Study on Efficient Frequency Guard Band Decision Rule for Interference Avoidance

Woo Chul Park[1] · Eun Cheol Kim[2] · Jin Young Kim[2] · Jae Hyun Kim[3]

Abstract

When we assign frequency resources to a new radio service, the existing services need not to be interfered with by the new service. Therefore, when we make a frequency assignment, a guard band is necessary to separate adjacent frequency bands so that both can transmit simultaneously without interfering with each other. In this paper, we propose an efficient frequency guard band decision rule for avoiding interference between radio services. The guard band is established based on the probability of interference in the previously arranged scenario. The interference probability is calculated using the spectrum engineering advanced Monte Carlo(MC) analysis tool(SEAMCAT). After applying the proposed algorithm to set up the frequency guard band, we can decide on the guard band appropriately because the result satisfies the predefined criterion.

Key words : Frequency Guard Band, Interference, Monte-Carlo Simulation.

Ⅰ. Introduction

When we want to allocate a new radio service to the frequency band where several radio services already exist, some international conditions need to be satisfied. Otherwise, the existing services are interfered with by the new service. If this interference level exceeds the critical point, they cannot operate normally. Therefore, when we make a frequency assignment, a guard band is necessary to separate adjacent frequency bands so that both can transmit simultaneously without interfering with each other.

In this paper, we propose an efficient frequency guard band decision rule for avoiding interference between radio services. After setting the parameters of interference and victim systems according to the interference scenario, an interference probability is calculated. The spectrum engineering advanced Monte Carlo(MC) analysis tool(SEAMCAT)[1],[4] is adopted in order to estimate the interference probability. Then, the optimal guard band is established by making a comparison between this interference probability and permissible interference probability.

The remainder of this paper is organized as follows. Section Ⅱ describes various conventional guard band establishment methods. Then, the proposed algorithm is presented in Section Ⅲ. In Section Ⅳ, experimental results for setting the guard band employing the proposed algorithm are shown. Digital and analog trunked radio systems(TRSs) are selected for the experiment. Finally, the conclusions are discussed in Section Ⅴ.

Ⅱ. Conventional Guard Band Establishment Methods

The interference level at the receiver is a function of the gains and losses the interference signal will incur between interferer and victim receiver. This can be expressed by [2]

$$I = P_t + G_t + G_r - L_b(d) - FDR(\Delta f), \tag{1}$$

where I is an interference power level in dBW, P_t is an interference transmission power in dB, G_t is an antenna gain of interferer in direction of receiver in dBi, G_r is an antenna gain of receiver in direction of interferer in dBi, $L_b(d)$ is a basic transmission loss for a separation distance d between interferer and receiver in dB[3], and $FDR(\Delta f)$ is a measure of the rejection produced by the receiver selectivity curve on an unwanted transmitter emission spectra in dB.

After calculating the interference power level by using (1), the carrier power-to-interference power ratio(C/I) or interference power-to-noise power ratio(I/N) is compared with the interference criterion. Then, we determine whether the new service can be allocated to the spectrum or not.

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There are several methods of establishing a guard band, and they are minimum coupling loss(MCL), snapshot, analytic simulation, and dynamic system level simulation[4]~[7]. In practical situations, more than one method is employed; that is, a combined algorithm of several guard determination methods is utilized.

2-1 Minimum Coupling Loss

The MCL method calculates the isolation required between interferer and victim to ensure that there is no interference. The method is simple to use and does not require a computer for implementation. The important shortcoming is that the analysis is applied in the worst situation and produces a spectrally inefficient result for scenarios of a statistical nature.

2-2 Snapshot

The snapshot method is one type of the system-level simulations using the MC model. It is also referred to as a static model. In the system-level simulation, actual users are randomly distributed, and the system capacity is calculated in consideration of interference among them. Then, the guard band that maximizes the system capacity is produced. When it takes an extremely long time to investigate many interference scenarios, such a long runtime may become restrictive. In such a case, the snapshot model is used. But we cannot get the results about various situations at one time.

2-3 Analytic Simulation

The analytic simulation method is a simplified system-level simulation. After uniformly distributing lots of mobile stations in the cell, the probability distribution of the received signal power-to-noise power ratio(SNR) is determined. Then, the average sector throughput is calculated, applying the probability distribution of the received SNR to the link-level simulation result. Finally, we can determine a guard band or analyze an outage according to the amount of interference.

