Statistic Microwave Path Loss Modeling in Urban Line-of-Sight Area Using Fu y Linear Regression

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Abstract: This paper presents a method to model the path loss characteristics in microwave urban line-of-sight (LOS) propagation. We propose new upper- and lower-bound models for the LOS path loss using fuzzy linear regression (FLR). The spread of upper- and lower-bound of FLR depends on max and min value of a sample path loss data while the conventional upper- and lower-bound models, the spread of the bound intervals are fixed and do not depend on the sample path loss data. Comparison of our models to conventional upper- and lower-bound models indicate that improvements in accuracy over the conventional models are achieved.

Keywords: Microwave path loss modeling, urban areas, Fuzzy Linear Regression

1. INTRODUCTION

The estimation of microwave path loss is necessary for system and cell design of modern mobile communication network [1]-[9]. However it is difficult to accurately estimate path loss in urban areas because of dispersion caused by reflection and blocking due to vehicles, pedestrians, and other objects on the road. Therefore, some researchers have measured radio waves and statistically modeled their results [10],[11] by using upper- and lower- bound formulas. However these estimations have still been over estimated because the slopes of the upper- and lower- bound are fixed and do not depend on the real path loss data. To solve this problem, we propose new upper and lower bound models using fuzzy linear regression (FLR). The spread of upper- and lower-bound of FLR depends on max and min value of a sample path loss data, therefore the FLR is a realistic model and suitable for the system and cell design of fourth-generation multimedia mobile communication systems in microwave bands.

2. UPPER AND LOWER OUND MODELS

The upper and lower bounds for propagation path loss model in UHF and microwave band can be calculated by using (1) and (2) in [10],[11]

$$L_{LOS,l} = L_{bp} + \begin{cases} 20\log_{10}\left(\dfrac{d}{R_{bp}}\right), & for\ d \le R_{bp} \\ 40\log_{10}\left(\dfrac{d}{Rbp}\right), & for\ d > R_{bp} \end{cases} \quad (1)$$

and

$$L_{LOS,u} = L_{bp} + 20 + \begin{cases} 25\log_{10}\left(\dfrac{d}{R_{bp}}\right), & for\ d \le R_{bp} \\ 40\log_{10}\left(\dfrac{d}{Rbp}\right), & for\ d > R_{bp} \end{cases} \quad (2)$$

where

$L_{LOS,\ell}$ and $L_{LOS,u}$ lower and upper bouds of LOS path loss;
L_{bp} propagation loss at R_{bp}
d distance between transmitter and receiver.

In case of no breakpoint when the mobile antenna height approached the effective road height [3], the path loss model can be calculated by

$$L_{LOS,u} = L_S + 20 + 30\log_{10}\left(\frac{d}{R_S}\right), \quad for\ d > R_S \quad (3)$$

where R_S is 20 m based on measurement results using different propagation parameters. L_S is the basic propagation loss at R_S. The lower limit can be approximated by

$$L_{LOS,l} = L_S + 30\log_{10}\left(\frac{d}{R_S}\right), \quad for\ d > R_S \quad (4)$$

where

$$L_S = \left|20\log_{10}\left(\frac{\lambda}{2\pi R}\right)\right| \quad (5)$$

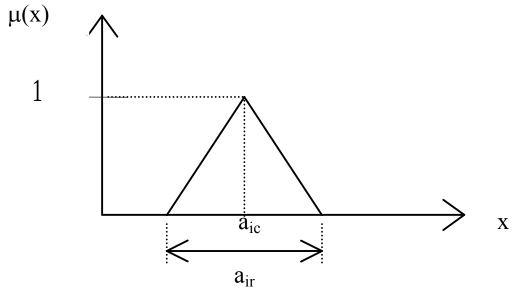


Fig. 1. Triangular from of fuzzy number

3. FU LINEAR REGRESSION MODELS

Fuzzy linear regression model can be represented in the from [12]-[15]

$$= Z \quad (6)$$

where:

$$y_i(z_I) = {}_0 + {}_1 z_{i1} + \quad + {}_k z_{ik}, \qquad i=1,2, \quad ,n \quad (7)$$

The fuzzy linear regression model (7) is represented using symmetric triangular fuzzy parameters $_i = [a_{ic}, a_{ir}]$ as shown in fig. 1 [3] [4] by:

$$y_i(z_i) = [a_{0c}, a_{0r}] + [a_{1c}, a_{1r}] z_{i1} + \quad + [a_{kc}, a_{kr}] z_{ik} \quad (8)$$

$$y_{ic}(z_i) = a_{0c} + a_{1c} z_{i1} + \quad + a_{kc} z_{ik} \quad (9)$$

$$y_{ir}(z_i) = a_{0r} + a_{1r} z_{i1} + \quad + a_{kr} z_{ik} \quad (10)$$

where: y_c, a_c are center parameters of fuzzy numbers (membership function $\mu = 1$), y_r, a_r are spreads of fuzzy numbers (geometrically the spread is a half of the base of the triangular).

