



**Recommendation ITU-R M.1841-1**  
(02/2013)

**Compatibility between FM  
sound-broadcasting systems in the  
frequency band of about 87-108 MHz and  
the aeronautical ground-based  
augmentation system in the frequency band  
108-117.975 MHz**

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

## Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

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*Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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## RECOMMENDATION ITU-R M.1841-1\*

**Compatibility between FM sound-broadcasting systems in the frequency band of about 87-108 MHz and the aeronautical ground-based augmentation system in the frequency band 108-117.975 MHz**

(2007-2013)

**Scope**

Resolution 413 (WRC-03) invited ITU-R to study any compatibility issues between the broadcasting and aeronautical services operating around 108 MHz and to develop new or revised ITU-R Recommendations as appropriate. This Recommendation provides technical and operational requirements that may be used by administrations as a technical guideline for establishing the compatibility of the ICAO ground-based augmentation system (GBAS) above 108 MHz and frequency modulation (FM) broadcasting systems operating up to 108 MHz.

The ITU Radiocommunication Assembly,

*considering*

- a) that, in order to improve the efficiency of spectrum utilization, there is a need to refine the criteria used when assessing compatibility between the FM sound-broadcasting service and the aeronautical services in the nearby frequency band;
- b) that there is a need for a compatibility analysis method for identifying potential incompatibilities associated with a large broadcasting assignment plan;
- c) that there is a need for a detailed, case-by-case compatibility analysis method to investigate potential incompatibility cases identified by a large scale analysis or for individual assessment of proposed broadcasting or aeronautical assignments;
- d) that there is a need to continue the refinement of the compatibility criteria and assessment methods,

*recommends*

- 1 that the criteria given in Annex 1 may be used for compatibility calculations;
- 2 that the method given in Annex 2 may be used for predicting potential incompatibilities associated with a large broadcasting assignment plan;
- 3 that the techniques in Annex 3 may be used for detailed, case-by-case compatibility calculations concerning potential interference cases identified by the method given in Annex 2 or concerning individual assessment of proposed assignments to broadcasting or aeronautical stations;
- 4 additionally, that results of practical verification of predicted compatibility situations as well as other relevant information may be used for coordination and to effect further refinement of the compatibility criteria, assessment method and techniques given in Annexes 1, 2 and 3 respectively.

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\* This Recommendation should be brought to the attention of Radiocommunication Study Group 6.

**Annex 1****Interference mechanisms, system parameters  
and compatibility assessment criteria**

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## **1 Background and introduction**

FM broadcasting service interference to aeronautical mobile systems used for navigation and surveillance purposes is a widely recognized problem among users of aviation facilities. In airborne GBAS receivers, the interference problem causes errors in navigation correction information. The interference to these receivers is a serious problem, especially during the critical approach and landing phase, as it is not readily evident to the pilot.

The effects of interference to aircraft receivers vary with the aircraft location, altitude and intermodulation and spurious emission conditions. The way in which the presence of such interference is flagged varies with the make and model of the receiver. There is an increasing probability of harmful interference due to the growing need for additional aeronautical and broadcasting frequency assignments.

This Annex describes:

- interference mechanisms;
- system parameters of the aeronautical mobile systems affected;
- system parameters of the FM broadcasting stations;
- compatibility assessment criteria for GBAS receivers.

## **2 Types of interference mechanisms**

In general, from a GBAS receiver point of view, FM broadcasting transmission modulation can be regarded as noise.

### **2.1 Type A interference**

#### **2.1.1 Introduction**

Type A interference is caused by unwanted emissions into the aeronautical band from one or more broadcasting transmitters.

#### **2.1.2 Type A1 interference**

A single transmitter may generate spurious emissions or several broadcasting transmitters may intermodulate to produce components in the aeronautical frequency bands; this is termed Type A1 interference.

#### **2.1.3 Type A2 interference**

A broadcasting signal may include non-negligible components in the aeronautical bands; this interference mechanism, which is termed Type A2 interference, will in practice arise only from broadcasting transmitters having frequencies near 108 MHz and will only interfere with aeronautical mobile services with frequencies near 108 MHz.

### **2.2 Type B interference**

#### **2.2.1 Introduction**

Type B interference is that generated in an aeronautical receiver resulting from broadcasting transmissions on frequencies outside the aeronautical band.



### 2.2.2 Type B1 interference

Intermodulation may be generated in an aeronautical receiver as a result of the receiver being driven into non-linearity by broadcasting signals outside the aeronautical band; this is termed Type B1 interference. In order for this type of interference to occur, at least two broadcasting signals need to be present and they must have a frequency relationship which, in a non-linear process, can produce an intermodulation product within the wanted RF channel in use by the aeronautical receiver. One of the broadcasting signals must be of sufficient amplitude to drive the receiver into regions of non-linearity but interference may then be produced even though the other signal(s) may be of significantly lower amplitude.

Only third-order intermodulation products are considered; they take the form of:

$$f_{intermod} = 2f_1 - f_2 \quad \text{two-signal case or}$$

$$f_{intermod} = f_1 + f_2 - f_3 \quad \text{three-signal case}$$

where:

$$f_{intermod}: \quad \text{intermodulation product frequency (MHz)}$$

$$f_1, f_2, f_3: \quad \text{broadcasting frequencies (MHz) with } f_1 \geq f_2 > f_3.$$

### 2.2.3 Type B2 interference

Desensitization may occur when the RF section of an aeronautical receiver is subjected to overload by one or more broadcasting transmissions; this is termed Type B2 interference.

## 3 Compatibility assessment parameters

### 3.1 Introduction

This section identifies the parameters of GBAS aeronautical transmitters and receivers relevant for a compatibility assessment.

### 3.2 Characteristics of aeronautical systems

#### 3.2.1 Designated operational coverage

GBAS can be operated in the following two modes:

- a) a precision approach service; or
- b) a positioning service.

ICAO requires that GBAS offers at least the precision approach service. Moreover, optionally a positioning service may be provided.

##### 3.2.1.1 Precision approach service

Figure 1A illustrates the horizontal extension of a typical designated operational coverage (DOC) for GBAS precision approach service based on the requirements described in Annex 10 to the Convention on International Civil Aviation. It covers a keyhole-shaped area composed of a sector with a width of  $\pm 35^\circ$  extending 28 km (15 NM) from the runway stop-end and a second sector with a width of  $\pm 10^\circ$  extending additional 9 km (5 NM). Further details are depicted in Fig. 1B.

The lower coverage boundary (H) at the maximum distance from the landing threshold point (LTP) for a given glide path angle ( $\alpha$ ) shall be computed as follows:

$$H = \left( Dist_{max} + \frac{TCH}{\tan(\alpha)} \right) \cdot \tan(0.3 \cdot \alpha)$$

where:

$Dist_{max}$ : maximum distance in metres from LTP;

$TCH/\tan(\alpha)$ : distance in metres from LTP to the glide path intercept point (GPIP i.e. the point where the final approach path intercepts the local level plane);

$\alpha$ : glide path angle (nominal value is 3 degrees);

TCH: threshold crossing height (height of the approach path above LTP), nominal value is 15 m.

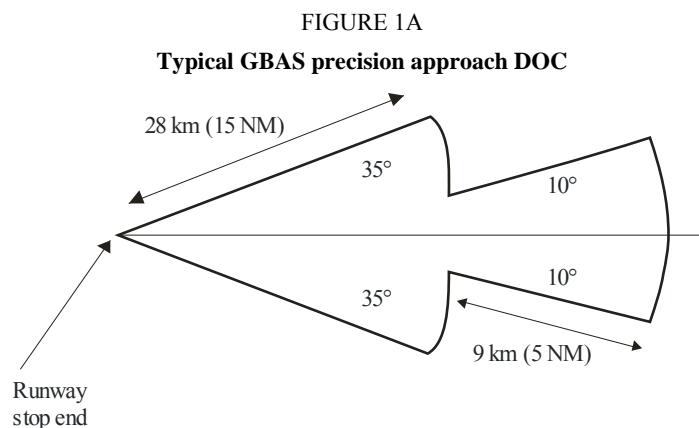
This is further illustrated in Fig. 1B.

