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Attenuations in Wireless Radio Communication

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Abstract: ***A radio wave is part of the electromagnetic spectrum, used in wireless communication to convey information from a transmitting station to a receiving station. The Radio wave signal gets attenuated or faded during propagation due to the variation of the channel parameters with time, several factors cause this attenuation especially the effects of the different ionization densities of the atmosphere and other layers of the earth surface, atmospheric absorption, multipath propagation due to reflection, diffraction and scattering by buildings, hills, etc. all contributed to the reduction of the radio wave signal strength or power as such it gets attenuated or faded before reaching its destination, this lead to poor reception of the transmitted information and at worst case may lead to communication breakage This paper reviewed some of the causes of this Radio wave signal attenuation and their effects.***
Keywords: Radio wave, information, communication, propagation, attenuation

I. INTRODUCTION

A. *Wireless Communication*

The importance of wireless communication cannot be over emphasized, primarily, it makes distance communication possible by connecting devices that send and receive information without any physical connection between the devices. Satellite communication, mobile cellular communication, AM and FM radio communication, Wi-Fi are some of the wireless communication systems that are used nowadays to connect people and also for them to access what is far from their environment as well as space remotely, which are inaccessible before. Wireless communication is characterized by a transmitting part, communication channel, and a receiving part, information is carried by a signal called electromagnetic wave that travels with the speed of light and propagates through space or any transmission media, depending on the communication range and the complexity of the system the Radio wave frequency range is divided according to the type of the communication system to be used. For AM (amplitude modulation) and FM (frequency modulation) radio communication, radio wave frequency in the range of kHz and MHz are used respectively and for mobile phones the frequency is several hundreds of MHz, for satellite communication, RADAR application the signal frequency is in GHz called microwaves. Establishing a reliable connection between transmitter and receiver ensured the effectiveness of the wireless communication system, hence the transmitted signal must be able to reach its destination otherwise connectivity will be broken and therefore no communication. Distance cover is proportional to the signal power or strength, therefore a reduction in signal power during propagation which is called attenuation or fading will degrade the communication system or even at the worst case may lead to communication loss, this attenuation is caused by the effect of atmospheric gases, ionospheres absorption, multipath propagation, etc.

B. *Electromagnetic Wave*

The backbone of wireless communication is the electromagnetic wave, the evolution of electromagnetic wave by James Clark Maxwell marked the beginning of microwave engineering. He came up with four sets of equations that described at a classical level the behavior and relationship between electric and magnetic fields, based on his work electromagnetic waves are formed as a result of vibrations between an electric and magnetic field, hence the name 'electromagnetic' waves. The electric and magnetic fields are perpendicular to each other and the direction of the EM waves. The four equations also prove the existence of electromagnetic wave propagation and light is a form of energy [1].

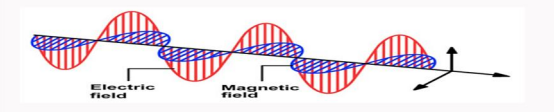

Fig. 1.1: Electromagnetic wave (https://commons.wikimedia.org/wiki/File:EM-Wave.gif)

C. Electromagnetic Spectrum

The electromagnetic spectrum consists of different kinds of electromagnetic waves, it classified the EM waves based on their frequency in ascending order or based on their wavelength on descending order. The spectrum consists of visible light waves, radio waves, microwave, infrared wave, ultraviolet, X-rays, and gamma rays [2].

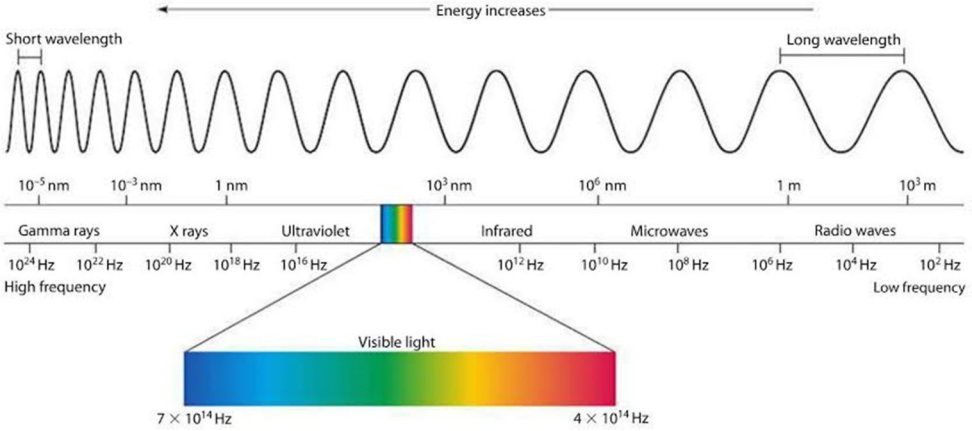

Fig.1.2: Spectrum of electromagnetic wave.
(https://commons.wikimedia.org/wiki/File:EM-Wave.gif)

D. Radio Wave

The radio wave is an electromagnetic wave that traveled with the speed of light used in wireless communication to convey information from a transmitting station to a receiving station. The radio wave has the lowest frequency but longer wavelength in the electromagnetic spectrum, its frequency range is very broad from few kHz to thousands of GHz which are classified into many frequency bands for various wireless communication systems.

