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An Efficient Path loss Prediction mechanism in Wireless Communication Network Using Fuzzy Logic

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Abstract- ***Fuzzy logic have been applied in many process and engineering applications to solve problems. In the case of control systems, where physical mechanisms are not well known due to high complexity and non-linearity, a fuzzy relational model may be useful. The aim of this paper is to propose the predicting the path loss with the field measurement models and represent them in a more convenient form for the proposed Fuzzy Logic modeling. This paper proposes method to predict path loss for cellular mobile communication systems using fuzzy logic. The propagation medium is classified in to several well-established propagation environments defined as a fuzzy set such as free space, flat area terrain, light vegetation terrain, heavy vegetation terrain, and village terrain. A unique mean path loss exponent (n) is assigned to each propagation environment, which is established by means of the experimental. Fuzzy logic is used to determine "n" number for an unknown environment, which will be obtained using linguistic rules that provide a fine-tuning of the known propagation environments. HATA model proposed by M. Hata has been used for the present analysis.***

Keywords: Path loss data, Path loss prediction, Fuzzy logic, HATA Model.

1. INTRODUCTION

The mechanisms behind electromagnetic wave propagation are diverse, but they are characterized by reflection, refraction, path loss, fading, scattering and shadowing. Path loss is an attenuation that signal suffers when propagate from transmitter to the receiver. Propagation path loss increased not only with frequency but also with distance [5].

$PL \alpha R^{-\alpha}$

Shadowing is the gradual variation of the received signal strength around its average value and fading is the rapid variation in the received signal strength due to multipath propagation. Efficient path loss prediction is important for proper design of wireless network. Efficient path loss prediction depends upon Vegetation Density, Buildings, and Atmosphere etc. Various outdoor propagation models are available to determine path loss over irregular terrain. While all these models aim to predict signal strength at a particular receiving point or in a specific local area (called zone/sector), the methods vary widely in their approach, complexity and accuracy. Most of these models are based on a systematic interpretation of measurement data obtained in the service area [5]. However accuracy of these models suffers when they are used in the environment other than for which they have been designed. Performing ON SITE calculations and considering link loss in the practical environment and their result may be applied to existing models for correction [1]. Both theoretical measurement based propagation models indicate that average received signal power decreases logarithmically with distance, whether in outdoor or indoor radio channels. The average large-scale path loss for an arbitrary T-R separation is expressed as a function of distance by using a path loss exponent "n

$$PL\ (dB) = PL\ (d_0) + 10n\log\ (d/d_0) \qquad .\ .... (1)$$

Where n is the path loss exponent, which indicates the rate at which the path loss increases with distance, d_0 is reference distance and d is the T-R separation distance [5]. n depends on specific propagation environment for free space n=2 and when obstruction are present n will have a larger value. The reference distance should always be in the far field of the antenna so that near field effects do not alter the reference path loss. Its typical value is 1 Km in macro cell system, 100m in micro cell systems and 1 m in Pico cell systems.

The Okumura curves [18] are known for their practical use and passed on over HATA presented an empirical formula for prediction of path loss [9]. In this paper an empirical path loss model for a typical suburban city of India has been proposed. (Mehuwala, Dehradun, Uttarakhand).

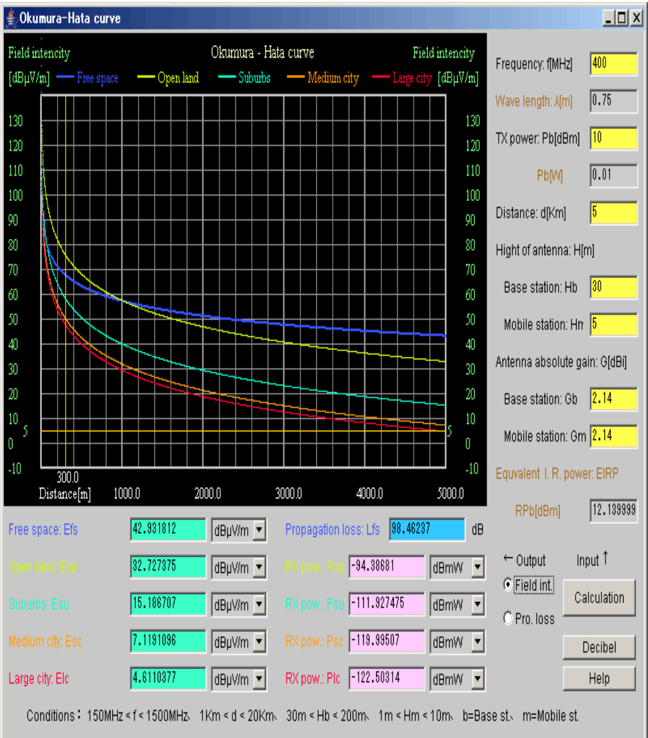

Fig.1 Okumura-Hata curve calculation window

The field measurements were carried out in the suburban city of Mehuwala, Dehradun of its CDMA based System. The developed model is also compared with HATA model, which is widely used for path loss prediction in CDMA based systems.

