Interference analysis of DTV into LTE uplink systems

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Abstract

In this paper, to investigate the effects of interference resulting from the standard setting of Block Edge Mask (BEM), assuming the use of LTE systems in the Digital Dividend, the minimum separation distances according to the size of guard band between DTV transmitter and LTE base station for a specific BEM are calculated.

Keywords : Block Edge Mask, DTV, LTE

1. Introduction

As an introduction of an open spectrum allocation approach with technology and service neutrality is expected as a way to solve problems of frequency shortage due to the expansion of demand for wireless multimedia communications recently, a new management model of interferences and its standard setting are required. There are some known interference management models of the open spectrum allocation method such as block edge mask (BEM), aggregate power spectral density (PSD), aggregate power flux density (PFD) and so on. Among them, BEM approach controls interference between radio systems by specifying a maximum in-block transmission power in addition to out of band powers that radio transmitters must follow. By managing interference only with defining maximum power, technology and service neutral interference management is available. BEM is largely divided into in-block limit, transition level, and baseline level as shown in Fig. 1.

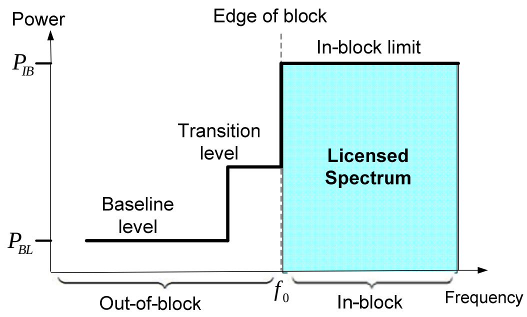

Figure 1: Block Edge Mask

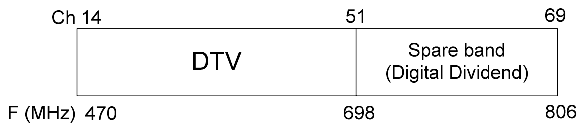

Figure 2: Frequency arrangement plan in Korea

In this paper, with BEM approach for an interference management model, coexistence scenario of DTV service and LTE service is analyzed by assuming the allocation of LTE systems in the Digital Dividend in Korea as shown in Fig. 2. And for a DTV transmitter interfering to a LTE base station, the minimum separation distances between a DTV transmitter and a LTE base station to protect LTE uplink systems is calculated. And the minimum distances according to the size of the guard band are also derived.

In Section 2, deployment scenario and radio parameters for the interference analysis are defined and the minimum distances between a DTV transmitter and a LTE base station according to the size of the guard band are derived in Section 3. Finally, conclusions are presented in Section 4.

2. Parameters settings

2.1 Deployment scenario

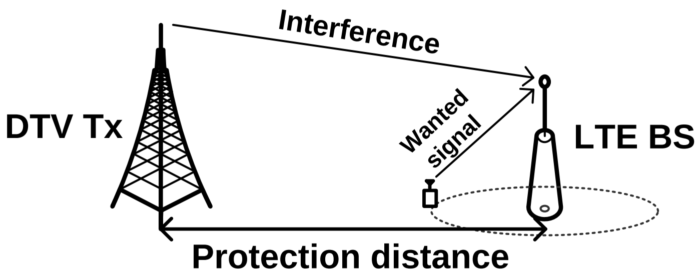

Figure 2: Deployment of DTV transmitter and LTE Base station

The deployment scenario to analyze the interference from a DTV transmitter to a LTE base station is shown in Fig. 2. In LTE uplink systems transmitting signals from mobile equipments to a LTE base station, the base station receives interference from a DTV transmitter, and under this environment the minimum protection distance from the DTV transmitter is required to guarantee the minimum QoS [1].

2.2 **Radio parameters and Block edge mask**

The radio parameters of DTV systems and LTE systems are used from [2] and [3],[4], respectively and are shown as follows.

