Journal of Theoretical and Applied Information Technology
30th June 2017. Vol.95. No 12

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

SPECTRUM SHARING AND COMPATIBILITY BETWEEN THE INTERNATIONAL MOBILE TELECOMMUNICATION-ADVANCED AND DIGITAL BROADCASTING IN THE DIGITAL DIVIDEND BAND

MOHAMMED B. MAJED[1,2,*], THAREK A. RAHMAN[1]

[1]Wireless Communication Center (WCC), Faculty of Electrical Eng. Universiti Teknologi Malaysia (UTM), Johor. Malaysia

[2]Department of Computer Science, College of Science and Technology, University of Human Development (UHD), Assulaymaniyah. Iraq

* Email: (mohammed.majed@uhd.edu.iq)

ABSTRACT

The International Telecommunication Union for Radiocommunication (ITU-R) became involved with the spectrum allocation for next generation mobile communication services in World Radio Communication conference 2007 (WRC- 07). The reason is to minimize the adjacent channel interference between Mobile service and DVB-T system within the same geographical area. Therefore, this paper investigates the spectrum sharing requirements such as separation distance and studies the compatibility between Mobile services (IMT-Advanced) and Digital Video Broadcasting – Terrestrial (DVB-T) in the 790 to 862 MHz frequency band. This paper also involves the studies of propagation characteristics within this band which can provide better coverage. Possibility of coexistence and sharing analysis were obtained by taking into account the detailed calculations of the path loss effect by using the practical parameters of DVB-T and Mobile service. The interference has been analyzed and simulated for suburban environment in different channel bandwidths for Mobile service at 5MHz and 20MHz, and in different transmitted power for Digital Video Broadcasting – Terrestrial. The best separation distance between these two systems found are 4.65 Km and 3.42 Km for bandwidth of 5MHz and 20 MHz respectively.

Keywords*: DVB-T, IMT-Advance, Propagation model, Adjacent Channel Interference, Separation Distance*

1. INTRODUCTION

In recent years, the inefficient utilization of spectrum motivates many communication engineers to pay attention to spectrum management such as resource allocation, coexistence, and spectrum sharing in order to promote more flexibility in spectrum usage [1]. Due to scarcity of the frequency spectrum, many bands are allocated for more than one radio service and thus the sharing is necessity. Consequently, the increased sharing of spectrum translates into a higher likelihood of users interfering with one another [2]. Broadcasting services in band IV (470 – 582) and V (582 – 862) MHz would be limited to the frequency band 470-790 MHz, when deploying mobile services in the frequency range 790-862 MHz there is a potential risk of adjacent channel interference into existing digital TV services using channels below channel 61 (below 790 MHz) [3]. The technical analysis considers the different interference mechanisms and shows that unacceptable interference can be caused even by DVB-T transmitters that are located several kilometers away from the affected Mobile Station [4]. Interference between two wireless communication systems (intersystem interference) occurs when these systems operate at overlapping frequencies, sharing the same physical environment, at the same time with overlapping antenna patterns which leads to capacity loss and coverage limitation [5]. This frequency band plan for mobile services in the UHF band will play a crucial role in enabling mobile operators to make the most efficient use of this spectrum, and also it is

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

currently used by broadcasting services in most of the world countries [6]. This means that interference probability due to frequency sharing between these two systems is bound to happen if the two systems operate in adjacent areas with same carrier frequency (co-channel frequency) or in the same area with an adjacent carrier frequency.

The reminder of this paper is organized as follows. In Sections 2 and 3, IMT-Advanced and DVB-T services parameters, Propagation model, are described. Coexistence scenarios, calculation of separation distance and interference analysis methods are detailed in Section 4. Section 5 is devoted to the coexistence results, analysis and compatibility between the services. Finally, the conclusion is presented in Section 6.

2. IMT-ADVANCED AND DVB-T SYSTEM PARAMETERS

In order to study and examine coexisting and sharing issues, it is necessary to clarify the parameters of both IMT-Advanced and DVB-T system. These parameters are shown in Tables 1, 2 and 3.

