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# Diversity performance of modurated scattering array antenna

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**Abstract:** The diversity performance of the modurated scattering array antenna (MSAA) with various array spacing is measured in Rayleigh fading environment to investigate experimentally the relation between the array spacing and the diversity performance of the MSAA. A 2-element modulated scattering monopole array antenna with various array spacing which is supposed to be used for mobile handset applications is used as the measurement model. It is found that the diversity performance of the MSAA can be improved by reducing the array spacing as small as about 0.2 wavelength.

**Keywords:** antenna, array antenna, modulation, wireless communications, mobile handset

**Classification:** Microwave and millimeter wave devices, circuits, and systems

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## 1 Introduction

Array antennas have been widely studied for cellular base stations because

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they are effective in solving the problems of multipath fading and co-channel interference to improve the performance and capacity in wireless communication systems. However, little effort has been made for developing array antennas suitable for mobile handsets [1, 2, 3], because it is difficult to mount an antenna array with sufficiently low spatial correlation on a handset and because it costs very much to implement a very complicated electrical circuits for operating adaptive algorithm. Therefore, it is required to develop array antennas with simple configurations for mobile handsets. A new concept of array antennas, which is called modulated scattering array antenna (MSAA), has been proposed based on the modulated scattering technique to overcome these difficulties by the present authors [4]. The configurations of the MSAA are very simple compared with that of the ordinary array antenna because only one branch of the front-end circuit is required. The effectiveness was demonstrated by experimental investigations which showed that a 3-element MSAA composed of one quarter-wavelength monopole and two quarter-wavelength modulated scattering monopoles with a quarter-wavelength array spacing resulted in a diversity gain up to 8 dB at 0.1% of the cumulative distribution function in Rayleigh fading environment.

It is supposed that reducing the array spacing between the modulated scattering elements (MSE) and the receiving antenna element could help to increase the scattered signal and further to improve the diversity performance. However, a small array spacing may result in a high correlation between array elements and may degrade the diversity performance. Therefore, a parameter study of array spacing of the MSAA is necessary for optimizing the performance of the MSAA in receiving diversity use. In this research, the diversity performance of the MSAA with various array spacing is measured in Rayleigh fading environment to investigate the relation between the array spacing and diversity performance of the MSAA.

## 2 Experimental Configuration

A 2-element MSAA for mobile handset applications operating at 2.4 GHz is used as the experimental model whose configuration is shown in Fig. 1. The array antenna is composed of two quarter-wavelength monopoles. The right element is the normal antenna element and the left one is the MSE. The MSAA with array spacing $d$ of 0.1 to 0.5 wavelength were fabricated for the measurement. A schottky diode between the MSE monopole and the ground plane is used as the nonlinear impedance for modulation. In the measurement, the normal monopole antenna is connected to a real-time spectrum analyzer (Tektronix RSA3303A) as the RF receiver, which is capable of capturing time-varying RF signal with 15 MHz bandwidth. A 3 MHz local signal generated by a signal generator (NF function Synthesizer WF-1966) was applied to the MSE. The measurement was performed in a Rayleigh fading environment realized in a non-line-of-sight (NLOS) indoor environment as described in [4].


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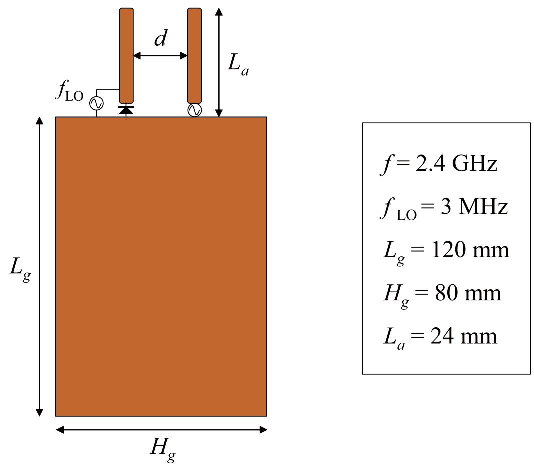


**Fig. 1.** Configuration of 2-element MSAA for mobile handset applications.

## 3 Experimental Results

The normal monopole antenna of the MSAA receives both 2.4 GHz signal and $f_{IF}$ signal scattered by the MSE. Figure 2 shows one captured spectrum received by the real-time spectrum. The cumulative distribution function (CDF) is obtained from 120,000 flames of the spectrum recorded in time-domain. The selection diversity level at two branches of 2.4 GHz and 2.4 GHz–3 MHz at CDF = 0.1% were calculated for evaluating the diversity performance. Figure 3 shows the CDF of the received lever of RF, IF and selection diversity when the array spacing is a half-wavelength. It is found that the level IF signal is so low at this array spacing that the advantage of diversity is insignificant.

