Experimental Examination of the Influence on AOA Estimation Accuracy of Elevation Angle by Ground Reflection

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Abstract

Wireless communication system is moving onto microcell configuration. The base station location become high to reduce the radius of the cell, AOA estimation of elevation is important. We verify the ground reflection effects on AOA estimation accuracy, and we show the estimation method to improve the estimation accuracy in actual environment. As a result, it is shown that the AOA estimation accuracy in outdoor actual environment improved by suppressing the reflected wave from ground and using inner product method.

Keywords : AOA estimation MUSIC calibration matrix inner product outdoor experiment

1. Introduction

In recent years, wireless communication system is moving onto microcell configuration. The evaluation of both azimuth and elevation angle of waves is important to evaluate communication environments. AOA estimation of waves has been evaluated mainly in azimuth angle. However, the base station location become high to reduce the radius of the cell, AOA estimation of elevation is important. In this paper, the AOA estimation of elevation angle is evaluated with 4-element uniform linear array in outdoor LOS (line of sight) environments. The measurements with/without radio wave absorber verify the ground reflection effects on AOA estimation accuracy. Then we show the estimation method to improve the estimation accuracy in actual environment.

2. Power estimation and inner product method

In this paper, the AOA estimation is carried out by using MUSIC [1] and inner product method [2]. MUSIC is an algorithm using the orthogonalization between the signal subspace and the noise subspace, and the angle scanning of the steering vector provides the AOA. It is obtained from the angle corresponding to the peak of MUSIC spectrum. This power estimation is formulated by eqs. (1) and (2),

$$S = (A^H A)^{-1} A^H (R_{xx} - \sigma^2 I) A (A^H A)^{-1} \quad (1)$$

$$S = diag[P_{\theta 1}, P_{\theta 2}, \cdots, P_{\theta n}] \quad (2)$$

where, **A** is a steering vector, $\mathbf{R_{xx}}$ is correlation matrix of received signal, **S** is signal covariance matrix, $P_{\theta n}$ is estimated power of n*th* wave's. The angle of wave is examined from the transition of power estimation by the change in steering vector of arbitrary wave.

On the other hand, inner product method is an algorithm calculating an inner product between calibrated eigen vector of the signal subspace and ideal steering vectors in the database [2]. The calibration matrix changes by combining the reference signals. This method is an algorithm that judges the proper calibration matrix and estimates the AOA at the same time, and then a lot of reference signals are necessary to make proper calibration matrix. However, this method is suitable for the measurement in actual environment.

3. Experimental discussion

1-D AOA estimation is carried out in the outdoor LOS environment as shown in Fig. 1. Uniform linear array antenna consists of 2GHz band, 4 element patch antennas. These antennas with half-wavelength element spacing are adopted in the receiving antenna as shown in Fig. 2. The influence of the number of element is examined from received data corresponding to each element. The estimation algorithm uses MUSIC and inner product method. The transmitting signals are from cellular base station. The receiving system is moved by hand to each receiving position (1~4) after data are acquired at one position.

As the first step, we estimate AOA of elevation angel in the outdoor LOS environment as shown in Fig. 1. The estimation errors by two or four elements are shown in Table. 1. We find two signal eigen vectors in the measurements. Two signal eigen vectors denote direct and reflected wave from the ground. The absorber is set up as shown in Fig. 2 so that the reflected wave from the ground is suppressed. It is considered how the measurements with the absorber effects on estimation accuracy. The estimation error by two elements without the absorber is larger than that with the absorber as shown in Fig. 3. The estimation errors by four elements are also similar to that by two elements. It depends on the suppression of reflected wave by the absorber. For the two waves estimation case, MUSIC algorithm is carried out by using two signal subspaces and the noise subspace. The error by four elements with the absorber is larger than that without the absorber as shown in Fig. 3. This reason is that the number of estimation waves is different from the number of arrival waves by suppression of the reflected wave. The influence on the reflected wave caused by the absorber is shown by power estimation in Fig. 4. The peaks of power estimation without absorber are larger than those with absorber at the angle of the reflected wave. These are almost same peaks of MUSIC spectrum as shown in Fig. 4. Considering the power estimation at position4, not the estimation reflection angle but rather the theoretical reflection angle is wrong because of downhill between transmitter and receiver. These results show that reflected wave seriously affect the estimation accuracy.

Secondly, we show the inner product method to improve the estimation accuracy. When the reference calibration signal cannot be decided due to no AOA information on receiving, we use the following process as shown in Fig. 5. After, the received signal is calibrated by reference signal that covers all angles and elevation AOA is estimated approximately, the received signal is calibrated by “vicinity reference signal” near the estimated angle, and elevation AOA is estimated again. These results are shown in Fig. 6 and Table. 3. From these results, it is confirmed that the estimation error is less than 3“degree” , which shows that using the neighbourhood reference signal is effective. However, the estimation accuracy is deteriorated in high elevation AOA due to the increase of the estimation error by the reduction of the aperture plane in high elevation.