Table 1: IMT-Advanced Mobile Station Parameters

Parameter	Value
Frequency of operation	800 MHz
Channel bandwidth	5, 20 MHz
EIRP	24.5 dBm
Antenna Gain	0 dBi
Antenna Height	1.5 m
Antenna pattern	Omni
Interference limit power	-100.8, -94.8 dBm
Interference to noise ratio I/N	-6 dB
Noise Figure	4 dB
Receiver thermal noise, N=KTB	-136.8, -130.8 dBW
Antenna height correction factor	-1.588

Table 2: IMT-Advanced Base Station Parameters

Parameter	Value
Frequency of operation	800 MHz
EIRP	43 dBm
Base station antenna gain	15 dBi
Base station antenna height	20 m
Interference limit power	-100.8, -94.8 dBm
Channel bandwidth	5, 20 MHz
Interference to noise ratio I/N	-6 dB
Noise Figure	4 dB

Table 3: DVB-T System Parameters

Parameter	Value
Frequency of operation	800 MHz
EIRP	72.15, 48.4 dBm
Base station antenna height	30 m
Channel bandwidth	8 MHz
Noise Figure	7 dB
Antenna pattern	Omni
Interference limit power	-100.8, -94.8 dBm

3. PROPAGATION MODEL

It is an empirical mathematical formulation for the characterization of radio wave propagation as a function of frequency, distance and other conditions. A single model is usually developed to predict the behavior of propagation for all similar links under similar constraints. Created with the goal of formalizing the way radio waves are propagated from one place to another, such models typically predict the path loss along a link or the effective coverage area of a transmitter [7].

3.1 HATA MODEL

It is also known as the Okumura-Hata model for being a developed version of the Okumura Model, is the most widely used model in radio frequency propagation for predicting the behavior of cellular transmissions in city outskirts and other rural areas. This model incorporates the graphical information from Okumura model and develops it further to better suite the need. This model also has two more varieties for transmission in Urban Areas, Suburban Areas and Open Areas [8].

Hata Model predicts the total path loss along a link of terrestrial microwave or other type of cellular communications. And is a function of transmission frequency and the average path loss in urban areas. This model is suited for both point-to-point and broadcast transmissions. The model is typically applied in the frequency range of 150 MHz to 1.5 GHz [9].

4. INTERFERENCE ASSESSMENT FROM DVB-T INTO MOBILE SERVICE

The interference power received from the DVB-T transmitter at Mobile service depends on many specifications. The DVB-T output power in the direction of the Mobile service, the radio propagation loss, the Mobile service gain and the isolation at the receiving site. To find the separation distance, two scenarios have been proposed in terms of channel bandwidth for Mobile service. First scenario is when channel bandwidth 5MHz for Mobile service and second when channel bandwidth 20MHz.
The assessment would establish the maximum permissible level of interference signal from the DVB-T station which would cause interference with the Mobile service and as shown the formulas to calculate the Maximum permissible level of interference level:

$$C/I = (I/N + C/N)\ dB = (-6 + 19)\ dB = 13\ dB \quad (1)$$

Where C/I is carrier to interference ratio and C/N is the required carrier to noise ratio (19dB) [10] [13], I is the interference level, C is the carrier signal, N is the receiver noise level.

It follows that

$$I = (C - 13)\ dB \quad (2)$$

Furthermore

$$C = C/N + 10 \log (KTB)\ dBW \quad (3)$$

Where the KTB is the thermal noise floor, K is the Boltzmann's constant ($1.38 * 10^{-23}$), B is the channel band width and T is noise temperature [11] [14].

By substitute all the values the carrier power can calculated:

$$C = 19 + (-136.8) = -117.8\ dBW$$

By substitute C in (2), the I will be equaled to -130.8 dBW (-100.8 dBm).
The separation distance calculated by depending on the formula that uses it to calculate the permissible received interference power as shown:

$$I = EIRPDVB\text{-}T - LDVB\text{-}T\ (d) + Gr \quad (4)$$

Where EIRPDVB-T is off-axis EIRP from the DVB-T transmitter (dBW), LDVB-T (d) is path loss (dB) and Gr is Mobile service antenna receiving gain (dBi).

