Study on Adaptive Array and Carrier Diversity Hybrid OFDM Receiver for ISDB-T Mobile Reception

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Abstract—**This paper proposes an MMSE adaptive array antenna and MRC carrier diversity hybrid receiver for mobile OFDM digital TV receivers. By utilizing RLS algorithm for MMSE array antenna, long delayed signal more than Guard Interval (GI) can be suppressed. The RLS algorithm successfully demonstrated high speed array weight convergence less than 3 to 4 OFDM symbols. By the combination of the multi-beam adaptive array antenna and carrier diversity, higher mobile reception performance under more than GI delay Doppler shift condition is achieved.**

Index Terms—**OFDM, Adaptive Array, Rayleigh fading, MRC, MMSE, Carrier Diversity**

I. Introduction

In a high-speed moving vehicle like car or Sinkansen, the OFDM receivers's reception performance degrades severely. The objective of this research is to improve the quality of TV reception perfromance under Doppler shift and more Guard Interval delay multipath condition. The radio wave from transmitter is refrected by many objects such as bulidings, mountaines and so on. Then receiver sees many incoming refrected waves, whitch is called multipath[1]. This multipath degrades the amplitude of some OFDM sub-carrisers and degrades the reception peformace. Then, It is preferable to suppress multipath delays at receivers.

Because of it's spectrum efficiency, OFDM is becoming very popular as a wireless communication modulation method. And, OFDM is adopted as a modulation method of terrestrial Integrated Services Digital Broadcasting(ISDB-T) standard in Japan. OFDM is well-known as a high-spectral efficiency transmisson method in the multi-path environment[2]. In order to decrease the multipath effects, Guard Interval(GI) is inserted in OFDM symbols. Multiplexing by using different frequencies (sub carriers) produces high bandwidth parallel communication. Although OFDM is such an attractive system, Inter Carrier Interference (ICI) is easely induced by the Doppler frequency Shift. In this paper, we proposes an multi-beam MMSE adaptive array antenna and MRC carrier diversity hybrid receiver as shown in Figure 1. By utilizing adaptive array antenna, long delay signal is suppressed.

The rest of paper is organized as follows: Section II reviews the Adaptive Array Antenna. Section III, IV describes the MRC, MMSE in Proposed algorithm. Simulation result is shown in section V. In Final section presents conclusion of this paper.

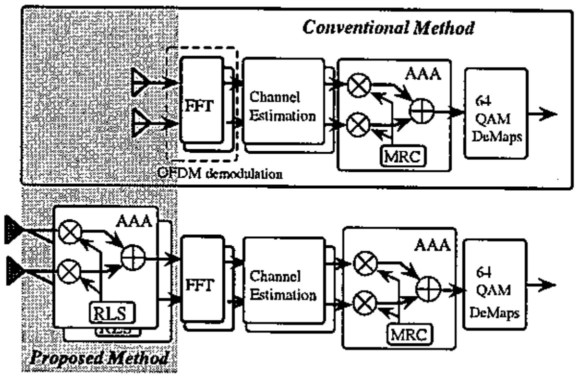

Fig. 1. Conventional & Proposed method

II. Adaptive Array Antenna

When an OFDM receiver is used in moving vehicles such as automobiles etc., the radio frequency wave suffers from Doppler frequency shift. The Doppler shift destroys the orthogonality between OFDM subcarrier signals and increases the inter carrier interference (ICI). A longer multipath over GI length causes inter symbol interference (ISI). Both Doppler induced ICI and long delay induced ISI degrade the OFDM receiver performance. Therefore, it is a severe challenge to improve the reception quality in mobility circumstances with over GI delay multipath condition.

One well-known way to improve the performance of an OFDM receiver is to exploit a spatial diversity by utilizing multiple antenna elements[3].

