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Enhanced the Accuracy of Specification of Maximum Permitted Emission Levels for TV White Space Devices

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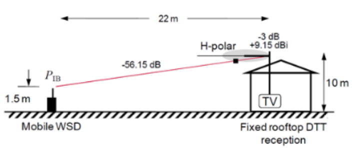
Graphical abstract



Abstract

In this paper, we present a proposed geo-location database calculations which needs to perform in order to obtain high accuracy of maximum permitted emission levels for TV white space devices (WSDs) operating in the digital terrestrial television (DTT) frequencies. The study is mainly aimed at to analuze the impact of channel power condition in band (P_{IB}) and power out band (P_{OB}) for WSD for DTT reception in hilly environment under different altitudes. The proposed methodology for the calculation of such emission levels considers the effect of environment and hight of DTT reception. Both theoretical study and mathematical investigations are conducted in order to model and characterize such complex communication medium for WSDs. The propagated maximum permitted emission levels varies from one place to another due to time varying channel condition as a result of obstacles and distance between the transmitter and receiver. The study achieved according to the methodologies, results and recommendations addressed by the European Conference of Postal and Telecommunication administration CEPT. The comparison between proposed model and traditional one has been done by CEPT. The result shows that the proposed model with various altitudes in the hilly terrain environment obtain more accurate maximum permitted emission levels for WSDs, Which increase by 25.609 dBm and 25.61 dBm for P_{IB} and P_{OB} respectively at 100 altitude accordingly.

Keywords: TV white space devices; maximum permitted emission; different altitudes

1.0 INTRODUCTION

The wireless communication performances rely on the channel characteristic between the transmitter and receiver. An obstacle between the transmitter and receiver can acutely influence transmitted power's propagation. Interestingly, conducting wireless communication research in rugged terrain at UHF frequency band has attracted many researchers due to its significance [1]. Keeping good signal quality in woody and hilly environment considers as main challenge which needs more intensive research and serious analysis. Due to multipath, refraction, diffraction and reflection the signal power attenuated, which finally hinder the effectiveness and performance of communication [2-4]. The nature of the environment and obstacles between the transmitting and receiving station has a harmful influence on the received power [5]. The VHF/UHF bands are used for television broadcast have some advantages, such as the quality of reception is extremely significant obtaining superior video quality output [6]. Many of these objects can scatter and reflect the propagated radio waves [7-9]. The hilly environment has interfered to path losses and speedy changes in signal power [10-11].

In May 2004 [12], released Notice of Proposed Rulemaking (NPR), and latest released in November 2008 [13], Federal Communications Commission (FCC) indicated that TV channels band could be used for fixed broadband access systems within cognitive radio (CR). Therefore the interest both researchers and the communications industry have been in the use of UHF digital terrestrial television (DTT) frequencies by CR or white space devices WSDs [14]. Then this high level of interests in this field has been regulated by national regulatory authorities universal to guarantee that suitable levels of protection are afforded to the incumbent DTT services. Many research works investigate the operation of independent WSDs. These devices must sense the existing DTT channel using spectrum sensing techniques and algorithms, and just transmit where interference to the DTT service is deemed unlikely. It is inevitable that the specification of the policy maximum emission limits for the operation of such independent WSDs in DTT bands has to be according to a) worst-case geometries relating to the interfering WSD and the victim DTT receiver, and b) worst-case sensing environments [15]. Accordingly, acceptable protection of the DTT service can result in very strict WSD regulatory emission limits and sensing levels, both applied uniformly in all locations. This concurrently reduces the utility of independent WSDs and increases their complexity [15].

This problem is solved by associate geo-location database with WSDs operates on DTT channels [16]. This is for the reason that the influence of harmful interference on a DTT receiver is a main indicator of the quality of the DTT range in a particular geographical location wherever the DTT receiver is located. The maximum emission limits WSD can be considerably increased in areas where the DTT signal to noise plus interference ratio is high then no of WSDs (i.e., good quality of DTT), and also enhance the utility of the WSDs, but also eliminate the required for sensing technique and detection of very low-power DTT signals such it needs for independent WSDs. A WSD would just need to send its location details to the database, and then the database will return to WSD details with the maximum permitted emission levels with which it can transmit. More Studies should be conducted for the enhancement of the accuracy of specification of maximum permitted emission levels for WSDs to explore the areas where the existing research work does not cover, however some work just consider the horizontal distance between WSD and DTT reception and did not consider height [17].

