Motley-Keenan Model Adjusted to the Thickness of the wall

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***Abstract* — This work proposes an adjustment in the Motley-Keenan Model, considering the thickness of the wall. To validate the proposal, measures were made in environments indoor, as it will be presented. The results demonstrate the reliability of the adjustment, being obtained smaller errors in the predicted values in comparison with the measured values, indicating a better accuracy in the prediction of the propagation with the use of this model.**

***Index Terms* — Indoor Radio Communication, Channel, Propagation.**

I. Introduction

Nowadays, the wireless communication in environments indoor is an inherent need to the world, be in mobile telephony or in WLAN (Wireless Local Area Network), used in commercial or residential buildings. Providing a trustworthy coverage in such environments is an arduous task and should be preceded by a meticulous propagation study, in order to avoid interference problems, to maintain the safety of the information and to avoid damages to the health due to the electromagnetic emission.

In the study of the coverage area system, on use deterministic models or empiric models. Deterministic models need a great amount of information about the environment, structure of the construction and existent furniture in the place where there is the emission or reception of the signal. The deterministic models allow very good results, without the need of the local measures, but it is necessary a great computational effort. The empiric models need few information about the environment in study, besides demanding a reduced computational effort, because it presents a simplified mathematical expressions to calculate the path loss by the signal between the transmitter and the receiver.

Several works have been published [1 - 4] regarding the prediction of the propagation in environments indoor with the use of empiric models, and some of these consider the penetration loss in walls. However, there are challenges related with the thickness of the wall. Many models consider the kind of the wall, but do not establish an appropriate method to verify the effects of the thickness in each wall.

On intend, here, to propose that a Motley-Keenan Model may be adjusted to predict the propagation with different thickness walls in the environments indoor. The results and conclusions on this work can be analysed below.

II. Motley-Keenan Model

The multiple walls model [4] at equation (1) provides a way to obtain the loss in the environment when the signal impinges several types and amounts of walls. In this equation, $\mathbf{PL_r}$ is the reference loss [dB] taken at 1 (one) meter of distance among transmitter and receiver, **n** is the decay rate of the received sign level, **N** is the number of walls between the transmitter and the receiver, $\mathbf{k_i}$ is the number of type **i** walls and $\mathbf{Lw_i}$ is the penetration loss in the type **i** walls.

$$PL(d)[dB]=PLr[dB]+10n\log(d)+\sum k_i Lw_i \qquad (1)$$

On observe that the penetration loss is the same to each kind of the material of the wall, independent of its thickness. In important Brazilian government departments, mainly in older buildings, very wide walls exist, which introduce a high attenuation in the signal, impeding, in some cases, any propagation through the same ones. An example is the case of the National Congress, showed in the Figure 1, where exist concrete walls of up to 40 cm.

Fig. 1. National Congress building in Brasília-Brazil.

To evaluate the effect of the width of the walls in the signal attenuation, exhausting measures were accomplished in the Chamber of Deputies. The obtained results were equivalent to the accomplished by Zhang and Hwang [5]. To evaluate the penetration loss in indoor environments, Zhang and Hwang executed measurements of the loss of the sign transmitted through concrete and plasterboard walls with different thickness. It can be noticed that the penetration loss is doubled, when the wall thickness is triplicate.

III. Multiple Walls Empiric Model Adjusted

Considering the results obtained in the accomplished measures, a term was defined in the attenuation equation, in way to adjust the model so that the width of the walls is considered. The propose is, with the knowledge of the penetration loss in a reference wall built with a type **i** material and thickness $\mathbf{e_0}$, to define the term (2) to sum in the equation (1), resulting in the equation (3), where L_{0i} is the penetration loss in the type **i** reference wall, $\mathbf{e_{0i}}$ is the thickness of the reference wall and $\mathbf{e_i}$ is the thickness of the type **i** wall which obstructed the signal.

$$\textit{Adjusted Term} = \sum_{i=1}^{N} k_i L_{0i} 2^{\log_3\left(\frac{e_i}{e_{0i}}\right)} \qquad (2)$$

$$PL(d)\ [dB] = PLr\ [dB] + 10n\log(d) + \sum_{i=1}^{N} k_i L_{0i} 2^{\log_3\left(\frac{e_i}{e_{0i}}\right)} \qquad (3)$$

IV. Results

In way to validate the proposed model, calculations were accomplished for all of the positions of accomplished measures. The results obtained with the equation were compared with the measured results.

