伝送工学研究会資料
Vol. 2013, No. 557-3, 2013 年 10 月

変調散乱ダイポールアレーアンテナの受信性能の実験的評価

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***Abstract*ð** The concept of modulated scattering antenna array (MSAA) has been proposed and its performance in receiving antenna array for the mobile handset has been evaluated. However, the previous researches have shown that the IF (Intermediate Frequency) signal level is seriously lower than RF signal level. In this paper , we studied experimentally the relationship between the receiving performance of MSAA and some factors such as, distance between transmitting and receiving antenna, antenna spacing of MSAA and LO (Local Oscillator) signal frequency in order to clarify the performance of MSAA. And it is shown that antenna spacing has great impact on improving IF signal level.
キーワード**:** Modulated scattering antenna array, RF front-end, Multiple-Input Multiple-Output (MIMO)

1. INTRODUCTION

MIMO (Multiple-Input Multiple-Output) communication is the attractive technology for wireless communications since MIMO communication can enhance daterate without expanding the spectral band-width [1]. LTE (Long-Term Evolution) standard allows multiple antennas on both ends of the wireless channel to support the mobile handsets communication [2]. However, it is very difficult to develop multi-antenna arrays suitable for mobile handsets. Because it is difficult to mount an antenna array with sufficiently low mutual coupling and low spatial correlation on a handset[3]–[4]. Moreover, since a number of separate RF front-end circuits are required corresponding to the number of antenna elements, a large amount of packaging space for the RF front-end circuits is necessary. Therefore, it is essential to develop multi-antenna arrays with simple configurations which are suitable for mobile handsets.

Recently, the concept of modulated scattering antenna array (MSAA), based on the modulated scattering technique (MST) has been proposed to overcome these difficulties[5]–[7]. MSAA consists of one receiving antenna element and several modulated scattering elements (MSEs), and the configurations of that are very simple compared with that of the ordinary array antenna for MIMO communications. This is because only one branch of the front-end circuit is required for the MSAA. However, the receiving IF (Intermediate Frequency) signal level of MSAA is seriously lower than RF signal level of that. The previous researches have shown that the receiving IF signal level of the modulated scattering monopole antenna array (MSMAA) can be improved by decreasing antenna array spacing [4]. However, a small array may result in a high correlation between array elements. Moreover, since we made different prototypes of modulated array antennas with different array spacing in the previous experiment, some errors were included in the measurement results because of individual diode performance has a little difference between each other.

In this paper, we used modulated dipole antenna array (MSDAA) with various array spacing in order to exactly evaluate the receiving performance of MSAA. Moreover, some parameter study of the MSAA is necessary for optimizing the receiving performance of the MSAA for MIMO communications. In this research, we studied experimentally the relationship between the receiving performance of MSAA and some factors such as, distance between transmitting and receiving antenna, antenna spacing of MSAA and LO (Local Oscillator) signal frequency in order to clarify the performance of MSAA.

2. EXPERIMENTAL CONFIGURE

2.1. *Modulated Scattering Technique*

The configuration of the MSAA with diodes is shown in Fig. 1. The MSAA is composed of one receiving antenna element and MSEs. The receiving antenna element is connected with the RF front-end and is applied RF signal, while MSEs are seen as antennas or scatters without their own receiving circuits. And Nonlinear impedance are mounted at MSEs for modulation and are fed by LO signals with low frequencies $f_{\mathrm{LO}i}$. When MSAA is excited by the RF signal f_{RF}, modulated scattering signals $f_{\mathrm{IF}i} = mf_{\mathrm{RF}} \pm nf_{\mathrm{LO}i}$ (m,n = 0, 1, 2, ..., and i = 1, 2, ..., N) will be obtained. This is because the nonlinear loads connected to the MSE and will be received

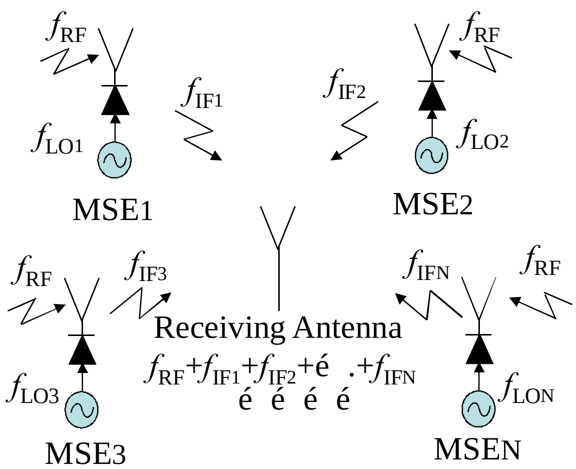

Figure 1. Configuration of MSAA

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by the receiving antenna. Since only one branch of the RF receiver is needed in MSAA, this feature of MSAA is attractive for the mobile handsets in MIMO systems where compactness and energy-saving are of primary concerns.