It is essential for the gelocation database to determine the maximum permitted WSD emission levels across all DTT channels by providing correct levels of protection for the DTT service in all coverage areas where the DTT service is operational. To achieve this, the database requires the following informations[18]:

- The percentage coverage of national DTT within a suitable spatial area (example: 100 m x 100 m)
- Determine allowable interference to the DTT service
- Determine interferer geometries for DTT reception and WSD
- Adequate protection ratios of WSD-to-DTT [19],[20].
- A methodology for drive the proper WSD regulatory emission limits

The main objective of this work is to investigate the impact of altitude of DTT reception and maximum permitted emission levels P_{IB} for TV WSD. The remaining of this paper is organized as follows. Section 2 mainly focuses on system parameters and assumptions, proposed signal-path loss altitude model and propagation from WSDs and calculating WSD received power for DTT reception. In Section 3 describes the results and discussion. Finally, draw conclusions in Section 4.

2.0 SYSTEM PARAMETERS AND ASSUMPTIONS

2.1 Theoretical Background

Based on the fact that it is known that the received power vary from one location to another based on the environment and medium, therefor system and parameters and the enviromemnt factors are critical value in our calculations. The environmental factors, for example; blocking, trees, rocks, buildings, climate and so on affected received power [21-22]. The value of receiving power attenuation in outdoor and indoor environment is completely different. In indoors, human and objects can culminate to drastic loss in the received power. Whereas in outdoor scenario the different height or altitude in a heterogeneous environment is had a complex losses secnarios.
In this work, the influence of environmental condition and altitude of the test site are considered. This accordingly will affect on the P_{IB} of WSD. The P_{IB} depend on the suburban Hata model as it has been described .

2.2 Reference Geometry

Every country's regulator has different reference geometries for spectrum sharing between WSDs and DTT. This work considers the mobile WSD operation and fixed roof-top DTT reception from United Kindom UK, as shown in Figure 1 [23].

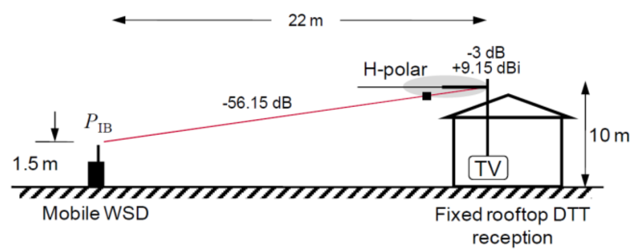


Figure 1 Reference geometry for mobile-WSD distance between WSD and DDT reception 22m in 650 MHz [23]

2.3 Proposed Signal-Path Loss Altitude Model and Propagation from WSDs

The TV signal transmission in a hilly terrain has been studied mathematically using different altitude to characterize and model the influence of the channel condition on the propagated P_{IB} as shown in Figure 1. The TV signal transmission power is decreases as terrain irregularity increases [21]. Similarlry the transmission is effected when buildings, mountains and trees are added to the surface this will cause the TV signal strength to be reduced due to shadowing, absorption, and scattering along its way. This leads to the conclusion that the received power dependent on the medium and weather condition [24-25].

After WSD receives the information from geo-location database it will consider the possible location of any licensed DTT receivers as an input parameter for its power transmission calculations. Based on this information, the WSD will derive the maximum emission allowed. Eventually, in this methodology the calculation of the permitted transmit power for a given location is performed. This is done by the use of the mathematical expression of a certian propagation model that predicts the variation in signal level between that WSD and DTT receivers for a certain environment.

