Delay Time Estimation in Frequency Selective Fading Channels

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***Abstract*—**This paper aims to estimate the delay time of multiple signals in a multi-path environment. It also seeks to carry out a comparative analysis with the existing delay time under the proposed algorithm to develop a new algorithm that applies the space average method in a MUSIC algorithm.

Unlike the existing delay time estimation algorithm, the developed algorithm was able to estimate the delay time in 5ns low. Therefore, the algorithm proposed in this paper improved the existing delay time estimated algorithm.

***Index Terms*—**Adaptive Array antenna, Delay Time, Estimate, Correlation, MUSIC, Direction of arrival

I. INTRODUCTION

A multi-path signal is a crucial factor in communications technology because it greatly reduces communication quality in mobile communications. Fading fluctuation velocity is a large rather than a short wave communication or fixing microwave communication influenced in a natural environment. Mobile communication is high in communication form, but because reception signaling is extremely deformed by fading, transmission performance is faulty, and needs fading countermeasures involving diversity or an adaptation equalizer, adaptive array, etc. to compare with different communication forms. [1]-[4]

When there is no delay time difference in each party, the composite wave complex gauss with the important duty is limited, depending on the random signal in multiple transmitted waves. [3][4] A random signal multiplied in a transmitted wave is enveloped, and the phase of the reception signal is changed as a mean.

When a delay time difference among the parties exists, a multiplex electric wave path through a filter can change in time. In this instance, the amplitude phase status change in angular frequency does not appear flat. It is known that this type of fading is frequency selectivity fading or flat fading. The propagation delay time of a multi-path wave is an important parameter that decides fading, and exerts a big influence on the choice of technology. [5][6] The existing delay time measuring mean is PN (Pseudo Noise) with the Fourier transformation (FT) process, M-sequence. However, many multiplex factions have resolving power number ns' high time because each receives a point by a short delay time difference in indoor wireless local area networks, and it is desirable to measure a simple system.

Therefore, this paper aims to estimate the delay time of propagation in using the space average method and the MUSIC algorithm. This paper is arranged as follows. The delay time estimation (DTE) algorithm is described in Chapter 2, while Chapter 3 illustrates the results via simulation in the proposed algorithm, and the conclusion is stated in Chapter 4.

II. FOURIER TRANSFORMATION METHOD ALGORITHM

Consider the sweep frequency in an environment where the direction of arrival L number is shown in Figure 1, and obtains a complex wave's reception data.

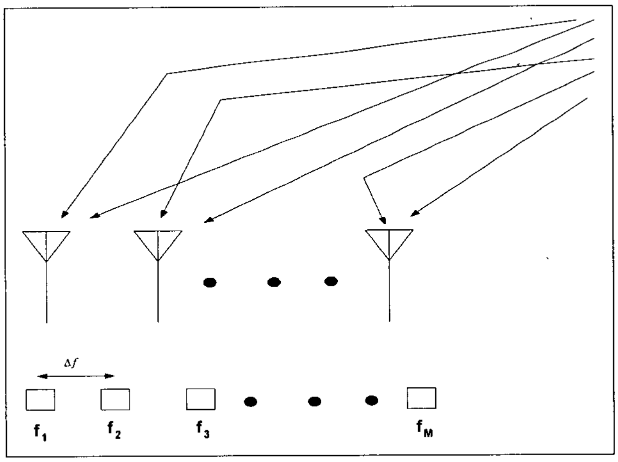

Fig. 1 Receive a Complex frequency

This time, the complex voltage $V(f)$ of a receiving antenna is as the following, if the internal noise in frequency f is ignored.

$$V(f) = \sum_{l=1}^{L} \tilde{F}_l \tilde{D}(\theta_l, \phi_l, f) e^{(-j2\pi f \tau_l)} \qquad (1.1)$$

Only, $\tilde{F}_l$ is a complex amplitude of one wave, (θ_l, ϕ_l) is the arrival direction of one wave, τ_l is the propagation delay time of l wave, and $\tilde{D}(\theta, \phi, f)$ is the directivity factor. If the directivity pattern of a

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receiving antenna stays in the measurement frequency range here, $\widetilde{D}(\theta,\phi,f)$ can appear as the following.

$$\widetilde{D}(\theta,\phi,f)=D_a(\theta,\phi)D(f) \quad (1.2)$$

$$X(f)=\frac{V(f)}{D(f)} = \sum_{l=1}^{L} F_l \exp(-j2\pi f\tau_1) \quad (1.3)$$

If equation(1.3) does the inverse Fourier transformation, the delay time distribution appears as the following.

