

## RECOMMENDATION ITU-R BO.1293-2

**Protection masks and associated calculation methods for  
interference into broadcast-satellite systems  
involving digital emissions**

(Question ITU-R 223/11)

(1997-2000-2002)

The ITU Radiocommunication Assembly,

*considering*

- a) that protection ratios and associated protection masks are essential characteristics for the television signals in the broadcasting-satellite service (BSS) and associated feeder links;
- b) that the Radio Regulations (RR) Appendices 30 and 30A Plans have been developed by using values of protection ratio and interference calculation methods based on fixed frequency offsets and given types of signal;
- c) that new systems submitted to the Radiocommunication Bureau (BR) for implementation in these plans propose to use new types of signals for which no protection masks and only limited interference calculation methods are available;
- d) that the BR has requested Radiocommunication Study Group 6 to provide additional methodologies and protection criteria to assess interference from and to these new types of signals;
- e) that the definition of protection masks and associated calculation methods provides very useful technical information when revising the RR Appendices 30 and 30A Plans for Regions 1 and 3;
- f) that several studies have now been carried out by various administrations and organisations that validate the proposed interference calculation method,

*recognizing*

- a) that protection masks extend the usefulness of protection ratios, which are themselves associated with fixed frequency offsets;
- b) that appropriate protection masks for interference calculation between digital emissions can be derived by using the methodology provided in Annex 3;
- c) that the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000) has established new BSS and associated feeder-link plans for Regions 1 and 3, based on digital modulation, and new Regions 1 and 3 Lists, thus updating Appendices 30 and 30A;
- d) that Administrations are entitled to implement their Plan assignments at any time without any further restrictions with respect to the characteristics on which the plans are based,

*recommends*

1 that for any EPM/OEPM compatibility analysis carried out under Articles 4 and 5 of Appendices 30 and 30A, Annex 1 should be applied;

2 that the associated interference calculation methods of EPM/OEPM provided in Annex 2, should be used for the compatibility analyses referred to in *recommends* 1.

NOTE 1 – The calculation method to generate protection masks provided in Annex 3 for BSS networks employing all types of digital phase shift keyed emissions may be applied in compatibility analyses for bilateral coordination between administrations.

NOTE 2 – Further studies are needed to develop masks for interference between other types of emission (i.e. for analogue into analogue, digital into analogue and analogue into digital interference). Until such time as these masks are available, the method described in Annex 1 should be used when calculating interference between emissions when the interference is digital.

## ANNEX 1

### Calculation of digital interference in the absence of appropriate protection masks

When applying the calculation method of Annex 2, it is desirable to apply the most appropriate protection mask for the digital interference situation under consideration (i.e. the most appropriate value for  $D_i(f_{oi})$  in Annex 2). For example, for digital interference into a digital emission, this mask can be derived using the calculation method given in Annex 3.

Further studies are required to derive suitable generic protection masks for the case of digital into analogue interference.

Until such time as these masks are available, the method given below should be used to calculate the interference between two emissions, where the interferer is a digital emission.

The value for  $D(f_o)$  is calculated as follows:

$$D(f_o) = 10 \log_{10}(B/b(f_o)) + K$$

where:

$b(f_o)$ : overlapping bandwidth between the interfering carrier and the wanted carrier (MHz)

$B$ : necessary bandwidth of the interfering digital carrier (MHz)

$K$ : positive weighting coefficient.

In general, a protection mask calculation method such as that given in Annex 3 quantifies the value  $K$  which may vary depending upon the wanted and interfering signal parameters and the frequency offset between the two signals (in fact, the method of Annex 3 does not explicitly calculate the factor  $K$  but rather calculates directly the value  $-D(f_o)$ ).

In the absence of suitable protection masks which quantify the factor  $K$ , either directly or indirectly, it should be assumed that  $K = 0$  which corresponds to the worst case.

## ANNEX 2

### Interference calculation methods associated with Annexes 1 and 3\*

#### 1 Introduction

The purpose of this Annex is to define a generic method to calculate the interference situation in the BSS Plans, taking into account different categories of interference (e.g. co-channel, adjacent-channel, etc.).