For nominal values of the glide path angle 3 degrees and a threshold crossing height of 15 m at a typical maximum distance of 37 km (20 NM) the following lower coverage boundary is obtained:

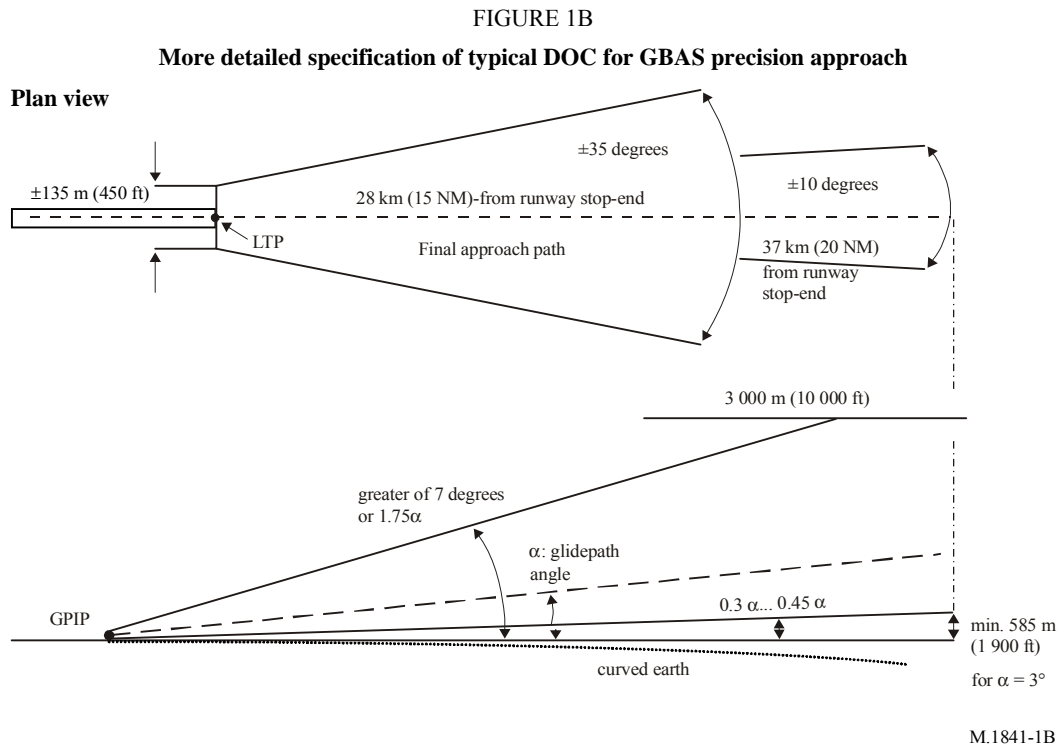
$$H = \left( 37\,000 + \frac{15}{\tan(3^\circ)} \right) \cdot \tan(0.3 \cdot 3^\circ) = 586\,m \quad (\approx 1900\,ft)$$

This DOC is defined on a per runway basis. As a single GBAS ground station may serve multiple aerodromes with multiple runways in its vicinity, the overall DOC may be considered as the sum of the DOCs.

Some administrations may also use the GBAS in a way such that the DOC may not be aligned with a runway.



NOTE – Not drawn to scale.



NOTE – Not drawn to scale.

*Editorial Note* – The DOC is derived from the requirements for GBAS in Annex 10 to the Convention on International Civil Aviation. The depicted elevation diagram for GBAS is not the same as for ILS in Fig. 1 of Recommendation ITU-R SM.1009-1.

### 3.2.1.2 Positioning service

The DOC of a GBAS for positioning can vary from one installation to another: a typical DOC for GBAS for positioning may be circular and have a radius of 43 km (23 NM) from the GBAS transmitter. Some installations may have a greater radius depending on the operational requirements and frequency planning constraints. Details can be obtained from the appropriate national Aeronautical Information Publication (see definitions in Annex 4) (AIP).

### 3.2.2 Field strength

The minimum field strength to be protected throughout the DOC (see § 3.5.4.4.2.2 of Appendix 1) is 215  $\mu\text{V/m}$  (46.6 dB( $\mu\text{V/m}$ )).

### 3.2.3 Frequencies

GBAS frequencies lie in the band near to the FM broadcasting band, and can operate on ILS/VOR frequencies as well as those in between. GBAS frequencies occupy channels at 25 kHz intervals and may be as follows: 108.025, 108.050 ... 117.950 MHz.

### 3.2.4 Polarization

There are two types of polarization that can be used by GBAS; horizontal and an optional additional vertical polarization. It is only the horizontal polarization that is intended for international civil aviation use and therefore only aircraft with horizontally polarized antennas are considered in this Recommendation. The use of the optional vertical polarization is only intended for national use.



**3.3 Characteristics of FM broadcasting stations**

**3.3.1 Maximum effective radiated power**

The most accurate available value of maximum e.r.p. should be used for compatibility calculations.

**3.3.2 Horizontal radiation pattern**

The most accurate available information for horizontal radiation pattern (h.r.p.) should be used for compatibility calculations.

**3.3.3 Vertical radiation pattern**

The most accurate available information for vertical radiation pattern (v.r.p.) should be used for compatibility calculations.

**3.3.4 Spurious emission suppression**

In the North American experience, it has not generally been necessary to require the suppression of spurious emissions by more than 80 dB. Considering special circumstances within some areas of Region 1 and some areas of Region 3, the values given in Table 1, for spurious emission suppression in the aeronautical band 108-137 MHz, may be recommended for the case of radiated intermodulation products from co-sited broadcasting transmitters.

TABLE 1

Maximum e.r.p. (dBW)	Suppression relative to maximum e.r.p. (dB)
≥ 48	85
30	76
< 30	46 + maximum e.r.p. (dBW)

NOTE 1 – Linear interpolation is used between maximum e.r.p. values of 30 and 48 dBW.

**3.3.5 Frequencies**

The bands of operation may be found in the Radio Regulations. In Region 1 and certain parts of Region 3, the band is 87.5-108 MHz, with channels every 100 kHz (87.6, 87.7 ... 107.9 MHz). In Region 2, the band is 88-108 MHz, with channels every 200 kHz (88.1, 88.3 ... 107.9 MHz).

**3.3.6 Polarization**

The polarization of an FM signal may be horizontal, vertical or mixed.

**3.3.7 Free-space field-strength calculation for broadcasting signals**

The free-space field strength is to be determined according to the following formula:

$$E = 76.9 + P - 20 \log d + H + V \tag{1}$$

where:

- E*: field strength (dB(μV/m)) of the broadcasting signal;
- P*: maximum e.r.p. (dBW) of broadcasting station;

- $d$ : slant path distance (km) (see definition in Annex 4);  
 $H$ : h.r.p. correction (dB);  
 $V$ : v.r.p. correction (dB).

In the case of a broadcasting station with mixed polarization, the maximum e.r.p. to be used is the larger of the horizontal and vertical components. However, where both the horizontal and vertical components have equal values, the maximum e.r.p. to be used is obtained by adding 1 dB to the value of the horizontal component.

### 3.4 Receiver input power

Assuming an aircraft antenna radiation pattern with no directivity, the field strengths of the broadcasting signal and of the aeronautical signal are to be converted to power at the input to an aeronautical receiver according to the following formulas:

- a) for a broadcasting signal in the band 87.5-108.0 MHz:

$$N = E - 118 - L_s - L(f) - L_a \quad (2)$$

where:

- $N$ : broadcasting signal level (dBm) at the input to the aeronautical receiver;  
 $E$ : field strength (dB( $\mu$ V/m)) of the broadcasting signal;  
 $L_s$ : signal splitter loss of 3.5 dB;  
 $L(f)$ : antenna system frequency-dependent loss at broadcasting frequency  $f$  (MHz) of 1.2 dB per MHz below 108 MHz (for a horizontally polarized antenna);  
 $L_a$ : antenna system fixed loss of 9 dB.

