

Study on successive wave separation Adaptive Array OFDM receiver for DTV mobile reception.

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Abstract Conventionally, after separating the received wave from which arrival directions differ with an adaptive array antenna, research which realizes receiving performance gain is done by getting over, respectively and carrying out diversity composition at our laboratory. This paper proposes an MMSE adaptive array antenna and PI algorithm and MRC used noise receiver for mobile OFDM digital TV receiver. By utilizing SMI algorithm for MMSE array antenna, in order to suppress undesired waves. This MMSE used for two part. One part for desired wave. Other part for delay wave. Two PI systems use in order to extract a delay wave.

Keyword OFDM, Adaptive Array, SMI, MMSE, PI, MRC

1. Introduction

OFDM is well-known as a high-spectral efficiency transmission method in the multi-path environment [1]. And, OFDM is adopted as a modulation method of terrestrial Integrated Services Digital Broadcasting (ISDB-T) standard in Japan. In order to decrease delay wave effects, Guard Interval (GI) is inserted in OFDM symbols. Multiplexing by using different frequencies (sub carriers) produces high bandwidth parallel communication. Therefore Inter Carrier Interference (ICI) is easily induced and the reception quality degrades awfully by the Doppler frequency shift in a high-speed moving vehicle like a car.

One well-known way in order to improve the problem is to exploit a spatial diversity by utilizing multiple antenna elements [2].

In the proposed system, two antennas adaptive array antenna method is used as front side. Conventional method as shown Figure 1.

In this paper, we proposed an MMSE adaptive array antenna and PI algorithm and MRC used noise receiver for mobile OFDM digital TV receiver as shown in Figure 2.

This receiver extracts a desired wave by MMSE1 which is first-MMSE, and PI algorithm extracts a delay wave by using this desired wave. And this delay wave is combined by MMSE2 and the result of MMSE1 and MMSE2 is combined by MRC with noise presumption.

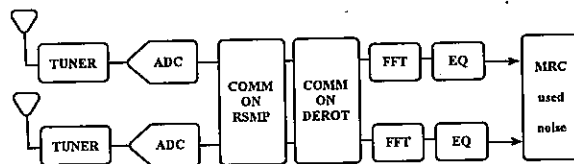


Fig. 1. Conventional method.

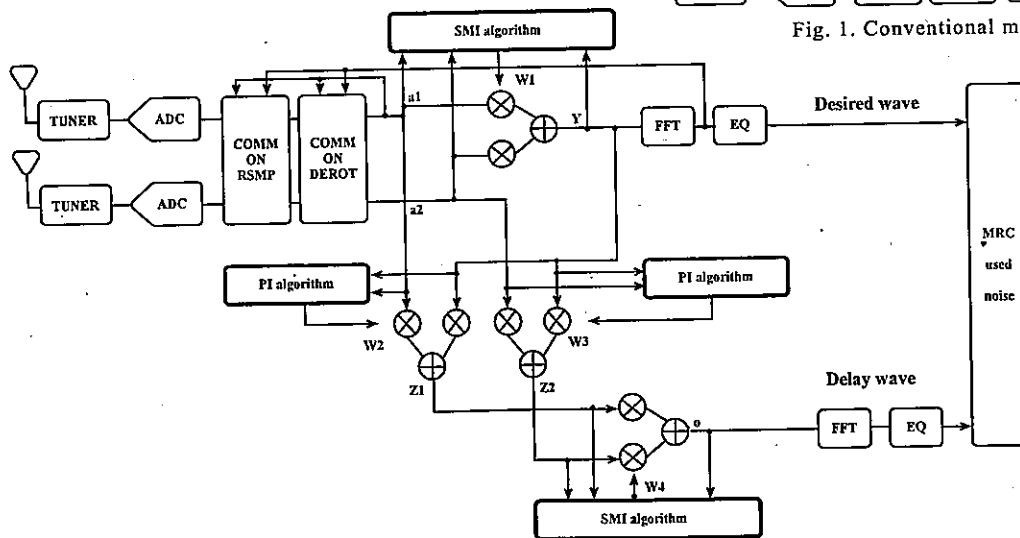


Fig. 2. Proposed method.

Under multi-path environment, reception quality degrades by a "desired wave" and a "delay wave" being mixed. For the reason, it is distinguished by the name a "desired wave" and "undesired wave", but an "undesired wave" is a original "desired wave" for which it reflected in objects, such as a building and mountain, and arrival was delayed. That is, when sees from a "desired wave", it is "having shifted", and originally it is what was a "desired wave". Therefore, if it adjusts well and treats, this "delay wave" can be used for the quality improvement of a received signal. In this research, this character was used and the improvement of quality was aimed at by combined a "desired wave" and "delay wave".

The rest of paper is organized as follows: Section 2 reviews the Successive wave separation by Maximum Ratio Combining used noise. Section 3, 4, 5 describes the EVMP by HD decision, MMSE and PI in Proposed algorithm. Simulation result is shown in section 6. In Final section presents conclusion of this paper.

