Evaluating Impact of Tag Element Spacing on Bit-error-rate Performance Using Passive MIMO Testbed

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***Abstract* – In this study, we experimentally assessed the impact of tag element spacing on Bit-Error-Rate (BER) performance of passive Multiple-Input Multiple-Output (MIMO), which uses multiple antennas at both Radio Frequency Identification (RFID) tag and its reader to improve data-rate of the backscattering load modulation. Since a small RFID tag needs miniaturized multiple antennas, the antenna element spacing must be narrow. However, no studies have evaluated the effect of the element spacing in passive MIMO. This paper experimentally reveals the relationship between the BER and the element spacing using own-developed passive MIMO testbed. From the experimental result, it is shown that the passive MIMO with 0.2-wavelength spacing yields feasible BER ($< 10^{-2}$) at 1 m communication distance even with realistic noise power (> -90 dBm).**

***Index Terms* — MIMO, RFID, load modulation, element spacing, BER**

I. Introduction

In recent years, RFID (Radio Frequency Identification) system gets a lot of attention. It has been used for electronic money and employee ID card and so on. Passive RFID scheme can read data from tag by using load modulation technique, where tag does not transmit but reflects signals from its reader, and it has become mainstream in RFID systems. But, passive RFID has the problem that there is the limit of data-rate between reader and tag [1]. In order to improve the data-rate, passive Multiple-Input Multiple-Output (MIMO) has been proposed [2]. The data-rate can be increased by applying load modulation to multiple tag antennas. However, if multiple antennas are in small space such as in a tag, element spacing must be narrow. In this case, the correlation of the propagation channel is degraded. Even though this effect is quite important in realizing tags using passive MIMO, the impact of the element spacing on its performance has not been clarified so far.

In this study, we experimentally evaluated the effect of the tag element spacing on the passive MIMO performance. In order to clarify the effect of narrow tag element spacing, the relationship between BER performance and tag element spacing is measured using own-developed testbed. In the following, the overview of the passive MIMO testbed and its performance is briefly introduced, and the discussions on the antenna spacing are presented.

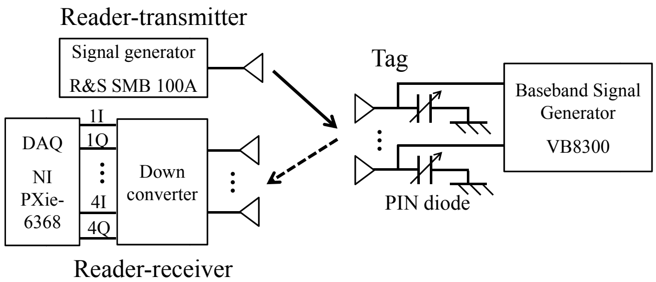

Fig.1. Experimental setup

Table 1 Experimental conditions

Antenna	Patch antenna			
Frequency	2.47 GHz			
Transmit power	10 dBm			
The number of antennas	4			
The distance between Reader to Tag L	0.5 m		1.0 m	
Antenna height	1.0 m			
Reader element spacing	0.5 λ			
Tag element spacing d	0.2 λ	0.3 λ	0.5 λ	1.0 λ
Data rate	400 kBits/s			

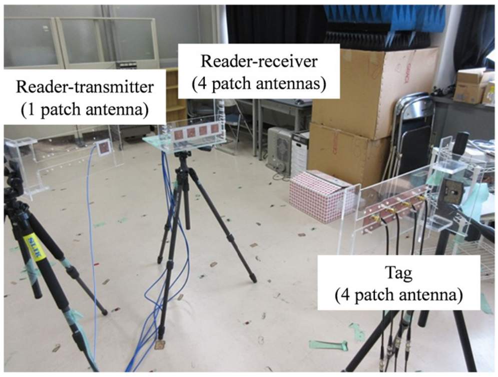

Fig.2. Experimental environment

II. Experimental Conditions

Figure 1 shows overview of the passive MIMO testbed. The signal generator (R&S SMB 100A) transmit the 2.47 GHz carrier wave. At the tag side, carrier wave is modulated and reflected to the reader receiver. Tag antennas are connected with variable impedance (PIN diode). The load modulation is realized by controlling bias voltage using baseband signal generator (VB8300). The reader receiver comprises down converter and data acquisition (DAQ) unit.