- b) for an aeronautical signal and a Type A1 signal in the band 108-118 MHz:

$$N_a = E_a - 118 - L_s - L_a \quad (3)$$

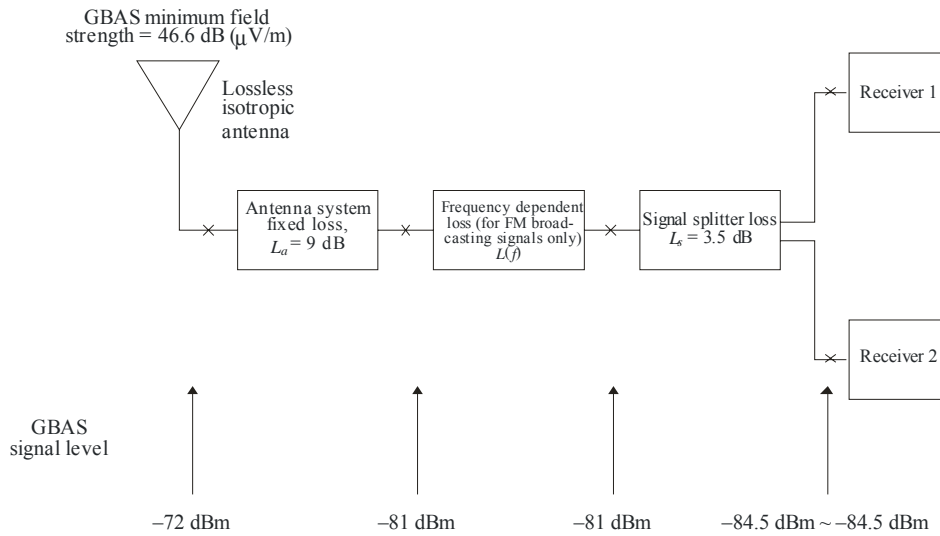
where:

- $N_a$ : signal level (dBm) at the input to the aeronautical receiver;  
 $E_a$ : field strength (dB( $\mu$ V/m)) of the aeronautical or Type A1 signal.

Figure 2 illustrates how the GBAS minimum field strength of 46.6 dB( $\mu$ V/m) is converted to -84 dBm at the receiver input of a typical aircraft receiver installation using formula (3).

FIGURE 2

**Conversion of the GBAS minimum field strength to a signal level at the input to an aeronautical receiver**



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Note 1 – Typical aircraft installation includes a signal splitter to feed two aeronautical receivers.

Note 2 – The frequency dependent loss  $L(f)$ , is equal to 0 for aeronautical frequencies and therefore does not appear in formula (3).

## 4 Compatibility assessment criteria

### 4.1 Standard interference thresholds

#### 4.1.1 GBAS

The interference threshold for GBAS receivers is:

- a message failure rate less than or equal to one failed message per 1 000 full-length (222 bytes) application data messages.

### 4.2 Interference assessment criteria – GBAS receivers

#### 4.2.1 Type A1 interference

Table 2 gives the values of the protection ratio that may be used. Type A1 interference need not be considered for frequency differences greater than 200 kHz.

TABLE 2

Frequency difference between wanted signal and spurious emission (kHz)	Protection ratio (dB)
0	14
50	7
100	-4
150	-19
200	-38

#### 4.2.2 Type A2 interference

Table 3 gives the values of the protection ratio that may be used. Type A2 interference need not be considered for frequency differences greater than 300 kHz.

#### 4.2.3 Type B1 interference

##### 4.2.3.1 Compatibility assessment formulas

The following formulae may be used to assess potential incompatibilities.

a) *Two-signal case*

$$2 \left\{ N_1 - 20 \log \left( \frac{\max(0.4; 108.1 - f_1)}{0.4} \right) \right\} + N_2 - 20 \log \left( \frac{\max(0.4; 108.1 - f_2)}{0.4} \right) + K - L_c + S > 0 \quad (4)$$

where:

$N_1, N_2$ : broadcasting signal levels (dBm) at the input to the aeronautical receiver for broadcasting frequencies  $f_1$  and  $f_2$  respectively;

$f_1, f_2$ : broadcasting frequencies (MHz)  $f_1 > f_2$ ;

$K = 78$  for GBAS;

$L_c$ : correction factor (dB) to account for changes in wanted signal levels (see § 4.3.3.3);

$S$ : 3 dB margin to take into account of the fact that the receiver immunity criteria equations given in Annex 10 to the Convention on International Civil Aviation do not provide comprehensive compatibility assessment formulae.

b) *Three-signal case*

$$N_1 - 20 \log \left( \frac{\max(0.4; 108.1 - f_1)}{0.4} \right) + N_2 - 20 \log \left( \frac{\max(0.4; 108.1 - f_2)}{0.4} \right) + N_3 - 20 \log \left( \frac{\max(0.4; 108.1 - f_3)}{0.4} \right) + K + 6 - L_c + S > 0 \quad (5)$$

where:

$f_1, f_2, f_3$ : broadcasting frequencies (MHz)  $f_1 \geq f_2 > f_3$ ;

$N_1, N_2, N_3$ : broadcasting signal levels (dBm) at the input to the aeronautical receiver for broadcasting frequencies  $f_1, f_2$  and  $f_3$  respectively;

$K = 78$  for GBAS;

$L_c$ : correction factor (dB) to account for changes in wanted signals (see § 4.3.3.3);

$S$ : 3 dB margin to take into account of the fact that the receiver immunity criteria equations given in Annex 10 to the Convention on International Civil Aviation do not provide comprehensive compatibility assessment formulae.

TABLE 3

Frequency difference between wanted signal and broadcasting signal (kHz)	Protection ratio (dB)
150	-41
200	-50
250	-59
300	-68

**4.2.3.2 Frequency offset correction**

Before applying formulae (4) and (5), a correction from Table 4 is applied to each signal as follows:

$$N(\text{corrected}) = N - \text{correction term}$$

Type B1 interference need not be considered for frequency differences greater than 150 kHz; in such cases, signal levels would be so high that Type B2 interference would occur.

TABLE 4

Frequency difference between wanted signal and intermodulation product (kHz)	Correction term (dB)
0	0
50	2
100	5
150	11

**4.2.3.3 Correction factor to account for changes in Type B1 interference immunity resulting from changes in wanted signal levels**

The following correction factor may be applied for GBAS, two and three-signal cases:

$$L_c = N_A - N_{ref} \tag{6}$$

where:

- $L_c$ : correction factor (dB) to account for changes in the wanted signal level;
- $N_A$ : wanted signal level (dBm) at the input to the aeronautical receiver;
- $N_{ref}$ : reference level (dBm) of the wanted signal at the input to the aeronautical receiver for the Type B1 interference immunity formula;  
= -72 dBm for GBAS.

**4.2.3.4 Trigger and cut-off values (see definitions in Annex 4)**

$$\text{Trigger value (dBm)} = \frac{(L_c - K - S)}{3} + 20 \log\left(\frac{\max(0.4; 108.1 - f)}{0.4}\right) \text{ dBm} \tag{7}$$

where:

- $L_c$ : correction factor (dB) (see § 4.2.3.3);
- $K = 78$  for GBAS for 2-signal cases;
- $K = 84$  for GBAS for 3-signal cases;
- $f$ : broadcasting frequency (MHz);
- $S$ : 3 dB margin to take into account of the fact that the receiver immunity criteria equations given in Annex 10 to the Convention on International Civil Aviation do not provide comprehensive compatibility assessment formulae.

$$\text{Cut-off value (dBm)} = -66 + 20 \log \left( \frac{\max(0.4; 108.1 - f)}{0.4} \right) \quad \text{dBm} \quad (8)$$

where:

- $f$ : broadcasting frequency (MHz).

Experience has shown that the use of lower cut-off values merely associates additional intermodulation products with each trigger value, but at lower levels of potential interference.

#### 4.2.4 Type B2 interference

For an assessment of Type B2 interference, the following empirical formula may be used to determine the maximum level of a broadcasting signal at the input to the airborne GBAS receiver to avoid potential interference:

For aeronautical frequencies from 108.025 to 111.975 MHz:

$$N_{max} = \min \left( 15; -10 + 20 \log \left( \frac{\max(0.4; 108.1 - f)}{0.4} \right) \right) + L_c - S \quad (9)$$

For aeronautical frequencies from 112 to 117.975 MHz:

$$N_{max} = \min \left( 15; 20 \log \left( \frac{\max(0.4; 108.1 - f)}{0.4} \right) \right) + L_c - S \quad (10)$$

where:

- $N_{max}$ : maximum level (dBm) of the broadcasting signal at the input to the aeronautical receiver;
- $f$ : broadcasting frequency (MHz);
- $S$ : 3 dB margin to take into account of the fact that the receiver immunity criteria equations given in Annex 10 to the Convention on International Civil Aviation do not provide comprehensive compatibility assessment formulae;
- $L_c$ : correction factor (dB) to account for changes in the wanted signal level.  
 $L_c = \max(0; 0.5(N_A - N_{ref}))$ ;
- $N_A$ : wanted signal level (dBm) at the input to the aeronautical receiver;



$N_{ref}$ : reference level (dBm) of the wanted signal at the input to the aeronautical receiver for the Type B2 interference immunity formula;  
= -72 dBm for GBAS.