The parameters $_i$ of the vector of the FLR model are determined by a solution of a linear programming (LP) problem which is to minimize the sum of spreads $y_r(z_i)$ of elements of vector y Therefore the following LP problem is formulated.

$$C = y_{1r}(z_1) + y_{2r}(z_2) + \quad + y_{nr}(z_n) \rightarrow \text{Minimum} \quad (11)$$

Subject to $\quad y_i \in (z_I), \qquad i = 1,2, \quad ,n \quad (12)$

$$a_{ir} \geq 0, \qquad i = 0,1,2, \quad ,k \quad (13)$$

from (8) - (10), the LP problem (11) - (13) can be written as follows:

$$\sum_{i=1}^{n} (a_{0r} + a_{1r}|z_{i1}| + \quad + a_{kr}|z_{ik}|) \rightarrow \text{Minimum} \quad (14)$$

$$a_{0c} + \sum_{j=1}^{k} (a_{jc} z_{ij}) - a_{0r} - \sum_{j=1}^{k} (a_{jr}|z_{ij}|) \leq y_i, i=1,2,..,n \quad (15)$$

$$a_{0c} + \sum_{j=1}^{k} (a_{jc} z_{ij}) - a_{0r} + \sum_{j=1}^{k} (a_{jr}|z_{ij}|) \geq y_i, i= 1,2,..,n \quad (16)$$

The parameters $a_i = [a_{ic}, a_{ir}]$ of vector are determined as the optimal solution of the LP problem (14) (16). Since the LP problem always has feasible solutions, the fuzzy parameters are obtained from the LP problem, for any data.

4. NUMERICAL EXAMPLE

The FLR model (4) was determined and compared with conventional models (1) and (2). The FLR model was calculated from measured data in [6]. The fuzzy model was then presented in from:

$$L_{LOS} = [a_{0c}, a_{0r}] + [a_{1c}, a_{1r}] \log(d) \quad (17)$$

where

$$L_{LOS,u} = [a_{0c} + a_{0r}] + [a_{1c} + a_{1r}] \log(d) \quad (18)$$

and

$$L_{LOS,l} = [a_{0c} - a_{0r}] + [a_{1c} - a_{1r}] \log(d) \quad (19)$$

and d = distance between transmitter and receiver. The LP problem corresponding to the given data was formulated from (14) (16). By solving this LP problem, the following FLR models are obtained:

4.1 Without reakpoint

for frequency of . GHz

$$L_{LOS,u} = [63.45] + [37.02] \log(d/do) \quad (20)$$

and

$$L_{LOS,l} = [41.12] + [34.42] \log(d/do) \quad (21)$$

for frequency of 8. GHz

$$L_{LOS,u} = [78.8] + [29.2] \log(d/do) \quad (22)$$

and

$$L_{LOS,l} = [56.85] + [29.2 \log(d/do) \quad (23)$$

for frequency of 1 .7 GHz

$$L_{LOS,u} = [79.97] + [36.44] \log(d/do) \quad (24)$$

and

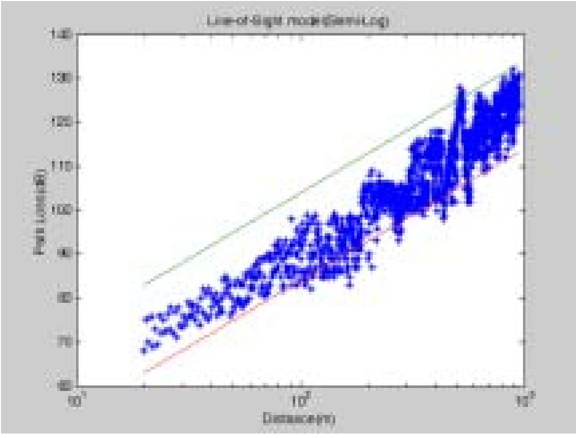
$$L_{LOS,l} = [73.16] + [29.6] \log(d/do) \quad (25)$$

