the radio line-of-sight for each area service at the limit of the DOC (coverage). This method provides frequency protection throughout the DOC of the area service and establishes for each of the area services a buffer zone equal to the distance to the radio horizon for an aircraft at maximum altitude of the relevant DOC. The minimum separation to protect the two area services from harmful interference is established at the closest point between the service areas.

2.7.2.3.2 In many cases, for large DOC areas of area services, a single ground station cannot provide coverage throughout the service area. In these cases, where required, additional coverage is provided through installing extended range stations (forward relay). These stations can operate on the same frequency (using the offset carrier system as specified in Annex 10, Volume III) or on a discrete frequency. Full VHF coverage may not be provided in all cases, in particular for lower flight levels.

2.7.2.3.3 When the same frequency used by an area service is also used by a broadcasting service (which is a circular service), the minimum separation is the larger value of the following:

a) To protect the aircraft receiver at the edge of the area coverage, the minimum distance to the ground broadcast transmitter should be at least the distance to the radio horizon +15 NM from the limit of the DOC of the area service.

b) The minimum distance from the aircraft broadcast receiver to the airborne transmitter at the edge of the area service should be at least the sum of the distance to the radio horizon (radio line-of-sight) for each aircraft. The minimum distance from the edge of the DOC of the area service to the broadcast transmitter should be at least the sum of the distance to the radio horizon for each aircraft plus the range of the broadcast station.

2.7.2.3.4 The methodology for establishing the minimum separation distances is also applied in 2.7.3 and 2.7.4. However, in order to ensure protection of area services throughout the DOC, separation distances for area services are measured from the limit of the DOC rather than from the ground station(s) providing the area service.

2.7.2.3.5 As pointed out in Note 2 to 2.7.2.2, the use of the 5:1 distance ratio for co-frequency assignment planning for area services is not recommended.

2.7.2.4 *Broadcast services (ATIS and VOLMET)*

2.7.2.4.1 Broadcast services such as ATIS and VOLMET are characterized by ground-to-air transmissions only and do not involve airborne transmissions. Consequently, only interference from the (undesired) ground broadcast station needs to be considered; due to the continuing nature of the broadcast transmissions, protection of the (desired) signal down to the muting level of the receiver is necessary.

2.7.2.4.2 A VOLMET (ATIS) broadcast station normally has a maximum DOR of 200 NM and a maximum designated operational height of 45 000 ft (see 2.6.3 and Table 2-5). For an (undesired) VOLMET transmitter with an EIRP of 100 W, the field strength at the (desired) aircraft, when the VOLMET station is 15 NM beyond the radio horizon of the (desired) aircraft, will be approximately at the receiver muting level of 5 μV/m (–105.6 dBm).

2.7.2.4.3 The DOC for these broadcast stations is normally the maximum that can be achieved (200 NM at flight level 450). The interference mechanism is shown in Figure 2-11.

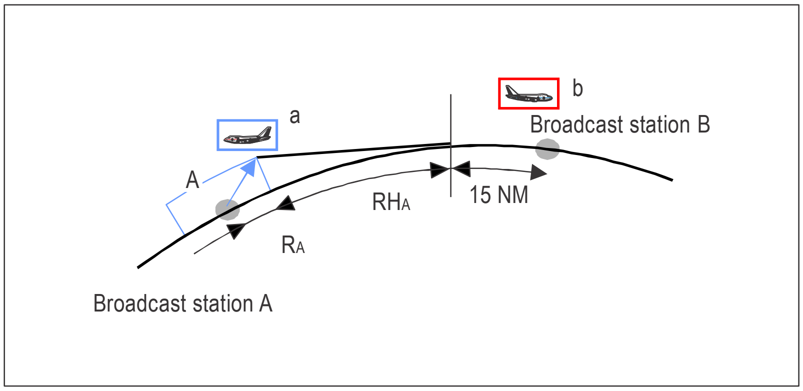

Figure 2-11. Interference mechanism between broadcast services

The minimum separation distance between two (ground) broadcast stations is:

$$R_A + RH_A + 15\ (NM)$$

To ensure compatibility when ground station **B** is the wanted broadcast station and aircraft station **b** is the desired receiving aircraft station, the minimum separation distance between the (ground) broadcast stations **A** and **B** is:

$$R_B + RH_B + 15\ (NM)$$

To ensure compatibility between the two broadcast stations, the minimum separation distance to be maintained between the ground broadcast stations **A** and **B** respectively is the larger value of:

$$(Max)\ RH_A + R_A + 15 \text{ or } RH_B + R_B + 15$$

where:

R_A: is the DOR for ground broadcasting station **A**;

R_B: is the DOR for ground broadcasting station **B**;

RH_A: is the distance to the radio horizon of aircraft station **a**; and

RH_B: is the distance to the radio horizon of aircraft station **b**.

(Distances in NM)

The minimum separation distances between the edge of the DOC of each facility is 15 NM.

2.7.2.5 *Broadcast and air-ground services*

2.7.2.5.1 To protect an aircraft station receiving broadcasts from a ground station from another station providing air-ground communications, the mechanism as shown in Figure 2-12 applies.

2.7.2.5.2 In order to protect aircraft station **b**, which is receiving (only) broadcast information from ground broadcast station **B** (e.g. VOLMET or ATIS), from interference that can be caused by transmissions from aircraft station **a**, the same methodology as described in 2.7.2.2 applies (separation distances are calculated if both the undesired and the desired stations provide air-ground communication services).

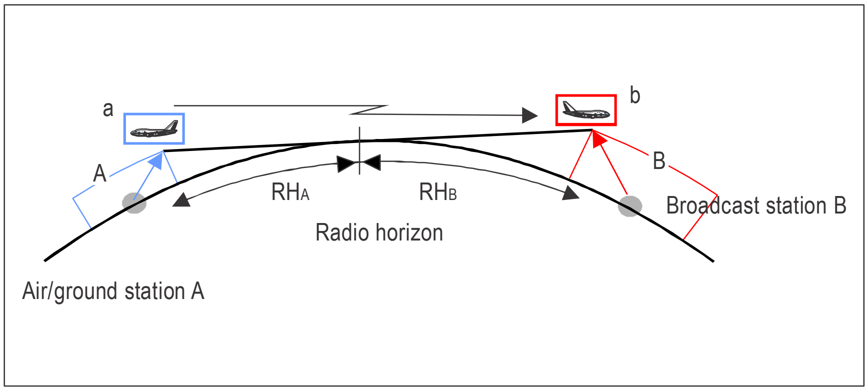

Figure 2-12. Interference mechanism between broadcast services and air-ground services

2.7.2.5.3 To protect aircraft station **a** from interference that can be caused by (ground) broadcast station **B**, the minimum separation between the two ground stations needs to be (see 2.7.2.4):

$$R_A + RH_A + 15\ NM$$

However, the distance to protect aircraft station **b** from interference from transmissions from aircraft station **a** is always greater than the distance to protect aircraft station **a** from interference that can be caused by broadcasting station **B**. Geographical separation between the facilities should be based on the method as described in 2.7.2.1.

2.7.2.6 *Aerodrome surface (AS) communications*

2.7.2.6.1 Aerodrome surface (AS) communications provide an essential safety service. If the separation distance is not sufficient, clearances or other instructions that are intended to be used solely on a nearby ("undesired") aerodrome can be understood as a valid instruction on the desired aerodrome. For AS communications, the actual difference in height (above MSL) at a nearby airport or the effect of anomalous propagation may need to be considered. A height difference of 100 m at the nearby aerodrome would result in the radio horizon (of the nearby aerodrome) being increased to about 25 NM. The resulting D/U would be 15.5 dB.

2.7.2.6.2 Along the same principles, as for aircraft in flight, as described in 2.7.2.2, the minimum separation distance can be calculated with the formula $RH_A + RH_B$ as illustrated in Figure 2-13.

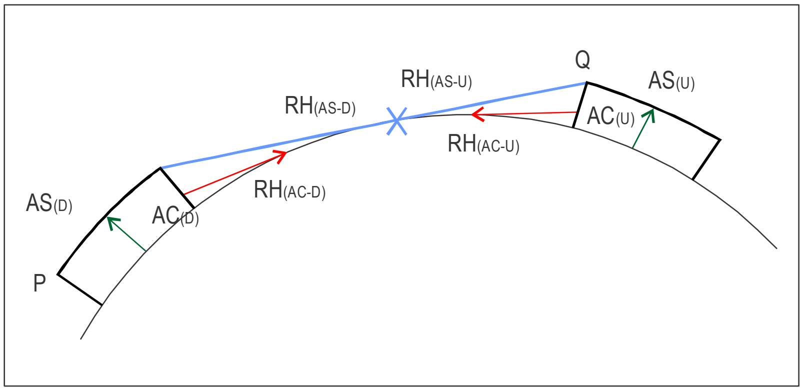

Figure 2-13. Geometry for calculating separation distances for AS communication services

In Figure 2-13, the parameters are:

$AS_{(D)}$ and $AS_{(U)}$:	DOC for aerodrome surface communications (5 NM/100 ft)
$AC_{(D)}$:	Desired aircraft (antenna height 30 ft)
$AC_{(U)}$:	Undesired aircraft (antenna height 30 ft)
$AS_{(D)}$:	Desired AS ground [base] station (antenna height 100 ft)
$AS_{(U)}$:	Undesired AS ground [base] station (antenna height 100 ft)
$RH_{(AS\text{-}D)}$ and $RH_{(AS\text{-}U)}$:	Distance to the radio horizon from the edge of coverage (12.3 NM)
$RH_{(AC\text{-}D)}$ and $RH_{(AC\text{-}U)}$:	Distance to the radio horizon from the aircraft at maximum range (6.7 NM for 30 ft)

Using formulas (1) and (3) in Chapter 1, the required transmission loss can be calculated as:

$$\frac{D}{U} = L_u - L_d$$

In this formula $L_d = 20 \log d_d = 13.9\ dB$ (d_d = 5 NM)

and $L_u = 20 \log d_u + A = 13.9\ dB$ (d_u is the distance to the radio horizon between the two ground stations which is for stations at a height of 100 ft (30 m) above the terrain 2 x 12.3 NM. **A** is the required transmission loss beyond the radio horizon):

$$\frac{D}{U} = L_u - L_d = 20 \log\ (RH_{(AS-d)} + RH_{AS-u}) + A - 13.9 = 20$$

For $RH_{(AS-d)} + RH_{AS-u}$ = 24.6, the factor **A** (transmission loss beyond the radio horizon) equals 6 dB. This corresponds to a distance of 12 NM. As a result, the total minimum separation between the edges of the DOC of the two ground stations should be 36.3 NM (37 NM). Since the antenna height above the terrain of the ground station (100 ft) is higher than that of the aircraft station, this separation distance will protect the communications with an aircraft (on the surface of an airport) as well as vehicles using AS frequencies.

Note.— When using the two-ray propagation model (see Chapter 1, 1.3.4), the minimum separation distance between the two ground stations would be slightly more than 25 NM.

2.7.2.6.3 In frequency assignment planning, the DOC for AS services is circular with a DOC of 5 NM (100 ft). The minimum separation distance between the DOC of two (co-frequency) AS services is equal to the sum of the distance to the radio horizon of each station. This would provide for a co-frequency separation distance of 35 NM between the ground stations.

2.7.2.6.4 If so desired, on the basis of regional agreements, the separation distances to be applied can be amended. In addition, consideration could be given to increase the minimum separation distance to a value that would reduce the undesired signal to below a squelch level of 5 μV/m at the airborne and ground receiver antennas. However, when considering that more realistic propagation models for ground-ground propagation as in Chapter 1, 1.3.2 will result in better protection, the separation distance of 35 NM between AS ground stations may provide sufficient protection.

2.7.2.6.5 Adjacent channel protection for AS services needs to be provided by ensuring that the DOC of the undesired (interfering) station is separated by at least 10 NM from the DOC of the desired station.

2.7.2.7 *Unprotected services*

2.7.2.7.1 Certain services are not protected from interference and in many cases no coverage has been determined for these services. An example is the use of frequencies for aeronautical operational control or for special uses, such as for gliders and hot air balloons.

2.7.2.7.2 Assignment of frequencies to stations is, in these cases, normally determined on the basis of the traffic loading that can be expected by the users of these "unprotected" frequencies. As long as these frequencies are in operation exclusively for unprotected use, these assignments should not be subject to interference calculations.

2.7.2.7.3 When these frequencies are shared with protected services, consideration needs to be given to whether the use of the unprotected frequencies may cause interference to frequencies (co- and adjacent frequency) which do require protection from harmful interference and an assessment of potential interference should be undertaken. This may result in a situation that while the protected service is to be protected from interference from the unprotected service, the unprotected service is in turn also protected from interference from the protected service. In these cases, establishing a DOC for the unprotected service is necessary.

2.7.2.7.4 In the interest of efficient frequency assignment planning, it is important to realize that when frequency assignments to unprotected services are being made, these should preferably be concentrated in one (or more) sub-bands solely reserved for unprotected services. Where feasible, such sub-bands should be established.

2.7.3 Adjacent frequency separation

2.7.3.1 *Air-ground communication facilities using the same channel bandwidth (either 25 kHz or 8.33 kHz)*

2.7.3.1.1 For stations operating with the same frequency characteristics, no adjacent frequency assignment planning constraints apply. However, when one or both facilities are operating with 8.33 kHz frequency separation and at least one of these facilities operates on offset carrier frequencies as per Annex 10, Volume III/V, the separation distances are to be determined using co-frequency assignment planning separation criteria.

2.7.3.1.2 The criteria in 2.7.3.1.1 are based on the consideration that air-to-air, air-to-ground and ground-to-air adjacent frequency interference is not harmful. The area within which such interference may occur is limited to a small area and is transient in nature.

2.7.3.1.3 For stations operating on the first adjacent frequency with the same characteristics (25 kHz or 8.33 kHz), a separation distance of 10 NM is to be maintained between the **ground transmitter** and the **ground receiver**. This is considered to be not a frequency assignment planning constraint but rather an implementation issue for States to consider when implementing or modifying frequency assignments. A practical measure may be to avoid assigning a first adjacent frequency to the same location. When a State is planning to implement a (ground) station closer than 10 NM to the border of a neighbouring State, bilateral coordination or coordination through the relevant ICAO Regional Office may be required to avoid potential interference from one ground transmitter into another ground receiver.

2.7.4 Co-frequency and adjacent frequency assignment planning in a mixed environment where both 25 kHz and 8.33 kHz frequency separation is being deployed

2.7.4.1 *Both facilities operate on the same (carrier) frequency*

2.7.4.1.1 Co-frequency geographical separation distances should be used when one facility is operating on the same frequency and with a channel bandwidth of 8.33 kHz as that of the other facility which is operating with a channel bandwidth of 25 kHz (e.g. channels 119.000 and 119.005 operate on the same frequency 119.000 MHz).

2.7.4.2 *Both facilities operate on a (carrier) frequency with a frequency separation of 8.33 kHz*

2.7.4.2.1 Co-frequency geographical separation distances should also be used when one facility is operating on a frequency separated by 8.33 kHz from the other facility which is operating with a channel bandwidth of 25 kHz (e.g. channels 119.010 and 118.990 using the frequency 119.0083 MHz and 118.9917 MHz respectively are to be considered as co-frequency to the (25 kHz) frequency/channel 119.000 MHz).

2.7.4.3 *Both facilities operate on a (carrier) frequency with a frequency separation of 16.67 kHz*

2.7.4.3.1 A geographical separation of 10 NM between the edges of the coverage of both stations must be maintained when one facility is operating on a frequency separated by 16.67 kHz from the other facility which is operating with a channel bandwidth of 25 kHz (e.g. channel 119.015 is operating on the (carrier) frequency 119.0167 MHz and 119.000 is operating on the (carrier) frequency 119.000 MHz).

2.7.4.4 Both facilities provide an aeronautical broadcast service (e.g. ATIS, VOLMET) and operate on a (carrier) frequency with a frequency separation of 16.67 kHz.

2.7.4.4.1 When both facilities operate with a frequency separation of 16.67 kHz and both facilities provide an aeronautical broadcast service, the minimum requirement is that the ground station of each facility is located at least 10 NM outside the DOC of the other facility.

Note 1.— The frequency assignment planning criteria in this section apply when the ground station is located inside the DOC.

Note 2.— It is generally recommended to avoid the use of adjacent channels at the same airport (or radio station).

Note 3.— See section 2.9 for separation distances for VDL Mode 2 and VDL Mode 4.

2.8 SEPARATION DISTANCES (AIR-GROUND COMMUNICATION SERVICES AND GROUND-BASED BROADCASTING SERVICES)

2.8.1 Calculation of distances to the radio horizon

2.8.1.1 By applying the methodology as described in 2.7.2, separation distances between the edges of the DOC areas are calculated using the distance to the radio horizon (R_{LOS}), as indicated in Table 2-7.

2.8.1.2 The minimum separation distances between the closest point of the DOC area of each service are summarized in Table 2-8 and are in accordance with the methods described in 2.7.2. Separation distances involving air-ground communication services are calculated as shown in 2.7.2.1.1 and are limited to the sum of the radio horizon of each facility. When using non-uniform values for the DOC of the services in Table 2-5, the minimum geographical separation distance between the edges of the DOC areas can be calculated as shown in 2.7.2.2 (separation distance based on radio line-of-sight distance).

2.8.1.3 The minimum separation distance between broadcast services (VOLMET, ATIS) assumes a DOC for these services of 260 NM/45 000 ft (see also 2.7.2.4).

Table 2-7. Distance to radio horizon with aircraft at maximum altitude

Symbol	*Service range (NM)*	*Service height*	*Radio horizon*
TWR	25 NM	4 000 ft	78 NM
AFIS	25 NM	4 000 ft	78 NM
AS	Limits of aerodrome	Surface	N/A
APP-U	150 NM	45 000 ft	260 NM
APP-I	75 NM	25 000 ft	195 NM
APP-L	50 NM	12 000 ft	134 NM
ACC-U	Specified area	45 000 ft	260 NM
ACC-L	Specified area	25 000 ft	195 NM
FIS-U	Specified area	45 000 ft	260 NM
FIS-L	Specified area	25 000 ft	195 NM
VOLMET	260 NM	45 000 ft	260 NM
ATIS	260 NM	45 000 ft	260 NM

2.8.2 Table of separation distances

2.8.2.1 *Separation distances between the edges of the designated coverage areas (see Table 2-8)*

Table 2-8. Minimum geographical co-frequency separation distances between the edges of the DOC

		VICTIM											
	Service	*TWR 25/4000*	*AFIS 25/4000*	*AS Surface*	*APP-U 150/450*	*APP-I 75/250*	*APP-L 50/120*	*ACC-U Area/450*	*ACC-L Area/250*	*FIS-U Area/450*	*FIS-L Area/250*	*VOLMET 260/450*	*ATIS 200/450*
INTERFERENCE	TWR	156	156		338	273	212	338	273	338	273	338	338
	AFIS	156	156		338	273	212	338	273	338	273	338	338
	AS (Note 2)			25									
	APP-U	338	338		520	455	394	520	455	520	455	520	520
	APP-I	273	273		455	390	329	325	390	455	390	455	455
	APP-L	212	212		394	329	268	394	329	394	329	394	394
	ACC-U (Note 1)	338	338		520	455	394	520	455	520	455	520	520
	ACC-L (Note 1)	273	273		455	390	329	455	390	455	390	455	455
	FIS-U (Note 1)	338	338		520	455	394	520	455	520	455	520	520
	FIS-L (Note 1)	273	273		455	390	329	455	390	455	390	455	455
	VOLMET	338	338		520	455	394	520	455	520	455	15	15
	ATIS	338	338		520	455	394	520	455	520	455	15	15

Note 1.— All distances are in NM.

Note 2.— Frequencies for aerodrome surface communications should be selected from the band 121.550–121.990 MHz. This band is reserved exclusively for AS communications. No separation distances with other services are provided. Should it be necessary to share frequencies for AS with air-ground communication services, the minimum geographical separation distance can be calculated as shown in 2.7.2.6 and assuming a DOC for AS communications of 5 NM/100 ft.

2.8.2.2 In the EUR Region, the table of separation distances has been developed, taking into account:

a) different values for the uniform DOC (see 2.6.3.1 and Table 2-5); and

b) application of the separation distance ratio method (5:1) using the D/U protection ratio of 14 dB.

For information purposes, this table is reproduced below (Table 2-9):

Table 2-9. EUR table of separation distances

Service	*AFIS/TWR 16/3000*	*TWR 25/4000*	*APP-U 50/250*	*APP-I 40/150*	*APP-L 25/100*	*ACC-U Area/450*	*ACC-I Area/350*	*ACC-L Area/250*	*ACC/LL Area/150*	*VOLMET 271/450*	*ATIS 60/02050*
AFIS/TWR	*80*	*125*	*250*	*200*	*125*	328	297	261	218	328	241
TWR	*125*	*125*	*250*	*200*	*125*	339	308	272	229	339	252
APP-U	*250*	*250*	*250*	*250*	*250*	455	424	388	345	455	*300*
APP-I	*200*	*200*	*250*	*200*	*200*	412	381	345	302	412	*300*
APP-L	*125*	*125*	*250*	*200*	*125*	384	353	317	274	384	297
ACC-U (Note 1)	328	339	455	412	384	522	491	455	412	522	*300*
ACC-I (Note 1)	297	308	424	381	353	491	460	424	381	491	*300*
ACC-L (Note 1)	261	272	388	345	317	455	424	388	345	455	*300*
ACC-LL	218	229	345	302	274	412	381	345	302	412	*300*
VOLMET	328	339	455	412	384	522	491	455	412	10	211
ATIS	241	252	*300*	*300*	297	*300*	*300*	*300*	*300*	211	124

Note 1.— Separation distances are in NM.

Note 2.— Separation distances between VOLMET and ATIS were calculated assuming an antenna height of the VOLMET/ATIS transmitter of 65 ft (20 m).

2.9 SEPARATION DISTANCES FOR VDL (VDL MODE 2 AND VDL MODE 4)

2.9.1 VDL operating co-frequency with other VDL or VHF communications voice systems

2.9.1.1 The same planning criteria as those used between VHF voice systems (20 dB protection ratio) should be used. The separation criteria are calculated as described in 2.7.2. The DOC for VDL Mode 2 and VDL Mode 4 facilities needs to be separated from the DOC of a co-frequency VHF communications voice (DSB-AM) system by at least the sum of the distance to the radio horizon of each service.

Note.— This applies also to frequency assignments between VDL facilities not operating in the same network.

2.9.2 VDL operating on adjacent frequencies with other VDL or VHF communications voice systems

2.9.2.1 The first frequency adjacent (25 kHz) to either a DSB-AM frequency or a VDL frequency should not be used in the same airspace.

2.9.2.2 The second frequency adjacent (25 kHz) to a DSB-AM frequency should not be used in the same airspace for VDL Mode 4 (see Table 2-10).

Table 2-10. 25 kHz guard band (channels) between DSB-AM, VDL Mode 2 and VDL Mode 4 (air-air)

		Interference source		
		DSB-AM	*VDL 2*	*VDL 4*
Victim	DSB-AM		1	2
	VDL 2	1	1	1
	VDL 4	2	1	1

Note.— The numbers in Table 2-10 are guard bands (channels). The next frequency that can be used without a frequency planning constraint is one channel higher (e.g. a desired DSB-AM station that is interfered by a VDL Mode 2 aircraft station requires one 25 kHz guard band). The next frequency, 50 kHz away, can be used in the same DOC without any frequency assignment planning constraint.

2.9.3 Operation of VDL on the surface of an airport

2.9.3.1 Attention is drawn to the possibility of interference between DSB-AM and VDL Mode 2/4 when these systems are used on the surface of an airport. The following adjacent channel constraints have been developed under the assumption that the minimum separation between an aircraft on the surface of an airport and the ground station (transmitter/receiver) is at least 210 m. This is considered a realistic scenario at most airports. However, aircraft on the surface of an airport can be separated at closer ranges. Protection has been considered at the minimum required field strength and calculations have been made assuming free-space propagation. Measurements at a number of representative airports showed that, in many cases, the minimum field strength is about 10–12 dB higher than the minimum required.

2.9.3.2 On the basis of an analysis performed by the ICAO Aeronautical Communications Panel, the following frequency assignment planning constraints have been developed for VDL Mode 2 and VDL Mode 4, when operating aircraft on the surface of an airport (see Table 2-11).

Table 2-11. 25 kHz guard band (channels) between DSB-AM and VDL (Modes 2 and 4) on the surface of an airport

		Interference source		
		DSB-AM	*VDL 2*	*VDL 4*
Victim	DSB-AM	–	4	4
	VDL 2	4	1	1
	VDL 4	4	1	1

2.9.3.3 Interference can occur if the frequency separation between a VDL frequency assignment (guard band) is four channels (25 kHz) or less. In this case, interference between aircraft stations can be prevented through ensuring that the minimum field strength of these systems is at least 70 dBm at the antenna. Any interference that may be caused in ground-based receiving stations (i.e. not aircraft stations) can be mitigated through using cavity filters that block the reception of unwanted signals from transmissions from aircraft operating on the surface of an airport.

Note.— Detailed information is available in the documents VDL Assignment Planning Criteria (117.975–137 MHz) *and* VDL Mode 4 and VOR Compatibility (112–117.975 MHz), *which can be downloaded from the following website:* http://www.icao.int/safety/acp/repository.

2.10 GUIDANCE ON THE IMPLEMENTATION AND USE OF BACKUP FREQUENCIES

2.10.1 Assessment of the need for backup frequencies

2.10.1.1 Backup frequencies may be operationally required to provide an alternative air-ground communication channel in cases where an operational radio frequency is not available. Examples include: intentional interference; unintentional interference (e.g. badly designed FM broadcasting stations); stuck microphone; and phony air traffic controllers.

2.10.1.2 Implementation of backup frequencies should be limited only to the following ATC services:

AS:	Aerodrome surface communications
TWR:	Tower services
APP-L, APP-I and APP-U:	Approach services
ACC-L, ACC-U:	Area control services
VOLMET:	Meteorological information
FIS-L, FIS-U:	Flight information services

Other air-ground communication services such as ATIS, AFIS, generic unspecified air-to-air (A/A) services, generic unspecified air-to-ground (A/G) services, generic unspecified general purpose (GP) services and aeronautical operational control services (AOC) do not require backup communication channels.

2.10.1.3 Backup frequencies should not be provided when communication channels are lost due to malfunctioning of the ground infrastructure. Adequate backup facilities in cases of malfunctioning ground infrastructure (or parts thereof) should be in place. Examples are: equipment failure; power loss; and loss of ground communication links to remote transmitter/receiver sites.

2.10.1.4 The assessment of the required number of backup frequencies should be kept to the minimum needed. Where possible, it should be based on experience (e.g. number of days per year that a communication channel is not available).

2.10.1.5 Where operationally feasible, arrangements should be in place to share backup frequencies either between different services (at the same ATC centre) or between different facilities (e.g. different aerodromes or different ACC/FIS from different ATC centres).

2.10.1.6 In the COM list in the global table of frequency assignments, backup frequencies are identified as such.

2.10.2 Backup frequency for short distance communications

2.10.2.1 Short distance communications that may require backup frequencies include AS, TWR and APP services.

2.10.2.2 Backup frequencies should only be implemented at aerodromes with a clear operational requirement.

2.10.2.3 The number of backup frequencies for the combined services described in 2.10.2.1 should not exceed two (with a maximum of one backup frequency for TWR and one backup frequency for APP services).

Note.— A single backup frequency can in principle be used for a backup communications channel for both a TWR and an APP service or for a TWR and an AS service.

2.10.2.4 Adjacent air traffic service (ATS) units are encouraged to make suitable arrangements to share backup frequencies where possible, operationally feasible and spectrally efficient.

2.10.3 Backup frequencies for long distance communications

2.10.3.1 A study or safety case should be presented to justify the number of backup frequencies required for ACC and FIS services.

2.10.3.2 Adjacent ATS units are encouraged to make suitable arrangements to share backup frequencies where possible, operationally feasible and spectrally efficient.

2.11 COMPATIBILITY WITH GBAS VDB

2.11.1 Protection requirements

The protection criteria necessary to protect VHF communications systems from interference from GBAS VDB transmissions are provided in Table 2-11.

Table 2-11. Protection ratio for VHF communications receivers when the interferer is a GBAS VDB

Δf (kHz)	*D/U (dB)*
50	–26
5.833	–39
75	–41
100	–42
1000	–44
1500	–51
1800	–55
> 1800	n/a

Note 1.— Δf *is the difference between the (desired) VHF communications frequency and the (undesired) GBAS VDB frequency.*

Note 2.— D/U includes an equipment variation margin of +6 dB.

Note 3.— These D/U ratios do not include the effect of cross-polar isolation between the VHF communication signals (vertically polarized) and the GBAS VDB signals (horizontally polarized).

2.11.2 Separation distances

2.11.2.1 The minimum signal level (P_d) for VHF communications systems is 75 µV/m or –82 dBm or –112 dBW.

When assuming that the EIRP of a typical GBAS VDB station is 17 dBW (50 W), the minimum separation distance between a VDB facility and a VHF communications receiver can be calculated using formula (16):

$$L = Tx - P_d + D/U$$

where:

Tx (VDB) is 17 dBW, the antenna height (VDB) is 45 ft, P_d is –112 dBW, and the ITU-R propagation curve is for 5 per cent of the time. Values for D/U are provided in Table 2-12.

Table 2-12. Example calculations of minimum separation distances

Δf (kHz)	*D/U (dB)*	*L (dB)*	*D (NM)*
50	–26	103	28.5
58.33	–39	90	6
75	–41	88	4.8
100	–42	87	4.4
1000	–44	85	3.6
1500	–51	78	1.6
1800	–55	74	1
> 1800	n/a	n/a	no restriction

2.11.2.2 For the purposes of frequency assignment planning, it is recommended to maintain a minimum separation of 50 kHz between an assigned VHF communications frequency and a GBAS VDB frequency.

2.11.2.3 Alternatively, to avoid the need for compatibility calculations between VHF communications and GBAS VDB facilities, the frequency 117.950 MHz should not be used.

2.11.2.4 If a frequency assignment for a GBAS VDB facility is made within the range of 117.000–117.900 (117.965) MHz, States are advised to ensure that GBAS VDB transmissions do not cause harmful interference to the reception of VHF communications signals operating on frequencies greater than 117.975 MHz. In practice, the interference that may be predicted using the method described in this section may be lower, taking into account the actual characteristics of the GBAS VDB facility.

2.11.2.5 Figure 2-14 shows the relevant propagation curves used in the analysis as well as the interception of these curves at several frequency separation distances between the desired VHF communications frequency and the undesired GBAS VDB frequency.