2. HATA MODEL

HATA model is an empirical formulation of the graphical path loss data provided by Okumura and is valid from 150 MHz to 1500 MHz. HATA presented the urban area propagation loss as a standard formula and supplied correction equations for suburban and rural areas [9].

The standard formula for Median path loss (dB) in suburban areas is given by:

$$PL_{dB} = X + Y \log d - Z \qquad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where

$$X = 69.55 + 26.16 \log_{10} fc - 13.82 \log_{10} h_b\,(\mathrm{m}) - \alpha\,[h_m\,(\mathrm{m})]$$

$$Y = [44.9 - 6.55 \log_{10} h_b\,(\mathrm{m})] \log_{10} d\,(\mathrm{Km}).$$

$$Z = 5.4 + 2[\log_{10} f_c\,(\mathrm{MHz})/28]^2$$

For small and medium city

$$\alpha[h_m(\mathrm{m})] = (3.2[\log_{10} 11.75\, h_m(\mathrm{m})]^2 - 4.97, \quad f > 400\mathrm{MHz}$$

For the suburban environment of Mehuwala, Dehradun, the following parameters were used: mobile height h_b(m) = 42(m), h_m(m)=2(m) and carrier frequency f_c = 875 MHz. With these parameters, the values obtained are X = 124.67, Y = 34.26, and Z = 9.87. Therefore, equation (2) becomes

$$L_{P\,(d)} = 114.8 + 34.26 \log (d) \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Equation (3) is a HATA modified path loss model for the suburban city of Mehuwala, Dehradun.

3. PATH LOSS MODEL BASED ON THE FIELD MEASUREMENTS

Performing field measurements in the environment for which a path loss model is to be developed, explicitly, has the advantage of taking into account all the environmental effects regardless of whether they can be separately recognized. From the measurement data, a path loss model is developed by statistical analysis of the data. After observing the field measurements Efficiency of such a models will be high. Field measurements were performed in the suburban city Mehuwala; Dehradun for its CDMA based WLL system. All the measurements were taken for mobile terminal using 3GHz MICRONIX Spectrum Analyzer MSA338. Noise Figure < 4db and 16.5dB antenna gain. Transmitted power is 5 KW. Measurements were taken in all three zones/sectors. For macro cellular system, the reference distance is taken as d_0 = 1 km. Starting from 1 km, measurements were taken in intervals of 0.5 km in three zones. As the maximum coverage of CDMA based mobile terminals is 3 km to 5 km, measurements were performed up to a distance of 5 km from the transmitter. Range of clear signal is 5 km to 10 km power measured by Spectrum Analyzer at different locations in intervals of 0.5 km three sectors is summarized in Table-1.

Table-1 Received Power Median Value Using Spectrum Analyzer

Distance from transmitter d (km)	Received power in different zones, (dBm)			Median value, (dBm)
	α	β	γ	
1.0	-48	-73	-64	-62
1.5	-47	-76	-65	-63
2.0	-49	-78	-68	-65
2.5	-50	-80	-71	-67
3.0	-54	-81	-73	-69

3.5	-57	-84	-76	-72
4.0	-60	-86	-79	-75
4.5	-62	-87	-81	-77
5.0	-65	-90	-84	-80

As the measurement varies at the same distance in different sectors, mean or median valued for ungrouped frequency distribution of the received power for model development may be used. The corresponding path loss is given in Table -2.

$PL_{dB} = 10 \log_{10} Pt/Pr$ .... (4)

From Table-2, the reference path loss Lp (d_0) is 98.9 dB. The value of path loss exponent n is obtained form the measured data, by linear regression such that the difference between the measured and estimated path loss is minimized in a mean square sense.

Table-2 Measured Path Loss Vs. distance

Distance from transmitter d , km	Measured Ungrouped Median Path Loss,dB
1.0	98.9
1.5	99.9
2.0	101.9
2.5	103.9
3.0	105.9
3.5	108.9
4.0	111.9
4.5	113.9
5.0	116.9

The sum of squared error is given by :

$$E(n) = \sum_{i=1}^{k} \{L_p(d_i) - \acute{L}p(d_i)\}^2 \quad ....(5)$$

Where Lp (di) is the measured path loss at distance di and Ĺp (di) is its estimate using equation (1). The value of n, which minimizes the mean square error, is obtained by equating the derivative of equation (5) to zero, and when solving for n.

