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RADIOWAVE PROPAGATION MODELS FOR VHF AND UHF BAND

Ajit Singh Department of Computer Science Patna Women's College, INDIA

ABSTRACT : Radiowave propagation model is an empirical mathematical formulation for characterization of radiowave propagation as a function of frequency, distance and other conditions. This study explains the various attenuating factors prevalent in radiowave propagation. It highlights the various types of radiowave propagation; its classification based on their propagation paths; its layers in the atmosphere, its frequency bands and propagation mechanism. The study also entails the various radiowave propagation models and their application in VHF and UHF band.

KEYWORDS: *Radiowave Propagation Models, VHF Band, UHF Band, Attenuating Factors, Radiowave Propagation.*

1. Introduction

Radiowave Propagation is the transfer of energy by electromagnetic radiation at radio frequencies from one point, a transmitter to another, a receiver. Radiowave Propagation comprises of two types: The Guided and Free (unguided). Free (unguided) Radiowave Propagation occurs between corresponding antennas in the earth's atmosphere, underwater or in free space while the Guided Radiowave Propagation takes place in manmade guiding systems such as wirelines, coaxial cables, waveguides and optical fibers [1]. VHF and UHF bands belong to the free (unguided) as opposed to the guided. VHF and UHF bands are seen as the "line of sight transmission" on account of their app. VHF is defined as the portion of the radio spectrum from approximately 30MHz to 300MHz while UHF band is the portion of radio spectrum from 300MHz to 3GHz [2].

1.1 Classification of Radiowave Based on their Propagating Paths

There exists four major propagating paths of radiowave namely surface wave, space wave, tropospheric and ionospheric [3].

Surface wave. Propagates in direct contact with the earth's surface and as a result suffers severe "frequency-dependent attenuation" occasioned by absorption into the ground, "space waves on account of their being radiated from an antenna with many wavelengths above the surface are far from being attenuated as no part of it is in contact with the surface of the earth. It is, however, worthy of note that the propagation modes of both the VHF and UHF bands are exclusively tied to space wave."

Space wave. Space wave as shown in figure 1 comprises two components "direct" and "reflected" and albeit it is grouped together with "surface wave" as "ground wave", their varied propagation characteristics warrant their being considered exclusively.

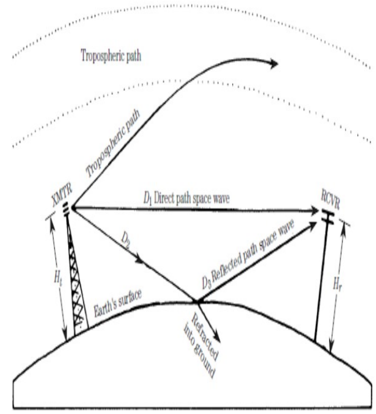

Fig. 1 Showing Space Wave Propagation [3]

Ionospheric. Ionospheric propagation is dependent on the ionization of the earth's atmosphere as a result of its being impacted upon by intervening factors such as ultra-violet radiation from the sun and cosmic rays. Ionospheric path is important to medium wave and HF Propagation but it is insignificant for VHF, UHF or microwave propagation. This phenomenon predisposes variation in electron density between day and night conditions with peaks in electron clarity that are in tandem with the height at which the evolved gases settle within the region of the upper atmosphere.

1.2 Classification of Layers in the Atomsphere Layers in the upper atmosphere are classified into:

C layer

D layer

E layer

summarized their localized frequencies and heights in order of magnitude comparison as shown in Table 1:

Table 1 Showing the Virtual Height, Critical Frequency and Maximum Single-Hop Range of the Ionospheric Layers

IONOSPHERIC LAYERS	VIRTUAL HEIGHT	CRITICAL FREQUENCY	MAXIMUM SINGLE-HOP RANGE
C and D layers	60-80km	Reflects low and very low frequencies	
E layer	110km	4MHz	2350km
1 layer	180km	5MHz	3000km
2 layer	300km(day-time) and 350km(night time)	8MHz(day time) and 6MHz(night time)	3840km(day time and-4130km(night time)

The study describes propagation of SURFACE WAVE as following the curvature of the earth due to refraction and categorizes it (Surface Wave) as being of importance at frequencies below about 2MHz with the conductivity and permittivity of the earth surface playing an important role in its propagation. This is due largely to the fact that it could introduce both displacement and conduction currents in the surface.

The study further states that at the highest frequency, these currents may penetrate depths ranging from about 1m to ten of meters at the lowest.

Attenuation thus occurs as the radio wave passes over the earth surface, even in an increased dimension as the frequency increases. Hence, the limitation of the usefulness of the SURFACE WAVE to frequencies below about 2MHz.