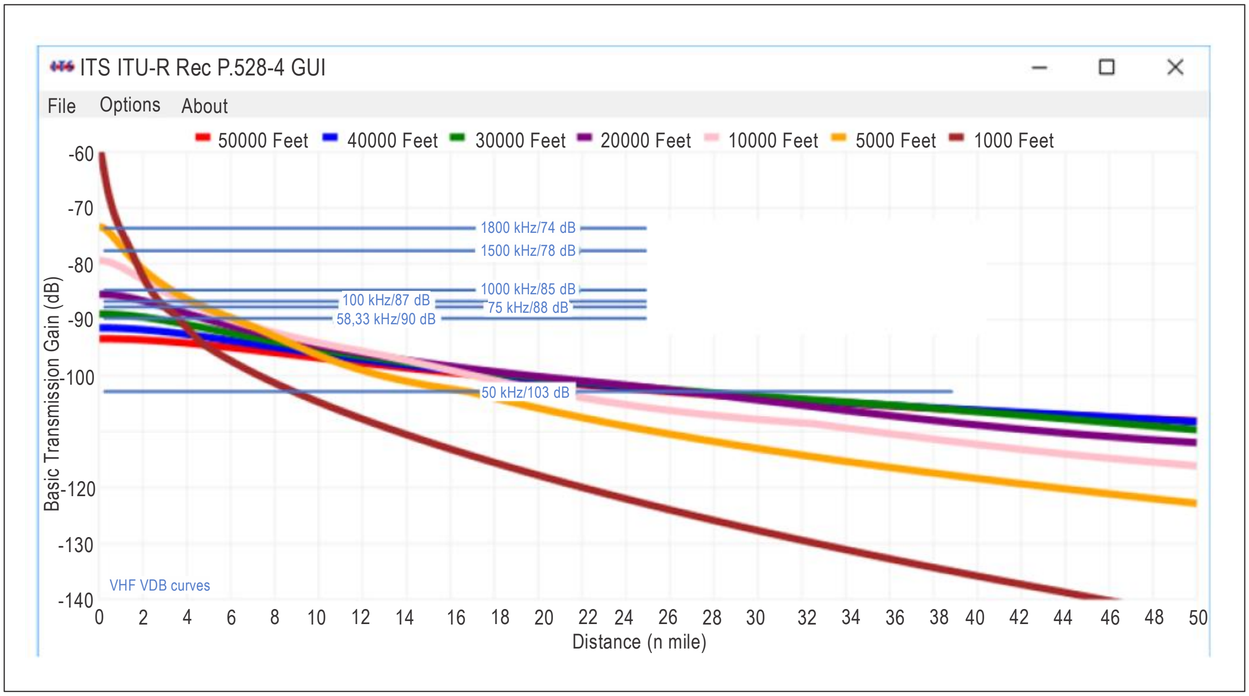

Figure 2-14. Propagation curves for calculating minimum separation distances for VHF communications and a GBAS VDB

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Chapter 3

INSTRUMENT LANDING SYSTEM (ILS)

3.1 INTRODUCTION

3.1.1 An instrument landing system (ILS) is designed to provide an aircraft on final approach with horizontal and vertical guidance relative to the runway.

3.1.2 The ILS ground equipment consists of:

a) a localizer providing horizontal guidance (azimuth relative to the extended runway centre line); and

b) a glide path providing vertical guidance.

3.1.3 Information on the distance of the aircraft relative to the runway threshold is provided by either VHF marker beacons or distance measuring equipment (DME).

3.2 DESIGNATED OPERATIONAL COVERAGE (DOC)

3.2.1 The DOC of the ILS localizer and the ILS glide path is shown in Figure 3-1. The DOC outside the sector of plus or minus 35 degrees is optional (Annex 10, Volume I).

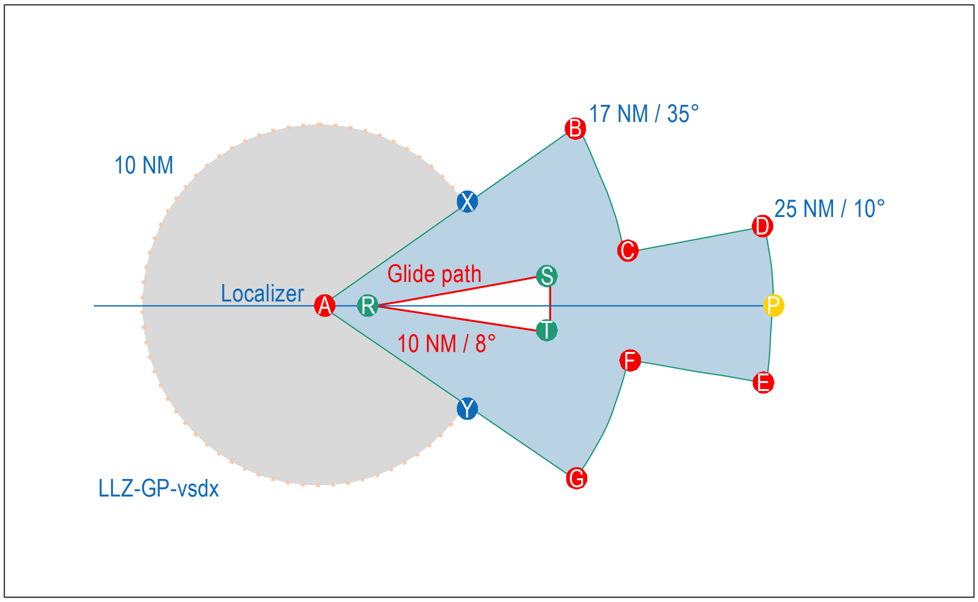

Figure 3-1. DOC of the ILS localizer and glide path

3.2.2 For the purposes of frequency assignment planning, protection of the desired ILS signal is provided throughout the DOC of the localizer as per polygon ABCDEFGA in Figure 3-1, and for the glide path as per polygon RST. The maximum protection height is 6 250 ft for the localizer DOC, and 2 500 ft for the glide path DOC. These heights are relative to the elevation of the localizer transmitter.

Note.— With the advent of highly directional ILS localizer antenna arrays, the most critical protection point will not be along the extended runway centre line. Directive antennas result in critical protection points at maximum distance, either plus or minus 10 degrees or plus or minus 35 degrees off the runway centre line. Protection of these points should be examined during the frequency assignment process.

3.2.2.1 The DOC can be extended (optionally) with a range of 10 NM outside the clearance sector (segment XY in Figure 3-1) of the localizer, as promulgated by States.

3.2.3 States may modify the coverage to meet specific operational requirements. Unless a (modified) DOC is provided, the standard DOC as in 3.2.1 is used in the frequency assignment planning process.

3.2.4 When the ILS is associated with DME, the DOC of the DME is typically the same as that of the localizer. However, States may require that the associated DME provide coverage in a larger area.

Note.— In practice, many frequency assignments for DME associated with an ILS have a DOC of 10 000 ft/100 NM. Frequency assignment planning criteria for DME are provided in Chapter 5.

3.2.4.1 The minimum field strength for a localizer is 40 μV/m (or 32 dB(μV/m) or –116 dBW) throughout the DOC. For a glide path, the minimum field strength is 400 μV/m (or 52 dB(μV/m) or –106 dBW).

3.2.5 When the main direction of the ILS radiation is not known, for frequency assignment planning purposes, the coverage is assumed to be omnidirectional. The localizer coverage originates from the location of the localizer, and the glide path coverage originates from the location of the glide path.

3.2.6 As the wanted and unwanted carriers may produce a heterodyne note, the protection ratio ensures that the instrumentation is not affected. However, in cases where a voice facility is used, the heterodyne note may interfere with this facility.

3.2.7 ILS serving both ends of the same runway

3.2.7.1 To alleviate frequency congestion problems at locations where two separate ILS facilities serve opposite ends of the same runway or different runways at the same airport, the assignment of identical ILS localizer and glide path paired frequencies should be permitted, provided that:

a) the operational circumstances permit;

b) each localizer is assigned a different identification signal; and

c) arrangements are made whereby the localizer and glide path not in operational use cannot radiate.

Note.— Annex 10, Volume I specifies the equipment arrangements to be made.

3.3 FREQUENCIES

3.3.1 Frequency band and channel spacing

3.3.1.1 *Frequency band*

3.3.1.1.1 Localizers operate in the frequency band 108–112 MHz. This band is also used for VOR and GBAS VDB systems. Localizers cannot be assigned a frequency allotted to a VOR, or vice versa. Glide paths operate in the frequency band 328.6–335.4 MHz. The radio frequency (RF) signals for localizers and glide paths are horizontally polarized.

3.3.1.2 *100 kHz channel spacing*

3.3.1.2.1 The channel spacing for localizers is 100 kHz. For glide paths, the channel spacing is 300 kHz. Localizers operate on odd 100 kHz channels in the VHF band (for example, 108.100 MHz and 108.300 MHz).

3.3.1.3 *50 kHz channel spacing*

3.3.1.3.1 The use of 50 kHz channels for localizers (and 150 kHz for glide paths) is permitted, as stipulated in Annex 10, Volume V. Such use must not cause harmful interference to ILS receivers not capable of tuning to these channels (50/150 kHz) and is subject to the condition that the operational service to international operators using airborne equipment designed for 100 kHz channel spacing (150 kHz for glide paths) is not derogated.

3.3.1.3.2 The use of 50 kHz channels for localizers and 150 kHz channels for glide paths for general use is permitted on the basis of a regional agreement, as provided for in Annex 10, Volume V. Such an agreement typically requires all aircraft operating within a region to be equipped with receivers designed for 50 kHz (localizer) and 150 kHz (glide path) channel spacing.

3.3.1.4 For regional frequency assignment planning, frequencies for ILS facilities must be selected in the following order (Annex 10, Volume V):

a) 100 kHz localizer frequencies (and the associated 300 kHz glide path frequencies); and

b) 50 kHz localizer frequencies (and the associated 150 kHz glide path frequencies).

3.3.1.4.1 Frequencies for ILS facilities must be selected from those listed in Table 3-1. Localizer and glide path frequency pairings are shown in Table 3-1 and Figure 3-2 (information taken from Annex 10, Volume I).

Table 3-1. Localizer/glide path frequency pairing

Localizer / glide path (MHz)	
108.100 / 334.700	110.100 / 334.400
108.150 / 334.550	110.150 / 334.250
108.300 / 334.100	110.300 / 335.000
108.350 / 333.950	110.350 / 334.850
108.500 / 329.900	110.500 / 329.600
108.550 / 329.750	110.550 / 329.450

Localizer / glide path (MHz)	
108.700 / 330.500	110.700 / 330.200
108.750 / 330.350	110.750 / 330.050
108.900 / 329.300	110.900 / 330.800
108.950 / 329.150	110.950 / 330.650
109.100/ 331.400	111.100 / 331.700
109.150 / 331.250	111.150 / 331.550
109.300 / 332.000	111.300 / 332.300
109.350 / 331.850	111.350 / 332.150
109.500 / 332.600	111.500 / 332.900
109.550 / 332.450	111.550 / 332.750
109.700 / 333.200	111.700 / 333.500
109.750 / 333.050	111.750 / 333.350
109.900 / 333.800	111.900 / 331.100
109.950 / 333.650	111.950 / 330.950

3.3.1.5 The DOC for localizers is much larger than that for glide paths (see Figure 3-1). When a localizer frequency has been assigned, the associated glide path frequency is automatically protected from harmful interference from other co-channel ILS facilities (see also 3.9). However, when a non-co-channel localizer frequency has been assigned, a separate adjacent channel compatibility assessment is necessary for the glide path frequency with regard to other nearby ILS facilities operating on adjacent glide path frequencies.

3.3.1.5.1 For example, the localizer frequency 108.900 MHz is paired with the glide path frequency 329.300 MHz. The first adjacent glide path frequency 329.600 MHz (300 kHz channel spacing for the glide path) is paired with the localizer frequency 110.500 MHz. While the localizer frequencies are protected from each other, as they are separated by 1.6 MHz, the glide path frequency protection criteria prohibit the use of the frequency 329.600 MHz by an (undesired) glide path transmitter that is located not only inside, but also within, a buffer zone of 36 NM (for glide path receivers designed for 300 kHz channel spacing) beyond the DOC of the (desired) glide path facility operating on 329.300 MHz.

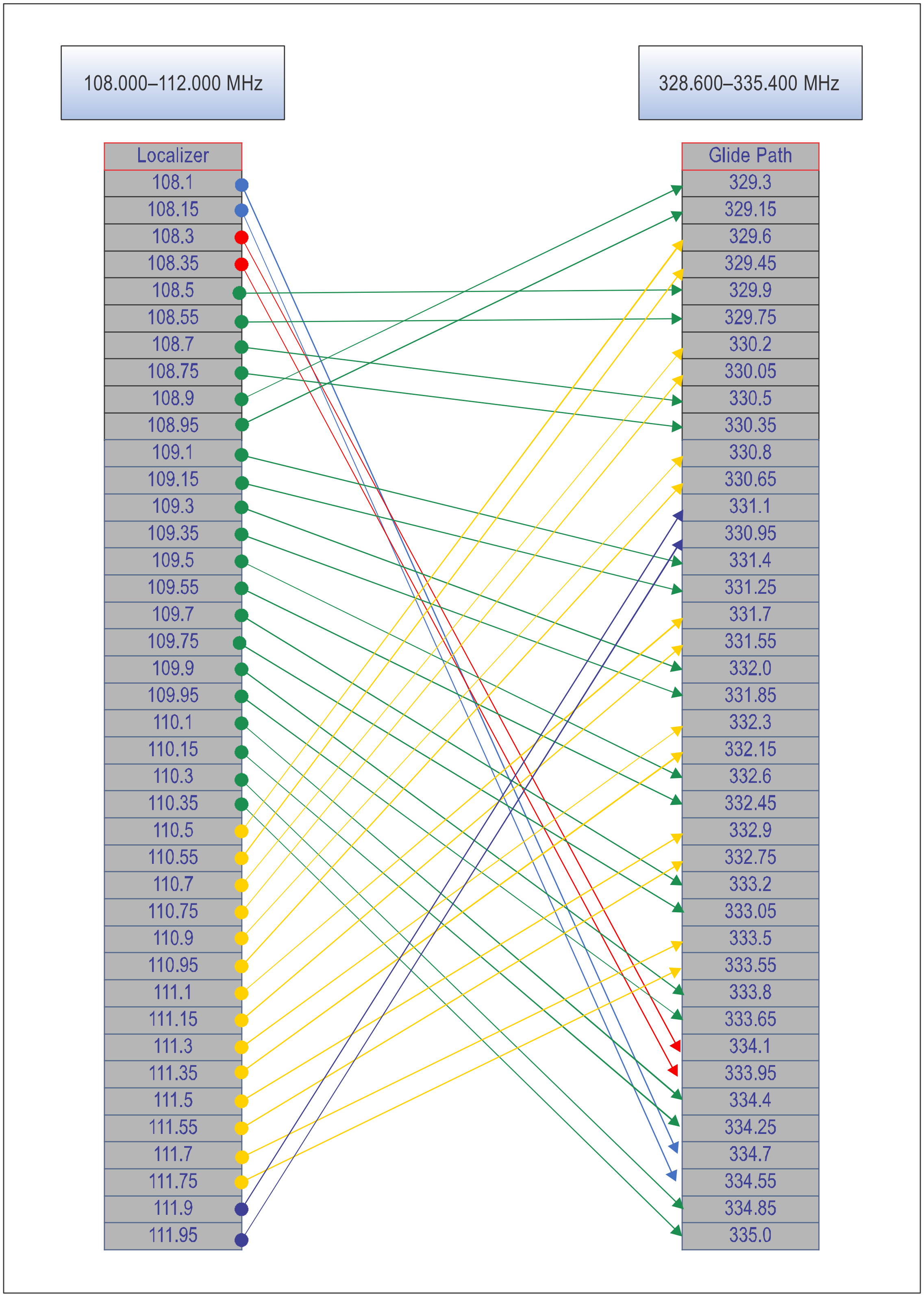

Figure 3-2. Localizer/glide path frequency pairing (Annex 10, Volume I)

3.3.1.6 When the ILS is associated with DME, the DME channels must be selected as per Annex 10, Volume I, paragraph 3.5.3.3.3, and from Annex 10, Volume I, Table A, which provides the frequency pairing between localizer and DME facilities. Further guidance on DME frequency assignment planning, including the ILS/DME channel pairing, is provided in Chapter 5 of this Handbook.

3.3.2 Interleaving of frequency assignments for localizer and VOR facilities

3.3.2.1 Localizer and VOR frequencies in the frequency band 108–112 MHz are interleaved as shown in Figure 3-3. Localizer facilities operate on odd tenths of a megahertz (or odd tenths plus a twentieth of a megahertz), and VOR facilities operate on even tenths of a megahertz (or even tenths plus a twentieth of a megahertz). Localizer and VOR systems are not allowed to operate on the same frequency.

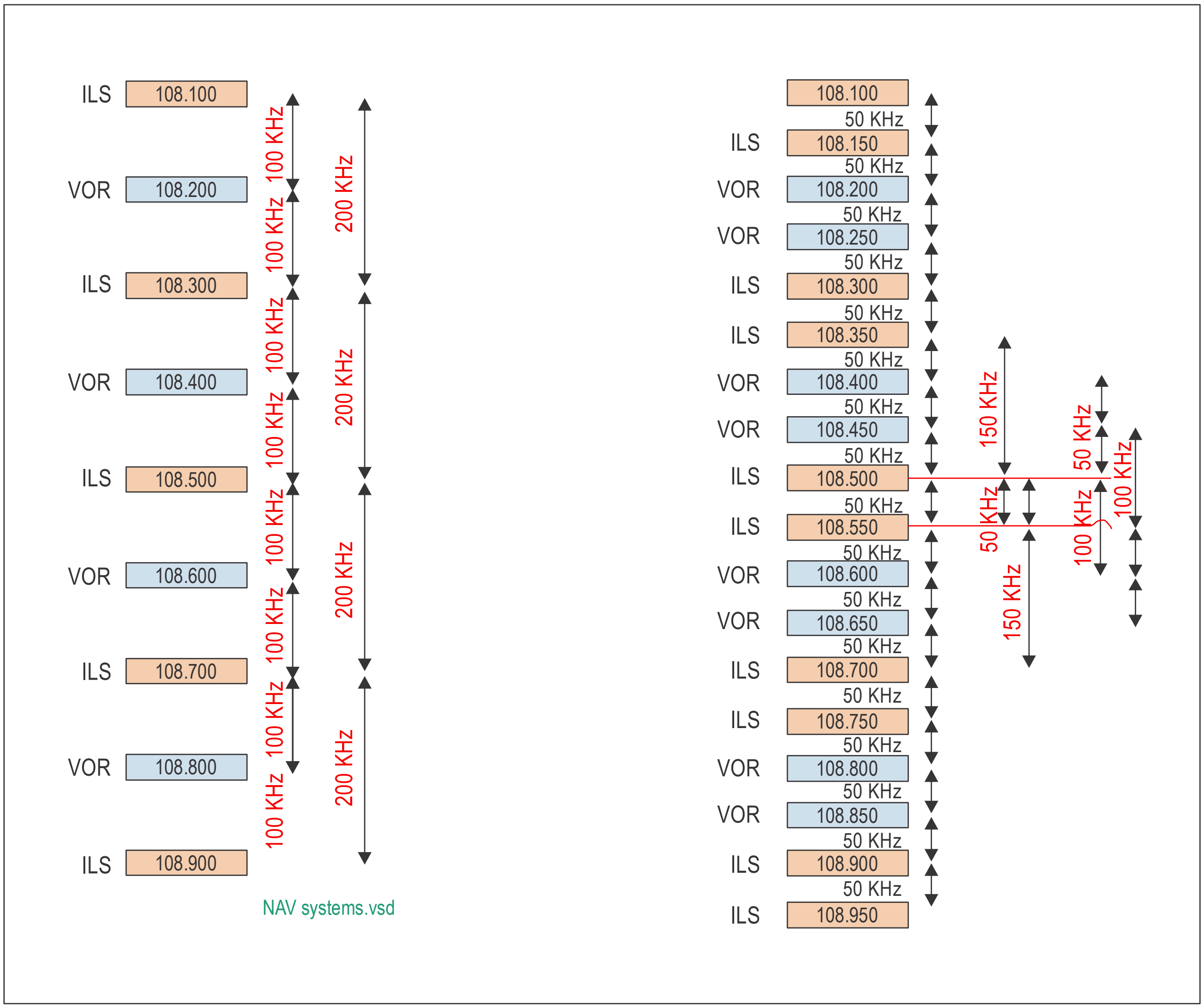

Figure 3-3. ILS/VOR frequency allotment in the band 108–112 MHz

3.3.2.2 In regions where frequency assignment planning for ILS/VOR is solely based on 100 kHz channel spacing, the assignable localizer frequencies are separated by 200 kHz. No compatibility assessment is required for adjacent localizer frequency assignments separated by 100 kHz or more. However, compatibility with an adjacent 100 kHz VOR frequency assignment needs to be ensured, as described in 3.8. In these regions, the D/U ratios in Table 3-3 are to be applied. In addition, a compatibility assessment is necessary for adjacent glide path frequencies, as described in 3.3.1.5. The D/U ratios in Table 3-5 are to be applied. For compatibility with a GBAS VDB, the D/U ratios in Table 3-6 are to be applied, as described in 3.10.

Note.— The D/U ratios in 3.5 for assessing interference from a GBAS VDB to an ILS receiver are based on ILS receivers designed for 50 kHz channel spacing and may not fully protect ILS receivers designed for 100 kHz channel spacing from harmful interference.

3.3.2.3 In areas or regions where frequency assignment planning for ILS/VOR is solely based on 50 kHz channel spacing, compatibility with adjacent localizer frequency assignments at 50 kHz or 150 kHz separation needs to be established. In addition, a compatibility assessment of adjacent VOR frequency assignments that can be separated by 50 kHz, 100 kHz or 150 kHz from the (desired) localizer frequency assignment is required, as described in section 3.7. For these compatibility assessments, the protection criteria in 3.4.3.1.1 (Table 3-2) should be used. Glide path compatibility (for adjacent channel compatibility) should be based on the protection requirements in 3.4.3.2.1 (Table 3-4). The D/U ratios in Table 3-5 are to be applied. For compatibility with a GBAS VDB, the D/U ratios in Table 3-6 are to be applied, as described in 3.10.

3.3.2.4 *Regions or areas where both 50 kHz and 100 kHz frequency assignments are in use*

3.3.2.4.1 In these regions, localizer receivers designed for 100 kHz channel spacing and for 50 kHz channel spacing are in use. Both receivers need to be protected from harmful interference. For 100 kHz receivers, the protection requirements in 3.4.3.1.2 (Table 3-3) apply. For 300 kHz glide path receivers, the protection criteria in 3.4.3.2.2 (Table 3-5) apply. For 50 kHz receivers, the protection requirements in 3.4.3.1.1 (Table 3-2) apply, and, similar to 150 kHz glide path receivers, the protection requirements in 3.4.3.2.1 (Table 3-4) apply.

3.3.2.4.2 In practice, in cases where it is not determined whether a frequency assignment on a 100 kHz assignment is intended to be used with 50 kHz receiver, the following method may be used:

a) for frequency assignments on 100 kHz frequencies, ILS receivers designed for 100 kHz/300kHz may be assumed; and

b) for frequency assignments on 50 kHz frequencies, ILS receivers designed for 50 kHz/150kHz may be assumed.

This method may lead to the overprotection of 50 kHz receivers that are operating on 100 kHz frequencies.

3.4 PROTECTION REQUIREMENTS FOR A DESIRED LOCALIZER AND UNDESIRED LOCALIZER OR VOR FACILITY, AND FOR A DESIRED GLIDE PATH AND UNDESIRED GLIDE PATH FACILITY

3.4.1 The minimum required separation distances between the desired ILS system and potentially interfering ILS systems are based on the assumption that the protection ratio against interference afforded to the desired signal from the undesired signal is 20 dB. This corresponds to a disturbance of not more than 15 microamperes at the limit of the service distance of the ILS.

3.4.2 The applicable co-frequency protection ratio depends on the frequency offset between the carriers of the desired and the undesired localizer or glide path signals. For frequency offsets of less than 152 Hz, the applicable co-frequency protection ratio is 36 dB, whereas for greater frequency offsets the co-frequency protection ratio is 20 dB (for the localizer as well as the glide path). These protection ratios ensure that the aircraft instrumentation is not affected. In practice, the use of a 20 dB protection ratio has been proved to be sufficient.

Note 1.— The frequency offset between carriers depends on their frequency stability, which should be also considered in choosing the applicable protection ratio.

Note 2.— The generic method is used to ensure the required protection for the desired and undesired signal-in-space (at the aircraft antenna). No compensation is provided for specific non-omnidirectional aircraft antennas nor for differences in the on-board transmission loss for the different frequencies.

3.4.3 When calculating the minimum required separation distances, the receiver protection criteria in 3.4.3.1 (localizer) and 3.4.3.2 (glide path) are applied.

3.4.3.1 *Localizer systems*

3.4.3.1.1 Localizer receivers designed for 50 kHz channel spacing are protected:

a) when the desired signal exceeds an undesired co-channel signal by 20 dB or more, except as indicated in 3.4.2, where a D/U ratio of 36 dB may be required;

b) when an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

c) when an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB; and

d) when an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

This can be summarized in Table 3-2.

Table 3-2. Minimum D/U ratios for 50 kHz localizer receivers

Localizer	
∆f (kHz)	*D/U (dB)*
0	20 (36)
50	–34
100	–46
≥ 150	–50

Note.— These D/U ratios are also applied to desired localizer and undesired VOR signals.

3.4.3.1.2 Localizer receivers designed for 100 kHz channel spacing are protected:

a) when the desired signal exceeds an undesired co-channel signal by 20 dB or more, except as indicated in 3.4.2, where a D/U ratio of 36 dB may be required;

b) when an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

c) when an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB; and

d) when an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

This can be summarized in Table 3-3.

Table 3-3. Minimum D/U ratios for 100 kHz localizer receivers

∆f (kHz)	*D/U (dB)*
0	20 (36)
50	–7
100	–46
≥ 150	–50

Note.— These D/U ratios are also applied to desired localizer and undesired VOR signals.

3.4.3.2 *Glide path systems*

3.4.3.2.1 Glide path receivers designed for 150 kHz channel spacing are protected:

a) when a desired signal exceeds an undesired co-channel signal by 20 dB or more, except as indicated in 3.4.2, where a D/U ratio of 36 dB may be required;

b) when an undesired glide path signal, 150 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB; and

c) when an undesired glide path signal, 300 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

Note.— When a localizer frequency has been assigned, the associated glide path frequency is automatically protected against interference from other co-frequency glide path facilities. No compatibility assessment is necessary for the co-frequency glide path. However, a compatibility check for adjacent frequency glide path facilities is necessary.

This can be summarized in Table 3-4.

Table 3-4. Minimum D/U ratios for 150 kHz glide path receivers

∆f (kHz)	D/U (dB)
0	20 (36)
150	–20
≥ 300	–40

3.4.3.2.2 Glide path receivers designed for 300 kHz channel spacing are protected:

a) when a desired signal exceeds an undesired co-channel signal by 20 dB or more, except as indicated in 3.4.2, where a D/U ratio of 36 dB may be required;

b) when an undesired glide path signal, 150 kHz removed from the desired signal, does not exceed the desired signal (0 dB signal ratio);

c) when an undesired glide path signal, 300 kHz removed from the desired signal, exceeds the desired signal by up to 20 dB; and

d) when an undesired glide path signal, 450 kHz or further removed from the desired signal, exceeds the desired signal by up to 40 dB.

This can be summarized in Table 3-5.

Table 3-5. Minimum D/U ratios for 300 kHz glide path receivers

∆f (kHz)	D/U (dB)
0	20 (36)
150	0
300	–20
≥ 450	–40

3.4.3.2.3 The protection of localizers is based on localizer receivers designed for 100 kHz channel spacing and glide path receivers designed for 300 kHz channel spacing. Minimum geographical separation distances between localizer and glide path facilities are based on the receiver characteristics in 3.4.3.1.2 and 3.4.3.2.2.

3.4.3.2.4 In regions where both 100 kHz and 50 kHz localizer channels are being used (300 kHz and 150 kHz channels for the glide path), the protection of localizers is based on receivers designed for 100 kHz channel spacing. In these regions, the minimum geographical separation distances between localizer facilities and glide path facilities operating on 100 kHz (localizer) and 300 kHz (glide path) channels are based on the receiver characteristics indicated in 3.4.3.1.2 and 3.4.3.2.2. For frequency assignments on 50 kHz (localizer) and 150 kHz (glide path) channels, the protection requirements are indicated in 3.4.3.1.1 and 3.4.3.2.1.

3.4.3.2.5 In regions where 50 kHz channel spacing for localizers is exclusively used, the protection of localizers is based on receivers designed for 50 kHz channel spacing (and, for glide paths, 150 kHz channels). The minimum geographical separation distances between localizer and glide path facilities in these regions are based on the receiver characteristics indicated in 3.4.3.1.1 and 3.4.3.2.1.

3.4.3.2.6 In the above cases, when the frequency offset is greater than 150 kHz for the localizer and 450 kHz for the glide path, practical experience has shown that freedom of using such frequencies can be applied.

3.5 PROTECTION CRITERIA FOR A DESIRED LOCALIZER AND AN UNDESIRED GBAS VDB

Note.— Criteria to protect a desired GBAS VDB facility from interference that can be caused by a localizer are provided in Chapter 6.

3.5.1 A GBAS can operate on any of the 25 kHz frequency channels between 108.100–117.975 MHz and on a co-frequency or adjacent frequency to a localizer frequency assignment. The protection ratio for ILS localizer facilities operating on the same frequency as an undesired GBAS VDB facility is 26 dB.

3.5.2 The (assumed) minimum D/U ratios to protect localizer receivers designed for 50 kHz channel spacing from interference that can be caused by GBAS VDB signals are listed in Table 3-6.

Table 3-6. Assumed D/U ratios to protect localizers from GBAS VDB signals

∆f (frequency offset)	*D/U*
0 co-frequency	26 dB
+/–25 kHz	0 dB
+/–50 kHz	–34 dB
+/–75 kHz	–46 dB
+/–100 kHz	–65 dB

Note 1.— For areas or regions with frequency congestion, a more precise determination of separation may be required using the appropriate criteria.

Note 2.— The geographical separation between a GBAS and an ILS localizer facility must take into account the performance of localizer receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing localizer receivers were not specifically designed to reject VDB transmissions, D/U signal ratios for co-channel and adjacent channel rejection of the VDB were determined empirically for VOR receivers designed for 50 kHz channel spacing.

Note 3.— No protection criteria for a compatibility assessment between GBAS VDB and localizer receivers designed for 100 kHz channel spacing have been developed yet.

3.5.3 When the frequency separation between the localizer and the GBAS VDB facility is 100 kHz or greater, no compatibility assessment is required (see also 3.10).

3.6 COMPATIBILITY OF ILS LOCALIZERS WITH FM BROADCASTING STATIONS

3.6.1 A compatibility assessment for potential interference from FM broadcasting stations operating in the frequency band 87–108 MHz is necessary before a localizer frequency can be put into operational use.

3.6.2 The FM immunity performance requirements for localizer receivers are provided in Annex 10, Volume I. Additional information on the process to assess compatibility with FM broadcast stations is in ITU Recommendation ITU-R SM.1009.