$dE(n)/ dn = 0$

we get n = 2.67. Therefore, the resultant path loss model is

$L_p(d) = 98.9 + 26.7 \log (d)$ ....(6)

Equation (6) is the measured path loss model for the suburban city of Mehuwala,Dehradoon.

4. FUZZY LOGIC PATH LOSS MODELS

Fuzzy Logic is a branch of science, which rationalizes uncertain events. It manipulates vague concepts and provides a rational outcome. Fuzzy Logic has been extensively used in many commercial products where a precise mathematical model is not available [7,8]. It is this logic which enables us to apply the concept of Fuzzy logic to characterize an unknown propagation environment from a set of known environments. This concept is illustrated in Fig.2 where the propagation medium is classified into several propagation environment mass defined as an input fuzzy set such as X1 = Structural mass and X2 = Vegetation mass. These crisp inputs are classified by fuzzifier to fuzzy sets and then implemented using fuzzy rule base into fuzzy output. To have crisp output, this requires a method call “de-fuzzifier” to extract a crisp value that best represents the path loss output.

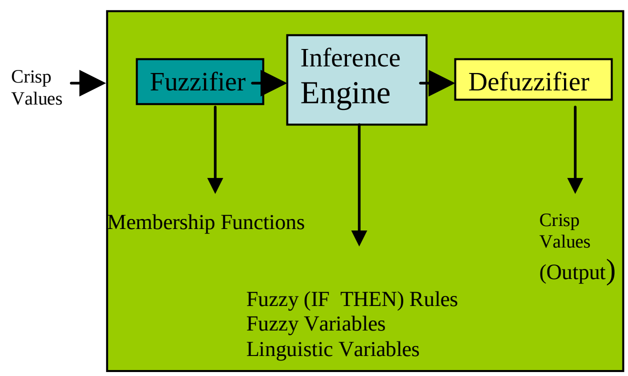

Fig.2 Fuzzy Inference Engine

Fuzzy logic reasons are then applied to determine the path slope for a propagation environment which is neither known environment mass but closely resembles one of these environments mass. The environment mass inputs are fuzzy sets which have membership function as shown in Fig. 3.

...........................(6)

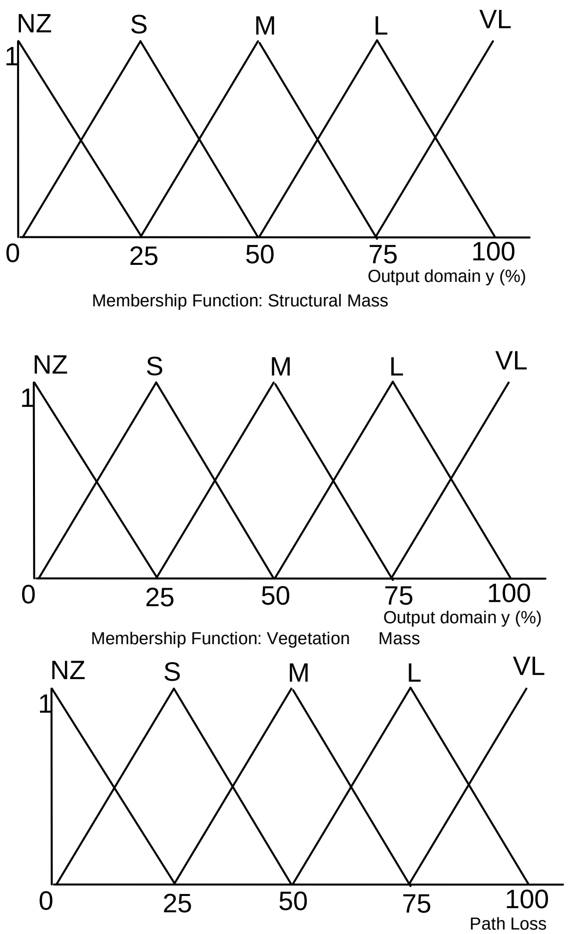

Fig 3 : Membership Function of Fuzzy Input and Output

We use triangular membership functions and classify the fuzzy variable into 5 levels as follows, NZ : Nearly zero, S : Small, M : Medium, L : Large, and VL : Very large.

The environment mass may be classified as :

For input X1, Structural mass,
Very large = Dense Urban : Down-town having high rise buildings and very high mass.

Large = Urban : Down-town having high rise buildings on both sides of the vegetations.

Meduim = Suburban : Just outside of down-town area, residential areas.