4. Conclusion

This paper discussed AOA estimation in the outdoor LOS environment by using 4 elements linear array experimentally. It was confirmed that the suppression of the reflected wave from ground is effective to improve the estimation accuracy of elevation angle. These were especially shown that AOA estimation error by two elements improves more than 5[degree]. In addition, we showed the inner product method to improve the estimation accuracy. The estimation error by inner product method was less than 3[degree], which were better than that of MUSIC algorism. As a result, it was shown that the AOA estimation accuracy in outdoor actual environment improved by suppressing the reflected wave from ground and using inner product method.

References

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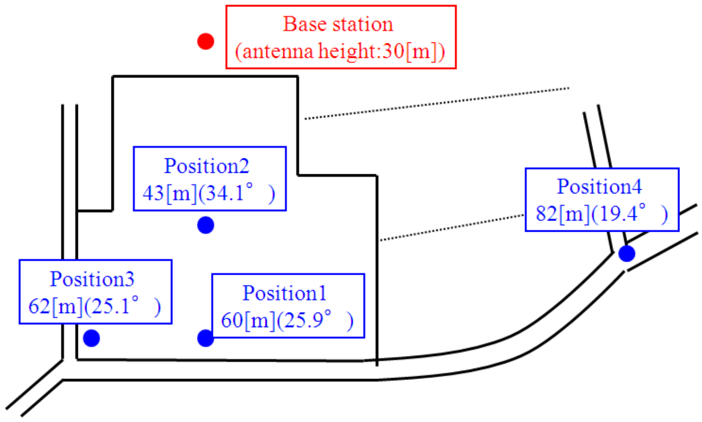

