PAPER

Characteristics and Applicability of Frequency Sharing Criteria in the Broadcasting Satellite Link

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SUMMARY Two frequency sharing criteria for BSS (Broadcasting-Satellite Service) are enacted in Sect. 1 of Annex 1 to Appendix 30 to Radio Regulations. These two criteria are pfd (power flux-density) and EPM (Equivalent Protection Margin) values. In this paper, the two criteria are compared and studied from the view point of applicability to the sharing cases between BSS and BSS. In particular, it is shown that in some cases, the EPM criterion contributes to alleviate the problem of "sensitive satellite network", i.e., one that has relatively low transmission power and is very weak against interference and blocks the new satellite to enter.

Disclaimer The views and positions expressed by the authors are strictly personal and do not constitute, nor can be interpreted as, the position of the International Telecommunication Union on the topics addressed in this paper.

key words: *broadcasting-satellite service, frequency sharing criteria, equivalent protection margin, power flux-density*

1. Introduction

This paper describes the two frequency sharing criteria between BSS (Broadcasting-Satellite Service) networks. In Section 1 of Annex 1 to Appendix 30 to RR (Radio Regulations), two types of threshold value triggering coordination are given: a) pfd (power flux-density) and b) EPM (Equivalent Protection Margin). According to the provision in RR as cited below [1], a proposed satellite network does not need to coordinate with others if either the pfd criterion or the EPM criterion is met.

.., an administration in Region 1 or 3 is considered as not being affected if either of the following two conditions is met:
a) .., the power flux-density at any test point within the service area .., does not exceed the following values: (WRC-15)
...
b) ... the equivalent downlink protection margin corresponding to a test point of its assignment ... does not fall more than 0.45 dB below 0 dB or, if already negative, more than 0.45 dB.

For the allocation of frequencies the world has been divided into three Regions. Region 1 is Europe including countries belonging to the former Soviet Union and Africa; Region 2 is America and Region 3 is Asia and Oceania. The pfd criterion was introduced in addition to the EPM criterion by WRC-2000 (World Radiocommunication Conference in 2000) for BSS only in Region 1 and Region 3, but not for BSS in Region 2. In Regions 1 and 3, since a new satellite only needs to meet one of the two criteria, it is easier for the new satellite to be successfully coordinated than in case of Region 2. In this paper, the comparison between the two criteria and their characteristics are studied thus focusing only on Regions 1 and 3.

This study is useful for satellite broadcasting system designs including the selection of an orbital position, in which the possible impact of interference on the BSS satellite networks can be taken into account. Concerning the selection of an orbital position, this study also explains which criterion should be used by a proposed new network so that the proposed new network can transmit higher power and at the same time other BSS networks will not be considered as being affected by the proposed new network.

From the aspect of regulations, it was not clear about the features and merits of the two criteria. In this paper the consideration is given, and in particular it is shown that the EPM criterion contributes to alleviate the problem of "sensitive satellite network", that has a low transmitting power and is very weak against interference, then results in the irrational blockage to a new comer. It means the EPM criterion contributes to the efficient use of orbit/spectrum resources. Examples of such "sensitive satellite networks" can be found in BR-IFIC (Space services) (Radiocommunication Bureau - International Frequency Information Circular) data issued by ITU-R (International Telecommunication Union – Radiocommunication Sector). The mechanism for the alleviation of such a problem is explained.

2. Pfd Criterion

This section explains the pfd criterion and its features. The pfd value is derived as e.i.r.p. (Equivalent Isotropically Radiated Power) divided by $4 * \pi * d^2$, where d is the distance between the satellite and the receiving point on the Earth where the pfd value will be calculated. The pfd criterion is easy to be calculated and understood. Therefore, it was proposed in WRC-2000 to suppress the EPM criterion and only the pfd criterion was introduced for the BSS and BSS sharing in Regions 1 and 3.

The threshold pfd value triggering coordination is shown below in italics (cited from RR [1]), as a function of orbital separation angle θ between two BSS satellites.