## Appendix 1 to Annex 1

### GBAS coverage and minimum field strengths

*Extract from:* “International Standards, Recommended Practices and Procedures for Air Navigation Services: Aeronautical Telecommunications, Annex 10 to the Convention on International Civil Aviation, Volume I”, International Civil Aviation Organization, Montreal, 1985.

The following extract pertains to GBAS<sup>1</sup>:

#### “3.7.3.5.3 Coverage

3.7.3.5.3.1 The GBAS coverage to support each Category I precision approach shall be as follows, except where topographical features dictate and operational requirements permit:

- a) laterally, beginning at 140 m (450 ft) each side of the landing threshold point/fictitious threshold point (LTP/FTP) and projecting out  $\pm 35$  degrees either side of the final approach path to 28 km (15 NM) and  $\pm 10$  degrees either side of the final approach path to 37 km (20 NM); and
- b) vertically, within the lateral region, up to the greater of 7 degrees or 1.75 promulgated glide path angle (GPA) above the horizontal with an origin at the glide path interception point (GPIP) and 0.45 GPA above the horizontal or to such lower angle, down to 0.30 GPA, as required, to safeguard the promulgated glide path intercept procedure. This coverage applies between 30 m (100 ft) and 3 000 m (10 000 ft) of the height above touchdown (HAT).

NOTE – LTP/FTP and GPIP are defined in Appendix B, 3.6.4.5.1.

3.7.3.5.3.2 **Recommendation** – The GBAS coverage should extend down to 3.7 m (12 ft) above the runway surface.

3.7.3.5.3.3 **Recommendation** – The data broadcast should be omnidirectional to support future applications.

NOTE – Guidance material concerning GBAS coverage for Category I precision approach and for the GBAS positioning service is provided in Attachment D, 7.3.

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<sup>1</sup> For references to “Category I precision approach” in this extract, see Annex 4 to this Recommendation under “Precision Approach”.

#### 3.7.3.5.4.4 Data broadcast RF field strength and polarization

NOTE – GBAS can provide a VHF data broadcast with either horizontal (GBAS/H) or elliptical (GBAS/E) polarization that employs both horizontal polarization (HPOL) and vertical polarization (VPOL) components. Aircraft using a VPOL component will not be able to conduct operations with GBAS/H equipment. Relevant guidance material is provided in Attachment D, 7.1.

##### 3.7.3.5.4.4.1 GBAS/H.

3.7.3.5.4.4.1.1 A horizontally polarized signal shall be broadcast.

3.7.3.5.4.4.1.2 The effective radiated power (ERP) shall provide for a horizontally polarized signal with a minimum field strength of 215 microvolts per metre ( $-99$  dBW/metres-squared) and a maximum field strength of 0.350 volts per metre ( $-35$  dBW/metres-squared) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and any VPOL components shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL users throughout the coverage volume.

##### 3.7.3.5.4.4.2 GBAS/E.

3.7.3.5.4.4.2.1 **Recommendation** – An elliptically polarized signal should be broadcast whenever practical.

3.7.3.5.4.4.2.2 When an elliptically polarized signal is broadcast, the horizontally polarized component shall meet the requirements in 3.7.3.5.4.4.1.2, and the effective radiated power (ERP) shall provide for a vertically polarized signal with a minimum field strength of 136 microvolts per metre ( $-103$  dBW/m<sup>2</sup>) and a maximum field strength of 0.221 volts per metre ( $-39$  dBW/m<sup>2</sup>) within the GBAS coverage volume. The field strength shall be measured as an average over the period of the synchronization and ambiguity resolution field of the burst. The RF phase offset between the HPOL and VPOL components, shall be such that the minimum signal power defined in Appendix B, 3.6.8.2.2.3 is achieved for HPOL and VPOL users throughout the coverage volume.

NOTE – The minimum and maximum field strengths in 3.7.3.5.4.4.1.2 and 3.7.3.5.4.4.2.2 are consistent with a minimum receiver sensitivity of  $-87$  dBm and minimum distance of 200 metres (660 ft) from the transmitter antenna for a coverage range of 43 km (23 NM).”

## Annex 2

### General assessment method

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## **1 Introduction**

The purpose of this Annex is to provide an assessment method for the analysis of compatibility between stations of the aeronautical radionavigation services and stations in a large broadcasting assignment plan. The techniques given in Annex 3 may be used to carry out a more detailed analysis, or to verify the results obtained from an analysis.

### **1.1 Philosophy of the general assessment method**

The central objective of the General Assessment Method (GAM) is to calculate all significant potential incompatibilities within an aeronautical volume at a number of defined calculation points or test points (see Note 1). For a particular set of broadcasting and aeronautical frequency combinations, the maximum potential incompatibility associated with a particular aeronautical service is identified in the form of a protection margin.

An extension of the compatibility assessment method contained in the Geneva Agreement, 1984, is needed because of subsequent refinement of the compatibility criteria and identification of the need for a more thorough assessment method. In addition, because of the need to identify and examine potential incompatibilities associated with a large assignment plan, it is necessary to develop an assessment method suitable for automated implementation in an efficient manner.

The GAM is based upon the need to protect the aeronautical radionavigation service at specified minimum separation distances (see Note 1) from broadcasting station antennas, depending on the aeronautical service (GBAS) (see Note 1) and the particular use made of that service.

NOTE 1 – See definitions in Annex 4.

### **1.2 GBAS**

The DOC employed for a GBAS as a positioning service is circular. When an aircraft, however, is using GBAS as a precision approach service, each protected DOC is the same as that for ILS. Therefore, the test points required for GBAS are the same as those for VOR when used as a positioning service. When used as a precision approach service, for each supported DOC the test points required are the same as for ILS.

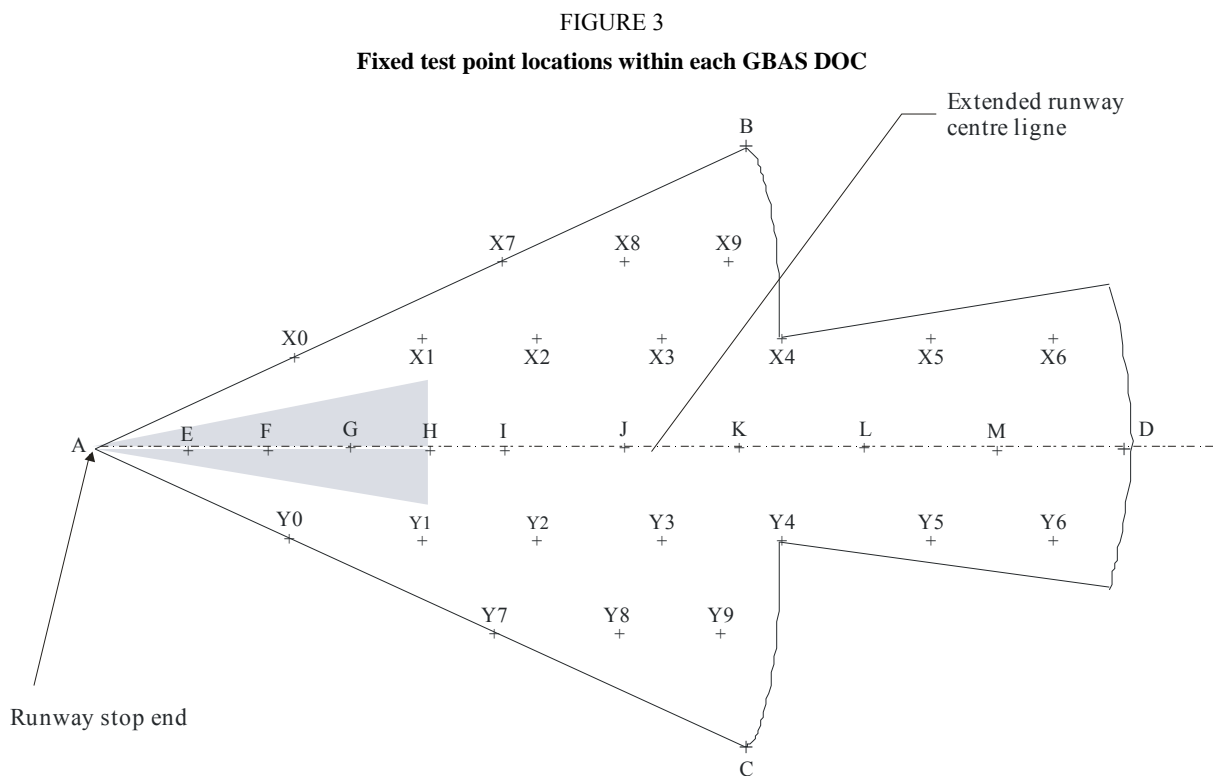
## 2 Location and height of GBAS test points for each DOC

