A Received Signal Estimation Method at an Arbitrary Remote Location

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Abstract **–Various applications utilizing the locality of the fading characteristics have recently been developed. In contrast, if received signal at a remote location can be estimated beyond the correlation distance of the multipath fading environment, a wide variety of new applications becomes possible. In this paper we present an estimation method of the received signal at an arbitrary remote location. We also discuss the estimation performance of the method by computer simulations.**

Index Terms **—Estimation of received signals, MUSIC method, Least squares method, Multipath environment.**

I. Introduction

Applications of wireless technology based on the locality of the fading characteristics have been proposed [1, 2]. In contrast, if received signal at a remote location can be estimated beyond the locality, a wide variety of new applications can be realized. We have studied the estimation method of received signal characteristics at an arbitrary remote location [3]. In this paper, we present the method and evaluate the estimation performance of the received signal at a remote location assuming practical multipath environment.

II. Received Signal Estimation Method at an Arbitrary Location

A. Principle of estimation method

In our estimation method, we assume we have received signals at different multiple locations in a multipath environment. Based on the plane wave assumption for each arriving wave, multipath environment is analyzed by estimating the directions of arrival using the Multiple Signal Classification (MUSIC) method and the complex amplitudes of the received signals using the least squares method. Based on the estimated directions of arrival and the complex amplitudes of the arriving waves and considering the phase rotation of the waves, the estimated received signal at a remote location is calculated.

B. Environment and system model

Figure 1 presents the assumed multipath environment and the estimation system model discussed in this paper. Here we discuss a two dimensional space. We assume N received points are placed in a line with equal separation d and L plane waves arrive to the receiving points. The received signal at the n-th receiving point is expressed by c_n (n=1, … , N). θ_l is the arriving angle of the l-th wave (l=1, … , L). The reference point is where we estimate the complex amplitude of each arriving wave. In this paper it is at the origin of the coordinates. The target point is where we want to estimate the received signal. The position of the target point is denoted by (r, φ) in the polar coordinate. All the lengths and distances are expressed using the normalized values by the wavelength.

C. Estimation procedure of received signal

We estimate the received signal at the target point by the following procedure.

Step 1: Using the N signals at the receiving points c_n, we estimate the arriving angle of the l-th arriving wave as $\hat{\theta}_l$ by MUSIC.

Step 2: Using $\hat{\theta}_l$, we estimate the complex amplitude of the l-th arriving wave at the reference point as $\hat{F}_l$ by the least squares method. Using $\hat{\theta}_l$ and $\hat{F}_l$, the estimated received signal at the n-th receiving point $\hat{c}_n$ is expressed by:

$$\hat{c}_n = \sum_{l=1}^{L} \hat{F}_l \exp(-j2\pi \frac{(2n-N-1)d}{2} \sin\hat{\theta}_l) \tag{1}$$

$\hat{F}_l$ is obtained by minimizing the difference between c_n and $\hat{c}_n$ in the least squares criterion. That is, $\hat{F}_l$ is obtained by:

$$\hat{F}_l = \arg\min \sum_{n=1}^{N} |\hat{c}_n - c_n|^2 \tag{2}$$

Step 3: By considering the arriving angle and the phase rotation corresponding to the distance between the reference point and the target point, the complex amplitude at the target point of the l-th wave is calculated. The estimated received signal $\hat{s}$ is presented by the sum of the L complex amplitudes:

$$\hat{s} = \sum_{l=1}^{L} \hat{F}_l \exp\{-j2\pi(r\sin\varphi\sin\hat{\theta}_l + r\cos\varphi\cos\hat{\theta}_l)\} \tag{3}$$

III. Evaluation of Estimation Accuracy

A. Parameters of environment and estimation system

We evaluated the estimation accuracy of the proposed system by computer simulations. Table 1 summarizes the environment and estimation system parameters assumed in the simulations. We change L from 1 to 19. θ_l is randomly chosen between -60° and 60° from the boresight of the array. In the estimation, L is unknown, instead the number of the arriving waves estimated in Step 1 is used in Steps 2 and 3. The antenna separation is half wavelength and the number of the antennas N is 20. The number of the snapshots used in the MUSIC estimation is 40.