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$$
\begin{aligned}
&-147\ dB(W/(m^2\cdot 27\ MHz))\ for\ 0^\circ \le \theta < 0.23^\circ \\
&-135.7 + 17.74\log(\theta)\ dB(W/(m^2\cdot 27\ MHz))\ for\ 0.23^\circ \le \theta < 2.0^\circ \\
&-136.7 + 1.66\,\theta^2\ dB(W/(m^2\cdot 27\ MHz))\ for\ 2.0^\circ \le \theta < 3.59^\circ \\
&-129.2 + 25\log(\theta)\ dB(W/(m^2\cdot 27\ MHz))\ for\ 3.59^\circ \le \theta < 9.0^\circ
\end{aligned} \tag{1}
$$

where θ is the minimum geocentric orbital separation in degrees between the wanted and interfering space stations, taking into account the respective East-West station-keeping accuracies.

Regarding the satellite station-keeping above, RR requires that space stations in BSS must be maintained in position with an accuracy equal to or better than $+/-0.1$ degrees in the East - West directions.

The threshold pfd value above is depicted in Fig. 1 (WRC-2003, Blue line). Note that the pfd value in Fig. 1 is expressed per 1 MHz bandwidth, instead of 27 MHz, in order to be consistent with other sharing cases. The threshold pfd value is the single–entry interference level as indicated "*I*" of an interfering satellite (new comer) in Fig. 1. It is an absolute value regardless of the wanted level as indicated "*C*" of an interfered-with satellite (existing) in Fig. 1.

The threshold pfd value was derived based on the antenna discrimination of 60 cm to 2.4 m diameters. The reference receiving earth station antenna pattern is given in Fig. 7 *bis* in Sect. 3.7.2, Annex 5 of Appendix 30 to RR. Figure 2 overwrites the pfd value (WRC-2003) with the antenna discrimination of 60 cm diameter. Note that the angles in the abscissa for the 60 cm antenna is transformed from a geocentric angle to a topocentric angle under the assumption that the earth station antenna locates at a latitude of 33 degrees North and the difference between its longitude and the satellite orbital position is 13 degrees. The location of the earth station is the same throughout this paper.

For the purpose of comparison, the threshold pfd value developed in WRC-2000 [2] is also shown in Fig. 1 (WRC-2000, Red line). The pfd value was reduced by 1.7 dB between 2° and 9° (See Fig. 3) in WRC-2003 in order to reflect the reduction of PR (Protection Ratio) by 3 dB (24 dB to 21 dB) [3]. In effect, this reduction of the threshold pfd value plays a role to protect a smaller antenna.

Since the threshold pfd value is an absolute interference power expressed in terms of pfd, it can be converted to $\Delta T/T$ (the increase of noise temperature caused by the interference and the system noise temperature ratio), $\Delta C/N$ (the degradation of C/N, Carrier to Noise ratio) defined as $(C/N)-(C/(N+I))$, where $C/(N+I) = -10\log(10^{-(C/N)/10} + 10^{-(C/I)/10})$, and I/N (Interference to Noise ratio). Note that the $\Delta T/T$, I/N and $\Delta C/N$ are equivalent and can be converted from one to another [4].

In the conversion of the pfd value to $\Delta T/T$ etc., the total link noise temperature of the earth station is assumed to be 174 K (Sect. 2, Annex 6, AP30). Then the system noise N is given as follows.

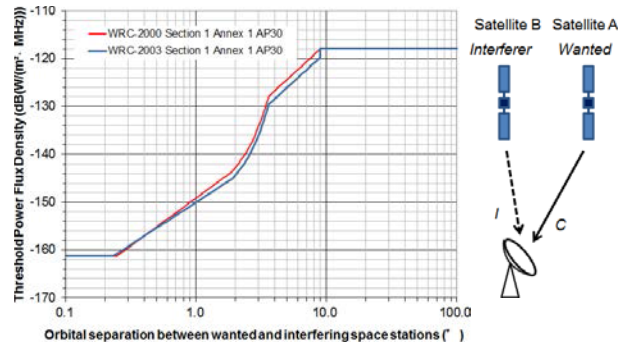


Fig. 1 Comparison of WRC-2000 and WRC-2003 pfd masks in Section 1, Annex 1, AP30.

