Journal of Information Engineering and Applications
ISSN 2224-5782 (print) ISSN 2225-0506 (online)
Vol.3, No.7, 2013 www.iiste.org

UHF band Radio Wave Propagation Mechanism in Forested Environments for Wireless Communication Systems

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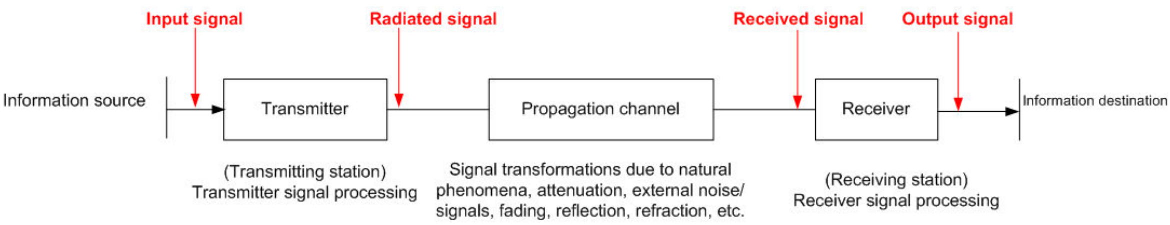
Abstract
Radio frequency propagation is the mechanism of the transfer of energy or information at radio frequencies from one point, a transmitter, to another, a receiver. The energy radiated by a transmitter may take several paths before it is received. The path to be taken by radio wave depends on certain factors, such as: frequency, antenna type and height, atmospheric conditions and terrain. In this research work, UHF broadcast signal strength measurements were taken for both wet season (trees in leafs) and dry season (trees relatively out of leaf) in Akure-Ilara route of Ondo state, Nigeria and the result obtained were validated against the theoretical estimations. However, in the wet season, there were more attenuation of signal compared to dry season and signal degradation is a function of leaf density. The lower the leaf density, the better the signal received. It is thereby required, in wet season more power is expected to be pumped out from the transmitter in order to cover the targeted areas.
Keywords: Radio wave, Forest, Measurements, Signal strength, UHF, Akure-Ilara

1. Introduction

Achieving optimal performance is a paramount concern in wireless networks [1]. The appearance of the foliage medium in the path of the communication link as presented in Fig. 1 has found to play a significant role on the quality of service (QoS) for wireless communications over many years [2]. Discrete scatterers: the randomly distributed leaves, twigs, branches and tree trunks can cause attenuation, scattering, diffraction, and absorption of the radiated waves. This will severely constrain the design of modern wireless communication systems. Wireless communication is



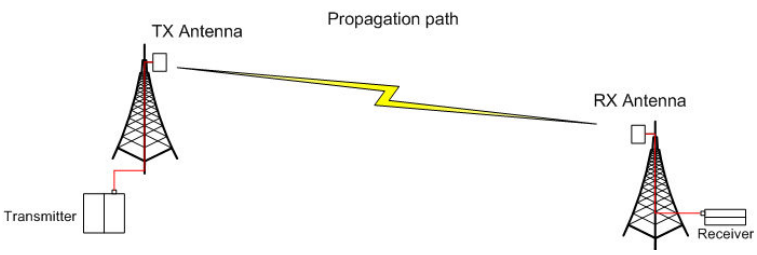


Figure 1: Radio wave Propagation Mechanism

affected by many environmental factors not foreseen by developers, not accounted for by simulators, and not considered by theoretical models [3, 4]. This is especially true for an arable farming environment in which growing crops (foliage) and ever-changing weather conditions have an unknown effect on the exact propagation of the radio waves.

Since the year 1960s, a significant amount of work has been done to investigate the radio wave propagation in forested environment. Analytical and empirical works on the modeling and characterization of the forested channel have been carried out. Some useful and significant results and analysis are reported in [5]. It is reported that the foliage medium can attenuate the propagating radio wave significantly. There are many external factors that will cause the variation in radio wave propagation and even the complete breakdown of communication link in the forest.

In the recent years, the development of wireless sensor networks with low-power wireless transceiver for scientific and military surveillance applications within the forest environments has attracted a lot of attention. Analytical [6, 7] and experimental [8, 9] work have been performed. However, there is still a significant amount of research work that needs to be performed, especially for the empirical work [8, 9] which is site-specific, and limits the practical application of the existing research work. In order to build a robust system that operates well in dense foliage environment, the implementation of MIMO and UWB techniques is often examined. These techniques provide a potential solution to the implementation of a reliable wireless sensor network. However, the successful employment of these techniques in forest environment requires detail knowledge of the effects of the foliage medium on the propagating radio waves.

2. Propagation Mechanisms

Propagation mechanisms may generally be attributed to reflection, diffraction and scattering Ostlin et. al. (2003) [10]. Free space conditions are almost never at hand and the effect of the atmosphere can usually be ignored for the very high frequency (VHF) and the ultra high frequency (UHF) bands.

