Compact MIMO Antenna with Cross Polarized Configuration

Wannipa Yadum, Nobuo Nakajima
Department of Human Communication
The University of Electro-Communications
Chofugaoka 1-5-1, Chofu-shi, Tokyo 182-8585
JAPAN

Abstract: - MIMO is the key technology to improve spectrum efficiency in the wireless communications. However, MIMO may perform poorly as a mobile terminal with a very small antenna. This paper describes an experimental study on the performance of a compact MIMO antenna. In order to improve the performance, a cross polarized configuration was investigated as well as a co-polarized configuration. Experiments were carried out in 2.6 GHz band with antenna element spacing from 6 mm to 5 cm. A helical antenna with a ceramic substrate is used as a radiator to make the antenna small. The experiments verified that the cross polarized configuration enables better performance compared to the co-polarized configuration. The average correlation was about 0.1 in the case of 1 cm antenna element spacing.

Key-Words: - Antenna, MIMO, Mobile communication, Portable phone, Correlation, Cross polarization

1 Introduction

MIMO is one of the breakthrough technologies for improving spectrum efficiency in wireless communication systems [1]. Many researches focus their study on multiplexing and de-multiplexing algorithm [2]. In their study, correlation among antenna elements is supposed to be very low. This assumption is acceptable for base station antennas because enough distance is available between antennas. However, such a condition may not stand for portable terminals.

Relations between antenna separation and correlation are investigated in many papers [3][4][5][6]. However, the correlation performance of actual antennas located at very close distance is still unclear. This paper presents experimental study on the performance of a compact MIMO antenna, especially for its cross polarized configuration, since better performance is expected than co-polarized configuration for the mobile communication environments [7].

A helical antenna with ceramic substrate is applied as a compact radiator. A number of antenna elements are 4. Co-polarized configuration was also employed as the baseline.

Correlations were measured under indoor Rayleigh fading environments. Mutual coupling among antenna elements was also measured, since it causes the degradation in effective antenna gain [8].

2 MIMO Antenna Configuration

2.1 Radiator and antenna elements

Figure 1 and Fig.2 show a radiator and antenna elements. The vertically-polarized antenna element is composed of a radiator with a micro strip line feeder, whereas the horizontally polarized antenna element is composed of two radiators and an impedance matching circuit attached on the micro strip feeder.

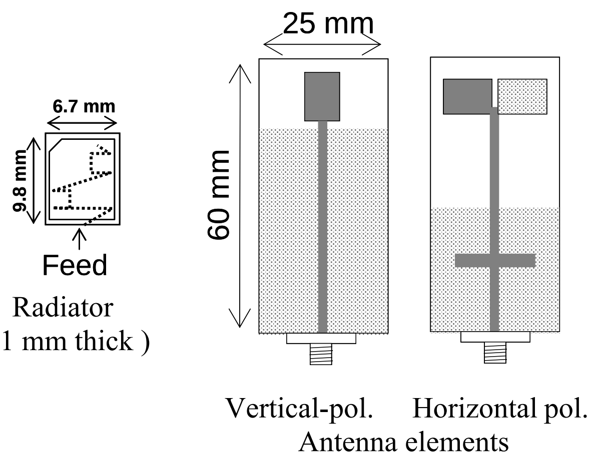


Fig.1 Antenna structure

Return losses of both antenna elements are shown in Fig.3. Bandwidth of the vertical antenna element is wider than the horizontal antenna element. This is because a ground plane of the micro strip line acts as a radiator in the vertical antenna and effective size of the antenna element becomes larger than the horizontal antenna element.

Measured antenna gain of the horizontally polarized antenna was about 3dB lower than that of the vertically polarized antenna. This may be also due to the difference in effective size of the antennas.

