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Prediction of Attenuation Characteristics of E.M. Wave in Built-Up Urban Areas

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ABSTRACT - In this paper we present about prediction of attenuation characteristics of e.m. wave in built-up urban areas. In Physics, attenuation (in some contexts also called extinction) is the gradual loss in intensity of any kind of flux through a medium. For instance, sunlight is attenuated by dark glasses, X-rays are attenuated by lead, and light and sound are attenuated by water.

KEYWORDS: E.M. Wave, Radiation, Attenuation, Frequency.

I. INTRODUCTION

In Physics, attenuation (in some contexts also called extinction) is the gradual loss in intensity of any kind of flux through a medium. For instance, sunlight is attenuated by dark glasses, X-rays are attenuated by lead, and light and sound are attenuated by water. In electrical engineering and telecommunications, attention affects the propagation of waves and signals in electrical circuits, in optical fibers, as well as in air (radio waves). In many cases, attenuation is an exponential function of the path length through the medium. In chemical spectroscopy, this is known as the Beer-Lambert law. In engineering, attenuation is usually measured in units of decibels per unit length of medium (dB/cm, dB/km, etc.) and is represented by the attenuation coefficient of the medium in question. Frequency-dependent attenuation of electromagnetic radiation in standard atmosphere. Attenuation also occurs in earthquakes; when the seismic waves move farther away from the epicenter, they grow smaller as they are attenuated by the ground.

II. ELECTROMAGNETIC

Attenuation decreases the intensity of electromagnetic radiation due to absorption or scattering of photons. Attenuation does not include the decrease in intensity due to inverse-square law geometric spreading. Therefore, calculation of the total change in intensity involves both the inverse-square law and an estimation of attenuation over the path. The primary causes of attenution in matter are the photoelectric effect, Compton scattering and for photon energies of above 1.022 MeV, pair production.

III. ABSORPTION (ELECTROMAGNETIC RADIATION)

In physics, absorption of electromagnetic radiation is the way by which the energy, of a photon is taken up by matter, typically the electros of an atom. Thus, the electromagnetic energy is transformed to other forms of energy for example, to heat. The absorption of waves does not depend on their intensity (linear absorption), although in certain conditions (usually, in optics), the medium changes its transparency dependently on the intensity of waves going through, and the saturable absorption (or nonlinear absorption) occurs. Path loss (or path attenuation) is the reduction in power density (attenuation) of an electromagnetic wave as it propagates through space. Path loss is a major component in the analysis and design of link budget of a telecommunication system. This term is commonly used in wireless communications and signal propagation. Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas.

3.1 Causes

Path loss normally includes propagation losses caused by the natural expansion of the radio wave front in free space (which usually takes the shape of an ever increasing sphere), absorption losses (sometimes called penetration losses), When the signal passes through media not transparent to electromagnetic waves, diffraction losses when part of the radio wave front is obstructed by an opaque obstacle, and losses caused by other phenomena. The signal radiated by a transmitter may also travel along many and different paths to a receiver simultaneously; this effect is called multipath. Multipath waves combine at the receiver antenna, resulting in a received signal that may vary widely, depending on the distribution of the intensity and relative propagation time of the waves and bandwidth of the transmitted signal. The total power of interfering waves in a Rayleight fading scenario vary quickly as a function of space (which is known as small scale fading).

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Small-Scale fading refers to the rapid changes in radio signal amplitude in a short period of time or travel distance.

3.2 Loss exponent

In the study of wireless communication is, path loss can be represented by the path loss exponent, whose value is normally in the range of 2 to 4 (where 2 is for propagation in free space, 4 is for relatively lossy environments and for the case of full specular reflection from the earth surface-the so-called 1 flat-earth model). In some environments, such as buildings, stadiums and other indoor environments, the path loss exponent can reach values in the range of 4 to 6. On the other hand, a tunnel may act a waveguide, resulting in a path loss exponent less than 2.

Path loss is usually expressed in dB. In its simplest form, the path loss can be calculated using the formula. Where L is the path loss in decibels, n is the path loss exponent, d is the distance between the transmitter and the receiver, usually measured in meters, and C is a constant which accounts for system losses.

IV. RADIO ENGINEER FORMULA

Radio and antenna engineer use the following simplified formula (also known as the Friis transmission equation) for the path loss between two isotropic antennas in free space; Path loss in dB: where L is the path loss in decibels, is the wavelength and d is the transmitter-receiver distance in the same units as the wavelength.