2.2. *Configuration of MSAA*

The geometry of a 2-element MSDAA is shown in Fig.2. This MSAA is composed of two half-wavelength dipole elements with from 0.1 to 0.5wavelengths spacing in this experiment. And two dipole elements are arranged in parallel. In Fig. 2, the above element is the MSE which is connected with nonlinear impedance, while below element is receiving antenna which is connected with the receiver circuit. A Schottky diode is mounted at the centre of MSE which is used as the nonlinear impedance for modulation. The MSAA is fed by LO signal and scatters IF signals, while the receiving antenna can receive both RF signal and IF signals. In this paper, RF signal frequency f_{RF} set to 2.50 GHz and LO signal frequency is set from10 to 100 MHz. Therefore, the IF signals f_{IF} = 2.51 ~ 2.60 GHz were observed in this experiment.

2.3. *Measurement System*

The measurement environment and system are shown in Fig. 3 and Fig.4, respectively. The measurement was performed by using 4 ports Agilent N5224A PNA in two types of environment. The transmitting antenna is one log-period dipole antenna array (LPDAA) and the receiving antenna array is the 2-element MSDAA. The RF signal which was applied to the LPDAA, is 2.50 GHz CW signal with 10 dB. And MSDAA could obtain the both RF and IF signals.

Figure 3 (a) shows the room of a laboratory, and it is line-of-sight (LOS) environment between transmitting antenna and receiving antennas. In this figure, *D* indicates the distance between transmitting and receiving antennas. We changed the distance *D* every 0.25λ from 3λ to 20λ, and measured receiving power at each distance as shown in Fig. 4 (a).

Figure 3 (b) shows the room of a basement with concrete structure, and it is non line-of-sight (NLOS) environment. The distance between the transmitting and receiving antennas was about 6 meters. In this measurement, the position of transmitting antenna is also fixed, while the position of receiving antenna array was changed by a step of 0.1λ in a 3.0λ ×3.0λ area as shown in Fig. 4 (b). therefore, measurement was repeated 31 ×31 times.