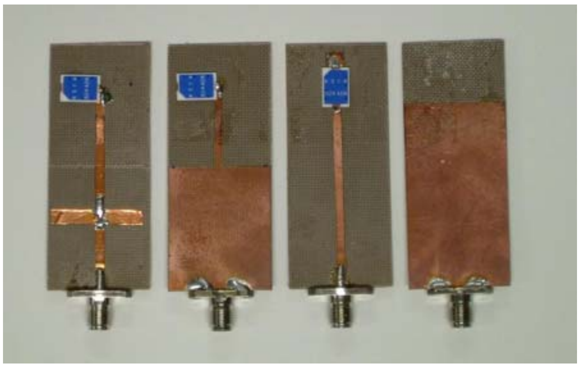


Fig. 2 Photo of antenna elements

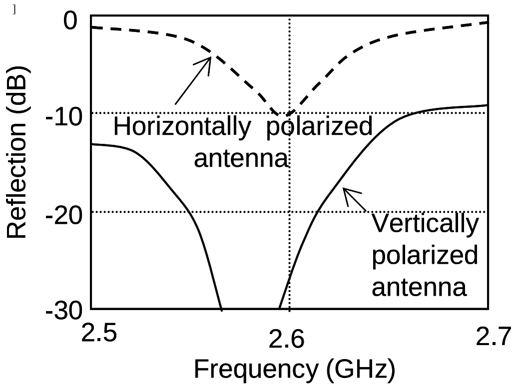


Fig.3 Reflection from antennas

2.2 Antenna Configurations

A MIMO antenna is composed of plural antenna elements. A number of the antenna elements are independent between the transmitter and the receiver, but the same number of antenna elements is usually employed. In most of the case, 3 or 4 antenna elements are used. In this research, 4 antenna elements configuration is investigated.

In a general application, polarization of the transmitting wave is vertical in wireless communication systems. Therefore MIMO antenna was assumed to be polarized vertically. On the other hand, a portable telephone terminal is used with various inclination angles. This means that the polarization of the antenna can not be determined. In this sense, the cross polarized antenna configuration is preferable for portable terminals.

The trial antenna configurations for both co-polarization and cross polarization are shown in Fig. 4. Antenna element spacing is selected to be 6 mm, 1 cm, 2 cm, 3 cm, 4 cm and 5 cm for experiments. These correspond to 0.05 λ, 0.09 λ, 0.17 λ, 0.26 λ, 0.35 λ and 0.43 λ, respectively (λ=wavelength). Dimension of the trial MIMO antenna is shown in table 1.

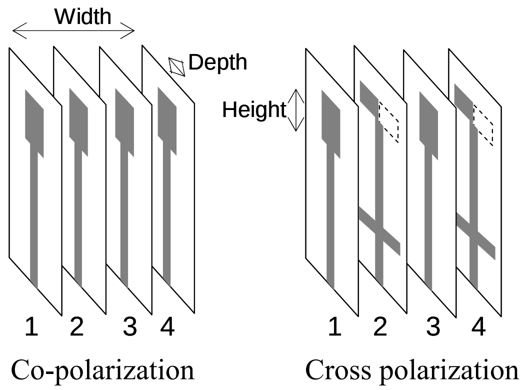


Fig.4 MIMO antenna configuration

	Height	Depth	Width
Co-pol.	10	7	18 -- 150
Cross pol.	10	20	

Table 1 MIMO antenna dimension (in mm)

2.3 Theoretical Correlation

Supposing that multiple incident waves come from random directions, the correlation between the separated antennas can be derived theoretically. Figure 5 shows the relationship between the correlation and antenna element spacing for co-polarized configuration.

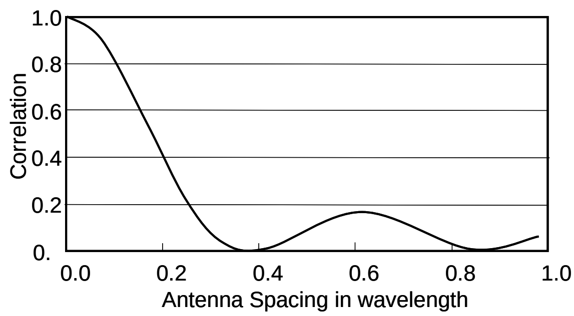


Fig.5 Theoretical Correlation between antennas

2.4 Mutual Coupling

When the antenna spacing is very close, transmit power from an antenna element couples to the other antenna elements. This coupling causes transmit power loss. This effect is described at chapter 5.

