다양한 감쇄 채널에 대한 B-FWA 상향링크 Equalization 시스템

이연우[*], 조광문[**]
[*]목포대학교 정보통신공학전공
[**]목포대학교 전자상거래학전공
ylee@mokpo.ac.kr

B-FWA Uplink Equalization System for Various Attenuation Channels

Yeonwoo Lee[*], Kwang Moon Cho[**]
[*]Dept. of Information & Communication, Mokpo National University
[**]Dept. of Electronic Commerce, Mokpo National University

요   약

본 논문에서는 B-FWA의 상향링크에 적용할 수 있는 equalization 시스템 중에서 pre-equalization 시스템에 대해서 다양한 감쇄 채널에 대해서 성능을 분석하였다. 고려한 감쇄채널은 세가지의 강우감쇄 채널에 (rain, intermittent light rain and thundershower) 대해서 분석하였다. 본 논문에서 제안하는 pre-equalization 시스템에 적용된 adaptive 알고리즘은 LMS와 RLS로서, 각각의 트레이닝 시퀀스의 길이 대비 채널환경에 따른 성능을 평가하였다. 실험결과, LMS 알고리즘을 사용하는 equalization 알고리즘은 알고리즘의 복잡도를 어느 정도 허용되는 범위에서 delay에 심한 부분에 적합하는 것으로 결론지었고, RLS 알고리즘은 짧은 트레이닝 시퀀스로 빠른 송신이 가능한 곳에 성능이 우수함을 확인하였다.

1. Introduction

The broadband wireless local loop (B-WLL) system is millimeter wave broadband wireless access systems whose base station (BS) and subscribers'positions are fixed. Usually individual subscribers have a fixed antenna mounted on a building that provides unobstructed line of sight (LOS) to the BS, such that the channel environment of B-WLL systems is not hostile to users. Forthis reason, such systems are less vulnerable to Doppler effect than conventional mobile communication systems with high mobility. On top of this advantage, the B-WLL system, e.g. local multipoint distribution service (LMDS), can exploit wide frequency bands such as 27.5 ~31.225 GHz, which provide the wide channel bandwidth and the possibility of implementing small-size transceivers [1][2]. However, it was well known that wireless communication link using millimeter wave suffered severe rain attenuation. The presence of raindrops can severely degrade the reliability and the performance of communication link in B-WLL frequency band (i.e. Ka-band). In this paper, the performance of pre-equalizer technique for the B-WLL system under rain attenuation channel environments is evaluated and discussed along with two proponent convergence algorithms such as LMS and RLS.

This paper is organized as follows: In Section 2, channel propagation model based on IEEE 802.16 standard and rain attenuation channel model which is studied in a fixed satellite communication are discussed. In Section 3,we describe pre-equalization technique, procedure, requirement, cons and pros of pre-equalization technique. We analyze and compare performance of pre-equalizer and post-equalizer by computer simulation results in Section 4. Finally, concluding remarks are given in Section 5.

2. Channel Model and rain Attenuation Model

2.1 Channel propagation and ISI model

Among three kinds of IEEE 802.16 standard propagation channel model as proposed in [3], a typical deployment scenario with weak multi-path components (type 2 in [3]) is considered in this paper. Since the channel model must be modified as symbol rate changes, symbol rate is assumed 10240

Ksymbol/sec.

Table I. propagation model in 10240 Ksymbol/sec

Propagation model	Tap number	Tap delay(ns)	Tap amplitude
type 0	0	0	1.0000
type 1	0	0	0.9990
	1	97.66	0.0447
type 2	0	0	0.9017
	1	97.66	0.4323

It is a clear fact that the necessity of equalizer gets reduced in type 0 and type 1channel, thus mainly type 2 as a channel propagation model of following simulation process is studied in this paper.

2.2 Rain attenuation model

Ka band channel models studied in [4][5] are taken into account in this paper without loss of generality, since these channel models are built up based on a Ka-band frequency with a LOS and furthermore, characteristics of these can be applied to B-WLL channel model. In this model, envelope of received signal is represented by Gaussian distributed probability density function. This Gaussian distributed model can be given as proposed in [4] as following

$$f(s) = \frac{1}{\sigma_s \sqrt{2\pi}} \exp(-\frac{(s - \mu_s)^2}{2\sigma_s^2}) \tag{1}$$

Three rain attenuation models such as rain, intermittent light rain and thundershower are considered. The mean and variance of signal envelope for each rain attenuation model is given as Table II.