4.2 With reakpoint

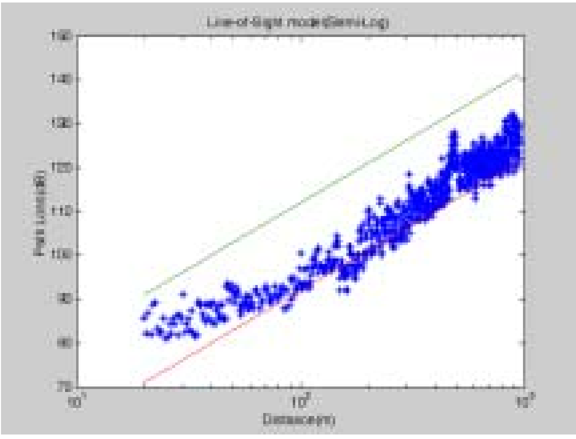
for frequency of . GHz

$$L_{LOS,u} = \begin{cases} 97.2 + 31.9 \log_{10}\left(\frac{d}{R_{bp}}\right), & for\, d \leq R_{bp} \\ 95.9 + 35.2 \log_{10}\left(\frac{d}{Rbp}\right), & for\, d > R_{bp} \end{cases} \quad (26)$$

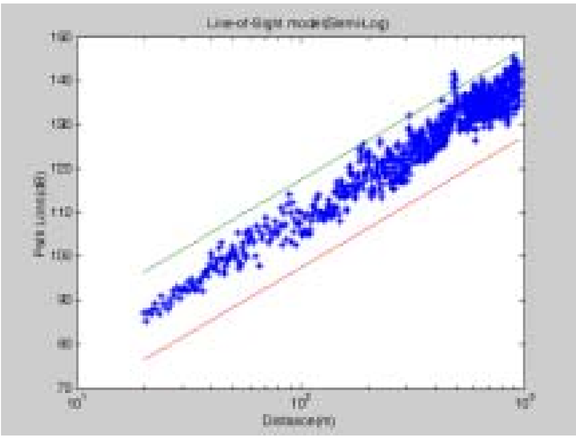
and



a frequency . GHz



b frequency 8. GHz

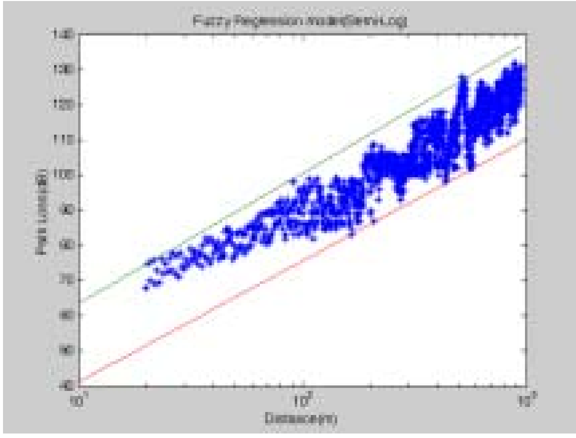


c frequency 1 .7 GHz

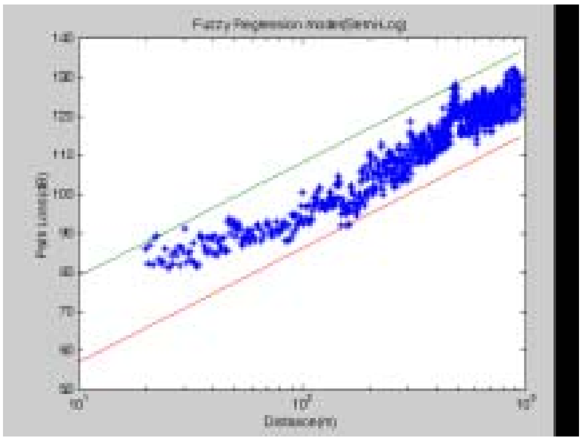
Fig. 2 The conventional model without breakpoint

$$L_{LOS,l} = \begin{cases} 83.7 + 25.0\log_{10}\left(\frac{d}{R_{bp}}\right), & for\, d \le R_{bp} \\ 81.8 + 28.4\log_{10}\left(\frac{d}{Rbp}\right), & for\, d > R_{bp} \end{cases} \quad (27)$$