The study equally states that the DIRECT WAVE and the GROUND REFLECTED WAVE(both of which comprise the SPACE WAVE) are at low enough frequencies(where transmitting antenna height above ground, in terms of wavelength, is small) capable of cancelling out each other; with the corollary of leaving only the SURFACE WAVE.

Nevertheless, at higher frequencies, the height of the antenna may be such that makes the SPACE WAVE comparable in magnitude to the SURFACE WAVE, which results in the PHASOR SUM. The resultant wave in this instance is referred to as the GROUND WAVE, which should not in any way be confused as SURFACE WAVE alone.

1.3 Classification of Radiowave Based on Frequency Bands sees radiowaves as being classified either by frequency bands or by propagation mechanisms nced Researches and Engineering Journal 05(02): 000-000, 2021

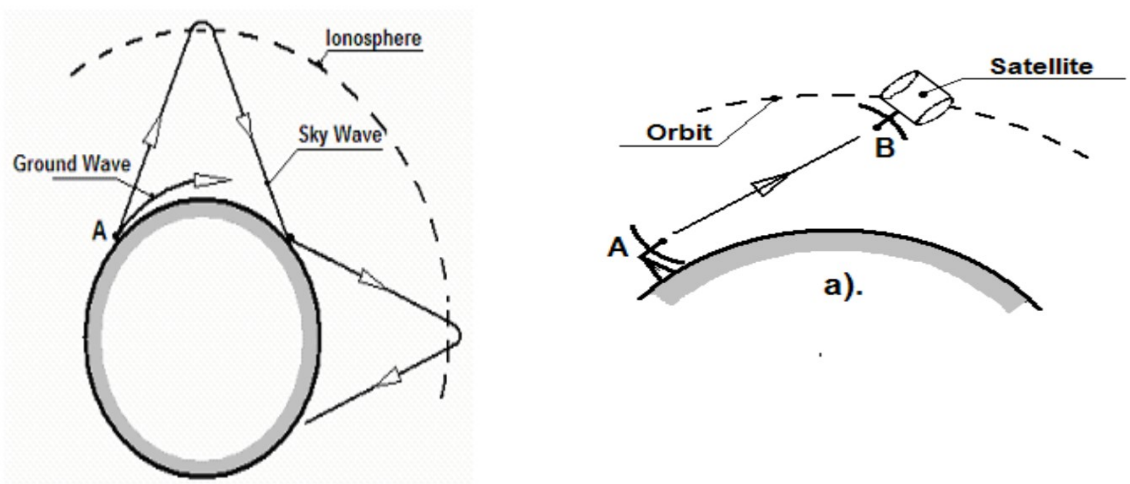

Fig.2 Showing Sky Wave Propagation [1]

“ground waves” as radio waves that propagate from a source in the vicinity of the surface of the earth as opposed to having its propagating path in the ionosphere. The study also sees two ground wave modes: “surface waves” and “space waves” as existing independently. This varies slightly from the position of [2] which sees “ground waves” as consisting of “surface waves”, “direct waves”

and “ground-reflected waves”. While highlighting “ground waves” and “sky waves” as those based on spatial area, [1] outlines four radio waveforms as falling into the category of THOSE EVOLVING UNDER THE

MECHANISM BETWEEN THE TRANSMITTING AND RECEIVING ANTENNAS. They are:

- Direct radio waves(or simply direct waves)
- Reflected radio waves(or reflected waves)
- Scattered(or secondary) radio waves
- Diffracted radio waves (or simply diffracted waves).
- Reflected Radio Waves. Reflected radio waves are those waves that travel to the receiving point via a reflection from an object, which has large dimensions compared to the wavelength [1, 5]. Occasioned by impedances between the air and the encountered object, a part of the energy is reflected whilst the

remaining part is refracted into the other medium. Figure 4 shows an ideal representation of this occurrence.

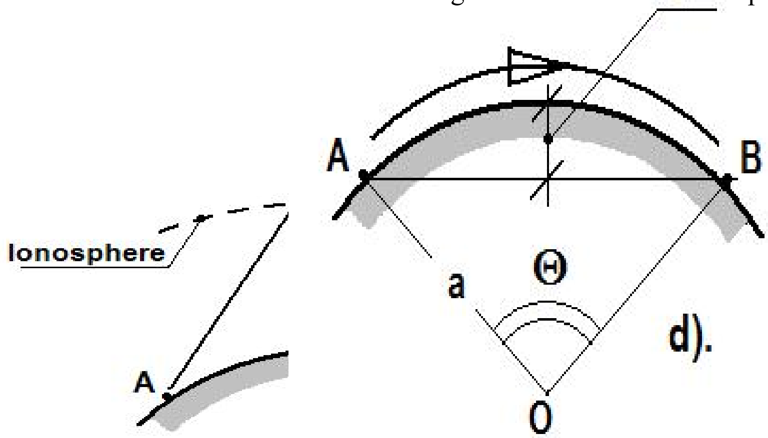

Fig. 4 showing a reflected radio wave [1]

A Scattered (Or Secondary) Radio wave. Scattered (or secondary) radio waves is referred as scattering, which it construes as related to reflection and could be referred to as diffuse reflection [6]. Its occurrence causes the energy of the radio wave to be distributed in all directions. According to [1], the phenomenon of scatter propagation through the irregularities of the ionosphere is peculiar to the VHF frequency band as shown in Figure 5.