### 2.1 GBAS precision approach test points

#### 2.1.1 Fixed test points

For each of the fixed test points shown in Fig. 3, the minimum height, distance from the localizer site and the bearing relative to the extended runway centre line are given in Table 5.

The fixed test points A, E, F, G and H have minimum heights (see also § 3.2.1) of 0, 0, 150, 300 and 450 m, respectively, above the runway stop end elevation. These values represent a glide path with a slope of 3°. All other fixed test points have minimum heights of 600 m.



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Note 1 – The shaded zone extends 12 km from the runway stop end and is within  $\pm 7.5^\circ$  of the extended runway centre.

#### 2.1.2 Test points related to broadcasting stations

If the broadcasting station is within the shaded zone in Fig. 3:

- an additional test point is generated having the geographic coordinates of the broadcasting station and the same height as the broadcasting antenna.

If the broadcasting station is within or below the GBAS DOC but outside the shaded zone in Fig. 3, an additional test point is generated having the geographic coordinates of the broadcasting station. The minimum height of the test point is the greater of:

- 600 m above the runway stop end; or
- 150 m above the broadcasting antenna.

TABLE 5

Points on or above the extended runway centre line			Points off the extended runway centre line (all at height of 600 m)		
Identification	Distance (km)	Minimum height (m)	Identification	Distance (km)	Bearing relative to the runway centre line (degrees)
A	0	0	B, C	31.5	-35, 35
E	3	0	X0, Y0	7.7	-35, 35
F	6	150	X1, Y1	12.9	-25.5, 25.5
G	9	300	X2, Y2	18.8	-17.2, 17.2
H	12	450	X3, Y3	24.9	-12.9, 12.9
I	15	600	X4, Y4	31.5	-10, 10
J	21.25	600	X5, Y5	37.3	-8.6, 8.6
K	27.5	600	X6, Y6	43.5	-7.3, 7.3
L	33.75	600	X7, Y7	18.5	-35, 35
M	40	600	X8, Y8	24.0	-27.6, 27.6
D	46.3	600	X9, Y9	29.6	-22.1, 22.1

## 2.2 GBAS positioning test points

### 2.2.1 Test points related to broadcasting stations that are inside each DOC

A test point is located at the geographic coordinates of the broadcasting station, at a minimum height which is the greatest of:

- 600 m above local terrain (approximated as 600 m above the site height of the broadcasting station); or
- 300 m above the antenna of the broadcasting station.

### 2.2.2 Test points related to broadcasting stations that are outside each DOC

Broadcasting stations which are outside the DOC but no more than 3 km from the boundary of the DOC are treated as in § 2.2.1. For stations more than 3 km outside the DOC, but within the distance limits specified in § 3.1.2, a test point is generated at the nearest point on the boundary of the DOC, and at a minimum height which is the greatest of:

- 600 m above mean sea level; or
- the broadcasting antenna height above mean sea level.

Test points on the boundary of the DOC which are separated by less than 250 m are regarded as co-located.

### 2.2.3 Additional test points

Additional test points within the DOC may be specified to cover a particular use of a GBAS, for instance where it is used as a landing aid, or where a service is required at an elevation angle of less than 0° (see also § 3.2.3.2).

### **3 Application of general assessment method**

#### **3.1 General**

The compatibility criteria are contained in Annex 1.

##### **3.1.1 Test point selection**

Test points are selected in accordance with the criteria set out in § 2.

##### **3.1.2 Broadcasting stations to be included in the analysis at a test point**

Broadcasting stations are included in the analysis at a test point:

- if there is a line-of-sight path (see definitions in Annex 4) from the broadcasting antenna to the test point and if the calculated signal level is greater than the B1 cut-off value (§ 4.2.3.4 of Annex 1);
- if the free-space field strength (§ 3.3.7 of Annex 1) is at least the value which can cause Type A1 or A2 or B2 incompatibility (§ 4.2 and 4.3 of Annex 1) subject to a maximum separation distance of 125 km in the A1 and B2 cases.

##### **3.1.3 Compatibility calculations**

In order to assess the compatibility of the set of broadcasting stations which meet the conditions of § 3.1.2 at any selected test point (see § 3.1.1), it is necessary to:

- calculate the free-space field strength (§ 3.3.7 of Annex 1) from each of the broadcasting stations at the test point taking account of the slant path distance (see definitions in Annex 4), the maximum e.r.p. and the antenna characteristics (see § 4);
- calculate the GBAS signal level;
- calculate the input power to an aeronautical receiver using § 3.4 of Annex 1.

Taking into account the frequency of the aeronautical service and the information obtained above, the compatibility for each type of interference may be assessed as in § 3.1.3.1 to 3.1.3.4.

###### **3.1.3.1 Type A1 interference**

The frequencies of the two and three component intermodulation products which can be generated by any sub-set of co-sited broadcasting stations are calculated. Any product for which the frequency falls within 200 kHz of the aeronautical frequency is examined further to determine if its field strength is sufficient to cause Type A1 interference, taking account of the criteria in § 4.2.1 of Annex 1.

###### **3.1.3.2 Type A2 interference**

Each of the broadcasting stations (identified as in § 3.1.2) is examined to determine if its frequency falls within 300 kHz of the aeronautical frequency and, if so, if its field strength is sufficient to cause Type A2 interference, taking account of the criteria in § 4.2.2 of Annex 1.

###### **3.1.3.3 Type B1 interference**

The frequencies of the two and three component intermodulation products which can be generated by any sub-set of broadcasting stations (identified as in § 3.1.2) which contains at least one component reaching the trigger value (see § 4.2.3.4 of Annex 1) and for which all components are above the cut-off value (see definitions in Annex 4) (see § 4.2.3.4 of Annex 1) at the input to the aeronautical receiver are calculated. Any product whose frequency falls within 150 kHz of the aeronautical frequency is examined further to determine if the sum (dBm) of the powers at the input



to the aeronautical receiver (see § 3.4 of Annex 1) is sufficient to cause Type B1 interference, taking account of the criteria in § 4.2.3 of Annex 1.

#### **3.1.3.4 Type B2 interference**

Each of the broadcasting stations (identified as in § 3.1.2) is examined to determine if its power at the input to the aeronautical receiver (see § 3.4 of Annex 1) (see Note 1) is sufficient to cause Type B2 interference, taking account of the criteria in § 4.2.4 of Annex 1.

NOTE 1 – The term “equivalent input power” is used to mean “the power at the input of an aeronautical receiver after taking into account any frequency dependent terms”.

### **3.2 Special considerations regarding compatibility assessments**

#### **3.2.1 Test point heights greater than the minimum values**

To ensure that all potential Type B1 interference situations are considered, additional calculations for greater test point heights should be carried out, subject to the test point height not exceeding:

- the maximum height of the DOC; or
- the maximum height at which the trigger value can be achieved.

A more detailed explanation of this matter and the reasons for its restriction to Type B1 interference are given in § 7 of Appendix 1.

#### **3.2.2 GBAS precision approach test points**

##### **3.2.2.1 Fixed test points**

The slant path distance between the broadcasting antenna and a test point is used in field-strength calculations. However, this is subject to the following minimum value:

- 150 m if the broadcasting station is within the shaded zone in Fig. 3, or
- 300 m if the broadcasting station is not within the shaded zone in Fig. 3.

