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System Environment Propagation Modeling for a Wi-Fi-like Network Operating in TV White Space

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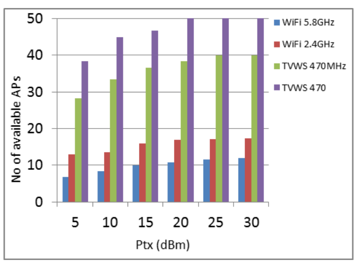
Graphical abstract



Abstract

In paper, the effect of different environment has been studied. For the next Wi-Fi generation at different frequencies 470 MHz, 790 MHz, 2.4 GHz and 5.8 GHz. since USA and UK open up unitized portions of UHF Band for unlicensed usesecondary use. The purpose and interest in using these TV white spaces (TVWS) for providing services to end user as broad-band services through Wi-Fi like connectivity. There is awareness that Wi-Fi operating in TVWS will increase coverage range, speeds, and more reliable connections than traditional Wi-Fi at 2.4 GHz or 5.8 GHz. The Log-distance path loss model simulated by Matlab in variable environments, for instant indoor urban, outdoor urban, outdoor suburban and outdoor rural. Different graphs are illustrated to view the effect of the environment and frequencies to path loss and power received within versus distances. A comparison between traditional Wi-Fi based systems working in the 2.4 GHz and 5.8 GHz and TVWS systems in 470 MHz and 790 MHz, and results show that the favorable propagation conditions characterizing the TVWS frequencies may lead to better coverage with the additional benefit of lower transmit power levels.

Keywords: TVWS; Wi-Fi; different environment

1.0 INTRODUCTION

The performance of wireless communication depends greatly on the channel characteristic between the transmitter and receiver. An obstacle between the transmitter and receiver can seriously affect the propagated signal strength. The pathloss (PL) in decibels (dB) can be expressed in Equation [1]:

$$LP = PT + GT + GR - PR - LT - LR \tag{1}$$

where,
LP is the path loss between transmitter and receiver (dB)
PT is transmit power (dBm)
PR receive power (dBm)
GT is the gains of transmitting antenna (dBi)
GR is the gains of receiving antenna (dBi)
LT is feeder losses for the transmitter (dB)
LR is feeder losses for the receiver (dB)

Conducting wireless communication research in rugged terrain at UHF frequency band has attracted many researchers due to its significance [2-3]. Maintaining signal quality in different environment has been a major challenge which requires more intensive research and critical analysis. The degradation of signal strength is primarily due to multipath, refraction, diffraction and reflection which eventually hinder effective and efficient communication [4-7]. The nature of the environment and obstacle between the transmitting and receiving station has detrimental impact on the received signal strength [8]. It is very obvious that most VHF/UHF frequency bands are used for television broadcast in which the quality of reception is extremely important in achieving higher video quality output. The structure andcomposition of the building plays an important role in determining the overall signal attenuation. The physical barriers and object within building can also cause losses as well.

Moreover, metal cabinets, walls and ceilings can attenuate the signal level. Many of these objects can scatter and reflect the propagated radio waves [9-11].

The nature of the terrain has an impact on the radio wave propagation. In plain terrain, the radio waves propagation at UHF band can be reflected by ground surface [12]. The tip edge of rocks and large trees can cause diffraction of the propagated radio wave. The height of the transmitting antenna will avoid interference if placed at higher altitude. Apart from the outdoor scenario, the hilly nature of the environment has been taken into consideration. This study is primarily aimed to investigate the signal path loss and attenuation in outdoor environment under such condition. The characteristic of radio wave in different environment and frequency is investigated. This paper is organized as follows: Section 2 illustrates the methodology explain the radio propagation losses and system parameters. Section 3 presents the results and discussion. Finally conclusions are draw in Section 4.

2.0 METHODOLOGY

The general idea is based on the comparison of radio propagation models in different environment and frequency to find the favored model for specific deployed environment of the Wi-Fi. This done by obtaining path loss evaluation, which depends on the separation distance between the access point (AP) and user.

2.1 Radio Propagation Losses

The radio propagation losses in both indoor and outdoor environments calculates based on separation distance and exponent value k [1].