Small = Rural : Open area, roads and highways, having no residential areas.

Nearly zero = Free Space : A propagation environment having no obstructions.

For input X2, Vegetation mass,

Very large vegetation mass: Virgin forest

Large vegetation mass: Thick forest, timber forest.

Medium vegetation mass: Public Park, zoo garden.

Small vegetation mass: Rose garden, flower garden.

Nearly zero = Free Space: A propagation environment having no vegetation.

The unknown environments may be obtained by means of the following Linguistic Rule:

Rule1: if X1 = VL, then Y → 6
Rule2: if X1 = L, then Y = L
Rule3: if X1 = M, then Y = M
Rule4: if X1 = S, then Y = S
Rule5: if X1 = NZ, then Y → 2
Rule6: if X2 = VL, then Y → 6
Rule7: if X2 = L, then Y = L
Rule8: if X2 = M, then Y = M
Rule9: if X2 = S, then Y = S
Rule10: if X2 = NZ, then Y → 2
Rule11: if X1 = M, and X2 = L, then Y = L
Rule12: if X1 = M, and X2 = M, then Y = M
Rule13: if X1 = M, and X2 = S, then Y = S

Apparently, the above linguistic rule provides a fine tuning of propagation environments which have already been established experimentally. Now, we implement the above rules to find the output results. Fuzzy output value has very little practical use as most application requires non fuzzy (crisp) control actions therefore it is necessary to produce a crisp value to represent the possibility distribution of the output using defuzzification. Weighted average method for defuzzification is used for the present analysis can be expressed as:

$$f(y) = \frac{\sum \mu(y).y}{\sum \mu(y)}$$

and applying Weighted Average Method output becomes :

$$f(y) = \frac{\sum_{m=1}^{n} E^{m.} D^{m}}{\sum_{m=1}^{n} D^{m}}$$

Where *:*

f(y) is the crisp out put value
$E^{m.}$ is the crisp weighting for the linguistic value LV^m
D^m is the membership value of y with relation to the linguistic value LV^m

5. RESULTS

In this model, the path loss increases at the rate of 26.7 dB per decade with distance. The path loss rate is not very high because the environment is well-open with the scattered buildings. With the HATA model the path loss increases at the rate of 114.8 dB per decade with distance. A comparison of the measured model with the HATA based model gives significance difference. This is because of the terrestrial environment of a typical Indian Suburban city terrestrial environment of a typical Indian suburban city is quite different from a Japanese city where HATA Model is designed.

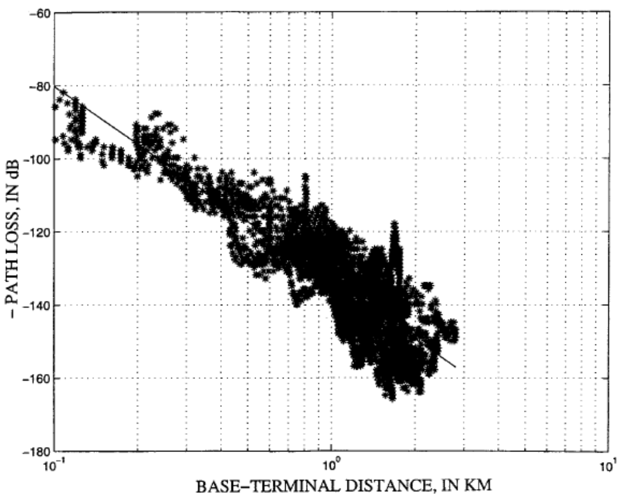

Fig 4: Scatter plot of path loss and distance for a macrocell in the fringe area (base antenna height was 42 m)

The experimental data were analyzed to find path loss slope for each terrain by linear regression. The results are shown in Table-3, obtained with fuzzy logic approximation.

Table -3
Numerical Values of Path Loss Slope using Fuzzy approach

Terrain Type	Fuzzy Path Loss Slope (n)
Clear Area	2.4
Light Vegetation	3.9
Small Town	4.2
Heavy Vegetation	4.9

6. CONCLUSIONS

Path loss models based on measured data have been presented using linear regression and Fuzzy logic. The models are based on a simple d^n exponential path loss Vs. distance relationship. It has been shown from the above considerations and relations; the fuzzy logic set approach to path loss prediction puts a new method for communication analysis in complex system, which RF propagation is chaotic in multipath environment owing to numerous RF barriers and scattering phenomena from several objects in the environment. We have examined HATA propagation models and applied fuzzy logic approximation to determine an unknown environment from a set of known environment. Thus we came to a conclusion that propagation prediction is a combination of Engineering and Art. An experience engineers and experts have to be compromise between theory and practice.

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