2. Successive wave separation by Maximum Ratio Combining (MRC) used noise

The back side of the combiner is a post-FFT carrier diversity (CD) combiner. The combining coefficient C_{MRC} can be expressed as equation (1). [3]

$$C_{MRC} = \frac{H1^* \times rvconst1 + H2^* \times rvconst2}{|H1|^2 + |H2|^2} \quad (1)$$

H1 and H2 are the channel transfer functions. 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 $C_{noiseMRC}$ is used in the proposed system. [3]

$$C_{noiseMRC} = \frac{\frac{rvconst1}{H1} \times \frac{|H1|^2}{evmp1} + \frac{rvconst2}{H2} \times \frac{|H2|^2}{evmp2}}{\frac{|H1|^2}{evmp1} + \frac{|H2|^2}{evmp2}} \quad (2)$$

Where evmp1 and evmp2 means the average noise power of branch1 and branch2. According to Equation (2), when noise power at branch 1 increases, the combining

coefficients $C_{noiseMRC}$ become small and will contribute less to the combining.

3. EVMP by HD decision

EVMP is Error Vector Magnitude Power. That is a difference in symbol position between original and received. This difference is caused by the influence of a noise. For that reason, using EVMP can carry out composition in consideration of this noise. EVMP is calculated by following formula. [4]

$$EVM = \frac{|Dem - Ref|}{|Ref|} \quad (3)$$

$$EVMP = \frac{|Dem - Ref|^2}{|Ref|^2} \quad (4)$$

And, the formula of the Equation(5) which uses the forgetting-factor λ performed calculated type EVMP one by one this time.

$$EVMP_{n+1} = (EVMP_{n-1})(\lambda) + (1 - \lambda) \cdot EVMP_n \quad (5)$$

This paper, the value calculated by this HD-decision is used when compounding MMSE1 and MMSE2 by MRC. For the reason, EVMP of MMSE1 and MMSE2 is calculated here. Therefore, the signal that was generated first as for the result of MMSE1 and MMSE2 is compounded. Next, it gets over, after demap the result by 64QAM. By comparing the signal after this value and MMSE composition, respectively, the value of each EVMP that is gap with the original position of MMSE1 and MMSE2 is acquired. EVMP to the point of each position is updated by the thing which removed pilot for this calculation and for which it calculates one symbol at a time. The system is calculated as follows

$$W1 = \frac{sn1}{sn1 + sn2}, W2 = \frac{sn2}{sn1 + sn2} \quad (6)$$

$$C_{tmp} = Z1 \cdot W1 + Z2 \cdot W2 \quad (7)$$

Value of HD is calculable using C_{tmp} .

$$EVMP = (1 - \lambda) \cdot EVMP + \lambda \cdot |HD - Z|^2 \cdot |H|^2 \quad (8)$$

4. MMSE by SMI (Sample Matrix Inversion)

By minimizing the MSE (Mean Square Error) with the well-known Winer-Hoff equation, the optimum coefficients are derived as [3]

$$W_{MMSE} = \text{normalize}(R_{xx}^{-1}r_{xr}) \quad (9)$$

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

In this system implementation, MMSE calculation is realized by SMI algorithm to suppress undesired delayed waves. SMI is the method of calculating the optimal value of weight, directly by substituting for the theoretical formula of the optimal weight which presumes a correlation matrix and a correlation vector from the input data by which the sample was carried out, and is given in closed form. Weight is calculated directly as follows.[6]

$$r_{xr} = \frac{H - GI \cdot T - GI^H}{GI - \text{size}} \quad (10)$$

$$R_{xx} = \frac{1}{GI - \text{size}} \sum_{i=1}^{GI - \text{size}} H - GI(i) \cdot H - GI(i)^H \quad (11)$$

$$W = R_{xx}^{-1} \cdot r_{xr} \quad (12)$$

GI is a copy of constant length of the tail, we called original tail as "Tail-GI" while the GI is called as "Head-GI". W that extracts a desired wave by using H-GI and T-GI was generated. (Fig 3) [5]

After extraction of an undesired wave takes out two undesired waves by PI, it is compounded by MMSE. At this time, a delayed part shifts, and it takes out and calculates GI part.

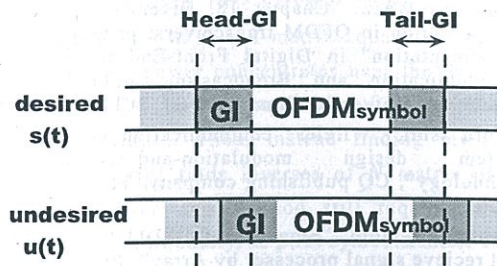


Fig. 3. Position of "Head-GI" and "Tail-GI" in symbol.