The path loss will be as follows [12]:

$$LDVB\text{-}T\ (d) = 69.55 + 26.16 \log(f) - 13.82 \log(hb) - Ch + (44.9 - 6.55 \log(hb)) * \log(d) \quad (5)$$

Finally, the calculation of required protection distance d, is where the interference power from DVB-T transmitter to the Mobile service reaches the threshold level and is given by substituted the (5) in (4), the protection distance (separation distance) will be:

$$d = 10^{((-I + EIRPDVB\text{-}T - 69.55 - 26.16 \,Log\, (f) + 13.82 \,Log\, (hb) + Ch + Gr) / 35.22)} \quad (6)$$

Where hb is height of base station antenna and Ch is antenna height correction factor.

5. RESULTS AND DISCUSSIONS

As seen from Figs 1,2 and 3, the interference from T-DVB Transmitter into 5MHz and 20MHz mobile service, respectively, as a victim receiver is applied, where the minimum separation distance and frequency separation for the minimum I/N ratio of -6 dB are analyzed in the suburban area.
For adjacent channel coexistence, it can be observed that the minimum separation distance between the two services must be greater than 4.65 km and 3.42km for bandwidth of 5MHz and 20 MHz respectively.
The entire requirements are summarized in Table 4 and 5 clarifies the relationship between minimum separation distances, required height of base station antenna DVB-T, required interference level to get safe sharing and coexistence. It is also clear from the results that as the bandwidth increases therefore the separation distance between DVB-T and mobile service decreases.
Coexistence of mobile service with DVB-T reception will require the application of the same available mitigation techniques and careful network

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

planning. Possible ways to mitigate the interference may include limiting the maximum transmit power of the mobile service and DVB-T.
The calculation of the separation distance between the DVB-T station with the mobile service by applying equation (6) by considering interference level (I) is -130.8 dBW, as shown in Figure 1.

Table 4: Separation Distance In Different Interference Level

separation distance (Km), DVB-T transmitter (EIRP=42.15 dBW)	separation distance (Km), DVB-T transmitter (EIRP=18.4 dBW)	Height of base station Antenna (DVB-T)	maximum permissible interfering (I)in dBw
11.21	2.28	30	-120
16.15	3.46	30	-125
21.73	4.65	30	-130
40.03	8.64	30	-140

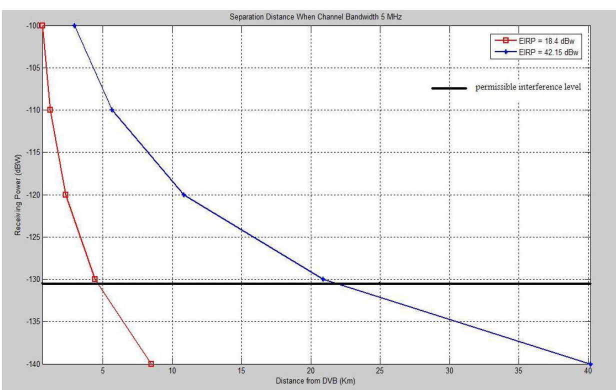

Figure 1: The Separation Distance Between Mobile Service 5mhz Channel Bandwidth And DVB-T Station In Different Transmitted Power.

Also, the calculation of the separation distance by considering interference level (I) is -124.8 dBW and height of base station antenna (DVB-T) will taken as range in measurement from 30 to 100 m as shown in Figure 2.