3.7 GEOGRAPHICAL SEPARATION DISTANCES BETWEEN LOCALIZER FACILITIES

Note.— This section provides the separation distances between the edge of coverage of a desired localizer and the location of an undesired localizer facility.

3.7.1 For the calculation of minimum separation distances between desired and undesired localizer facilities, the generic model described in Chapter 1, 1.4 has been applied.

3.7.2 Geographical separation criteria are established on the basis of a regional agreement. Regions and States may apply different compatibility criteria that differ from those described in this Handbook, taking into account more detailed specifications of the desired and undesired facilities.

3.7.3 The generic model described in Chapter 1, 1.4, establishes the minimum separation distance between the edge of coverage of a desired localizer and the location of an undesired localizer. This model is used to protect the minimum required field strength of the desired localizer at the aircraft antenna. The undesired facility should be separated by a distance such that, taking into account the EIRP of the undesired localizer, the minimum desired localizer signal is protected from harmful interference. The undesired facility as described in this section can be a co- or adjacent frequency localizer.

3.7.4 To establish the minimum geographical separation distances between a desired and undesired localizer, the following parameters are used:

a) a minimum field strength of the desired localizer of 40 μV/m (or 32 dB(μV/m) = –116 dBW);

b) the D/U ratio, specifically:

   1) 36 dB or 20 dB for co-frequency compatibility with another localizer; and

   2) the D/U ratios in 3.4.3.1 for adjacent frequency compatibility;

c) the EIRP of the undesired facility (dBW);

d) the DOR of the desired facility; and

e) the ITU-R aeronautical propagation curve for 5 per cent of the time.

3.7.4.1 *Example calculation of co-frequency localizer versus localizer separation distance*

3.7.4.1.1 The minimum field strength (E) of a localizer is 40 μV/m (32 dB(μV/m)) at the edge of the DOC. The DOR is 25 NM and the designated operational height is 6 250 ft. The assumed EIRP of the undesired localizer is typically in the order of 27–30 dBW (in the front course sector, which is the worst case). Outside of the front course sector, the EIRP is normally in the order of 17 dBW. The D/U ratio is 36 dB or 20 dB, as in 3.4.2. In this example:

a) The minimum received desired power at the aircraft, assuming there is an isotropic antenna, is –116 dBW (Chapter 1, formula (13)).

b) The maximum undesired power (P_u) at the edge of the DOC of the desired localizer is calculated using formula (14):

$$-116 - 36 = -152 \text{ dBW}$$

c) The EIRP of the undesired localizer is 30 dBW,[1] and the required transmission loss (*L*) between the location of the undesired localizer and the edge of the DOC of the desired localizer is calculated using formula (16):

$$30 - (-116) + 36 = 182 \text{ dB}$$

d) The ITU-R propagation curve for the antenna heights of 6 250 ft (h1) and 10 ft (h2) and 5 per cent of the time shows that this transmission loss is achieved at a distance of 267 NM.

   1) For the same ITU-R propagation curve as that used in d) and for a D/U of 20 dB, the minimum required transmission loss is 166 dB, which corresponds to a separation distance of 136 NM.

The variables in this method are:

a) in formula (16), the appropriate D/U ratio is selected from those presented in 3.4.3.1. This applies when the undesired facility is either a localizer or a VOR;

b) the EIRP of the undesired facility; and

c) the DOR of the desired localizer (typically 25 NM).

3.7.5 Table 3-7 provides the minimum geographical separation distances (*D*) between the edge of the coverage of the desired localizer and the location of the undesired localizer, established using the method in 3.7.4. The undesired localizer transmitter height is 6 ft. The desired localizer receiver is at 6 250 ft. The ITU Recommendation ITU-R P.528-5 propagation curves for 5 per cent of the time are used.

Table 3-7. Minimum geographical separation distances between the edge of coverage of a desired localizer and the location of an undesired localizer facility

E dB (μV/m)	*f* (MHz)	P_d (dBW)	*D/U* (dB)	P_u (dBW)	*Tx* (dBW)	*L* (dB)	***D* (NM)**	*Δf* (kHz)	*Remarks*
32	108	–116	36	–152	30 17	182 169	**246** **135**	0	Co-frequency undesired localizer, 36 dB
32	108	–116	20	–136	30 17	166 153	**131** **112**	0	Co-frequency undesired localizer, 20 dB
32	108	–116	–7	–109	30 17	139 126	**81** **44**	50	Undesired adjacent localizer, 100 kHz receiver

1. The radiated power in the front course sector of a localizer typically varies between 27 and 30 dBW.

E *dB (μV/m)*	*f* *(MHz)*	P_d *(dBW)*	*D/U* *(dB)*	P_u *(dBW)*	*Tx* *(dBW)*	*L* *(dB)*	***D*** ***(NM)***	*Δf* *(kHz)*	*Remarks*
32	108	–116	–34	–82	30 17	112 99	**21** **10**	50	Undesired adjacent localizer, 50 kHz receiver
32	108	–116	–50	–66	30 17	96 83	**9** **1**	150	Undesired adjacent localizer, 50 and 100 kHz receiver

Note 1.— For the protection of a desired localizer from interference from an undesired VOR, see 3.8, and, for the protection from interference from an undesired GBAS VDB, see 3.10.

Note 2.— These separation distances are calculated assuming that the interfering localizer facility radiates with an EIRP of 30 dBW (1 000 W), which is typical for a 20 element localizer. Other localizer facilities typically radiate with 27 dBW (500 W). These values are limited to the front course sector of the localizer.

*Note 3.— The transmission loss (*L*) is calculated using formula (16).*

*Note 4.— To calculate the separation distance between the location of the desired and the undesired localizer facilities, the DOR of the desired localizer must be added to the distances (*D*) in Table 3-7.*

3.7.6 No compatibility assessment is necessary when the frequency separation between the desired and the undesired localizer is 200 kHz or more.

3.7.7 Once the compatibility between a desired localizer and an undesired localizer or VOR facility has been assessed, a second compatibility assessment is necessary to ensure that no interference is caused to the “undesired” facilities by the desired localizer.

3.8 GEOGRAPHICAL SEPARATION DISTANCES BETWEEN (DESIRED) LOCALIZER AND (UNDESIRED) ADJACENT FREQUENCY VOR FACILITIES

3.8.1 The criteria for the geographical separation of ILS localizer and VOR facilities take into account the following:

a) the localizer protection ratios for interference from VOR facilities are as indicated in 3.4.3.1 and 3.4.3.2 (localizer receivers designed for 100 kHz and 50 kHz channel spacing);

Note.— This assumes that the protection of (desired) localizer signals from VOR signals is the same as for the localizer signals;

b) the EIRP of the VOR varies from 17 dBW to 30 dBW; and

c) the volume of the DOC of the (desired) localizer.

3.8.2 To establish the geographical separation distance between an ILS facility and adjacent frequency VOR facilities, it is assumed that the susceptibility of the ILS receiver to interference from VOR signals is the same as for interference caused by ILS signals, and that the protection criteria in 3.4.3.1 apply equally to undesired VOR signals.

Note.— This also applies to a VOR receiver’s susceptibility to undesired localizer signals.

3.8.3 In accordance with the channelling plans for the localizer and VOR facilities, the localizer and VOR will not operate on the same frequency. Only an assessment of localizer and VOR facilities operating on adjacent frequencies is necessary.

3.8.4 In areas where frequency assignment for localizer facilities is based on 100 kHz channel spacing, the nearest assignable VOR frequency is separated by 100 kHz. However, when a frequency assignment on a 50 kHz channel is made, compatibility also needs to be assessed taking into account the receiver characteristics, as in 3.4.3.1.1.

3.8.5 When the frequency separation between the localizer and VOR is equal to or more than 200 kHz, compatibility assessment may not be necessary. However, care should be taken when a VOR is located close to the localizer centre line.

3.8.5.1 Protection of the ILS system from VOR interference is necessary when a VOR facility is located near an ILS approach path. In such circumstances, to avoid disturbance of the ILS receiver output due to possible cross modulation effects, suitable frequency separation between the ILS and VOR channel frequencies should be applied. The frequency separation will be dependent upon the ratio of the VOR and ILS field densities, and the characteristics of the airborne installation.

3.8.6 Table 3-8 provides the minimum geographical separation distances (*D*) between the edge of the DOC (at 6 250 ft) of the desired ILS localizer and the location of an undesired VOR facility (operating on frequencies adjacent to the desired localizer), established using the method in 3.7.4 and using propagation curves as calculated in accordance with Recommendation ITU-R P.528-5, for 5 per cent of the time. The antenna of the (undesired) VOR is at 20 ft above local terrain.

Table 3-8. Minimum separation distances between the edge of coverage of a desired localizer and the location of an undesired VOR facility

E *dB (µV/m)*	*f (MHz)*	P_d *(dBW)*	*D/U (dB)*	P_u *(dBW)*	*Tx (dBW)*	*L (dB)*	***D (NM)***	*Δf (kHz)*	*Remarks*
32	108	–116	–7	–109	17	126	**72**	50	Undesired VOR, 17 dBW, 100 kHz receiver
32	108	–116	–34	–82	17	99	**15**	50	Undesired VOR, 17 dBW, 50 kHz receiver
32	108	–116	–46	–70	17	87	**5**	100	Undesired VOR, 17 dBW, 50/100 kHz receiver
32	108	–116	–50	–66	17	83	**3**	150	Undesired VOR, 17 dBW, 50/100 kHz receiver
32	108	–116	–7	–109	20	129	**80**	50	Undesired VOR, 20 dBW, 100 kHz receiver
32	108	–116	–34	–82	20	102	**19**	50	Undesired VOR, 20 dBW, 50 kHz receiver
32	108	–116	–46	–70	20	90	**7**	100	Undesired VOR, 20 dBW, 50/100 kHz receiver

E *dB* *(μV/m)*	*f* *(MHz)*	P_d *(dBW)*	*D/U* *(dB)*	P_u *(dBW)*	*Tx* *(dBW)*	*L* *(dB)*	***D*** ***(NM)***	*Δf* *(kHz)*	*Remarks*
32	108	–116	–50	–66	20	86	**4**	150	Undesired VOR, 20 dBW, 50/100 kHz receiver
32	108	–116	–7	–109	30	139	**107**	50	Undesired VOR, 30 dBW, 100 kHz receiver
32	108	–116	–34	–82	30	112	**36**	50	Undesired VOR, 30 dBW, 50 kHz receiver
32	108	–116	–46	–70	30	100	**16**	100	Undesired VOR, 30 dBW, 50/100 kHz receiver
32	108	–116	–50	–66	30	96	**13**	150	Undesired VOR, 30 dBW, 50/100 kHz receiver

*Note 1.— The transmission loss (*L*) is calculated using formula (16).*

Note 2.— *Material relevant to the protection of VOR from ILS signals is presented in Chapter 4, which covers VOR geographical separation criteria.*

3.9 GEOGRAPHICAL SEPARATION DISTANCES BETWEEN CO- AND ADJACENT FREQUENCY GLIDE PATH FACILITIES

Note.— The minimum separation distances calculated are between the edge of the coverage of a desired glide path facility and the location of an undesired glide path facility.

3.9.1 To establish the minimum geographical separation distances between a desired and undesired glide path, the following parameters are required:

a) a minimum field strength of the desired glide path of 400 μV/m (or 20log400 = 52 dB(μV/m));

b) the D/U ratio, specifically:

   1) 36 dB or 20 dB for co-frequency compatibility with another glide path; and

   2) the D/U ratios in 3.4.3.2 for adjacent frequency compatibility;

c) the EIRP of the undesired facility (dBW) (a typical EIRP of a glide path is 20 dBW (100 W));

d) the DOR of the desired glide path; and

e) ITU-R aeronautical propagation curve for 5 per cent of the time.

3.9.2 *Co-frequency glide path versus glide path separation distance (example calculation)*

3.9.2.1 The minimum field strength (E) of a glide path is 400 μV/m (52 dB(μV/m)) at the edge of the DOC. The DOR is 10 NM and the designated operational height is 2 500 ft. The assumed EIRP of the undesired glide path is 20 dBW. The D/U ratio is 36 dB (or 20 dB).

$$P_d = E - 20\log f - 106.2 = 52 - 20\log 333 - 107.2 = 52 - 50 - 107.2 = -105 \text{ dBW}$$

(f = 333 MHz)

a) The minimum received desired power at the aircraft, assuming an isotropic antenna is used, is –105 dBW (Chapter 1, formula (13)).

b) The maximum undesired power at the edge of the DOC of the desired glide path is calculated using formula (14):

$$P_u = -105 - 36 = -141 \text{ dBW}$$

c) The EIRP of the undesired glide path is 20 dBW, and the required transmission loss (L) between the location of the undesired glide path and the edge of DOC of the desired glide path is calculated using formula (16):

$$L = 20 - (-105) + 36 = 161 \text{ dB } (L = 145 \text{ dB for D/U} = 20 \text{ dB})$$

d) The ITU-R propagation curve for antenna heights of 2 500 ft (h1) and 10 ft (h2) and for 5 per cent of the time is used. This shows that such transmission loss is achieved at a distance of 88 NM.

   For a D/U of 20 dB, the minimum separation distance is 71 NM.

3.9.2.2 The minimum separation distance between co-frequency glide path facilities, as in the example in 3.9.2.1 (88 NM), is less than that required for localizer facilities, as calculated in 3.7.4.1.1. It is therefore sufficient to only undertake a compatibility assessment for the localizer in the case of co-frequency operation of a desired ILS and an undesired ILS.

3.9.3 *Adjacent frequency glide path versus glide path separation distance (5 per cent of the time*)

3.9.3.1 For the first adjacent (Δf = 150 kHz) channel, the D/U is –20 dB for a 150 kHz glide path receiver. The minimum required transmission loss is 20 – (–106) – 20 = 106 dB. Therefore, D = 11 NM.

3.9.3.2 For the first adjacent (Δf = 150 kHz) channel, the D/U is 0 dB for a 300 kHz glide path receiver. The minimum required transmission loss is 20 – (–106) + 0 = 126 dB. Therefore, D = 36 NM.

3.9.3.3 For the second adjacent (Δf = 300 kHz) channel, the D/U is –40 dB for a 150 kHz glide path receiver. The minimum required transmission loss is 20 – (–106) – 40 = 86 dB. Therefore, D = 1 NM.

3.9.3.4 For the second adjacent (Δf = 300 kHz) channel, the D/U is –20 dB for a 300 kHz glide path receiver. The minimum required transmission loss is 20 – (–106) – 20 = 106 dB. Therefore, D = 11 NM.

3.9.3.5 For the third adjacent (Δf = 450 kHz) channel, the D/U is –40 dB for a 300 kHz glide path receiver. The minimum required transmission loss is 20 – (–106) – 40 = 86 dB. Therefore, D = 1 NM.

Note.— The minimum separation distances in this section (3.9) are calculated from the edge of the DOC of the desired glide path to the location of the undesired glide path.

3.9.4 Table 3-9 lists the separation distances between ILS facilities (measured from the edge of coverage of the desired ILS facility). The ITU propagation curve is for 5 per cent of the time.

Table 3-9. Separation distances between the edge of coverage of a desired ILS facility and the location of an undesired ILS facility

Undesired facility					
Localizer (EIRP = 30 dBW)	*Δf*	*Distance for 100 kHz receiver (desired facility)*	*D/U*	*Distance for 50 kHz receiver (desired facility)*	*D/U*
	0 kHz	268 NM	36 dB	268 NM	36 dB
	0 kHz	135 NM	20 dB	135 NM	20 dB
	50 kHz	94 NM	–7 dB	36 NM	–34 dB
	100 kHz	n/a	n/a	n/a	n/a
	150 kHz	9 NM	–50 dB	9 NM	–50 dB
Glide path (EIRP = 20 dBW)	*Δf*	*300 kHz receiver*	*D/U*	*150 kHz receiver*	*D/U*
	0 kHz	88 NM	36 dB	74 NM	36 dB
	0 kHz	71 NM	20 dB	58 NM	20 dB
	150 kHz	36 NM	–0 dB	11 NM	–20 dB
	300 kHz	11 NM	–20 dB	1 NM	–40 dB
	450 kHz	1	–40	-	-

3.10 SEPARATION DISTANCE BETWEEN THE DESIRED LOCALIZER AND THE LOCATION OF AN UNDESIRED GBAS VDB

3.10.1 The criteria for the geographical separation of localizer and GBAS VDB facilities are based on the following assumptions:

a) the localizer protection ratios for interference from GBAS VDB facilities are as in 3.5.2 (only for localizer receivers designed for 50 kHz channel spacing);

b) the EIRP of the GBAS VDB is typically 17 dBW; the height of the VDB antenna is 45 ft above local terrain;

c) the DOC for the localizer is as in 3.2.1; and

d) the ITU-R aeronautical propagation curves used are for 5 per cent of the time.

3.10.2 To establish geographical separation distances between an ILS localizer facility and GBAS VDB facilities, it is assumed that the susceptibility of the ILS localizer receiver to interference from GBAS VDB signals is the same as for VOR receivers.

3.10.2.1 In accordance with the channelling plans for the localizer and the GBAS VDB facilities, the GBAS may operate co-frequency with a localizer or on adjacent frequencies. The channel separation for a GBAS VDB is 25 kHz.

3.10.3 For the protection of the localizer signals from interference that can be caused by GBAS VDB signals with a frequency separation of 100 kHz or more, no compatibility assessment is required.

3.10.4 Table 3-10 provides the minimum geographical separation distances (*D*) between the edge of the coverage (DOC) of the desired ILS localizer and the location of the undesired GBAS VDB facility, established using the method in 3.7.4.

Table 3-10. Geographical separation distances between a desired localizer and an undesired GBAS VDB

E dB (µV/m)	*f* (MHz)	P_d (dBW)	*D/U* (dB)	P_u (dBW)	*Tx* (dBW)	*L* (dB)	***D* (NM)**	*Δf* (kHz)	*Remarks*
32	108	–116	26	–142	17	159	**187**	0	
32	108	–116	0	–116	17	133	**108**	25	
32	108	–116	–34	–82	17	99	**20**	50	
32	108	–116	–46	–70	17	87	**5**	75	
32	108	–116	–65	–51	17	68	**0**	100	Planning freedom

Note.— D *is calculated using the ITU aeronautical propagation curve for 108 MHz, 6 250 ft and 5 per cent of the time. The distance is measured from the edge of the coverage of the desired localizer to the location of the undesired GBAS VDB facility.*

Chapter 4

VHF OMNIDIRECTIONAL RANGE (VOR)

Note.— The guidance in this chapter is based on the assumption that only ILS localizer or VOR receivers specifically designed for either 100 kHz or 50 kHz channel spacing are used.

4.1 INTRODUCTION

4.1.1 A VHF omnidirectional range (VOR) is a radio navigation aid used for determining, at the aircraft, the bearing of the aircraft relative to the magnetic North measured from the location of the VOR.

4.1.2 A VOR is often used in conjunction with co-located distance measuring equipment (DME) to provide the aircraft with its distance relative to the VOR and DME.

4.2 COVERAGE

4.2.1 The designated operational coverage (DOC) of a VOR is determined through the operational requirement as promulgated by States. In many cases, the DOC is circular and can be as large as 200 NM, normally up to flight level 450. Sectorized coverage (in the horizontal plane), which improves efficiency in frequency assignment planning, is also used and is further described in 4.9. Vertical coverage may be extended up to flight level 600 to meet specific operational requirements. Protection from harmful interference is only provided within the DOC.

4.2.2 *Guidance relating to VOR and Doppler VOR (DVOR) equivalent isotropically radiated power (EIRP) and coverage*

4.2.2.1 The field strength specified in Annex 10, Volume I is based on the following consideration:

Airborne receiver sensitivity	–117 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+7 dB
Power required at antenna	–110 dBW

Note.— Transmission line loss includes mismatch losses and antenna polar pattern variations relative to an isotropic antenna.

The required power of –110 dBW is obtained at 118 MHz with a power density of –107 dBW/m^2, which is equivalent to 90 µV per metre, that is, +39 dB referenced to 1 µV per metre.

The power density for the case of an isotropic antenna can be calculated using the following formula:

$$P_d = P_a - 10\log_{10}\frac{\lambda^2}{4\pi}$$

where:

P_d: power density in dBW/m^2;

P_a: power of receiving point in dBW; and

λ: wavelength in metres.

4.2.2.2 The necessary EIRP to achieve a field strength of 90 µV per metre (–107 dBW/m^2) is given in Figure 4-1. The field strength is directly proportional to the antenna elevation pattern. The actual radiation patterns of the antennas depend on a number of factors, such as the height of the antenna phase centre above ground level (AGL), surface roughness, terrain form and conductivity of ground and counterpoise. However, to account for the lowest EIRP in notches between the lobes of the real elevation antenna pattern, a conservative value has been provided. Whenever more precise system data are available, a more precise estimation of range is permissible.

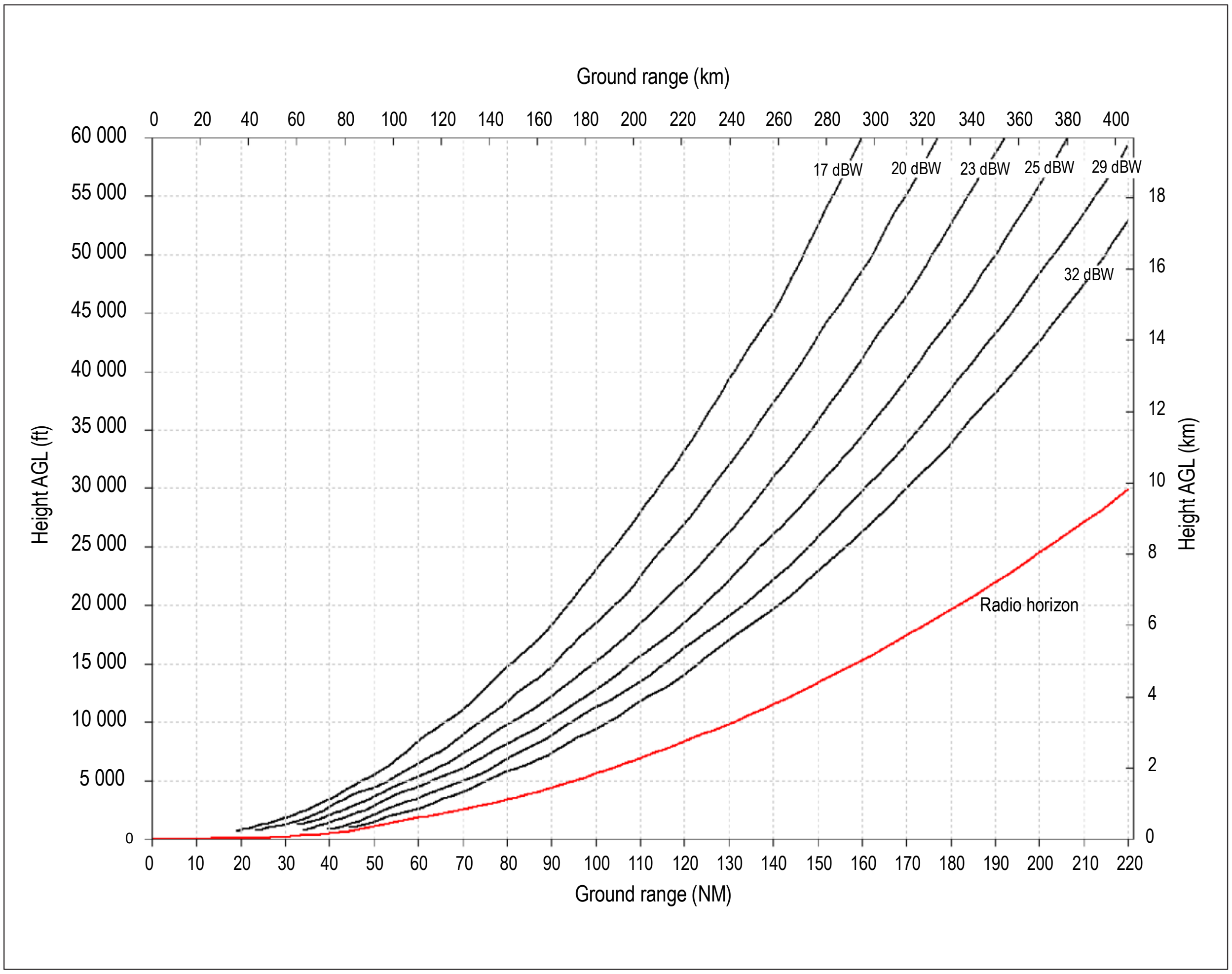

Figure 4-1. Necessary EIRP to achieve a field strength of 90 μV per metre (−107 dBW/m²) as a function of height above and distance from the VOR/DVOR

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 earth radius which has been confirmed by measurements.

Note 2.— The guidance provided assumes that the VOR/DVOR counterpoise height AGL that defines the antenna pattern is at 3 m (10 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— The transmitted power required to achieve an EIRP value as shown depends upon transmitting antenna gain and cable losses. For example, an EIRP of 25 dBW can be achieved by a VOR with an output power of 100 W, a cable loss of 1 dB and an antenna gain of 6 dBi.

4.2.3 Typical EIRP values for a VOR are listed in Table 4-1.

Table 4-1. Typical EIRP values for a VOR

Range (NM)	*EIRP (dBW)*
< 50	17
50–100	20
100–150	23
> 150	27–30

4.3 FREQUENCIES

4.3.1 Channelling

4.3.1.1 A VOR operates in the frequency band 108–117.975 MHz. The channel spacing is 100 kHz. The use of 50 kHz channel sparing is permitted, as described in 4.3.1.2 and 4.3.1.3.

4.3.1.2 The use of 50 kHz VOR channels is permitted as stipulated in Annex 10, Volume V. Such use must not cause harmful interference to VOR receivers not capable of tuning to these channels, and the operational service to international operators using airborne 100 kHz equipment is not derogated. In addition, the performance of ILS or VOR equipment (receivers) not capable of operating on these frequencies will be protected from harmful interference, and a general requirement for the carriage of ILS or VOR airborne equipment capable of operating on these frequencies will not be imposed.

4.3.1.3 The use of 50 kHz VOR channels is permitted for general use on the basis of a regional air navigation agreement, as provided for in of Annex 10, Volume V. Such use requires all aircraft to be equipped with VOR receivers capable of tuning on 50 kHz VOR channels.

Note.— The frequency 113.250 MHz is reserved as a common signalling channel for VDL Mode 4 (Annex 10, Volume V).

4.3.2 Order of VOR channel selection

4.3.2.1 Table 4-2 indicates the order in which frequency assignments for VOR facilities should be made, as stipulated in Annex 10, Volume V.

Table 4-2. Preferred order when making frequency assignments

Order	*Band (MHz)*	*Frequency*
1	111.975–117.975	Ending in odd tenths of a megahertz (“100” kHz channels), for example 112.100 MHz, 112.300 MHz and 112.500 MHz
2	111.975–117.975	Ending in even tenths of a megahertz (“100” kHz channels), for example 112.200 MHz, 112.400 MHz and 112.600 MHz
3	108.000–111.975	Ending in even tenths of a megahertz (“100” kHz channels), for example 108.200 MHz, 108.400 MHz and 108.600 MHz
4	111.975–117.975	Ending in odd tenths of a megahertz plus 50 kHz (“50” kHz channels), for example 112.150 MHz, 112.350 MHz and 112.550 MHz
5	111.975–117.975	Ending in even tenths of a megahertz plus 50 kHz (“50” kHz channels), for example 112.050 MHz, 112.250 MHz and 112.450 MHz
6	108.000–111.975	Ending in even tenths of a megahertz plus 50 kHz (“50” kHz channels), for example, 108.250 MHz, 108.450 MHz and 108.650 MHz

4.3.3 VOR facilities associated with DME

4.3.3.1 VOR facilities are often associated with DME facilities. The associated DME channels must be selected in accordance with Annex 10, Volume I. This material is reproduced in Chapter 5.

4.3.3.2 A separate compatibility assessment for the DME facilities associated with a VOR facility is required in all cases. Chapter 5 of this Handbook contains guidance material on the compatibility of DME frequency assignments with other DME/TACAN assignments in the ICAO frequency assignment plan.

4.3.4 VOR systems operating in the band 108–112 MHz

4.3.4.1 In the band 108–112 MHz, VOR systems operate only on channels ending in even tenths of a megahertz (for example, 108.200 MHz, 108.400 MHz and 108.600 MHz) or on 50 kHz channels ending in even tenths of a megahertz plus 50 kHz (for example, 108.250 MHz, 108.450 MHz and 108.650 MHz). The VOR channels are interleaved with localizer channels, as described in Chapter 3, paragraph 3.3.2, and as shown in Figure 3-2.

4.3.4.2 Localizer and VOR facilities cannot operate on the same frequency. Adjacent channel compatibility with an (undesired) localizer is assessed in the same way in which adjacent channel interference from a VOR is assessed, and takes into account the EIRP of the localizer.

Note.— Guidance on assessing the compatibility between a desired localizer and an undesired VOR is provided in Chapter 3, section 3.8.

4.3.5 Compatibility of a VOR with FM broadcast stations operating in the frequency band 87–108 MHz

4.3.5.1 A compatibility assessment for potential interference from FM broadcasting stations operating in the frequency band 87–108 MHz is necessary.

The FM immunity performance requirements for VOR receivers are contained in Annex 10, Volume I. Additional information on the process to assess compatibility with FM broadcast stations is in ITU Recommendation ITU-R SM.1009.

4.3.5.2 The VOR receiver immunity performance defined in Annex 10, Volume I must be measured against an agreed measure of degradation of the receiving system's normal performance, and in the presence of, and under standard conditions for, the input wanted signal. This is necessary to ensure that the testing of receiving equipment on the bench can be performed to a repeatable set of conditions and results, and to facilitate their subsequent approval. Additional information can be found in ITU Recommendation ITU-R SM.1140 — *Test procedures for measuring aeronautical receiver characteristics used for determining compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–118 MHz.*

Note.— Receiver test procedures are also given in the VOR receiver Minimum Operational Performance Standards (MOPS) (RTCA DO-196 and EUROCAE ED-22B).

4.3.5.3 Commonly agreed formulas should be used to assess potential incompatibilities to receivers meeting the general interference immunity criteria specified in Annex 10, Volume I. The formulas provide clarification of immunity interference performance of spurious emission (type A1) interference, out-of-band channel (type A2) interference, two-signal and three-signal third order (type B1) interference, and overload/desensitization (type B2) interference. Additional information can be found in ITU Recommendation ITU-R SM.1009-1 — *Compatibility between the sound-broadcasting service in the band of about 87–108 MHz and the aeronautical services in the band 108–137 MHz.*

4.4 PROTECTION CRITERIA FOR A DESIRED VOR AND UNDESIRED VOR OR LOCALIZER SIGNAL

4.4.1 The protection of VOR facilities operating on the same frequency is based on a desired to undesired (D/U) signal ratio of 20 dB. This corresponds to a bearing error of less than 1 degree due to unwanted signals.

