Performance Evaluation of Equalization based On-Channel Repeater for Terrestrial Digital Multimedia Broadcast

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ABSTRACK : In this paper, the performance of equalization-based on-channel repeater for terrestrial DMB is analyzed. A primary concern in on-channel repeater is the performance degradation due to the echo and one of key component for on-channel repeater is the echo canceller, which usually employs LMS algorithm utilizing the repeater output as a reference for echo channel estimation and compensation. One problem using LMS algorithm is the tracking capability and there necessarily exists residual echo that has not been cancelled. To effectively remove the residual echo, we consider an equalization based on-channel repeater where the echo-canceller is followed by an equalizer that performs channel estimation using pilot symbol and the channel inversion utilizing homomorphic decomposition. According to the simulation result, the performance degradation caused by the residual echo can be considerably alleviated by using the equalizer following the echo-canceller.

1. INTRODUCTION

Because Terrestrial Digital Multimedia Broadcast system has merits that are able to provide services free and various sky wave broadcasting contents services, T-DMB service are increasingly demanded. And because of this, various T-DMB applications, for example, mobile phone, navigation and portable TV for T-DMB system, etc. are variously developing and their demands are rapidly increasing. Much information have to be supplied in order to supply these various new demand, but because of both limit of radio transmitter technology and characteristics of radio wave , there exist many NLOS(Non Line of sight)areas which have less possibility of receiving. This problem can be solved by using gap filler. [1~6]

Currently the American Terrestrial Digital TV Broadcast service does not use the frequency efficiently because that increases coverage or solve NLOS areas problem by allocating multi carriers to each receivers or to each transmitter[9]. In order to use frequency efficiently, Broadcast network that their multi transmitter and multi receivers use same frequency bandwidth, namely we can use frequency resource efficiently and average signal power will be enhanced if Broadcast network that consist of SFN(Single Frequency Network) have to be used.[4~6]

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Preexisting On Channel Repeaters are RF processing On Channel Repeater and IF processing On Channel Repeater, Baseband decoding On Channel Repeater.[9] RF processing On Channel Repeater and IF processing On Channel Repeater has limit of transmit power and they does not compensate interference by echo signals. Baseband decoding On Channel Repeater can not apply to On Channel Repeater to have long system delay.

Equalization based On Channel Repeater consist of Equalizer and Echo canceller appeared to solve these problems [6~8]. At structure of [6~8] system, equalizer is placed next to echo canceller. First echo canceller cancel interference signal that is echo signals which power is greater than signal power that is transmitted at the transmitter. If echo signal in the receiver received signal is cancelled first and echo signal power level is lower than received signal that is transmitted from transmitter, it is possible that frame and symbol synchronization. Therefore channel estimation and equalization is possible by using pilot symbol, etc. Equalizer after interference canceller is used to cancel the residual echo signal that is not cancelled at the interference canceller and this is used to compensate effect of multipath between main transmitter and repeater.

In this paper we analyze gain between equalizer based simulation model simulator and equalizer not based simulation model simulator to analyze the performance of at the [6~8] proposed repeater which include equalizer and interference canceller.

2. EQUALIZATION BASED ON CHANNEL REPEATER

2.1 Structure of Equalization-based Repeater

In Equalization based OCR which we consider in this paper, echo-canceller is followed by an equalizer. Basically it is different from baseband processing OCR and general baseband decoding OCR. It performs echo cancellation and equalization without Time-deinterleaving and FEC demodulation. We show the structure of equalization based T-DMB repeater system in Fig.1 If we use this structure, frame and symbol synchronization is possible since echo canceller cancels echo signals first. Therefore channel estimation equalization using Pilot symbol is possible. Except cancelling the residual echo, it can compensate distortion by multipath channel between main transmitter and repeater antenna. So we expect partial enhance of signal quality.

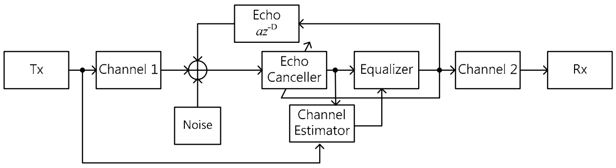


Fig.1 Structure of Equalization based T-DMB Repeater System

If OCR operates at steady state, Echo signal is assumed that which power is bigger than received signal through the Channel 1. Consequently, Echo canceller must be used with first element at OCR. If echo signal has not been cancelled, channel estimation is impossible. Because echo signal power is much bigger than signal which go through the Channel 1.

