A Study on Two-Way Microwave Communication link at 26 GHz frequency band

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ABSTRACT

This paper presents the studies on wireless channel modeling and reverse link synchronization of CATV. This paper analyzes multi-path fading channel to the cause of signal distortion in the wireless communication environment. We represent the microwave link characteristics according to the channel model. Multi-path channel can affect fading.

I. Introduction

Two way CATV system consists by broadcasting part and receiving part from subscribers. If information can be transmitted by CATV system in two way, we can know exact system link margin. We have to know forward link margin and reverse link margin. The facts which have an effect on margin are weather, distance between transmitter and receiver, obstacle between transmitter and receiver, reflection, refraction. All these facts have an effect on multi-path fading and multi-path fading has an effect on synchronization between transmitter and receiver. But, we cannot obtain specific analysis data on wireless channel at 26GHz. Therefore, we study and experiment on wireless channel. We analyze the channel by the known fading model and examined it by experiment. This paper analyzes multi-path fading channel to the cause of signal distortion in the wireless communication environment and also presents the studies on wireless channel modeling and reverse link synchronization of wireless CATV. The result of this paper is used at the wireless CATV synchronization and wireless communication system.

II. Multipath channel Modeling

Wireless communication is important to the realization of LMDS (Local Multi channel Distribution Service). Especially, wireless communication in micro cell is gaining importance compared for current macro cell, which envoy voice and data to the subscriber of CATV in a building. Wireless communication channel is modeled by a multi-path fading channel because of the fact that microwave is transmitted from the transmitter to the receiver through the multi-path channel caused by reflection and refraction. In general, a multi-path fading channel can bemodeled by a linear filter that varies with time. We can find output signal on any input signal by using the linear filter channel model. Multi-path fading channel model can be divided into a diffused multi-path channel, a discrete multi-path channel model, and a wideband tapped delay line channel model.[1]

1. Diffused multi-path channel model

Diffused multi-path channel model is also called *continuous multi-path channel*, which

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assumes that the path exists corresponding to every delayed time from 0 to infinity. Channel impulse response is expressed in terms of a continuous function (t, τ). Variable t means that impulse response varies with time in this equation. Therefore, channel output is expressed by convolution of the channel input x(t) with the channel impulse response (t, τ) as follows.[6]

$$y(t) = \int_{-\infty}^{\infty} x(t-\tau)\rho(t,\tau)d\tau$$

This channel model is appropriate for the electrolyte dissociation layer reflection model such as communication channel in which a reflection object is uniformly spread. Therefore, this model is somewhat different from the mobile communication channel model.

2. Discrete multi-path channel model

Turin first proposed this channel model, in which it is supposed that the path exists only *when its delayed time has a discrete value.* Mobile communication channel can be modeled appropriately by the discrete multi-path channel model, in which a reflecting object such as a building, etc. nonuniformly exists and is grouped. In case of wideband signals, channel impulse response can be expressed as follows:

$$h(t) = \sum_{k=0}^{N-1} \alpha_k \delta(t-\tau_k) e^{j\theta_k}$$

In this expression, $\{\alpha_k\},\{\tau_k\},\{\theta_k\}$ are time functions, which express the magnitude, arriving time, phase of the signal that is received through the multi-pathchannel. Because this model consists of several discrete signals that have a wide time interval, this model can be applied to the case such as that its channel impulse response has a noncontinous structure. In other words, this model may be applied to thecircumstance in which the channel impulse response consists of a few signal groups and the signal groups are arranged wider than the object system's time dividing capability. Therefore, the discrete multi-path channel model can be realized as shown in Fig. 1.

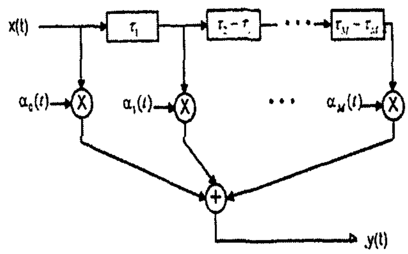


Fig. 1 Discrete multi-path channel model

3. Wideband TDL (Time Delayed Line) channel model

Mobile wireless communication uses the discrete multi-path channel model generally. But in the case that the time delay spread is small such as in PCS, especially in-building *wireless channel or micro cell, we cannot* differentiate discrete characteristics of the channel. Therefore, the discrete multi-path channel model that has a wide tap space cannot express the channel certainly. In this case, the wideband channel TDL model that is applicable by the sampling theorem is used. In this case, the bandwidth of the given signal is limited and each sample has to satisfy Nyquist criterion. The path exists with continuity and variation in delayed time. The delayed time has the time flowing effect to the mutual interference randomly. Therefore, the wideband channel model can be realized as shown in Fig. 2.