4.4.2 When the undesired frequency is offset from the desired frequency, the minimum D/U ratios for receivers designed for 100 kHz channel spacing are as indicated in 4.4.2.1 and Table 4-3. The minimum D/U ratios for receivers designed for 50 kHz channel spacing are as indicated in 4.4.2.2 and Table 4-4. Protection of (the desired) VOR receivers is based on the receiver characteristics in 4.4.2.1 (100 kHz receivers) and 4.4.2.2 (50 kHz receivers).

4.4.2.1 Receivers designed for 100 kHz channel spacing are protected:

a) when an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 7 dB;

b) when an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB; and

c) when an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

Table 4-3. Minimum D/U ratios for 100 kHz receivers

Δf (kHz)	*D/U (dB)*
0	20
50	–7
100	–46
≥ 150	–50

4.4.2.2 Receivers designed for 50 kHz channel spacing are protected:

a) when an undesired signal, 50 kHz removed from the desired signal, exceeds the desired signal by up to 34 dB;

b) when an undesired signal, 100 kHz removed from the desired signal, exceeds the desired signal by up to 46 dB; and

c) when an undesired signal, 150 kHz or further removed from the desired signal, exceeds the desired signal by up to 50 dB.

Table 4-4. Minimum D/U ratios for 50 kHz receivers

Δf (kHz)	*D/U (dB)*
0	20
50	–34
100	–46
≥ 150	–50

Note.— The undesired signal can be a VOR or a localizer signal.

4.5 PROTECTION CRITERIA FOR A DESIRED VOR AND UNDESIRED GBAS VDB

4.5.1 A GBAS can operate on any of the frequencies (25 kHz channels) between 108.100 and 117.975 MHz. The protection ratio for VOR facilities operating on the same frequency as an undesired GBAS VDB facility is 26 dB.

4.5.2 When the undesired frequency is offset from the desired frequency, the (assumed) minimum D/U ratios to protect VOR receivers designed for 50 kHz channel spacing from potential interference from GBAS VDB signals are as in Table 4-5.

Table 4-5. Assumed D/U ratios to protect VOR from GBAS VDB (Annex 10, Volume I)

Δf (frequency offset)	*D/U*
0–co-frequency	26 dB
+/–25 kHz	0 dB
+/–50 kHz	–34 dB
+/–75 kHz	–46 dB
+/–100 kHz	–65 dB

Note 1.— For areas or regions with frequency congestion, a more precise determination of separation may be required using the appropriate criteria.

Note 2.— The geographical separation between a VOR and a GBAS VDB facility must take into account the performance of VOR receivers, including co-channel and adjacent channel rejection of VDB signals. Since existing VOR receivers were not specifically designed to reject VDB transmissions, D/U signal ratios for co-channel and adjacent channel rejection of the VDB were determined empirically. Table 4-5 summarizes the assumed signal ratios based upon empirical performance of numerous VOR receivers designed for 50 kHz channel spacing.

Note 3.— For VOR receivers designed for 100 kHz channel spacing, no criteria has been developed for protection from GBAS VDB facilities.

4.5.3 When the frequency separation between the VDB station and a VOR station is 100 kHz or greater, no compatibility assessment is required.

4.5.3.1 It is recognized that, in the case of adjacent channel operation, there is a small region in the vicinity of a VOR facility in which interference may be caused to an aircraft using another VOR facility. However, the width of this region is so small that the duration of the interference would be negligible, and, in any case, it is probable that the aircraft would change its usage from one facility to the other.

4.6 AREAS WHERE BOTH 50 KHZ AND 100 KHZ VOR RECEIVERS ARE IN USE

In certain regions there may be a mixed use of 50 kHz and 100 kHz VOR receivers. In these cases, a compatibility assessment for frequency assignments made on 100 kHz channels needs to comply with the minimum D/U ratios in Table 4-3. A compatibility assessment for frequency assignments made on 50 kHz channels needs to comply with the D/U ratios in Table 4-4.

4.7 CONSIDERATION OF THE HARMONICS CAUSED BY THE 9 960 HZ VOR SUBCARRIER

4.7.1 With regard to the emission of harmonics from the 9 960 Hz VOR subcarrier, frequency assignment planning is based on the assumption that the VOR facilities comply with Annex 10, Volume I, Chapter 3, paragraphs 3.3.2.2 and 3.3.5.7, and Volume V, Chapter 4, paragraph 4.2.4, as reproduced below.

4.7.1.1 The general deployment of 50 kHz VOR channel spacing requires compliance with the provisions of Annex 10:

a) Volume I, Chapter 3, 3.3.2.2, which states:

> The frequency tolerance of the radio frequency carrier of all new installations implemented after 23 May 1974 in areas where 50 kHz channel spacing is in use shall be plus or minus 0.002 per cent.

b) Volume I, Chapter 3, 3.3.5.7, which states:

> Where 50 kHz VOR channel spacing is implemented, the sideband level of the harmonics of the 9 960 Hz component in the radiated signal shall not exceed the following levels referred to the level of the 9 960 Hz sideband:

Subcarrier	*Level*
9 960 Hz	0 dB reference
2nd harmonic	–30 dB
3rd harmonic	–50 dB
4th harmonic and above	–60 dB

c) Volume V, Chapter 4, 4.2.4, which states:

> To protect the operation of airborne equipment during the initial stages of deploying VORs utilizing 50 kHz channel spacing in an area where the existing facilities may not fully conform with the Standards in Annex 10, Volume I, Chapter 3, all existing VORs within interference range of a facility utilizing 50 kHz channel spacing shall be modified to comply with the provisions of Annex 10, Volume I, 3.3.5.7.

4.7.1.2 States that operate VOR facilities that do not comply with these provisions are requested to inform ICAO accordingly. This will be taken into account in frequency coordination.

4.8 GEOGRAPHICAL SEPARATION DISTANCES BETWEEN VORS AND BETWEEN A VOR AND GBAS VDB

4.8.1 For the calculation of minimum separation distances between a (desired) VOR facility and an (undesired) localizer, VOR or GBAS VDB facility, the generic model, as described in Chapter 1, 1.4, has been established.

4.8.1.1 Adjacent channel protection of the VOR system is effectively obtained without geographical separation of the facilities. However, protection of the localizer needs to be afforded as indicated in Chapter 3, section 3.8.

4.8.2 Geographical separation criteria are established on the basis of a regional agreement. Regions and States may apply different compatibility criteria that differ from those described in this Handbook, taking into account more detailed specifications of the desired and undesired facilities.

4.8.3. The generic model establishes the minimum separation distance between a desired and an undesired facility on the basis of the protection of the minimum required VOR signal of the (desired) VOR. The undesired facility should be separated by a distance that, taking into account the EIRP of the undesired facility, protects the minimum desired signal as per sections 4.4 and 4.5. The undesired facility can be a co-frequency VOR or GBAS facility or an adjacent localizer, VOR or GBAS facility.

4.8.4 To establish minimum geographical separation distances between a desired VOR and an undesired localizer, VOR or GBAS facility, the following parameters are required:

a) a minimum field strength of the desired VOR of 90 μV/m or 39 dB(μV/m), or –110 dBW for 118 MHz (Annex 10, Volume I);

b) the D/U ratio, specifically:

1) 20 dB for co-frequency compatibility with another localizer or VOR;

2) 26 dB for co-frequency compatibility with a GBAS; and

3) the D/U ratios in 4.4.2 and 4.5.2 for adjacent frequency compatibility; and

c) the EIRP of the undesired facility (dBW).

4.8.4.1 The generic method establishes the minimum geographical separation distance between the edge of the DOC of the desired VOR (maximum range and maximum height) and the location of the undesired facility. This distance is required for the transmission loss (attenuation) of the undesired signal to remain at a level that meets the D/U requirement for the desired signal. This distance is obtained by using the relevant (frequency) ITU propagation curve applicable to the maximum height of the DOC of the desired facility and the site elevation of the undesired facility. When such elevation is not provided, the height of the antenna of the undesired facility above ground is used. This height is typically between 10 and 30 ft.

4.8.4.2 When the minimum distance from the edge of coverage of the desired VOR to the undesired facility has been established, the station-to-station separation distance can be obtained by adding the DOR to the minimum distance from the edge of coverage to the undesired facility.

4.8.4.3 These steps need to be carried out in the reverse direction if the desired VOR becomes the undesired facility and the undesired facility becomes the desired facility. The larger of the two distances calculated by taking into account both directions determines the minimum separation between the two facilities.

4.9 CALCULATION EXAMPLE FOR A DESIRED AND UNDESIRED VOR

In this example, the DOC of VOR 1 is 25/100 (25 NM, 10 000 ft), and the EIRP is 20 dBW (100 W). The DOC of VOR 2 is 100/450 (100 NM, 45 000 ft), and the EIRP is 26 dBW (400 W). VOR 1 and VOR 2 operate on the same frequency. The D/U is 20 dB.

4.9.1 Compatibility of VOR 1 and VOR 2

The minimum required transmission loss (L) from the location of VOR 2 to the edge of the DOC of VOR 1 is calculated using formula (16):

$$L = Tx - P_d + D/U$$

where:

Tx: the EIRP of the undesired facility (dBW) (26 dBW);

P_d: the minimum required field strength of the desired facility (–110 dBW); and

D/U: 20 dB.

This results in:

$$L = Tx - P_d + D/U = 26 - (-110) + 20 = 156 \text{ dB}$$

The VOR antenna height is 20 ft. The ITU-R propagation table for 20 ft/10 000 ft (5 per cent of the time) shows that this transmission loss is obtained at a distance of 156 NM.

The minimum station-to-station separation distance is calculated as follows:

156 + 25 = 181 NM

4.9.2 Compatibility of VOR 2 and VOR 1

The minimum required transmission loss (*L*) from the location of VOR 2 to the edge of the DOC of VOR 1 is calculated using formula (16):

$$L = Tx - P_d + D/U$$

where:

Tx: the EIRP of the undesired facility (dBW) (20 dBW);

P_d: the minimum required field strength of the desired facility (–110 dBW); and

D/U: 20 dB.

This results in:

$$L = 20 - (-110) + 20 = 150 \text{ dB}$$

The VOR antenna height is 20 ft. The ITU-R propagation table for 10 ft/45 000 ft (5 per cent of the time) shows that this transmission loss is obtained at a distance of 272 NM.

The minimum station-to-station separation distance is calculated as follows:

272 + 100 = 372 NM

4.9.3 The minimum geographical (station-to-station) separation distance between VOR 1 and VOR 2 is the largest obtained in 4.9.1 and 4.9.2 (372 NM).

4.9.4 To assess the compatibility of a desired VOR with an undesired facility operating on adjacent channels, the relevant D/U ratios in Table 4-3 (100 kHz receivers) or Table 4-4 (50 kHz receivers) must be used in the equations above.

4.9.5 Tables 4-5A to 4-5D present the co- and adjacent frequency separation distances between the edge of the DOC of the desired VOR and the location of the undesired VOR or ILS localizer facility. The calculations are based on the following:

a) P_d = –110 dBW;

b) D/U ratios as indicated in Tables 4-3 and 4-4;

c) *T*x = EIRP of undesired facility (calculations are for Tx = 17 dBW, 20 dBW and 30 dBW);

d) *L* is calculated using formula (16); and

e) *D* is established with the ITU-R propagation curve for 108 MHz and 5 per cent of the time. The antenna height of the desired aircraft receiver is indicated in the "Remarks" column, and the antenna height of the undesired facility is 20 ft above ground.

Table 4-5A. Minimum separation distances between desired and undesired VORs

Δf (kHz)	*D/U (dB)*	*Tx = 17 dBW*		*Tx = 20 dBW*		*Tx = 30 dBW*		*Remarks*
		L (dB)	*D (NM)*	*L (dB)*	*D (NM)*	*L (dB)*	*D (NM)*	*Desired VOR at 45 000 ft*
0	20	147	268	150	271	160	284	50/100 kHz receiver
50	–7	120	134	123	174	133	231	100 kHz receiver
50	–34	93	5	96	11	106	43	50 kHz receiver
100	–46	81	< 0.5	84	< 0.5	94	7	50/100 kHz receiver
150	–50	77	< 0.5	80	< 0.5	90	< 0.5	50/100 kHz receiver

*Note.— The separation distances (*D*) are between the edge of coverage of a desired VOR at 45 000 ft and the location of an undesired VOR (or localizer) facility.*

Table 4-5B. Minimum separation distances between a desired and undesired VOR

Δf (kHz)	*D/U (dB)*	*Tx = 17 dBW*		*Tx = 20 dBW*		*Tx = 30 dBW*		*Remarks*
		L (dB)	*D (NM)*	*L (dB)*	*D (NM)*	*L (dB)*	*D (NM)*	*Desired VOR at 25 000 ft*
0	20	147	208	150	212	160	225	50/100 kHz receiver
50	–7	120	115	123	131	133	175	100 kHz receiver
50	–34	93	9	96	13	106	42	50 kHz receiver
100	–46	81	< 0.5	84	< 0.5	94	10	50/100 kHz receiver
150	–50	77	< 0.5	80	< 0.5	90	5	50/100 kHz receiver

Note.— The separation distances are between the edge of coverage of a desired VOR at 25 000 ft and the location of an undesired VOR (or localizer) facility.

Table 4-5C. Minimum separation distances between a desired and undesired VOR

∆f (kHz)	*D/U (dB)*	*Tx = 17 dBW*		*Tx = 20 dBW*		*Tx = 30 dBW*		*Remarks*
		L (dB)	*D (NM)*	*L (dB)*	*D (NM)*	*L (dB)*	*D (NM)*	*Desired VOR at 10 000 ft*
0	20	147	143	150	147	160	161	50/100 kHz receiver
50	–7	120	71	123	82	133	115	100 kHz receiver
50	–34	93	10	96	14	106	29	50 kHz receiver
100	–46	81	1	84	3	94	11	50/100 kHz receiver
150	–50	77	< 0.5	80	1	90	7	50/100 kHz receiver

Note.— The separation distances are between the edge of coverage of a desired VOR at 10 000 ft and the location of an undesired VOR (or localizer) facility.

Table 4-5D. Minimum separation distances between a desired and undesired VOR

∆f (kHz)	*D/U (dB)*	*Tx = 17 dBW*		*Tx = 20 dBW*		*Tx = 30 dBW*		*Remarks*
		L (dB)	*D (NM)*	*L (dB)*	*D (NM)*	*L (dB)*	*D (NM)*	*Desired VOR at 5 000 ft*
0	20	147	108	150	113	160	127	50/100 kHz receiver
50	–7	120	49	123	57	133	83	100 kHz receiver
50	–34	93	9	96	11	106	24	50 kHz receiver
100	–46	81	2	84	3	94	10	50/100 kHz receiver
150	–50	77	1	80	2	90	7	50/100 kHz receiver

Note.— The separation distances are between the edge of coverage of a desired VOR at 5 000 ft and the location of an undesired VOR (or localizer) facility.

4.10 CALCULATION EXAMPLE FOR A DESIRED VOR AND UNDESIRED GBAS VDB FACILITY

Note.— Separation distances between desired GBAS VDB and undesired VOR facilities are provided in Chapter 6.

4.10.1 To protect the VOR from interference from GBAS VDB signals, it is necessary to ensure that the minimum signal level of the VOR is protected from harmful interference. The co-frequency protection ratio (D/U) for the VOR is 26 dB (see Table 4-5). The undesired GBAS VDB signal at the VOR aircraft antenna must be below –135 dBW.

4.10.2 The transmission loss (*L*) between the undesired GBAS VDB and the edge of coverage of the desired VOR facility can be calculated using formula (16):

$$L = Tx - P_d + D/U$$

where:

L: the transmission loss (as per the ITU-R aeronautical curve);

Tx: the EIRP of the GBAS station (dBW);

P_d: the minimum VOR signal level (–110 dBW); and

D/U: the required D/U ratio as in Table 4-5.

4.10.3 In this example:

a) the DOC of the VOR is 200/450 (200 NM up to 45 000 ft);

b) the EIRP of the VDB is 17 dBW;

c) the D/U is 26 dB (co-frequency);

d) the frequency is 112 MHz;

e) the ITU-R propagation curve used is for an aircraft receiver antenna height of 45 000 ft and VDB antenna height of 45 ft; and

f) the required transmission loss (*L*) is calculated as follows:

26 + 17 – (–110) = 153 dB

With the ITU-R propagation curve for a VOR receiver height of 45 000 ft and VDB antenna height of 45 ft for 5 per cent of the time, the separation distance is 284 NM. This separation distance is measured from the edge of coverage of the desired VOR to the location of the undesired VDB station. The station-to-station separation is calculated as follows:

284 + 200 = 484 NM (5 per cent of the time)

Table 4-6 presents the co- and adjacent frequency separation distances between the edge of the DOC of the (desired) VOR and the location of the (undesired) GBAS VDB station. The D/U ratios are indicated in Table 4-5. The (undesired) GBAS VDB antenna is at 45 ft above local terrain. The ITU Recommendation ITU-R P.528-5 propagation curves for 5 per cent of the time are used.

Table 4-6. Minimum separation distances to protect a VOR from interference from a GBAS VDB

	Distance between the edge of the DOC of the desired VOR (50 kHz receiver) and the location of the undesired GBAS VDB (VDB EIRP of 17 dBW)				
VOR height (ft)	*Co-frequency D/U = 26 dB L = 153 dB*	*1st adjacent frequency (+/–25 kHz) D/U = 0 dB L = 126 dB*	*2nd adjacent frequency (+/– 50 kHz) D/U = –34 dB L = 92 dB*	*3rd adjacent frequency (+/–75 kHz) D/U = –46 dB L = 87 dB*	*4th adjacent frequency (+/– 100 kHz) D/U = –65 dB L = 61 dB*
5 000	127 NM	80 NM	9 NM	5 NM	Frequency assignment planning freedom
10 000	161 NM	111 NM	8 NM	5 NM	
15 000	186 NM	135 NM	8 NM	4 NM	
20 000	206 NM	155 NM	8 NM	3 NM	
25 000	225 NM	172 NM	8 NM	2 NM	
30 000	242 NM	189 NM	7 NM	Frequency assignment planning freedom	
35 000	237 NM	203 NM	6 NM		
40 000	271 NM	217 NM	5 NM		
45 000	284 NM	228 NM	3 NM		
50 000	297 NM	242 NM	Planning freedom		
60 000	320 NM	264 NM			

Note 1.— With minimum separation distances of less than 0.5 NM, frequency assignment planning freedom is assumed.

Note 2.— Separation distances less than or equal to 5 NM may be considered as operationally insignificant.

4.11 SECTORIZED COVERAGE

4.11.1 Application of the calculation methods described above may produce incorrect results if sectorization (key-holing) is used. This is illustrated in Figure 4-2.

4.11.2 In Figure 4-2, A can be considered as the desired VOR facility, and B as the undesired facility. The critical point is the point that is most exposed to interference from facility B because it is the point of the DOC of facility A that is nearest to transmitter B.

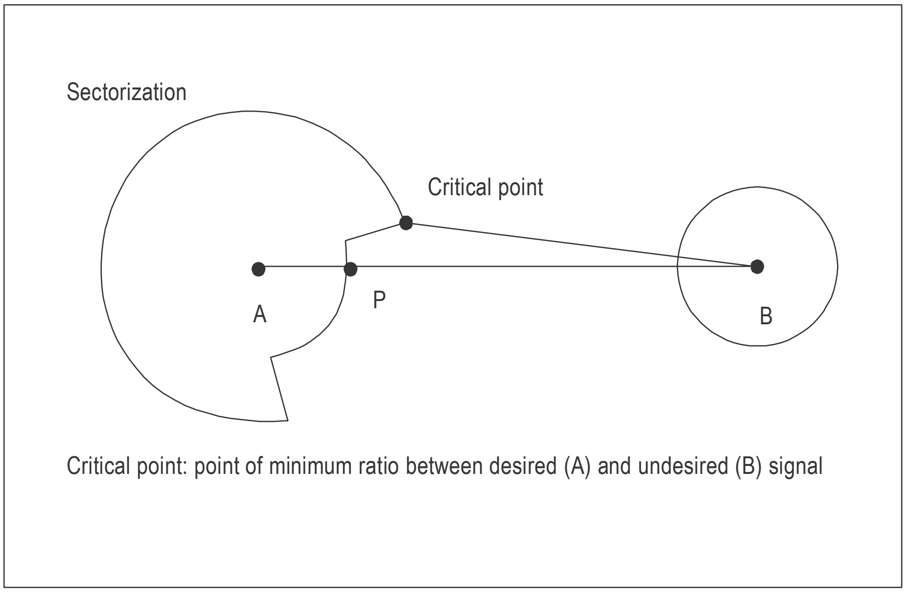

Figure 4-2. Geometry for determining test points

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Chapter 5

DISTANCE MEASURING EQUIPMENT (DME)

Note.— This chapter covers the use of distance measuring equipment (DME) using X and Y channels only.

5.1 INTRODUCTION

5.1.1 DME provides aircraft with continuous and accurate information on the slant range distance between an aircraft-based DME interrogator and a ground-based DME transponder. When in operation, the aircraft-based interrogator interrogates the ground-based transponder, which, in turn, transmits replies to the interrogator (see Figure 5-1). The time difference between the transmission of the interrogation and the received reply from the DME transponder provides means for an accurate measurement of the distance (slant range) between the aircraft and the transponder.

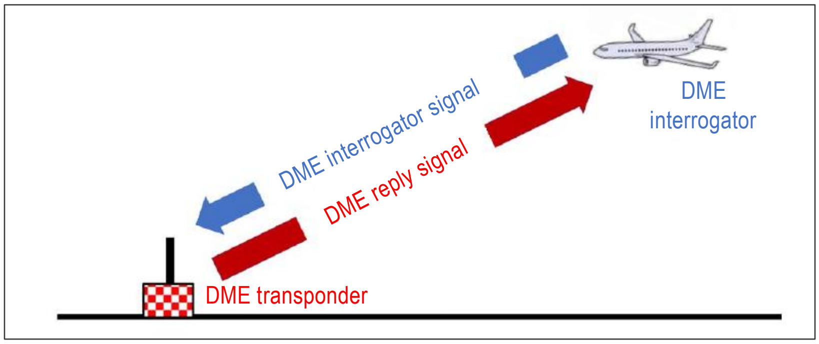

Figure 5-1. DME interrogations and replies

5.1.2 DME is in many cases associated with an instrument landing system (ILS) or VHF omnidirectional radio range (VOR). Stand-alone DME facilities to support area navigation (RNAV) are increasingly being used.

5.2 DESIGNATED OPERATIONAL COVERAGE

5.2.1 The designated operational coverage (DOC) of DME is normally promulgated by States. When DME is associated with an ILS or a VOR, the DOC of the DME is normally not less than the DOC of the ILS or VOR.

5.2.2 DME coverage is typically:

a) 25 NM/10 000 ft (EIRP of 27 dBW) when associated with an ILS;

b) 25 NM/10 000 ft (EIRP of 27 dBW) for landing DME;

c) 100 NM/25 000 ft (EIRP of 30 dBW) for terminal DME; and

d) 200 NM/45 000 ft (EIRP of 37 dBW) for en-route DME.

Note.— The above provides typical EIRP values. States may provide more precise information to be considered in frequency assignment planning. See also 5.3.3.1.

5.2.2.1 States may require different combinations of range and height in accordance with operational requirements.

5.2.3 The data in Figure 5-2 can be used to determine whether a particular installation can provide the required DOC. The transmission loss in Figure 5-2 is based on the IF-77 propagation model.

5.2.3.1 Whenever DME provides coverage using either a directional or bi-directional DME antenna, the antenna pattern in azimuth and elevation has to be taken into account to achieve the full benefit of the reduced separation requirements outside the antenna main lobe. The actual radiation patterns of the antennas depend on a number of factors, including height of the antenna phase centre, height of the DME counterpoise above ground level (AGL), terrain surface roughness, terrain form, site elevation above mean sea level (MSL), and conductivity of ground and counterpoise. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the equivalent EIRP. Conversely, practical experience has shown that under favourable siting conditions, and under the less pessimistic conditions often found in actual service, satisfactory system operation is achieved with a lower EIRP. However, to account for lowest EIRP in notches between the lobes of the real elevation antenna pattern, the values in Figure 5-2 are recommended.

5.2.4 EIRP OF DME/N FACILITIES

5.2.4.1 The power density figure prescribed in Annex 10, Volume I, Chapter 3, is based on the following example:

Airborne receiver sensitivity	–120 dBW
Transmission line loss, mismatch loss, antenna polar pattern variation with respect to an isotropic antenna	+9 dB
Power required at antenna	–111 dBW

Minus 111 dBW at the antenna corresponds to –89 dBW/m^2 at the mid-band frequency.

5.2.4.2 Nominal values of the necessary EIRP to achieve a power flux density of –89 dBW/m^2 are given in Figure 5-2. For coverage under difficult terrain and siting conditions, it may be necessary to make appropriate increases in the EIRP. Conversely, under favourable siting conditions, the stated power flux density may be achieved with a lower EIRP.

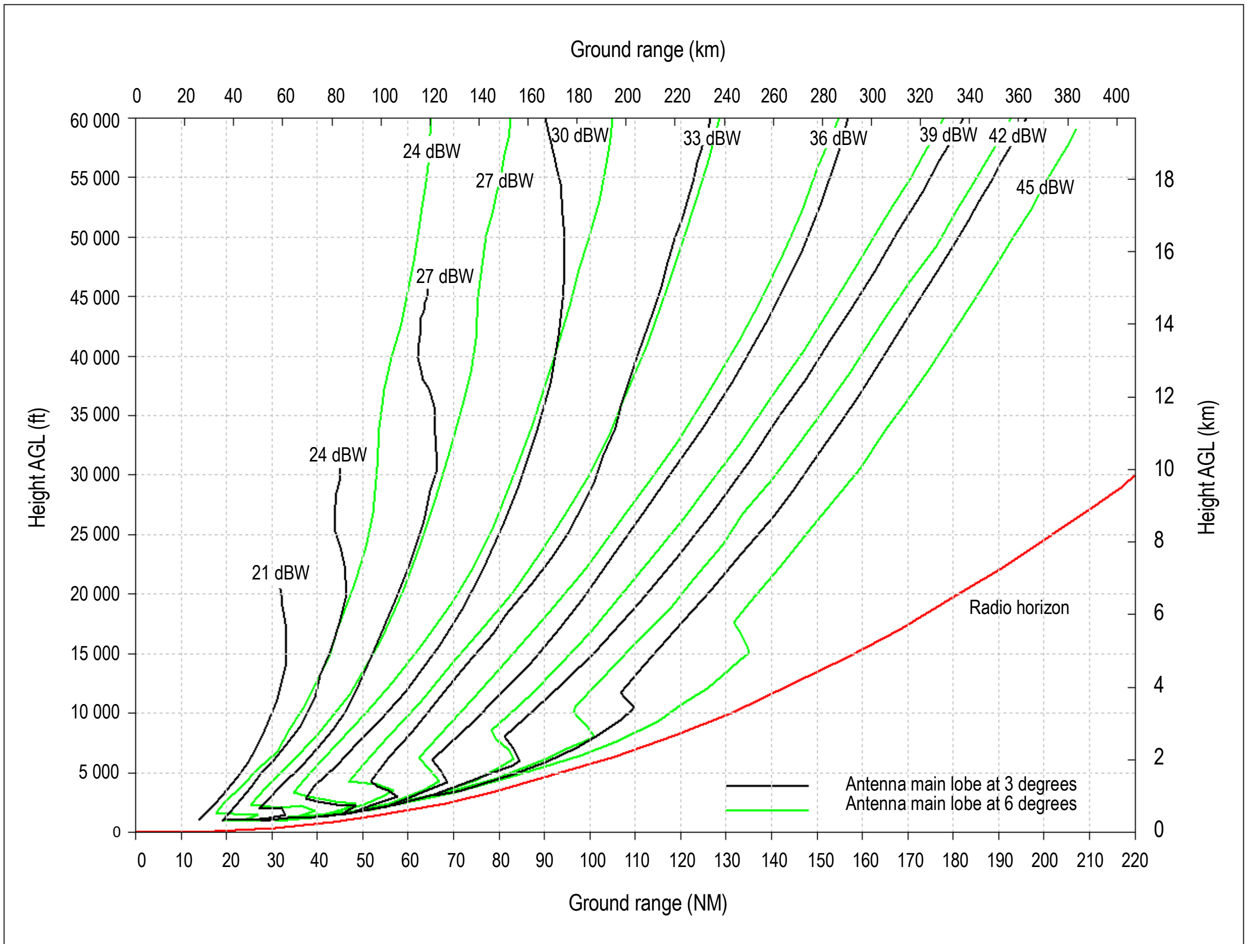

Figure 5-2. Necessary EIRP to achieve a power density of –89 dBW/m^2 as a function of height above and distance from the DME

Note 1.— The curves are based on the IF-77 propagation model with a 4/3 earth radius which has been confirmed by measurements.

Note 2.— The radio horizon in Figure 5-2 is for a DME antenna located 5 m (17 ft) AGL over flat terrain. Terrain shielding will reduce the achievable range.

Note 3.— If the antenna is located significantly higher than the assumed reference antenna, the radio horizon and power density will increase.

Note 4.— An antenna main lobe of 6 degrees is typical for a UHF tactical air navigation aid (TACAN); an antenna lobe of 3 degrees is typical for DME.

5.3 FREQUENCIES AND CHANNELLING

5.3.1 DME operates on paired interrogation and reply frequencies (each combination of these frequencies is a "channel") in the frequency band 960–1 215 MHz. A number of these channels are in turn paired with ILS or VOR VHF frequencies. The DME channelling arrangement is shown in Figure 5-3 and Table 5-2. The frequency band 960–1 215 MHz is also used for TACAN. TACAN operates with the same channelling scheme as DME and can be paired with a VOR (VOR/TAC). From a frequency assignment planning point of view, TACAN is equivalent to DME.

5.3.2 The sub-band 1 164–1 215 MHz is shared with radio navigation satellite services (RNSSs) with the condition that the latter do not claim protection from aeronautical radio navigation services (for example, DME). For more details on the use of this band, see Volume I of this Handbook.

5.3.3 In the DME channelling arrangement, the aircraft DME interrogator sends an interrogation on a frequency in the band 1 025–1 150 MHz. The ground transponder sends a reply:

a) for X channels, in the bands 962–1 024 MHz and 1 151–1 213 MHz; and

b) for Y channels, in the band 1 025–1 150 MHz.

Note.— The frequencies between 1 025 MHz and 1 151 MHz in Figure 5-3 are used as the interrogator frequency of the X and Y channels as well as the reply frequency for the Y channels.