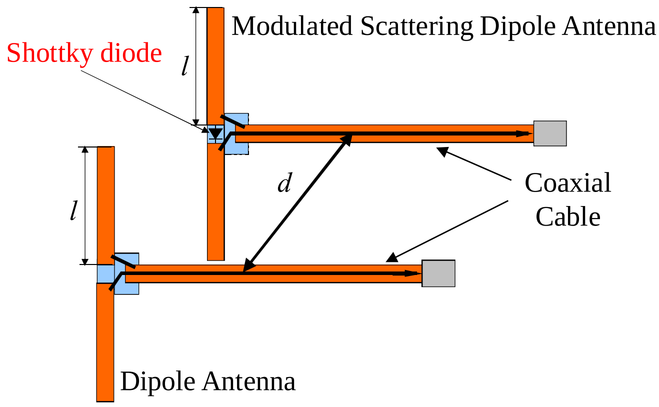


Figure 2. Geometry of MSDAA

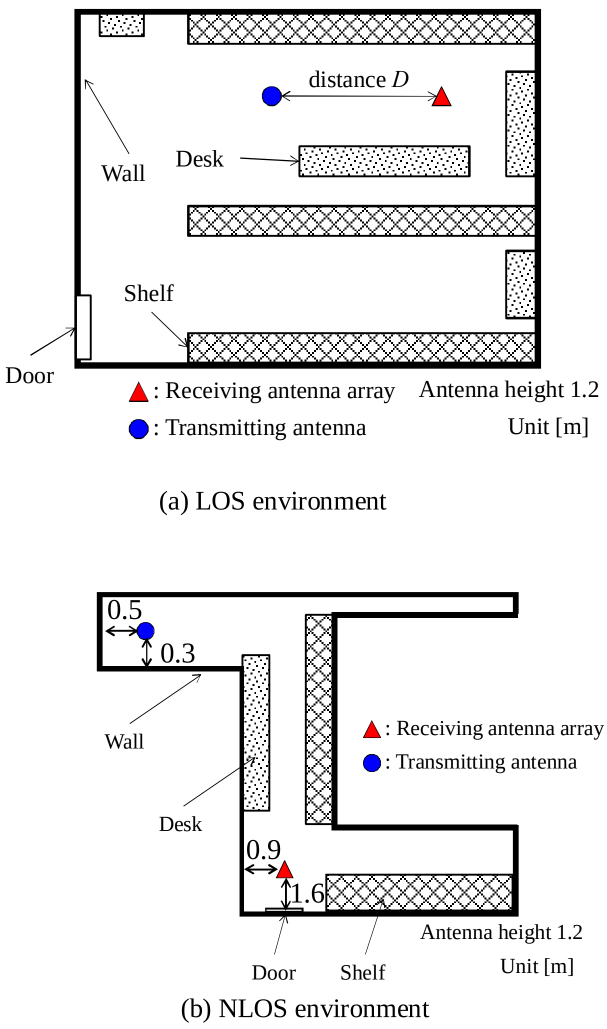


Figure 3. Measurement environment

3. EXPERIMENTAL RESULTS AND EVALUATIONS

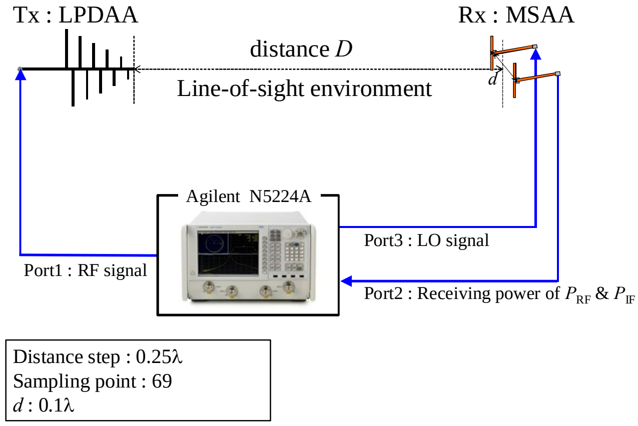
The receiving dipole antenna of MSDAA receives both 2.5 GHz signal and f_{IF} signal scattered by the MSE. The receiving power level of the RF signal P_{RF}, IF signal P_{IF} versus distance D is shown in Fig. 5, and the ratio of P_{IF} to P_{RF} is also shown in the same figure. In this result, LO signal frequency f_{LO} is set to 10 MHz, and array spacing is set to 0.1λ, respectively. And we measured receiving power in LOS environment. From this result, it is found that the receiving power of both P_{RF} and P_{IF} is improved as the distance D is shortened. And we also found that the ratio of P_{IF} to P_{RF} is about 25 dB and is almost independent of the distance D.

Figure 6 shows the relationship between the receiving performance and array spacing. In this result, LO signal frequency f_{LO} is set to 10 MHz. And we measured the receiving power in NLOS environment. From this result, it is found that the narrow spacing of MSDAA can improve IF signal level P_{IF} while the effect on the RF signal level P_{RF} is low. Moreover, it is also found that the ratio at 0.1λ has 10 dB improvement comparing to that at 0.5λ. This is because the narrow spacing of MSDAA improves the transmission characteristic between the receiving antenna and MSE as shown in Fig. 7. The definition of the port is that port1 is receiving antenna and port2 is MSE, respectively. We also found that the transmission characteristic has 1–2 dB difference between each frequency.

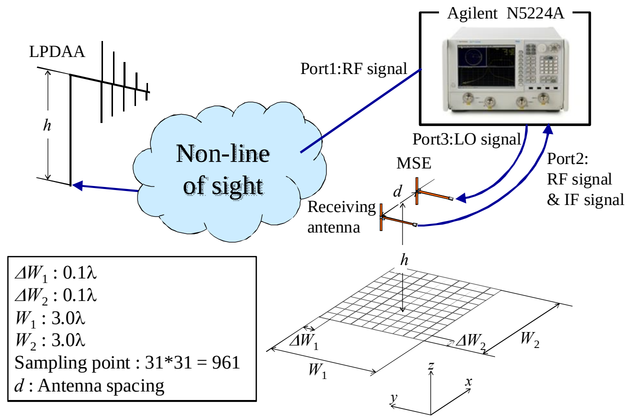
Moreover, the relationship between the receiving performance and LO signal frequency is shown in Fig. 8. In this result, antenna spacing is set to 0.1λ, and we changed LO signal frequency from 10 MHz to 100 MHz. From this result, we found that ratio of P_{IF} to P_{RF} is about –26 dB and is seen almost independent of the LO signal frequency. However, the MSAA has frequency characteristics, and we think that both input power of LO signal and receiving power of IF signal is not constant at different LO frequency. Therefore, we should investigate the relationship between LO frequency and frequency characteristics of MSAA.