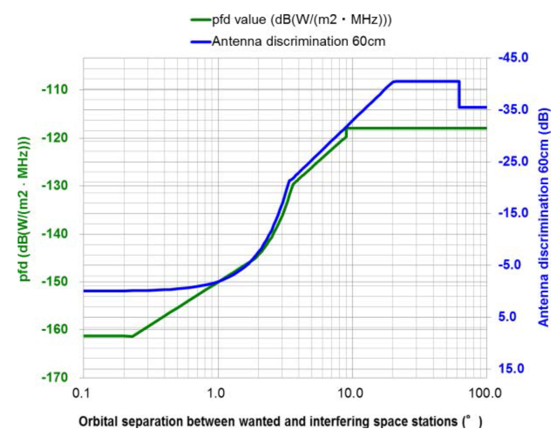


Fig. 2 Comparison of WRC-2003 pfd masks and the antenna discrimination (60 cm).

Fig. 3 Difference in pfd masks by WRC-2000 and WRC-2003.

$$
N = kTB = -228.6\,(\mathrm{dBW/Hz/K}) + 10\log(174)\,(\mathrm{dBK}) + 10\log(10^6)\,(\mathrm{dB}) = -146.2\,(\mathrm{dBW/MHz}) \tag{2}
$$

The interference power I to the receiver of the earth station is derived by using the antenna discrimination D (dB) and the effective antenna area Ae (m^2) as follows.

$$
I = \mathrm{pfd} + D + 10\log(Ae)\,(\mathrm{dBW/MHz}) \tag{3}
$$

The antenna efficiency is assumed to be 61.4%, which gives the absolute maximum antenna gain of 35.5 dBi at 12.1 GHz (See Fig. 7*bis*, Sect. 3.7.2, Annex 5, AP30). The $\Delta T/T$, $\Delta C/N$ and I/N converted from the pfd mask are shown in Fig. 4. The specific example values for $3.59^\circ \le \theta < 9.0^\circ$ are

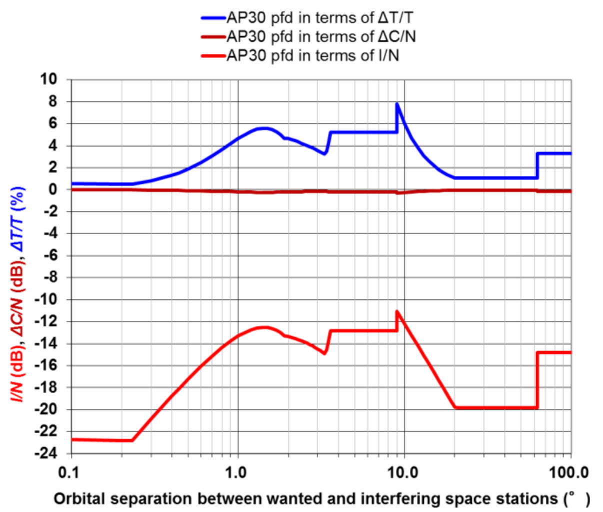


Fig. 4 $\Delta T/T$, $\Delta C/N$ and I/N corresponding to the pfd mask (WRC-2003).

Table 1 Example of $\Delta T/T$, $\Delta C/N$ and I/N corresponding to the pfd values.

θ	pfd	$\Delta T/T$	$\Delta C/N$	I/N
3.59°≤ θ < 9.0°	-129.60 to -119.7 dB(W/(m^2· MHz))	5.24 %	-0.22 dB	-12.81 dB

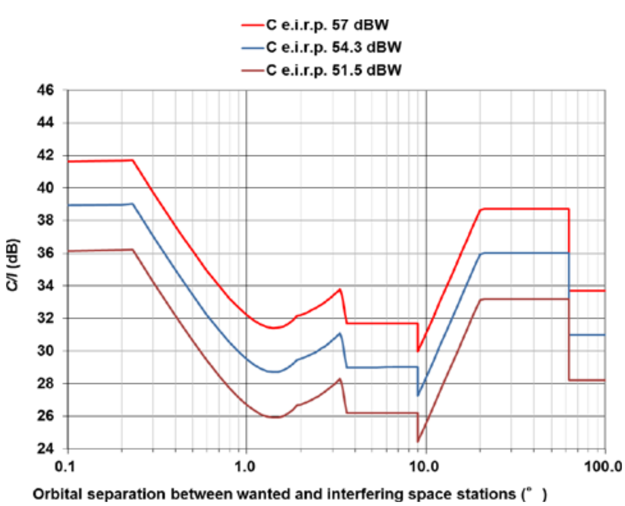


Fig. 5 C/I corresponding to pfd mask (WRC-2003).

shown in Table 1.