B. *Metric of estimation accuracy*

In this paper, we show the accuracy of the estimation by the standard deviation of the ratio between the correct and estimated amplitudes. The amplitude ratio is defined as:

$$20\log\left|\frac{\hat{s}}{s}\right| \quad [\mathrm{dB}] \tag{4}$$

where s is the correct received signal at the target point. The standard deviation is calculated over 100 independent estimation trials. We abbreviate the standard deviation as "SD".

IV. Estimation Result of Received Signal

A. *Example of estimation*

Figure 2 shows an example of the result of the estimation. The horizontal axis of the figure, "Trials", means the number of the independent estimation count. In this example, the target point is at the reference point, Signal to Noise power Ratio (SNR) is set as 40 dB, and L is 5. The figure indicates up to 1dB estimation errors occur, however most of the errors are negligibly small. In this paper we use the SD to express the estimation accuracy. For instance, it is 0.18 dB in Fig. 2.

B. *Influence of distance to target point*

We assume three cases for the location of target point to evaluate the influence of the distance to the target points. They are (0, 0°) (=reference point), (10, -10°) and (100, -10°). Figure 3 shows the SD characteristics for the three cases when SNR is varied. L is set as (a) 5 and (b) 10. From the figure it is seen that when SNR is high enough, SD is less than 1 dB. The estimation accuracy deteriorates as the target locates far from the reference. The deterioration is small when the target is located at the distance of 10 wavelength from the reference point, however it becomes remarkably large at the 100 wavelength distance.

C. *Influence of number of arriving waves*

Figure 4 shows the SD characteristics when L is varied. SNR is set as 40 dB and the target points are the same three cases in Fig. 3. As L increases, the SD values increase at any target point.

As shown in this analysis, in order to realize accurate estimation, there is a requirement between the number of antennas N, the number of the arriving waves L, and the distance to the target point.

V. Conclusion

In this paper we presented an estimation method of received signal at a remote location. Through computer simulations, we evaluated the estimation performance of the method quantitatively and clarified the influence of the several parameters of the estimation system to the estimation performance. In this paper the assumed model was 2 dimension but we plan to change the environment to a 3 dimensional space.

TABLE 1. Parameters of Environment and Estimation System

Multipath environment	
Number of arriving waves: L	1~19
Arriving angles	Random (-60°~60°)
Complex amplitudes of arriving waves	Amplitude: Rayleigh-distributed Phase: Random(0~2π)
Estimation system	
Antenna separation	Half wavelength
Number of antennas: N	20
Snapshots of MUSIC	40

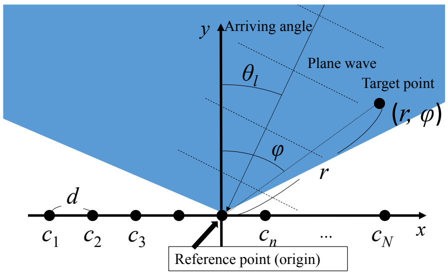


Fig. 1. Environment and system model.

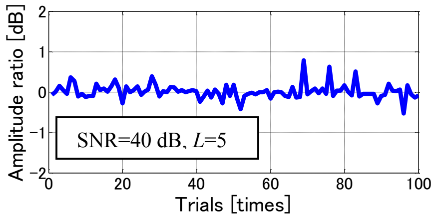
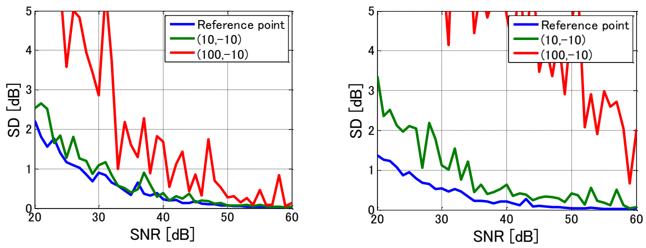


Fig. 2. Example of estimation.



(a) L=5 (b) L=10

Fig. 3. SD characteristics at three target points.

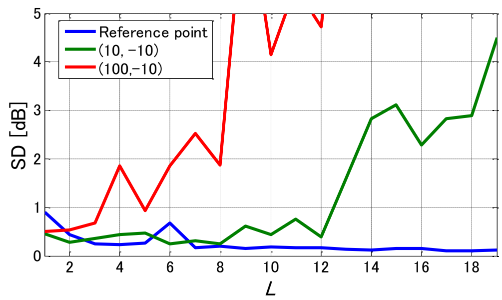


Fig.4. Influence of number of arriving waves.

References

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