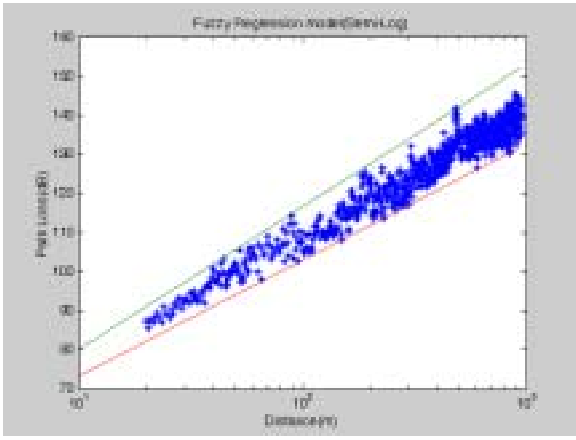
for frequency of 8. GHz



a frequency . GHz



b frequency 8. GHz

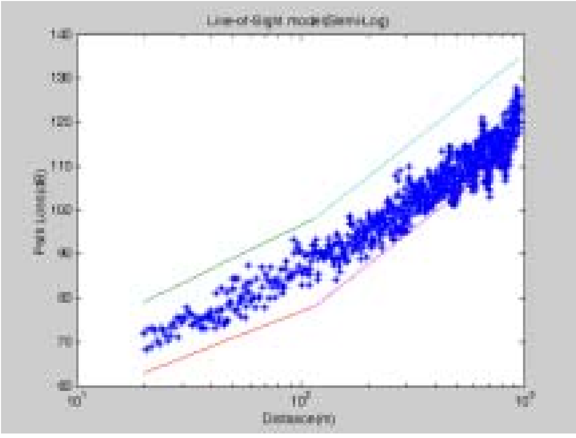


c frequency 1 .7 GHz

Fig. 3 FLR path loss model without breakpoint

$$L_{LOS,u} = \begin{cases} 107.9 + 17.8\log_{10}\left(\frac{d}{R_{bp}}\right), & for\, d \le R_{bp} \\ 115.1 + 35.9\log_{10}\left(\frac{d}{Rbp}\right), & for\, d > R_{bp} \end{cases} \quad (28)$$

and



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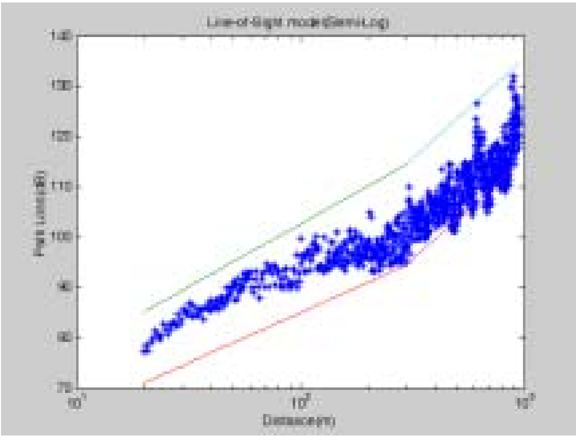

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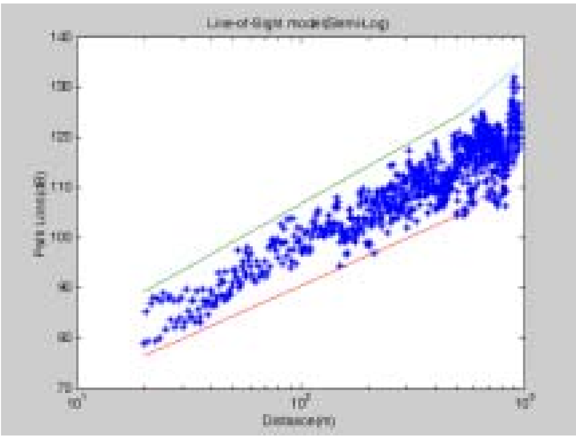
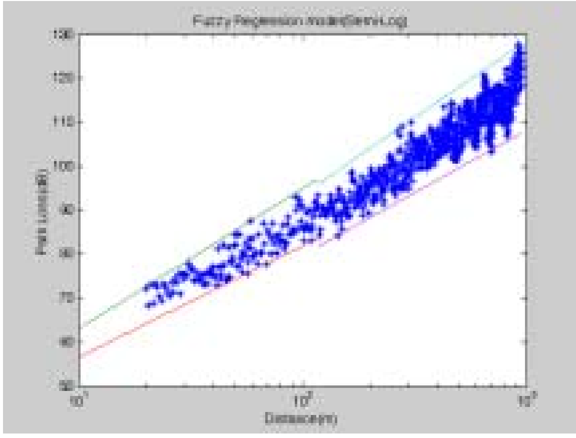