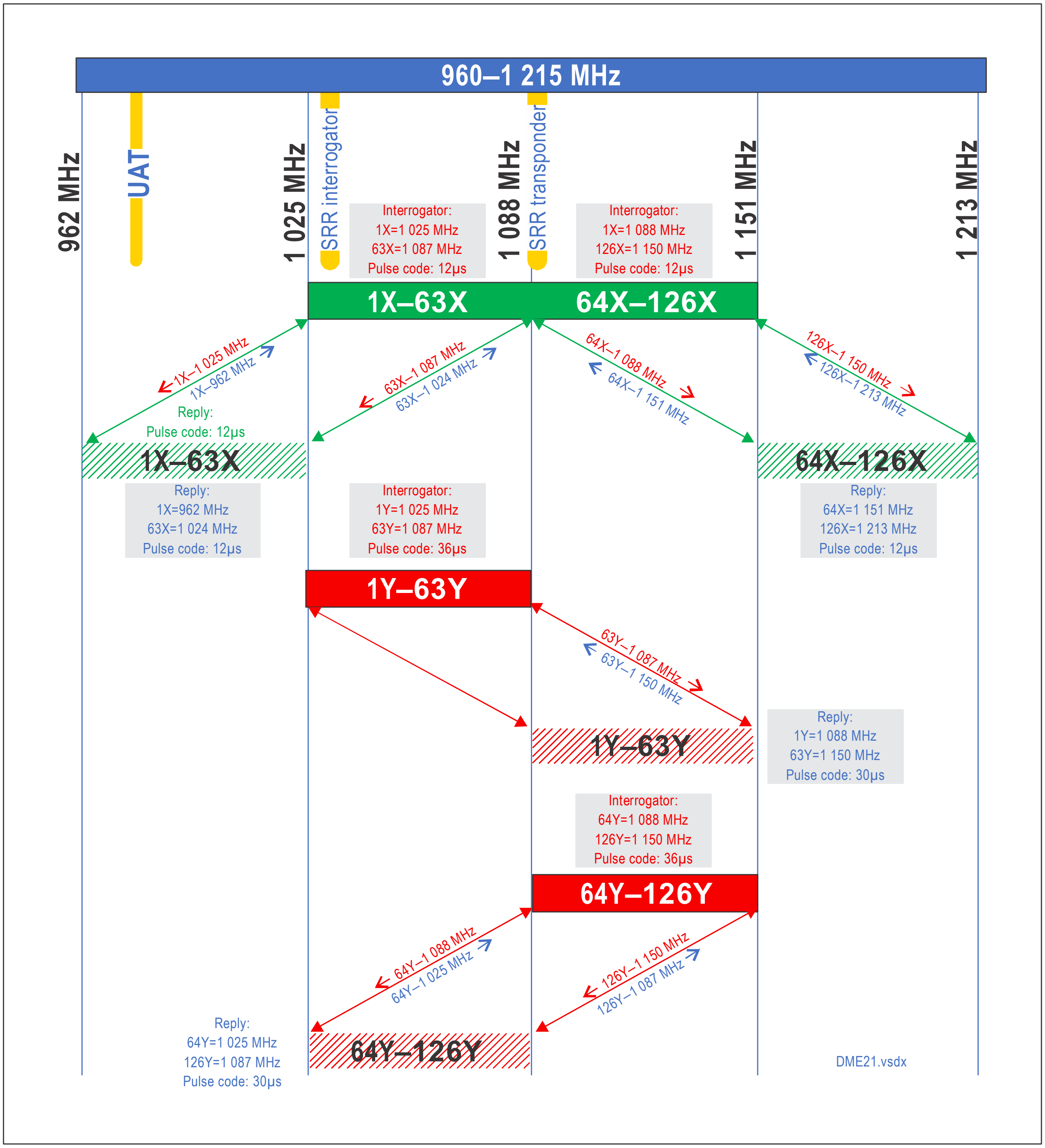

Figure 5-3. DME channelling arrangement

5.3.3.1 The spacing between DME channels is 1 MHz. DME X and Y channels with the same channel number use the same interrogator frequency but with different pulse coding for the X and Y channels. The reply frequency for the X and Y channels is different, as is the pulse coding. The Y channels reuse the reply frequencies within the interrogation frequency block (1 025–1 150 MHz).

5.3.3.2 The aircraft interrogator can send interrogation pulses on channel 1X or on channel 1Y (see Figure 5-3 and Table 5-2). The interrogation that is transmitted on channel 1X and 1Y is on the same frequency (1 025 MHz). The DME interrogation pulses have a different pulse code/spacing on channel 1X (12 µs) and on channel Y (36 µs). When the ground transponder operating on channel 1X receives the interrogation pulses with a pulse spacing of 12 µs, it responds on the frequency 962 MHz with a reply signal with a pulse spacing of 12 µs. Any aircraft transmission on the frequency 1 025 MHz with a pulse spacing that is different from 12 µs is discarded by this transponder.

5.3.3.2.1 If the aircraft transmission on channel 1Y on the frequency 1 025 MHz with a pulse spacing of 36 µs is received by transponder 1Y, this transponder replies with a signal on the frequency 1 088 MHz with a pulse spacing of 30 µs. Any signal that is received by transponder 1Y on the frequency 1 025 MHz but with a different pulse spacing is discarded by transponder 1Y (for example, from an interrogator operating on channel 1X (1 025 MHz but with a pulse spacing of 12 µs)).

5.3.3.2.2 In summary, DME channels 1X and 1Y can operate in the same or overlapping DME. Since the transponder sends reply signals on different frequencies (and with different pulse coding and spacing), the two channels do not interfere with each other.[1]

5.4 PAIRING OF DME CHANNELS WITH AN ILS OR VOR

DME channels are paired with an ILS or VOR as in Table 5-1 and Table 5-2.

Table 5-1. DME channel pairing with ILS or VOR frequencies

DME channel	*Paired with*	*Navigation aid*	
18X–56X (even numbers)	108.100–111.900 MHz	ILS localizer, 100 kHz	
18Y–56Y (even numbers)	108.150–111.950 MHz	ILS localizer, 50 kHz	
19X–55X (odd numbers)	108.200–111-800 MHz	VOR, 100 kHz	
19Y–55Y (odd numbers)	108.250–111.850 MHz	VOR, 50 kHz	
57X–59X	112.000–112.200 MHz	VOR, 100 kHz	
57Y–59Y	112.050–112.250 MHz	VOR, 50 kHz	
70X–126X	112.300–117.900 MHz	VOR, 100 kHz	
70Y–126Y	112.350–117.950 MHz	VOR, 50 kHz	See note

1. The channel assignment process explicitly considers only the assignment of beacon reply frequencies. Air-to-ground frequency protection is provided by appropriate specifications imposed on the ground equipment in terms of off-code and off-frequency signal rejection. These specifications require that ground transponders be equipped with both: (1) a Ferris Discriminator which will inhibit the generation of replies for all signals 900 kHz and more removed from the desired channel nominal frequency; and (2) a decoder which will inhibit the generation of replies for all signals less than 75 dB above the minimum receiver sensitivity level with the received pulse pair ±2 J µs removed from the nominal channel code spacing.

Note.— The channels 70Y–79Y cannot be used when protection of the secondary surveillance radar (SSR) system is required.

5.5 FREQUENCIES USED BY THE SSR SYSTEM

5.5.1 SSR is also operational in the frequency band 960–1 215 MHz. SSR operates on:

a) 1 030 MHz – interrogator (ground-to-air); and

b) 1 090 MHz – transponder (air-to-ground).

These frequencies are also used for the airborne collision avoidance system (ACAS). The frequency 1 090 MHz is also used with SSR Mode S extended squitter signals to support automatic dependent surveillance — broadcast (ADS-B) functionality and multilateration (MLAT) systems (Annex 10, Volume IV), as demonstrated in Figure 5-4.

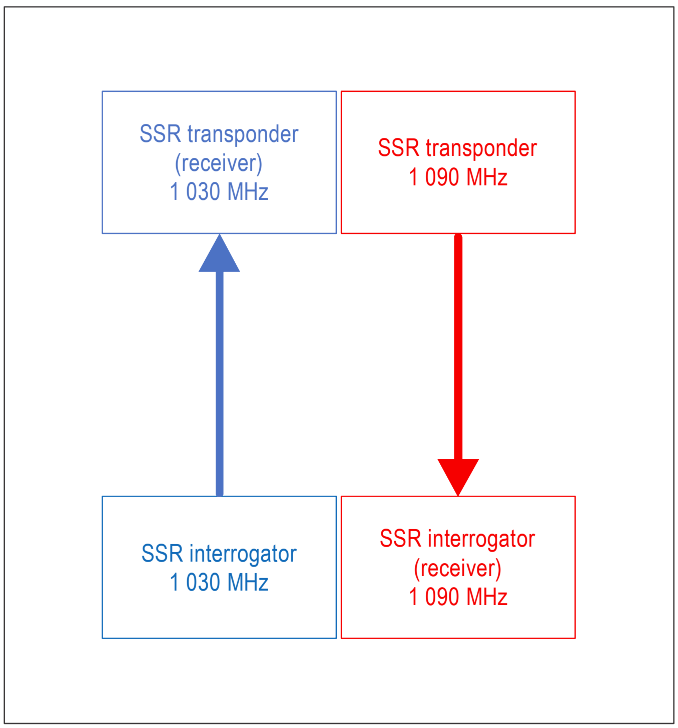

Figure 5-4. SSR frequency utilization

5.5.2 In order to protect the secondary surveillance system from interference that can be caused by emissions from DME transmitters (and, conversely, to protect DME signals from interference that can be caused by transmissions from these surveillance systems), the use of DME channels on and around the frequencies 1 030 MHz and 1 090 MHz is restricted. This affects the following DME channels:

a) 01X–16X, DME interrogations on the frequencies 1 025–1 040 MHz;

b) 01Y–16Y, DME interrogations on the frequencies 1 025–1 040 MHz and DME replies on the frequencies 1 088–1 103 MHz;

c) 60X–63X, DME interrogations on the frequencies 1 084–1 087 MHz and DME replies on the frequencies 1 021–1 024 MHz;

d) 60Y–63Y, DME interrogations on the frequencies 1 084–1 087 MHz;

e) 64X–69X, DME interrogations on the frequencies 1 088–1 093 MHz;

f) 64Y–69Y, DME interrogations on the frequencies 1 088–1 093 MHz and DME replies on the frequencies 1 025–1 030 MHz;

g) 70Y–79Y, DME interrogations on the frequencies 1 094–1 103 MHz and DME replies on the frequencies 1 031–1 040 MHz; and

h) 124Y–126Y, DME replies on the frequencies 1 084–1 087 MHz.

5.5.3 It is recommended that the DME channels 01X–16X, 01Y–16Y, 60X–69X, 60Y–69Y, 70Y–79Y and 124Y–126Y are not used for international aircraft operations (see also Table 5-2). Channel 17X is only used for emergency applications.

5.6 UNIVERSAL ACCESS TRANSCEIVER (UAT)

5.6.1 *Use of the frequency 978 MHz by the universal access transceiver (UAT)*

5.6.1.1 Use of the frequency 978 MHz by both the UAT and DME (channel 17X) is not recommended. In areas where the UAT is being implemented, the use of DME channel 17X should be terminated or blocked.

5.6.2 Besides the siting restrictions referred to in 5.6.3, the use of the frequency 978 MHz for UAT does not place restrictions on using DME channel 16X (977 MHz) or lower and DME channel 18X (979 MHz) or higher.

5.6.3 Siting restrictions for use of the UAT with regard to DME/TACAN usage of frequencies adjacent to 978 MHz are in the *Manual on the Universal Access Transceiver (UAT)* (Doc 9861).

5.7 PROTECTION REQUIREMENTS

5.7.1 Desired to undesired (D/U) signal ratios at the airborne receiver for X and Y channels

5.7.1.1 In making an assignment, each DME facility must be treated as the desired source, while other DME facilities must be treated as the undesired source. If both satisfy their unique D/U requirement, then the channel assignment may be made. This “reverse” check is necessary if the DME facilities being considered radiate with different EIRP or have a different DOC.

Frequency assignment planning for DME is aimed at protecting the DME signal at the aircraft receiver.

5.7.1.2 As described in 5.3.3.1 and 5.3.3.2, for each DME X and Y channel, a unique reply frequency has been established. For DME frequency assignment planning purposes, channel 17X (reply frequency 978 MHz), 18X (reply frequency 979 MHz), 19X (reply frequency 980 MHz) and others are adjacent channels. Similarly, channels 17Y (reply frequency 1 104 MHz), 18Y (reply frequency 1 105 MHz), 19Y (reply frequency 1 106 MHz) and others are adjacent channels. The adjacent X channels use the same pulse code. The adjacent Y channels use the same pulse code, which is different from the pulse code used by the X channels. Channel 1X (reply frequency 978 MHz) and channel 1Y (reply frequency 1 104 MHz) are not adjacent channels. Note that channel 126Y (reply frequency 1 087 MHz) is an adjacent channel to channel 1Y (reply frequency 1 088 MHz), channel 63X (reply frequency 1 024 MHz) is adjacent to channel 64Y (reply frequency 1 025 MHz) and channel 63Y (reply frequency 1 150 MHz) is adjacent to channel 64X (1 088 MHz).

However, for DME facilities operating on Y channels, the reply frequency may be the same as the interrogator frequency of another DME facility operating on X channels. This requires special attention, as described in the following paragraphs.

5.7.1.3 A specific reply frequency within the band 960–1 215 MHz corresponds to each X or Y DME channel. X and Y DME channels do not have reply frequencies in common. Hence, for the protection of the desired transponder replies from other co-channel transponder replies, it is sufficient to consider only DME facilities with the same channel designation (including the pulse code).

5.7.1.4 Protection of the first adjacent channel is based upon the assumption that the DME first adjacent frequency rejection is 50 dB. In this case, a distinction is to be made between undesired DME facilities with an EIRP that is greater than 43 dBW (20 kW) and DME facilities with an EIRP that is less than 43 dBW.

When the EIRP of the undesired facility is greater than 43 dBW, the adjacent frequency D/U ratio is –42 dB.

When the EIRP of the undesired facility is less than 43 dBW, consideration needs to be given to the out-of-band radiation of the DME transponder on the first adjacent channel. As shown in Figure 5-5, the spectrum in a band of 0.5 MHz and centred at 0.8 MHz above (or below) the nominal frequency (of the undesired facility) is 200 mW (–7 dBW). This is co-frequency interference to the desired facility and requires a D/U ratio of 8 dB.

5.7.1.5 Protection of the second adjacent channel is based upon the assumption that the DME second adjacent frequency rejection is 70 dB. In this case, a distinction is to be made between undesired DME facilities with an EIRP that is greater than 63 dBW (2 000 kW) and DME facilities with an EIRP that is less than 63 dBW.

When the EIRP of the undesired facility is greater than 63 dBW, the D/U ratio is –72 dB.

When the EIRP of the undesired facility is less than 63 dBW, consideration needs to be given to the out-of-band radiation of the DME transponder on the second adjacent channel. As shown in Figure 5-5, the spectrum in a band of 0.5 MHz and centred at 2 MHz above (or below) the nominal frequency (of the undesired facility) is 2 mW (–27 dBW). This is co-frequency interference to the desired facility and requires a D/U ratio of 8 dB.

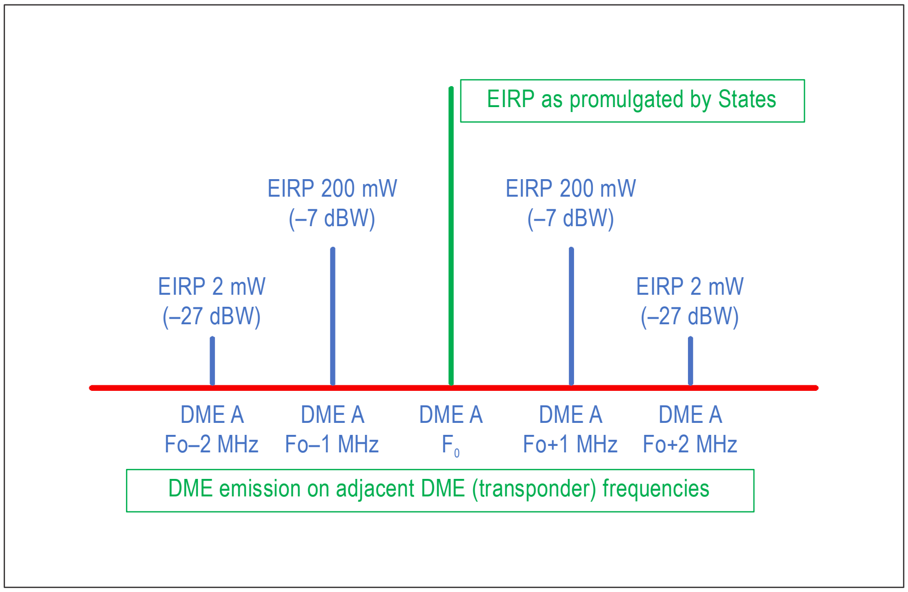

Figure 5-5. Out-of-band radiation of DME transponders (Annex 10, Volume I, Chapter 3)

5.7.1.6 The protection requirements specified in this section (5.7) are implemented in the ICAO Regions. Only DME X and Y channels are being implemented, and protection of adjacent channel interference is based on the out-of-band radiation of DME transponders. A full set of D/U signal ratios at the airborne receiver is, for information, reproduced at the end of this chapter in section 5.10. Note that these signal ratios include protection requirements for DME W and Z channels, which are currently not implemented.

5.8 GEOGRAPHICAL SEPARATION DISTANCES

5.8.1 The signal ratios necessary to ensure the interference-free operation of DME facilities are provided in 5.2. Geographical separation distances are established using the generic method described in Chapter 1, 1.4 and 1.5.

5.8.2 The generic model establishes the minimum separation distance between a desired and an undesired DME facility based on the protection of the minimum signal of the (desired) DME (–111 dBW) at the aircraft antenna. The undesired facility should be separated by a distance that, taking into account the EIRP of the undesired facility, protects the minimum desired signal as per 5.2. The protection is provided through the path loss of the undesired signal using the aeronautical propagation curves in ITU Recommendation ITU-R P.528-5 for 5 per cent of the time.

Note.— A brief description of the ITU-R propagation curves is provided in Chapter 1, 1.3.3, and a description of the use of these curves in aeronautical frequency assignment planning is provided in Chapter 1, 1.4 and 1.5.

5.8.3 In summary, in order to establish the minimum geographical separation distances between a desired DME and the location of an undesired DME, the following parameters are used:

a) the minimum required signal level at the aircraft antenna of –111 dBW;

b) the EIRP of the undesired DME (see 5.2.4.2);

c) the protection point at the edge of the DOC of the desired DME (see 5.8.2); and

d) the required co-channel D/U ratio (8 dB).

5.8.3.1 The EIRP of the DME station (P_u) is normally provided by the State responsible for the DME station. In case no such information is provided, the following typical EIRP values, based on standard transmitter output power, feeder losses and antenna gain, are assumed for ICAO frequency assignment planning purposes:

a) landing and terminal DME: 27 dBW (500 W) (29 dBW for directional DME);

b) En-route DME: 37 dBW (5 kW); and

c) TACAN: 40 dBW (10 kW).

5.8.3.1.1 To improve spectrum economy, it is highly recommended that technical measures are taken to not exceed the EIRP of a landing DME above 29 dBW (800 W).

5.8.3.2 For the calculation of geographical separation distances between DME facilities operating on adjacent channels, the equivalent co-frequency EIRP values of the undesired facility (P_u) are:

a) –7 dBW for the first adjacent channel; and

b) –27 dBW for the second adjacent channel.

5.8.3.3 The maximum height of the DOC of the desired facility determines the ITU-R propagation curve to be used when assessing the minimum geographical separation distance between the location of the undesired facility and the edge of coverage of the desired facility. This distance needs to result in the minimum transmission loss, which can be calculated using formula (16).

5.9 CALCULATION EXAMPLES

5.9.1 The required transmission loss (L) between the location of the undesired facility and the edge of coverage of the desired facility that protects the desired signal from harmful interference can be calculated using formula (16):

$$L = Tx - P_d + D/U$$

5.9.2 *Co-channel geographical separation distances*

5.9.2.1 For the landing and terminal DME:

a) the EIRP of the undesired DME is 27 dBW;

b) the DOC of the desired DME is 25/100; and

c) the D/U is 8 dB.

The minimum required transmission loss (L) is calculated as follows:

27 – (–111) + 8 = 146 dB

The ITU-R propagation curve for 1 080 MHz, antenna heights of 20 ft (h1) and 10 000 ft (h2), and for 5 per cent of the time shows that the required transmission loss of 146 dB is obtained at a separation distance (to the edge of coverage of the desired DME) of 129 NM. The minimum separation between the location of the desired and the undesired DME is calculated as follows:

$$129 + 25 = 154 \text{ NM}$$

where 25 NM is the DOR of the desired DME.

5.9.2.2 For the en-route DME 1:

a) the EIRP is 37 dBW; and

b) the DOC is 100/250.

The minimum required transmission loss (*L*) is calculated as follows:

$$37 – (–111) + 8 = 156 \text{ dB}$$

The ITU-R propagation curve for 1 080 MHz, antenna heights of 20 ft (h1) and 25 000 ft (h2), and 5 per cent of the time shows that the required transmission loss of 156 dB is obtained at a separation distance (to the edge of coverage of the desired DME) of 201 NM.

5.9.2.3 For the en-route DME 2 or TACAN:

a) the EIRP is 40 dBW; and

b) the DOC is 200/450.

The minimum required transmission loss (*L*) is calculated as follows:

$$40 – (–111) + 8 = 159 \text{ dB}$$

The ITU-R propagation curve for 1 080 MHz, antenna heights of 20 ft (h1) and 45 000 ft (h2), and 5 per cent of the time shows that the required transmission loss of 159 dB is obtained at a separation distance (to the edge of coverage of the desired DME) of 263 NM.

5.9.3 *Adjacent channel separation: first adjacent channel (1 MHz)*

5.9.3.1 When considering the co-channel interference that can be caused by the out-of-band emissions for a DME, the D/U ratio is 8 dB. On the first adjacent channel, the undesired signal (P_u) has a signal level of –7 dBW. The minimum desired power (P_d) at the aircraft antenna is –111 dBW.

$$L = P_u – P_d + D/U \ (D/U = 8 \text{ dB})$$

$$L = P_u – P_d + 8$$

$$–7 – (–111) + 8 \text{ dB} = –112 \text{ dB}$$

$$D = 10 \text{ NM}$$

The ITU-R propagation curve for 5 per cent of the time and antenna heights of 20 ft (h1) and 10 000 ft (h2) is used. D is measured from the edge of the desired facility to the location of the undesired (first adjacent channel) DME ground station.

5.9.4 *Adjacent channel separation: second adjacent channel (2 MHz)*

For the second adjacent channel, the undesired signal (P_u) is –27 dBW.

$$L = P_u - P_d + D/U$$

$$D/U = 8 \text{ dB} - (P_u + 19)$$

$$L = -27 - (-111) + 8 = -92 \text{ dB}$$

$$D = 0.5 \text{ NM}$$

Free-space transmission loss is used. D is measured from the edge of the desired facility to the location of the undesired (first adjacent channel) DME ground station.

Note.— Because of the short minimum separation distances, the transmission loss is calculated using the free space formula. At these short distances, using the ITU-R curve is not recommended because the interference scenario should consider the protection of the DME signal when the aircraft is operating at low altitudes.

5.10 SEPARATION REQUIREMENT FOR DME REPLY FREQUENCIES SEPARATED BY 63 MHZ

5.10.1 A potential interference situation may occur between DME X and DME Y channels since interference between two DME (ground) transponders that are 63 MHz apart may occur (for example, the transmissions (replies) from a transponder operating on channel 64Y (1 025 MHz) could interfere with the reception of the transmission from an (aircraft) interrogator operating on channel 1X (1 025 MHz), resulting in desensitization of the transponder operating on channel 1X). This is illustrated in Figure 5-6. In this case, the (desired) DME operating on channel 1X may become overloaded with the replies from the DME transponder on channel 64Y, which replies to the aircraft on the same frequency on which the DME transponder on 1X is receiving. The transponders should be separated by a distance that is at least the distance of the radio horizon between the two facilities.

5.10.2 In general, a minimum separation distance of 15 NM between these (ground) facilities would be required.

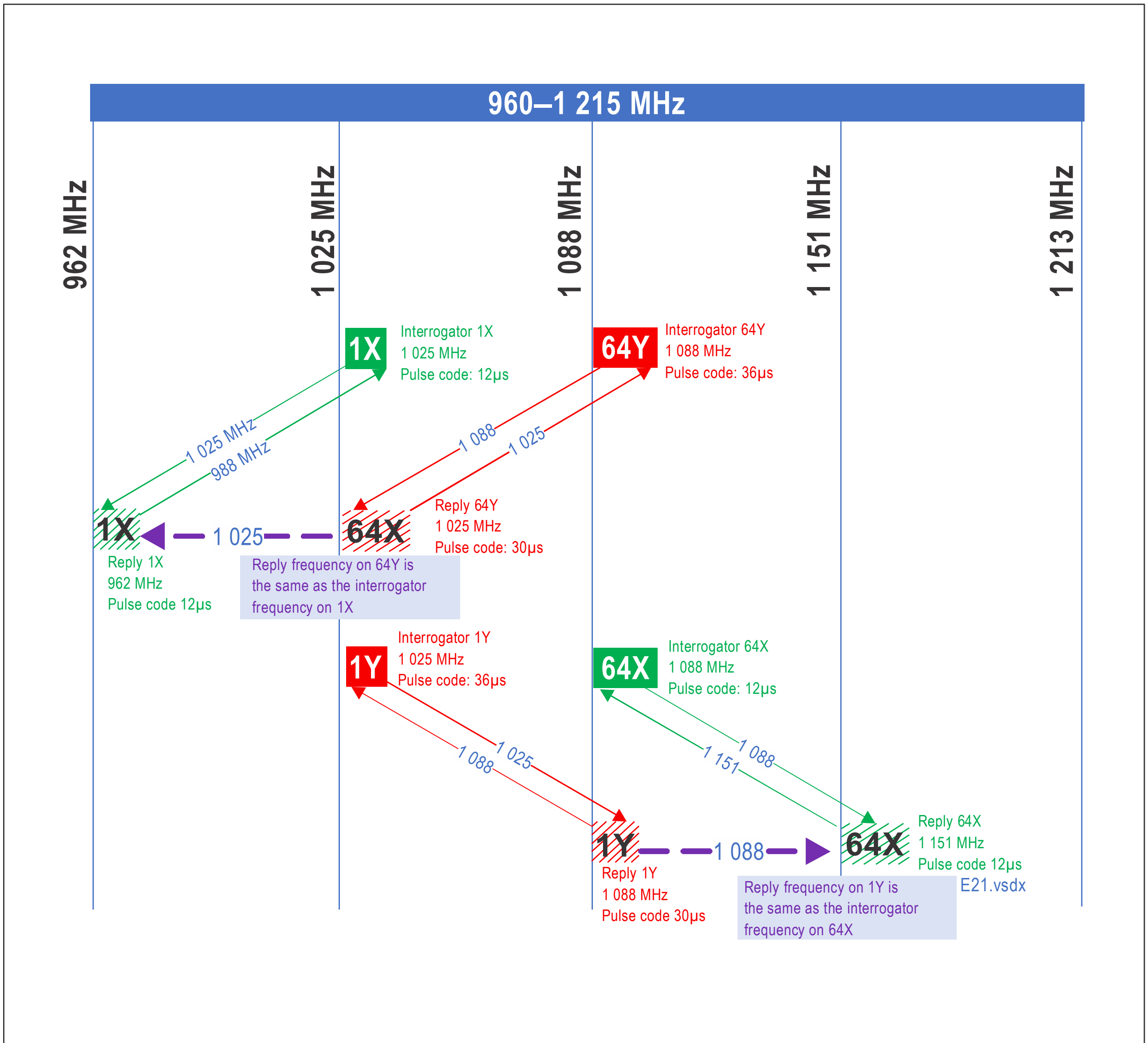

Figure 5-6. Interference scenario between two DME transponders separated by 63 MHz

5.11 SECTORIZED DOC OF THE DME

Similar to a VOR (as described in Chapter 4), the DME DOC many be sectorized (instead of circular). In this case, compatibility of the DME with other DME assignments needs to be ensured at the critical point, which is the closest point of the DOC of the desired DME (with sectorized DOC) and any potential interfering DME transponder.

5.12 USE OF DIRECTIONAL ANTENNAS

5.12.1 When an omnidirectional DOC is not required, the use of a DME with directional antennas is encouraged, provided that the operational requirements for the provision of this service by this facility are met. In particular, directional antennas are useful for the replacement of ILS marker beacons. The directional DME could provide a means to mitigate frequency congestion.

5.12.2 The compatibility of DME with directional antennas can essentially be examined in a similar way as for directional antennas developed for omnidirectional DME. It is noted in particular that, because of the orientation of DME with directional antennas, the minimum D/U value is not necessarily attained along the direct line connecting desired and undesired facilities, as opposed to in the case of compatibility between omnidirectional DME.

5.12.3 If at least one DME facility is used with directional antennas, first, an appropriate number of points must be selected along the edge of the DOC of the desired DME, regardless of the type of antenna. Subsequently, the required D/U criteria must be checked at all the points. Compatibility is ensured if the required D/U criteria are met at all the points.