Table II. Parameters of Rain Attenuation Model

	Envelope Parameter	
	Mean	*Variance*
Rain	0.662	0.02
Intermittent light rain	0.483	0.00003
Thundershower	0.346	0.01386

3. Pre-Equalization Techniques for the B-FWA System

In order to support higher data rate services, the signal characteristics are severely distorted by either an inter-symbol-interference (ISI) or additive thermal noise. These degradation factors limit the use ofconventional equalizer technique (herein after we call it post-equalizer) due to the fact that this kind of equalizer can reduce the ISI effect, but it enhances the thermal noise on the contrary, i.e. noise enhancement effect since noise component can be boost up during the equalizing process. Thus, in an effort to tackle this problem, the pre-equalizing technique is taken into account in this paper, since this can utilize the channel characteristics before sending a signal to channels. By doing such a procedure, the pre-equalizer can utilize almost perfect channel coefficients and thus, eliminate noise enhancement effect [5]. Moreover, the pre-equalizer techniques are quite suitable for burst transmission mode since tap coefficients can be frequently updated on a burst basis.

3.1 Noise enhancement of general equalizer

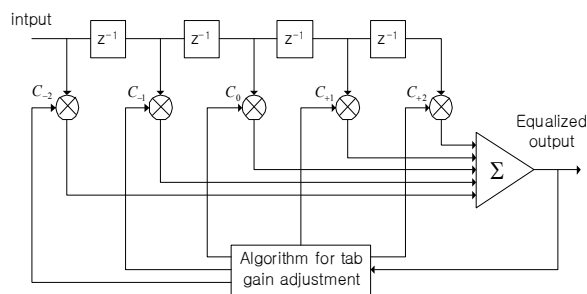The Figure 1 is the general structure of an equalizer, which is called here the post-equalizer.

Figure 1. The structure of a general equalizer.

This equalizer adds up delayed version of received signal multiplied by suitable coefficient to restore desired signal.

Using the equalizer technique, ISI distorting the signal can be almost perfectly eliminated. However, during the equalization process, additive noise is also multiplied and added up. As a result, the additive noise is enhanced by the equalizer [7]. As received signal is consist of transmitted signal and additive white Gaussian noise, $r(t) = s(t) + n(t)$. The output of equalizer can be written as follows.

$$\begin{aligned} d(t) &= \sum_{i=-N}^{N} c_i r(t-i) \\ &= \sum_{i=-N}^{N} c_i \{s(t-i) + n(t-i)\} \\ &= \sum_{i=-N}^{N} c_i s(t-i) + \sum_{i=-N}^{N} c_i n(t-i) \end{aligned} \tag{2}$$

Where c_i is the channel coefficient (tap gain) of the equalizer and 2N+1 is the total number of taps. The first term is the restored signal containing data, and the second term is the noise component enhanced by the equalizer. From this equation, it is clearly inferred that the degree of noise enhancement is mainly influenced by the coefficient of the equalizer. In equalizing procedure, this weighted noise enhancement term becomes dominant, and consequently, this makes the signal-to-noise ratio (SNR) decreased, which cause the degradation of the system performance.

3.2 Pre-equalization technique

Definition of the pre-equalization is that the transmitter performs equalization before the signal is transmitted. It means that the pre-equalizer distorts the signal to make it more reliable by eliminating ISI when the signal reaches the receiver. The knowledge of the channel state information is necessary in order to pre-equalizing the signal.
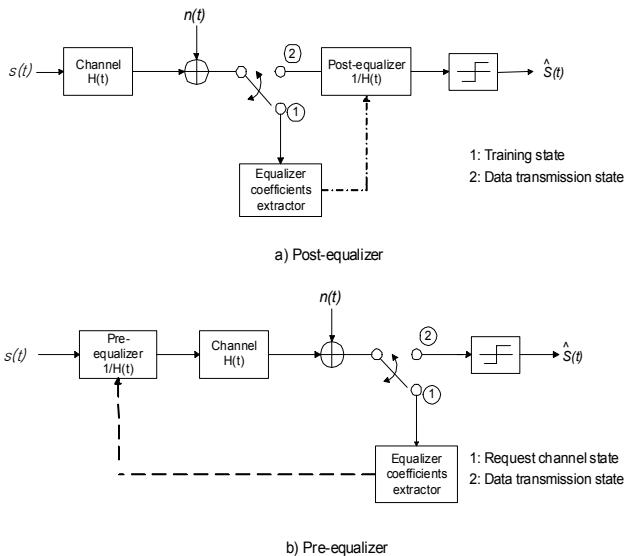