##### **3.2.2.2 Test points related to broadcasting stations**

If the broadcasting station is within the shaded zone in Fig. 3:

- additional calculations are made for a horizontal separation distance of 150 m, using the maximum value of the e.r.p. and the height specified in § 2.1.2.

If the broadcasting station is within or below the GBAS DOC but outside the shaded zone in Fig. 3:

- additional calculations are made for a test point location above the broadcasting station for the height specified in § 2.1.2. The relevant maximum vertical radiation pattern correction derived from § 4.4 is applied.

#### **3.2.3 GBAS positioning test points**

##### **3.2.3.1 Additional test points**

The slant path distance between the antenna of the broadcasting station and any additional test point (see § 2.2.3) is used in field-strength calculations. However, this is subject to a minimum value of 300 m.

### 3.2.4 Calculation of GBAS field strength at test points

For test points with elevation angles greater than  $0^\circ$  and less than  $2.5^\circ$ , the following formula is applicable for installations where the GBAS transmitting antenna is no more than 7 m above ground level:

$$E_{GBAS} = E_{MIN} + \max(20 \log(\theta D_{MX} / D_{TP}); 0) \quad (11)$$

where:

$E_{MIN}$ : ICAO minimum field strength (46 dB( $\mu$ V/m))

$D_{MX}$ : specified range of GBAS (km) in the direction of the test point

$D_{TP}$ : slant path distance (km) from GBAS transmitter site to test point

$\theta$ : elevation angle (degrees) of the test point with respect to the GBAS antenna, given by:

$$\theta = \tan^{-1} \left( \left[ H_{TP} - H_{GBAS} - (D_{TP}/4.1)^2 \right] / [1\ 000 D_{TP}] \right) \quad (12)$$

where:

$H_{TP}$ : test point height (m) above sea level

$H_{GBAS}$ : GBAS antenna height (m) above sea level.

For elevation angles which exceed the value of  $2.5^\circ$ , the field strength is calculated using the elevation angle of  $2.5^\circ$ .

For installations where the GBAS transmitting antenna is more than 7 m above ground level, or where there is a requirement for a service at elevation angles of less than  $0^\circ$ , the minimum value of GBAS field strength (46 dB( $\mu$ V/m)) is to be used for all test points.

The method described above is an interpolation method based on a minimum field-strength value and therefore there is no requirement for a safety margin.

### 3.2.5 Calculation of Type A1 potential interference

Spurious emissions, except radiated intermodulation products, should, as a general measure, be kept at such a low level that there will be no incompatibility to be considered further in the compatibility analysis. Hence A1 calculations are made only for the case of radiated intermodulation products from co-sited broadcasting stations.

Because the e.r.p. of the intermodulation product may not be known, the Type A1 interference margin is calculated indirectly by taking account of the unwanted field-strength value at a test point for each of the transmissions from co-sited broadcasting stations, together with the relevant A1 suppression value for each of these transmitters.

The Type A1 interference margin is calculated as:

$$IM = \max((E_i - S_i); \dots; (E_N - S_N)) + PR - Ew \quad (13)$$

where:

$IM$ : A1 interference margin (dB)

$N$ : number of intermodulation components ( $N = 2$  or  $3$ )

$E_i$ : unwanted field strength (dB( $\mu$ V/m)) of broadcasting transmission  $i$  at the test point

- $S_i$ : A1 suppression (dB) of broadcasting transmitter  $i$
- $PR$ : protection ratio (dB) appropriate for frequency difference between the intermodulation product and the aeronautical frequencies (see Table 2)
- $E_w$ : field strength (dB( $\mu$ V/m)) of the aeronautical signal at the test point (at least 46 dB( $\mu$ V/m) for GBAS).

In a case where the A1 suppression value for a broadcasting transmitter is known, this value should be used when calculating compatibility.

### 3.2.6 Calculation of Type B1 potential interference

To ensure that worst-case B1 results are obtained for broadcasting stations which are sited close to one another, any broadcasting station within 3 km of a test point is regarded as being beneath that test point (see also Appendix 1).

### 3.2.7 Calculation of Type B2 potential interference

In the calculation of Type B2 potential interference, no allowance for the level of the aeronautical signal is made and thus the minimum value of 46 dB( $\mu$ V/m) for GBAS is used.

### 3.2.8 Multiple interference

In principle, the combined effect of multiple sources of potential interference to an aeronautical service at a given test point should be taken into account. However, within the GAM:

- the use of a free-space calculation method normally provides an overestimate of any broadcasting field strength;
- the use of the calculation method given in § 3.2.4 normally provides an underestimate of any aeronautical field strength.

Therefore, it is not considered necessary to take multiple interference into account in the GAM.

However, in the case of A1 compatibility calculations, when the frequency difference between the wanted signal and the spurious emission is either 0 or 50 kHz, the protection ratio should be increased by 3 dB to provide a safety margin.

## 4 Broadcasting station antenna corrections

### 4.1 General

Account is taken of the directional properties of broadcasting station transmitting antennas when calculating field-strength values (§ 3.3.7 of Annex 1).

### 4.2 Polarization discrimination

No account is taken of any polarization discrimination between broadcasting and aeronautical transmissions (except as indicated in § 3.3.7 of Annex 1).

### 4.3 Horizontal radiation pattern

For a broadcasting station which has a directional antenna, the horizontal radiation pattern (h.r.p.) data are specified at 10° intervals, starting from true north. The h.r.p. correction,  $H$  (dB), is given by:

$$H = (\text{e.r.p. in the relevant direction}) - (\text{maximum e.r.p.}) \quad (14)$$

#### 4.4 Vertical radiation pattern correction

Vertical radiation pattern (v.r.p.) corrections are applied only for elevation angles above the horizontal plane through the broadcasting antenna.

Broadcasting antennas vary from a simple antenna such as a dipole, as often used at low power stations, to the more complex multi-tiered antenna normally used at high power stations.

In a case where the actual antenna aperture is not known, Table 6 is used to relate the maximum e.r.p. to the vertical aperture and is based upon a statistical analysis of operational practice.

The v.r.p. corrections described in § 4.4.1 and 4.4.2 apply to both horizontally and vertically polarized transmissions and the limiting values quoted take account of the worst-case slant path.

TABLE 6

Maximum e.r.p. (dBW)	Vertical aperture in wavelengths
e.r.p. $\geq$ 44	8
$37 \leq$ e.r.p. $<$ 44	4
$30 \leq$ e.r.p. $<$ 37	2
e.r.p. $<$ 30	1

##### 4.4.1 v.r.p. corrections for vertical apertures of two or more wavelengths

In order to model the envelope of the vertical radiation pattern of antennas with apertures of two or more wavelengths, the v.r.p. correction,  $V$  (dB), is calculated by using the following formula:

$$V = -20 \log (\pi A \sin \theta) \quad (15)$$

where:

$A$ : vertical aperture (wavelengths)

$\theta$ : elevation angle (relative to the horizontal).

It should be noted that for small elevation angles this expression can produce positive values for  $V$ . In such cases,  $V$  is set to 0 dB (i.e. no v.r.p. correction is applied).

For large elevation angles,  $V$  is limited to a value of  $-14$  dB, that is,  $0 \geq V \geq -14$  dB.

Where the actual maximum v.r.p. correction is known, this should be used as the limiting value in place of  $-14$  dB.

##### 4.4.2 v.r.p. corrections for vertical apertures of less than two wavelengths

When using low gain antennas (those with vertical apertures of less than two wavelengths) the values in Table 7 characterize the envelope of the v.r.p.

For intermediate angles linear interpolation is used.

TABLE 7

Elevation angle (degrees)	v.r.p. correction (dB)
0	0
10	0
20	-1
30	-2
40	-4
50	-6
60	-8
70	-8
80	-8
90	-8

#### 4.4.3 v.r.p. corrections for spurious emissions in the band 108-118 MHz

The v.r.p. corrections given in § 4.4.1 and 4.4.2 are also applied to spurious emissions in the band 108-118 MHz.

#### 4.5 Combination of horizontal and vertical radiation patterns

The relevant values, in dB, of the h.r.p. and v.r.p. corrections are added arithmetically subject to a maximum combined correction of -20 dB, or the maximum v.r.p. correction, whichever is larger. At elevation angles above 45°, no h.r.p. corrections are made.