Table1 and Figure 2 shows experimental conditions. The measurement was conducted in the indoor environment. In this experiment, patch antennas are used for all antenna elements. Two distances between Reader and Tag, L, i.e. 0.5 m, 1.0 m, are evaluated. The tag element spacing is varied over the range, i.e. d = 0.2 λ ~ 1.0 λ. The demodulation algorithm is Maximum Likelihood Detection.

III. Experimental Results

Figure 3 shows an example of constellations of the received signals at the reader, where L is 1.0 m, transmit power is −10 dBm. In this figure, the ideal received signals are shown by circles, and the received signals including the noise are shown by crosses. From Figure 3 (a), it can be seen the narrow tag element spacing, i.e. d is 0.2 λ, suffers from close distance among the signal points. In this situation, it is difficult to demodulate the tag data unless the noise power is sufficiently small. This problem is caused by high correlation of propagation channel due to the narrow tag element spacing. On the other hand, Figure 3 (b) shows the constellation when the tag element spacing is sufficiently wide, i.e. d is 1.0 λ. The wide tag element spacing improves the correlation of propagation channel. In this case, the demodulation can be easily performed because of the low correlation of the received signals.

Figure 4 shows BER versus noise power. Here, the Gaussian noise is added to the measured signals in this evaluation. BER results with various the tag element spacing are presented. From the result of (a), it is found that BER performance is considerably improved when d is over 0.5 λ. From the result of (b), it is found that tag antenna spacing affects significantly BER performance when the distance between reader and tag is long. Nevertheless, BER lower than 10^{-2} is achieved even with the narrow spacing (0.2 λ) at 1 m distance when the noise power is −90 dBm. Since the observation bandwidth at the reader was narrower than 1 MHz, the actually expected noise power is much lower than −90 dBm. This means the passive MIMO even with quite narrow antenna spacing at tag side can really work with feasible receiver performances.

Conclusion

In this paper, the effect of the tag elements spacing on passive MIMO performance has been experimentally evaluated using our testbed. Even though the narrow tag element spacing causes the BER deterioration, the tag antenna with 0.2 wavelength spacing has achieved BER lower than 10^{-2} when the communication distance is 1 m and noise power is −90 dBm. These results support the feasibility of the passive MIMO for small RFID tags.

Acknowledgment

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References

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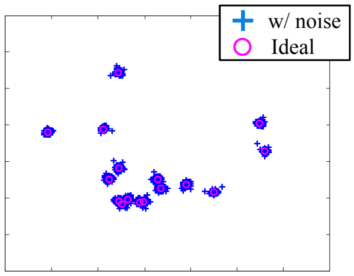
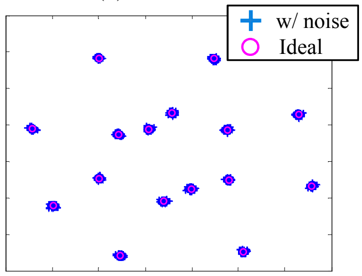
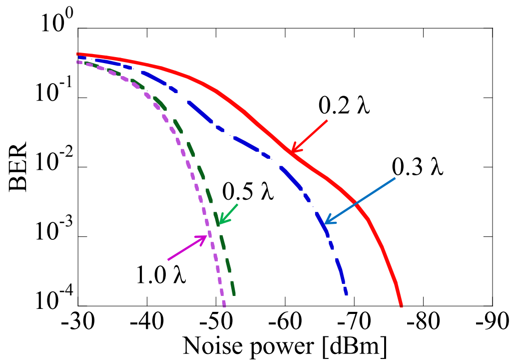


(a) d = 0.2 λ

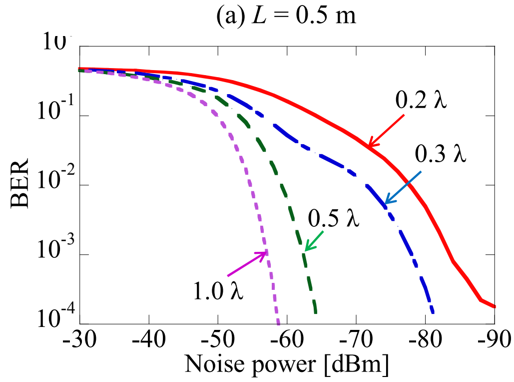


(b) d = 1.0 λ

Fig.3. An example of constellation



(a) L = 0.5 m



(b) L = 1.0 m

Fig.4. BER performance versus noise power