The proposed propagation model used in this study is suburban Hata model as recommended by CEPT 2011 [26]. The suburban Hata model for suburban is formulated as the following equation [26]. The pathloss for Hata model for suburban areas (H_{sub}) in dB is :

$$H_{Sub}(dB) = A + Blog(d) - C \quad (1)$$

where;

$$A = 69.55 + 26.16log(f_c) - 13.28\,log(h_b) - a(h_m) \quad (2)$$

and;

$$B = 44.9 - 6.55\,log(h_b) \quad (3)$$

Where
d in (m) is the horizontal distance between the base and mobile stations in (km). f_c is the frequency of transmission in (MHz). H_b in (m) is the height of antenna's base station and $H_m$is the height of mobile station antenna, unit in meter (m).

For small and medium-size cities in equation the antenna gain correction factor a(h_m) in (m) is :

$$a(h_m) = (1.1\log(f_c) - 0.7)h_m - (1.56\log(f_c) - 0.8) \quad (4)$$

When substituting Equations (2), (3) and (4) in Equation (1), (H_{sub}) becomes:

$$H_{Sub}(dB) = 69.55 + 26.16log(f_c) - 13.28\,log(h_b) - a(h_m) + [44.9 - 6.55\,log(h_b)]\,log(d) - 2(log\left(\frac{f_c}{28}\right))^2 + 5.4 \quad (5)$$

Since all frequencies of interest, the antenna gain correction factor $a(h_m)$ is small value so it can be ignored $(h_b) = 1.5\,m$ then the Equation (5) can be simplified as follows:

$$H_{Sub}(dB) = 55.68 + 26.16log(f_c) + 38.35\,log(d)\,2(log\left(\frac{f_c}{28}\right))^2 + 5.4 \quad (6)$$

Where:
H_{Sub} is path loss in suburban areas, unit in decibel (dB)
h_b is height of base station Antenna, unit in meter (m)
$h_m$is height of mobile station Antenna, unit in meter (m)
f_c is frequency of transmission, unite in megahertz (MHz).
$a(h_m)$ is antenna height correction factor
$d$is the horizontal distance between the base and mobile stations, unite in kilometer (km).

Proposed signal-path loss altitude model of the terrain is hilly as can be seen from Figure 2, the height of the site that was investigated is designated as P_{IB} *(dBm)* is varied fordifferent height from 0 to 100 m from the ground level, and separation distance between WSD and DTT receiption is 22m.
Unlike the study [15] consider just the horizontal distance between WSD and DTT reception using Reference geometry for mobile-WSD sa shown if Figure 1. Some time the DTT is in different height, thus the assume vertical distance is different from 0 m to 100 m for DTT,

The proposed methodology illustrate in Figure 2, from this figure optain the Equation (7), which consider theheight of FTT receiption,

$$d_i = (d^2 + h_i^2)^{1/2} \quad (7)$$

Where
d_i m is direct distance between WSD and DTT reception
d mis the horizontal distance between WSD and DTT reception
h_i m height of DTT reception.Then will substitute d_i instead of d in Equation (7).

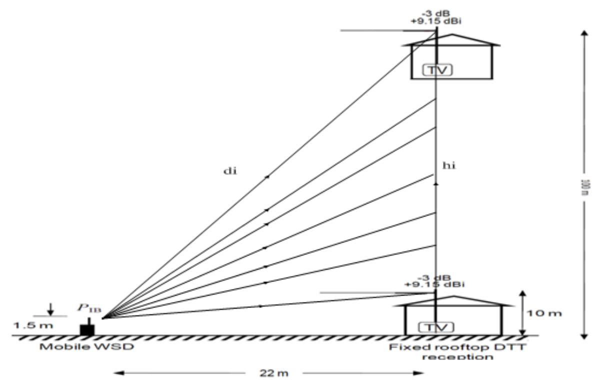


Figure 2 Proposed signal-path loss altitude model

2.4 Calculating WSD Received Power for DTT Reception

The accuracy of WSD received power for DTT reception is very important, because it's main factor for DTT Reception interference. Thue WSD received power should be very sensitive and precise to grantee no harmful for DTT reception.

To achieve that enhanced for WSD maximum permitted emission we will investigate the proposed propagation model as mentioned before, based on the European Conference of Postal and Telecommunication [26], the WSD maximum permitted emission calculation details in equation below [26]:

$$P_{IB} = DTT_{signal\,power} - r(\Delta f) - G \quad (8)$$

Where
P_{IB} is maximum permitted WSD in-block EIRP is DTT at reception
$r(\Delta f)$ is protection ratio WSD-to-TV
G is WSD-to-TV separation coupling gain.

