A Wideband MIMO Antenna Using Leaf-Shaped Monopole and Notch Antennas

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***Abstract*— This paper presents a design of a wideband 4-port antenna array being useful for MIMO applications. In the designed antenna array that operates over the frequency band of 7.25–10.25GHz, a leaf-shaped monopole and notch antennas are employed as the array elements. By using these orthogonal polarization elements, both low coupling level between adjacent array elements and miniaturization of the antenna structure are realized. In order to demonstrate the effective performance of the presented configuration, characteristics of the designed MIMO antenna are evaluated by the finite-difference time domain (FDTD) analysis. Over the above-mentioned frequency band, the designed antenna has the reflection coefficient of less than −10 dB and the mutual coupling between ports below −12 dB. In addition, the antenna port envelope correlation coefficient is observed to be less than 0.22.**

Keywords—MIMO Antennas, wideband antennas, leaf-shaped monopole and notch antennas

I. INTRODUCTION

In recent years, MIMO (Multiple-Input Multiple-Output) communication technology has attracted considerable research attention, and has widely applied for various kinds of communication systems, such as Wi-Fi, LTE and WiMAX. Employing a wideband MIMO antenna [1]–[3] is effective way for covering multiple communication systems for which MIMO technology is adopted.

This paper presents a design of a wideband 4-port antenna array being useful for MIMO applications. In the designed antenna array that operates over the frequency band of 7.25–10.25 GHz, a leaf-shaped monopole and notch antennas are employed as the array elements. The designed antenna is composed of two leaf-shaped monopole antennas and two leaf-shaped notch antennas. These antennas are arranged on the same dielectric substrate such that the polarizations of adjacent antennas are orthogonal to each other. By adopting these orthogonal polarization elements, both low coupling level between adjacent array elements and miniaturization of the antenna structure are realized.

In order to demonstrate the effective performance of the presented configuration, characteristics of the designed wideband MIMO antenna are evaluated by the finite-difference time domain (FDTD) analysis. Over the above-mentioned frequency band, the designed antenna has the reflection coefficient of less than −10 dB and the mutual coupling between ports below −12 dB. In addition, the antenna port envelope correlation coefficient is observed to be less than 0.22.

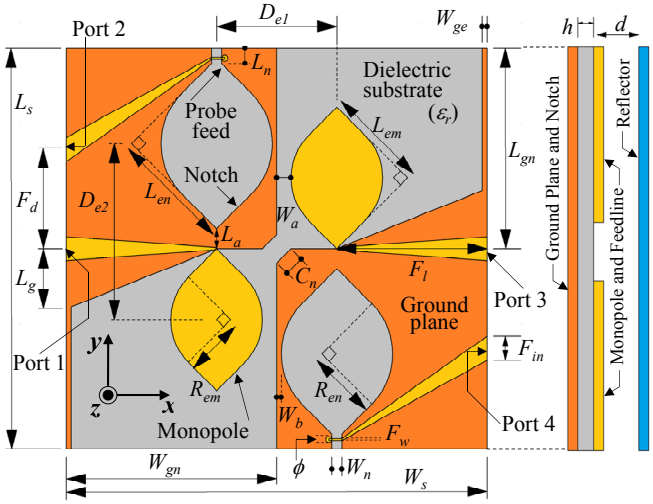


Fig. 1. Configuration of the wideband 4-port MIMO antenna.

TABLE I. STRUCTURAL PARAMETERS OF THE DESIGNED ANTENNA. ALL DIMENSIONS ARE INDICATED IN MILLIMETER.

ε_r	h	d	W_s	L_s	R_{em}	L_{em}	R_{en}	L_{en}
2.17	0.76	11	42	40	6	10	7.1	12
D_{e1}	D_{e2}	W_n	W_{ge}	W_{gn}	W_a	W_b	C_n	ϕ
17.5	12	1	0.5	21	1.4	0.45	2	0.6
F_{in}	F_l	F_w	F_d	L_g	L_{gn}	L_n	L_a	
2.4	15	0.2	10	6	20	1.5	2	