The received lever of the RF signal, IF signal and the lever using the selection diversity versus the array spacing is shown in Fig. 4. As the array spacing is reduced, the RF signal becomes small because of existence of the mutual coupling, but the receiving lever using the selection diversity increases

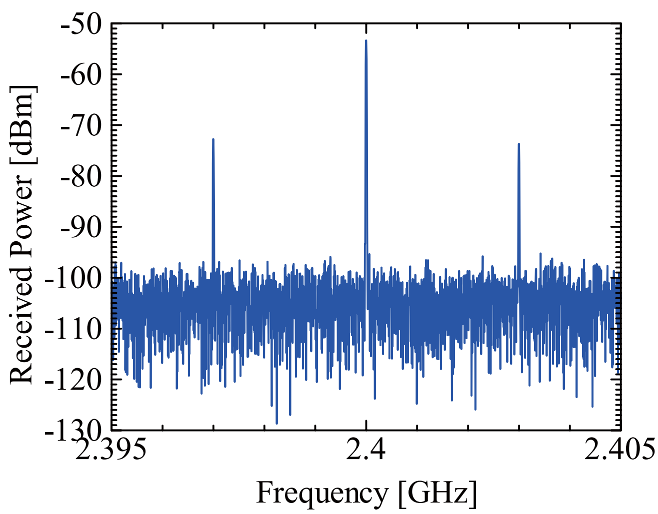


**Fig. 2.** Spectrum of RF and IF signals received by MSAA.


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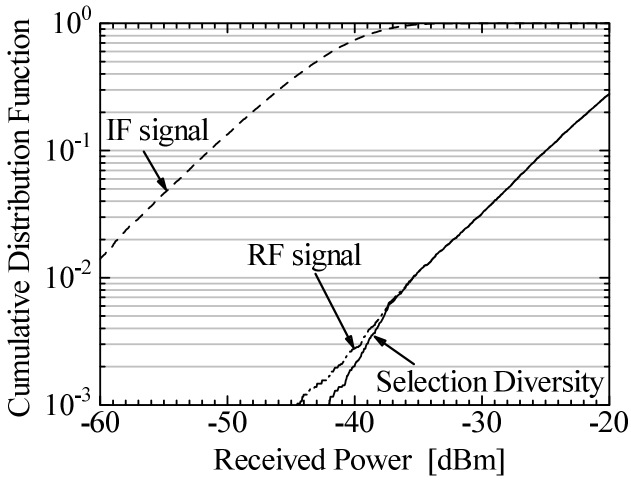


**Fig. 3.** CDF of received lever of RF, IF signals and selection diversity when array spacing is a half-wavelength.

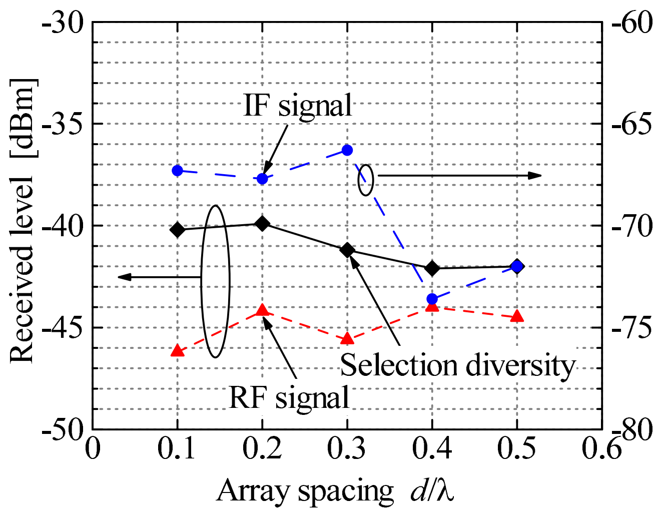


**Fig. 4.** Received level of RF signal, IF signal and selection diversity at 0.1% of CDF as a function of array spacing.

till the array spacing becomes as small as 0.2 wavelength. The receiving level using the selection diversity at the array spacing of 0.2 wavelength is about 2 dB higher than that at half-wavelength, while corresponding increase of the level of IF signal is about 5 dB.

The experimental results indicate that the diversity performance of the MSAA can not be improved by simply increasing the array spacing, but it may be improved by locating the array elements with a compact spacing to the contrary, because a higher lever of the scattered IF signal can be received by the antenna element as the array spacing becomes small. An increased IF signal can reduce the level difference between the RF and IF branches as shown in Figs. 2 and 3, which then benefits the selection diversity performance.


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## 4 Conclusions

The diversity performance of the MSAA with various array spacing has been measured in Rayleigh fading environment to investigate experimentally the relation between the array spacing and diversity performance of the MSAA.

It has been found that the diversity performance of the MSAA can not be improved by simply increasing the array spacing, but it may be improved by mounting the array elements with a compact spacing to the contrary. A small array spacing reduces the level difference between the RF and IF branches and then benefits the selection diversity performance. The experimental study demonstrated that a good diversity performance can be archived by using the compact MSAA where a small array spacing and only one branch of front-end circuit are required, which indicates that the MSAA can be one of the possible solutions to mount array antenna to the mobile handset applications where mounting space and manufacturing cost are strictly limited.


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