$$x(t)\cong\sum_{l=1}^{L} F_l\delta(t-\tau_l) \quad (1.4)$$

$\delta(t)$: delta coefficient

However, this is the result of the inverse Fourier conversion in a frequency band that is wide enough, and measurement is impossible in broadband to establish familiarity with directivity. If internal noise is considered, the reception voltage $V(f)$ is expressed as the following.

$$V(f)=D(f)\sum_{l=1}^{L} F_l \exp(-j2\pi f\tau_1)+\widetilde{N}(f) \quad (1.5)$$

$$X(f)=\sum_{l=1}^{L} F_l \exp(-j2\pi f\tau_1)+N(f) \quad (1.6)$$

Equation(1.6) if the written vector is expressed as the following.

$$X=A_M F+N \quad (1.7)$$

The expression of equation (1.7) is formed, such as the input vector of the linear array in the arrival direction measurement. Therefore, an application is possible in a MUSIC algorithm, measuring the propagation delay time of a multi-path wave by resolving power high time.

III. PROPOSALS ALGORITHM

Correlation matrix derived from the input vector of equation (1.3) is expressed by the following equation.

$$R_{xx}\cong E[XX^H]=A_M S A_M^H+\sigma^2 I \quad (2.1).$$

Here $S=E[FF^H]$, σ^2 is an internal noise electric power, only that the internal noise does different frequencies and is uncorrelated. Matrix S is expressed as the following by a matrix that displays the correlation of L number.

$$S=\begin{bmatrix} E[|F_1|^2] & E[F_1F_2^*] & \cdots & E[F_1F_L^*] \\ E[F_2F_1^*] & E[|F_2|^2] & \cdots & E[F_2F_L^*] \\ \vdots & \vdots & \ddots & \vdots \\ E[F_LF_1^*] & E[F_LF_2^*] & \cdots & E[|F_L|^2] \end{bmatrix} \quad (2.2)$$

In case of obtaining input vector for a sweep frequency, there is a cross-correlation of a multi-path wave in an angular frequency to receive data because it is equal with the correlate relation of a sine carrier wave of a soldier trillion basically, and the cross-correlation of a multi-path wave is very high. Therefore, there is a need to introduce the space average method, as described in the previous chapter to stop cross-correlation as a pre-treatment.

In this case, it is said that there are many occasions that call for the mobile average or the frequency average, considering physical meaning because this processing is not spaced as a mean or as a mobile average. The frequency of the M component extracts $M-K+1$, avoiding the component that does the sub-array data of the K component ($K << M$) from the array data in a mobile average.

Therefore, it is expressed as a correlation matrix, following the mobile average.

$$\overline{R}_{xx}=A\overline{S}A^H+\delta^2 I \quad (2.3)$$

$\overline{S}$ is the signal correlation matrix after the mobile average.

$$A=[a(\tau_1),a(\tau_2),\ldots,a(\tau_L)] \quad (2.4)$$

$$a(\tau_l)=[e^{(-j2\pi f_1\tau_l)},e^{(-j2\pi f_2\tau_l)}\cdots e^{(-j2\pi f_K\tau_l)}]^T \quad (2.5)$$

$$f_i=f_1+(i-1)\Delta f \quad (2.6)$$

$(i,l=1,2,\cdots,K)$ Can appear as the following if written eigenvalue of the correlation matrix $\overline{R}_{xx}$ and eigenvector of each λ_i, e_i

$$\overline{R}_{xx}e_i=\lambda_i e_i \quad (2.7)$$

$$\lambda_1\ge\lambda_2\ge\cdots\ge\lambda_L>\lambda_{L+1}=\cdots=\lambda_K=\sigma^2 \quad (2.8)$$

can save the eigenvalue of the correlation matrix, and measure the number L of the incoming wave from a bigger eigenvalue than an internal noise electric power.

Eigenvector that correspond to the eigenvalue of the internal noise electric power is expressed as the following.

$$\overline{R}_{xx}e_i=(A\overline{S}A^H+\sigma^2 I)e_i \quad (2.9)$$

Eigenvector that corresponds to eigenvalue, such as internal noise electric power does $a(\tau_l)$, orthogonal with a delay time vector of all the direction of arrival waves. The MUSIC spectrum appears as the following.

$$P_{MU}(\tau) = \frac{a^H(\tau)a(\tau)}{a^H(\tau)E_N E_N^H a(\tau)} \quad (2.10)$$

Spectrum $P_M(\tau)$ about τ can yield years and find the L number of the correlativity ($\tau_1, \cdots, \tau_L$) peak.