The table 1 indicates the values used as penetration loss in reference walls for the comparison among the models presented by the equations (1) and (3), with values of the path losses measured in the environments of the Chamber of Deputies, in Brasília - Brazil, in 1.8 GHz and with several concrete walls with 15 cm, 30 cm and 40 cm of thickness.

To make the comparison were calculated the square means relative error (SMRE) and the standard deviation (σ) between the calculated values and the measured values, in order to define the accuracy and the precision of each model. Like this, with the model specified by the equation (1) it was obtained a SMRE of 5% and σ of 9.93 dB. Already for the case of the new model, with the equation (3), it was obtained a SMRE of 3% and σ of 7.97 dB. The Figures 2 and 3 shows some results obtained.

TABLE 1
MEASURES OF THE PENETRATION

Type of Wall	Thickness of the Wall (cm)	Penetration Loss (dB)
Soft Partition	5	2,5
Plasterboard	12	2,5
Concrete Wall	15	6

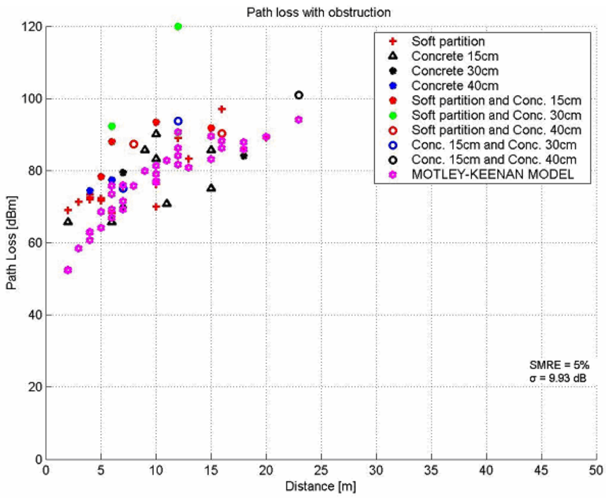

Fig. 2. Motley-Keenan model in environments with obstruction for multiple walls, without adjustments.

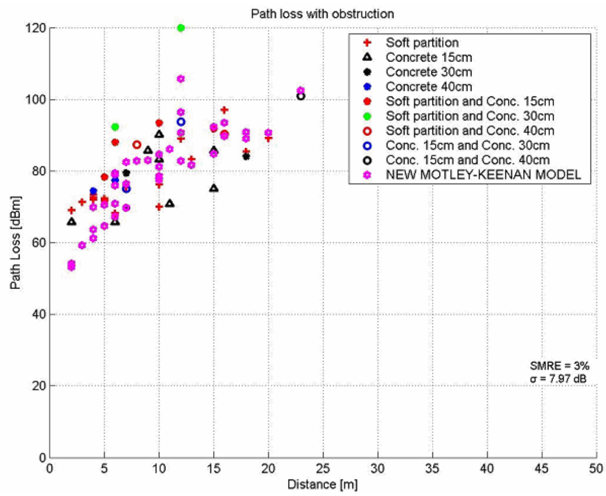

Fig. 3. Motley-Keenan model in environments with obstruction for multiple walls, with adjustments.

V. CONCLUSION

This work showed that the prediction model of the propagation in indoor environments with multiple walls proposed can be established without the need of previously knowing the penetration loss in all of the walls that obstruct the signal. Therefore, is enough to know the penetration loss just in some reference walls and the thickness of the other walls, which can be easily found in the low plant of the environments studied. Besides, as it can be evaluated, the new model has good accuracy and precision.

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