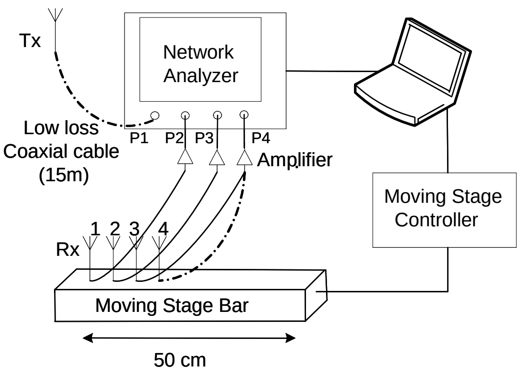
The mutual coupling gives effect to radiation patterns. Hence, the correlation characteristics become different compared to the simple antenna model where mutual coupling is ignored.

3 Experimental System

3.1 Configuration

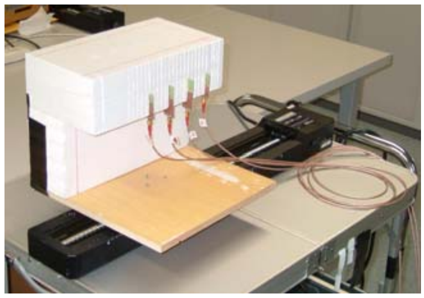
The experimental system is composed of a transmit antenna, a MIMO antenna, a network analyzer, amplifiers and a moving stage bar as shown in Fig. 6. CW RF signal is fed to the transmit antenna from Port 1 of the network analyzer. Received signals at the MIMO antenna are guided to Port 2, Port 3 and Port 4. The amplitude and the relative phase of 3 input signals are measured simultaneously. The MIMO antenna moves on the moving stage bar. In this experiment, the antenna moves from 0 to 50 cm with 1 cm interval.

Since the data of each measurement is not enough to obtain statistical results of correlation, the measurement was repeated 17 times at different locations. As a result, 867 data were used to evaluate the correlation characteristics. Amplifiers are used to compensate the propagation loss and cable loss between the output and input ports of the network analyzer.



(a) Configuration

Fig. 6 Experimental system



(b) Photograph

Fig. 6 Experimental system

3.2 Measurement Environment

Measurements were carried out in the indoor environment as shown in Fig.7. In order to simulate Rayleigh fading environment, the direct path between the transmitter and receiver antennas was obstructed by the office-partitions with a height of 1.6 m. The transmitter antenna is mounted at a height of 65 cm above the floor and the MIMO antenna is fixed 95 cm high above the floor. In the measurements, the MIMO antenna was successively located at difference locations within the area shown in Fig.7.

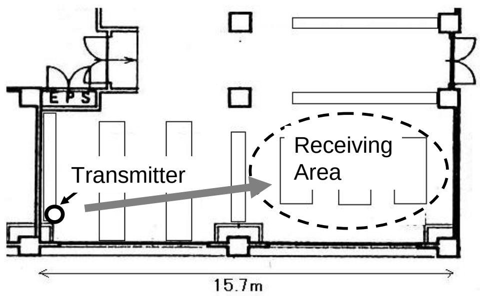


Fig.7 Experimental Environment

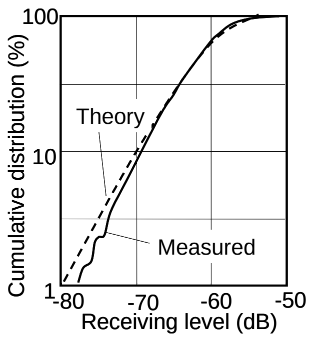


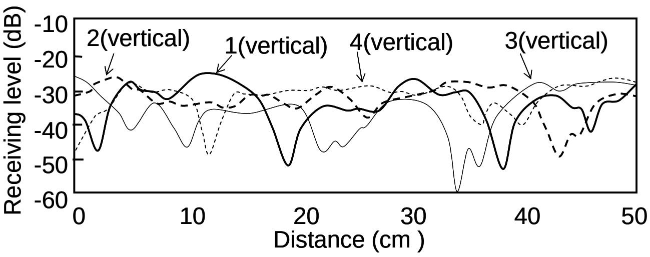
Fig.8 Cumulative distribution of Receiving level