2-4 Dynamic System-Level Simulation

In the dynamic system-level simulation, a practical interference situation is modelled as stated in the snapshot method. But the throughput of mobile stations is calculated in consideration of the channel variation. Therefore, this method is suitable for analyzing the cellular system transmitting packet data. Besides, interference analysis of the system employing a link adaptation technique such as adaptive modulation and coding-based packet scheduling is possible. However, this method requires a lot of calculation so it takes a long time to obtain the results.

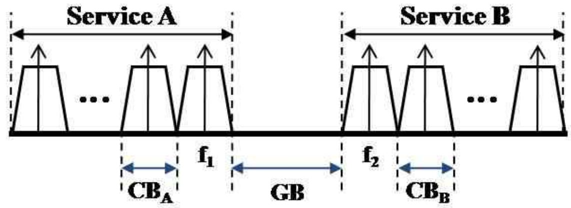

Fig. 1. Concept of guard band.

Ⅲ. Frequency Guard Band Decision Rule

The concept of the guard band is shown in Fig. 1. The guard band between service A and service B can be calculated by

$$GB=(f_2-f_1)-\frac{(CB_A+CB_B)}{2}, \tag{2}$$

where GB is the guard band, CB_A and CB_B are the channel bandwidths of the service A and service B, respectively. f_1 is the center frequency of the rightmost channel in the service A and f_2 is the center frequency of the leftmost channel in the service B.

Fig. 2 illustrates the guard band decision rule that is proposed in this paper. The steps are as follows:

① Calculate the interference probabilities in the cases of the maximum and minimum guard bands. The maximum guard band is selected when a scenario is the worst.

② If the interference probability calculated at the minimum guard band is less than or equal to the interference criterion, which is the maximum permissible interference probability, the algorithm is terminated. The reason is that there is no interference, although the guard band is the minimum.

③ If the interference probability estimated at the minimum guard band is more than the interference criterion, compare the interference criterion with the interference probability calculated at the maximum guard band.

④ If the calculated interference probability is more than or equal to the criterion, the maximum guard band value needs to be adjusted because this bandwidth is too small. And begin the first step again.

⑤ If the calculated result is less than the criterion, set up a new maximum guard band whose value is given by

$$GB_{\max\_new}=\frac{(GB_{\max}+GB_{\min})}{2}, \tag{3}$$

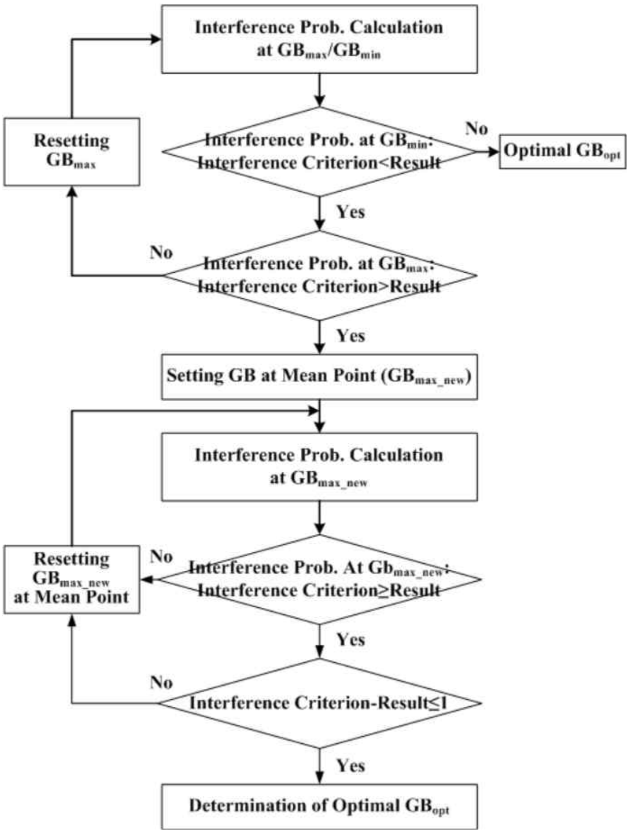

Fig. 2. Guard band decision rule.

where GB_{max_new} is a new maximum guard band, and GB_{max} and GB_{min} are the maximum and minimum guard bands, respectively.

