Indoor Radio Mobile Communication

Dr.Ashok Chandra,
Government of India,
Ministry of Communications,
Department of Telecommunications,
Wireless Planning and Co-ordination Wing,
Dak Bhavan,New Delhi-110001
Tele Fax :+91 11 335 9564
Telephone : +91 11 616 1546

1.0 Introduction:

The astonishing success and tremendous growth of cellular mobile radios in providing telecommunication services to the moving people and the anticipated need for personal communications has paved the way towards breaking the location barriers. More demand for multimedia services arising from wireless users has stipulated particular interest in the design of high quality ,high speed wireless networks. These networks are mainly in building communication systems and may operate in 300 MHz –3GHz, 5GHz,11GHz and mm frequency bands.The system designers wishing to design indoor mobile communication with optimal frequency assignment and reuse,must study in detail the channel characteristics such as the median path loss channel fading and pulse delay and spread. Indoor radio networks have inherent advantages over conventional telephone wire networks. An indoor channel is highly complicated and path loss is very severe most of the time. As there is no universally accepted path loss model yet available the channel should derive it’s performance from the actual field measurements. In-building path loss information is essential for determination of the size of the coverage area and for selecting an optimum location for the installation of the base antenna. The study reported in this paper discusses about mathematical modelling of indoor channel,a computer simulation model , and a simple path loss attenuation model. The salient features of the locations of typical measurement sites are described .The paper also presents description of measurement techniques and procedures.

2.0 Modelling Of Indoor Channel Parameters And Computer Simulation Studies

2.1 Mathematical Modelling Of Indoor Channel

The short range indoor channel can be modelled by summing for each point in three dimensional space, a linear time varying filter with a complex impulse response h(t,x) .The channel is completely characterised by parameters namely path amplitude,arrival time of each path and it's phase.If a rdio signal :

$m(t) = \text{Real}\{ X(t) \exp(jwt) \}$ ……………………….(1)

of carrier frequency 'w' is transmitted in an indoor environment ,then signal received r(t) via many paths at the receiver locaiton is :

$r(t)=m(t)*h(t,x)$ …………………………..(2)

The transmitted ray reaches the mobile receiver via one or more significant paths.The main wave is the Line of Sight (LOS) ray and the other significnt waves (Non-LOS)may be coming after reflection,scattering,refraction and diffracton by the walls,ceiling,windows,and other structures present in the bulding.

2.2 Path Loss Attenuantion Model

A simple distance/power realtionship to estimate the attenuation of transmitted radio signal at frequency 'f' is used and according to this model, when the transmitter and the receiver both are located in the same place i.e. LOS situation, the attenuation in dB is given as :

$A(LOS)=A0+n\log d$ ……………………………………(3)

Where 'd' is the distance between the transmitter and the receiver, 'n' is the path loss exponent (an important indoor channel parameter),which is equal to a value of '2' in case of free space path loss and it's value varies in non-direct LOS situations,may be > or <2.The floors and walls crossing cause significant attenuation and lead to a Non-LOS situation .A correction factor accounts for the floor attenuation ,modifies the equation (3) as:

2.3 rms Time Delay Spread

The root mean square (rms) time delay spread (or rms delay spread) is a measure of spreading of the received signal power over time. The power delay profile (PDF) gives the distribution of received signal over time. The PDF is defined as:

$PDF=P(t)=h(t)\, h^*(t)$…………. (5)

$=|h(t)|^2$ ……………..(6)

In practice situations, PDF is calculated as:

$P(t)=|r(t)|^2$ …………………(7)

The rms delay spread is the square root of the second central moment of a PDF. Strong echoes (relative to LOS path) with long delays contribute significantly to rms delay spread and performance of communication systems in such an environment. The rms delay spread depends on size and type of a building, presence or absence of a clear LOS path, and transmitter-receive (T-R) separation.

2.4 Computer Simulation Studies

Inside a building, radio waves experience reflection, refraction, scattering, and diffraction by indoor structures. Due to these effects, the transmitted signal post often arrives at the receiver via more than one path and after long delays. Two significant geometric features occur one between ceiling and furnishings of floor and other one at the interior and exterior walls that govern the indoor propagation. The building structures arc assumed as lossy dielectric blocks with uniform complex dielectric properties represented by complex dielectric constants. The raytracing technique predicts the field strength of the received vector field by including direct, reflected, refracted, and diffracted fields. The raytrace tool uses a combination of ray launching and ray imaging methods. In a first step valuable transmission paths are being scratched including propagation effects like reflection, transmission and diffraction. In a second step, ray imaging method is used to correct the geometrical data of each transmission path found in the first step. As a result ray tracer gives the complex channel impulse response h(t,x). From power delay profile, field distribution and rms time delay namely raytracer, geometry, and material properties. The raytracer is first invoked. The geometry file gives the geometry of various indoor obstacles, whereas the material file contains parameters such as types/number of materials used (metal, glass, wood etc), thickness of the layers, and the complex dielectric constants. The geometry and material files and introduced I raytrace programme. A regression line is fitted to the plots of attenuation vs T-R separation to determine the path loss exponent ‘n’,A0 and rms time delay spread.