The C/I (Carrier to Interference ratio) values corresponding to the pfd value is a function of the wanted level (C) (See Fig. 5). The specific example values of C/I for $3.59° \leq \theta < 9.0°$ are shown in Table 2. Note that the C/I value corresponds to a single-entry interference.

3. EPM Criterion

This section explains the EPM criterion and its features. The

Table 2 Example of C/I corresponding to the pfd values.

θ	pfd	57 dBW	54.3dBW	51.5dBW
3.59°≤ θ< 9.0°	-129.60 to -119.7 dB(W/(m^2· MHz))	31.7 dB	29.0 dB	26.2 dB

EPM, referred to as M in this paper, is defined in Sect. 3.4 of Annex 5 to Appendix 30 to RR, as follows.

$$M = -10\log\left(10^{\frac{-M_1}{10}} + 10^{\frac{-M_2}{10}} + 10^{\frac{-M_3}{10}}\right) \tag{4}$$

where M_1 is the value (dB) of the protection margin for the same channel (co-channel). This is defined in the following expression where the powers are evaluated at the receiver input:

$$M_1 = \frac{\text{wanted power}}{\text{sum of the co-channel interfering powers}} \ (dB) - (\text{co-channel protection ration}) \ (\text{dB}) \tag{5}$$

where co-channel protection ration is the required value of the aggregate C/I used in the BSS Plan and is given in Annex 5 to Appendix 30 to RR.

M_2 and M_3 are the values (dB) of the upper and lower adjacent-channel protection margins respectively.

The co-channel protection ratios (PR) in Regions 1 and 3 are as follows.

31 dB for 1977 BSS Plan.
24 dB for WRC-97 revision of BSS Plan for downlink.
21 dB for WRC-2000 digital BSS Plan.

While the EPM in Eq. (4) is expressed from the view point of frequency assignments, it is expressed as the ratio of carrier to aggregate interference by the next equation (See also Fig. 6).

$$M = \frac{C}{I_{aggr}} - PR = \frac{C}{\sum_{i=1}^{n} I_i} - PR \tag{6}$$

A certain amount of spectrum in the BSS band is assigned equally to all countries for future use in order to guarantee equitable access to the geostationary orbit and spectrum among countries, which constitutes a BSS Plan. For example, in the Regions 1 and 3 BSS Plan, 12 channels in the 11.7–12.2 GHz band are assigned to all Region 3 countries. In addition, the BSS band in Regions 1 and 3 is used through the coordination procedure and such spectrum is registered in the List, which are additional uses of satellites beyond the Plan (i.e. use of assignments with characteristics different from those appearing in the Regions 1 and 3 Plan and which are capable of causing more interference than the corresponding entries in the Plan or use of assignments in addition to those appearing in the Plan). For an assignment, Reference EPM (*Ref. EPM*) is defined in ITU-R to be the EPM when all the interfering assignments in the Plan and

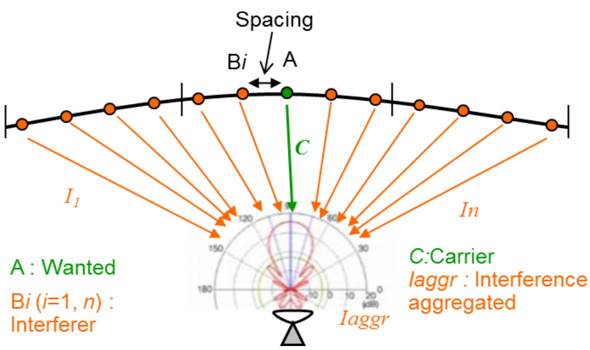


Fig. 6 Mechanism of EPM.

Table 3 Example of the relation among transmitting power, *Ref. EPM*, threshold *C/ Inew*. etc.

C e.i.r.p. (dBW)	54.30	54.30	54.30	54.30	54.30
PR (dB)	21.0	21.0	21.0	21.0	21.0
C/Iaggr (dB)	36.0	26.0	21.0	16.0	6.0
Iaggr (dBW)	18.3	28.3	33.3	38.3	48.3
Ref. EPM (dB)	**15.0**	**5.0**	**0.0**	**-5.0**	**-15.0**
C/Inew (dB)	**20.7**	**22.0**	**30.6**	**25.6**	**15.6**
Inew (dBW)	33.6	32.3	23.7	28.7	38.7
C/(Iaggr+Inew) (dB)	20.55	20.55	20.55	15.55	5.55
EPM (Iaggr+Inew) (dB)	**-0.45**	**-0.45**	**-0.45**	**-5.45**	**-15.45**
Degradation(dB)	-15.45	-5.45	-0.45	-0.45	-0.45

the List located within 9 degrees coordination arc of that assignment are considered. Note that the *Ref. EPM* is updated by ITU-R every time a new assignment is entered in the Plan or the List or an assignment in the List is cancelled.