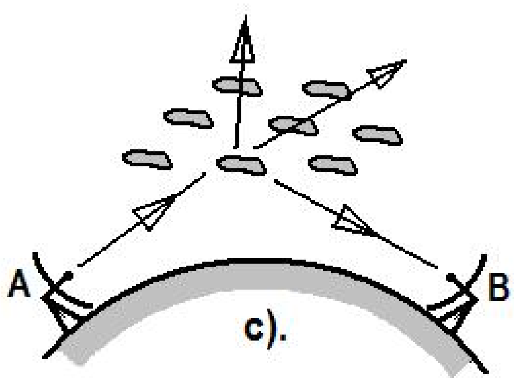

Fig. 5 Showing Scattered Radio Waves [1]

Diffracted Radio Waves (Or Diffracted Waves).

Diffracted radio waves is defined as electromagnetic wave that has been modified by an obstacle or spatial inhomogeneity in the medium by means other than a reflection or refraction [1]. [5] concurs with this assertion when it sees the phenomenon as occurring when the obstructing object is large compared to the wavelength of the radio wave. [1] sees it as occurring when h≤λ as shown in figure 6.

Fig 6 Showing Diffracted Radio Waves [1]

2. Dynamics of Attenuating Factors prevalent in Radiowave Propagation

Several attenuating factors are prevalent in radiowave propagation namely: Shadowing Effects, Multipath distortion, Picket Fencing, Path loss, Diffraction, Multipath Spread, Noise and Interference.

Shadowing Effect. “Shadowing” is the loss of field strength typically contributed to a diffracted wave emanating from an obstacle between transmitter antenna and receiver antenna [7, 8]. VHF and UHF waves exhibit a tendency of being attenuated with every rule of distance

This is just as ridges and hills could form shadows of VHF and UHF waves. The study, however, gave an exception concerning sharp ridges or other kinds of abrupt barriers usually caused by diffraction.

Multipath Distortion. Multipath distortion has to do with a situation where VHF and UHF waves are reflected off of dense surfaces like rocks or conductive earth, just like a beam of light can be reflected of a wall or a ceiling [2]. It sometimes occurs with several paths between a transmitting and receiving antenna as evinced in Figure 7.

In much the same vein, [3] outlines four major propagation paths: “surface wave”, “space wave”, “tropospheric” and “ionospheric.” While the study sees the ionospheric path as important to medium-wave (MW) and HF propagation, it sees it as insignificant for VHF, UHF or microwave propagation.

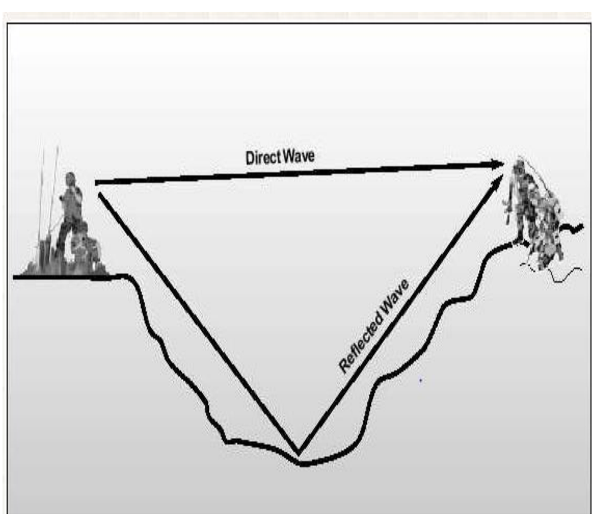

Fig. 7: Showing wave reflections caused by multipath distortion [2]

Figure 7 shows a direct LOS path between two radios that is inclusive of a reflected path from the bottom of a valley between them. The two paths are of different length with the direct path being the shorter of the two. And since radio waves travel at a constant velocity, the direct path wave arrives at the receiver before the reflected path. Thus, the same broadcast information reaches the receiver at two different times. It is much like echoes in an acoustically poor room. It is hard to understand what is being said if the echoes are close enough to each other.

Picket Fencing. Picket fencing is a form of multipathing that is common to vehicular mounted radios [2]. Its occurrence is usually associated with interference or reflections of signals from man-made objects such as buildings, houses, and other structures. Picket fencing is prevalent with VHF and UHF.