c frequency 1 .7 GHz

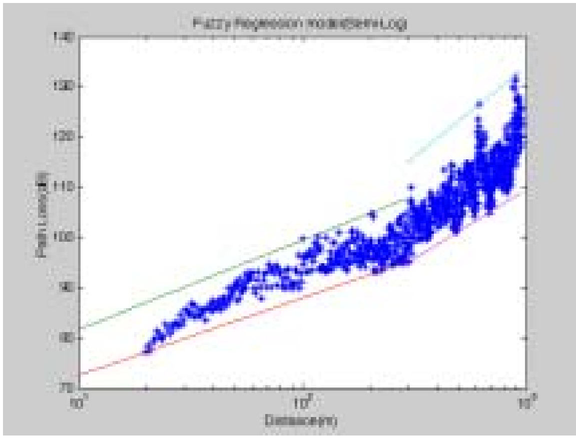
Fig. 4 The conventional model with breakpoint

$$L_{LOS,l} = \begin{cases} 99.9 + 15.4\log_{10}\left(\frac{d}{R_{bp}}\right), & for\, d \le R_{bp} \\ 95.0 + 27.7\log_{10}\left(\frac{d}{Rbp}\right), & for\, d > R_{bp} \end{cases} \quad (29)$$

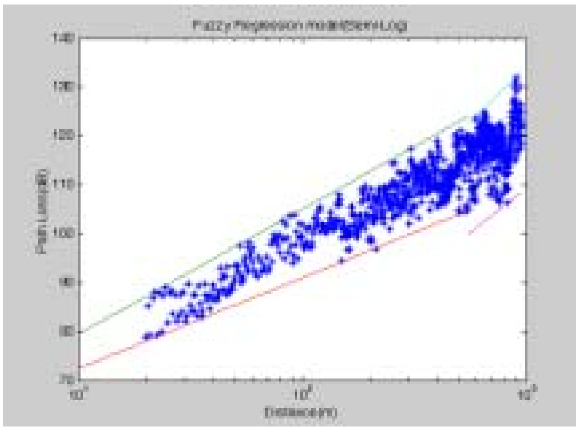
for frequency of 1 .7 GHz



a frequency . GHz



b frequency 8. GHz



c frequency 1 .7 GHz

Fig. 5 FLR path loss model with breakpoint

$$L_{LOS,u} = \begin{cases} 124.1 + 25.6\log_{10}\left(\frac{d}{R_{bp}}\right), & for\, d \le R_{bp} \\ 122.6 + 44.7\log_{10}\left(\frac{d}{Rbp}\right), & for\, d > R_{bp} \end{cases} \quad (30)$$

and

$$L_{LOS,l} = \begin{cases} 104.8 + 18.6\log_{10}\left(\frac{d}{R_{bp}}\right), & for\, d \le R_{bp} \\ 99.5 + 36.4\log_{10}\left(\frac{d}{Rbp}\right), & for\, d > R_{bp} \end{cases} \quad (31)$$

The results are shown in Fig 2-3 and 4-5 for the distance characteristics of the path loss without break point and with break point respectively. We found that the FLR provide high accuracy within the upper- and lower- bound as shown in Fig. 3 and 5 while the conventional models predict the path loss over estimation at the upper- and lower- bound as shown in Fig. 2 and 4

5. Conclusions

We propose the Microwave path loss models based on measured data in LOS urban environment using the fuzzy linear regression. The models are based on a simple d^n exponential path loss vs. distance relationship and used for frequency of 3.35, 8.45 and 15.75 GHz. The spread of the upper- and lower- bound of the fuzzy models depends on max and min value of a given data while the width of the upper and lower regression lines are fixed as shown in eq. (1)-(4) that cause they provide the error prediction at the outside of the boundary. From the reasons above, the FLR is a realistic model and suitable for the system and cell design of fourth-generation multimedia mobile communication systems in microwave bands.

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