The generic interference calculation method defined below, associated with the appropriate protection mask calculation methods, should be applied to establish the values necessary to assess the interference situation between different emissions of the BSS Plans.

#### 2 Terminology, symbols and operators

In order to simplify this Annex and to facilitate its understanding, the following terminology, symbols and operators are defined:

Single entry, se: a single interfering carrier is considered

Aggregate, ag: all interfering carriers are considered

Equivalent, eq: combination of co-frequency and frequency offset interference

Overall, ov: combination of feeder-link (up) and downlink (dn) interference

$f_o$ : frequency offset = difference between the centre frequencies of two carriers

$C/I$ : carrier-to-interference ratio (dB)

PR: protection ratio (dB)

EPM: equivalent protection margin (dB)

OEPM: overall equivalent protection margin (dB)

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\* This method has been developed to carry out the compatibility analysis of assignments, submitted to the BR under the provision of RR Appendices 30 and 30A, with parameters different from those used in the establishment of the Plans (channel bandwidth, centre frequency, type of emission, etc.).

$X$ : reduction of the overall  $C/I$  due to interference in the feeder link (dB)

$$\text{Operator } \oplus: A \oplus B = -10 \log \left( 10^{-A/10} + 10^{-B/10} \right)$$

$$\text{Operator } \ominus: A \ominus B = -10 \log \left( 10^{-A/10} - 10^{-B/10} \right)$$

$$\text{Operator } \Sigma\oplus: \sum_{n=1}^N \oplus A_n = -10 \log \left( 10^{-A_1/10} + 10^{-A_2/10} + \dots + 10^{-A_n/10} \right)$$

### 3 Interference calculation methods

In order to calculate the interference situation of an assignment, two major elements are needed:

- the equivalent aggregate carrier to interference ratio,  $C/I_{eq, ag}$ , on both up and downlinks,  $C/I_{eq, ag, up}$ ,  $C/I_{eq, ag, dn}$ , respectively;
- the overall co-channel (or co-frequency) protection ratios of the wanted carrier,  $PR_{ov}$ .

In addition, definitions for the EPM (see Note 1) and OEPM are required.

NOTE 1 – EPM is not needed in case of application of this method to the Region 2 BSS Plan.

**3.1** The first elements, i.e. the equivalent aggregate carrier to interference ratios, are calculated as follows for both the up and downlinks:

$$C/I_{eq, ag, up} = \sum_{i=1}^m \oplus \left( C/I_{i, se, up} + D_i(fo_i) \right)$$

$$C/I_{eq, ag, dn} = \sum_{i=1}^n \oplus \left( C/I_{i, se, dn} + D_i(fo_i) \right)$$

where:

$m$ : number of interfering carriers on the feeder link

$n$ : number of interfering carriers on the downlink

$fo$ : frequency offset between the centre frequencies of the wanted carrier and one interfering carrier; a positive or negative value (MHz)

$D(fo)$ : difference (dB) between the appropriate protection mask's value with no frequency offset (i.e. the centre value at 0 MHz) and the protection mask's value with a frequency offset of  $fo$  MHz.

For the case of a digital wanted carrier and a digital interfering carrier, the value  $D(fo) = -I(fo)$ , where  $I(fo) (\equiv I(\Delta f))$  is defined in Annex 3 assuming a linear or non-linear channel.

For other combinations of wanted and interfering carrier types (digital into analogue interference) appropriate masks remain to be defined. Until such time as these masks are available, the model given in Annex 1 should be applied to evaluate  $D(fo)$ .

From these first elements the overall equivalent aggregate carrier-to-interference ratio (denoted  $C/I_{ov, eq, ag}$ ) can be calculated as follows:

$$C/I_{ov, eq, ag} = C/I_{eq, ag, up} \oplus C/I_{eq, ag, dn}$$

**3.2** The second major element, i.e. the overall protection ratio,  $PR_{ov}$ , is associated to the type of the wanted carriers.