The k value is variants depends on the type of propagation environment, for example, material of construction, architecture, and position within a building [13]. For instance, free space propagation model k value is 2 and when obstructions appear the value of n will increase. Since the nature of the environment is terrain and the distance is less than 60 kilometers, Log-distance Path Loss Model has been used in order to predict the path loss of the radio propagation link. More importantly, the frequency range (470 MHz to 5.8 GHz) can be effectively used in our scenarios for the path loss prediction. The model is widely used and has been developed based on the real data collected around the world. It is characterized by the flowing Equation (2)

$$PL = -27.55 + 20\log(f) + 10klog(d) + Xg \quad (2)$$

Where:
PL is path loss between transmitter and receiver in dB
f is carrier frequency in MHz
k is the path loss exponent
Xg is a random variable noise to take into account fading, cable and body losses (6 dBm)

It is obvious that the range obtained by the terminal operating in 470 MHz and 790 MHz is much larger than that which works in the 2.4 GHz and 5.8 GHz . In this analytical model, an extensive performance analysis obtain from a set of simulations compared between TVWS (470-790) MHz traditional Wi-Fi (2.4 -5.8) GHz.

2.2 System Parameters and Scenarios

In order to conduct different scenarios, the system parameters are required to deployment proposed scenarios that are used in our simulations are described in Tables 1-3. Log-distance Path Loss Model is implemented for four cases, i.e. indoor urban, outdoor urban, outdoor suburban outdoor rural and respectively.

Table 1 System model parameters for different scenarios

	Indoor Urban	Outdoor Urban	Outdoor Suburban	Outdoor Rural (free space)
Propagation model (k)	4 and 18 dB wall loss	3	2.5	2

Table 2 Different frequency bands for Wi-Fi operation

Frequency	470 MHz	790 MHz	2.4 GHz	5.8 GHz
AP channel Width	2.4 MHz 3 adjacent TV channales	2.4 MHz 3 adjacent TV channales	20 MHz	20 MHz

Table 3 Parameters scenario of TVWS and Wi-Fi

Parameters	Wi-Fi	TVWS
Radio frequency	(2.4-5.8) GHz	(470-790) MHz
EIRP	20/4.77 dBm	20/4.77 dBm
Channel bandwidth	20 MHz	8 MHz
Receiver sensitivity	-82 dBm	-82 dBm
No of APs	50	50

3.0 RESULTS AND DISCUSSION

The study considered four scenarios are; indoor urban, outdoor urban, outdoor suburban outdoor rural and respectively. The test effect of the received signal level for these four scenarios is presented. In the following a comparative results based on the received signal level for each with respect to specific scenario are presented.

Matlab simulations results are shown in Figure 1-4. From Figure 1, rural scenario is the best performance (ideal case almost free space), and the power received best compared with other scenario, because is any obstacle in the path (clear LOS). While the others scenarios are low performance and power received as well, and that are resulting from local clutter ant signal attenuated from material of construction, architecture, and building. Notice also, that the low performance is indoor urban, because of material of construction, architecture, and position within a building beside of path loss wall (18 dB). Two different frequencies in same scenario ,such as 630 MHz and 2.4 GHz outdoor urban, obtain that low frequency better performance and power received. And same trend for all other scenarios, this is one of TVWS advantages. In Figure 2 the discuss in specific scenario bur different frequencies The Log-distance Path Loss Model is simulated in considered four are 470 MHz, 790 MHz, 2.4 GHz and 5.8 GHz respectively. The important is test the effect of the received signal level for these four frequencies. In the following a comparative results based on the received signal level for each with respect to specific frequencies are presented. In Figure 2, 470 MHz is the best performance (low frequency), and the power received best compared with other high frequencies, because this is advantage of UHF provide high coverage distance. While the others scenarios are low frequencies and power received as well. Also, that the low performance is high frequencies 2.4 GHz and 5.8 GHz. And that are resulting from spectrum characteristic. This comes from the relationship between frequency and coverage expressed in Equation (3)