5.13 PAIRING OF AN ILS, VOR AND MICROWAVE LANDING SYSTEM (MLS) WITH DME CHANNELS

Table 5-2. Pairing of ILS, VOR, MLS and DME channels (Annex 10, Volume I)

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N µs*	*Initial approach µs*	*Final approach µs*	*Frequency MHz*	*Pulse codes µs*
*1X	–	–	–	1 025	12	–	–	962	12
**1Y	–	–	–	1 025	36	–	–	1 088	30
*2X	–	–	–	1 026	12	–	–	963	12
**2Y	–	–	–	1 026	36	–	–	1 089	30
*3X	–	–	–	1 027	12	–	–	964	12
**3Y	–	–	–	1 027	36	–	–	1 090	30
*4X	–	–	–	1 028	12	–	–	965	12
**4Y	–	–	–	1 028	36	–	–	1 091	30
*5X	–	–	–	1 029	12	–	–	966	12
**5Y	–	–	–	1 029	36	–	–	1 092	30
*6X	–	–	–	1 030	12	–	–	967	12
**6Y	–	–	–	1 030	36	–	–	1 093	30
*7X	–	–	–	1 031	12	–	–	968	12

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
**7Y	–	–	–	1 031	36	–	–	1 094	30
*8X	–	–	–	1 032	12	–	–	969	12
**8Y	–	–	–	1 032	36	–	–	1 095	30
*9X	–	–	–	1 033	12	–	–	970	12
**9Y	–	–	–	1 033	36	–	–	1 096	30
*10X	–	–	–	1 034	12	–	–	971	12
**10Y	–	–	–	1 034	36	–	–	1 097	30
*11X	–	–	–	1 035	12	–	–	972	12
**11Y	–	–	–	1 035	36	–	–	1 098	30
*12X	–	–	–	1 036	12	–	–	973	12
**12Y	–	–	–	1 036	36	–	–	1 099	30
*13X	–	–	–	1 037	12	–	–	974	12
**13Y	–	–	–	1 037	36	–	–	1 100	30
*14X	–	–	–	1 038	12	–	–	975	12
**14Y	–	–	–	1 038	36	–	–	1 101	30
*15X	–	–	–	1 039	12	–	–	976	12
**15Y	–	–	–	1 039	36	–	–	1 102	30
*16X	–	–	–	1 040	12	–	–	977	12
**16Y	–	–	–	1 040	36	–	–	1 103	30
∇ 17X	108.00	–	–	1 041	12	–	–	978	12
17Y	108.05	5 043.0	540	1 041	36	36	42	1 104	30
17Z	–	5 043.3	541	1 041	–	21	27	1 104	15
18X	108.10	5 031.0	500	1 042	12	12	18	979	12
18W	–	5 031.3	501	1 042	–	24	30	979	24
18Y	108.15	5 043.6	542	1 042	36	36	42	1 105	30
18Z	–	5 043.9	543	1 042	–	21	27	1 105	15
19X	108.20	–	–	1 043	12	–	–	980	12
19Y	108.25	5 044.2	544	1 043	36	36	42	1 106	30
19Z	–	5 044.5	545	1 043	–	21	27	1 106	15
20X	108.30	5 031.6	502	1 044	12	12	18	981	12
20W	–	5 031.9	503	1 044	–	24	30	981	24

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N μs*	*Initial approach μs*	*Final approach μs*	*Frequency MHz*	*Pulse codes μs*
20Y	108.35	5 044.8	546	1 044	36	36	42	1 107	30
20Z	–	5 045.1	547	1 044	–	21	27	1 107	15
21X	108.40	–	–	1 045	12	–	–	982	12
21Y	108.45	5 045.4	548	1 045	36	36	42	1 108	30
21Z	–	5 045.7	549	1 045	–	21	27	1 108	15
22X	108.50	5 032.2	504	1 046	12	12	18	983	12
22W	–	5 032.5	505	1 046	–	24	30	983	24
22Y	108.55	5 046.0	550	1 046	36	36	42	1 109	30
22Z	–	5 046.3	551	1 046	–	21	27	1 109	15
23X	108.60	–	–	1 047	12	–	–	984	12
23Y	108.65	5 046.6	552	1 047	36	36	42	1 110	30
23Z	–	5 046.9	553	1 047	–	21	27	1 110	15
24X	108.70	5 032.8	506	1 048	12	12	18	985	12
24W	–	5 033.1	507	1 048	–	24	30	985	24
24Y	108.75	5 047.2	554	1 048	36	36	42	1 111	30
24Z	–	5 047.5	555	1 048	–	21	27	1 111	15
25X	108.80	–	–	1 049	12	–	–	986	12
25Y	108.85	5 047.8	556	1 049	36	36	42	1 112	30
25Z	–	5 048.1	557	1 049	–	21	27	1 112	15
26X	108.90	5 033.4	508	1 050	12	12	18	987	12
26W	–	5 033.7	509	1 050	–	24	30	987	24
26Y	108.95	5 048.4	558	1 050	36	36	42	1 113	30
26Z	–	5 048.7	559	1 050	–	21	27	1 113	15
27X	109.00	–	–	1 051	12	–	–	988	12
27Y	109.05	5 049.0	560	1 051	36	36	42	1 114	30
27Z	–	5 049.3	561	1 051	–	21	27	1 114	15
28X	109.10	5 034.0	510	1 052	12	12	18	989	12
28W	–	5 034.3	511	1 052	–	24	30	989	24
28Y	109.15	5 049.6	562	1 052	36	36	42	1 115	30
28Z	–	5 049.9	563	1 052	–	21	27	1 115	15
29X	109.20	–	–	1 053	12	–	–	990	12
29Y	109.25	5 050.2	564	1 053	36	36	42	1 116	30
29Z	–	5 050.5	565	1 053	–	21	27	1 116	15
30X	109.30	5 034.6	512	1 054	12	12	18	991	12

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N µs*	*Initial approach µs*	*Final approach µs*	*Frequency MHz*	*Pulse codes µs*
30W	–	5 034.9	513	1 054	–	24	30	991	24
30Y	109.35	5 050.8	566	1 054	36	36	42	1 117	30
30Z	–	5 051.1	567	1 054	–	21	27	1 117	15
31X	109.40	–	–	1 055	12	–	–	992	12
31Y	109.45	5 051.4	568	1 055	36	36	42	1 118	30
31Z	–	5 051.7	569	1 055	–	21	27	1 118	15
32X	109.50	5 035.2	514	1 056	12	12	18	993	12
32W	–	5 035.5	515	1 056	–	24	30	993	24
32Y	109.55	5 052.0	570	1 056	36	36	42	1 119	30
32Z	–	5 052.3	571	1 056	–	21	27	1 119	15
33X	109.60	–	–	1 057	12	–	–	994	12
33Y	109.65	5 052.6	572	1 057	36	36	42	1 120	30
33Z	–	5 052.9	573	1 057	–	21	27	1 120	15
34X	109.70	5 035.8	516	1 058	12	12	18	995	12
34W	–	5 036.1	517	1 058	–	24	30	995	24
34Y	109.75	5 053.2	574	1 058	36	36	42	1 121	30
34Z	–	5 053.5	575	1 058	–	21	27	1 121	15
35X	109.80	–	–	1 059	12	–	–	996	12
35Y	109.85	5 053.8	576	1 059	36	36	42	1 122	30
35Z	–	5 054.1	577	1 059	–	21	27	1 122	15
36X	109.90	5 036.4	518	1 060	12	12	18	997	12
36W	–	5 036.7	519	1 060	–	24	30	997	24
36Y	109.95	5 054.4	578	1 060	36	36	42	1 123	30
36Z	–	5 054.7	579	1 060	–	21	27	1 123	15
37X	110.00	–	–	1 061	12	–	–	998	12
37Y	110.05	5 055.0	580	1 061	36	36	42	1 124	30
37Z	–	5 055.3	581	1 061	–	21	27	1 124	15
38X	110.10	5 037.0	520	1 062	12	12	18	999	12
38W	–	5 037.3	521	1 062	–	24	30	999	24
38Y	110.15	5 055.6	582	1 062	36	36	42	1 125	30
38Z	–	5 055.9	583	1 062	–	21	27	1 125	15
39X	110.20	–	–	1 063	12	–	–	1 000	12
39Y	110.25	5 056.2	584	1 063	36	36	42	1 126	30
39Z	–	5 056.5	585	1 063	–	21	27	1 126	15

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N μs*	*Initial approach μs*	*Final approach μs*	*Frequency MHz*	*Pulse codes μs*
40X	110.30	5 037.6	522	1 064	12	12	18	1 001	12
40W	–	5 037.9	523	1 064	–	24	30	1 001	24
40Y	110.35	5 056.8	586	1 064	36	36	42	1 127	30
40Z	–	5 057.1	587	1 064	–	21	27	1 127	15
41X	110.40	–	–	1 065	12	–	–	1 002	12
41Y	110.45	5 057.4	588	1 065	36	36	42	1 128	30
41Z	–	5 057.7	589	1 065	–	21	27	1 128	15
42X	110.50	5 038.2	524	1 066	12	12	18	1 003	12
42W	–	5 038.5	525	1 066	–	24	30	1 003	24
42Y	110.55	5 058.0	590	1 066	36	36	42	1 129	30
42Z	–	5 058.3	591	1 066	–	21	27	1 129	15
43X	110.60	–	–	1 067	12	–	–	1 004	12
43Y	110.65	5 058.6	592	1 067	36	36	42	1 130	30
43Z	–	5 058.9	593	1 067	–	21	27	1 130	15
44X	110.70	5 038.8	526	1 068	12	12	18	1 005	12
44W	–	5 039.1	527	1 068	–	24	30	1 005	24
44Y	110.75	5 059.2	594	1 068	36	36	42	1 131	30
44Z	–	5 059.5	595	1 068	–	21	27	1 131	15
45X	110.80	–	–	1 069	12	–	–	1 006	12
45Y	110.85	5 059.8	596	1 069	36	36	42	1 132	30
45Z	–	5 060.1	597	1 069	–	21	27	1 132	15
46X	110.90	5 039.4	528	1 070	12	12	18	1 007	12
46W	–	5 039.7	529	1 070	–	24	30	1 007	24
46Y	110.95	5 060.4	598	1 070	36	36	42	1 133	30
46Z	–	5 060.7	599	1 070	–	21	27	1 133	15
47X	111.00	–	–	1 071	12	–	–	1 008	12
47Y	111.05	5 061.0	600	1 071	36	36	42	1 134	30
47Z	–	5 061.3	601	1 071	–	21	27	1 134	15
48X	111.10	5 040.0	530	1 072	12	12	18	1 009	12
48W	–	5 040.3	531	1 072	–	24	30	1 009	24
48Y	111.15	5 061.6	602	1 072	36	36	42	1 135	30
48Z	–	5 061.9	603	1 072	–	21	27	1 135	15
49X	111.20	–	–	1 073	12	–	–	1 010	12
49Y	111.25	5 062.2	604	1 073	36	36	42	1 136	30
49Z	–	5 062.5	605	1 073	–	21	27	1 136	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
50X	111.30	5 040.6	532	1 074	12	12	18	1 011	12
50W	–	5 040.9	533	1 074	–	24	30	1 011	24
50Y	111.35	5 062.8	606	1 074	36	36	42	1 137	30
50Z	–	5 063.1	607	1 074	–	21	27	1 137	15
51X	111.40	–	–	1 075	12	–	–	1 012	12
51Y	111.45	5 063.4	608	1 075	36	36	42	1 138	30
51Z	–	5 063.7	609	1 075	–	21	27	1 138	15
52X	111.50	5 041.2	534	1 076	12	12	18	1 013	12
52W	–	5 041.5	535	1 076	–	24	30	1 013	24
52Y	111.55	5 064.0	610	1 076	36	36	42	1 139	30
52Z	–	5 064.3	611	1 076	–	21	27	1 139	15
53X	111.60	–	–	1 077	12	–	–	1 014	12
53Y	111.65	5 064.6	612	1 077	36	36	42	1 140	30
53Z	–	5 064.9	613	1 077	–	21	27	1 140	15
54X	111.70	5 041.8	536	1 078	12	12	18	1 015	12
54W	–	5 042.1	537	1 078	–	24	30	1 015	24
54Y	111.75	5 065.2	614	1 078	36	36	42	1 141	30
54Z	–	5 065.5	615	1 078	–	21	27	1 141	15
55X	111.80	–	–	1 079	12	–	–	1 016	12
55Y	111.85	5 065.8	616	1 079	36	36	42	1 142	30
55Z	–	5 066.1	617	1 079	–	21	27	1 142	15
56X	111.90	5 042.4	538	1 080	12	12	18	1 017	12
56W	–	5 042.7	539	1 080	–	24	30	1 017	24
56Y	111.95	5 066.4	618	1 080	36	36	42	1 143	30
56Z	–	5 066.7	619	1 080	–	21	27	1 143	15
57X	112.00	–	–	1 081	12	–	–	1 018	12
57Y	112.05	–	–	1 081	36	–	–	1 144	30
58X	112.10	–	–	1 082	12	–	–	1 019	12
58Y	112.15	–	–	1 082	36	–	–	1 145	30
59X	112.20	–	–	1 083	12	–	–	1 020	12
59Y	112.25	–	–	1 083	36	–	–	1 146	30
**60X	–	–	–	1 084	12	–	–	1 021	12
**60Y	–	–	–	1 084	36	–	–	1 147	30
**61X	–	–	–	1 085	12	–	–	1 022	12
**61Y	–	–	–	1 085	36	–	–	1 148	30

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N μs*	*Initial approach μs*	*Final approach μs*	*Frequency MHz*	*Pulse codes μs*
**62X	–	–	–	1 086	12	–	–	1 023	12
**62Y	–	–	–	1 086	36	–	–	1 149	30
**63X	–	–	–	1 087	12	–	–	1 024	12
**63Y	–	–	–	1 087	36	–	–	1 150	30
**64X	–	–	–	1 088	12	–	–	1 151	12
**64Y	–	–	–	1 088	36	–	–	1 025	30
**65X	–	–	–	1 089	12	–	–	1 152	12
**65Y	–	–	–	1 089	36	–	–	1 026	30
**66X	–	–	–	1 090	12	–	–	1 153	12
**66Y	–	–	–	1 090	36	–	–	1 027	30
**67X	–	–	–	1 091	12	–	–	1 154	12
**67Y	–	–	–	1 091	36	–	–	1 028	30
**68X	–	–	–	1 092	12	–	–	1 155	12
**68Y	–	–	–	1 092	36	–	–	1 029	30
**69X	–	–	–	1 093	12	–	–	1 156	12
**69Y	–	–	–	1 093	36	–	–	1 030	30
70X	112.30	–	–	1 094	12	–	–	1 157	12
**70Y	112.35	–	–	1 094	36	–	–	1 031	30
71X	112.40	–	–	1 095	12	–	–	1 158	12
**71Y	112.45	–	–	1 095	36	–	–	1 032	30
72X	112.50	–	–	1 096	12	–	–	1 159	12
**72Y	112.55	–	–	1 096	36	–	–	1 033	30
70X	112.30	–	–	1 094	12	–	–	1 157	12
**70Y	112.35	–	–	1 094	36	–	–	1 031	30
71X	112.40	–	–	1 095	12	–	–	1 158	12
**71Y	112.45	–	–	1 095	36	–	–	1 032	30
72X	112.50	–	–	1 096	12	–	–	1 159	12
**72Y	112.55	–	–	1 096	36	–	–	1 033	30
73X	112.60	–	–	1 097	12	–	–	1 160	12
**73Y	112.65	–	–	1 097	36	–	–	1 034	30
74X	112.70	–	–	1 098	12	–	–	1 161	12

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N μs	Initial approach μs	Final approach μs	Frequency MHz	Pulse codes μs
**74Y	112.75	–	–	1 098	36	–	–	1 035	30
75X	112.80	–	–	1 099	12	–	–	1 162	12
**75Y	112.85	–	–	1 099	36	–	–	1 036	30
76X	112.90	–	–	1 100	12	–	–	1 163	12
**76Y	112.95	–	–	1 100	36	–	–	1 037	30
77X	113.00	–	–	1 101	12	–	–	1 164	12
**77Y	113.05	–	–	1 101	36	–	–	1 038	30
78X	113.10	–	–	1 102	12	–	–	1 165	12
**78Y	113.15	–	–	1 102	36	–	–	1 039	30
79X	113.20	–	–	1 103	12	–	–	1 166	12
**79Y	113.25	–	–	1 103	36	–	–	1 040	30
80X	113.30	–	–	1 104	12	–	–	1 167	12
80Y	113.35	5 067.0	620	1 104	36	36	42	1 041	30
80Z	–	5 067.3	621	1 104	–	21	27	1 041	15
81X	113.40	–	–	1 105	12	–	–	1 168	12
81Y	113.45	5 067.6	622	1 105	36	36	42	1 042	30
81Z	–	5 067.9	623	1 105	–	21	27	1 042	15
82X	113.50	–	–	1 106	12	–	–	1 169	12
82Y	113.55	5 068.2	624	1 106	36	36	42	1 043	30
82Z	–	5 068.5	625	1 106	–	21	27	1 043	15
83X	113.60	–	–	1 107	12	–	–	1 170	12
83Y	113.65	5 068.8	626	1 107	36	36	42	1 044	30
83Z	–	5 069.1	627	1 107	–	21	27	1 044	15
84X	113.70	–	–	1 108	12	–	–	1 171	12
84Y	113.75	5 069.4	628	1 108	36	36	42	1 045	30
84Z	–	5 069.7	629	1 108	–	21	27	1 045	15
85X	113.80	–	–	1 109	12	–	–	1 172	12
85Y	113.85	5 070.0	630	1 109	36	36	42	1 046	30
85Z	–	5 070.3	631	1 109	–	21	27	1 046	15
86X	113.90	–	–	1 110	12	–	–	1 173	12
86Y	113.95	5 070.6	632	1 110	36	36	42	1 047	30
86Z	–	5 070.9	633	1 110	–	21	27	1 047	15
87X	114.00	–	–	1 111	12	–	–	1 174	12

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N µs*	*Initial approach µs*	*Final approach µs*	*Frequency MHz*	*Pulse codes µs*
87Y	114.05	5 071.2	634	1 111	36	36	42	1 048	30
87Z	–	5 071.5	635	1 111	–	21	27	1 048	15
88X	114.10	–	–	1 112	12	–	–	1 175	12
88Y	114.15	5 071.8	636	1 112	36	36	42	1 049	30
88Z	–	5 072.1	637	1 112	–	21	27	1 049	15
89X	114.20	–	–	1 113	12	–	–	1 176	12
89Y	114.25	5 072.4	638	1 113	36	36	42	1 050	30
89Z	–	5 072.7	639	1 113	–	21	27	1 050	15
90X	114.30	–	–	1 114	12	–	–	1 177	12
90Y	114.35	5 073.0	640	1 114	36	36	42	1 051	30
90Z	–	5 073.3	641	1 114	–	21	27	1 051	15
91X	114.40	–	–	1 115	12	–	–	1 178	12
91Y	114.45	5 073.6	642	1 115	36	36	42	1 052	30
91Z	–	5 073.9	643	1 115	–	21	27	1 052	15
92X	114.50	–	–	1 116	12	–	–	1 179	12
92Y	114.55	5 074.2	644	1 116	36	36	42	1 053	30
92Z	–	5 074.5	645	1 116	–	21	27	1 053	15
93X	114.60	–	–	1 117	12	–	–	1 180	12
93Y	114.65	5 074.8	646	1 117	36	36	42	1 054	30
93Z	–	5 075.1	647	1 117	–	21	27	1 054	15
94X	114.70	–	–	1 118	12	–	–	1 181	12
94Y	114.75	5 075.4	648	1 118	36	36	42	1 055	30
94Z	–	5 075.7	649	1 118	–	21	27	1 055	15
95X	114.80	–	–	1 119	12	–	–	1 182	12
95Y	114.85	5 076.0	650	1 119	36	36	42	1 056	30
95Z	–	5 076.3	651	1 119	–	21	27	1 056	15
96X	114.90	–	–	1 120	12	–	–	1 183	12
96Y	114.95	5 076.6	652	1 120	36	36	42	1 057	30
96Z	–	5 076.9	653	1 120	–	21	27	1 057	15
97X	115.00	–	–	1 121	12	–	–	1 184	12
97Y	115.05	5 077.2	654	1 121	36	36	42	1 058	30
97Z	–	5 077.5	655	1 121	–	21	27	1 058	15
98X	115.10	–	–	1 122	12	–	–	1 185	12
98Y	115.15	5 077.8	656	1 122	36	36	42	1 059	30

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N µs*	*Initial approach µs*	*Final approach µs*	*Frequency MHz*	*Pulse codes µs*
98Z	–	5 078.1	657	1 122	–	21	27	1 059	15
99X	115.20	–	–	1 123	12	–	–	1 186	12
99Y	115.25	5 078.4	658	1 123	36	36	42	1 060	30
99Z	–	5 078.7	659	1 123	–	21	27	1 060	15
100X	115.30	–	–	1 124	12	–	–	1 187	12
100Y	115.35	5 079.0	660	1 124	36	36	42	1 061	30
100Z	–	5 079.3	661	1 124	–	21	27	1 061	15
101X	115.40	–	–	1 125	12	–	–	1 188	12
101Y	115.45	5 079.6	662	1 125	36	36	42	1 062	30
101Z	–	5 079.9	663	1 125	–	21	27	1 062	15
102X	115.50	–	–	1 126	12	–	–	1 189	12
102Y	115.55	5 080.2	664	1 126	36	36	42	1 063	30
102Z	–	5 080.5	665	1 126	–	21	27	1 063	15
103X	115.60	–	–	1 127	12	–	–	1 190	12
103Y	115.65	5 080.8	666	1 127	36	36	42	1 064	30
103Z	–	5 081.1	667	1 127	–	21	27	1 064	15
104X	115.70	–	–	1 128	12	–	–	1 191	12
104Y	115.75	5 081.4	668	1 128	36	36	42	1 065	30
104Z	–	5 081.7	669	1 128	–	21	27	1 065	15
105X	115.80	–	–	1 129	12	–	–	1 192	12
105Y	115.85	5 082.0	670	1 129	36	36	42	1 066	30
105Z	–	5 082.3	671	1 129	–	21	27	1 066	15
106X	115.90	–	–	1 130	12	–	–	1 193	12
106Y	115.95	5 082.6	672	1 130	36	36	42	1 067	30
106Z	–	5 082.9	673	1 130	–	21	27	1 067	15
107X	116.00	–	–	1 131	12	–	–	1 194	12
107Y	116.05	5 083.2	674	1 131	36	36	42	1 068	30
107Z	–	5 083.5	675	1 131	–	21	27	1 068	15
108X	116.10	–	–	1 132	12	–	–	1 195	12
108Y	116.15	5 083.8	676	1 132	36	36	42	1 069	30
108Z	–	5 084.1	677	1 132	–	21	27	1 069	15
109X	116.20	–	–	1 133	12	–	–	1 196	12
109Y	116.25	5 084.4	678	1 133	36	36	42	1 070	30
109Z	–	5 084.7	679	1 133	–	21	27	1 070	15

Channel pairing				DME parameters					
				Interrogation				Reply	
					Pulse codes				
						DME/P mode			
DME channel number	VHF frequency MHz	MLS angle frequency MHz	MLS channel number	Frequency MHz	DME/N µs	Initial approach µs	Final approach µs	Frequency MHz	Pulse codes µs
110X	116.30	–	–	1 134	12	–	–	1 197	12
110Y	116.35	5 085.0	680	1 134	36	36	42	1 071	30
110Z	–	5 085.3	681	1 134	–	21	27	1 071	15
111X	116.40	–	–	1 135	12	–	–	1 198	12
111Y	116.45	5 085.6	682	1 135	36	36	42	1 072	30
111Z	–	5 085.9	683	1 135	–	21	27	1 072	15
112X	116.50	–	–	1 136	12	–	–	1 199	12
112Y	116.55	5 086.2	684	1 136	36	36	42	1 073	30
112Z	–	5 086.5	685	1 136	–	21	27	1 073	15
113X	116.60	–	–	1 137	12	–	–	1 200	12
113Y	116.65	5 086.8	686	1 137	36	36	42	1 074	30
113Z	–	5 087.1	687	1 137	–	21	27	1 074	15
114X	116.70	–	–	1 138	12	–	–	1 201	12
114Y	116.75	5 087.4	688	1 138	36	36	42	1 075	30
114Z	–	5 087.7	689	1 138	–	21	27	1 075	15
115X	116.80	–	–	1 139	12	–	–	1 202	12
115Y	116.85	5 088.0	690	1 139	36	36	42	1 076	30
115Z	–	5 088.3	691	1 139	–	21	27	1 076	15
116X	116.90	–	–	1 140	12	–	–	1 203	12
116Y	116.95	5 088.6	692	1 140	36	36	42	1 077	30
116Z	–	5 088.9	693	1 140	–	21	27	1 077	15
117X	117.00	–	–	1 141	12	–	–	1 204	12
117Y	117.05	5 089.2	694	1 141	36	36	42	1 078	30
117Z	–	5 089.5	695	1 141	–	21	27	1 078	15
118X	117.10	–	–	1 142	12	–	–	1 205	12
118Y	117.15	5 089.8	696	1 142	36	36	42	1 079	30
118Z	–	5 090.1	697	1 142	–	21	27	1 079	15
119X	117.20	–	–	1 143	12	–	–	1 206	12
119Y	117.25	5 090.4	698	1 143	36	36	42	1 080	30
119Z	–	5 090.7	699	1 143	–	21	27	1 080	15
120X	117.30	–	–	1 144	12	–	–	1 207	12
120Y	117.35	–	–	1 144	36	–	–	1 081	30
121X	117.40	–	–	1 145	12	–	–	1 208	12
121Y	117.45	–	–	1 145	36	–	–	1 082	30

Channel pairing				*DME parameters*					
				Interrogation				*Reply*	
					Pulse codes				
						DME/P mode			
DME channel number	*VHF frequency MHz*	*MLS angle frequency MHz*	*MLS channel number*	*Frequency MHz*	*DME/N µs*	*Initial approach µs*	*Final approach µs*	*Frequency MHz*	*Pulse codes µs*
122X	117.50	–	–	1 146	12	–	–	1 209	12
122Y	117.55	–	–	1 146	36	–	–	1 083	30
123X	117.60	–	–	1 147	12	–	–	1 210	12
123Y	117.65	–	–	1 147	36	–	–	1 084	30
124X	117.70	–	–	1 148	12	–	–	1 211	12
**124Y	117.75	–	–	1 148	36	–	–	1 085	30
125X	117.80	–	–	1 149	12	–	–	1 212	12
**125Y	117.85	–	–	1 149	36	–	–	1 086	30
126X	117.90	–	–	1 150	12	–	–	1 213	12
**126Y	117.95	–	–	1 150	36	–	–	1 087	30

* These channels are reserved exclusively for national allotments.

** These channels may be used for national allotment on a secondary basis. The primary reason for reserving these channels is to provide protection for the secondary surveillance radar (SSR) system.

∇ 108.0 MHz is not scheduled for assignment to ILS service. The associated DME operating channel No. 17X may be assigned for emergency use. The reply frequency of channel No. 17X (i.e. 978 MHz) is also utilized for the operation of the universal access transceiver (UAT). Standards and Recommended Practices for UAT are found in Annex 10, Volume III, Part I, Chapter 12.

5.14 GEOGRAPHICAL SEPARATION CRITERIA FOR DME, INCLUDING DME X, Y, W AND Z CHANNELS

Note.— This section includes protection criteria for DME W and Z channels, which are currently not used. The guidance in this section is provided for information purposes only.

5.14.1 To enable consideration of actual antenna designs, equipment characteristics and service volumes, the signal ratios that are needed to ensure interference-free operation of the various facilities operating on DME channels are provided below. Given these ratios, the geographical separations of facilities may be readily evaluated by accounting for power losses over the propagation paths.

5.14.2 D/U signal ratios at the airborne receiver

5.14.2.1 Table 5-3 indicates the necessary D/U signal ratios needed to protect the desired transponder reply signal at an airborne receiver from the various co-frequency/adjacent frequency, same code/different code, undesired transponder reply signal combinations that may exist. The prerequisite for any calculation using the provided ratios is that the required minimum power density of the desired DME is met throughout the operationally published coverage volume. For initial assignments, the D/U ratios necessary to protect airborne equipment with 6-microsecond decoder rejection should be used. In making an assignment, each facility must be treated as the desired source with the other acting as the undesired. If both satisfy their unique D/U requirement, then the channel assignment may be made.

5.14.2.2 Accordingly, DME channel assignments depend upon the following:

a) *For co-channel assignments:* This condition occurs when both the desired and undesired signals operate on a channel (W, X, Y or Z) that is co-frequency, same code. The D/U signal ratio should be at least 8 dB throughout the service volume.

b) *For co-frequency, different code assignments*: This condition occurs when one facility operates on an X channel with the other on a W channel. A similar Y channel and a Z channel combination also applies.

c) *For first adjacent frequency, same code assignments*: This condition occurs when both the desired and undesired facilities are of W, X, Y or Z type.

d) *For first adjacent frequency, different code assignments*: This condition occurs when one facility operates on an X channel with the other on a W channel, but with a frequency offset of 1 MHz between transponder reply frequencies. A similar Y channel and a Z channel combination also applies.

e) *For second adjacent frequency, same or different code assignments*: The second adjacent frequency combinations generally do not need to be frequency protected. However, special attention should be given to Note 4 of Table 5-3, especially if the undesired facility is a DME/P transponder.

Table 5-3. Protection ratio D/U (dB)

Type of assignment	*A*	*B*
Co-frequency:		
Same pulse code	8	8
Different pulse code	8	–42
First adjacent frequency:		
Same pulse code	$-(P_u - 1)$	–42
Different pulse code	$-(P_u + 7)$	–75
Second adjacent frequency:		
Same pulse code	$-(P_u + 19)$	–75
Different pulse code	$-(P_u + 27)$	–75

Note 1.— The D/U ratios in column A protect those DME/N interrogators operating on X or Y channels. Column A applies to decoder rejection of 6 microseconds.

Note 2.— The D/U ratios in column B protect those DME/N or DME/P interrogators utilizing discrimination in conformance with Annex 10, Volume I, Chapter 3 and providing a decoder rejection conforming to Annex 10, Volume I, Chapter 3.

Note 3.— P_u is the peak effective radiated power of the undesired signal in dBW.

Note 4.— The frequency protection requirement is dependent upon the antenna patterns of the desired and undesired facility and the EIRP of the undesired facility.

Note 5.— In assessing adjacent channel protection, the magnitude of D/U ratio in column A should not exceed the magnitude of the value in column B.

5.14.3 Special considerations for DME Y and Z channel assignments

The channel assignment plan for DME is such that the transponder reply frequency for each Y or Z channel is the same as the interrogation frequency of another DME channel. Where the reply frequency of one DME matches the interrogation frequency of a second DME, the two transponders should be separated by a distance greater than the radio horizon distance between them. The radio horizon distance is calculated taking into account the elevations of the two transponder antennas.

5.14.4 Special considerations for DME/P associated with ILS

5.14.4.1 For those runways where it is intended to install DME associated with ILS and where early MLS/RNAV operations are planned, installation of DME/P is preferred.

5.14.4.2 When it is intended to use the DME/P ranging information throughout the terminal area, interrogation pulse pairs with the correct spacing and nominal frequency must trigger the transponder if the peak power density at the transponder antenna is at least –93 dBW/m^2. This sensitivity level is based on the values contained in Annex 10, Volume I, Chapter 3, and is applied to DME/P IA mode, where at this level DME/P IA mode is intended to comply with DME/N reply efficiency and at least DME/N accuracy.

Chapter 6

GROUND-BASED AUGMENTATION SYSTEM (GBAS)

6.1 INTRODUCTION

6.1.1 A GBAS is an element of the Global Navigation Satellite System (GNSS) and is defined in Annex 10, Volume I, Chapter 3. Guidance material for GBAS is provided in Annex 10, Volume I, Attachment D. A GBAS provides services for precision approach with vertical guidance to the aircraft.

6.1.2 A GBAS includes a ground (broadcast) transmitter (VHF data broadcast (VDB)) and an associated aircraft receiver. The GBAS ground transmitter can support all aircraft, within the coverage, with approach data, GNSS corrections and GNSS integrity information for GNSS satellites within view. GBAS systems also include multiple reference receivers. These receivers process GNSS satellite signals. The GBAS system generates the data messages to augment the GNSS signals. The data messages are transmitted by the VDB transmitter.

Note.— A GBAS VDB system can include multiple transmitters to provide adequate coverage.

6.1.3 A GBAS can provide:

a) approach service to provide guidance to the aircraft within the approach service volume; and

b) positioning service to provide horizontal position information to support area navigation (RNAV) operations.

6.1.4 A more detailed description of GBAS is contained in Annex 10, Volume I, Attachment D. Figure 6-1 illustrates the main components of GBAS operation.