In addition to this second element, a feeder-link protection ratio and a downlink protection ratio,  $PR_{up}$  and  $PR_{dn}$  respectively, can be defined. Assuming a given increase,  $X$ , in the downlink protection ratio to allow for interference in the feeder link,  $PR_{up}$  and  $PR_{dn}$  are defined as follows:

$$PR_{dn} = PR_{ov} + X$$

$$PR_{up} = PR_{ov} \odot PR_{dn}$$

**3.3**  $EPM_{up}$ ,  $EPM_{dn}$  and OEPM definitions

$$OEPM = C/I_{ov, eq, ag} - PR_{ov}$$

$$EPM_{up} = C/I_{eq, ag, up} - PR_{up}$$

$$EPM_{dn} = C/I_{eq, ag, dn} - PR_{dn}$$

## ANNEX 3

### Calculation of protection masks for interference between various types of digital carriers

#### 1 Method

It is assumed that the interfering digital carrier can, for interference calculation purposes, be modelled as a white noise source followed by a square-root, raised cosine pulse shaping filter. The roll-off factor,  $\alpha_i$ , of this filter may be freely specified in the range  $0 \leq \alpha_i \leq 1$  (0% to 100% roll-off). The filter's 3 dB bandwidth is specified by the transmitted symbol rate,  $R_i$ , for the interfering digital signal.

The level of digital interference affecting the wanted digital signal is dependent upon:

- the frequency offset between the wanted and interfering signals,  $\Delta f$ ;
- the characteristics of the receiver's filter;
- the characteristics of the transmission channel that carries the interfering signal.

The receiver's filter is also modelled as a square-root, raised cosine filter with a roll-off factor,  $\alpha_w$ , where ( $0 \leq \alpha_w \leq 1$ ), and a 3 dB bandwidth specified by the wanted signal symbol rate  $R_w$ .

High power amplification of the interfering signal causes spectral side lobe re-growth. The interference contributed by the side lobes is negligible for low values of  $\Delta f$ , but becomes increasingly significant as the frequency offset is increased.

Only the first two side lobes need to be considered. The interference contribution from higher order side lobes is negligible in all practical transmission scenarios.

The level of each side lobe is adjusted with respect to the main spectral lobe to reflect the characteristics of the non-linear channel. The relative level of each side lobe comprises two components  $L_s$  and  $X$ :

- A value  $L_s$  that is dependent upon the non-linear characteristics of the high power amplifier (HPA) and upon the amplifier's drive level (backoff). The value of  $L_s$  is different for each side lobe.
- A value  $X$  that represents the effect of filtering at the output of the HPA. This attenuation value is assumed to be the same for all spectral side lobes. This approach is conservative, since the gain of the post-HPA filter is not flat, but rolls off with increasing frequency offset from the channel centre frequency.

The parameters  $L_s$  and  $X$  are expressed in decibels.

The parameters  $R_i$  and  $R_w$  are expressed in Msymbol/s. The total bandwidths of the wanted and interfering signals are given by  $R_w(1 + \alpha_w)$  MHz and  $R_i(1 + \alpha_i)$  MHz respectively. The frequency difference parameter  $\Delta f$  is expressed in MHz. The interference at the output of the receiver filter is assumed to be noise-like.

A common algorithm is used to calculate the wanted signal power at the input to the receiver and the interference power contributions from the main spectral lobe and from each of the spectral side lobes. The procedure for calculating each power contribution is as follows (see § 3 for definitions of the terms used below):

- a) set the input parameters ( $R_i$ ,  $R_w$ ,  $\alpha_i$ ,  $\alpha_w$ ,  $\delta f$ ,  $L_s$  and  $X$ ) to the appropriate values for the power contribution to be calculated (wanted signal, interfering signal main spectral lobe or interfering signal spectral side lobe);
- b) calculate the nine pairs of limits ( $U_n$ ,  $L_n$ ,  $n = 1, \dots, 9$ );
- c) calculate the five power contribution terms ( $C_m$ ,  $m = 1, \dots, 5$ );
- d) calculate the total received power,  $P$ :

$$P = 10^{\frac{L_s - X}{10}} \sum_{m=1}^5 C_m$$

The level of interference power  $I(\Delta f)$ , measured at the output of the receiver's filter and expressed relative to the wanted carrier power for a reference link  $C/I$  of 0 dB (i.e. assuming equal wanted and interfering carrier powers), is calculated as follows.