$$f = k/d \tag{3}$$

Where
k is constant
f is frequency
d is coverage distance

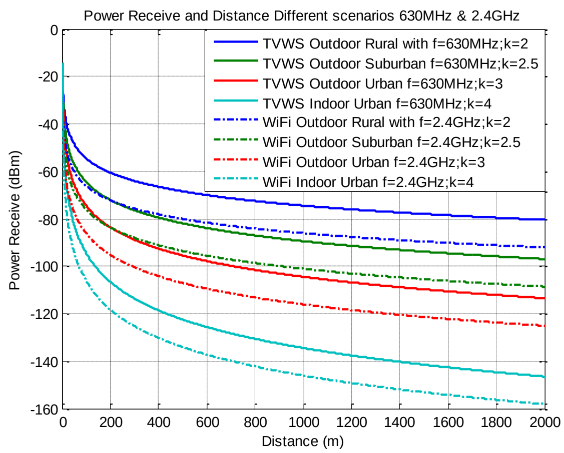


Figure 1 Power receive and distance different scenarios 630 MHz, 2.4 GHz, Ptx=20

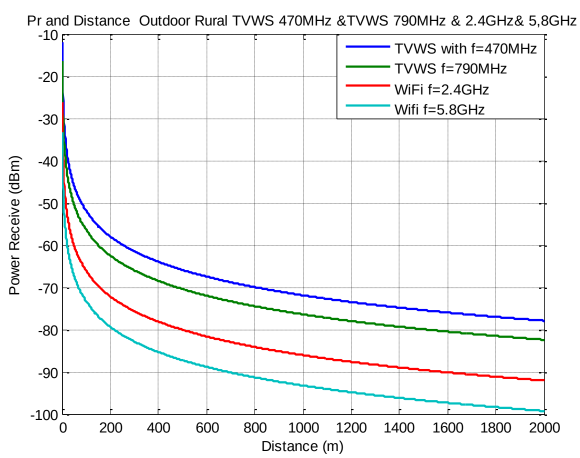


Figure 2 Power receive and distance outdoor (470,790) MHz, (2.4,5.8) GHz, Ptx=20

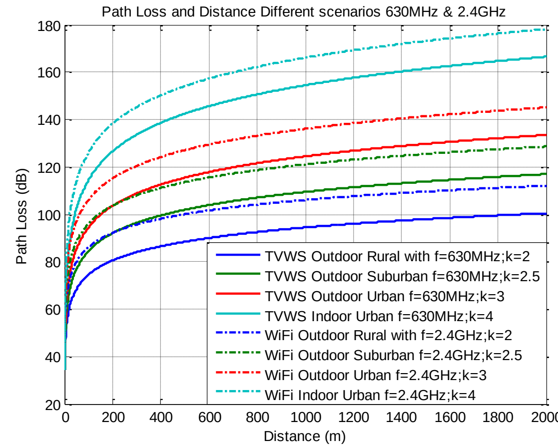


Figure 3 Path loss and distance different scenarios 630 MHz, 2.4 GHz, Ptx=20 dBm

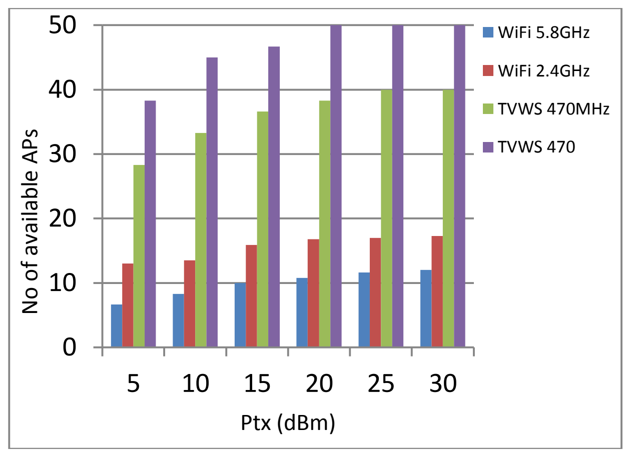


Figure 4 Number of reached APs for different spectral bands and transmit power

In Figure 3, the outdoor rural scenario is the low path loss (ideal case) almost free space becuase the propagation model k=2 is low compare with others scenarios. From Equation (1) the relationship between path loss and power received is Inverse relationship, then the power received best compared with other scenarios. While the others scenarios high path loss and that are resulting from signal attenuated from material of construction, architecture, and building till maximum path loss happened in indoor because include also path loss wall (18 dB). From the results recognized that high frequencies obtain high path loss, and low frequancies get low path loss,and this is one of TVWS advantages.

Based on Figure 4 it is evident that, for the same transmitted power such as; 5 dBm, the average number of APs reached by a TVWS device (both 470 and 790 MHz) is much greater than the Wi-Fi (2.4 GHz and 5.8GHz). The Wi-Fi APs can cover only a small more than 6 APs for its maximum transmitted power value, but when the TVWS (470 MHz-790 MHz) always reaches more than half of the total APs.

4.0 CONCLUSIONS

The main key the telecommunication engineering is propagation model, since it influane the performace of wireless communication. Investigating different scenario with the Log-distance path loss model for Wi-Fi system was conducted in this study and statistical analysis of the results are provided. The results clearly show that the path loss variables depend on scenarios, for example indoor urban is higher path losses comparing with others scenario, because of indoor material beside of path loss wall (18 dB), in other hand rural area (free space) is lowest path losses. Wi-Fi performance better coverage when operating in low frequencies. To choose which in best kind of propagation model, it depend on what your needed from deployment, scenario and important is environment and cost. Our future interest is to investigate and model the impact of vegetation and season on radio wave propagation.

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