Table 5. Separation Distance in Different Antenna Height

separation distance (Km), DVB-T transmitter (EIRP=42.15 dBW)	separation distance (Km), DVB-T transmitter (EIRP=18.4 dBW)	Height of base station Antenna (DVB-T)	maximum permissible interfering (I)in dBw
36.78	6.82	100	-125
27.95	5.33	70	-125
22.03	4.26	50	-125
15.88	3.42	30	-125

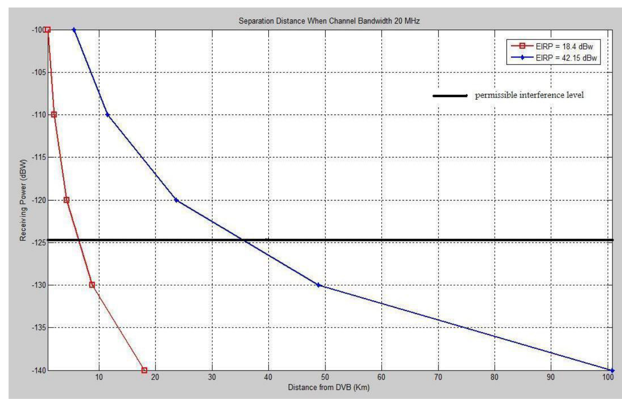

Figure 2: The Separation Distance Between Mobile Service 20mhz Channel Bandwidth And DVB-T Station In Different Transmitted Power, And Antenna Height (Hb) = 100 M.

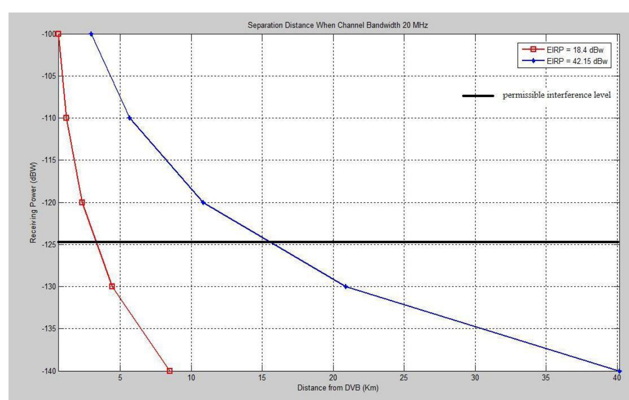

Figure 3: The separation distance between mobile Service 20mhz Channel Bandwidth And DVB-T Station In Different Transmitted Power, And Antenna Height (Hb) = 30 M.

For propagation coverage measurements ATDI (ICS-TELECOM) Simulation was used. And the used scenario is suburban area with buildings (low transmitted power), to find the effect of clutter loss (buildings terrain) in different points. Also, 5MHz and 20 MHz channel bandwidth will be applied for Mobile service.

In this scenario including buildings, ATDI applied on the high-resolution map in region located in French to study the coverage of DVB-T station and find the best regions to deploy Mobile service without any effective coming from DVB-T transmitter.

- Coverage and Measurements for 5MHz channel bandwidth

Simulation and analysis for DVB-T system and check the coverage for area around 400 Km^2 as shown in Figure 4, where the figure illustrates how well interference is reduced with terrain propagation effect.

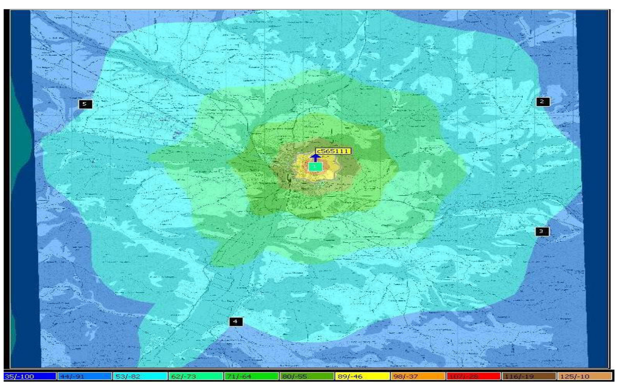

Figure 4: Coverage area in Terual state, French for 5MHz channel bandwidth.

Four points at different places at Terual state, French established using France map as displayed in Figure 5, then all these points are transferred the grid for each point to the ATDI simulation, to distribute these points at ATDI simulation using France map.