## Appendix 1 to Annex 2

### Location of test points with maximum interference potential

#### *An explanation of the General Assessment Method (GAM)*

This Appendix is a clarification of the interrelationship between test point location and local maxima of interference potential in relation to the GAM.

#### 1 Aircraft at the same height as a broadcasting station antenna

Consider the situation of an aircraft flying near a broadcasting station. If the aircraft flies at the same height as the broadcasting antenna, the maximum value of broadcasting field strength perceived by the aircraft will be at the point of nearest approach. In the case of an omnidirectional broadcasting antenna, the points of maximum field strength lie on a circle centred on the antenna.

## **2 Aircraft at a greater height than a broadcasting station antenna**

If the aircraft flies at a constant altitude on a radial line towards and over the site of a broadcasting antenna, the point of maximum field strength is vertically above the antenna (see Appendix 2 to Annex 2).

## **3 Relationship between vertical and horizontal separation distances**

If the maximum value of v.r.p. correction for the broadcasting antenna is  $-14$  dB, the maximum value of field strength achieved for a vertical separation of  $y$  m is the same as that for a separation of  $5y$  m in the horizontal plane through the broadcasting antenna (where the v.r.p. correction is 0 dB).

## **4 Location of maximum interference potential**

For A1, A2 and B2 calculations, the vertical separation and horizontal separation concepts are equivalent because the broadcasting signals have a common source location. In the B1 case, the contributing sources are generally not co-sited and the location of the maximum interference potential may not be immediately obvious if the horizontal separation concept is used.

However, if the vertical separation concept is used, the point of maximum interference potential is above one or other of the broadcasting antennas (see Appendix 2 to Annex 2).

Thus, a unique pair (or trio) of points has been defined for a worst-case calculation without having to rely on a very large number of calculation points on some form of three-dimensional grid.

## **5 Test points for GBAS positioning service**

In the GAM, this direct approach is used for GBAS positioning compatibility calculations and is extended by means of additional test points situated at (or near) the DOC boundary to ensure that broadcasting stations outside the DOC are properly taken into account.

## **6 Test points for GBAS precision approach service**

In contrast to the GBAS positioning situation, relatively few broadcasting stations are situated inside or below a GBAS precision approach DOC. In consequence it is easier to demonstrate that compatibility has been fully evaluated by using a set of fixed test points to supplement test points generated above or near any broadcasting stations inside the DOC.

Test points inside the shaded zone in Fig. 3 are chosen to permit assessment of compatibility from ground level upwards and the test point heights chosen represent a glide path with a slope of  $3^\circ$ .

## **7 Effect of increased test point height**

Calculations of 2 or 3 component Type B1 potential interference give worst-case results at the minimum test point height for any given sub-set of broadcasting stations which are within line-of-sight of the test point. However, at greater test point heights it is possible for additional broadcasting stations to become line-of-sight to the test point and further calculations are needed to determine if these stations can contribute to a Type B1 potential interference. The maximum value



of any potential interference occurs at the minimum height for which all relevant broadcasting stations are within line-of-sight of the test point. The greatest height which needs to be considered is the lower of:

- the maximum height of the DOC; or
- the maximum height at which the signal level from a broadcasting station achieves the trigger value.

## Appendix 2 to Annex 2

### Considerations regarding maximum field strength and interference potential

#### 1 Maximum field strength

Consider an aircraft flying on a path at constant altitude along a radial towards a broadcasting station with the aircraft height greater than that of the broadcasting antenna (see Fig. 4).

In the following:

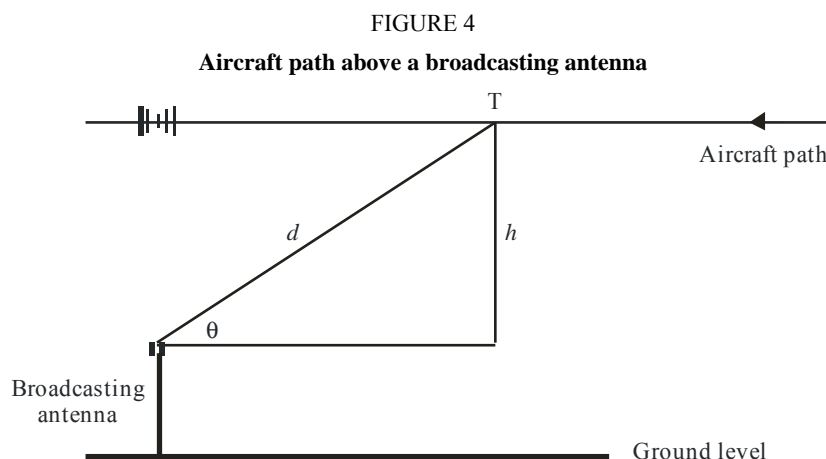
- $P$ : e.r.p. (dBW)
- $h$ : height difference (km)
- $d$ : slant path distance (km)
- $\theta$ : elevation angle, relative to the horizontal at the broadcasting antenna
- $V$ : v.r.p. correction (dB).

At any point T, the field strength  $E$  (dB( $\mu$ V/m)) (Note 1) is given by (see § 3.3.7 of Annex 1):

$$E = 76.9 + P - 20 \log d + V \quad (16)$$

NOTE 1 – For simplicity, it is assumed that there is no h.r.p. correction.

The v.r.p. correction is modelled as  $-20 \log (\pi A \sin \theta)$ , where  $A$  is the vertical aperture of the antenna, in wavelengths, subject to a maximum value of correction for high values of  $\theta$ .



**1.1** At low values of  $\theta$  (where  $V$  is between 0 and its maximum value),

$$E = 76.9 + P - 20 \log d - 20 \log (\pi A \sin \theta) \quad (17)$$

but  $d = h / \sin \theta$

therefore:

$$E = 76.9 + P - 20 \log \left( \frac{h \pi A \sin \theta}{\sin \theta} \right) = 76.9 + P - 20 \log (h \pi A) \quad (18)$$

the field-strength value is constant.

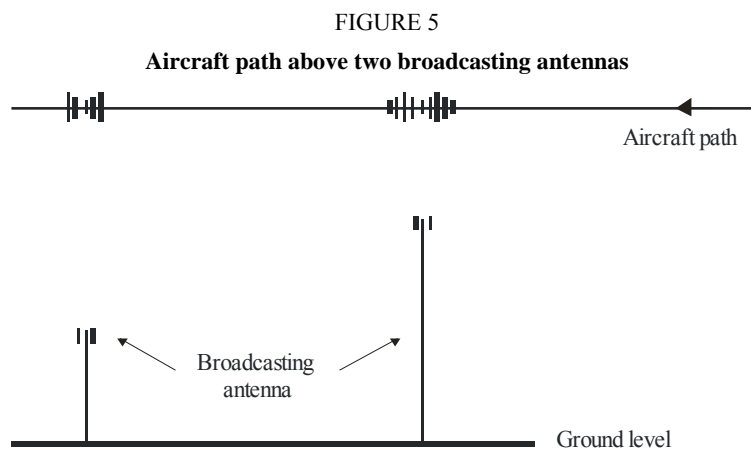
**1.2** At larger values of  $\theta$  (where  $V$  has reached its maximum value), that is near the broadcasting station (the zone shown shaded in Fig. 4), the v.r.p. correction remains constant at its maximum value. Thus:

$$E = 76.9 + P - 20 \log d + \text{constant} \quad (19)$$

The maximum value of field strength is achieved when  $d$  reaches its minimum value ( $= h$ ), directly above the broadcasting antenna.

## 2 Maximum Type B1 interference potential

Consider an aircraft flying on a path at a constant altitude above the line joining two broadcasting antennas (see Fig. 5).



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Outside the shaded areas, the field-strength values are constant (as described in § 1.1), their sum is constant and therefore the Type B1 interference potential is also constant.

Inside each shaded area, the field-strength value from the nearer transmitter increases to a local maximum directly above its antenna (as described in § 1.2).

In the GAM, both local maxima are examined thus permitting the worst case to be identified.

Similar reasoning applies to the three-station case.