⑥ Calculate the interference probability at the new maximum guard band.

⑦ If the calculated probability is more than the criterion, reset a new maximum guard band and repeat step ⑥. If the calculated result is less than or equal to the criterion, go to the next step.

⑧ If the difference between the criterion and the result is more than 1 %, create a new maximum guard band and go to step ⑥. It is because there is no interference at a smaller guard band compared to the previous one.

⑨ If the difference in step ⑧ is less than or equal to 1 %, the guard band is regarded as optimal, and this algorithm is terminated.

Ⅳ. Experimental Results

4-1 Guard Band Decision Scenario

We choose a mobile station of digital TRS as an interfering transmitter and a mobile station of analog TRS as a victim receiver. A 100 kHz frequency bandwidth from 876 MHz to 876.1 MHz and a 6 MHz bandwidth from 870 MHz to 876 MHz are assigned to analog and digital TRS, respectively. Among analog TRS channels, an interferer is assumed to operate at the nearest channel to digital TRS. Then, the operating frequency is 876.00625 MHz. The characteristic parameters of analog and digital TRS are shown in Tables 1 and 2, respectively[8].

And the blocking characteristic of analog TRS and the unwanted emission mask characteristic of digital TRS are presented in Tables 3 and 4, respectively. It is assumed that a link radius of the victim receiver is 2 km

Table 1. System parameters of analog TRS.

Parameter	Mobile station
Channel spacing	12.5 kHz
Transmit power	30 dBm
Receiver bandwidth	8 kHz
Antenna height	1.5 m
Antenna gain	0 dBi
Active interferer density range	variable
Receiver sensitivity	−107 dBm
Receiver protection ratio	21 dB
Power control characteristic	not used

Table 2. System parameters of digital TRS.

Parameter	Mobile station	Base station
Frequency band range	870～876 MHz	915～921 MHz
Minimum size of frequency band required for system operation	2 MHz	2 MHz
Channel spacing	25 kHz	25 kHz
Number of channels	80	80
Transmit power	30 dBm	44 dBm
Receiver bandwidth	18 kHz	18 kHz
Antenna height	1.5 m	30 m
Antenna gain	0.0 dBi	9 dBi
Receiver sensitivity	−103 dBi	−106 dBi
Receiver protection ratio	19 dB	19 dB
TDMA users/carrier	4	4
Power control characteristic	5 dBm steps to a minimum of 15 dBm. Threshold= −86 dBm	not used

Table 3. Blocking characteristics of analog TRS.

Frequency offset	Mobile station
50～100 kHz	－23 dBm

Table 4. Unwanted emission mask of digital TRS.

Frequency offset	Mobile station	Base station
25 kHz	－30 dBm	－16 dBm
50 kHz	－40 dBm	－26 dBm
75 kHz	－40 dBm	－26 dBm
100～250 kHz	－45 dBm	－36 dBm
250～500 kHz	－50 dBm	－41 dBm
＞ 500 kHz	－70 dBm	－56 dBm

and the density of interferers is 20/km^2. The free-space propagation model is also assumed.

4-2 Guard Band Decision Example

We set up the maximum and minimum guard bands. The minimum guard band is assumed to be the case when the guard band is not necessary; so it is 0 kHz. The maximum guard band is set at 37.5 kHz, which is the sum of channel spacing values of two systems. The maximum permissible interference probability, the interference criterion, is supposed to be 5 %.

When a guard band is the minimum value, an operating frequency of digital TRS is 875.9875 MHz. This situation is shown in Fig. 3.

In this case, the interference probability between both systems is about 14 %, which is over 5 %. From the result, we can see that a guard band between two systems is required as analog TRS is not free from intervention by digital TRS.

When the maximum guard band is applied, digital TRS works at the center frequency of 875.95 MHz. This condition is described in Fig. 4.

As stated above, the maximum guard band is assumed to be the sum of the channel bandwidth of each service,

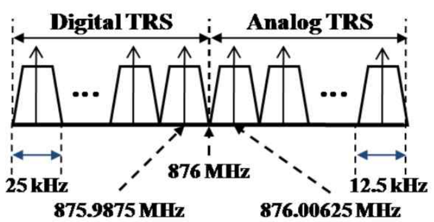

Fig. 3. Example of minimum guard band.