3.0 Locations of a Typical Measurement Sites

A research institute-cum-office building, where propagation measurements are conducted, has six floors, of which two floors (i.e. S and W) are below the ground floor. The S floor houses laboratories and W floor houses and modern workshop. The ground floor ahs 12 rooms in which theoffices, photolaboratory, and the library are located. There are 7 laboratory rooms including tow common rooms for computing facilities and a store on the first floor. The second floor has 11 laboratory rooms and a classroom. The top floor contains an antenna-measuring chamber. The dimensions (in m) of the ground, first, and second floors 32.84*15.30*3.59, 29.69*15.30*3.20*, and 36.04*15.30*3.20 respectively. The height of the transmitting antenna is 1.98m and receiving antenna is 1.72m respectively (on second floor). The mobile receiving unit traces paths in the corridors of the second, first, and ground floors upto a distance of 15m. The initial separation between transmitter and receiver is kept at 1m.

4.0 Measurement Techniques and Procedures

This section presents measurement techniques and procedures for radio wave propagation studies. A brief description about transmitting and receiving units are given here:

4.1 Transmitting Unit

A transmitting set-up consisting of sweep oscillator, microwave frequency counter and source synchronizer for locking the desired frequency are assembled on a rack measuring 60cm x 45cm x 90cm. A CW signal from the oscillator is fed to the transmitting antenna through directional coupler.

4.2 Mobile Receiving Unit

Dimensions of the mobile rack on which receiving system is installed, is 60cm x 60cm x 70cm. The Spectrum Analyser operating in the frequency band 0.01-33 GHz, and a PC are placed in the lower portion of the rack. A supply system which supplies power to the stepper motors, PC monitor with keyboard are placed on the top of rack. The PC controls the mobile unit, directs the whole measurements along a marked track, and stores measured data. For system correction, before start of each measurement, the reference level is measured by disconnecting both antennas and connecting rf power available at the output of the sweep oscillator ot the SA's input. For measurements a lamda/2 dipole antenna is used. For high resolution, the distance between two consecutive measurements is set to 15mm. The mobile rack takes 1001 runs to cover a distance of 15m.

5.0 Results of a propagation studies at 2 GHz

A CW signal from the source generator is fed to a half wave dipole antenna. The measurements are performed, when the transmitting system is positioned in the corridor of second (II) floor and the receiving system traces paths in the corridors of second, first(I) and ground floors. The ranges of attenuation on II,I and ground corridors are 40-90, 46-92 and 53-100dB respectively. It has been observed that when signal traverses from II floor toI floor, the floor attenuation is 8 dB. However, attenuation from II to ground floor is 20 dB and from I to ground is 13 dB. A regression line is fitted to the plots of attenuation vs T R separation to determine the path loss exponent 'n' and A0 as

FLOOR	n	A0 (dB)
Second	2.22	61.61
First	1.92	65.28
Ground	1.52	81.75

It implies that in non-direct LOS, the signal suffers severe attenuation.

5.1 Simulation studies at 2 GHz

It has been observed that when signal traverses from second floor to first floor, the floor attenuation is 18 dB. However, attenuation from second floor to ground floor is 32 dB and from first to ground is 13 dB. The values of range of path loss attenuation, rms time delay spread, n and A0 the three corridors are derived from the simulation studies and presented as :

FLOOR	n	A0 (dB)	rms Time Delay (ns)
Second	1.87	78.1	5-35
First	1.45	65.9	11-29
Ground	1.05	70.7	19-28

The observed and simulated values of path loss exponent for II, I and ground floors are 2.22,1.92, 1.52, and 1.87, 1.45, 1.05 respectively. These results show a close resemblance between observed and experimental data.

References

1. A.M.D. Turrkmani, etal, ‘Radio transmission at 1800 MHz into and within multistorey buildings’ IEE Proc-PartI, vol.138, no.6,PP.570-584, Dec.1991.
2. 2J.H.Tarng, etal, Three-dimensional modeling of 900 MHz and 2.44 GHz radio propagation in corridors, “IEEE Trans. On VT, vol.46, no.2,pp-519-527, May 1997.