*Step 1:* Calculate the wanted signal power,  $P_w$ , at the output of the receiver filter using the above algorithm and setting the input parameter values as follows:

$$R_i = R_w, \quad \alpha_i = \alpha_w, \quad \delta f = 0, \quad L_s = 0, \quad X = 0$$

*Step 2:* Calculate the interfering signal power contribution from the main spectral lobe,  $P_0$ , at the output of the receiver filter using the same algorithm and setting the input parameters as follows:

$$\delta f = \Delta f, \quad L_s = 0, \quad X = 0$$

*Step 3:* Calculate the interfering signal power contribution from the first spectral side lobe,  $P_1$ , with the input parameters set as follows:

$$\delta f = |\Delta f| - R_i, \quad L_s = L_1 \neq 0, \quad X \neq 0$$

The value for  $L_s$  depends upon the non-linear characteristics of the HPA and its drive level. The value of  $X$  depends upon the out-of-band attenuation characteristics of the post-HPA filter.

*Step 4:* Calculate the interfering signal power contribution from the second spectral side lobe,  $P_2$ , with the input parameters set as follows:

$$\delta f = |\Delta f| - 2R_i, \quad L_s = L_2 \neq L_1 \neq 0, \quad X \neq 0$$

The value for  $L_s$  again depends upon the non-linear characteristics of the HPA and its drive level. The value of  $X$  is the same as in Step 3.

*Step 5:* Calculate the relative interference power for the given signal parameters and frequency offset:

$$I(\Delta f) = 10 \log \left( \frac{P_0 + P_1 + P_2}{P_w} \right) \quad \text{dB}$$

## 2 Example calculation of a protection mask

As an (arbitrary) example, it is assumed that the wanted and interfering signal parameters are as follows:

*Wanted digital signal:*

Symbol rate,  $R_w = 27.5$  Msymbol/s

Roll-off factor,  $\alpha_w = 0.35$  (35% cosine roll-off).

*Interfering digital signal:*

Symbol rate,  $R_i = 27.5$  Msymbol/s

Roll-off factor,  $\alpha_i = 0.35$  (35% cosine roll-off).

*Side lobe levels:*

First side lobe level,  $L_{s1} = -17.0$  dB

Second side lobe level,  $L_{s2} = -27.5$  dB.

*Post-HPA filtering:*

Side lobe attenuation,  $X_f = 12.0$  dB.

The frequency offset between the wanted and interfering signals,  $\Delta f$ , is assumed to be 38.36 MHz. The application of the calculation method described in § 1 of this Annex, and detailed in § 3 of this Annex, gives the following:

*Step 1:* Calculate the wanted signal power,  $P_w$ , at the output of the receiver filter:

$$\begin{aligned} R_i &= R_w, & \alpha_i &= \alpha_w, & L_s &= 0, & X &= 0, & \delta f &= 0 \\ L_1 &= U_8 = U_9 = -8.937 \\ U_1 &= L_2 = U_2 = L_3 = U_3 = L_4 = U_4 = L_5 = U_5 = L_6 = L_7 = L_8 = L_9 = 8.937 \\ U_6 &= U_7 = 18.563 \\ C_1 &= 0.825, & C_2 &= 0, & C_3 &= 0, & C_4 &= 0.088, & C_5 &= 0 \\ P_w &= 0.913 \end{aligned}$$