Table 1: DTV radio parameters

DTV Parameters	Values
Frequency	470 ~ 698 MHz
Channel bandwidth	6 MHz
Tx power	67 dBm (5 kW)
Tx antenna gain	7.8 dBi
Tx antenna height	100, 200 m
Coverage	30 km

Table 2: LTE radio parameters

LTE Parameters	Values
Frequency (Uplink)	698 ~
Channel bandwidth	1.4, 3, 5, 10 MHz
BS Tx power	43 dBm (20 W)
BS Tx antenna gain	12 dBi
BS Tx antenna height	30 m
BS Rx noise figure	5 dB
BS Rx ACS	50 dB
MS Tx power	Maximum 24 dBm
MS Tx antenna gain	0 dBi
MS Tx antenna height	1.5 m
Coverage	1 km
Required minimum SINR at BS ($SINR_T$)	9 dB (for 1.4, 3, 5 MHz) 6 dB (for 10 MHz)

From 3GPP LTE Standard 1.4, 3, 5, 10 MHz bandwidth is available at frequency band around 698 MHz and we will present the results for all the bandwidth cases. And to guarantee more than 95 % of the total throughput in LTE systems, the minimum SINR for QPSK, 1/3 rate is 9 dB for 1.4, 3, and 5 MHz, and 6 dB for 10 MHz bandwidth.

To obtain block edge mask for the DTV transmitter we use the emission mask defined in FCC as shown in Fig. 3 [2]. And by applying the effective radiated power of 74.8 dBm and channel bandwidths of 5 MHz bandwidth block edge mask of Fig.4 is obtained. It is assumed that this BEM is defined as BEM of DTV transmitter.

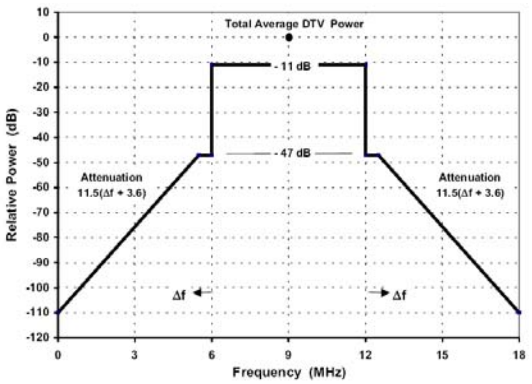

Figure 3: FCC DTV emission mask

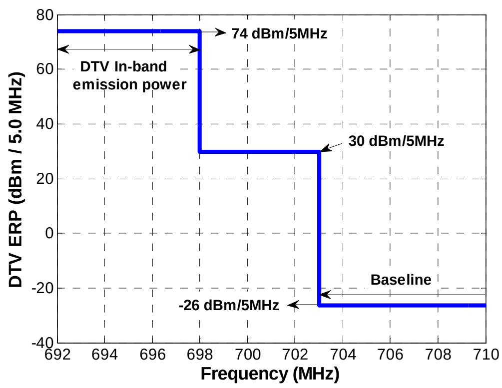

Figure 4: BEM of DTV Tx (dBm/5 MHz)

Radio propagation models are required for two cases. JTG 5-6 model for the path between a DTV transmitter and a LTE base station (BS) is used [5]. This model consists of Hata model for distance less than 100 m, ITU-R P.1546-3 model for distance more than 1 km, and the log-linear interpolation model of Hata and ITU-R P.1546-3 model for other cases. For a link between a LTE BS and a mobile station (MS) Macro cell propagation model [4] is used and defined as follows.

$$\mathrm{PL(dB)} = 40 \cdot (1 - 4 \cdot 10^{-3} \cdot hrf) \cdot \log_{10}(D) - 18 \cdot \log_{10}(hrf) + 21 \cdot \log_{10}(f) + 80 \qquad (1)$$

Where D is the distance between BS and MS (km), f is the carrier frequency (MHz), and hrf is the height (m) of BS measured from the average rooftop height of 15 m. Antenna azimuth between a DTV transmitter and a LTE BS is always assumed as 0 degree considering the worst case and antenna elevation is assumed to be ignored because of its relatively small value.

3. The required protection distances between DTV and LTE

To guarantee the operation of LTE base station (BS) from interference of DTV transmitter, the following SINR requirement has to be satisfied.

$$\mathrm{SINR} = \frac{P_S}{P_N + P_{I,CC} + P_{I,AC}} \geq \mathrm{SINR}_T \quad (2)$$

Where SINR_T is the minimum SINR for a LTE BS, P_S is the received power from a LTE mobile station (MS), P_N is the noise power at a LTE BS, $P_{I,AC}$ is the received interference power from the adjacent channel due to the imperfect receiver filtering capability, and $P_{I,CC}$ is the received interference power due to the out of band emission of DTV.