E. Radio Waves Propagation

Radio wave propagation is the traveling of the electromagnetic signal from a transmitting station to a receiving station either through space or media. In free space propagation the signal reaches its destination or receiver by a line of sight or with the help of some mechanisms such as reflection, refraction, diffraction, and scattering that resulted in multipath propagation of the signal before it reaches the receiver [3].

F. Propagation Modes

There are different ways by which the radio waves traveled from a transmitting station to a receiving station, depending upon the frequency of the signal and the range of communication needed to be cover.

1) *Ground Wave Propagation:* In-ground wave propagation the radio wave signal mostly has a frequency in the range of kilohertz (kHz) and few megahertz (MHz) and follows the contour of the earth, the signal covers a distance of few kilometers, ground wave propagation found application in AM and FM radio broadcasting [3].

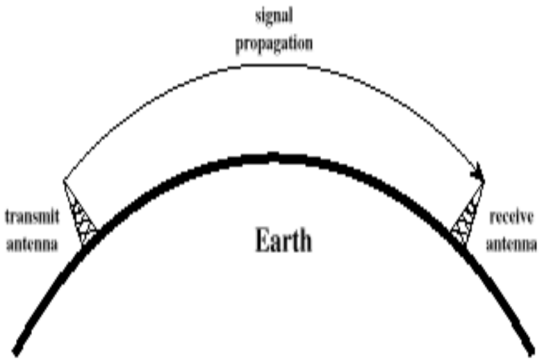

Fig.1.3: Ground wave propagation

2) *Skywave Propagation:* This is a type of wave propagation, in which the radio wave signal which is in the range of megahertz (MHz) gets reflected by the ionosphere to the earth surface, this resulted in multiple reflections of the signal before it reaches the receiver. These multiple reflections allow the signal to reach a very large distance by increasing the skip distance compare to the line of sight propagation, but this reduces the signal strength. Some of the areas of application of Skywave propagation are amateur radio, mobile telephone, CB radio, and International broadcasts [3].

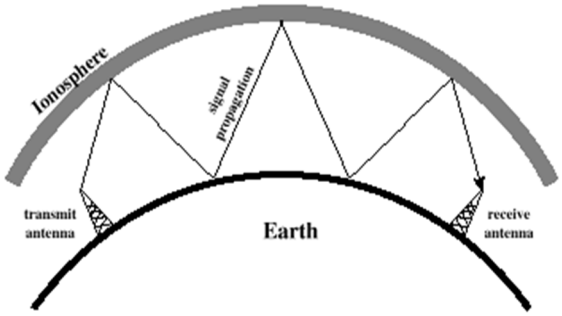

Fig.1.4: Sky wave propagation

3) *Space wave/Line-of-Sight Propagation:* Space wave propagation also called a line of sight propagation is a direct transmission of signal in which receiving and transmitting antennas are aligned to each other without obstruction, a high-frequency signal in the range of GHz called microwave is used for space wave propagation because ground wave and skywave propagation cannot work. In space wave propagation the signal can pass through the ionosphere that is why space wave propagation is also called tropospheric propagation, space waves are suitable for satellite communication [3].

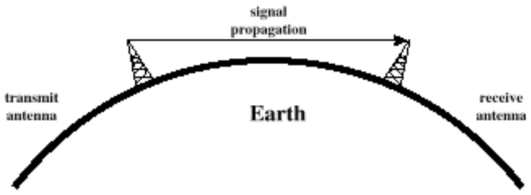

Fig.1.5: line of site propagation

G. Attenuation

Attenuation is the reduction or loss of signal strength as it propagates through space or medium before reaching the receiver. People nowadays rely more and more on mobile phones, wireless internet, television, satellite, etc. Therefore, attenuation is a parameter to be considered in any wireless telecommunication system design, because it determines the strength of the signal as distance increased. I.e. signal strength decreases with distance away from the transmitting station, to be able to communicate the microwave signal power has to be able to reach the destination [4]**.** Attenuation is measured in decibels (dB), which is the ratio of ten times the logarithm of the input signal power to the output signal power. The problem of attenuation is that when it is up to certain values the signal power will be very low, this will make the receiver encounter bits errors when decoding, or in the worst case the transmitting and receiving station losses connectivity [5].

