FIELD TRIAL RESULTS FOR A MIMO SYSTEM

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Abstract: These days much research on MIMO (multi-input multi-output) communication is being conducted in order to achieve faster radio communication by using limited frequency band more effectively. In this paper, experimental results demonstrating the feasibility of MIMO systems are given. For the case of indoor radio based on a PHS (Personal Handy-phone System) standard, we report the spatial correlation, the relationship between the spatial correlation and the BER and FER, and the proportion of a localized area in which stable MIMO communication was achieved.

INTRODUCTION

Many research groups have been studying SDMA [1]-[5] in an effort to improve channel efficiency. SDMA is a multiple access scheme for mobile communication that spatially separates multiple user signals sharing the same frequency simultaneously in the same area. Consequently, it can accommodate several times as many users as existing mobile communication systems. We developed SDMA technology for a PHS base station [1][2], which utilizes one of the Japanese wireless communication standards. Figure 1 shows the frame format of the PHS system. The base station can be made to function as a MIMO (multi-input multi-output) base station by installing MIMO software, in which case it is called an SDR (software-defined radio) base station.

In this paper, we evaluate the feasibility of MIMO communication with the SDMA base station. We used the method illustrated in Figure 2 to implement MIMO communication with PHS. On the base station side, we employed adaptive array technology to form a multi-beam for each path, while on the terminal side, we used two terminals with one antenna each, and different signals were transmitted from each element of the terminal antennas. In this system, the spatial correlation [6] of the array response vectors corresponding to the signals transmitted from each terminal affects the performance of the base station. In reference [6], the spatial correlation is defined as

\[ R = \frac{h_i^H h_j}{\sqrt{h_i^H h_i} \sqrt{h_j^H h_j}} \]

where \( h_i \) is the array response vector of signals from terminal \( i \), and \( [\cdot]^H \) denotes the Hermitian transpose of \( [\cdot] \).

First, we investigated the relationship between the antenna spacing and the spatial correlation. Then, we evaluated the performance under various conditions to confirm the feasibility of MIMO systems. Finally, we measured the error rates of MIMO communication at different points in the measurement area.

MEASUREMENT RESULTS

Antenna Spacing vs. Spatial Correlation. The measurement system we employed for spatial correlation is shown in Figure 3. The PHS base station has a 4-element antenna, while the terminal has one antenna. We measured the array response vectors on the side of the base station receiving signals from the PHS terminal. The base station antenna elements were laid out on a circle, and the element spacing was 0.5\( \lambda \), 1.0\( \lambda \), or 5.0\( \lambda \).
The experiment was conducted in a regular office space with no people present so as not to alter the paths of the radio waves. Figure 4(a) shows the results under line of sight conditions in an open space, while Figure 4(b) shows the results without a line of sight. In these graphs, the abscissa indicates the antenna spacing, while the ordinate indicates the spatial correlation calculated from the measured response vector. As observed from these results, when the antenna spacing at the base station was larger than 1.0λ, and that on the terminal side was larger than 0.3λ, the spatial correlation between paths 1 and 2 was less than 0.9.

![Figure 3: Measurement setup for spatial correlation](image)

![Figure 4: Antenna spacing vs. spatial correlation](image)

**Spatial Correlation vs. Error Rate.** Figures 5(a) and (b) show the relationship between the spatial correlation and the BER and FER, respectively, for MIMO communication. We changed the antenna spacing not only at the base station but also between the terminals. In the graphs, the abscissa indicates the spatial correlation and the ordinate indicates the BER or FER. The signal-to-noise ratio (SNR) was 50dB. As the results demonstrate, the relationships between the spatial correlation and the BER and FER exhibited the same tendency, regardless of the antenna spacing or the test location. In Figure 5(a), the BER did not exceed 10^{-5} as long as the correlation was not more than 0.9. This confirms that MIMO communication is feasible if the spatial correlation is below 0.9. That is to say, if the antenna spacing on the base station side is no less than 1.0λ and the antenna spacing on the terminal side is around 0.3λ, then MIMO communication can be utilized.

**MIMO Communication Area Performance.** Figure 6 shows the measurement results for the performance of MIMO communication in terms of area. The x- and y-axes of each graph indicate the measurement positions, and the z-axis indicates the BER or FER. We measured the BER and FER by moving the terminals, while placing the base station in the middle of the room. We took measurements at 80 positions, with a spacing of 80 cm. The antenna spacings of the base station and the terminals were both 0.5λ and the SNR was 50 dB. As shown in Figure 6(b), the FER exceeded 10^{-3} at only 5 positions. Hence, we can say that stable MIMO communication was feasible in more than 90% of the area. Based on the results shown in Figure 4, if the antenna spacings were larger, the proportion of area with effective MIMO communication would probably be higher.
CONCLUSION
We utilized an SDR base station to confirm the feasibility of MIMO communication. Our experimental results revealed that stable MIMO communication could be achieved if the antenna spacing on the base station side was $1.0\lambda$ and the antenna spacing on the terminal side was $0.3\lambda$. The antenna spacing for the terminal side corresponds to 1.8 cm for an indoor WLAN system using a 5-GHz frequency band.

In addition, we measured the BER and FER at 80 positions in a localized area. As a result, we found that stable MIMO communication could be achieved in more than 90% of the area, even though the antenna spacings of the base station and the terminal were both $0.5\lambda$.

REFERENCES