5. PI (Power Inversion)

Equally "the flexibility (K-1) of an array" to the number of undesired waves, PI is used, when desired wave electric power is smaller than undesired wave electric power. That is, since a desired wave and an undesired wave are distinguished by only the difference in input electric power, they do not need the preliminary knowledge about desired wave arrival directions at all.

The norm of PI is simple and it is minimizing output power, where one element weight's is fixed to a steady value.

A deep null is formed in the direction as the undesired wave of large electric power, as a result the desired wave which was weak at the input end is emphasized with an output, and remains, and since SIR is reversed with an input and an output, it is referred to as PI.

The optimal W in this is calculated follow as, [6]

$$\bar{S} = \begin{bmatrix} 1 \\ 0 \end{bmatrix} \quad (13)$$

$$R_{xx} = \sum_{i=1}^{9k} X(i) \cdot X(i)^H \quad (14)$$

$$W = R_{xx}^{-1} \bar{S} \quad (15)$$

6. Simulation Result

In this section, simulation results will be explained. Table 1 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 2 shows the channel conditions. Two path is used. The condition of undesired wave used when measuring change of the BER for every delayed point, and the condition used for change of the BER value for every DUR are indicated.

Table 1

Simulation Parameters (ISDB-T)	
Antenna elements #,	2,
Interval	2wave
Modulation	64QAM
Effective Symbol Length	1008μs
FFT point (Window-size)	8k (8192)

Length of guard interval	1k (1024)
Carrier #	5617
Forgetting-factor (λ)	0.05
W_0 (Initialization for MMSE)	$[1, 0]^T$
拘束ベクトル C_0	$[0, 1]^T$

Table 2
In coming wave

	Time Delay [point]	DUR [dB]	Angle [deg]
Wave1 (desired)	0	0.0	30
Wave2 (undesired) For Fig.3	100~2100 (step:100)	3	-60
Wave2 (undesired) For Fig.4	1200	0~20 (step:1)	-60

Figure 4 shows the relationship of delay and BER. Result with a more sufficient proposed system than the conventional one were achieved.

While BER of the conventional system was taking out the value of more than 10^{-1} in the bottom of the environment which over GI where a BER deteriorates remarkably especially, BER of the proposed system took out the very outstanding value of less than 10^{-5} .

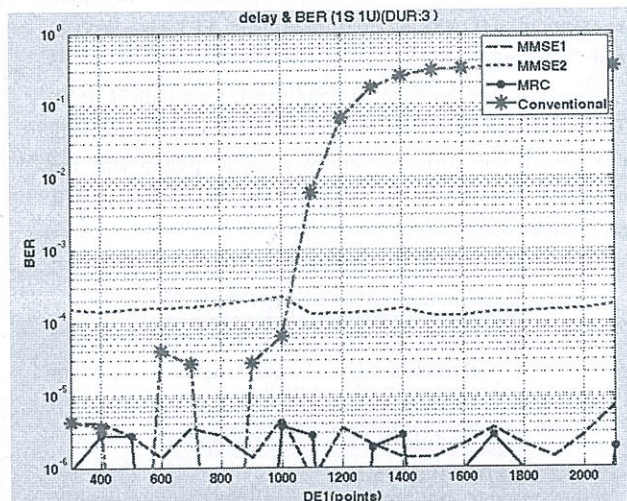


Fig.4 Delay & BER result.(DUR:3)

Figure 5 shows relationship of DUR and BER. It was stabilized also when there was a long delay wave which a proposed method in over GI delay condition, and the very good BER characteristic was shown.

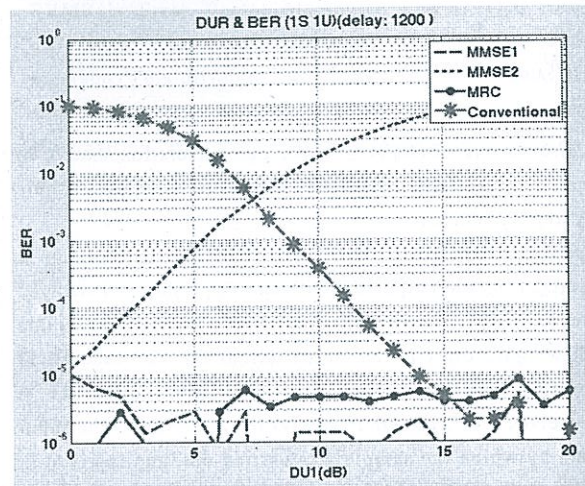


Fig.5 DUR & BER result.(Over GI version)

7. Conclusion

We have proposed a successive wave separation Adaptive Array OFDM receiver. This system has two first stages and one last stage. The one first stage is SMI-based MMSE adaptive array and orthogonal adaptive array a beam system. The other one first stage is separator system by SMI-based MMSE with two PI systems. The second stage is post-FFT modified MRC used noise. According to the simulation, the proposed method has shown improved BER performance than Conventional method.

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