H. Kinds Of Radio Wave Attenuation

1) *Free-Space Loss/Attenuation:* Free space loss is inevitable loss as the radio wave signal propagates in free space, this happens because as the wave propagates it strength reduces with increase in distance away from the transmitter due to dispersion, it is called free-space loss after all other impairments factors were sufficiently removed such as atmospheric absorption, rain effects, reflection, refraction, scattering, etc.
2) *Ionospheres' Attenuation:* The ionosphere is one of the layers of the atmosphere that exist after the troposphere, it is a region of concentrated ions and electrons that collectively form ionized gas or plasma. These ionized gases are formed as a result of radiation from the sun that ionizes atoms and molecules, when a radio wave signal enter this region the free electrons experience a force from the electric field this subjected them into motion. The ionosphere is made up different layers named as D, E and F layers according to the densities of the electrons, signals with a frequency below 40MHz are strongly reflected by the ionosphere back to the earth surface, while above this frequency the signal passes through the ionosphere but it gets

refracted due to different concentration of the layers of the ionosphere. Therefore, the effect of the ionosphere is observed based on the propagation mechanisms of the signal, the ionosphere may cause loss of connectivity between communication systems for certain low frequencies and also can cause refraction of the signal at certain higher frequencies [6].

3) *Attenuation due to Atmospheric Gases:* Atmospheric gases like oxygen, water vapor, etc. Have the absorptive capability of radio signal especially microwave signals at higher frequencies, these gases can absorb photons of energy naturally due to the absorption lines in the elements made up the atmospheric gases. Attenuation by these gases is more disastrous on microwave and millimeter-wave [6].
4) *Attenuation by Rain:* Raindrops and other precipitation can cause signal attenuation by absorption some of the energy of the signal and also by scattering effects diffraction and refraction. Attenuation is worse at higher frequencies of Gigahertz (GHz) and increases with an increase in frequency, this is because the wavelength of the signal reduces and approaches the raindrop size as the frequency increases. Thus, rain attenuation is worse for microwaves and millimeter waves. Also like the amount of rainfall increases rain drops increases and so the attenuation [7]. In another research work [8], a mathematical channel model was used to study the root mean square (RMS) delay spread due to scattering effects caused by rain, three rain intensities were considered, the result shows that there was a change in the time dispersion parameters of the mobile signal.
5) *Attenuation Due to Multipath:* In a multipath radio wave propagation, the signal reaches the receiver through different paths, this multipath is caused as a result of tropospheric reflection and refraction, other obstacles such as mountains, vegetation, buildings, water bodies, and other terrestrial bodies. Multipath produces multiple copies of the radio wave signal with varying delays and phase reaching the receiver. When these delayed copies of the signal arrived at the receiver can lead to destructive interference which may end of corrupting the signal, also multipath can lead to inter-symbol interference [9]. Some of the multipath propagation mechanisms are:

a) *Reflection:* This phenomenon occurs when the radio wave signal hits a surface that is larger compared to the signal wavelength. This makes the signal change direction of its propagation, as such multiple reflections lead to multipath propagation
b) *Scattering:* Is similar to reflection except that the object/surface size hits by the signal is closed to the signal wavelength
c) *Refraction:* This phenomenon occurs due to different media of propagation like layers of the atmosphere encounter by the radio wave signal, this makes the signal to bent small which resulted in the change of angle of transmitted signal.
d) *Diffraction:* Diffraction phenomenon occurs when the radio wave signal hits the edge of an object which has larger size compared to the signal wavelength.

6) *Attenuation by Buildings:* A wireless signal propagating between and within different buildings will enter the building through various means like reflection, diffraction, scattering, transmission, etc. because of the differences in the electrical properties of the building material their influence gives rise to attenuation of the signal to a certain level. Building elements such as walls, windows, doors, roofs, etc. causes a reflection, refraction, diffraction, and scattering of the radio signal. These building elements are dimensional structures with smooth, rough, and sharp edges. When the radio wave signal hits a wall, part of it will be reflected and this result in a loss, while the remaining will be transmitted through the building this also resulted in attenuation due to absorption by the loss nature of the building material. The phase and magnitude of the transmitted and reflected signal differ and is given by the Fresnel reflection and transmission coefficients, which is also related to the angle of incidence of the signal and the dielectric properties of the building materials [10]. In an experimental report that was conducted in twelve's different large building structures showered that there was a reduction in signal strength. This experiment was performed by a method called radio- mapping measurements that involve carrying radios or transmitters tuned to different frequencies within the twelve's structures, as well as recording the strength of the received signal outside the building, and finally it is compared with the reference signal strength transmitted with an unobstructed line of sight propagation [11]. Attenuation was also observed in a research work conducted on two different carrier signals, the 802.11 Wi-Fi signal, and the 900MHz GSM carrier signal. The behavior of these signal in passing through building material was studied, the result indicated that there was an attenuation of the two signals, but the Wi-Fi signal is more affected especially with the increase of the material thickness [12]. Modern building construction is made using reinforced concrete walls with many glass windows and doors, attenuation measurement result for the wireless radio signal in the range of 800MHz-18GHz was reported. Based on the report it shows that the walls give much attenuation value than the glass windows when the radio signal passes through the building [13].
7) *Attenuation due to noise Effects:* A noise which is simply an unwanted signal is always inevitable and present in any communication channel. Therefore, what matters is to reduce this noise so that its effects will not cause much attenuation. Thermal noise, intermodulation noise, crosstalk, impulse noise are some of the categories of noise [3].