The EPM criterion is hard to be calculated and understood, but it considers all interference sources coming from other BSS networks. In Regions 1 and 3, according to RR, only other BSS networks located within $+/-9$ degrees are taken into account in calculating EPM. It is useful to recognize the total amount of interference in terms of aggregate interference because the BSS Plan is for future use. The EPM criterion was adopted since the development of the BSS Plan back in 1977 and in WRC-2000 the EPM criterion was kept despite proposals to suppress it.

The EPM criterion giving the threshold value for coordination is described in Sect. 1, Annex 1 of Appendix 30 to RR (See **1. Introduction** of this paper). Table 3 shows an example of the relation among transmitting power, *Ref. EPM*, threshold $C/Inew$, etc., in particular it shows how much interference is allowed for a new comer depending on the *Ref. EPM* of an existing network so that the existing network is not considered as being affected by the new comer. The colors of the numbers in Table 3 correspond to Fig. 7 and Fig. 8, respectively.

In Table 3, the items are as follows.

Ce.i.r.p. is e.i.r.p. of the wanted satellite.

Ref. EPM is the current EPM value without taking into account the interference from the new comer.

C/Iaggr is the current value and derived by *PR* + *Ref. EPM*. The *C* as well as *Iaggr* should be, by definition, wanted and aggregate interference powers, respectively, at the

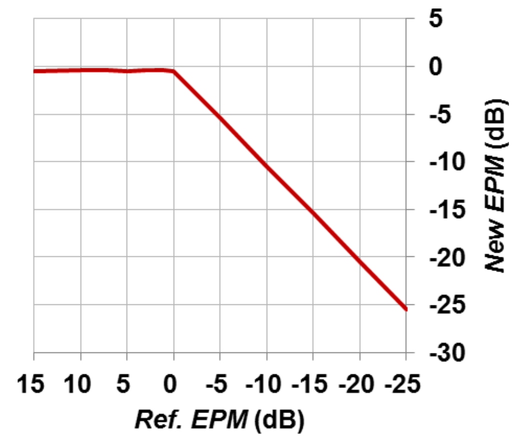


Fig. 7 EPM criterion in terms of EPM degradation.

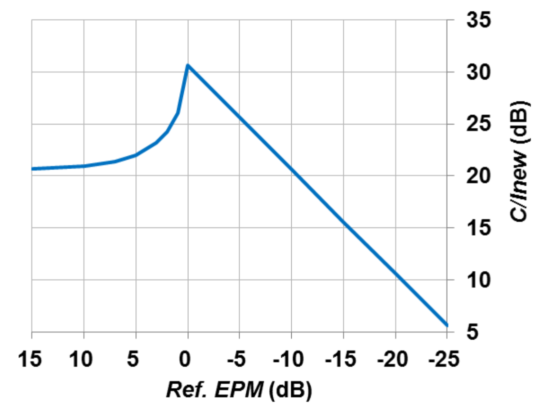


Fig. 8 EPM criterion in terms of *C/Inew*.

output of the interfered-with receiving earth station antenna. However, in this paper, *C* is expressed as the same as *Ce.i.r.p.* and *Iaggr* is expressed as the sum of (interfering e.i.r.p. + the discrimination (<= 0) of the interfered-with receiving earth station antenna). This expression does not change the conclusion of this study.

Iaggr is derived by $Ce.i.r.p. - C/Iaggr$. As mentioned above, the value of *Iaggr* (equivalent interfering e.i.r.p value) has been taken into account the discrimination of the interfered-with receiving earth station antenna between the wanted and the interfering satellites.

C/Inew is mathematically derived by $-10\log(10^{-(C/(Iaggr+Inew))/10} - 10^{-(C/Iaggr)/10})$. However, in Table 3, it is derived so that the *Inew* meets the EPM criterion (See Fig. 8 and b) from **1. Introduction** as cited from RR). This is the lowest *C/Inew* of the existing network due to interference from the new comer so that the existing network is not considered as being affected by the new comer.