The wideband TDL model is very similar to the discrete multi-path channel model in its realization in spite of the difference in the general concept. Each model is realized by the TDL filter that has the weighting factor which varies with time. The wide band TDL model can express the channel which is satisfied by Nyquist sampling rate and limited the bandwidth exactly.

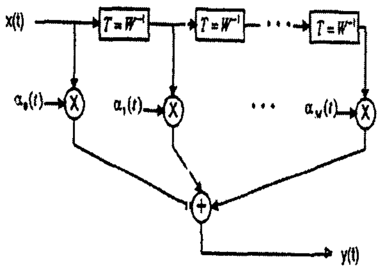


Fig. 2 Wideband TDL channel model

The hybrid model combines the discrete multi-path channel model with wideband TDL model. In the case of the small time delay diffusion, the wideband TDL model is used. In other cases, discrete multi-path channel model is used. Therefore, a hybrid model is used for wideband indoor and outdoor channels.

Ⅲ. Characteristics of channel impulse response.

The multi-path channel can be expressed in terms of the channel impulse response which varies with time and space. Therefore, it is important to examine the channel impulse response in channel modeling. The channel impulse response has major characteristics as follows:

1. Number of multi-paths
Let N is the number of signals which are within α dB of the largest signal in the receiver multi-path signal. The number of multi-paths N has normal distribution and its mean and variance are proportional to the distance from the antenna.

2. Signal arriving time
Generally, the arriving time of each multi-path component can be modeled by the Poission process. Path generating rate is only a function of time in the standard Possion process, but the modified Poission process's path generating rate varies according to the prior path generating result. The modified Poission distribution is considered as the most general model.

3. Signal Magnitude
The received signal magnitude has Rayleigh Distribution in the absence of LOS (Line Of Sight) path and has Rician distribution random variable in the situation that a direct path exists.

1) Rayleigh Distribution
This distribution can be expressed in terms of the sum of the multi-path signal that its in-phase signal and quadrature-phase signal cannot be distinguished by the system bandwidth. The magnitude of signal has Rayleigh distribution when the signals are independent from each other and has normal distribution with the mean of 0.

$$P_{\gamma} = \frac{r}{\sigma^2}\exp(-\frac{r^r}{2\sigma^2}), for \qquad r > 0$$

This Rayleigh distribution is determines its distribution by variance σ^2 of each channel.

2) Rician Distribution
This model is appropriate for the case when the signal received without varying its component, and is applicable to the micro cell or in-house environment.
3) Nakagami Distribution
This distribution has many applicable characteristics. It can model various channels by changing each parameter. This is the signal magnitude distribution which is

founded by real data and is expressed as follows:

$$P_r(r) = \frac{2m^m \cdot r^{2m-1}}{\Gamma(m) \cdot \Omega^m} \cdot \exp(-\frac{mr^2}{\Omega}), r \geq 0$$

(3-29)

$\Gamma(m)$: Gamma function

$\Omega = E\{r^2\}$,

$m = [E\{r^2\}]^2 / Var\{r^2\}(\geq 1/2)$

m=1: Rayleigh distribution
m=2: normal distribution

4) Log-Normal Distribution

The signal magnitude can be modeled by the multiplicative fading process because of the reflection in the multi-path channel. Therefore, the signal distribution based on the data is as follows:

$$P_r = \frac{1}{\sqrt{2\pi \cdot \sigma^2}} \cdot \exp\{-\frac{(Inr - \mu)^2}{2\sigma^2}\}, \qquad r \geq 0$$

Especially, Log-Normal distribution is more proper than the Rayleigh distribution in the case that the received signal magnitude is smaller than the median.

4. Rate of each signal and cross-correlation

The received signal magnitude and its cross-correlation is an important factor in designing the receiver. In the outdoor micro cell and indoor wireless environment, the result of measurement which measures the relationship of received signal with magnitude expressed by the rate of signal to power are shown in Table1. and Table2.