4.1 Prediction

Calculation of the path loss is usually called prediction. Exact prediction is possible only for simpler cases, such as the above-mentioned free space propagation or the flat-earth model. For practical cases the path loss is calculated using a variety of approximations. Statistical methods (also called stochastic or empirical) are based on measured and averaged losses along typical classes of radio links. Among the most commonly used such methods are Okumura-Hata, the COST Hata model, I W.C.Y.Lee, etc. These are also known as radio wave propagation models and are typically used in the design of cellular networks and PLMN. For wireless communications in the VHF and UHF frequency band (the bands used by walkie-talkies, police, taxis and cellular phones), one of the most commonly used methods is that of OKumura-Hata as refined by the COST 231 project. Other well-known models are those of Walfisch-Ikegami, I W.C.Y.Lee and Erceg. For FM radio and TV broadcasting the path loss is most commonly predicted using the ITU model as described in I P.1546 (former IP.370) recommendation. Deterministic methods based on the physical laws of propagation are also used; ray tracing is one such method. These methods are expected to produce more accurate and predictions of the path loss than the empirical methods; however, they are significantly more expensive in computational effort and depend on the detailed and accurate description of all objects in the propagation space, such as building, roofs, windows, doors, and walls. For these reasons they are used predominantly for short propagation paths. Among the most commonly used methods in the design of radio equipment such as antennas and feeds is the finite-difference time-domain method. The path loss in other frequency bands (MW, SW, Microwave) is predicted with similar methods, though the concrete algorithms and formulas may be very different from those for VHF/UHF. Reliable prediction of the path loss in he SH/HF band is particularly difficult, and its accuracy is comparable to weather predictions. Easy approximations for calculating the path loss over distances significantly shorter than the distance to the radio horizon: In free space the path loss increases with 20 dB per decade (one decade is when the distance between the transmitter and the receiver increases ten times) or 6 dB per octave (one octave is when the distance between the transmitter and the receiver doubles). This can be used as a very rough first-order approximation for SHF (microwave) communication links; For signals in the UHF/VHF band propagating over the surface of the Earth the path loss increases with roughly 35-40 dB per decade (10-12 dB per octave). This can be used in cellular networks as a first guess.

4.2 Mobile Radio Propagation and Characterization of Frequency Bands

The term wireless communication refer to transfer of information via electromagnetic or acoustic waves over atmospheric space rather than along a cable. The apparent wrinkle between such a scheme and conventional wired systems is the presence of the wireless channel as the medium over which the communication must take place. Unfortunately, more often than not, this medium is hostile in regards to attenuating delaying, and even completely distorting the transmitted signal. Thus when considering a general digital wireless communication system such as that in The design of each building block will be dependent on the channel between transmitter and receiver. Therefore, before moving on to specific issues such as modulation, source/channel coding synchronization, equalization, multi-access analysis, and radio resource management; it makes sense to analyze the appreciate one of the main obstacles that such techniques are trying to account for. Thus, for the particular case at hand, we will assume that the remaining blocks in have either been taken care of or are not being used. As frequency increases the sky wave separates from the sky wave, enabling long distance communication. More specifically, the sky wave propagates in space and returns to the earth via reflection in either the ionosphere or the troposphere, thereby enabling beyond the horizon communication through successive reflection. It is interesting to note that above 30 MHz the sky wave propagates in a straight line, and actually propagates is taken advantages of fro satellite communication.

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4.3 Characterization of Frequency Bands

Due to dissimilar propagation properties of different frequency travelling over the ionosphere and troposphere, it is logical to assign separate spectrum allocations to different applications. For example, for commercial cellular systems, small antenna size is a premium. This brings about the necessity of using radio waves with small wavelengths and hence high frequencies.

V. LARGE-SCALE MOBILE RADIO PROPAGATION AND PATH LOSS

5.1 Models for Macrocells

The general term f ading is used to describe fluctuations in the envelope of a, transmitted radio signal. However, when speaking of such fluctuations, one must consider whether a short observation interval (or small distance) has been taken, or whether a long observation interval (or large distance) has been taken. For a wireless channel, the former case will show rapid fluctuations in the signal's envelope, while the latter will give more of an slowly varying, averaged view. For this reason the first scenario is formally called small-wale f ading (or multipath), while the second scenario is referred to as large-scale path loss. In this presentation we will only focus on the large-scale effect. Received power or its reciprocal, path loss, is generally the most important parameter predicted by large scale propagation models. It is valuable to examine the three main propagation mechanisms that determine and describe path loss: Ref lection occurs when a radio wave collides with an object which has very large dimensions compared to the wavelength of the propagating wave. Reflections are very commonly caused by the surface of the earth and from buildings, walls, and other such obstructions. Diffraction occurs when the radio path between the transmitter/receiver pair is obstructed by a surface with sharp edges. This causes secondary waves to arise (in any conceivable direction) from the obstructing surface. There is a possibility that the secondary waves can bend around the obstacle and provide an almost artificial LOS between transmitter and receiver. Like reflection, this phenomenon is dependent on: frequency, amplitude, phase, and the angle of arrival of the incident wave. Scattering occurs when the radio wave travels through a medium consisting of objects with dimensions that are small compared to the wave's wavelength. In such a case the number of such particules per unit volume are usually very large. Typically scattered waves arise when the radio wave meets rough surfaces or small objects in the channel.