Like this, the signal correlation matrix can appear as the following by inverse matrix arithmetic if delay time is assumed.

$$\overline{S} = (A^H A)^{-1} A^H (\overline{R}_{xx} - \sigma^2 I) A (A^H A)^{-1} \quad (2.11)$$

Can get the received power of l direction of arrival wave from l diagonal component of this matrix $\overline{S}$. [7][8] Also, maximum delay time estimation in the received signal is expressed as the following.

$$\Delta f = \frac{1}{\tau_l} \quad (2.12)$$

IV. SIMULATION

This paper aims to estimate delay time when there is a correlation in a proposed algorithm, using the mobile average method. The antenna used linear array antenna, and the interval of each element was expressed in $\lambda/2$. Delay time estimation was [12ns 15ns 20ns], and center frequency was 2GHz.

Figure 2 shows the result that estimated delay time, using the Fourier conversion method and MUSIC algorithm. 15ns did not presume delay time.

However, Figure 3 showed the result that illustrated simulation in the proposed algorithm. The proposed algorithm correctly estimated all the delay time.

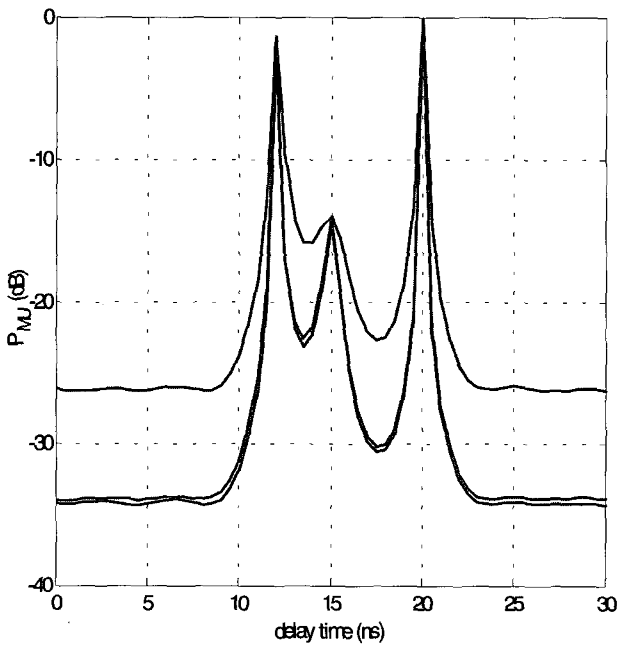

Fig. 2 DTE that used FT and MUSIC

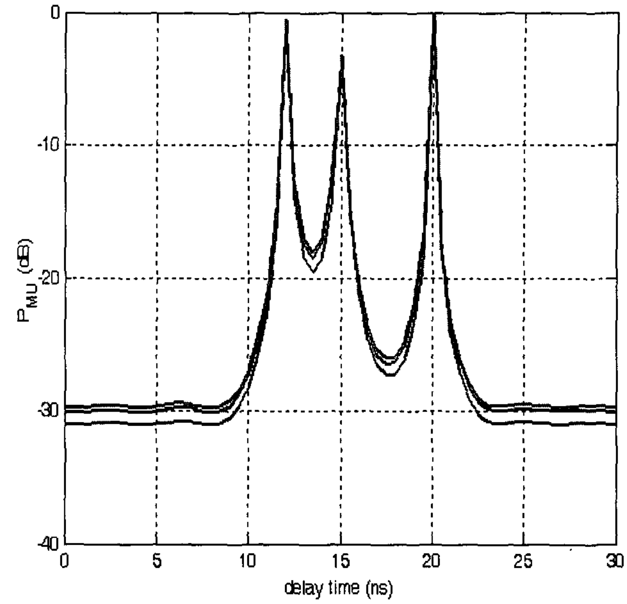

Fig 3. DTE that used proposed algorithm

V. CONCLUSIONS

Correlativity is an important element in estimating the direction of arrival, and, in the case of wireless mobile communications, it has high correlation on each other if the delay time difference in a multi-path wave is lesser.

In this study, the present estimation algorithm, in case there is signal correlativity, ran the computer simulation. The algorithm proposed in this paper, compared to the existing algorithm delay time estimation value of about 5ns, is recommended. The algorithm that correctly estimated the delay time in 5ns low should be studied.

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