Inew is derived by $Ce.i.r.p. - C/Inew$. It indicates the maximum allowable interference power. *Inew* should be, by definition, interference power at the output of interfered-with earth station antenna. However, in this paper, *Inew* is expressed as the interfering *e.i.r.p* + the discrimination of the interfered-with receiving earth station antenna. This expression does not change the conclusion of this study.

C/(*Iaggr* + *Inew*) is the resulting value and derived by $-10\log(10^{-(C/Iaggr)/10} + 10^{-(C/Inew)/10})$ or *PR* + *EPM* (*Iaggr* + *Inew*).

EPM (*Iaggr* + *Inew*) is the new EPM value taking into account the maximum allowable interference from the new comer. According to RR, an existing network is not considered as affected by the new comer if the *Ref. EPM* is not degraded more than 0.45 dB below zero if the *Ref. EPM* value is not negative or more than 0.45 dB if the *Ref. EPM* value is already negative (See Fig. 7). Thus, it is derived:

- If *Ref. EPM* >= 0, *EPM* (*Iaggr* + *Inew*) = −0.45
- If *Ref. EPM* < 0. *EPM* (*Iaggr* + *Inew*) = *Ref. EPM* − 0.45.

Degradation is the difference between *Ref. EPM* and *EPM* (*Iaggr* + *Inew*).

As same as above with the pfd criterion, it is assumed that the antenna is 60 cm in diameter, the earth station antenna locates at a latitude of 33 degrees North and the difference between its longitude and the satellite orbital position is 13 degrees.

The EPM criterion in terms of EPM degradation is depicted in Fig. 7. It shows the resulting EPM (*New EPM*) when the 0.45 dB degradation principle is applied.

The EPM criterion in terms of *C/Inew* is shown in Fig. 8. The *C/Inew* gives a threshold value, or a permissible value of the interference *Inew* when the 0.45 dB degradation principle is applied. Note that the *C/Inew* is independent of the value of *Ce.i.r.p.*

Table 4 below indicates minimum orbital separations for a new network to co-exist with an existing network based on the EPM criterion assuming both networks have the same characteristics (60 cm diameter of receiving antenna, same transmitting power, etc.). The earth station antenna is assumed to locate at a latitude of 33 degrees North and the difference between the longitude and the satellite orbital position is 13 degrees.

From Tables 3, 4, Fig. 7 and Fig. 8, the following items are observed.

(1) For an assignment with a high (positive) *Ref. EPM*, it allows relatively high interference caused by the new comer, while ensuring a good level of protection to the existing assignment, up to such a level corresponding to the EPM of −0.45 dB. For example, when the *Ref. EPM* is 15 dB, the *Inew* (maximum allowable interference) is 33.6 dBW, which is higher than 23.7 dBW of *Inew* when the *Ref. EPM* is 0 dB.

(2) For an assignment with a *Ref. EPM* around 0 dB, it allows relatively low interference to give a further degradation of EPM by −0.45 dB. Note that at 0 dB of *Ref. EPM*, the *C/Inew* is maximum and *Inew* is minimum (23.7 dBW in Table 3), which means the assignment is most sensitive when the *Ref. EPM* is 0 dB.

Table 4 Minimum orbital separation based on EPM criterion.

***Ref.EPM* (dB)**	***C/I* (dB)**	**Minimum orbital separation (deg.)**	**Minimum topocentric angle (deg.)**
10	20.96	3.33	3.78
5	22.01	3.68	4.18
0	30.62	8.10	9.22
-2	28.62	6.75	7.67
-4	26.62	5.61	6.38
-6	24.62	4.67	5.31
-8	22.62	3.88	4.11
-10	20.62	3.30	3.75
-15	15.62	2.88	3.27
-20	10.62	2.37	2.69
-25	5.62	1.73	1.96
-30	0.62	0.57	0.65
-30.6	0	0	0

(3) For an assignment with a very low *Ref. EPM* less than −10 dB, it allows relatively high interference caused by the new comer to give a further degradation of EPM by −0.45 dB, which means that the assignment will not be identified by ITU-R as being affected if a new comer does not produce up to such a high interference. In other words, it is easier for a new comer to meet the sharing criterion. For example, when the *Ref. EPM* is −15 dB, the *Inew* is 38.7 dBW, which is higher than 23.7 dBW of *Inew* when the *Ref. EPM* is 0 dB.