In the proposed system, two antennas adaptive array antenna method is used as a front side. OFDM-derected two array antennna Digital Beam-Forming(DBF) algorithms with lower computation requirements are introduced as shown in Figure 2. The DBF algorithms make use of the cyclic prefix's periodic property[4]. The vector input signals of the array antennna can be expressed as

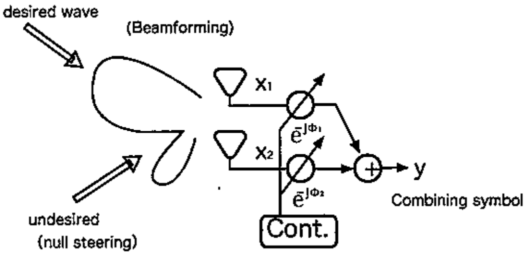

Fig. 2. Make Derectivity By W Cofficiency

$$X = [x_1(t) x_2(t)]^T \quad (1)$$

The output of the array antennna system is calculated as follows

$$y(t) = W^H X^T \quad (2)$$

$$W = [w_1 w_2]^T \quad (3)$$

is the coefficient vector of the array antennna.

III. Maximum Ratio Combining (MRC) Carrier Diversity

The back side of the combiner is a post-FFT carrier diversity(CD) combiner. The combining coefficient $C_l(i,k)$ can be expressed as equation (4).

$$C_l(i,k) = \frac{H_l^*(i,k)}{\sum_{l=1}^{M} |H_l(i,k)|^2} \quad (4)$$

Where $C_l(i,k)$ is the combining coefficient to the lth branch of the combiner at the kth subcarrier of ith OFDM symbol and $H_l(i,k)$ is the channel transfer function to the lth branch of the combiner at the kth subcarrier of the ith OFDM [5]. However, in the proposed system, the post-FFT CD combiner combines the first stage two AAA outputs. Since the two AAA outputs can not be assumed to has similar noise power level, following modified combining coefficient $C_l(i,k)$ is used in the proposed system [6].

$$C_l(i,k) = \frac{1}{H_l(i,k)} \cdot \frac{|H_2(i,k)|^2/\sigma_{n2}^2}{|H_1(i,k)|^2/\sigma_{n1}^2 + |H_2(i,k)|^2/\sigma_{n2}^2} \quad (5)$$

Where σ_{n1} and σ_{n2} means the avarage noise power of branch 1 and branch 2.

By using the modified MRC carrier diversity algorithm, the optimum combined output SNR can be achieved for each subcarrier by post-FFT CD scheme.

IV. Minimum Mean Square Error(MMSE)

Although the OFDM selective MRC algorithm emphasizes the desired OFDM signal, it does not minimize the interference. Assume a reference signal is $r(t)$. The error signal is given as:

$$e(t) = r(t) \quad W^H X(t) \quad (6)$$

The MSE (Mean Square Error) between the output of the array antenna and the reference signal is given as[7]:

$$MSE = E\left[|e(t)|^2\right] = E\left[|r(t) \quad W^H X(t)|^2\right] \quad (7)$$

By minimizing the MSE with the well-known Winer-Hoff equation, the optimum coefficients are derived as

$$W_{MMSE} = normalize(R_{xx}^{-1} r_{xy}) \quad (8)$$

Where $R_{xx} = E[X_h X_h^H]$ is the autocorrelation matrix of inputs. In real applications, R_{xx} can be obtained by a simple averaging scheme.

In this system implementation, MMSE calculation is relalized by RLS algorithm to suppress undesired delayed waves. In order to calculate the error $e(t)$, Guard Interval (GI) is utilized. Since GI is a copy of constant length of the tail, we call the original tail as "Tail-GI" while the GI is called as Head-GI.

By comparing these two Head-GI and Tail-GI, error $e(t)$ can be calclulated. (Fig 3) By using RLS based MMSE calculation with the error $e(t)$ inputs, the delayed undesired wave is suppressed. This is the first outputs of the array with weight coefficients of [w1, w2]. In the proposed system, the second output of the array is generated with coefficient of [w1, -w2] which is orthogonal to the [w1, w2]. Then the second orthogonal array output also can be generated. Those two outputs will be FFTed and combined by carrier diversity.