4. CONCLUSION

In this paper, an experimental measurement has been carried out to clarify the relationship between the receiving performance and some factors such as, antenna spacing and LO signal frequency, in actual indoor NLOS environment. In this measurement, we used MSDAA as



(a) LOS environment



(b) NLOS environment

Figure 4. Measurement system

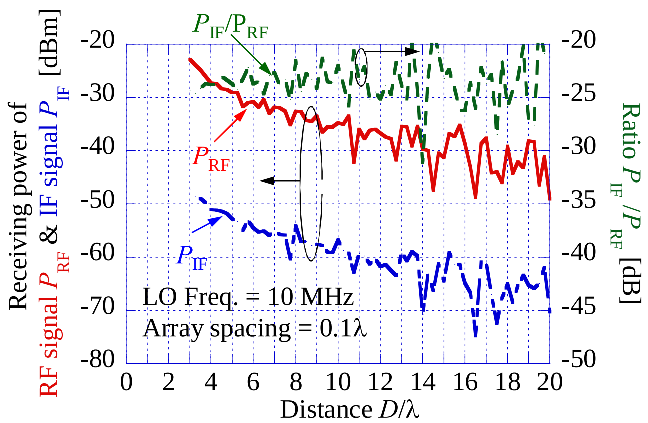


Figure 5. Receiving power versus distance D

the receiving antenna array in order to exactly evaluate the performance of MSAA.

From experimental result, we found that the ratio of PIF to PRF is almost independent of the distance between the transmitting and receiving antenna. And it has been found that the narrow antenna spacing improves the ratio of IF signal level P_{IF} to RF signal level P_{RF} since the narrow spacing also improves transmission characteristics between the receiving antenna and MSE. Moreover we also found that the effect of LO frequency on receiving performance is negligible. From these results, we clarified a part of the receiving performance of MSAA. However, we need to investigate the relationship between LO frequency and frequency characteristics of MSAA in the future.

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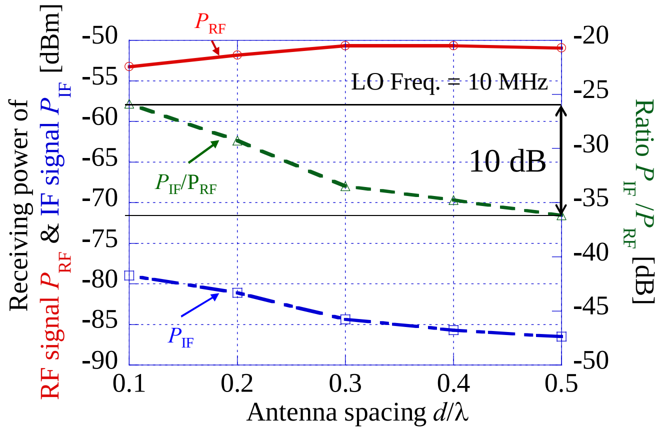

Figure 6. Receiving power versus antenna spacing

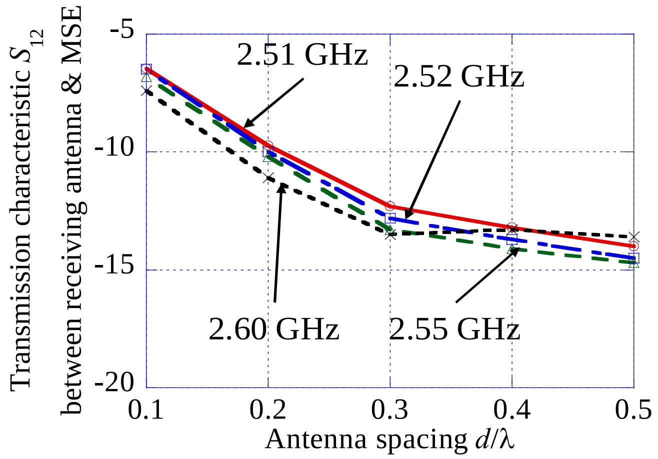

Figure 7. Transmission characteristics versus antenna spacing

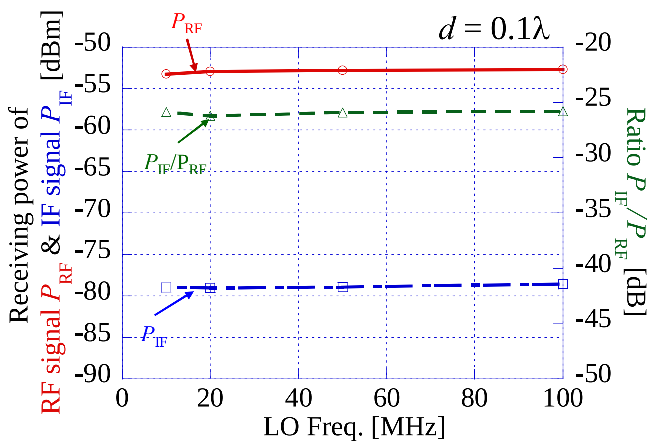

Figure 8. Receiving power versus LO signal frequency