## Annex 3

### Detailed compatibility assessment and practical verification

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#### **1 Introduction**

The general assessment method (GAM) predicts more potential incompatibilities to the aeronautical radionavigation service than may occur in practice. However, the results of correlation tests show that when measured data are used in a compatibility analysis, the calculated results match closely with practical experience. Thus, the use of measured data will improve the accuracy of a compatibility analysis.

As an extension to the GAM, a detailed, case-by-case analysis may be conducted using parameters derived from models with increased degrees of accuracy. These models may be used individually or in combination. They approach practical experience when the calculated values of individual parameters approximate more closely to measured values. The advantage of this modelling approach is that it provides opportunities for an efficient compatibility analysis and that it can provide accurate results, thus avoiding the need for extensive flight measurements and their associated practical difficulties.

#### **2 Matters requiring special attention**

##### **2.1 Prediction of broadcasting field strengths**

In the GAM the prediction of broadcasting field strengths is based on free-space propagation. However, measurements have shown that free-space propagation predictions may lead to a significant overestimation in a case where both the transmitting and receiving antennas are at low heights (for example, less than 150 m) above the ground.

In general, it is not possible to perform calculations which are more realistic than those based on free-space propagation because sufficient information is not readily available about the propagation path between the broadcasting station antenna and the test point. In particular, information about the ground profile along this path is required. However, where this information is available, for example from a terrain data bank, then more realistic field-strength calculations may be made. For the reasons given earlier, it is to be expected that the field-strength values calculated by a more detailed method, in particular for propagation paths with a restricted ground clearance, will be significantly lower than the values given using free-space propagation only. Under those circumstances, more detailed field-strength calculation methods will result in a significant reduction in potential incompatibility.

## 2.2 Test point considerations

When undertaking a detailed compatibility analysis for any test point at which the GAM has indicated a potential incompatibility, care should be taken to check the validity of the test point in relation to the aeronautical service volume. Because the GAM generates test points automatically, it is possible that some test points will coincide with locations where, in accordance with published aeronautical documentation:

- aircraft are not able to fly because of natural or man-made obstructions;
- aircraft are not permitted to fly because of specific flight restrictions;
- pilots are advised not to use the aeronautical navigation facility because it is known to give unreliable results in a particular area.

In addition, there can be circumstances where the test points generated by the GAM lie below and therefore outside the service volume of a GBAS positioning DOC. This is particularly likely to occur with lower power GBAS installations.

## 2.3 Consideration of operating stations

Because the GAM is intended to calculate all significant potential incompatibilities within an aeronautical service volume, a number of worst-case assumptions were included. There is thus likely to be an overestimation of potential interference and it may be found that the GAM indicates potential interference in situations where the relevant aeronautical and broadcasting stations are all operating and no interference problem appears to exist in practice. Such situations should be examined as they may provide useful information which will lead to an improvement of the assessment method.

## 3 Multiple interference

In a case where measured values, or reasonably accurate predictions of the wanted and unwanted field strengths are available, account must be taken of multiple intermodulation products, for each interference mode. This may be done by using the power sum of the individual interference margins,  $IM$ , at a given test point.

The total interference margin,  $IM$  (dB), is given by:

$$IM = 10 \log \left( \sum_{i=1}^N 10^{(IM_i/10)} \right) \quad (20)$$

where:

- $N$ : number of individual interference margins
- $IM_i$ : value of  $i$ -th interference margin.

#### **4 Detailed compatibility assessment**

In a detailed, case-by-case compatibility assessment, the most accurate data values available should be used. In particular, the accuracy of compatibility calculations will be improved by:

- replacing the predicted horizontal radiation pattern for a broadcasting antenna with the pattern measured for the antenna as installed;
- replacing the predicted vertical radiation pattern for a broadcasting antenna (see Annex 2, § 4) with the pattern measured for the antenna as installed.

Further improvements to the accuracy of the compatibility calculations will be obtained by:

- replacing predicted levels of broadcasting signals with values measured during flight trials;
- replacing predicted levels of aeronautical signals with values measured during flight trials.

#### **5 Practical verification process**

Verification of the results of compatibility assessment calculations may be obtained by:

- measuring the levels of broadcasting signals at the input to an aeronautical receiver;
- measuring the level of an aeronautical signal at the input to its receiver;
- using an aeronautical receiver with characteristics which have been measured by bench tests, taking into account an adequate range of broadcasting and aeronautical signal levels and frequencies and taking into account the difference between these measured characteristics and those used in the theoretical calculations;
- using an aircraft receiving antenna with a radiation pattern and frequency response which have been measured and taking into account the difference between these measured characteristics and those used in the theoretical calculations.

It is particularly important to use an aircraft receiving antenna with measured characteristics if it is desired to make an accurate comparison between predicted field-strength values for broadcasting stations and the levels of their signals at the input to an aeronautical receiver.

#### **6 Summary**

Improved accuracy may be obtained from a compatibility assessment calculation by using more accurate data, for example:

- measured broadcasting antenna horizontal radiation patterns;
- measured broadcasting antenna vertical radiation patterns.

Verification of a compatibility assessment calculation may be obtained by using:

- measured levels of broadcasting signals;
- measured levels of aeronautical signals;
- an aeronautical receiver with measured characteristics;
- an aircraft receiving antenna with measured radiation pattern and frequency response characteristics.

## Annex 4

### Definitions

#### **Aeronautical information publication (AIP)**

A document published by a Provider State describing, among other things, the characteristics and DOC of aeronautical facilities.

#### **Antenna corrections**

These are the reductions in effective radiated power (e.r.p.) on specified azimuthal bearings and elevation angles relative to the value of e.r.p. in the direction of maximum radiation. They are normally specified as horizontal and vertical corrections in dB.

#### **Designated operational coverage (DOC)**

The volume inside which the aeronautical service operational requirements are met. This is the coverage volume promulgated in aeronautical documents.

#### **Distance and distance calculation**

Where two locations are separated by more than 100 km, then the distance between them is calculated as the shorter great-circle ground distance. For distances less than 100 km, the height of the broadcasting transmitter antenna and the height of the test point are taken into account and if there is a line-of-sight path between them, the slant path distance is calculated.

#### **Effective Earth radius**

An effective Earth radius of 4/3 times the true value is used for distance calculations.

#### **Elevation angle**

The angle relative to the horizontal between two locations (positive above horizontal), using the effective Earth radius value defined above (see Fig. 4).

#### **Flag**

A visual warning device which is displayed in the pilot's indicator associated with a GBAS receiver, indicating when the receiver is inoperative, not operating satisfactorily or when the signal level or the quality of the received signal falls below acceptable values.

#### **Ground-based augmentation system (GBAS)**

An augmentation system in which an aircraft receives satellite navigation augmentation information directly from a ground-based transmitter.

#### **Instrument landing system (ILS)**

A radionavigation system specified in Annex 10 to the Convention on International Civil Aviation and agreed internationally as the current standard precision approach and landing aid for aircraft.

#### **Line-of-sight**

Unobstructed path between two locations using the effective Earth radius defined above.

#### **Minimum separation distances**

Minimum horizontal and vertical separation distances defining a zone around a broadcasting antenna within which aircraft would not normally fly.

**Potential incompatibility**

A potential incompatibility is considered to occur when the agreed protection criteria are not met at a test point.

**Precision approach**

A precision instrument approach and landing with a decision height not lower than 60 m (200 ft) and with either a visibility not less than 800 m or a runway visual range not less than 550 m.

**Provider State**

The authority responsible for the provision of aeronautical services for a country or other specified area.

**Runway threshold**

The beginning of that portion of the runway usable for landing.

**Runway touchdown point**

A point on a runway defining the start of the surface where the aircraft wheels may make contact with the ground, normally inset from the runway threshold.

**Runway stop end**

A point on a runway defining the end of the runway usable for landing.

**Slant path distance**

The shortest distance between two points above the Earth's surface (e.g. between a broadcasting antenna and a test point).

**Test point**

A point for which a compatibility calculation is made. It is completely described by the parameters of geographical position and height.

**Trigger value**

The minimum value of a FM broadcasting signal which, when applied to the input of an aeronautical receiver, is capable of initiating the generation of a third order intermodulation product of sufficient power to represent potential interference.

**VHF omnidirectional radio range (VOR)**

A short range (up to approximately 370 km or 200 nautical miles) aid to navigation which provides aircraft with a continuous and automatic presentation of bearing information from a known ground location.

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