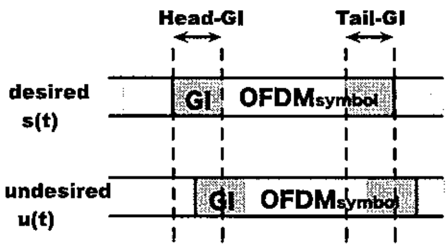

Fig. 3. Timing Of Extracted Symbol In RLS

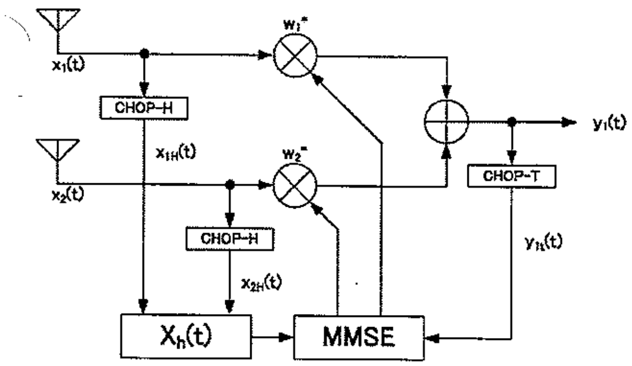

Fig. 4. MMSE Configure Does Utilizing GI

V. Simulation Result

In this section, simulation results will be explained. Table I shows simulation parameters. ISDB-T type 3, which is a terrestrial-digital-broadcasting system in japan, is assumed. 64QAM modulation is used, FFT size is 8192 and GI length of 1024 is used.

Table I shoes the channel conditions. Two path rayleigh is used. For short delay condition, delay time of the undesired wave is 200 points. For over GI delay condition, 1200 points is used.

TABLE I
Simulation Parameters (ISDB-T)

Antenna elements # , Interval	2 , wave-length / 2 wave
Modulation	64QAM
Effective Symbol Length	1008 μs
FFT point (Window-size)	8k (8192)
Length of guard interval	1k (1024)
Carrier #	5617
Forgetting-factor (λ)	0.999
δ^{-1} (Initialization for R^{-1})	1000
Iteration # (for RLS algorithm)	500

TABLE II
In Comming Wave

	Time Delay	DUR	angle[deg]
wave1 (desired)	0 point	0.0 dB	60
wave2 (undesired)	200,1200point	3.0 dB	-30

Figure 6 and 7 show BER vs maximum Doppler shift for rayleigh waves for short delay case and over GI delay case, respectively. For short delay case, the proposed and conventional CD method has same performance. But for over GI delay case, the proposed method has large improvement of BER is obtained. Over GI delay wave suppression was successfully realized by RLS-based MMSE AAA beamforming.

Figure 8 shows RLS forgetting factor lambda dependece. In order to achieve successful lower BER in over GI delay rayleigh condition, optimization of forgetting factor lambda

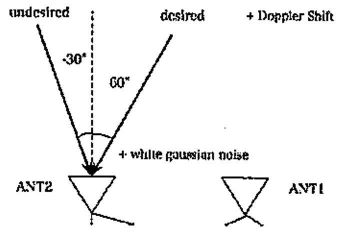

Fig. 5. Angle vs Incomming Wave

is required. According to the simulation, $lambda = 0.999$ showed better performance than 0.99 and 0.9.

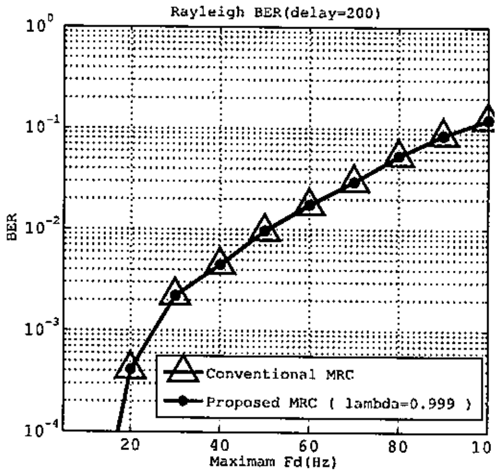

Fig. 6. BER Vs Fd (Delay Is Short GI)