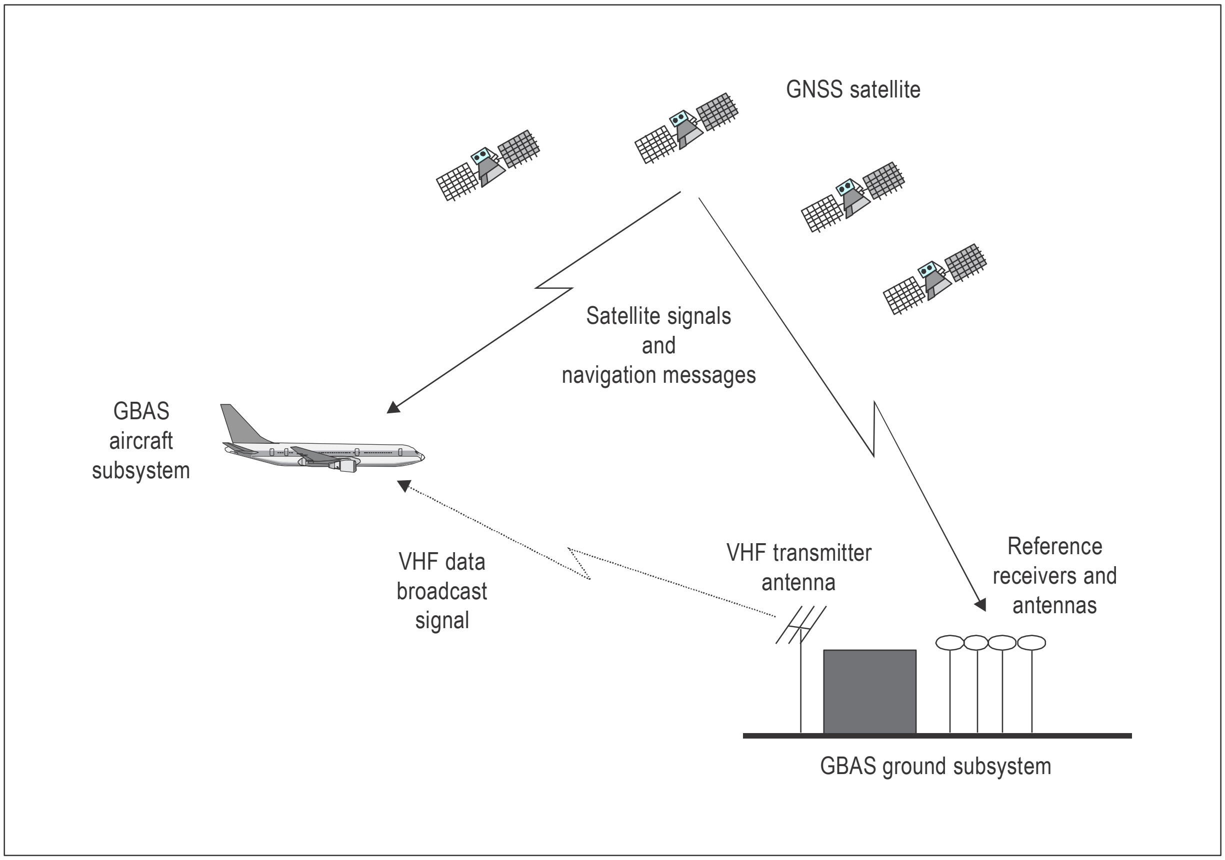

Figure 6-1. Main components of GBAS operation

6.2 DESIGNATED OPERATIONAL COVERAGE (DOC)

6.2.1 The minimum DOC required for a GBAS VDB to provide approach services is shown in Figure 6-2.

6.2.1.1 The vertical coverage extends up to 10 000 ft above the runway threshold.

6.2.1.2 States may, as required, specify an extended DOC based on operational requirements. It is recommended to use an omnidirectional coverage that extends to 23 NM from the runway threshold and up to a level of 10 000 ft above the runway threshold. States may specify different (larger) DOC areas.

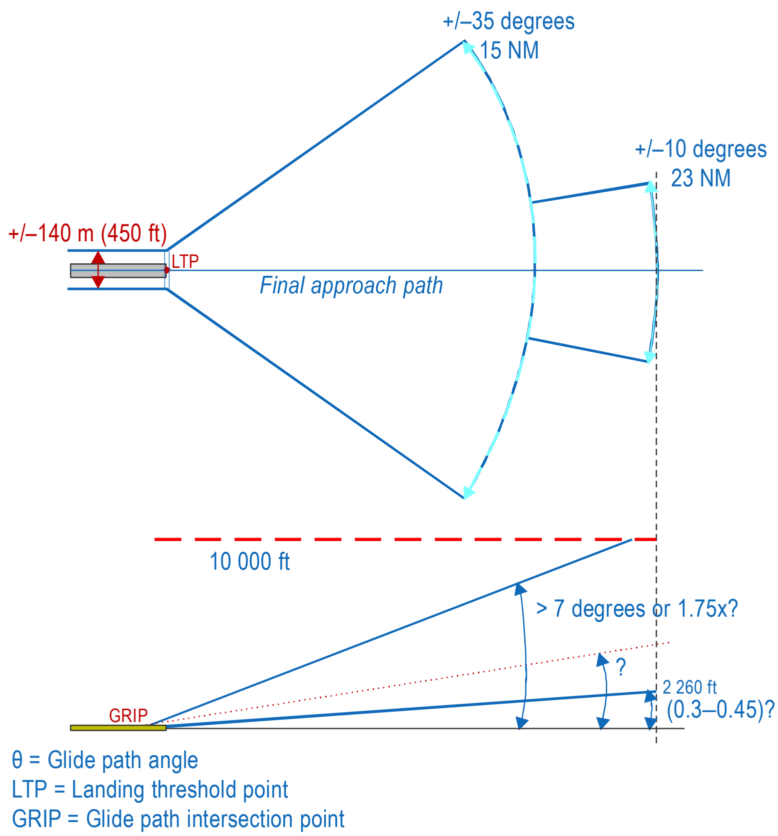

Figure 6-2. Minimum required DOC for a GBAS (Annex 10, Volume I, Chapter 3)

6.2.1.2.1 The vertical coverage is limited by a plane that extends from the glide path interception point with an angle of 0.3 times the glide path angle. For a glide path of 3 degrees, this angle is 0.9 degrees. At 20 NM, this plane is 2 260 ft above the earth. The upper limit of coverage is 10 000 ft that follows the earth curvature.

6.2.1.3 When GBAS supports multiple approaches, the use of a single omnidirectional VDB may be considered, if geographically feasible. In this case, frequency coordination should include all GBAS coverage areas.

Note.— The success rate for GBAS frequency assignments could be improved by using the minimum required DOC for each runway end.

6.2.2 The DOC for the GBAS VDB when providing the GBAS positioning service is the area as promulgated by States. More information on establishing the DOC is in Annex 10, Volume I, Attachment D.

6.2.3 Typically, the DOC for GBAS VDB facilities is referenced to the location and the elevation of the threshold of the runway. However, in cases where such information is not available, the coverage may be referenced to the location of the VDB transmitter. In this case, considering the offset of the VDB transmitter from the runway threshold, for frequency assignment planning purposes, the DOC of the GBAS should be extended by 3 NM from the location of the VDB transmitter or the aerodrome reference point (ARP), in which case a circular coverage may need to be considered or assumed.

6.2.4 GBAS VDB positioning service EIRP

6.2.4.1 The EIRP for the GBAS VDB when providing the approach service is typically 17 dBW (50 W) to provide service down to about 2 000 ft at the lower edge of the DOC.

6.2.4.2 The EIRP values for the GBAS VDB when providing positioning service are provided in Table 6-1. The values are based Annex 10, Volume I, Attachment D, and have been slightly modified.

Table 6-1. Typical EIRP values for GBAS VDB positioning service

Range (NM)	*EIRP (dBW)*	*EIRP (W)*
50	14	25
100	20	100
150	23	200
200	26	400

6.2.4.3 The link budget used for establishing these EIRP values is provided in Annex 10, Volume I, Attachment D. Only the horizontally polarized signals are considered.

6.3 GBAS VDB RF FREQUENCIES AND CHARACTERISTICS

6.3.1 A GBAS operates in the frequency band 108–117.975 MHz. The lowest assignable frequency is 108.025 MHz, and the highest assignable frequency is 117.950 MHz. The channel spacing is 25 kHz.

6.3.2 For use in civil aviation, the GBAS signal is horizontally polarized. This significantly reduces the minimum separation distances between vertically polarized signals such as those used in VHF communications systems, VDL Mode 2 and VDL Mode 4. In this chapter, consideration is given to the use of horizontally polarized GBAS signals only.

6.3.2.1 In areas where only horizontal polarization is in operation, the consideration of cross-polar isolation between a purely horizontal polarized GBAS system and a vertical polarized system like VHF communications will result in significantly reduced separation requirements. The value for cross-polar isolation between horizontal and vertical polarization is assumed to be 10 dB (see Annex 10, Volume I, Attachment D).

6.3.3 For the purposes of frequency assignment planning, it is assumed that the field strength of the desired GBAS corresponds to the minimum field strength, as defined in Annex 10, Volume I, throughout the DOC. The minimum field strength is 215 μV/m (–99 dBW/m^2), which is equivalent to a power level at the aircraft antenna output of –102 dBW with an ideal isotropic antenna (for the horizontal component of the GBAS VDB signal). The maximum field strength (SISmax) is 0.879 V/m (–27 dBW/m^2 or –29 dBW).

The minimum field strength is based on the following (see Annex 10, Volume I, Chapter 3 and Attachment D):

Required receiver sensitivity	–117 dBW
Maximum aircraft implementation loss	+15 dB
Power from isotropic aircraft antenna	–102 dBW

Note.— Actual aircraft implementation loss (including antenna gain, mismatch loss and cable loss) and actual receiver sensitivity may be balanced to achieve the expected link budget. For example, if the actual aircraft implementation loss for the horizontal component is 19 dB, the receiver sensitivity must exceed the minimum requirement and achieve –121 dBW to satisfy the nominal link budget.

6.4 FM IMMUNITY

6.4.1 Once a candidate frequency is identified for which the GBAS and VOR separation criteria are satisfied, compatibility with FM transmissions must be determined. This is to be accomplished using the methodology applied when determining FM compatibility with VOR. If FM broadcast violates this criterion, an alternative candidate frequency has to be considered.

6.4.2 The desensitization is not applied for FM carriers above 107.7 MHz and VDB channels at 108.050 MHz because the off-channel component of such high-level emissions from FM stations above 107.7 MHz will interfere with GBAS VDB operations on 108.025 and 108.050 MHz, hence those assignments will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate interference in the VDB receiver.

6.4.3 The FM intermodulation immunity requirements are not applied to a VDB channel operating below 108.1 MHz, hence, assignments below 108.1 MHz will be precluded except for special assignments in geographic areas where the number of FM broadcast stations in operation is small and would unlikely generate intermodulation products in the VDB receiver.

6.5 GBAS DATA SELECTOR AND TIME SLOT PLANNING CRITERIA

6.5.1 GBAS slot assignments and GBAS five-digit channel numbers require coordination when the same GBAS frequency is used at different airports within the respective DOC areas.

6.5.2 Reference path data selector (RPDS) and reference station data selector (RSDS) assignments are to be controlled to avoid duplicate use of channel numbers within the protection region for the data broadcast frequency. Therefore, the GBAS service provider has to ensure that an RPDS and RSDS are assigned only once on a given frequency within radio range of a particular GBAS ground subsystem. Assignments of RPDS and RSDS are to be managed along with assignments of frequency and time slots for the VHF data broadcast.

6.5.3 Time slot coordination among GBAS VDB systems operating on the same frequency will not be used initially; that is, all eight time slots (A–H) are assigned to a station together with the VDB frequency. If time slot coordination were to be used, up to eight times reuse of the frequency would be possible.

6.5.4 RPDSs and RSDSs must not be duplicated within the protection region of a given frequency. As long as time slot coordination is not used to share frequencies, as indicated above, RPDS and RSDS (zero to 48) compatibility is automatically established via frequency coordination; that is, all 49 data selectors are available together with the assigned VDB frequency.

Note.— More information on the use and coordination of RPDSs and RSDSs is in Annex 10, Volume I, Appendix B.

6.5.5 *GBAS reference path identifier*

6.5.5.1 Between GBAS installations within radio range of a particular GBAS ground subsystem, the reference path identifier is assigned to be unique. The requirement is found in Annex 10, Volume I, Appendix B.

6.5.6 *GBAS identifier*

6.5.6.1 The GBAS identifier (ID) is the four-character GBAS identification to differentiate between GBAS ground subsystems. The GBAS ID is normally identical to the location indicator at the nearest aerodrome. The requirement is found in Annex 10, Volume I, Appendix B.

6.5.7 *Slot assignments*

6.5.7.1 The relative assignment of slots to a GBAS ground subsystem can impact performance in instances where messages in multiple slots need to be received by the airborne subsystem prior to processing. This will occur when using linked messages and/or for a GAST D ground subsystem where correction data are contained in both the Type 1 and Type 11 messages. In these cases, slot assignments for all MT 1 and 11 should be adjacent to avoid unnecessary latency and complexity of design. Non-adjacent assignments may, depending on the design of the ground subsystem, result in a lack of time for the ground subsystem to process fault detections, render some slot combinations unusable and thus result in lower efficiency of spectrum use.

6.6 PROTECTION REQUIREMENTS

Note.— The guidance in this section is based on Annex 10, Volume I, Appendix B.

6.6.1 Protection requirements for GBAS VDB receivers

6.6.1.1 GBAS VDB receivers must be capable of achieving a message failure rate of not more than one failed message per 1 000 data messages. The D/U ratios in Table 6-2 are necessary to meet this requirement.

Table 6-2. Co- and adjacent channel protection requirements for GBAS VDB receivers

Frequency offset	*VDB/VDB*	*VDB/VOR*	*VDB/ILS*	*VDB/ VHF communications*
Co-frequency	26 dB	26 dB	26 dB	n/a
+/–25 kHz	–18 dB	0 dB	0 dB	n/a
+/–50 kHz	–43 dB	–34 dB	–34 dB	–32 dB
+/–58.33 kHz	n/a	n/a	n/a	–37 dB

Frequency offset	*VDB/VDB*	*VDB/VOR*	*VDB/ILS*	*VDB/ VHF communications*
+/–66.66 kHz	n/a	n/a	n/a	–41 dB
+/–75 kHz – +/–975 kHz	–46 dB	–46 dB	–46 dB	–44 dB
+/–83.33 kHz	n/a	n/a	n/a	–47 dB
+/–91.66 kHz	n/a	n/a	n/a	–49 dB
+/–100 kHz	–46 dB	–46 dB	–46 dB	
≥ 1000 kHz	–46 dB	–60 dB	–60 dB	

6.6.2 Airborne contribution factor

6.6.2.1 With the view to protect the desired VDB signals in space, an airborne contribution factor has been added. This airborne contribution factor compensates for antenna gain variations in the horizontal plane (between the direction of the desired versus the undesired transmitter) and on-board transmission line loss variation (between the frequency of the desired and undesired signal). The airborne contribution factor can be calculated with 15 + Min (6, 6 x frequency offset (in kHz) /1 000) with a maximum frequency offset of 1 000 kHz.

6.6.2.2 Table 6-3 contains the protection ratios that must be observed in frequency assignment planning to protect a desired GBAS VDB from interference that can be caused by an undesired GBAS VDB, VOR, ILS or VHF communications facility. The protection requirements for GBAS VDB receivers are presented in Figure 6-3.

Table 6-3. Co- and adjacent channel protection requirements for GBAS VDB, signal-in-space

Frequency offset	*VDB/VDB*	*VDB/VOR*	*VDB/ILS*	*VDB/VHF communications*
Co-frequency	41 dB	41 dB	41 dB	n/a
25 kHz	–3 dB	15 dB	15 dB	n/a
50 kHz	–27 dB	–18 dB	–18 dB	
+/–58.33 kHz	n/a	n/a	n/a	
+/–66.66 kHz	n/a	n/a	n/a	
75 kHz	–30 dB	–30 dB	–30 dB	
+/–83.33 kHz	n/a	n/a	n/a	
+/–91.66 kHz	n/a	n/a	n/a	
+/–100 kHz				
975 kHz	–25 dB	–25 dB	–25 dB	
≥ 1 000 kHz	–25 dB	–39 dB	–39 dB	

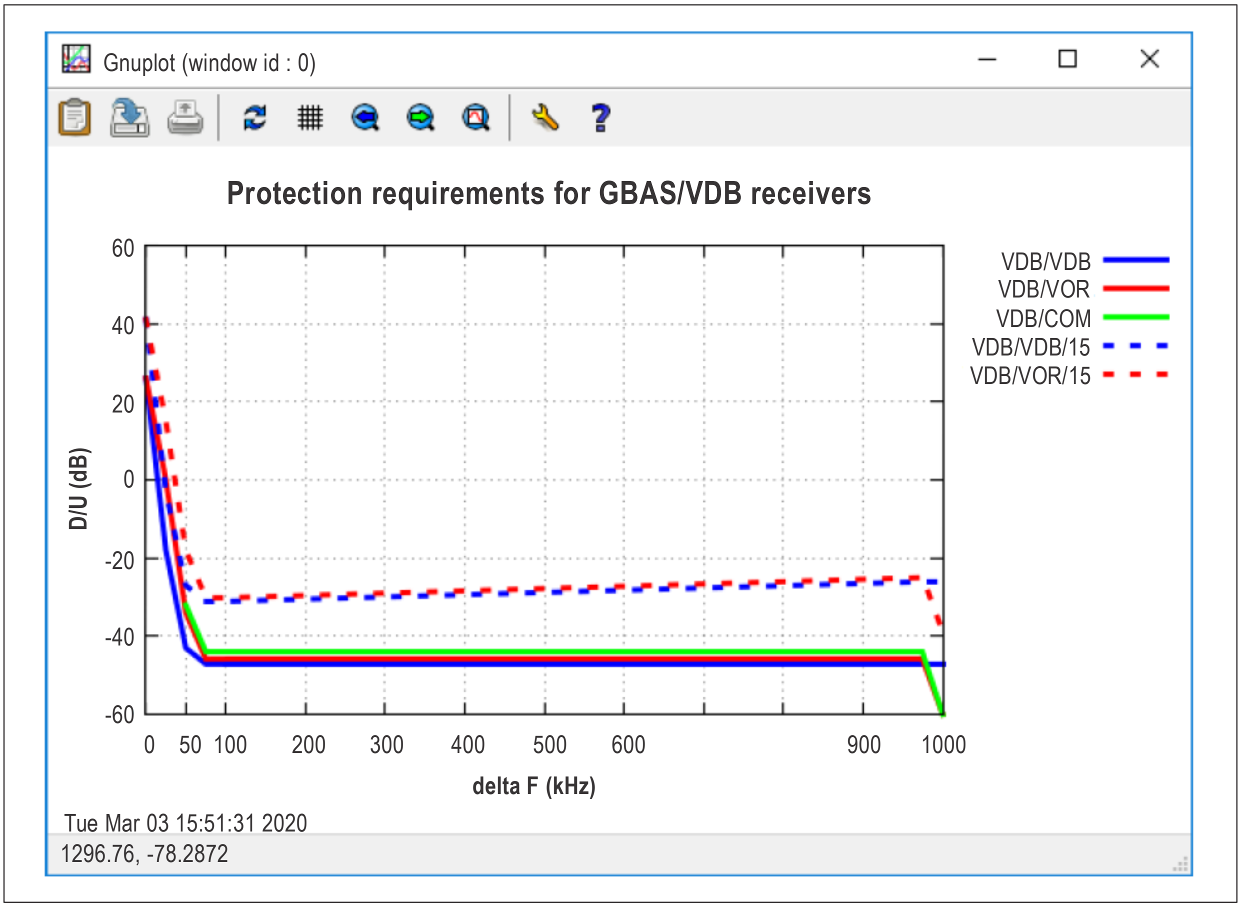

Figure 6-3. Protection requirements for GBAS VDB systems (see Tables 6-2 and 6-3)

6.6.2.2.1 The blue curves in Figure 6-3 indicate the D/U ratios between desired and undesired VDB signals. The solid line is for the D/U ratios at the receiver input, and the dotted line is for the D/U ratios at the aircraft antenna (signal-in-space).

6.6.2.2.2 The red curves in Figure 6-3 indicate the D/U ratios between the desired VDB signal and the undesired VOR or ILS localizer signals. The solid line is for the D/U ratios at the receiver input, and the dotted line is for the D/U ratios at the aircraft antenna (signal-in-space).

6.6.2.2.3 The green curve in Figure 6-3 indicates the D/U ratios between the desired VDB signal and the undesired VHF communications signal. The solid line is for the D/U ratios at the receiver input.

6.6.2.3 Compatibility criteria to protect ILS localizer and VOR signals from potential interference from GBAS VDB signals are provided in Chapters 3 and 4, respectively.

6.6.3 Interference from VHF communications signals

6.6.3.1 *On-board compatibility*

6.6.3.1.1 No frequency assignment planning constraints have been identified to ensure the compatibility between the on-board transmission of VHF communications signals and the reception of GBAS VDB signals on the same aircraft.

6.6.3.2 Air-to-air interference can be expected, as indicated in Table 6-4.

Table 6-4. Minimum separation distances between aircraft

ΔF (kHz)	*D/U*	*10 dBW*[1]		*14 dBW*[1]		*17 dBW*[1]		*20 dBW*[1]	
		L (dB)	*D (NM)*	*L (dB)*	*D (NM)*	*L (dB)*	*D (NM)*	*L (dB)*	*D (NM)*
50	–34 dB	78	< 1	82	1.5	85	3	88	4.5
58.3	–37 dB	75	< 1	79	< 1	82	1	85	3
66.6	–40 dB	72	< 1	76	< 1	79	< 1	82	1.5
75	–39 dB	73	< 1	77	< 1	80	< 1	83	2
83.3	–42 dB	70	< 1	76	< 1	77	< 1	80	1
91.5	–42 dB	70	< 1	76	< 1	77	< 1	80	1
100	–42 dB	70	< 1	76	< 1	77	< 1	80	1
125	–46 dB	66	< 1	70	< 1	79	< 1	76	< 1

The minimum required transmission loss (*L*) is calculated using formula (16):

$$L = Tx - P_d + D/U$$

where:

Tx: the EIRP of the undesired aircraft transmitter;

P_d: the minimum GBAS VDB signal at the (desired) aircraft (–102 dBW); and

D/U: the D/U indicated in Table 6-4.

6.6.3.2.1 The minimum separation distances in Table 6-4 are calculated assuming that isotropic antennas are on-board the desired and undesired aircraft. Taking into account the effect of the actual antenna diagram of the VHF communications and GBAS VDB antenna as well as the transient effect of air-to-air interference, at a frequency separation greater than 100 kHz, no air-to-air interference is expected.

Note.— An aircraft EIRP of 20 dBW (100 W) is not normally used. For an aircraft EIRP of 17 dBW (50 W) or less, a minimum frequency separation between the aircraft VHF communications and GBAS VDB receiver of 50 kHz may be recommended.

1. EIRP of the (undesired) aircraft transmitter.

6.6.3.3 *Ground-to-air interference*

6.6.3.3.1 At short distances, as shown in Table 6-4, interference from a VHF ground facility can be expected when the EIRP of the ground station is between 14 dBW (25 W) and 20 dBW (100 W). Maintaining a minimum frequency separation of 100 kHz between the assigned GBAS VDB and VHF communications frequency would avoid such interference. One option is to ensure that, in the frequency assignment planning process, a guard band of 100 kHz is introduced to prevent frequencies between 117.900 and 117.975 MHz from being used for GBAS VDB.

Note.— Using a guard band of 100 kHz as described above is quite conservative. Taking into account the actual antenna diagram and the geography of short distances to the (interfering) VHF communications station, it may be sufficient to prevent only the frequency 117.950 MHz from being assigned to a GBAS VDB station.

6.7 PROPAGATION MODEL

The propagation model that can be used to assess compatibility between GBAS VDB stations and ILS or VOR stations is described in Chapter 1. Details on this propagation model can be found in ITU Recommendation ITU-R P.528-5.

6.8 GEOGRAPHICAL SEPARATION DISTANCES BETWEEN CO- AND ADJACENT FREQUENCY FACILITIES

6.8.1 For the calculation of the minimum geographical separation distance between a desired GBAS VDB facility and an undesired GBAS VDB (or localizer, VOR or VDL Mode 4) facility, the generic model described in Chapter 1, section 1.4, must be applied.

6.8.2 The generic model establishes the minimum separation distance between a desired and undesired facility on the basis of the minimum required GBAS VDB signal of the desired GBAS VDB facility. The undesired facility should be separated by a distance that, taking into account the EIRP of the undesired facility, protects the minimum desired VDB signal as per 6.3.3.

6.8.3 For the calculation of the minimum separation distance, the required transmission loss, taking into account the minimum required field (signal) strength at the aircraft antenna of the desired facility, the D/U ratios as per Table 6-2 and the EIRP of the undesired facility are used. The minimum separation distance between the desired and the undesired facility is established using the relevant ITU-R propagation curves as per Recommendation ITU-R P.528-5. The required transmission loss (*L*) between the location of the undesired transmitter and the edge of coverage of the desired facility is calculated using formula (16):

$$L = Tx - P_d + D/U$$

where:

L: the required transmission loss;

Tx: the EIRP of the undesired facility (as specified by States, typically 17 dBW);

P_d: the minimum required field strength as per Annex 10. For a VDB facility, this is –102 dBW; and

D/U: the D/U ratio (signal-in-space) as per Table 6-2.

6.9 CALCULATION OF MINIMUM SEPARATION DISTANCES

6.9.1 Calculation of the minimum separation distance between a desired VDB and an undesired VDB

6.9.1.1 *Desired VDB and undesired VDB (co-frequency)*

Figure 6-4 provides an interference scenario for co-frequency GBAS stations.

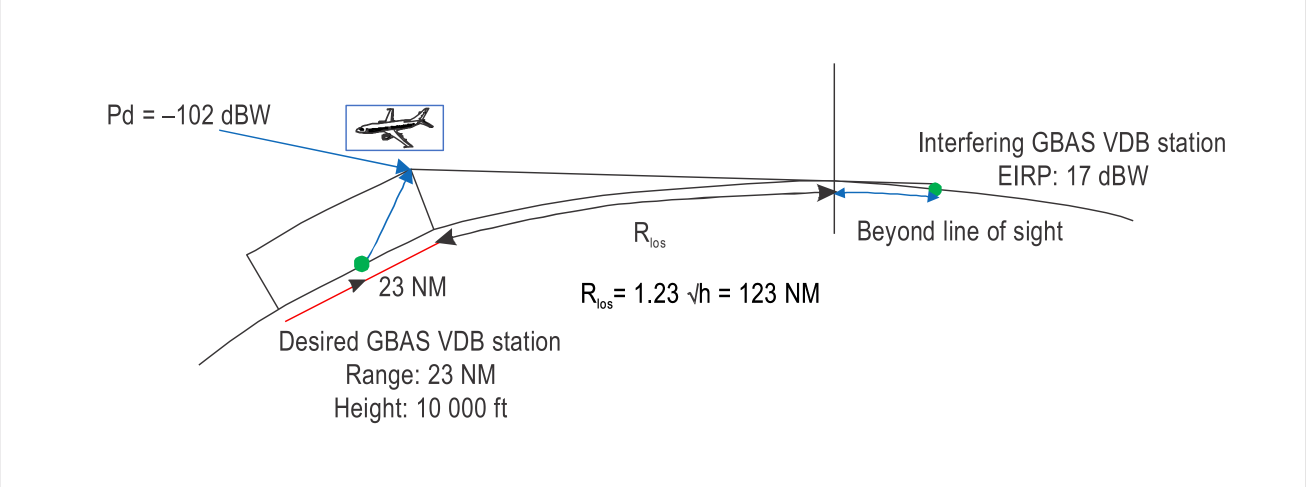

Figure 6-4. Interference scenario for co-frequency GBAS stations

The parameters used in this example are:

Tx: 17 dBW (paragraph 6.2.4);

P_d: –102 dBW (paragraph 6.3.3); and

D/U: 41 dB (signal-in-space, see paragraph 6.6.2 and Table 6-3).

The ITU-R aeronautical propagation curve for 112 MHz, antenna heights of 45 ft (h1) and 10 000 ft (h2), and 5 per cent of the time is used.

6.9.1.2 The required transmission loss (*L*) between the undesired GBAS VDB station and the edge of coverage of the desired GBAS VDB station is calculated using formula (16):

$$17 \text{ (dBW)} + 102 \text{ (dBW)} + 41 \text{ (dB)} = 160 \text{ dB}$$

6.9.1.3 With the ITU-R aeronautical propagation curve for 112 MHz and 5 per cent of the time, the height of the undesired VDB is 45 ft and the height of the desired aircraft receiver is 10 000 ft. The minimum required transmission loss of 160 dB is obtained with a separation distance of 213 NM. This is the minimum separation distance between an undesired VDB transmitter and an aircraft at the edge of coverage of the desired VDB facility. The station-to-station separation distance is calculated as follows:

213 + 23 = 236 NM

Note.— At this distance, propagation is by troposcatter.

6.9.1.4 Using the method described above, the separation distances between desired and undesired GBAS stations in Table 6-5 were calculated for desired GBAS facilities providing approach services.

6.9.1.4.1 These separation criteria do not allow for the use of a second VDB frequency within the DOC of the desired VDB, even for a frequency separation of greater than 1 MHz. For the use of a second VDB frequency, a more detailed analysis is necessary. Guidelines for such analysis are currently being developed.

Table 6-5. Minimum separation distances between desired and undesired GBAS stations

Frequency offset	*D/U (dB)*	*L (dB)*	*Distance from the DOC of the desired station to the undesired station*	*Distance between the GBAS stations*
∆f = 0 (co-frequency)	41	160	213 NM	236 NM
∆f = 25 kHz	–3	116	81 NM	104 NM
∆f = 50 kHz	–27	92	9 NM	32 NM
∆f = 75 kHz – 975 kHz	–30 to –25	89 to 94	6 to 11 NM	29 to 33 NM
∆f ≥ 1 000 kHz	–25	94	11 NM	33 NM

6.9.2 CALCULATION OF THE MINIMUM SEPARATION DISTANCE BETWEEN A DESIRED VDB AND AN UNDESIRED VOR OR LOCALIZER FACILITY (VOR OR LOCALIZER IS THE INTERFERER)

6.9.2.1 The calculation of the minimum separation distances between the edge of coverage (DOC) of a desired GBAS VDB facility and the location of an undesired VOR in Tables 6-6, 6-7 and 6-8 follows the same principles as described in 6.9.1.1.

The parameters used in this example are:

P_d: –102 dBW (paragraph 6.3.3);

D/U: as in Table 6-2; and

Tx: 17 dBW, 27 dBW and 30 dBW, respectively (EIRP of the undesired VOR or localizer).

The height of the antenna of the undesired VOR is 20 ft above local terrain, and the height of the antenna of the undesired localizer is 6 ft above local terrain.

Note.— For the purpose of specifying the curve to be used in a compatibility assessment, the local terrain is assumed at mean sea level. Information is provided in Chapter 1 to address differences in site elevation between desired and undesired facilities.

6.9.2.2 The frequency is 112 MHz, and the height of the desired VDB aircraft is 10 000 ft. The ITU-R aeronautical propagation curves (Recommendation ITU-R P.528-5) for 112 MHz and 5 per cent of the time are used.

6.9.2.3 The above calculation is applied in sections 6.9.2.4 to 6.9.2.6, which provide typical combinations of EIRP values for desired and undesired stations.