a) Post-equalizer

b) Pre-equalizer

Figure 2. The simplified structure of post-equalizer and pre-equalizer

If the pre-equalizer apply an unsuitable equalizer tap coefficients, ISI component of received signal still remains or unintentional distortion interferes decision of the receiver. In both cases performance of wholesystem rapidly degrades. Figure 2 is a simplified structure of post-equalizer and pre-equalizer.

The basic procedure of the pre-equalizer is as followings:

- When the subscriber demands a channel (i.e. connection request), BS extracts a post-equalizer tap coefficients based on the received signal (training sequence) that subscriber transmits.

- Once finding tap coefficients, BS transmits them to the corresponding subscriber by inserting them into a downlink burst frame (i.e. feedback channel).

- Subscriber arranges tap coefficients of pre-equalizer based on the informed tap coefficients, and then pre-equalized signal is transmitted to uplink.

- Finally, BS periodically updates equalizer tap coefficients through a feedback channel.

The pre-equalizer technique has advantage of power saving since it can reduce the noise enhancement and thus, increase SNR compared to post-equalization technique. As describe before, the pre-equalization technique is performed at the transmitter not at the receiver, such that the pre-equalizer could not induce noise enhancement. As a result pre-equalizer achieves the same signal to noise ratio with less transmit power than that of post-equalizer. Another advantage of pre-equalizer is no delay process. The post-equalizer is triggered after receiving the training sequence. The time spent in adjusting tap coefficients of equalizer (i.e. training mode) is unavoidable, which means that the receiver cannot process data promptly. On the contrary, the pre-equalizer can process data immediately.

In the equalizer coefficients extraction stage, the pre-equalizer must obtain the coefficients thatguarantee sufficient low mean square error (MSE). That means acquisition of suitable coefficients. If the length of training sequence is restricted, we should choose proper algorithm. In general learning rate depends on the characteristic of algorithm. LMS algorithm is simple and capable of achieving satisfactory performance. However,it has slow learning rate. On the contrary, RLS algorithm has fast learning rate and low MSE, while it has large computational complexity [8].

4. Simulation Results

Ka band channel models studied in [4] are taken into account in this paper without loss of generality, because these channel models are built up based on a Ka-band frequency with a LOS and furthermore, characteristics of these can be applied to B-WLL channel model. The ISI and multi-path model assumed in this simulation is type 2 as shown in Table I. Following Gaussian distributed model as proposed in [4], three kinds of rain attenuation models such as rain, intermittent light rain and thundershower are considered. The mean of signal envelope for each rain attenuation model is 0.662 (relatively stationary), 0.483 (medium stationary), and 0.436 (the worst case) in the order of rain, intermittent light rain and thundershower,

respectively.

Figure 3 shows the BER performances for the post-equalizer and the pre-equalizer using LMS algorithm as a function of various training sequence lengthsand rain attenuation models for a given signal-to-noise ratio (SNR) and four different channel scenarios, i.e. AWGN, rain, intermittent light rain, and thundershower. It is noticed that the BER performances of LMS pre-equalizer (preLMS) outperforms post-equalizer (postLMS) if enough training sequence length is guaranteed (i.e. at 250 symbols). In particular, the performanceby adopting a pre-equalizer at thundershowers gains considerably compared to that of post-equalizer in a thundershower case for 10dB of SNR with 1000 training symbols. Whereas, the performance of a post-equalizer shows the BER floor irrespective of a large training sequence length. This observation presents the design parameter to optimize the system performance. We can find the similar tendency in simulation results using RLS algorithm as LMS algorithm as shown in Figure 4. However, for a 15dB of SNR, the BER performance by post-equalizer RLS algorithm attains considerable gain compared to pre-equalizer RLS algorithm.