2.1 Reflection

Reflection occurs when a propagating electromagnetic radio wave encounters an object, which has large dimensions compared to the wave length. In practice, radio waves travel through air and encounter objects and surfaces, such as buildings, other large man-made or natural occurring objects, earth and water. Due to different 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 Parson, (2000) [11]. Typically, the encountered object is not a perfect conductor and hence signal power will be lost in the reflection. The proportion of energy reflected from and refracted into the encountered object is dependent on the electric properties of the media, the electromagnetic wave's reflection and incident angles (which are the same) and the properties of the electromagnetic wave.

2.2 Diffraction

The term diffraction is used to describe how radio waves bend over or around the edge of an obstruction. Diffraction occurs when the obstructing object is large compared to the wave length of the radio wave. Often Huygens–Fresnel principle Stein (1987) and Hagan and. Mehaj (1994) [12, 13], which may be extracted Rojas (1996) [14] from Maxwell's equations. Hagan and Demuth (1999) [15] is used to give an insight to the diffraction phenomenon.

2.3 Scattering

Scattering is related to reflection and is sometimes referred to as diffuse reflection. For example, when a reflecting planar surface becomes more irregular, scattering will occur with a higher probability. When scattering occurs, the energy of the radio wave is distributed in all directions. Typically, scattering objects consist of trees, uneven walls, cars, lamp posts and other small objects.

Mike, 2011 [16] reported; Vegetation and shrubs are forms of clutter. "Clutter" means things spoiling the view that are not part of the terrain which also get in the way of radio path. Clutter causes loss as it is usually made of "lossy" materials. Buildings are often thought to be completely opaque; but this is incorrect, because signals do penetrate buildings especially if there are many windows in an open plan design or if the walls are made of wood. Tree branches and leaves cause loss and they also scatter EM waves passing through them, resulting in a strong multipath component which varies with movement of the leaves and branches in the wind. Trees often have more foliage in the summer than the winter and this leads to seasonal variability in their effect on radio waves [16].

As trees move in the wind, the signal received through them which contains many multipath components varies rapidly with time, due to the continuous variations in the absorbed and reflected energy. This is illustrated in Figure 2 as obtained from Electromagnetic spectrum (2011) [17].

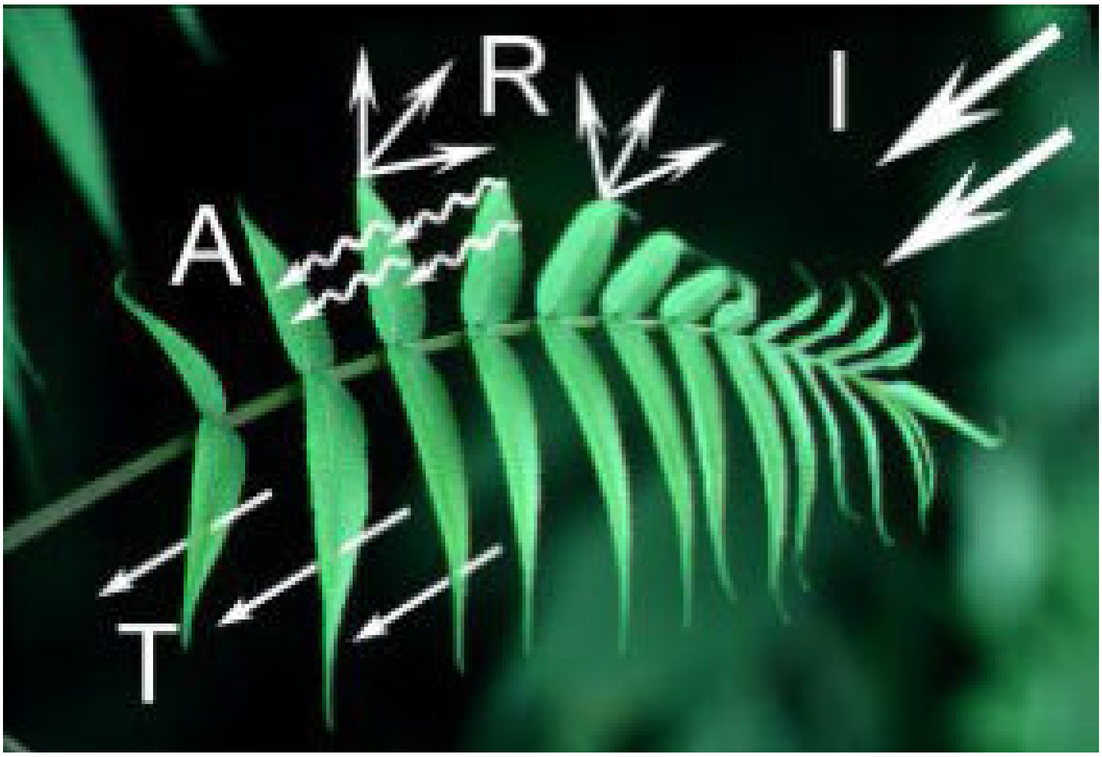


Figure 2: Incident (I), Transmission (T), Absorption (A) and Reflection (R) of EM waves by tree leaves (Electromagnetic spectrum, 2011)