*Step 2:* Calculate the interfering signal power,  $P_0$ , due to the main spectral lobe at the output of the receiver filter:

$$\begin{aligned} L_s &= 0, & X &= 0, & \delta f &= \Delta f \\ L_1 &= L_3 = L_4 = 29.422, & U_1 &= L_2 = L_5 = L_7 = 8.937, & L_6 &= L_9 = 47.297, & L_8 &= -18.563 \\ U_9 &= -8.937, & U_2 &= U_5 = -29.422, & U_3 &= U_4 = U_6 = 18.563, & U_7 &= U_8 = -19.797 \\ C_1 &= 0, & C_2 &= 0, & C_3 &= 0, & C_4 &= 0, & C_5 &= 0 \\ P_0 &= 0 \end{aligned}$$

*Step 3:* Calculate the interfering signal power,  $P_1$ , due to the first spectral side lobe at the output of the receiver filter:

$$\begin{aligned} L_s &= L_{s1}, & X &= X_f, & \delta f &= |\Delta f| - R_i \\ L_1 &= 1.923, & U_1 &= L_2 = L_3 = L_4 = L_5 = L_7 = 8.937, & U_2 &= U_5 = L_8 = -1.923 \\ U_3 &= U_4 = U_6 = 18.563, & L_6 &= L_9 = 19.797, & U_7 &= 7.703, & U_8 &= U_9 = -8.937 \\ C_1 &= 0.605, & C_2 &= 0, & C_3 &= 0, & C_4 &= 0, & C_5 &= 0 \\ P_1 &= 7.618 \times 10^{-4} \end{aligned}$$

*Step 4:* Calculate the interfering signal power,  $P_2$ , due to the second spectral side lobe at the output of the receiver filter:

$$\begin{aligned} L_s &= L_{s2}, & X &= X_f, & \delta f &= |\Delta f| - 2R_i \\ L_1 &= U_8 = U_9 = -8.937, & U_1 &= U_3 = U_4 = L_9 = -7.703, & L_2 &= L_3 = L_4 = L_5 = L_6 = 8.937 \\ U_2 &= U_5 = U_7 = 18.563, & L_7 &= L_8 = 25.578, & U_6 &= 1.922 \\ C_1 &= 0.395, & C_2 &= 0, & C_3 &= 0, & C_4 &= 0, & C_5 &= 0 \\ P_2 &= 4.431 \times 10^{-5} \end{aligned}$$

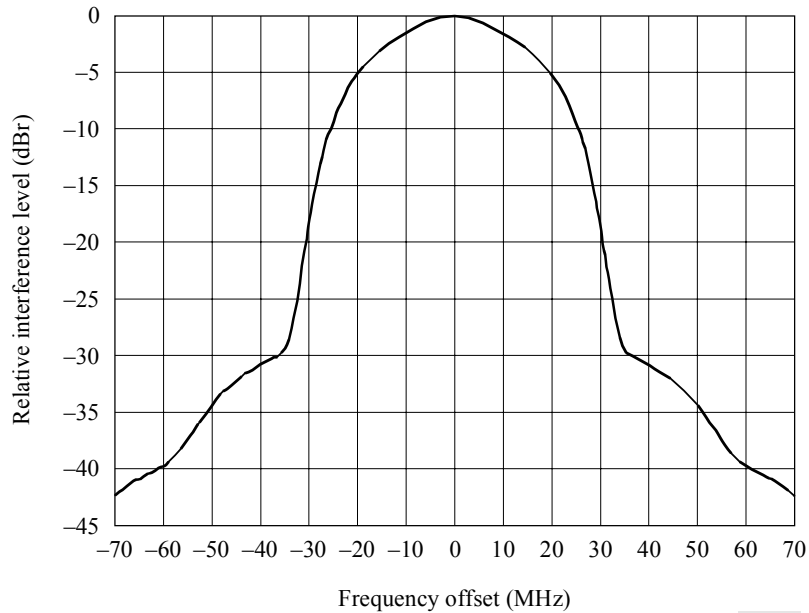


Step 5: Calculate the total interference power relative to the wanted signal power:

$$I(\Delta f) = -30.5$$

Following this procedure for a range of frequency offsets results in the example protection mask given in Fig. 1.