Also coupling gain G (dB) is described in Equation (9)

$$G = Pass\,Loss - G_{EFF-TV} + antenna\,polar\,Discrimination \quad (9)$$

Where
G_{EFF-TV} is effective TV antenna gain in Equation (10)

$$G_{EFF-TV} = G_{TV} - FL \quad (10)$$

where;
G_{TV} is TV antenna gain (dBi), and
FL cable feeder loss (dBi)

The maximum permitted emission levels out band P_{OB} (dBm) described ad Equation (11)

$$P_{OB} = P_{IB} - r(\Delta f) \quad (11)$$

The study done based on the studies, methodologies, results and recommendations conducted by the European Conference of Postal and Telecommunication administration [26].Table 1 below show a summary of database parameters which used in this work.

Table 1 Summary of database parameters used in this work [18]

Parameters	Value
$DTT\ signal\ power$	-70 dBm in every pixel
$ACLR_{WSD}$	33 dB for first adjacent channels
$ACLR_{WSD}$	36 dB for second adjacent channels
ACS_{DTT}	56 dB for first adjacent channels
ACS_{DTT}	61 dB for second adjacent channels
Protection Ration for co-channel, $\mathrm{r}(0)$ co − channel	16 dB for co-channel
$r(\Delta f)\ first\ adjacent\ channel$	-17 dB first adjacent channels
$r(\Delta f)\ second\ adjacent\ channel$	-20 dB second adjacent channels
Coupling gain (dB)	Suburban Hata path gain at 650 MHz
Polarization Discrimination (dBi)	3
$Feeder\ Loss\ FL$ (dBi)	3 dBi
G_{TV} TV antenna gain (dBi)	12.15 dBi

3.0 RESULTS AND DISCUSSION

The study mainly focuses on the investigation of the effect of hilly environment on TVWS reception frequency and analyzed the results based on different altitudes for DTT receiption. Figure 3 shows a comparison between proposed P_{IB} and P_{OB} at different altitudes with P_{IB} and P_{OB} for a fixed altitudes for selected reference geometry.

From Figure 3 it can be seenthat the proposed P_{IB} increased with height accordingly, which represent the accurate value start from -35.5829 dBm at zero height till -9.971 dBm at 100 m height. While P_{IB} fixed has fixed value -35.58 dBm which not accurate due to the influence of altitudes and propagation model and definitely will resulting harmful interference for DTT reception. The different between proposed P_{IB} and fixed P_{IB} at 100 height is 25.609 dBm. The same behavior happed for P_{OB}, proposed P_{OB} increased with height accordingly, which represent the accurate value start from -68.58 dBm at zero height till -42.97 dBm at 100m height. While P_{OB} has fixed value -68.58 dBm which not accurate due to influence of altitudes and propagation model. The different between proposed P_{OB} and fixed P_{OB} at 100 height is 25.61 dBm. Since the altitudes increases, the P_{IB} and P_{OB} increases consequently. That would be approved that maximum permitted emission levels for WSD will be increasing as the DTT reception height increases.

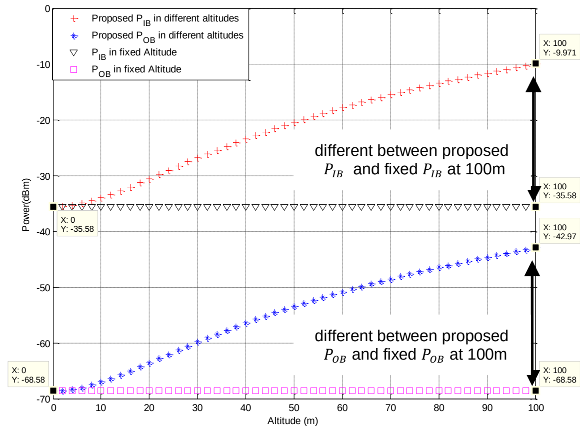


Figure 3 A comparison between proposed P_{IB} and P_{OB} at different altitudes with P_{IB} and P_{OB} in fixed Altitudes for selected reference geometry