II. CONCLUSION

Radio wave signal strength is an important factor to be maintained to a certain level for proper reception of an information signal during wireless communication between transmitter and receiver. The reduction of the signal strength is called attenuation which leads to degradation of a communication system. Effects of atmosphere, multipath propagation, rain effects, and building effects are some of the causes of the radio wave signal attenuation during propagation which were discussed in this paper review.

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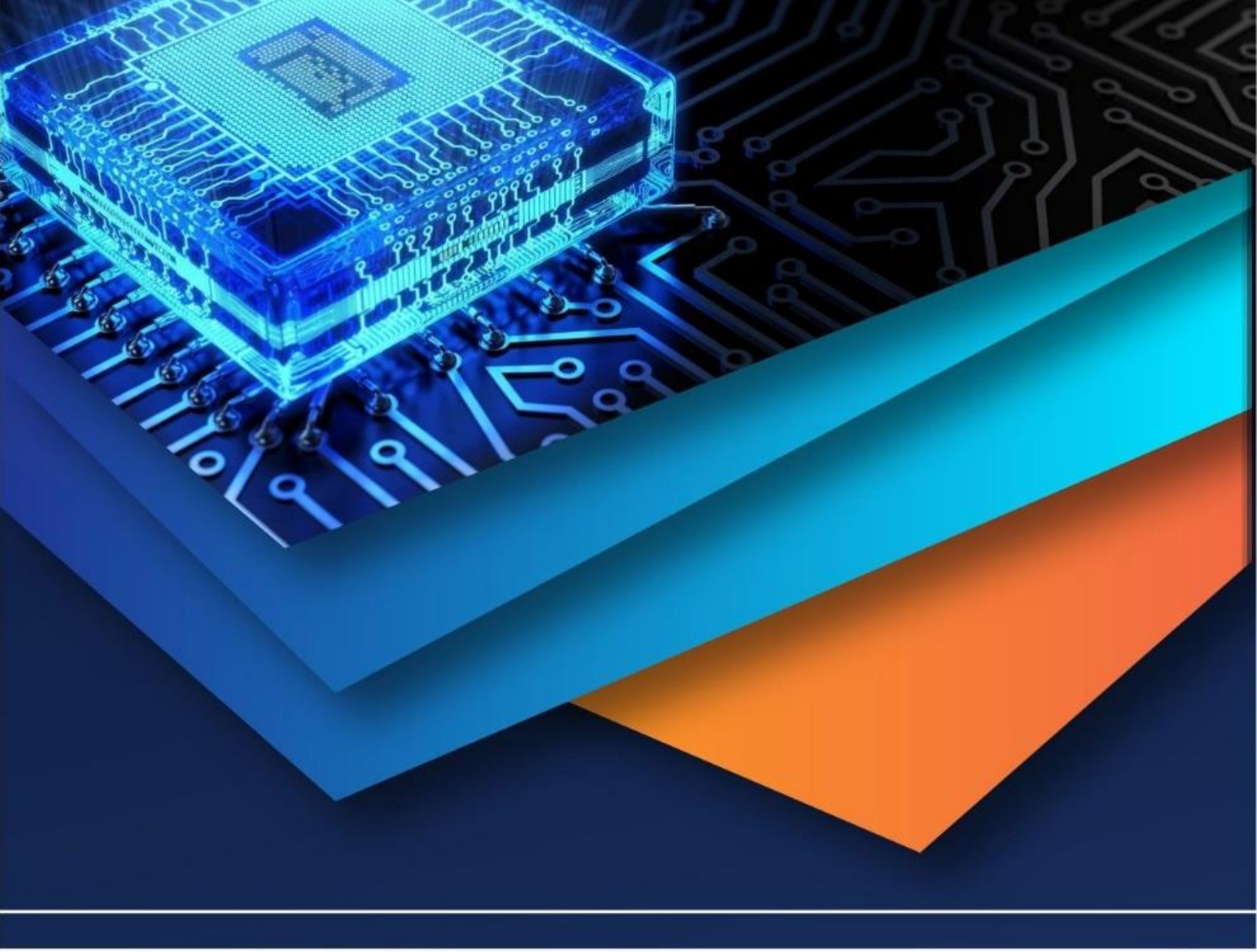

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