In outdoor micro cell, as seen in Table1., one lake branch can obtain 80% power to the 5 MHz signal bandwidth. In the case of 10 MHz or 15 MHz, three branches are required. Furthermore, it is sufficientto consider the standardized power distribution (0,-15,-17dB), (0,-9.5,-12dB), (0,-6,-8dB), (0,-2, -3dB), because the standard deviation of mean power is much smaller than the average value.[2]

Table1. Average power rate and standard deviation of 2nd and 3rd paths to the strongest path in the outdoor micro cell.

Signal bandwidth MHz	μ dB 2vs.1	σ dB 2vs.1	μ dB 3vs.1	σ dB 3vs.1
1.25	-14.7	1.2	-17.2	0.7
5	-9.5	1.7	-12.2	1.5
10	-5.8	0.9	--8.1	1.2
20	-2.2	0.3	-3.0	0.4

(μ: average power rate, σ: standard deviation)

Table2. Average power rate and standard deviation of 2nd and 3rd paths to the strongest path in the indoor wireless environment.

Signal bandwidth MHz	μ dB 2vs.1	σ dB 2vs.1	μ dB 3vs.1	σ dB 3vs.1
10	-11.7	1.8	-14.2	1.0
20	-9.5	1.7	-12.1	1.9

The multi-path channel component has correlation with each other as the delay diffusion of channel impulse response becomes smaller.

The result of measurement that measure the correlation of each component of multi-path are shown in Tables3. and Table4.

Table3.Mean and standard deviation of correlation coefficient of strong 1st & 2nd, 1st & 3rd paths to the strongest path in the outdoor micro cell.

Signal bandwidth MHz	μ, 1&2	σ, 1&2	μ, 1&3	σ, 1&3
1.25	0.42	0.31	0.59	0.24
5	0.32	0.25	0.38	0.34
10	0.54	0.23	0.55	0.29
20	0.79	0.16	0.79	0.16

Table4. Mean and standard deviation of correlation coefficient of strong 1st & 2nd, 1st & 3rd paths to the strongest path in the indoor micro cell.

Signal bandwidth MHz	μ, 1&2	σ, 1&2	μ, 1&3	σ, 1&3
10	0.55	0.23	0.39	0.35
20	0.25	0.30	0.36	0.37

The frequency diversity effect of receiver is decreased as much as is shown in the table.

5. Signal phase

The signal phase of multi-paths is independent, and is modeled by a random variable which exists within $[0,2\pi]$. It is change by 2πas a path length varies one wavelength because of the signal phase is sensitive to the path length.

6. RMS delay dispersion

RMS delay dispersion is very important in designing the receiver with magnitude of received signal and correlation. In the wireless environment, RMS dispersion is as shown in the following table:

Table5. RMS dispersion in the wireless environment.

Macro cell	0.1 - 10 sec
Micro cell	10 [illegible]0 nsec
Indoor	10 - 50 nsec

The facts that affect to the RMS delay dispersion in the wireless environment are as follows:

1) Antenna spacing

A theory is that antenna dispersion is increased with spacing of each transmit and receiving antenna, another theory is that antenna dispersion is increased by the geometrical effect regardless of the antenna spacing.[3]

2) Antenna height

Generally, RMS delay dispersion is proportionalto the height of an antenna. But the effect of antenna height is diminished greatly in the case that the height of an antenna is less than the half of the average height of the loop top.[4]

3) Antenna types

In the macro cell, the antenna pattern effect of directive antenna is minor but RMS delay dispersion is increased by the effect of antenna pattern because the channel is changed from the micro cell to micro cell.

In the micro cell, the base station antenna is closer than the macro cell. Therefore, the probability in which the antenna of the mobile station is in the main lobe of the antenna pattern of the base station is diminished.

4) Antenna inclination

In the case that the directive antenna has inclination, the main lobe of antenna radiation/pattern is inclined. Therefore, the near region to the base station is radiated by the larger signal magnitude, the distant region is radiated by the small signal than the near region. RMS delay dispersion is inversely proportional to the inclination of antenna inclination because of the smaller antenna gain than the multi-path signal by the far region objects.[4]