If echo signal has been cancelled, channel estimation using PRS symbol is possible and echo-canceller is followed by an equalizer can operate normally. In OFDM Frame structure, Second symbol is PRS symbol in frame. This can be used to estimate channel at OCR receiver, Channel estimator estimate channel which involve multipath effect and echo signal at every frame using PRS symbol which was known in advance. Equalizer process equalization based upon inverse channel impulse response using estimated channel. Specially, for generate inverse channel impulse response stably, Equalizer process the estimated channel using homomorphic decomposition[10] which divide estimated channel with minimum phase component and all pass component[7].

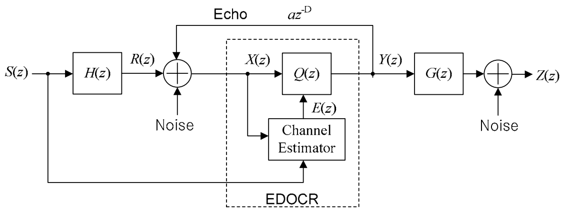


Fig.2 Analysis Model of Equalization T-DMB Repeater System

2.2 Analysis Model

Purpose of this paper is analysis about the gain when using equalizer. Therefore we assume that echo cancellation becomes well enough at the equalizer based T-DMB repeater system structure in Fig.2 And in this paper, we do not consider about the echo canceller. Equalizer based T-DMB repeater system analysis model which echo canceller is omitted expressed like Fig.2 In Fig.2, $S(Z)$ means Z-transform expression of input information signal $s[n]$, if we assume $s[n]$ OFDM signal, $S(Z)$ modeled random process that it's distribution is Gaussian, in this paper we assume signal average $E[s[n]]=0$, signal power $E[s[n]^2]=1$, a means the amplitude and a phase of the residual echo signal with complex number, $|a|^2$ means power of residual echo signal. $H(z)$ is multipath channel between main transmitter and repeater, $G(z)$ is multipath channel between repeater and mobile receiver which modeled as FIR filter. $Q(z)$ is Equalizer transfer function, $X(z)$ is equalizer input signal, $Y(z)$ is repeater output signal, $Z(z)$ is received signal at the mobile receiver antenna. $Y(z)$ go through $G(z)$ and added noise then it becomes $Z(z)$. We assume that most Residual echo signal is cancelled by echo canceller, consequently we assume that residual echo signal power $10\log_{10}|a|^2$is -5 ~ -15dB

From these repeater system model, repeater receiver input signal $X(z)$ can be expressed as

$$X(z) = S(z)H(z) + az^{-D}Y(z) + N(z) \qquad (1)$$

At (1), $N(z)$ means Z-transform of Noise $n[n]$. we assume $N(z)$ is Additive White Gaussian Noise(AWGN). Also we assume that average of $N(z)$ is zero and variance of $N(z)$ is $E[n[n]^2]=\sigma_1^2$, Channel transfer function $H(z)$ is assumed like following (2) for normalize signal power of $X(z)$

$$\sum_n |h[n]|^2 = 1 - |a|^2 \qquad (2)$$

Signal $X(z)$ received at the OCR receiver antenna go through equalizer $Q(z)$ and the equalizer output signal equal to Repeater output signal $Y(z)$. $Y(z)$ given by following (3).

$$Y(z) = X(z)Q(z) \qquad (3)$$

(3) substitutes to the (1) then (1) can be rewritten by $X(z)$. as (4).

$$X(z) = \frac{S(z)H(z)}{1-az^{-D}Q(z)} + \frac{N(z)}{1-az^{-D}Q(z)} \qquad (4)$$

Channel estimaion $E(z)$ is to divide repeater received signal $X(z)$ with phase reference symbol $S(z)$ that was known in advance. Therefore $E(z)$ given by following (5).

$$E(z) = X(z)/S(z) \qquad (5)$$

And, if (4) substitutes to the (5), $E(z)$ can be obtained as following (6).

$$E(z) = \frac{H(z)}{1-az^{-D}Q(z)} + N'(z) \qquad (6)$$

Where, First part of (6) $H(z)/1\text{-}az^{-D}Q(z)$ is transfer function of effective channel at repeater input which involves Echo channel, Second part of (6) $N'(z)=N(z)/(S(z)(1-az^{-D}Q(z)))$ is channel estimation error.