5. Conclusion

In this paper, the performance of pre-equalization technique which can be applicable for the B-WLL uplink is evaluated and compared to post-equalization under three kinds of rain attenuation channels such as rain, intermittent light rain and thundershower. Thus, the comparison of two algorithms (LMS and RLS) is investigated in the context of channel models and the length of training sequence. It is concluded that the pre-equalizer using LMS algorithm is preferable at delay-tolerant situation where the complexity of algorithm is not a strict factor, while one using RLS is suitable for fast burst transmission with a relatively short training sequence.

References

[1] T. Kwok, "Residential Broadband Internet Services and Application Requirements," IEEE Commun. Mag., p.76, June 1997.

[2] P. Mahonen, T. Saarinen, Z. Shelby, and L. Munoz, "Wireless Internet over LMDS: architecture and experimental implementation," IEEE Commun. Mag., Vol. 39, pp. 126-132, May 2001.

[3] IEEE 802.16, Draft "Standard Air Interface for Fixed Broadband Wireless Access Systems".

[4] C. Loo, "Statistical models for land mobile and fixed satellite communications at Ka band," in Proc. IEEE VTC'96, Vol. 2, pp. 1023-1027, 1996.

[5] DOCSIS, Radio Frequency Interface Specification, SP-RFIv1.1-106-001215.

[6] B. Fong, P. B. Rapajic, G.Y Hong, "The effect of rain attenuation on orthogonally polarized LMDS systems in tropical rain regions," ACM Antennas and Wireless Propagation Letters, Vol. 2, Issue 2, pp. 66-67, 2003.

[7] John G. Proakis, Digital Communications, 4th ed.,2001, pp. 617-621.

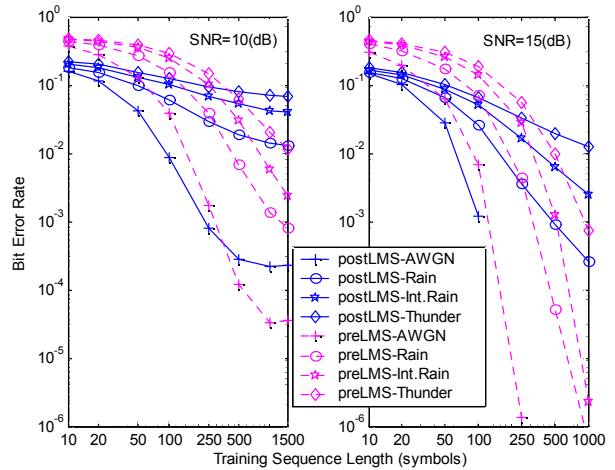[8] Simon Haykin, Adaptive Filter Theory, 3rd ed, 1996, pp. 12-13.

Fig. 3. BER of post−equalizer and pre−equalizer using LMS algorithm as a function of various training sequence lengths and rain attenuation models for a given SNR.
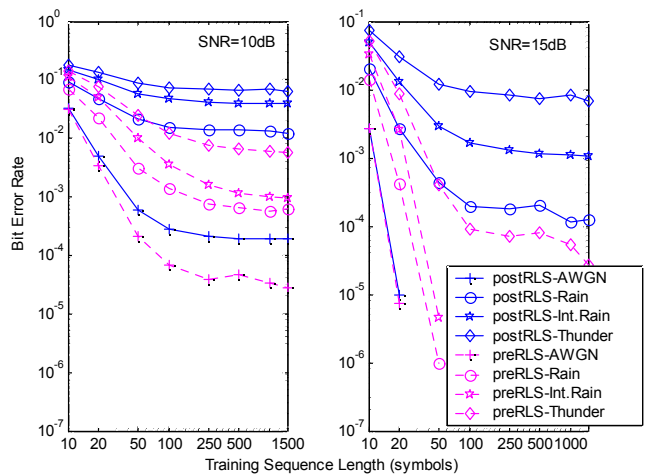

Fig. 4. BER comparison of post−equalizer and pre−equalizer using RLS algorithm as a function of various training sequence lengths and rain attenuation models for a given SNR.