FIGURE 1



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### 3 Algorithms: Calculation of the received (wanted or interfering) signal power

#### 3.1 Limits

$$A = (1 - \alpha_w) \frac{R_w}{2}$$

$$B = (1 + \alpha_w) \frac{R_w}{2}$$

$$C = (1 - \alpha_i) \frac{R_i}{2}$$

$$D = (1 + \alpha_i) \frac{R_i}{2}$$

$$L_1 = \max(-A; \delta f - C)$$

$$L_4 = \max(A; \delta f - C)$$

$$L_7 = \max(A; -\delta f + C)$$

$$U_1 = \min(A; \delta f + C)$$

$$U_4 = \min(B; \delta f + C)$$

$$U_7 = \min(B; -\delta f + D)$$

$$L_2 = \max(-A - \delta f; C)$$

$$L_5 = \max(A; -\delta f - C)$$

$$L_8 = \max(-B; -\delta f + C)$$

$$U_2 = \min(A - \delta f; D)$$

$$U_5 = \min(B; -\delta f + C)$$

$$U_8 = \min(-A; -\delta f + D)$$

$$L_3 = \max(-A + \delta f; C)$$

$$L_6 = \max(A; \delta f + C)$$

$$L_9 = \max(-B; \delta f + C)$$

$$U_3 = \min(A + \delta f; D)$$

$$U_6 = \min(B; \delta f + D)$$

$$U_9 = \min(-A; \delta f + D)$$

NOTE 1:

$\max(a; b)$ : maximum value of  $a$  and  $b$

$\min(a; b)$ : minimum value of  $a$  and  $b$

$\delta f$  = frequency of interfering signal – frequency of wanted signal.

### 3.2 Functions

When  $1 \leq n \leq 3$ :

$$p_n(a,b) = \begin{cases} f_n(a) - f_n(b) & \text{for } a > b \\ 0 & \text{for } a \leq b \end{cases}$$

$$f_1(x) = \left( \frac{x}{R_i} \right) \quad f_2(x) = \frac{\alpha_i}{2\pi} \cos\left( \frac{\pi}{2} \frac{2x - R_i}{\alpha_i R_i} \right) \quad f_3(x) = \frac{\alpha_w R_w}{2\pi R_i} \cos\left( \frac{\pi}{2} \frac{2x - R_w}{\alpha_w R_w} \right)$$

When  $4 \leq n \leq 5$ :

$$p_n(a,b,\delta f) = \begin{cases} f_n(a,\delta f) - f_n(b,\delta f) & \text{for } a > b \\ 0 & \text{for } a \leq b \end{cases}$$

$$f_4(x,y) = \begin{cases} f_{4a}(x,y) & \text{for } \alpha_w R_w = \alpha_i R_i \\ = f_{4b}(x,y) & \text{for } \alpha_w R_w \neq \alpha_i R_i \end{cases} \quad f_5(x,y) = \begin{cases} f_{5a}(x,y) & \text{for } \alpha_w R_w = \alpha_i R_i \\ = f_{5b}(x,y) & \text{for } \alpha_w R_w \neq \alpha_i R_i \end{cases}$$

$$f_{4a}(x,y) = \frac{1}{16\pi R_i} \left( 2\pi x \cos\left( \frac{\pi}{2} \frac{2y + R_i - R_w}{\alpha_i R_i} \right) - \alpha_i R_i \sin\left( \frac{\pi}{2} \frac{4x - 2y - R_i - R_w}{\alpha_i R_i} \right) \right)$$

$$f_{4b}(x,y) = \frac{\alpha_i \alpha_w R_w}{4\pi(\alpha_i^2 R_i^2 - \alpha_w^2 R_w^2)} \left( \alpha_i R_i \cos\left( \frac{\pi}{2} \frac{2x - R_w}{\alpha_w R_w} \right) \sin\left( \frac{\pi}{2} \frac{2y - 2x + R_i}{\alpha_i R_i} \right) + \alpha_w R_w \sin\left( \frac{\pi}{2} \frac{2x - R_w}{\alpha_w R_w} \right) \cos\left( \frac{\pi}{2} \frac{2y - 2x + R_i}{\alpha_i R_i} \right) \right)$$