Path Loss. Path loss is the loss in power density experienced by a wave as it traverses the path between the transmitter and the receiver [9]. It is also major component in the analysis and design of the link budget of a telecommunication system [10].

Diffraction. Diffraction is an exception to the rule where ridges and hills form shadows of VHF and UHF radio waves [2]. It occurs when VHF and UHF waves are subjected to having a portion of their waves bend around on reaching very sharp ridges and continue propagation as if a very low power radio was placed at the top of the ridge. Figure 8 shows VHF and UHF Diffraction.

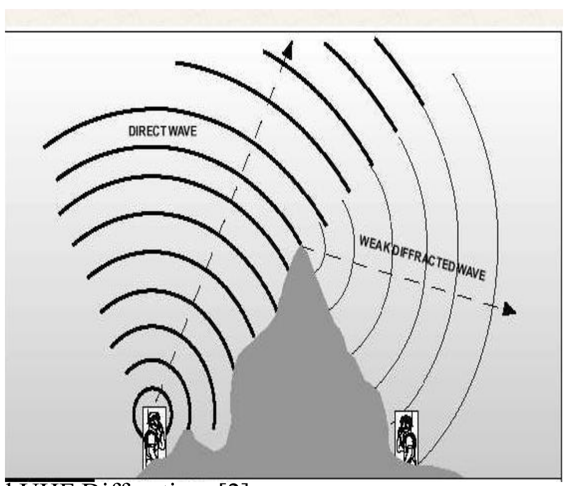

Fig. 8: Showing VHF and UHF Diffraction. [2]

Multipath Spread. Multipath spread is defined as the range of timed differences that it takes for radio signals to reach the receiving antenna when they arrive from several routes, which may include one or more sky wave paths and/or a ground-wave path [2]. This effect according to the study could be minimized by selecting a frequency that is as close as possible to the maximum usable frequency (MUF).

Noise and Interference. Receiver noise and interference comes from both external and internal sources [2]. While the internal noise originated from within the circuits of the receiver, other sources of noise within the radio that are of prominence are the power supplies and frequency synthesizers. External noise, however, comes from sources outside the radio and often exceeds internal receiver noise. The study went on to outline natural and man-made sources of noise and went on to highlight the VHF and UHF bands as being above atmospheric noise. Unintentional radio interference and intentional radio interference were also highlighted; with "collocation interference" as being typical of the former, while using "jamming" or deliberate interference as an example of the latter.

3. Radiowave Propagation Models

Radiowave propagation model is defined as an empirical mathematical formulation for characterization of radio wave propagation as a function of frequency, distance and other conditions [11, 12, 13 and 14].

It plays an important role in planning analysis and optimization of radio network. Hence, the imperative of developing effective propagation models for wireless communication systems. Radio Propagation models are not only used as mitigation measures, but used to predict the behavior of radio propagation in different environments. [15] categorized radio propagation models as falling into three categories, namely:

- Statistical Models
- Deterministic Models and
- Empirical Models.

3.1 Statistical Propagation Models. Their study outlines statistical propagation models as originally devised to provide estimations of signal field strengths (or signal power) in cases where there is insufficient knowledge of the terrain profile. Being models derived from data obtained from extensive measurements in different environments, they require a limited number of parameters (eg. effective antenna height, time and/or location variability, type of ground).

3.2 Deterministic (Geometrical) Propagation Models.

Their study outlines Deterministic models as making use of the laws governing electromagnetic wave propagation with a view to estimating the field strength(or signal power)directly from the path profile(which has to do with terrain and clutter between the transmitter and receiver). They are usually site specific and can be associated with indoor or outdoor propagation environments. Notable examples of it are the Fresnel model, Recommendation ITU-R P.525-2/526-4.

3.3 Empirical Propagation Models .Their study outlines Empirical path loss models as incorporating the benefits of deterministic and statistical models and is widely used for the planning and optimization of cellular networks. This model takes all environmental influences implicitly regardless of whether they could be separately recognized or not.

Their creation is hinged on fitting appropriate mathematical functions to extensive sets of measured path loss data with no due regard to base these functions on physical models of dominant propagation mechanisms. Wireless, Propagation and Network Engineers sees the simplicity and computational efficiency of this model as its main advantage.[16] and [17] sees the possibility of splitting empirical models into two subcategories namely, time dispersive and non-time dispersive; with the time dispersive models providing information about time dispersive characteristics of the channel such as delay spread of the channel during multipath. Examples of it are: Free space, Okumura-Hata, Cost 231, Ericsson propagation models, Recommendation ITU-RP. 1546, Okumura, Egli, ECC-33, SUI, Lee, Macro, COST-231-Walfisch-Ikeagami and Dual-slope, etc.

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