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Radio Wave Propagation

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Abstract: *This thesis deals with Radio Wave Propagation in environments where the propagation is severely influenced by surrounding objects, mainly walls and other building structures. As an introduction, a brief description is given on propagation terms like loss, delay and dispersion along with system functions relevant for the topic. The focus is then placed on propagation from an outdoor transmitter to an indoor receiver at frequency bands aimed at personal communications and wireless local area networks. Penetration loss is measured at 1.8 and 5.8 GHz for various small scale wall and window structures. Empirical models have been evaluated for the dependence on incidence angle in order to provide a simple yet accurate model for the loss.*

I. Introduction :

The advent of the Marconi Wireless in 1895 made possible transmission of messages in the form of Radio Waves. The frequency falling between 3 KHz to 300 GHz are called Radio Frequencies since they are commonly used in Radio Communication. We know that the Radio Frequency spectrum divided into different frequency bands. The basic principles that enable Radio Waves to be propagated through space are the same today as they were 100 years ago. Some people view Radio Wave Propagation confusing as it lacks the senses of sight and touch. Now talking about the mechanism of Radio Wave Propagation, I want to include that Radio Wave Propagation related with the phenomena that occur in the medium between transmitting antenna and receiving antenna.When a signal is transmitted from transmitter antenna, the Radio Wave which is actually radiated from antenna is spread in all directions. As the distance between transmitting antenna and receiving antenna is increased, the amplitude of Radio Wave is decreased. The electromagnetic waves in the frequency spectrum of 0.001 to 1000000 Hz are called to be **Radio Waves**.

As we know that in the surrounding environment in which the Radio Wave is propagating may have obstacles, discontinuities and propagation medium variations. The region far from earth's surface realized as a **Free Space Propagation**.

Or now we can say that Radio Propagation is the behavior of Radio Waves, when they are transmitted or propagated from one point on the earth to another or into various parts of the atmosphere.

Like light waves ; Radio Waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering. Understanding the effects of varying conditions on Radio Propagation has many practical applications, from choosing frequencies for international shortwave broadcasters, to designing reliable Mobile Telephone Systems, to Radio Navigation, to operation of Radar Systems. When an electromagnetic wave is transmit from an antenna, the radiated energy gets transmitted through reflection, refraction, diffraction and scattering in the free space. The basic mechanism of radio wave propagation are :

Reflection	Scattering	Interference
Refraction	Diffraction	Absorption

Radio Propagation has a strong connection to space weather. A sudden ionospheric disturbance or shortwave fadeout is observed when the X-ray associated with a solar flare ionize the ionospheric d-region.

Enhanced ionization in that region increases the absorption of radio signals passing through it. During the strongest solar X-ray flares, complete absorption of virtually all ionospherically propagated Radio Signals in the sunlit hemisphere can occur. These solar flares can disrupt High Frequency Radio Propagation and affect GPS accuracy. Since Radio Propagation is not fully predictable, such services as emergency locator transmitters, in-flight communication with ocean-crossing aircraft, and some television broadcasting have been moved to communications satellites. A satellite link, though expensive, can offer highly predictable and stable line of sight coverage of a given area.

The method by which the Radio Waves travel in the free space is called Mode of Propagation. When an electromagnetic wave is sent out from an antenna, part of the radiated energy travels along or near the surface of the earth while the other part travels upward in space. The energy may reach the receiving antenna over any of the possible propagation modes which are as follows –

Ground Wave Propagation
Sky Wave Propagation (Ionospheric Propagation)

Space Wave (Line of Sight) Propagation
Tropospheric Scatter Propagation
Duct Propagation

	Modes of Propagation	Frequency Range
1	Ground Wave or Surface Wave Propagation	upto 2 MHz.
2	Sky Wave or Ionospheric Wave Propagation	between 2 to 30 MHz.
3	Tropospheric Scatter Propagation or Forward Scatter Propagation	UHF and microwaves above 300 MHz.
4	Space Wave or Line of Sight Propagation	above microwave range.
5	Duct Propagation	above microwave range.

II. Space Wave Propagation :

Space Waves also known as Direct Waves, are Radio Waves that travel directly from the transmitting antenna to the receiving antenna. In order for this to occur, the two antennas must be able to see each other i.e. there must be a Line Of Sight path between them.

Effect of various parameters on Space Wave Propagation :
Curvature of the earth
Effect of earth's imperfections
Effect of hills, buildings
Effect of polarisation and transition between ground wave and space waves

III. Sky Wave Propagation :

Radio Waves in lower frequencies and middle frequencies ranges may also propagate as Ground Waves but suffer significant losses or are attenuated particularly at higher frequencies. But as the Ground Wave mode fades out, a new mode developed known as the Sky Wave. These waves are reflected back from the ionosphere.
The simplest manifestation of polarization to visualize is that of a plane wave, which is a good approximation of most light waves.

Polarization is basically classified in three ways :
Linear Polarization
Circular Polarization
Elliptical Polarization

IV. Tropospheric Scatter Propagation :

The technique is of practical importance at VHF, UHF and Microwaves. The UHF and Microwave Signals are found to be propagated much beyond to the Line of Sight Propagation through the forward scattering in the tropospheric irregularities. The Mode of Propagation which uses properties of scattering in Troposphere is known as Tropospheric Scatter Propagation. Here comes a term, the method for improving the reliability of troposcatter links is known as Diversity Operations.

V. Advantages of Tropospheric Scatter/Diffraction –

Provides reliable multichannel communication.
Reduces number of station required to cover a given large distance when compared to radio links.
It is best suited to meet tall connecting requirements of areas of population density.
It can be used in thin line military systems with links upto 1480 kms.
Desirable for multichannel communication.
Requires less maintenance staff per route kilometre than conventional line of sight microwave systems over the same route.

VI. Disadvantages of Tropospheric Scatter/Diffraction –

It typically displays larger losses then Radio Link Path.
More financial investment are laid in the installation of Tropospheric Scatter phenomena in comparison to the LOS Microwave installation.

VII. Duct Propagation :

The special refraction of electromagnetic waves is called Super Refraction and the process is called Duct Propagation.Duct is mainly formed by the temperature inversion. A duct is formed between the two such layer in which the electromagnetic wave guided as in a Wave Guide.

VIII. Conclusion:

Penetration characteristics have been further evaluated by using different simulation methods in order to calculate propagation parameters. Both ray-tracing and full wave methods like the method of moments have been applied. Comparisons of the results have been made in order to determine under what conditions each model can be considered valid. For propagation further inside a complex office environment, an empirical model showing non linear relation with the number of penetrated wall sections in the direct path is proposed. The structure of this model can be directly related to the wideband results obtained for the environment.The spatial properties of the radio wave were investigated in order to determine distributions for the angle of arrival while relating this to the propagation environment. Improvements in carrier to noise as well as carrier to interference ratios using Directive Antennas were estimated based on the spatial dispersion. Two types of antennas were compared, one Switchable Array and one Adaptive Circular Array. The performance of the Switched Array was further established by measurements. By applying the antenna diagrams on the measured angular spectra of the receiver, improvements of several dBs were obtainable.

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