4. Applicability of Pfd and EPM Criteria

In this section, the relation and applicability of pfd and EPM criteria are investigated. In order to compare the EPM criterion with the pfd criterion, the EPM criterion is converted into the threshold pfd values. Figure 9 shows an example of the characteristics of *Ref. EPM* vs threshold pfd values for the pfd and EPM criteria in order to clarify the applicability of the two criteria. In other words, it clarifies which criterion should be used so that a new comer can transmit more power and at the same time does not affect an existing network.

In Fig. 9, the *Inew* values in Table 3 derived under the EPM criterion are converted into the threshold pfd values at the receiving earth station.

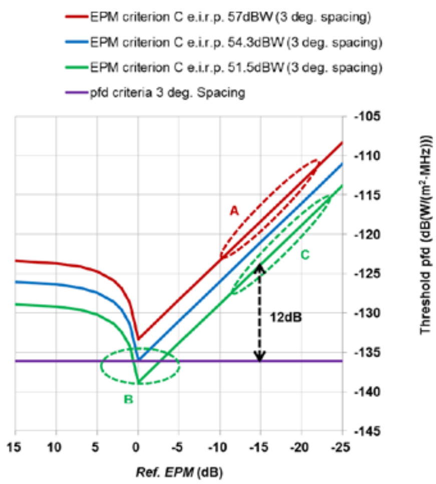
The following explains how the conversion of *Inew* to threshold pfd (dB(W/(m^2·MHz))) was done for a case of *Ce.i.r.p.* of 54.3 dBW, *Ref. EPM* of 0 dB and orbital separation of 3 degrees and 6 degrees.

Inew in 27 MHz: 23.7 dB(W/27MHz)

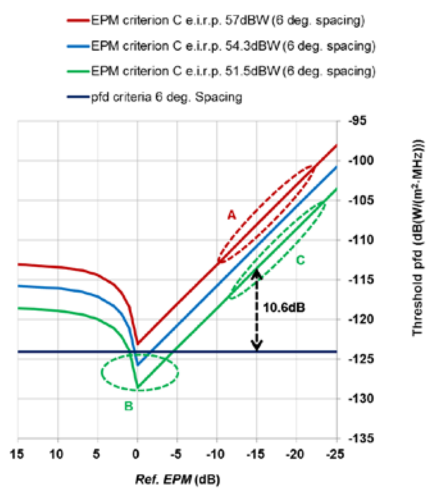
Inew in 1 MHz: 9.4 dB(W/MHz) i.e. (23.7 − 10 log(27))

pfd toward boresight: −153.8 dB(W/(m^2·MHz)) i.e. (9.4–162.4 (d = 37187 km))

Off axis angle of the receiving earth station antenna on the Earth (topo-centric angle toward the interfering satellite): 3.4 deg. for 3 deg. spacing, 6.7 deg. for 6 deg. spacing. Discrimination of 60 cm receiving earth station antenna on



(a) 3 deg. spacing



(b) 6 deg. spacing

Fig. 9 Example of EPM and pfd criteria in terms of threshold pfd.

the Earth at 3.4 deg: −17 dB, at 6.7 deg.: −27 dB
pfd produced by the new comer: −136.0 dB(W/(m^2·MHz)) (−153.8 + 17) for 3 deg. spacing, −126.0 dB(W/(m^2·MHz)) (−153.8 + 27) for 6 deg. spacing.

It is interesting to know that, in this case, the threshold pfd value (−136.1 dB(W/(m^2·MHz))) derived from the EPM criterion with 0 dB of *Ref. EPM* for *Ce.i.r.p.* of 54.3 dBW coincides to the one derived from the pfd criterion for the 3 deg. spacing between the wanted and interfering satellites.

It can be seen from Fig. 9 that in a range of *Ref. EPM* about from 0 dB to −5 dB, the pfd criterion is effective for low *Ce.i.r.p.* like 51.5 dBW.