To calculate the protection distances, some factors in (2) are calculated as follows. At first, P_S is obtained as $P_S = P_{UE} \cdot G_{A,UE} \cdot G_{PL,(UE,BS)} \cdot G_{A,BS}$ where P_{UE} is the transmitted power of MS, $G_{A,UE}$ is the antenna gain of MS, $G_{A,BS}$ is the antenna gain of BS, and $G_{PL,(UE,BS)}$ is the path loss gain from LTE BS to LTE MS and Macro cell propagation model is used for the path loss model. In this case, the distance between a BS and a MS is set as 1 km considering the worst case of the cell edge position. Secondly, $P_{I,AC}$ can be expressed as $P_{I,AC} = ACS^{-1} \cdot P_{IB,DTV} \cdot G_{PL,(DTV, BS)} \cdot G_{A,BS}$ where ACS is adjacent channel selectivity, and $P_{IB,DTV}$ is the effective radiated power of DTV, and $G_{PL,(DTV, BS)}$ is the path loss gain from DTV transmitter to LTE MS. JTG 5-6 model is used for this case and we can understand that $G_{PL,(DTV,BS)}$ is affected directly by the propagation distance. $P_{I,CC}$ can also be expressed as $P_{I,CC} = P_{OOB,TV} \cdot G_{PL,(DTV, BS)} \cdot G_{A,BS}$ where $P_{OOB,TV}$ is the out of band emission power of DTV, and the other two factors are the same as those of $P_{I,AC}$.

According to applying the parameter values of Table 1 and Table 2 to (2) for various distances between a DTV transmitter and a LTE BS, finally, the minimum distance satisfying (2) can be obtained. Especially by changing the size of guard band between DTV and LTE band the minimum distances for each case are also obtained. Fig. 5 represents BEM level set for 2 MHz guard band as an example. As a result, Table 3 presents the list of the required protection distances for four LTE channel bandwidth cases. By increasing the guard band by 500 kHz the protection distances are also gradually decreasing to 0 km although for 10 MHz channel bandwidth case, the decreasing rate of the protection distances according to the increase of guard band is relatively small compared to others because its bandwidth is larger than 6 MHz DTV channel bandwidth. For the realistic deployment of the coexistence of DTV and LTE this table can be utilized by itself. And from these process, we can learn that for interference management numerous realistic factors including the size of guard band, specific parameters defined in systems, deployment architectures, and so on should be considered and for technology and service neutral spectrum management like BEM approach various coexistence scenarios should be analysed preliminarily.

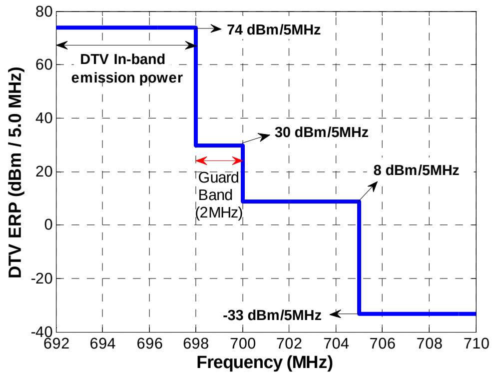

Figure 5: BEM for having 2 MHz guard band

Table 3: The required protection distances (km)

Guard Band (MHz) \ Channel B.W	1.4 MHz	3 MHz	5 MHz	10 MHz
0.0	19.42	19.75	20.01	17.21
0.5	15.78	16.09	16.39	14.14
1.0	10.93	11.34	11.85	10.60
1.5	7.21	7.77	8.64	8.53
2.0	4.64	5.17	6.35	7.29
2.5	2.91	3.35	4.91	6.54
3.0	1.80	1.83	3.93	5.99
3.5	1.11	1.13	3.11	5.53
4.0	0.54	0.56	2.41	5.11
4.5	0.26	0.26	1.70	4.71
5.0	0.14	0.14	0.15	4.33
5.5	0.01	0.01	0.01	3.97
6.0	0.01	0.01	0.01	3.60

4. Conclusions

In this paper, to investigate the effects of interference resulting from the standard setting of Block Edge Mask (BEM) the minimum separation distances according to the size of guard band between DTV transmitter and LTE base station with a specific BEM are calculated and analysed. From the result we can utilize it to the realistic deployment and find that BEM has to be set considering system requirements, system deployment, and various system radio parameters and so on.

References

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Acknowledgments

This work was supported by the IT R&D program of KCC/KCA. [2008-F-013-1, Development of Spectrum Engineering and Millimeterwave Utilizing Technology].