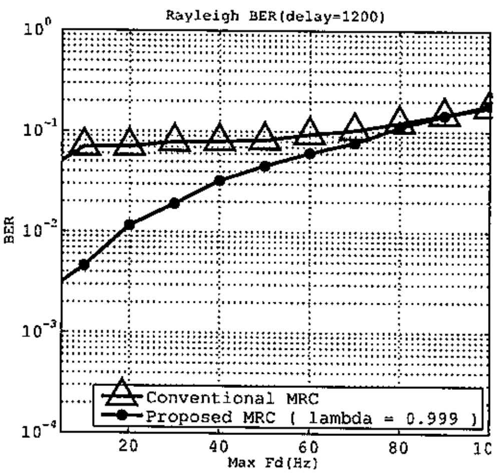

Fig. 7. Depend On Lambda In RLS

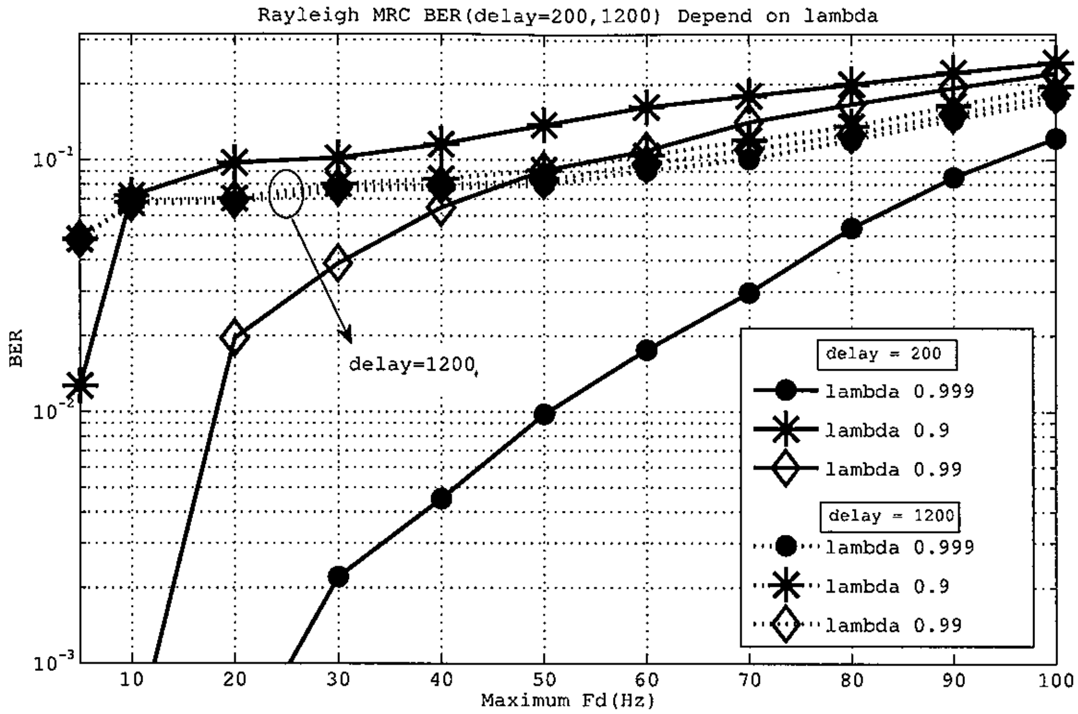

Fig. 8. BER Vs Fd (Over GI)

VI. Conclusion

We have proposed an Adaptive Array and Carrier Diversity Hybrid OFDM receiver. The first stage is RLS-based MMSE adaptive array and orthogonal adaptive array two beam systems. The second stage is post-FFT modified MRC based carrier diversity combiner. According to the simulation, the proposed system has shown improved BER performance under over GI delay rayleigh multipath condition.

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