2.3 Dynamic characteristic and Stability of Equalizer

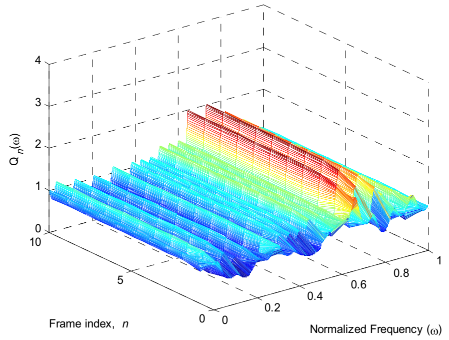
Dynamic characteristic of Equalizer : System in Fig.2 go through a transition period process from "Power-on" time of repeater to arrival time when system is stable state. And it can be explained as follows. We assume that there is not noise for simplify the explanation. (Namely, $N(z) = 0$) and equalizer transfer function at n-1th frame is $Q_{n-1}(z)$. At nth frame, Channel estimator $E_n(z)$ is like following (7).

$$E_n(z) = \frac{H(z)}{1-az^{-D}Q_{n-1}(z)} \qquad (7)$$

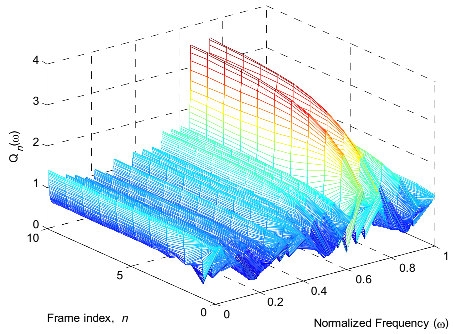
At nth frame, Equalizer transfer function $Q_n(z)$ is inverse of estimated channel, and it given by (8).

$$Q_n(z) = E_n^{-1}(z) = H(z)^{-1}[1 - az^{-D}Q_{n-1}(z)] \quad (8)$$

In (8), if $|a|$ is zero, simply $Q_n(z)=H(z^{)-1}$. But if $|a|>0$, $Q_n(z)$ is effected by equalizer $Q_{n-1}(z)$ at the n-1th frame and dynamic characteristic appear according to that.



(a) Echo power $10\log_{10}|a|^2 = -12\text{dB}$



(b) Echo power $10\log_{10}|a|^2 = -6\text{dB}$

Fig.3 Convergence of $|Q_n(w)|$ according to n increase

Fig.3 Shows example of equalizer dynamic characteristic, it shows a change of frequency characteristic of $Q_n(z)$ about first 10 frames from "Power-on" time at Echo power −12dB and −6dB. We haven't proved Convergence of $Q_n(z)$ so far, but it converged at all case of simulation.

Steady state characteristic of equalizer: if we assume that $Q_n(z)$converge according to n increase, $Q_n(z) = Q_{n-1}(z) = Q_\infty(z)$ Then (8) can be rewritten as following (9).

$$Q_\infty(z) = H(z)^{-1}[1 - az^{-D}Q_\infty(z)]$$

$$\Rightarrow Q_\infty(z) = \frac{1}{H(z)+az^{-D}} \quad (9)$$

And, (9) substitutes to the $Q_n(z)$of (3) then repeater ouput $Y(z)$ is as following (10)

$$Y(z) = Q_\infty(z)X(z) = \frac{H(z)}{Q_\infty(z)^{-1}-az^{-D}}S(z) = S(z) \quad (10)$$

If we assume that noise is not exist, (10) means that repeater output $Y(z)$ equal to information signal $S(z)$ which transferred on the steady state. Therefore according to n increase, if $Q_n(z)$ converges, equalizer operates well.

But if repeater transfer function $Y(z)/R(z)$ has deep null, repeater is on the unstable state and total system does not operates well. To solve this problem, in this paper use the way that if system frequency transfer characteristic between $Y(z)$ and $R(z)$ is bigger than price which is scheduled, equalizer stop operation and signal skip the equalizer. If we consider repeater system except noise which involves Echo signal only, transfer function of these system is $Y(z)/R(z)|_{N(z)=0}$ and given by (11).

$$T(z) = \frac{Y(z)}{R(z)} = \frac{Q(z)}{1-az^{-D}Q(z)} \quad (11)$$

In (11), $Q(z) = Q_\infty(z)$System stablilty depens on position of $T(z)$ pole, Namely it is required that position of $1\text{-}az^{-D}Q(z)$ zero have to place in unit circle on Z-plane, but it is difficult to track a position of $T(z)$ pole, instead, we operated equalizer when $|T(w)|$ is smaller than T_{th} which is scheduled.