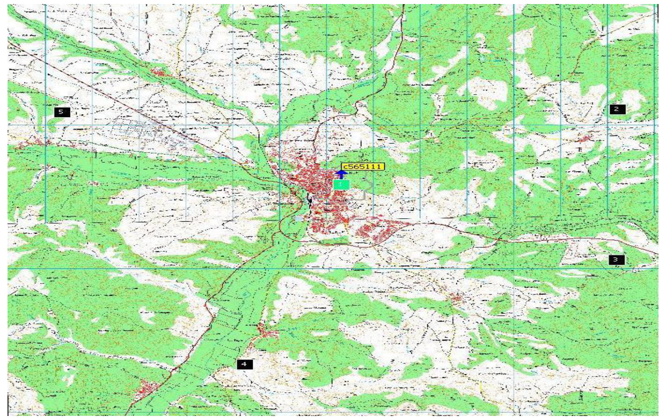

Figure 5: Points sites inside Terual state, French.

These points in Figure 5 represent the best site to deploy Mobile service because the interference level *I* becomes smaller than -100.8 dBm where there is no interference from DVB-T station, and Figure 6 illustrates the signal profile from DVB-T to point 4 that is 6.59 km far away from DVB-T base station.

Figure 6: Profile Terrain from DVB-T station towards Mobile service (point 4)

- Coverage and Measurements for 20MHz channel bandwidth

For 20MHz Mobile service the coverage will reduce as shown in Figure 7 because of interference level decreases from -100.8 dBm for 5MHz to -94.8 dBm for 20MHz.

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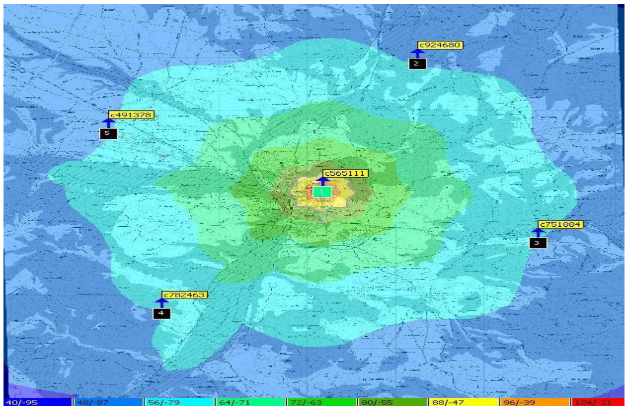

Figure 7: Coverage area in French for 20MHz channel bandwidth.

These 4 points in Figure 7 above represent the best site to deploy Mobile service where there is no impact from DVB-T station, and Figure 8 illustrates the signal profile from DVB-T to point 5 that is 5.22 km far away from DVB-T base station.

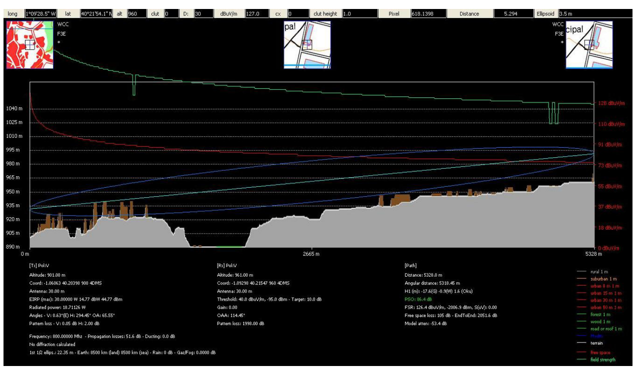

Figure 8: Profile Terrain from DVB-T station towards Mobile service (point 5)

6. CONCLUSION

The signal that received to the mobile service must be protected from the DVB-T station transmitter, by controlling the signal power in the same direction of the mobile service as well, the minimum required loss at mobile service must be specified and always be greater than or equal the path loss power, to make sure that the DVB-T transmitter not impact or block the signal received.
Also, it is difficult to share the same frequency channel between mobile service and DVB-T services without mitigation techniques due to high separation distance required to satisfy coexistence requirements. The separation distance in 5MHz channel bandwidth for Mobile service longer than the distance in 20MHz. Methods for enabling the coexistence of both systems would be inevitable especially at small geographical offset between two systems and at co-channel and adjacent channels frequencies.

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