Figure 4 shows a comparison between proposed P_{IB} in different distance between WSD and DTT reception at 20 m, 100 m, 500 m, 1 km and 3 km for 100 m altitudes for all distances at 650 MHz. It is clear that P_{IB} is varies with different distance between WSD and DTT reception. For example, P_{IB} for distance 20 m, is -37.17 dBm at zero height and -10.04 dBm at 100 height. The variance in 100 m is 27.13 dBm, meanwhile P_{IB} for distance 3 km, is 46.28 dBm at zero height and 46.29 dBm at 100 height. Thus the variance in 100 m is 0.01 dBm. This result proves, that when the distance is shorter between WSD and DTT the impact of altitudes for proposed P_{IB} is higher and considerable. On the other hand when the distance is very far the proposed P_{IB} is lower and could be ignore.

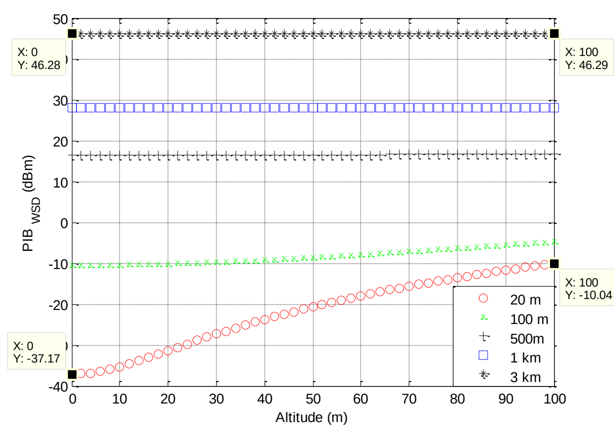


Figure 4 A comparison between proposed P_{IB} in different distance between WSD and DTT reception at 20 m, 100 m, 500 m, 1 km and 3 km for 100m altitudes for all distances at 650 MHz

4.0 CONCLUSION

This paper has analyes the effect of hilly and forested terrain on TVWS propagation for different altitude (height) at DTT reception. The study achieved according to the studies, methodologies, results and recommendations conducted by the European Conference of Postal and Telecommunication administration. The results obviously demonstrate that the proposed maximum permitted emission levels P_{IB} and P_{OB} for TV WSD increases with increase by 25.609 dBm and 25.61 dBm respectively in 100 altitude accordingly, which is accurate value for interest reference geometry. While the fixed P_{IB} is constant at the DTT reception in all heights, which is not accurate value. In addition, when the distance is shorter (meters) between WSD and DTT proposed P_{IB} is significant, while it very far (kilometers) P_{IB} value not considerable, which is more accurate. The future work is to study and model the influence of vegetation and season on WSD communication.

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References

[1] H. Nguyen, 2005. Characterization of the Indoor/Outdoor to Indoor MIMO Radio Channel at 2.140 GHz. *Wireless Personal Communications, Springer.* 35: 289–309.

[2] Y. T. Li . L, Kooi. P, Leong. M, and Koh. J. 1999. Analysis of Electromagnetic Wave Propagation in Forest Environment along Multiple Paths. *Progress In Electromagnetics Research*. 23: 137–164.

[3] M. Alsehaili, *et al.* 2010. Angle and Time of Arrival Statistics of a Three Dimensional Geometrical Scattering Channel Model for Indoor and Outdoor Propagation Environments. *Progress In Electromagnetics Research*. 109: 191–209.

[4] H. L. Martinez, F. and Ayestaran. R. 2007. Fast Methods for Evaluating the Electric Field level in 2D-Indoor Environments. *Progress In Electromagnetics Research*. 69: 247–255.

[5] J. S. Bello, G. L. Bertoni, Henry, L. 2000. Theoretical Analysis and Measurement Results of Vegetation Effects on Path Loss for Mobile Cellular Communication Systems. *IEEE Transactions on Vehicular Technology.* 49: 1285–1293.

[6] G. G. D. Joshi, C. B. Anderson, C. R. Newhall, W. G. Davis, W. A. Isaacs, J. Barnett, G, 2005. Near-ground Channel Measurements Over Line-of-Sight and Forested Paths. *IEE Proceedings Microwaves, Antennas and Propagation.* 589–596.