Measured cumulative distribution of the receiving level is shown in Fig.8. Comparing measured data with theoretical Rayleigh fading cumulative distribution, experimental circumstances can be approximated as Rayleigh fading environment.

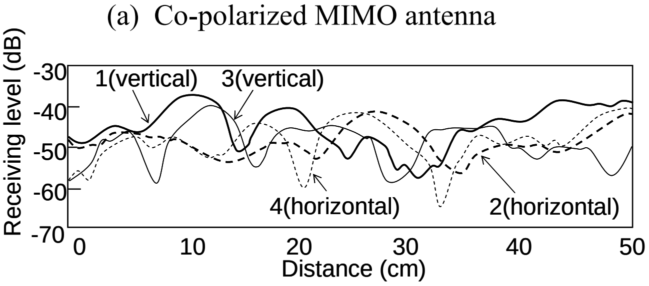
Transmitting antenna polarization is vertical. However, both vertical and horizontal polarized waves are received due to the multiple reflections. In this experimental environment, the measured average receiving level of cross (horizontal) polarized wave was approximately 1 dB lower than that of vertical polarized wave.

4 Correlation

Figure 9 shows the examples of receiving level variation along the movement of antennas in case that antenna element spacing is 6 mm. Figure 10 shows the correlations for co-polarized and cross polarized MIMO antennas.

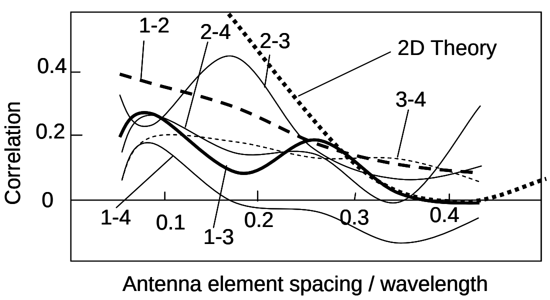


(a) Co-polarized MIMO antenna



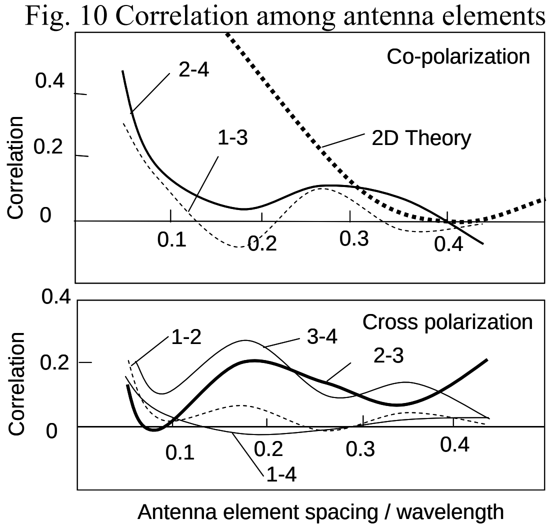
(b) Cross polarized MIMO antenna

Fig.9 Receiving level characteristics (6 mm spacing)

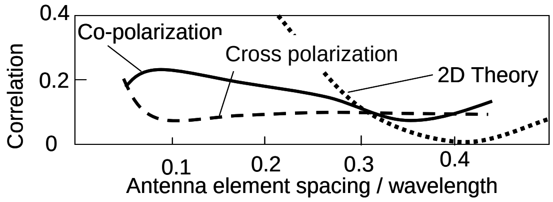


(a) Co-polarization

Fig. 10 Correlation among antenna elements



(b) Cross polarization



(c) Average correlation

Fig.10 Correlation among antenna elements (continued)

In Fig.10(c), average correlation was from 0.5 to 0.2 when antenna element spacing is more than 0.05λ. Compared to the correlation of the co-polarized MIMO antenna with theory, the experimental correlations were far smaller than theoretical one in the region of close antenna spacing as 0.05 λ– 0.2 λ (Fig.10 (a)). Discrepancy between the theory and the experiment will be due to the assumption in the theory. The theoretical model is 2 dimensional whereas experiments were carried out in the 3 dimensional condition.