5.2 Free Space Path Loss Model

To obtain a more quantitative view of the effects of path loss, it is useful to consider a few examples. The simplest case of which is the path loss model for free space due to the fact that the influence of all obstacles is ignored. Further easing the analysis, consider the model to be isotropic, where the transmitting antenna signaling with power pt, has its power radiate uniformly in all directions. Examining the path loss will tell us the amount of power available at the receive antenna a distance r meters away. This situation can be modeled as in Fig. 4 where the tramit antenna can be considered to be at the centre of a sphere with radius r. The total power density on the sphere (also referred to as f lux density) may be expressed as:

$$pd = EIRP/4\pi r^2 = Pt/4r^2 \text{ Watts/m}^2 \qquad (1)$$

wher EIRP is the effective radiated power from an isotropic source and 4πr2 is the surface area of the sphere. In this model, the power at the receive antenna will be only a function of the transmitted power and the characteristics of the receive antenna.

$$Pr = PdAe= PtAe/4\pi r^2 \text{ Watts} \qquad (2)$$

where Ae is the effective aperture of the receive antenna. As seen from (2), the received power Pd is inversely proportional to r2. It to happens that the inverse square relation is the ideal case due to the combination of free space, LOS, and isotropic assumptions.

The effective aperature of an antenna (Ae) is generally related to its "Gain" G by

$$G = 4Ae/\lambda 2 \qquad (2)$$

$$\text{Therefore, } Pr = PtG\, \lambda^2/(4\pi r)^2 = Pt\, GTGR\, \lambda/4\pi^2 \qquad (3)$$

where GT and GR are the transmitter and receiver gains, respectively. Eq. (4) is referred to as the Friis free space equation. In mobile systems the received power may change several orders of magnitude over a fraction of a typical coverage area. This coupled with the fact that mobile system employ low-power devices (order of milliwatts) leads to the choice of dBm (dB normalized to 1.0 mW) as the preferred unit for measuring power.

Thus the path loss for the free space model may be expressed as:

$$PL(dBm) = 10\log 10\ (Pt/0.001\ Pr) = -10\log 10\ (GTGR\lambda 2/0.001\ 4\pi^2) \qquad (5)$$

5.3 Propagation model for Near Earth's Surface

When considering the more realistic model (compared to that of the highly ideal free space) of near Earth propagation, we must consider a direct wave, ground reflected wave component. This scenario is depicted in Fig. 5, along with its equivalent flat Earth model. The main assumptions that lead to the flat Earth model are the absence of the ground waves due to the height of the antenna when compared to that of the wavelength, and the lack of curvature of the Earth (Very accurate for short distances). The received signal Et in this 2-ray model may be represented as:

$$E(t) = Eo\cos(\omega t) + \rho E0\cos\{\omega(t-\Delta t) + \Phi\} \qquad (6)$$

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where ρ and represent the attenuation and phase shift of the ground reflected wave, which is the second term. Eo, the signal field strength of the direct wave (assuming a free space model), exists in both the direct wave component and the reflected wave component. From (6) we can conclude that reflection upon earth brought about a phase change, an attenuation, and a time delay Δt with respect to the direct path. Making the additional assumption that the difference in path lengths between the two components is much less that the distance between the antennas (r), allows us to approximate p H1. Furthermore, assuming per f ect mirror reflection via the ground, give $\phi=\pi$. We can now state:

E(t) = Eo Cos (ωt) + ρE0 cos {ω(t-Δt) + Φ} = 2 Eo sin (ωΔt/2) cos (wt + ψ) (7)

where is the approximate phase, sing (.) is constant, and the resulting amplitude is E = 2E0 sin (ωt/2) the geometry of fig. 6 yields:

dD = $\sqrt{}r^2$ + h2 -- $h^1)^2$ (8)

$$d_R = \sqrt{r^2 + (h_2 + h_1)^2} \qquad (9)$$

another fair assumption would be: r >>h1 and h2. Invoking this in (8) and (9):

$$d_R \approx \left(1 + \frac{1}{2}\left(\frac{h_2+h_1}{r}\right)^2\right) \qquad (10)$$

$$d_R \approx r\left(1 + \frac{1}{2}\left(\frac{h_2+h_1}{r}\right)^2\right) \qquad (11)$$