[7] R. Ott. 1996. Electromagnetic Scattering by Buried Objects in The HF/VHF/UHF Frequency Bands. *Progress In Electromagnetics Research.* 12: 371–419.

[8] H. J. Li. Y, Wang and M, Zhang. J. 2008. Scattering Field for the Ellipsoidal Targets Irradiated by an Electromagnetic Wave With Arbitrary Polarizing and Propagating Direction. *Progress In Electromagnetics Research Letters.* 1.

[9] F. a. P. Blas. J, Lorenzo. R, and Abril. E. 2008. A model for Transition between Outdoor and Indoor Propagation. *Progress In Electromagnetics Research.* 85: 147–167.

[10] M. J. Gans and e. a. Amitay. 2002. Propagation Measurements for Fixed Wireless Loops (FWL) in a Suburban Region with Foliage and Terrain Blockages. *IEEE Transactions on Wireless Communications*. 1: 302–310.

[11] Y. Abdulrahman, *et al*. 2011. *Empirically Derived Path Reduction Factor for Terrestrial Microwave Links Operating at 15 GHz in Peninsula Malaysia*. *Journal of Electromagnetic Waves and Applications.* 25: 23–37.

[12] FCC. 2004. *Notice of Proposed Rule Making, in the matter of Unlicensed Operation in the TV Broadcast Bands*. Federal Communications Commission (FCC) USA.

[13] FCC. 2008. *Second Report and Order and Memorandum Opinion and Order*. Federal Communications Commission.

[14] C. Stevenson and e. a. Chouinard, 2009. IEEE 802.22: The First Cognitive Radio Wireless Regional Area Network Standard. *IEEE Communications Magazine.* 47: 130–138.

[15] MCMC. 2009. *Requirements For Digital Terrestrial Television (Including Digital Terrestrial Sound) (DTT) Service operating In the frequency Bands 174 MHz to 230 MHz And 470 MHz to 742 MHz*. Putrajaya, Malaysia

[16] C. OFCOM. 2010. *Implementing Geolocation (Regulatory Issues)*. Office of Communication.

[17] H. R. Karimi. 2011. *Geolocation Databases for White Space Devices in the UHF TV Bands: Specification of Maximum Permitted Emission Levels*. Presented at the New Frontiers in Dynamic Spectrum Access Networks (DySPAN), 2011 IEEE Symposium on.

[18] ECC. 2011. *Technical and Operational Requirement for the Possible Operation Cognitive Radio System in the White Space of the Frequency Band 470-790 MHz*. Electronic Communications Committee (ECC).

[19] ECCReport138. 2010. *Measurements on the Performance of DVB-T Receivers in the Presence of Interference from the Mobile Service (Especially from UMTS).* Electronic Communications Committee (ECC).

[20] ECCReport148. 2010. *Measurements on the Performance of DVB-T Receivers in The Presence of Interference from the Mobile Service (Especially from LTE)*," Electronic Communications Committee (ECC).

[21] M. H. S. Hashim, S. 2006. Measurements and Modelling of Wind Influence on Radiowave Propagation Through Vegetation. *IEEE Transactions on Wireless Communications*. 5: 1055–1064.

[22] H. Elshafie, *et al.* 2013. *Measurement of UHF Signal Propagation Loss under Different Altitude in Hilly Environment*. *Applied Mechanics and Materials.* 311: 37–42.

[23] ECC. 2013. *Technical and Operational Requirements for the Operation of White Space Devices Under Geo-Location Approach*. *ECC Report 186 CEPT.*

[24] e. a. S. Helhel, 2008. Investigation of GSM Signal Variation Depending Weather Conditions. *Progress In Electromagnetics Research*. 1: 147–157.

[25] L. H. Song.Y , Chong. B. 2009. The Effects of Tropical Weather on Radio-Wave Propagation Over Foliage Channel. *IEEE Transactions on Vehicular Technology.* 58: 4023–4030.

[26] E. R. 159. 2011. *Technical and Operational Requirement for the Possible Operation Cognitive Radio System in the White Space of the Frequency Band 470-790 MHz. Cardiff. ECC.*