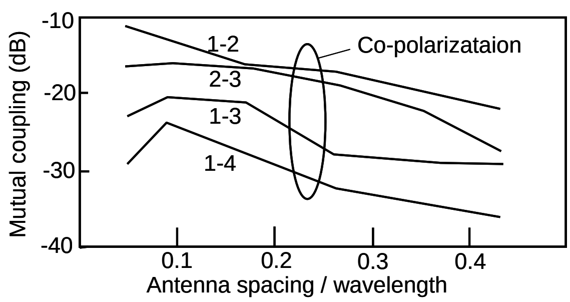
The experimental results are feasible for applying a small MIMO antenna to actual wireless systems. However, more precise simulations are necessary to analyze the experimental results.

The correlation of the cross polarized MIMO antenna was lower than that of the co-polarized MIMO antenna, (Fig.10(a),(b)). Especially, the correlation between adjacent cross polarized antenna elements (1:2, 2:3, 3:4) does not increase even when the antenna element spacing becomes small. In the case of polarization diversity, the correlation is almost zero between two receiving antennas under the fading. The mechanism is the same for the case of cross polarized MIMO antenna.

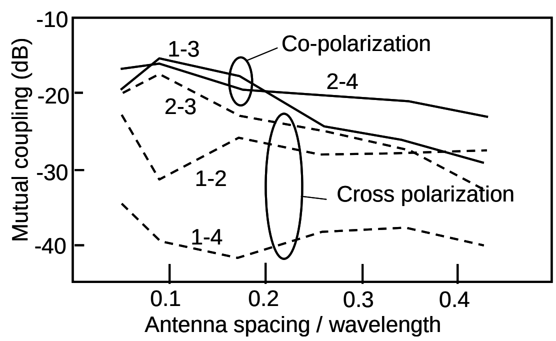
As a result, the average correlation of the co-polarized MIMO antenna was about 0.2, whereas it was about 0.1 for the cross polarized MIMO antenna when antenna elements were located closely.

5 Effect of Mutual Coupling

Figure 11 shows the measured mutual coupling loss among antenna elements. In the smallest antenna element spacing case (6 mm), the maximum coupling level is about -10 dB for the co-polarized MIMO antenna, whereas they are below -18 dB between adjacent antenna elements (cross polarized) and -15 dB between co-polarized antenna elements in the case of the cross polarized MIMO antenna. Since the mutual coupling of the cross polarized MIMO antenna is lower than co- polarized MIMO antenna, the effective antenna gain degradation of the cross polarized configuration is expected to be lower than that of the co-polarized configuration.



(a) Co-polarization



(b) Cross polarization

Fig.11 Mutual coupling among antenna elements

6 Conclusion

A small MIMO antenna was fabricated and performance was investigated experimentally. The cross polarized configuration enabled better performances, compared to the co-polarized configuration, in terms of the correlation and mutual coupling under the same antenna dimensions.

The minimum size of the proposed antenna is 10 x 20 x 18 mm^3 in the 2.6 GHz band. Thus, the MIMO antenna with multiple antenna elements may be applicable even for portable equipment under Rayleigh fading environments.

In the real world, Rayleigh fading condition cannot always be expected. Sometimes, a propagation path becomes line-of sight in mobile communications. In such a case, the performance of a compact MIMO antenna might be degraded than that of large scale MIMO antenna.

Thus, there still exist many issues for applying to actual wireless systems; however we can definitely expect the potential of compact MIMO antenna through the experimental results described in this paper.

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