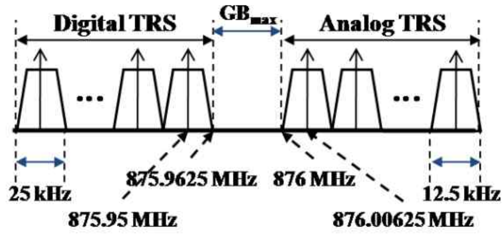

Fig. 4. Example of maximum guard band.

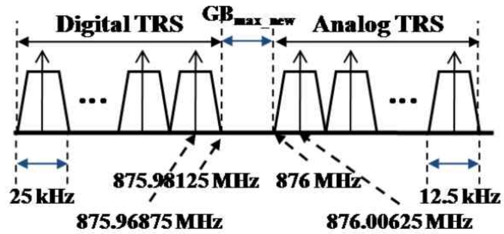

Fig. 5. Example of new maximum guard band.

adding up to 37.5 kHz. An interference probability is about 3.7 % at the maximum guard band. Even if this is below 5 %, the difference is more than 1 %. Therefore, the frequency gap between two systems can be reduced.

Now, a new maximum guard band has to be assigned using (3). It is 18.75 kHz. In this case, the center frequency of digital TRS that interferes with analog TRS is 876.96875 MHz. This is represented in Fig. 5.

An interference probability of this case is 4.8 %, and this satisfies a prior condition that a difference between the calculated interference value and the maximum permissible interference one is less than 1 %. Consequently the optimal guard band is determined as 18.75 kHz.

In Fig. 6, an interference probability according to a guard band variation from 0 kHz to 50 kHz is shown.

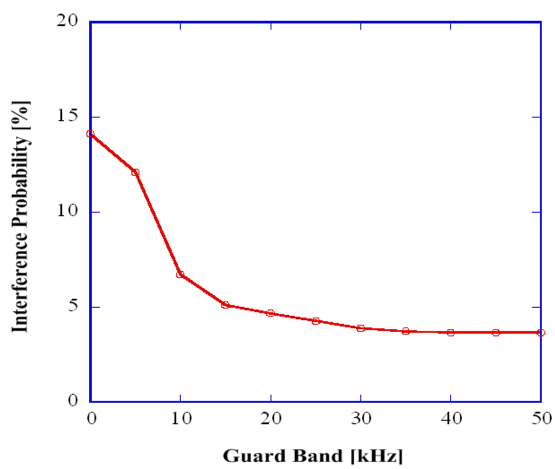

Fig. 6. Interference probability versus guard band.

Ⅴ. Conclusions

In this paper, we proposed the optimal decision rule for the frequency guard band. After defining a frequency assignment scenario, the guard band was decided by means of an interference probability. The interference probability was estimated depending on the MC simulation method, SEAMCAT. From the experimental results, it was shown that the resulting guard band through the proposed algorithm was proper in consideration of the interference criterion. It was also shown that the gap between the calculated result and the maximum permissible interference probability could be reduced as much as possible.

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References

[1] *Report ITU-R SM.2028-1*, "Monte carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems", Jan. 2002.

[2] *Recommendation ITU-R SM.337-5*, "Frequency and distance separations", Feb. 2007.

[3] *Recommendation ITU-R P.341-5*, "The concept of transmission loss for radio links", Oct. 1999.

[4] *ERC Report 101*, "A comparison of the minimum coupling loss method, enhanced minimum coupling loss method, and the Monte-Carlo simulation", May 1999.

[5] H. J. K. Jamshid, "CDMA uplink power control methodology in SEAMCAT(voice only)", CEPT WGSE PT SE21, QUALCOMM, Oct. 2003.

[6] 3GPP TS 25.848 V4.0.0(2001-03), "Physical layer aspects of UTRA high speed downlink packet access".

[7] 3GPP2 Technical Specification Group C, "1xEV-DV evaluation methodology addendum(v12.1)", TSG-C.R 1002.

[8] ERC Report 86, "Adjacent band compatibility of UIC direct mode with UIC GSM and 900 MHz TETRA-An analysis completed using a Monte Carlo based simulation tool", Jun. 2000.

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