Using the relations:

$$\Delta d = d_R - d_D \approx \frac{2h_1h_2}{r}$$

$$\Delta t = \frac{\Delta d}{c}$$

$$\omega = 2\pi f = \frac{2\pi c}{\lambda}$$

the magnitude of the received received wave in (7) can be modeled as:

$$|E| = 2E_0\left|sin\left(\frac{\omega\Delta t}{2}\right)\right| = 2E_0\left|sin\left(\frac{2\pi h_1h_2}{\lambda r}\right)\right| \qquad (12)$$

thus the received power is

$$\text{Pr} = 4E_0^2 sin^2\left(\frac{2\pi h_1h_2}{\lambda r}\right) \qquad (13)$$

Where E_0^2 is the power received in the free space model:

$$E_0^2 \triangleq \text{Pr (freespace)} = \frac{P_tG_tA_e}{4\pi r^2} \qquad (14)$$

$$Pr = \frac{P_tG_tA_e}{\pi r^2} sin^2\left(\frac{2\pi h_1h_2}{\lambda r}\right) \qquad (15)$$

when antenna elevations are small compared to distance between transmitted/receiver pair, i.e. $h_1h_2 <<\lambda r$, we can make the small angle approximation sin (x) ≈x to get:

$$Pr = \frac{4\pi P_tA_e(h_1h_2)^2}{\lambda^2r^4} \qquad (16)$$

the key point to be taken away from (13) is that for propagation close to the Earth's surface the received power of the signal is inversely proportional to r^A. Comparing this fourth order decay with with the second order decave (2) for the free space model leads us to conclude that received power decays more rapidly with distance once the ideal free space model is discarded in favour of the more realistic model for propagation near the Earth's surface.

Further examining (16) we may express the path loss (in dBm) as:

$$P_L(dBm) = 100log_{10}\left(\frac{P_t}{0.001P_r}\right) = -10log_{10}\left(\frac{(h_1h_2)^2}{0.001r^2}\right) \qquad (17)$$

The unfortunate aspect of (170 for path loss near the Earth's surface, is that is only a function of the antenna highest and the distance between transmitter and receiver. To be more explicit, the path loss obtained by (17) is independent of the carrier frequency used for the transmission. Thus, the above analysis is best characterized as very simplistic and good enough to give a ball-park estimate.

VI. CONCLUSIONS

The electromagnetic waves propagating in the vicinity of the building or through the inside of it are influenced by the shape of the wall of the building or structure of it, and therefore the propoagation becomes a complicated one. This brings about a portion where sufficient electric field strength can be obtained and a portion where such a factor cannot be obtained. This is a matter of seriousness with wireless communication. To solve this problem, it is necessary to be acquainted with first of all the electric field strength distribution in the vicinity of the building. Electromagnetic wave propagation simulation ins quite an effective measure to be very easily acquainted with such electric field strength distribution in the vicinity of the building, but simulation results different from the actual value are liable to be obtained depending on the occasion in a manner how the structure or shape of the wall of the building should be considered. Keeping such a situation in mind, the electric field strength distribution around the building was measured using a scaled-down model of the building having shapes of various walls or structure of them. As a results, it is explained that: (1) It is advisable to deal with the building as the one comprised of a all and inside structure rather than the one as a square pillar model filled with concrete to the extent of the inside (2) It is unnecessary to consider the structure of the wall inside so much as with the case of the reinforced concrete, but it is understood that the surface shape such as of tiles is preferable to consider. Meanwhile by investigative the dielectric constants of the concrete or cell sizes based on the comparison between the measurement and the simulation results, it is shown that simulation close enough

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to actual measurement becomes possible. Despite the above, no improvement has been attempted with the simulation to allow the electromagnetic waves to reach any place, taking account of the fact that there are not a few places where no electromagnetic waves are reached. Such being the case, a project is under way to develop new methods in future to decrease the regions where none of sufficient electric field strength is obtained due to change in the wall shape, taking up the examples actually full of problematic points. With the effectiveness of the method, recognition is to be made as a matter of course in accordance with the measurement method introduced in this chapter. When such research advances, possibilities are wide spread before us, availing ourselves of the technology with accomplishment of successful monitoring in a detailed manner, explaining what objects are in existence in what a place in what a situation in the building. This is connected to development of information communicating technology by which peoples' life is steered into a direction not a more abundant and wealthier state.

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