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Abstract	We recommend a flexible channel propagation model, which includes no more than three taps and has flexible tap gains and tap delays. The tap gains have a progressive decrease relationship, while the tap delays have a progressive increase one. The model is valid under the following assumptions: (1) there is line-of-sight propagation, (2) highly directional antennas are used at least at the receive; (3) heavy-rain attenuation effects are not taken into account, and (4) a –20 dB threshold is applied, which excludes multi-path components with amplitudes below the threshold. The available radio channel measurements support the model.
Purpose	To provide an input to the specific area ''Channel propagation model''.
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Recommendation on Channel Propagation Model for Local Multipoint Distribution Service

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Introduction

It is necessary and important to have a flexible channel propagation model, which provides multi-path information for channel equalization and can be used to evaluate the performance of fixed broadband wireless systems.

Local Multipoint Distribution Service (LMDS) operating at centimeter and millimeter wavelengths (above 20 GHz) requires line-of-sight (LOS) propagation conditions between a base station and subscriber stations. This requirement can be met by installing antennas that are higher than all obstacles in the propagation environment. Directional antennas with possibly high gain are recommended for use at least at the receiver, because they minimize multi-path effects, such as fading, delay, and interference from unexpected sources.

Due to the complexity of propagation environment, it is impossible to make a channel propagation model with a unique set of parameters that applies to all possible situations. Based on our studies of the LMDS radio channel, however, we recommend here a multi-path propagation channel model with a number of flexible parameters for use in the evaluation of LMDS systems. The parameters are: the maximum number of taps, the tap gains, and the tap delays. We also propose a linear relationship between the delay spread and the excess path loss (in excess of free-space loss) and discuss its relevance to the LMDS radio channel.

Channel Propagation Model and Its Parameters

The expression of channel propagation model is

$$h(t) = \sum_{n=0}^{N-1\leq 2} a_n \delta(t-\tau_n)\exp(-j\omega_c\tau_n) \qquad (1)$$

where $h(t)$ is the complex channel impulse response, N is the maximum number of taps, n is the tap index, a_n is the tap gain, τ_n is the tap delay, ω_c is the carrier frequency, and $\delta(t-\tau_n)$ is the delta function. Equation (1) represents a multi-path model that has no more than three rays.

The channel impulse response $h(t)$ is normalized in the sense that $20\log_{10} a_0 = 0$ dB and $\tau_0 = 0$ ns for the ray that has the maximum amplitude. For a narrow beam of LOS propagation resulting from a highly directional antenna installed at a relatively high location, the electric field components of the first Fresnel zone dominate the received signal. Therefore, we recommend a decreasing order for the tap gain a_n as

$$A_{\max} \geq 20\log_{10} a_1 > 20\log_{10} a_2 \geq A_{\min} \qquad (2)$$

and an increasing order for the tap delay τ_n as

$$\tau_{\min} \leq \tau_1 < \tau_2 \leq \tau_{\max}\,. \qquad (3)$$

Based on wideband radio channel measurements, the values of A_{max}, A_{min}, τ_{min}, and τ_{max} are determined and listed in Table 1.

Table 1: Values of A_{max}, A_{min}, τ_{min}, and τ_{max}.

Items	A_{max} (dB)	A_{min} (dB)	τ_{min} (ns)	τ_{max} (ns)
Values	-2.8	-20	3	50

Values of A_{max} and τ_{min} are determined on the basis of measurements reported in [1]. The value of τ_{max} applies under the assumptions of LOS propagation and use of a highly directional receiver antenna. The value of A_{min} is set at a threshold of –20 dB [1].

The model does not account for heavy-rain attenuation effects.

Available LMDS radio channel impulse response measurements support the flexible model presented above. As evidence, measurements of [1] are presented in Tables 2-4. It is seen that the good channel has one ray, the moderate channel has two rays, and the bad channel has three rays. Some measured data were obtained under non-LOS propagation conditions, which degraded the performance of the LMDS radio channel.