$$f_{5a}(x,y) = \frac{1}{16\pi R_i} \left( \alpha_i R_i \sin\left( \frac{\pi}{2} \frac{4x - 2y - R_i + R_w}{\alpha_i R_i} \right) - 2\pi x \cos\left( \frac{\pi}{2} \frac{2y + R_i + R_w}{\alpha_i R_i} \right) \right)$$

$$f_{5b}(x,y) = \frac{\alpha_i \alpha_w R_w}{4\pi(\alpha_i^2 R_i^2 - \alpha_w^2 R_w^2)} \left( \alpha_i R_i \cos\left( \frac{\pi}{2} \frac{2x + R_w}{\alpha_w R_w} \right) \sin\left( \frac{\pi}{2} \frac{2x - 2y - R_i}{\alpha_i R_i} \right) - \alpha_w R_w \sin\left( \frac{\pi}{2} \frac{2x + R_w}{\alpha_w R_w} \right) \cos\left( \frac{\pi}{2} \frac{2x - 2y - R_i}{\alpha_i R_i} \right) \right)$$

### 3.3 Power contributions

$$C_1 = p_1(U_1, L_1) + \frac{1}{2} \sum_{n=2}^5 p_1(U_n, L_n) + \frac{1}{4} \sum_{n=6}^9 p_1(U_n, L_n)$$

$$C_2 = p_2(U_2, L_2) + p_2(U_3, L_3) + \frac{1}{2} [p_2(U_6 - \delta f, L_6 - \delta f) + p_2(U_7 + \delta f, L_7 + \delta f) + p_2(U_8 + \delta f, L_8 + \delta f) + p_2(U_9 - \delta f, L_9 - \delta f)]$$

$$C_3 = p_3(U_4, L_4) + p_3(U_5, L_5) + \frac{1}{2} [p_3(U_6, L_6) + p_3(U_7, L_7) + p_3(-L_8, -U_8) + p_3(-L_9, -U_9)]$$

$$C_4 = p_4(U_6, L_6, \delta f) + p_4(U_7, L_7, -\delta f)$$

$$C_5 = p_5(U_8, L_8, -\delta f) + p_5(U_9, L_9, \delta f)$$

### 3.4 Total received signal power

$$\text{Power} = 10^{\frac{L_s - X}{10}} \sum_{m=1}^5 C_m$$

## APPENDIX 1

### TO ANNEX 3

#### Notification of parameters associated to digital emissions

Application of the method described in Annex 3 for calculation of protection masks for interference between digital emissions requires the notification of parameters associated with each digital emission. These parameters are:

- the digital modulation type (this method is applicable only to phase shift keyed signals);
- the transmitted symbol rate (Msymbol/s);
- the roll-off factor of the digital pulse shaping filter (assumed to be a cosine roll-off filter or an approximation thereof), a value in the range 0 to 1;
- the relative levels of the first and second side lobes,  $L_{s1}$  and  $L_{s2}$  (dB);
- the side lobe attenuation,  $X$  (dB) resulting from post-HPA filtering.

The first three of these items are already required by RR Appendix 4. In addition, the last two items are recommended to be provided to be added to RR Appendix 4 by a future competent conference.

Most downlink digital TV carriers occupy the whole of the transponder bandwidth and the transponder is operated at saturation for maximum downlink power. Studies have shown that, under these conditions, suitable side lobe relative levels are  $-18$  dB and  $-30$  dB respectively. Furthermore, since there is always filtering (an output multiplexer) at the output of the on-board HPA (travelling wave tube amplifier (TWTA)), the parameter  $X$  is non-zero. The precise value of  $X$  will vary from system to system. A value of 12 dB seems to be a conservative minimum value that should be exceeded by all new systems implementing contiguous co-polar channels.

For uplinks there is typically no post-HPA filter but the HPA is operated with a backoff to control the out-of-band side lobe levels. Side lobe levels of  $-29$  dB and  $-39.5$  dB are unlikely to be exceeded in feeder links to BSS systems.

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