6.9.2.4 *Separation distances between a desired VDB and an undesired VOR*

The EIRP for the undesired VOR is 17 dBW.

Table 6-6. Minimum separation distances between the DOC of the desired GBAS station and the location of the undesired VOR or localizer

D/U (dB)		*L (dB), 5 per cent*	*VOR (17 dBW) Distance (NM)*	*Localizer (17 dBW) Distance (NM)*
41	(Δf = 0)	160	160	146
15	(Δf = 25)	134	118	36
–18	(Δf = 50)	101	21	14
–30	(Δf = 75)	89	6	6
–25	(Δf = 975)	94	11	8
–39	(Δf ≥ 1 000)	80	1	1

6.9.2.5 *Separation distances between a desired VDB and an undesired VOR or localizer*

The EIRP for the undesired VOR or localizer is 27 dBW.

Table 6-7. Minimum separation distances between the DOC of the desired GBAS station and the location of the undesired VOR or localizer

D/U (dB)		*L (dB), 5 per cent*	*VOR (17 dBW) Distance (NM)*	*Localizer (17 dBW) Distance (NM)*
41	(Δf = 0)	160	160	146
15	(Δf = 25)	134	118	36
–18	(Δf = 50)	101	21	14
–30	(Δf = 75)	89	6	6
–25	(Δf = 975)	94	11	8
–39	(Δf ≥ 1 000)	80	1	1

6.9.2.6 *Separation distances between a desired VDB and an undesired VOR or localizer*

The EIRP for the undesired VOR or localizer is 30 dBW. P_d is –102 dBW and the propagation is as per ITU propagation curves.

Table 6-8. Minimum separation distances between the DOC of the desired GBAS station and the location of the undesired VOR or localizer

D/U (dB)		*L (dB), 5 per cent*	*VOR (30 dBW) Distance (NM)*	*Localizer (30 dBW) Distance (NM)*
41	(Δf = 0)	173	260	209
15	(Δf = 25)	147	143	129
–18	(Δf = 50)	114	51	29
–30	(Δf = 75)	103	24	16
–25	(Δf = 975)	107	31	20
–39	(Δf ≥ 1 000)	93	10	7

Note.— The separation distances in Tables 6-6, 6-7 and 6-8 are measured from the location of the undesired VOR or localizer facility to the edge of the coverage of the desired GBAS VDB facility. The protection height of the GBAS VDB facility is 10 000 ft.

6.10 FREQUENCY ASSIGNMENT PLANNING METHODOLOGY FOR A GBAS VDB

For the planning and coordination of frequency assignments, the following methodology can used:

Note.— Alternative methods may be developed on the basis of a regional agreement.

Step 1: For frequency coordination for a GBAS facility, all frequencies assigned to ILS localizer, VOR or VDB facilities within the DOC of +10 NM of the (desired) GBAS VDB facility and within the range of +/–975 kHz of the assigned localizer, VOR or VDB frequency should be excluded for consideration as a candidate frequency for the (desired) GBAS VDB facility.

Step 2: For the undesired stations (ILS, VOR, VDB) that are outside the DOC of the desired GBAS VDB facility, the frequency assignment planning criteria in 6.9.1 (GBAS VDB) and 6.9.2 (localizer and VOR) apply. These are based on the protection requirements in paragraph 6.6.2.1 to protect the signal-in-space. The undesired stations can operate throughout the band 108–117.975 MHz.

Step 3: Check if the required D/U ratio is always met with respect to the relative separation distance between the GBAS VDB receiver and ILS localizer or VOR stations located in the vicinity. This may include a detailed analysis taking into account the exact characteristics of the localizer and VOR facilities, and ground and flight measurements of actual signal strength (of the desired and the undesired signal). It is the State’s responsibility to ensure that this step is performed prior to putting a GBS VDB facility into operation.

Appendix A

Conversion sheet and formulas

Field strength

Convert μV/m to dB(μV/m):

$$dB(\mu V/m) = 20\log(\mu V/m) \quad (1A)$$

Example: The field strength is 90 μV/m. Therefore, 20log 90 dB(μV/m) = 39 dB(μV/m).

Convert dB(μV/m) to μV/m:

$$\mu V/m = 10^{(dB(\mu V/m)/20)} \quad (1B)$$

Example: The field strength is 32 dB(μV/m). Therefore, $10^{(32/20)}$ = 39.8 μV/m.

Power flux density (PFD)

Convert dB(μV/m) to dB(W/m^2):

$$dB(W/m^2) = dB(\mu V/m) - 145.8 \quad (2A)$$

Example: The field strength is 39 dB(μV/m). Therefore, the power flux density is 39 – 145.8 = –106.8 dB(W/m^2).

Convert dB(W/m^2) to dB(μV/m):

$$dB(\mu V/m) = dB(W/m^2) + 145.8 \quad (2B)$$

Example: PFD = –107 dB(W/m^2). Therefore, the field strength is –107 + 145.8 = 38.8 dB(μV/m).

The PFD, assuming free space propagation, is calculated with:

$$PFD = \frac{P_T}{4\pi D^2} \quad (3A)$$

$$10 * \log PFD = 10\log P_T - 10\log 4\pi - 20\log D \ \ (\text{dBW/m}^2) \quad (3B)$$

$10\log P_T$ is the radiated power in dBW, *D* is the distance in metres.

Formula (3B) can be rewritten for *D* in kilometres and $10\log P_T = eirp$ of the transmitter (dBW):

$$PFD\ (dBW/m^2) = \text{eirp} - 10\log 4\pi - 20\log 1000D_{km}$$

or

$$PFD\ (dBW/m^2) = \text{eirp} - 71 - 20\log D_{km} \quad (3C)$$

Formula (3C) can be rewritten for *D* in nautical miles:

$$PFD\ (dBW/m^2) = \text{eirp} - 10\log 4\pi - 20\log 1.852D_{km}$$

or

$$PFD\ \Phi\ (dBW/m^2) = \text{eirp} - 76.3 - 20\log D_{NM} \tag{3D}$$

When the PFD (dBW/m^2) and the EIRP (dBW) are known, the distance *D* to achieve the PFD from the given EIRP can be calculated with:

$$D = 10^{\frac{eirp - PFD\Phi - 71}{20}}\ \text{km} \quad \text{or} \quad D = 10^{\frac{eirp - PFD\Phi - 76.31}{20}}\ \text{NM} \tag{3E}$$

Effective area $Ae(f)$ of a lossless isotropic antenna:

$$Ae(f) = 10\log_{10}\frac{\left(c/f\right)^2}{4\pi} \tag{3F}$$

where *f* is the frequency in hertz and *c* is the speed of light (300x106) m/s.

Power

Convert W to dB(W):

$$dB(W) = 10\log W;\ \ dBm = 10\log W + 30 = dBW + 30 \tag{4A}$$

Convert dB(W) to W:

$$W = 10^{(dB(W)/10)};\ \ W = 10^{((dBm-30)/10)} \tag{4B}$$

Received power

Convert µV/m to dB(W):

$$P_d = E - 20logf - 107.2 \tag{5}$$

where:

P_d: isotropically received power at the antenna output (dB(W));

E: field strength (dB(µV/m)); and

f: frequency (MHz).

Example: *E* = 90 µV/m. Therefore, 39 dB(µV/m), *f* = 112 MHz. Therefore, 20logf = 41, P_d = 39 – 41 – 107.2 = 109.2 dB(W).

Frequency versus wavelength

Convert frequency to wavelength:

$$\lambda = c/f \tag{6A}$$

where:

λ: wavelength (m);

c: $3*10^8$ (m/sec); and

f: frequency (Hz).

Convert wavelength to frequency:

$$f = c/\lambda \tag{6B}$$

Free-space propagation

Free-space transmission loss:

$$L_{bf} = 20\log\frac{4\pi d}{\lambda} \tag{7A}$$

where:

L_{bf}: free-space basic transmission loss (dB);

d: distance; and

λ: wavelength;

Note.— Distance and wavelength have the same units of measurement.

or

free-space transmission loss:

$$L_{bf} = 32.4 + 20\log f_{MHz} + 20\log d_{km} \text{ (dB)} \tag{7B}$$

or

free-space transmission loss:

$$L_{bf} = 37.8 + 20\log f_{MHz} + 20\log d_{NM} \text{ (dB)} \tag{7C}$$

Distance to the radio horizon (4/3 earth radius) using nautical miles and feet or kilometres and metres

$$d_{RH} = 1.23\left(\sqrt{h_{TX}}\right) \tag{8A}$$

where:

d_{RH}: the distance from the station to the radio horizon (NM); and

h_{TX}: the height of the transmitter (or receiver) above the earth's surface (ft).

$$d_{RH} = 4.12(\sqrt{h_{TX}}) \qquad (8B)$$

where:

d_{RH}: distance from the station to the radio horizon (km); and

h_{TX}: the height of the transmitter (or receiver) above the earth's surface (m).

$$d_{RH} = 1.23(\sqrt{h_{TX}} + \sqrt{h_{RX}}) \qquad (8C)$$

where:

d_{RH}: the radio horizon separation distance between the transmitter and receiver (NM);

h_{TX}: the height of the transmitter above the earth's surface (ft); and

h_{RX}: the height of the receiver above the earth's surface (ft).

Angle conversion

Degrees to fractional degrees: DºM'S'' = D + M/60 + S/3600 fractional degrees

Fractional degrees to degrees	P.ABCDE:	Degrees is integer of P.ABCDE degrees = P degrees
		Minutes is integer of the fraction ABCDE*60
		Seconds is fraction of ABCDE *60
Convert degrees to radians	(Dfr)*π/180; Dfr = fractional degrees	
Convert radians to degrees	Drad*180/π; Drad = degrees in radians	

For spherical formulas, see https://www.edwilliams.org/avform.htm.

Earth radius: 6 371 km or 3 440 NM

1 NM = 1/60 degree or one minute of a great circle at the earth's surface.

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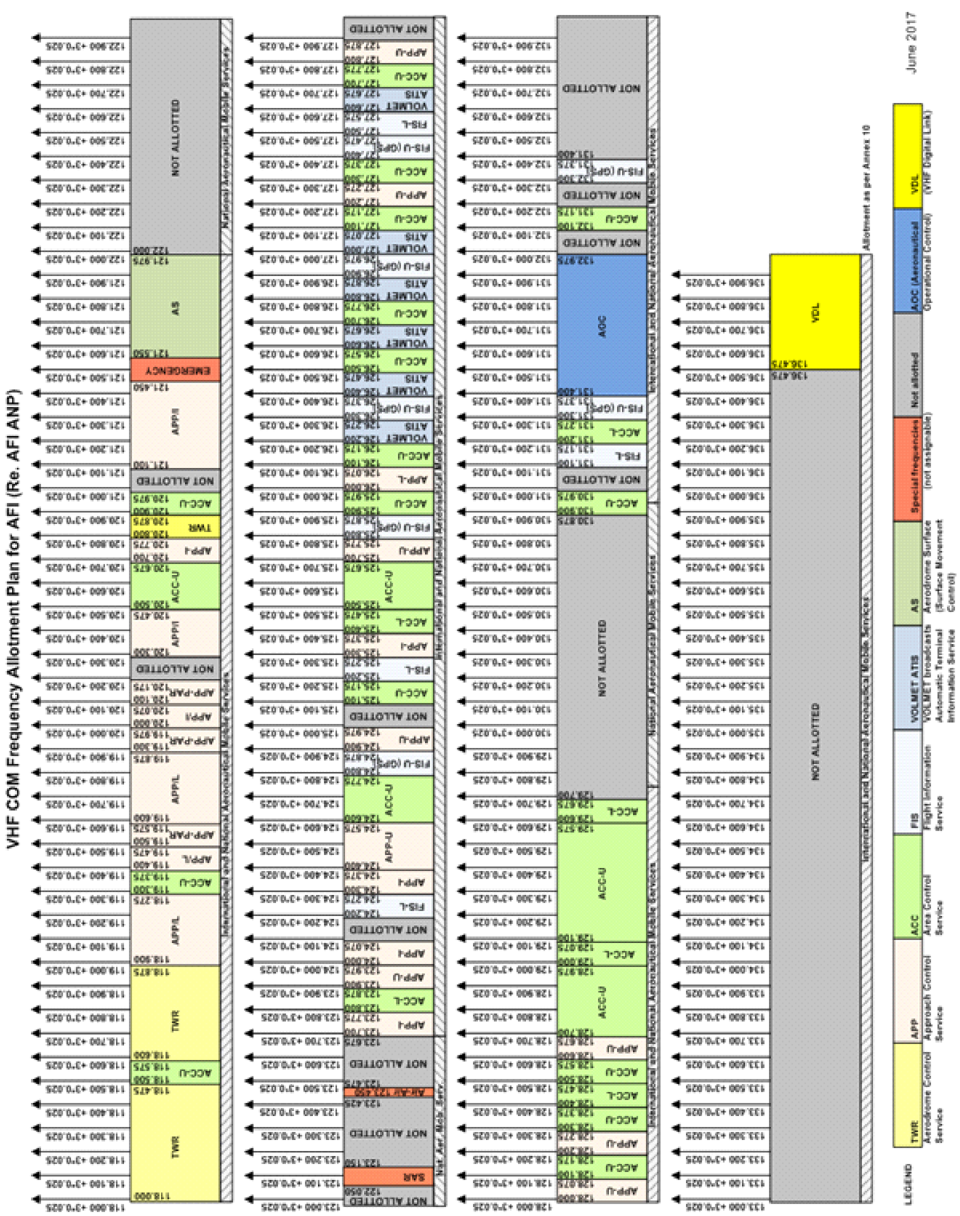
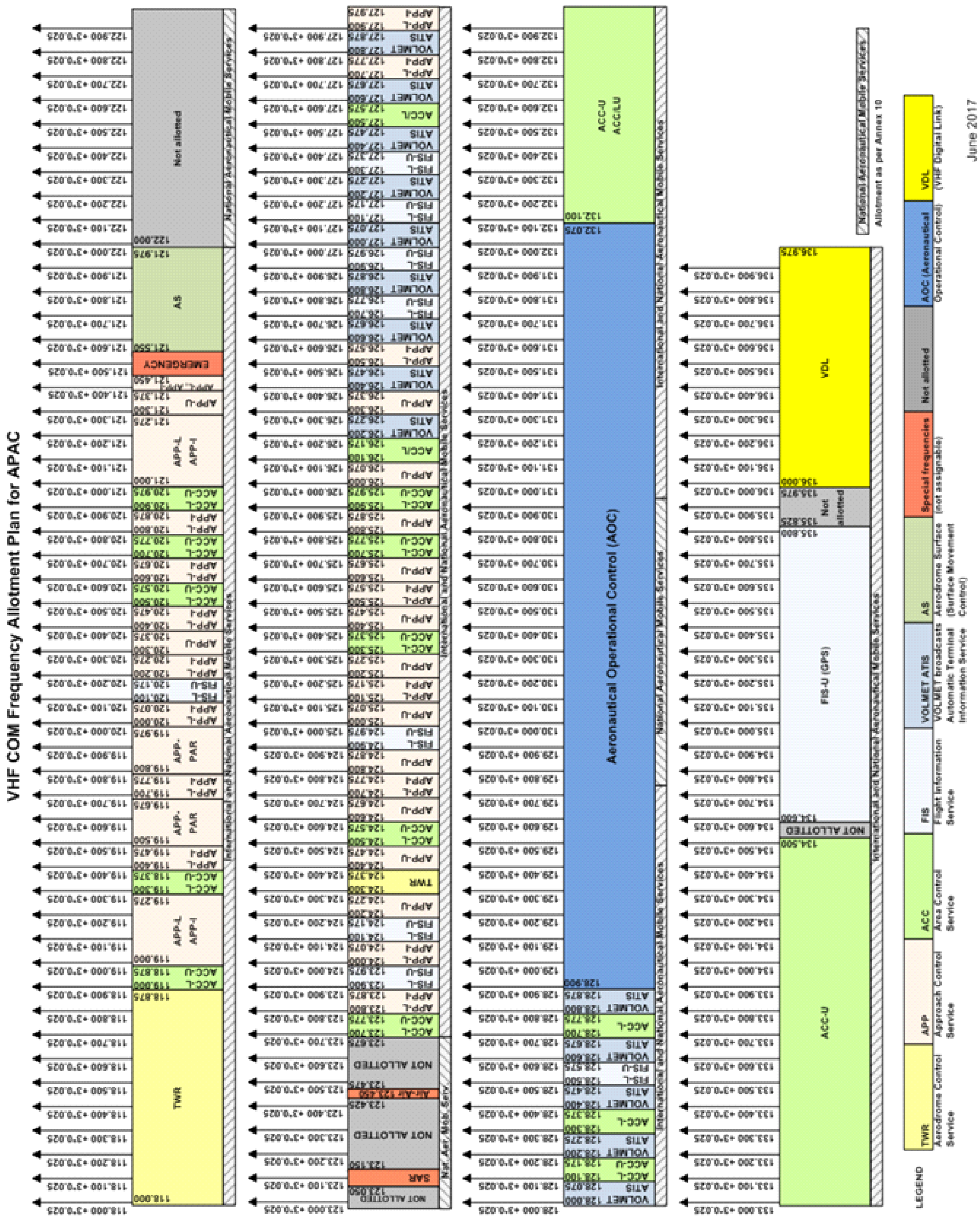
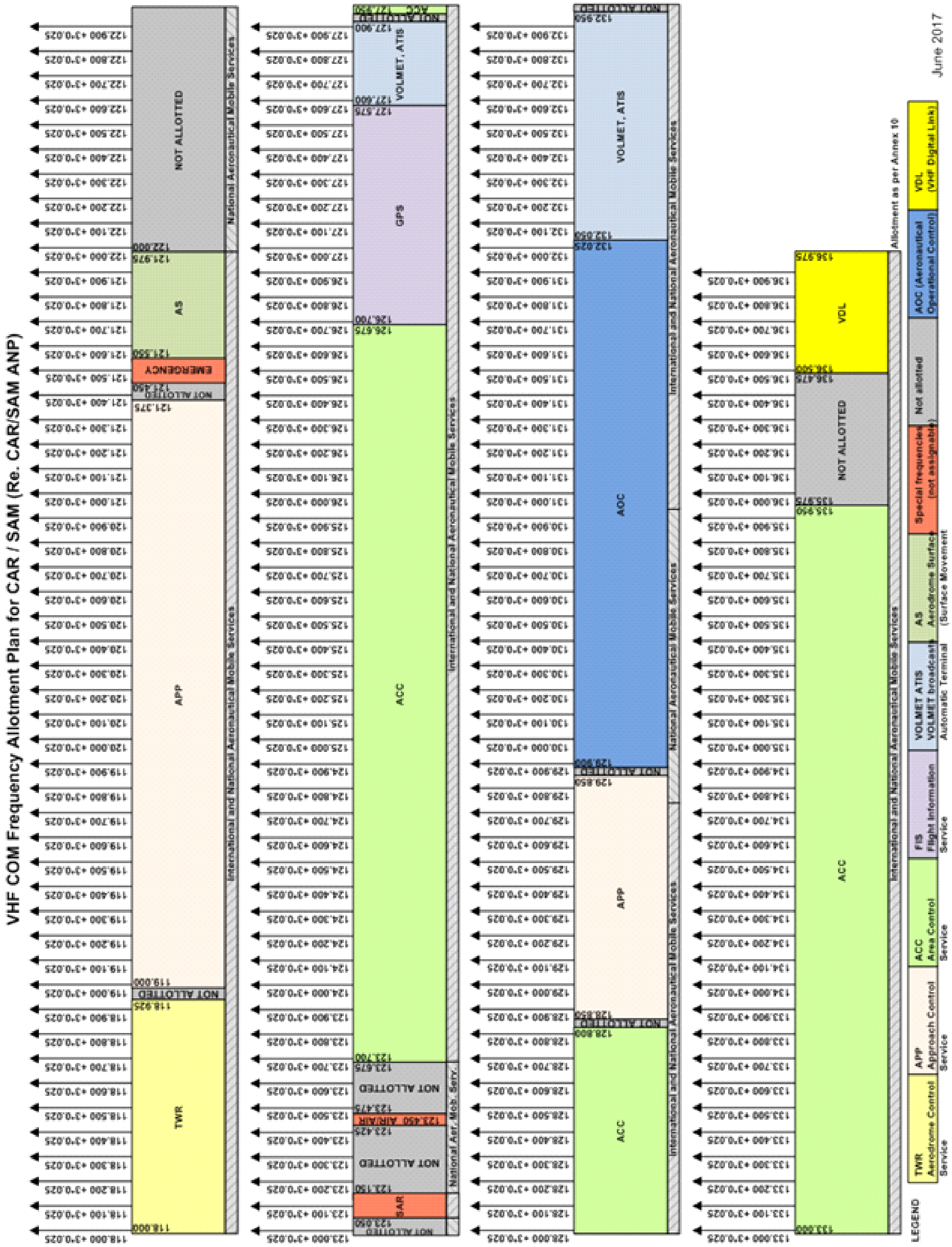
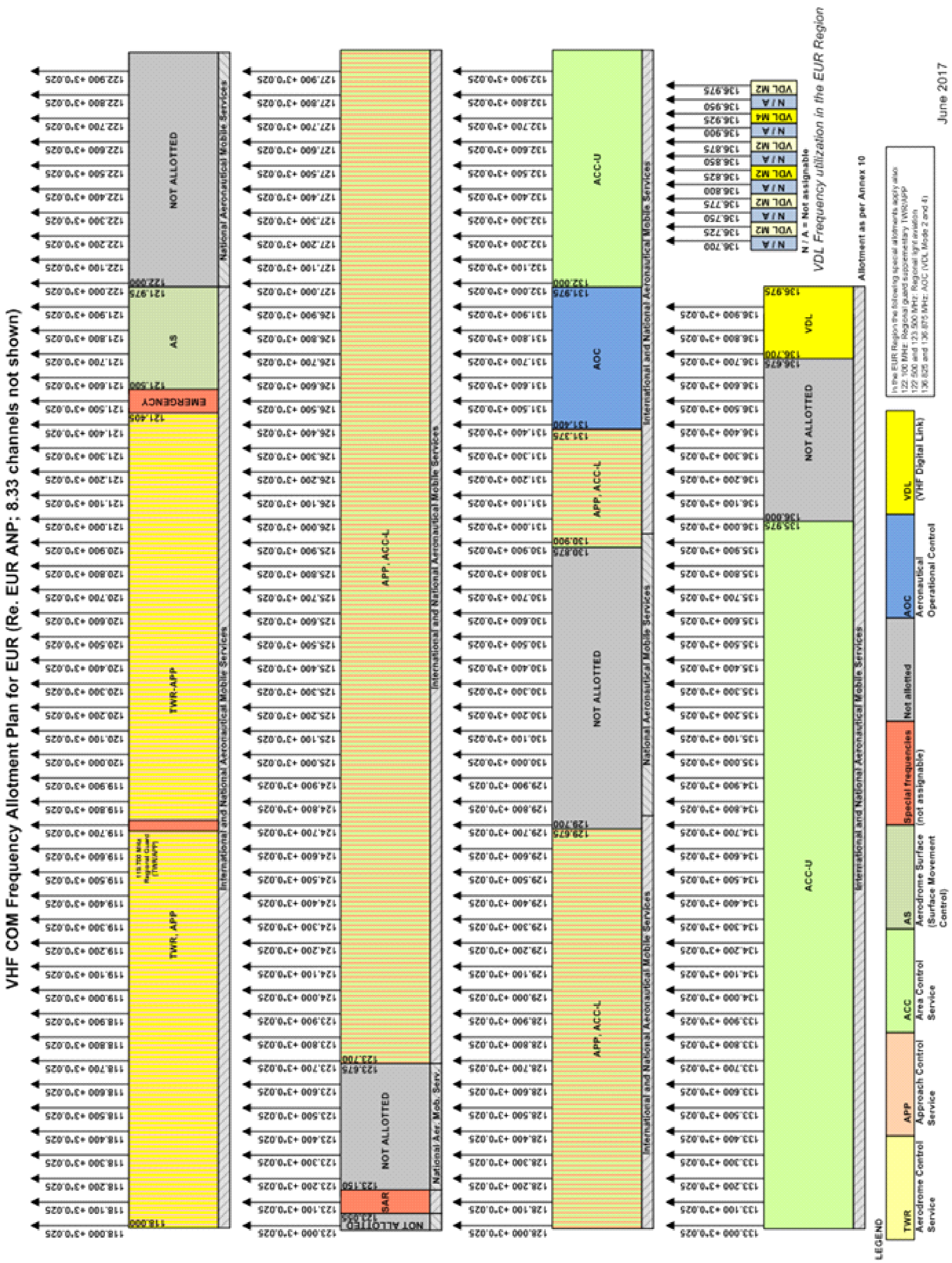
Appendix B

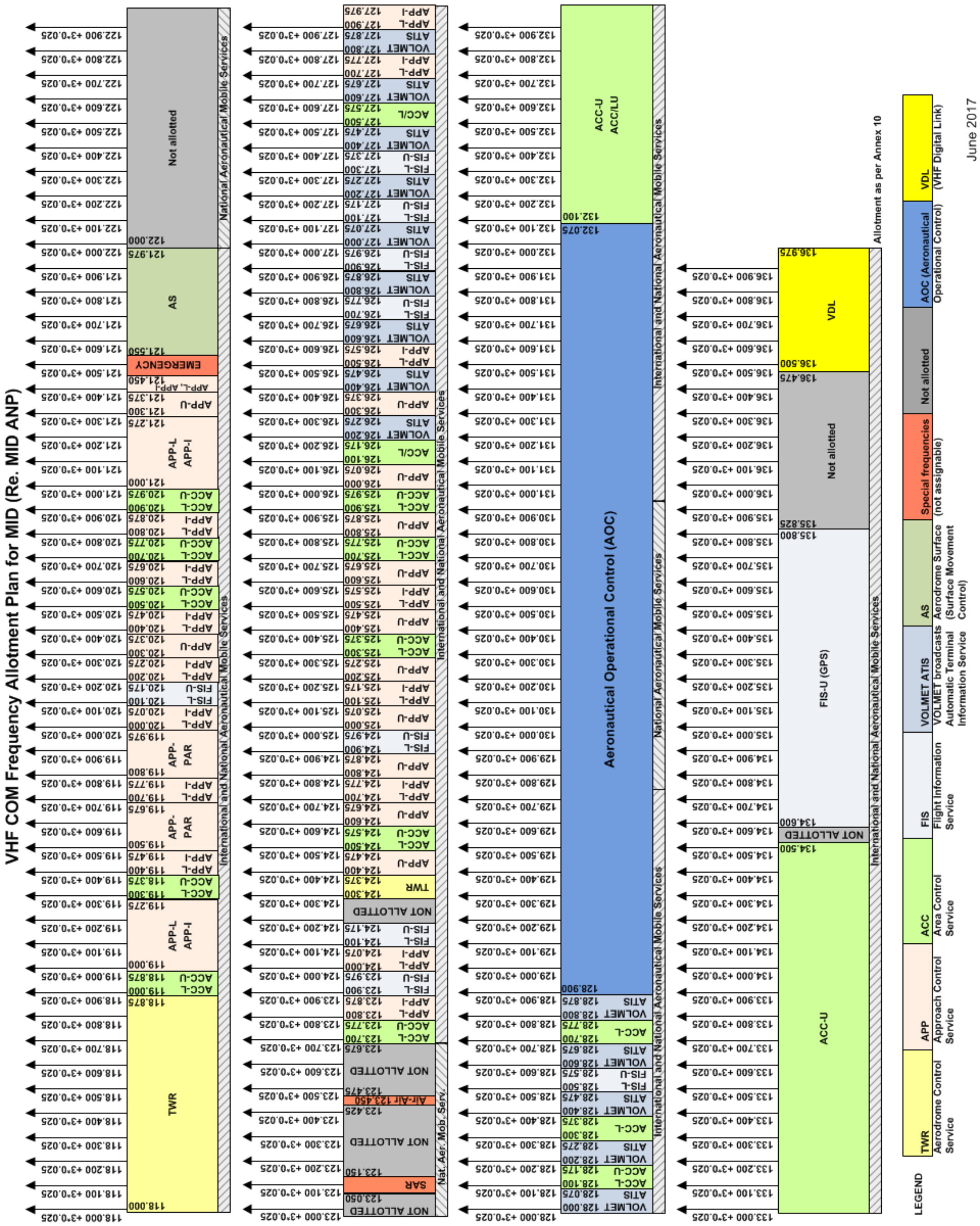
Regional frequency allotment plans




VHF COM Frequency Allotment Plan for APAC
Aeronautical Operational Control (AOC)
VDL
FIS-U (GPS)
ACC-U
TWR
AS
EMERGENCY
Not allotted
National Aeronautical Mobile Services
International and National Aeronautical Mobile Services
Allotment as per Annex 10
LEGEND
TWR Aerodrome Control Service
APP Approach Control Service
ACC Area Control Service
FIS Flight Information Service
VOLMET ATIS VOLMET broadcasts Automatic Terminal Information Service
AS Aerodrome Surface (Surface Movement Control)
Special frequencies (not assignable)
Not allotted
AOC (Aeronautical Operational Control)
VDL (VHF Digital Link)
June 2017


VHF COM Frequency Allotment Plan for CAR / SAM (Re. CAR/SAM ANP)
June 2017


VHF COM Frequency Allotment Plan for EUR (Re. EUR ANP; 8.33 channels not shown)
NOT ALLOTTED
AS
EMERGENCY
TWR-APP
TWR, APP
SAR
APP, ACC-L
ACC-U
AOC
VDL
International and National Aeronautical Mobile Services
National Aeronautical Mobile Services
N / A = Not assignable
VDL Frequency utilization in the EUR Region
Allotment as per Annex 10
LEGEND
TWR Aerodrome Control Service
APP Approach Control Service
ACC Area Control Service
AS Aerodrome Surface (Surface Movement Control)
Special frequencies (not assignable)
Not allotted
AOC Aeronautical Operational Control
VDL (VHF Digital Link)
June 2017


VHF COM Frequency Allotment Plan for MID (Re. MID ANP)
Aeronautical Operational Control (AOC)
Allotment as per Annex 10
LEGEND
TWR Aerodrome Control Service
APP Approach Control Service
ACC Area Control Service
FIS Flight Information Service
VOLMET ATIS VOLMET broadcasts Automatic Terminal Information Service
AS Aerodrome Surface (Surface Movement Control)
Special frequencies (not assignable)
Not allotted
AOC (Aeronautical Operational Control)
VDL (VHF Digital Link)
June 2017

Appendix C

Regional frequency allotment tables

The regional frequency allotment tables referred to in this Handbook (Volume II) are contained in a supplement to the Handbook and can be downloaded from the Frequency Spectrum Management Panel website at http://www.icao.int/safety/fsmp/documents/doc9718.

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Appendix D

ITU Recommendation ITU-R P.528-5

ITU Recommendation ITU-R P.528-5 can be found at https://www.itu.int/rec/R-REC-P.528-5-202109-I/en.

The integral software to generate basic transmission loss values and curves is also available at the above web page.

— END —

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