It is also interesting to know that, when the *Ref. EPM* is very low (less than about −10 dB to −15 dB), the EPM criterion is effective and it allows relatively high interference caused by the new comer. The BSS Plan is developed generally assuming *Ce.i.r.p.* of 59 dBW in a 27 MHz bandwidth at the peak and 56 dBW at the edge of coverage. The assignment with a low transmitting power, e.g., *Ce.i.r.p.* of 51.5 dBW, is possible, but if there are Plan assignments and/or List assignments near such a satellite with co-coverage/co-frequency, the low power satellite suffers from high interference and results in a very low *Ref. EPM* (Part “C” in Fig. 9), then it can never get a value of about 0 dB of *Ref. EPM* (Part “B” in Fig. 9).

For example, for the *Ref. EPM* of −15 dB, the difference between the threshold pfd’s of the EPM criterion (−124.1 dB(W/(m^2·MHz))) and the pfd criterion with 3 deg. separation (−136.1 dB(W/(m^2·MHz))) is about 12 dB. The relaxation of 12 dB under the EPM criterion makes the coordination much easier for a new comer than under the pfd criterion. In other words, by using the EPM criterion, a new comer can transmit 12 dB more power than using the pfd criterion while that sensitive network is not affected. The more negative the Ref. EPM is, the larger difference between the two criteria becomes. Therefore, it can be said that the EPM criterion contributes to alleviate the problem of “sensitive satellite network”, which has a low transmitting power and permits a low interference power under the pfd criterion.

On the contrary, in Part “A” in Fig. 9, both of the interfered-with satellite and the interfering satellite have a high *Ce.i.r.p.* In this case, the two satellites give detrimental interference to each other and suffer a very low EPM value. This situation should be avoided since both satellite services become destructive.

5. Conclusion

In this paper, two frequency sharing criteria (pfd and EPM) for BSS in Regions 1 and 3 are compared and studied from the view point of applicability to the sharing cases between BSS and BSS, which was not clear before. This study is useful for satellite broadcasting system designs including the selection of an orbital position. From the aspect of regulations, the mechanism for the alleviation of a problem of “sensitive satellite network” is clarified.

It was assumed in this paper that the receiving earth station antenna is 60 cm in diameter and locates at a latitude of 33 degrees North and the difference between its longitude and the satellite orbital position is 13 degrees.

The following conclusions are obtained.

(1) The threshold pfd value given by the pfd criterion is an absolute interference power. The threshold pfd value in the area of $3.59° \leq \theta < 9.0°$ (orbital separation angle) is converted and corresponds to $\Delta T/T$ of 5.24%, $\Delta C/N$ of −0.22 dB and I/N of −12.81 dB, which are all equivalent. In the same area, the pfd value corresponds to 29 dB of C/I for the *Ce.i.r.p.* of 54.3 dB(W/27 MHz).
(2) For an assignment with a high (positive) *Ref. EPM*, it allows relatively high interference levels from a new comer while maintaining a high level of aggregate *C/I* ratio.
(3) For an assignment with a *Ref. EPM* around 0 dB, it allows relatively low interference. At 0 dB of *Ref. EPM*, the *C/Inew* is maximum therefore *Inew* is minimum, which means the assignment is most protective (most sensitive).

(4) For an assignment with a very low *Ref. EPM* less than −10 dB, it allows relatively high interference and the assignment will not be identified by ITU-R as being affected if a new comer does not produce up to such a high interference. In other words, it is easier for a new comer to meet the sharing criteria.
(5) It is shown the applicability of the pfd and EPM criteria with respect to the *Ref. EPM*. The EPM criterion is mostly dominant, and the pfd criterion is dominant in a range of *Ref. EPM* about from 0 dB to −5 dB for low *Ce.i.r.p.*
(6) The low power satellite suffers from high interference and results in a very low *Ref. EPM*. The EPM criterion contributes to the alleviation of the problem of "sensitive satellite network", i.e., one that has relatively low transmission power and is very weak against interference and blocks the new satellite to enter under the pfd criterion when the orbital separation is small.

The impacts of the use of the antenna size other than 60 cm and the different receiving points are left for further study.

References

[1] ITU-R, Section 1, Annex 1 of Appendix 30 to Radio Regulations, 2016.
[2] ITU-R, Section 1, Annex 1 of Appendix 30 to Radio Regulations, 2001.
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[4] K. Shogen, M. Kamei, S. Nakazawa, and S. Tanaka, "Impact of interference on 12 GHz band broadcasting satellite services in terms of increase rate of outage time caused by rain attenuation," IEICE Trans. Commun., vol.E99-B, no.10, pp.2121–2127, Oct. 2016.

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