3. Methodology

Ilara is a neighbouring town of Akure where the base station is sited. Being a tropical region, the town has a large share of tall trees. The trees of this dense forest can be categorized into three: The tallest trees are distinguishable through their individuality and often about 45m in height; next to these are trees between 23m and 3.6m tall, whose branches extend to one another thereby forming quasi expansive canopy; while the last and most common species of trees in this area are of hard wood. These trees combine with those in others to form impenetrable forest [18]. Signal field strength measurements were carried out in two seasons: wet season in the month of August and dry season in the month of December using a professional TV signal field strength meter type UNAOHM model EP742A. A Yagi array receiving antennae covering both VHF and UHF frequency bands was used for measurements. This was mounted on support about eight meters above the ground to prevent grounding adverse effect on the reception. The Yagi array was coupled through a 50-ohm feeder to a UNAOHM TV strength meter type EP742A, designed for monitoring and measuring TV broadcast signals (vision and audio), in the VHF/UHF Bands I, III, IV and V. GPS (Global Positioning Satellite (GERMIN model)) was used to determine line of sight (LOS) distance between the transmitter and the observation points. Equation 1 as obtained from Rappaport 2002 was used to determine theoretical estimations. Some of the observation points are presented in plate 1 and 2.

$$E\left(\frac{V}{m}\right) = \frac{\sqrt{30P_tG_t}}{d(LOS)} \qquad (1)$$

Plate 1: Observation Point

Plate 2: Point of Observation

4. Results and Discussion

The measured broadcast signal strength was compared to the theoretical signal field strength calculated using equation 1 and the result is as shown in Figure 3 as a plot of signal field strength against line-of-sight distance LOS.

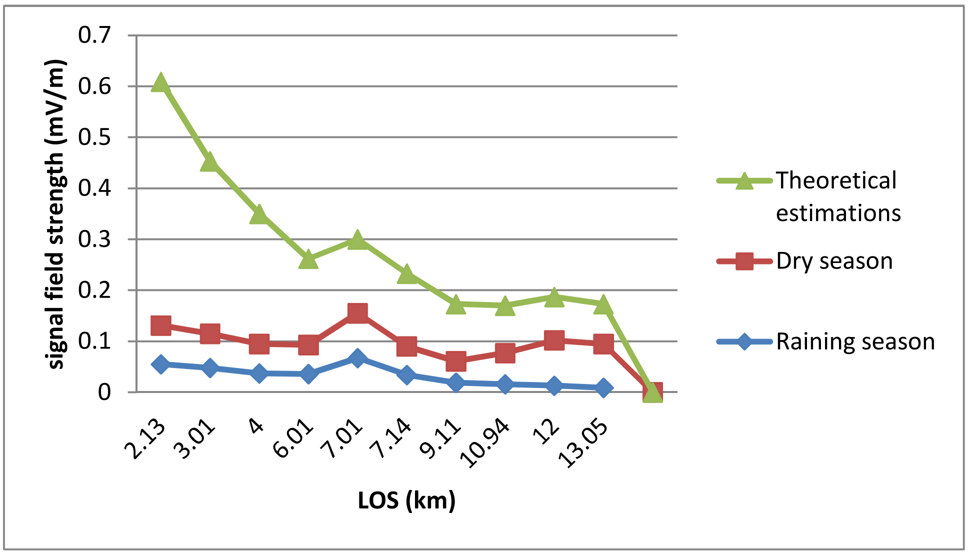


Figure 3: Graph of signal field strength against line-of sight distance

Apart from the losses due to distance "inverse square law", the tree density which is not uniformly distributed and with different permittivity is also responsible for the signal degradation. In the neutral atmosphere, delays are induced by refractivity of gases, hydrometeors, and other particulates, depending on their permittivity and concentration, and forward scattering from hydrometeors and other particulates. Changes in temperature, moisture, and pressure in the atmospheric column cause a change in atmospheric density, which in turn causes variations in the intensity of waves in both the vertical and horizontal. Reflection and diffraction caused by obstruction and the effect of tree density with foliages in that area. The presence of vegetation produces a constant loss, independent of distance between communications terminals that are spaced 1 km or more apart. Since the density of foliage and the heights of trees are not uniformly distributed in the area. The change in the humidity of forests correspondingly results in a variation in the electrical constants (conductivity and permittivity) of the forests, and thereby can influence the radio wave propagation.

5. Conclusion

In this paper, radiowave propagation in forested environment was examined both for the two prominent seasons in Nigeria. Trees often have more foliage in the raining season than the dry season and this leads to seasonal variability in their effect on radio waves. It is found that, many factors such as antenna heights; depolarization etc. can affect the radio wave propagation within a forested channel. Results from this research work are useful for the planning of a reliable communication link in the forest environment.

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