Figure. 1: Experimental environment

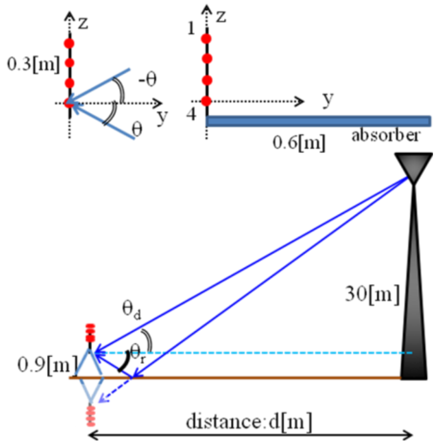

Figure. 2: Antenna and measurement setting

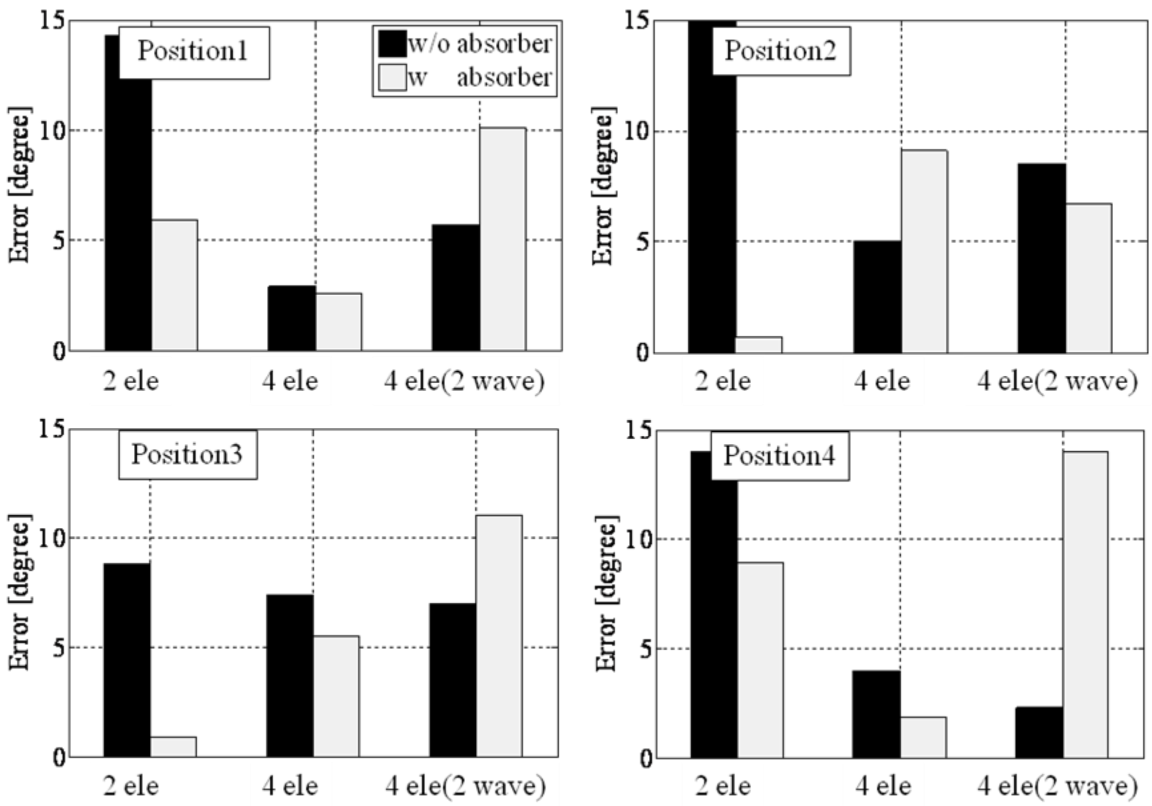

Figure. 3: Estimation error at each receiving position

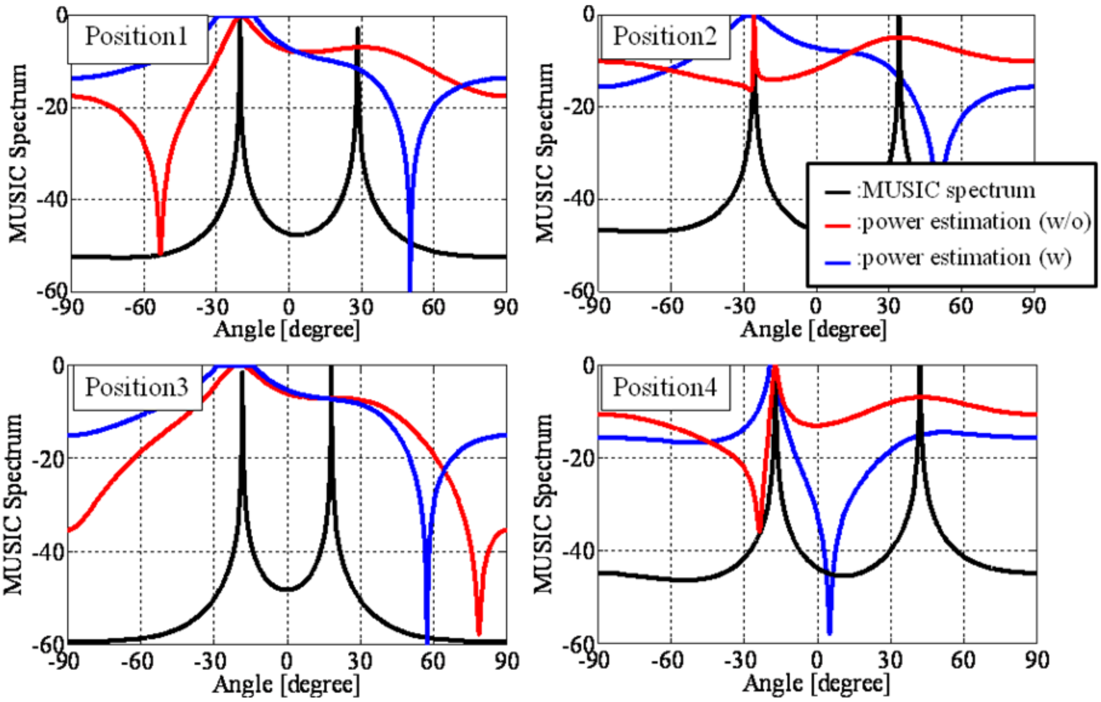

Figure. 4: Power estimation and MUSIC spectrum

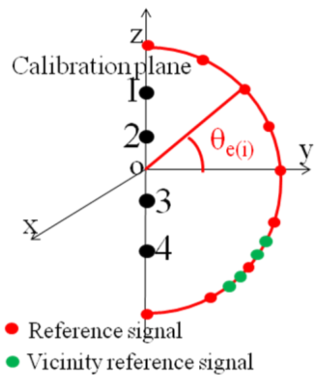

Figure 5: reference signal selection

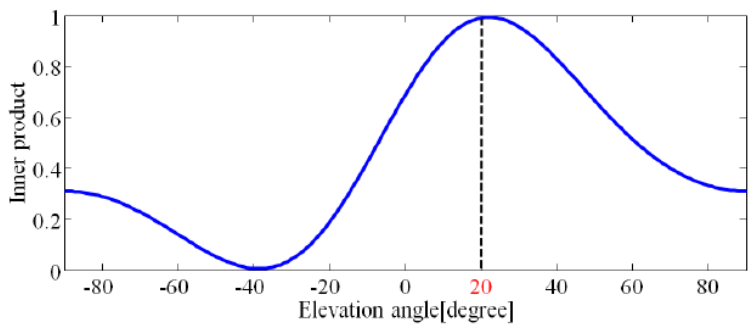

Figure 6: result of inner product (Position 4)

Table 1: one wave estimation accuracy

Error[degree]	Position 1	Position 2	Position 3	Position 4
2-element	14.3°	15°	8.8°	14°
4-element	2.9°	5°	7.4°	4°

Table 2: estimation error of reflected wave

	Position 1	Position 2	Position 3	Position 4
w/o absorber	2.4°	1.5°	8.6°	21.6°
with absorber	0.2°	2.5°	8.2°	22°

Table 3: estimation error by using inner product method

Reference signal	Position 1	Position 2	Position 3	Position 4
MUSIC method	2.6°	9.1°	5.5°	1.9°
●:all angle	3.5°	5.9°	3.2°	1.0°
●: vicinity angle	0.5°	2.8°	0.9°	1.3°