Table 2: Summary of good channel.

Tap index	$20\log_{10} a_0$ (dB)	τ_n (ns)
0	0	0

Table 3: Summary of moderate channel.

Tap index	$20\log_{10} a_0$ (dB)	τ_n (ns)
0	0	0
1	-13.7	5.3

Table 4: Summary of bad channel.

Tap index	$20\log_{10} a_0$ (dB)	τ_n (ns)
0	0	0
1	-2.8	3.6
2	-16.2	15.3

On the basis of wideband measurements at 29.5 GHz, a multi-path model was proposed in [2]. This model is summarized in Table 5. Some measurement data were obtained at non-LOS sites. For the positive tap indices, equation (1) agrees with the model in [2]. Physically, if tap index 0 indicates the direct ray, the taps having negative tap indexes disappear.

Table 5: Summary of a multipath model.

Tap index	$20\log_{10} a_0$ (dB)	τ_n (ns)
0	0	0
1	-15	20
2	-20	50
-1	-15	-20
-2	-20	-50

Relation Between Delay Spread and Excess Path Loss

Available measurements indicate that multi-path is more pronounced in non-LOS propagation conditions resulting in large signal attenuation. Therefore, we propose a linear relationship between delay spread τ in ns and excess path loss L_e (in excess of free-space loss) in dB as

$$\tau = t_0 + t_e L_e \qquad (4)$$

where L_e is in the range $L_e \geq 0$ dB, t_0 is in ns, and t_e is in ns/dB. Both t_0 and t_e are flexible and can be determined by using measurement data. For example, using measured data of three wideband channels [1], we have $t_0 = 0.75$ ns and $t_e = 30^{-1}$ ns/dB for $L_e < 35$ dB. A -20 dB threshold has been applied in the analysis of measured amplitude of channel impulse response [1]. Clearly, τ increases with L_e.

The excess path loss L_e can be expressed [3] as

$$L_e = L_R + L_{at} + L_o + L_m \qquad (5)$$

where L_R is the loss due to rain, L_{at} is the loss due to atmospheric gases, L_o is the loss due to obstruction by terrain obstacles, buildings, etc., and L_m accounts for the loss or fading due to multipaths such as atmospheric refraction and reflections of the propagation environment.

The rain loss L_R, which is severe and must be considered for LMDS systems, can be calculated by using the model in [4]. However, some refinements to the model may be necessary. For example, the model of [4] presented power-law parameters of rain specific attenuation, i.e., rain attenuation (loss) per kilometer only for one raindrop size distribution, but the raindrop size distribution changes with geographical location and it can strongly influence rain specific attenuation. We recommended [5] that the usage of an expanded set of power-law parameters for various raindrop size distributions in calculating the rain specific attenuation.

The methods for estimating L_{at}, which is less severe than L_R, can be traced in [4].

By installing high antennas, which enable LOS propagation, L_o can be made negligible or can be minimized. Two formulations presented in [6] account for multiple diffraction by rows of buildings and trees.

By using highly directional antennas with possibly high gains, L_m can be minimized. Some methods for calculating the effects of L_m and L_o may be found in [4]. Models for vegetation attenuation which is a part of L_o and L_m are available in [7].

Summary

We have recommended a flexible channel propagation model, which includes no more than three taps and has flexible tap gains and tap delays. The tap gains have a progressive decrease relationship, while the tap delays have a progressive increase one. This multi-path model is valid on conditions of (1) LOS propagation; (2) use of highly directional antennas at least at the receiver; (3) heavy-rain attenuation effects not included; and (4) a –20 dB threshold applied, excluding multi-path components with amplitudes below it. Available LMDS radio channel measurements support this model.

We have proposed a linear relation between delay spread and the excess path loss, based on available measurements. The propagation channel degrades as the excess path loss increases.

We discussed the excess path loss, which can be minimized by installing highly directional antennas at relatively high locations.

References

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