3. PERFORMANCE ANALYSIS

Because structure of whole system was explained from before, we will only explain about used channel characteristics in this part. Repeater receiver antenna is assumed that it is built in high place which is possible to see main transmitter antenna. So, we assume that $H(z)$ Channel between main transmitter and repeater is multipath channel which has LOS(Line Of Sight) path. And we assume mobile receiver antenna is not possible to see repeater antenna. Therefore $G(z)$ channel between repeater and mobile receiver antenna is assume that is multipath channel which has not LOS path. Especially, in this paper, channel between main transmitter and repeater is modeled as Brazil A channel, and channel between repeater and mobile receiver is modeled as Typical Urban(TU) 6 channel[11]. Power Delay Profile of each channel is summarized in Table .1 and Table .2

Table.1 Power delay profile of Brazil A channel

Brazil A	Time Delay(μs)	Attenuation(dB)
Multipath1	0.00	0.0
Multipath2	0.15	−13.8
Multipath3	0.22	−16.2
Multipath4	3.05	−14.9
Multipath5	5.86	−13.6

Table.2 Power delay profile of TU 6 channel

TU 6	Time Delay(μs)	Attenuation(dB)
Multipath1	0.00	−3.0
Multipath2	0.20	0.0
Multipath3	1.60	−6.0
Multipath4	2.30	−8.0
Multipath5	5.00	−10.0

In these channel environment, we have simulated about some Echo power(−6dB, −10dB, −15dB), we evaluated performance gain with compare case between simulator involves equalizer and simulator does not involve equalizer.

BER(Bit Error Probability) curve is given by Fig.4 about the each cases that echo power -10dB and Brazil A Channel SNR 10dB, 20dB, 30dB. And it is given two part, one is using equalizer another is not using equalizer. SNR in the X-axis means TU 6 Channel SNR, Y-axis means BER at the mobile receiver.

If BER is 10^{-3}, We obtained 1.5dB gain between each case one is not involves equalizer and another is involves equalizer. In simulation, we set the parameter T_{th}=10dB which decide stability of equalizer.

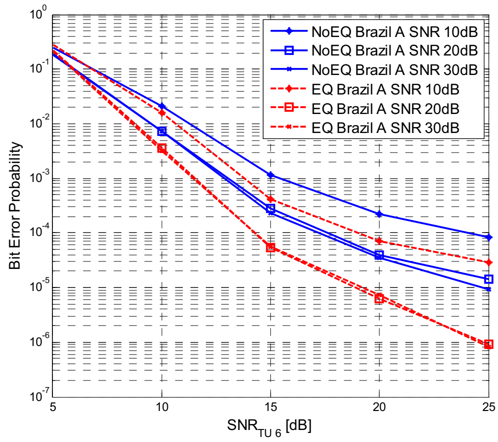


Fig.4 System BER performance according to TU 6 channel SNR increase; Brazil A channel SNR = 10, 20, 30, Echo Power$10\log_{10}|a|^2 = -10$dB, TU 6 channel doppler frequency = 22Hz

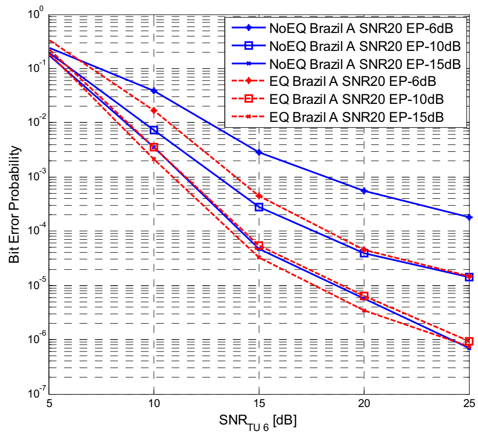


Fig.5 System BER performance according to TU 6 channel SNR increase; Brazil A channel SNR = 20 , Echo Power $10\log_{10}|a|^2 = -6\text{dB}, -10\text{dB}, -15\text{dB}$, TU 6 channel doppler frequency = 22Hz

In Fig.5, It shows the result of simulation case which Brazil A channel SNR is 20dB and echo power are -6dB, -10dB,-15dB. Blue curves show the case which using equalizer in simulator and red curves show the case which does not using equalizer in simulator. If echo power is -6dB and BER is 10^{-3}, we obtained equalizer gain about 4dB. If echo power is -10dB and BER is 10^{-3}, we obtained equalizer gain about 1.5 dB. If echo power is -15dB and BER is 10^{-3}, we obtained equalizer gain about 0.5dB. Namely , from Fig.5, we can know that equalizer gain is high when echo power is high and equalizer gain is low when echo power is low.

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