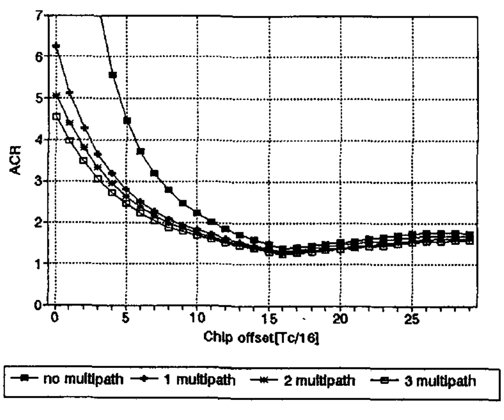
5) Surrounding environment

In the case of an outdoor micro cell environment, RMS delay dispersion at the point of crossover is larger than any other regions. This is, a radio wave is transmitted to follow the street and summed at this point. RMS delay dispersion of street of NLOS (Non-Line Of Sight) is increased within 10-30M but is decreased by the distance from that point because the scattering object is low in the number at surrounding of the base station.
In the case of an indoor wireless environment, such as a business office region and a factory area, there are different characteristics according to the structure of the object. The real result of measurement is greater than the theoretical value in general because of the fact that the theoretical channel model cannot express exactly the real topography or structure.[5]

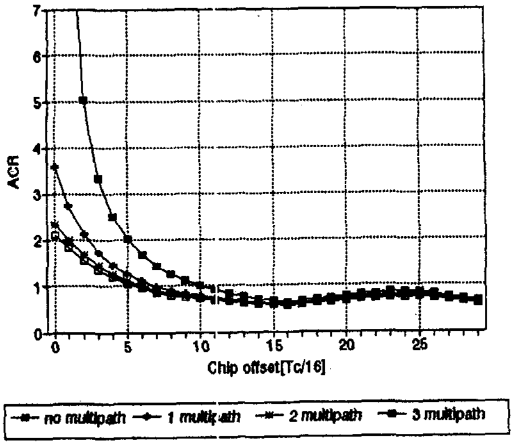
Ⅳ. Modeling and performance analysis of reverse link of wireless CATV

This chapter represents the performance variation by measuring ACR (Autocorrelation to Crosscorelation Ratio) in the account of wireless CATV environment which is analyzed in the above chapters.

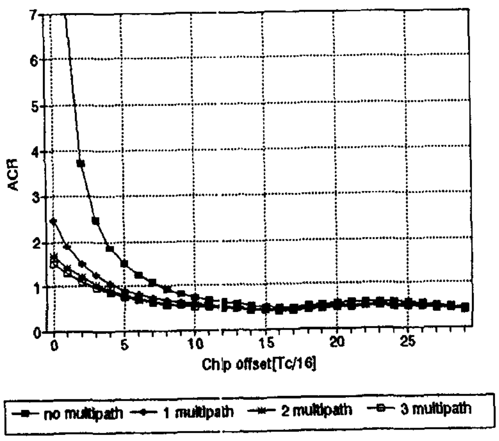
1. Performance variation by multi-paths
The fading channel has a specula component having the delay within $1T_c$ and a multi-path component having the delay over $1T_c$.
In this chapter, we analyze the effect of a multi-path component having the delay over $1T_c$ on reverse link synchronization.
Accumulation of cross-correlation is a source of interference in reverse synchronization.
Therefore, if we assume the multi-path component, it can have great effect because of the multi-path component without direct path component having cross-correlation with the code which is taken as a reference.
We represent the variation of performance by separation of ACR according to the chip offset with the number of users 10, 20, ..., 60.
Walsh code having 128 values is used to analyze the performance, and its pseudo noise code is ML sequence having which 214 lengths.
ACR variation according to the number of users is shown in the following figure:



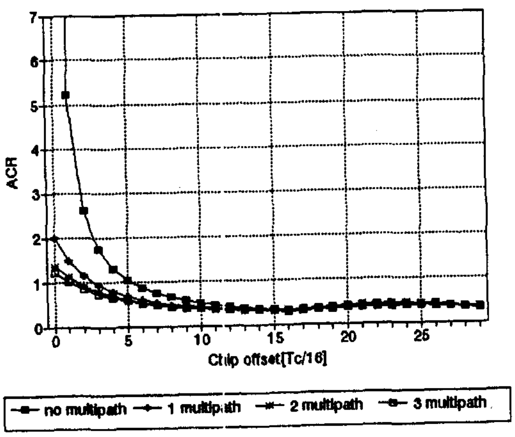
(a) Number of users: 10



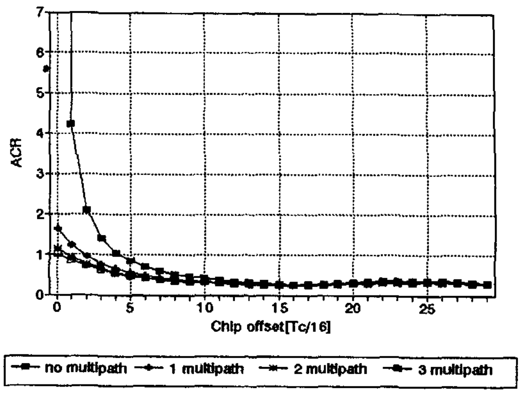
(b) Number of users: 20



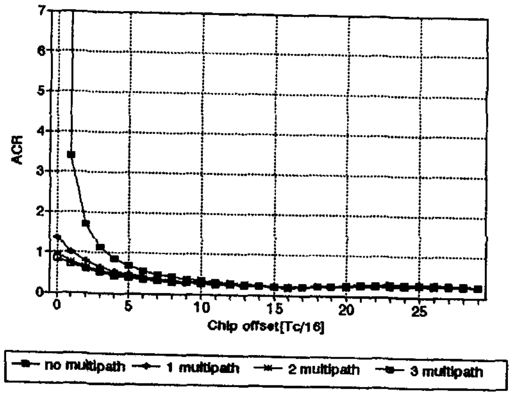
(c) Number of users: 30



(d) Number of users: 40



(e) Number of users: 50



(f) Number of users: 60

Fig. 3 Performance variation according to the multi-paths according to the number of users.

The above figure represents ACR according to the chip offset by varying the number of users.
The X-axis represents chip offset by resolution of $T_c/16$ and Y-axis represents ACR according to chip offset.
In each figure index, no multi-path represents not considering the multi-path component, 1,2,3 multi-paths represent the number of multi-paths with the multi-path component taken into consideration. We can understand the performance on the side of

ACR which varies with the number of multi-paths according to the results expressed in the above. We explain the case of 2 multi-paths distinctly. We assume that the number of paths which are transmitted from the user to the base station is three, LOS is within $1T_c$, and two multi-path components are extracted between $1T_c$ -$2T_c$ and $2T_c$ -$3T_c$. We use generally used experimental values to the magnitude decrease of multi-path components and assume that the magnitude of the multi-path component has Rayleigh distribution. If we see the result according to the number of users, the more increased, the number of multi-paths is the more performance of ACR is *diminished. The variation of ACR is* diminished gradually because the signal magnitude which has long delay is small. The above prediction is variable according to the situation but total appearance is same. Chip offset definition according to the number of users is that each user has all 3[$T_c/16$] delay, if the number of users is 60 and offset is 3[$T_c/16$]. We assume that the offset of all users is the same. We represent the result in which only the LOS component and three multi-path components are taken into consideration to analyze more precisely the effect of ACR by multi-path component.

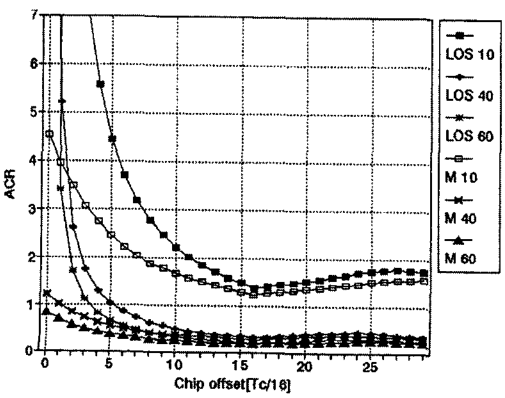


Fig. 4 Comparison of three multi-path case with no multi-path case.

In the above, fig. 4 *X-axis represents chip* offset, and Y- axis represents ACR.

Indexes LOS10, LOS 40, LOS 60 represent the case of that it has only the direct path without the multi-path components corresponding to result of the number of users of 10, 40, 60. M10, M40, M60 represent the resulting which up to three multi-path components are taken into consideration. If we consider the multi-path components, the multi-path component magnitude is diminished according to delay. Therefore, we assume only the direct path, ACR has a higher value than the case of 40 users. We can comprehend this result by looking at the M10 and LOS40.

V. Conclusion

We analyzed reverse characteristics of two-way wireless CATV. We analyzed multi-path fading channel to the cause of signal distortion in the wireless communication environment. We represent the characteristics according to the channel model. Multi-path channel can affect fading. We expect this thesis is used as the *foundation of realizing the reverse link* channel synchronization.

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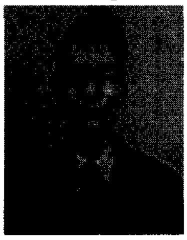

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