II. ANTENNA STRUCTURE

Fig. 1 illustrates the configuration of the designed 4-port antenna array for MIMO applications. As radiating elements of the antenna array, a leaf-shaped monopole and notch antennas are printed on a dielectric substrate having the thickness of h, relative permittivity of ε_r. These antennas are the modified forms of leaf-shaped bowtie dipole and slot antennas which have been previously proposed by the authors [4], [5]. The monopole and notch antennas are designed by rounding the corner of the square copper sheets with the curvature radii of R_{em} and R_{en}, respectively. The side lengths of the square copper sheets for monopole and notch antennas are denoted by L_{em} and L_{en}, respectively. Two monopole antennas and two notch antennas are arranged on the dielectric substrate such that the polarizations of adjacent antennas are orthogonal to each other. By employing this arrangement, both low mutual coupling between adjacent array elements and miniaturization of the antenna structure are realized in the proposed configuration. The notch antennas are cut on the ground plane printed on the top side of the substrate. On the other hand, the monopole antennas is arranged on the bottom side of the substrate.

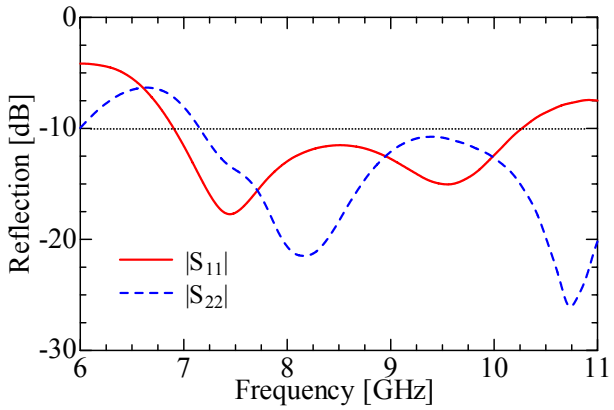


Fig. 2: Frequency response of reflection coefficient.

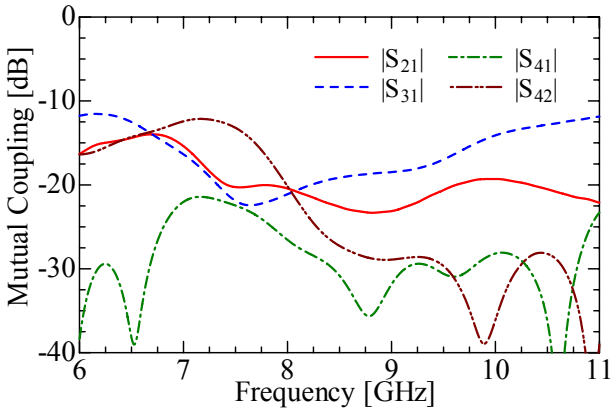


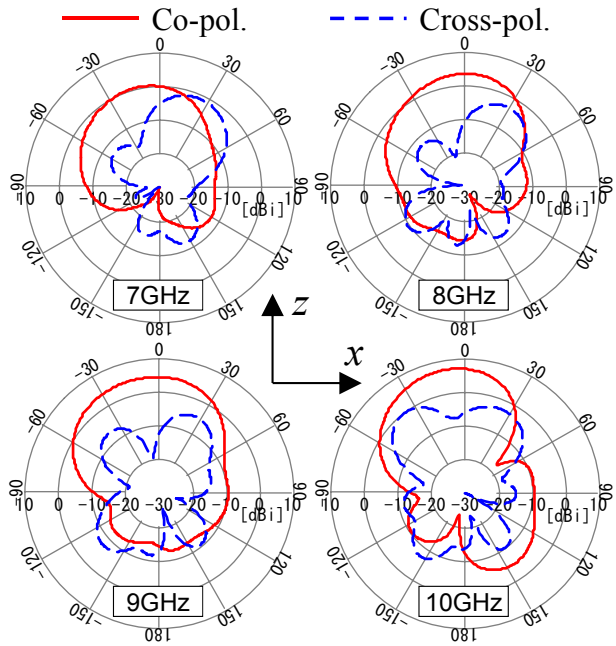
Fig. 3: Frequency response of mutual coupling.

Both monopole and notch antennas are fed by microstrip lines which are linearly tapered in order to achieve 50Ω impedance matching at each port. The strip conductors of the microstrip lines are printed on the bottom side of the substrate. For the monopole antennas, the end of the feedline is directly connected to the radiating elements. The notch antennas are connected to the end of the feedline by conducting posts. In order to obtain unidirectional radiation characteristics, a back reflector having the same dimension as those of the antenna substrate is placed underneath the antenna array.

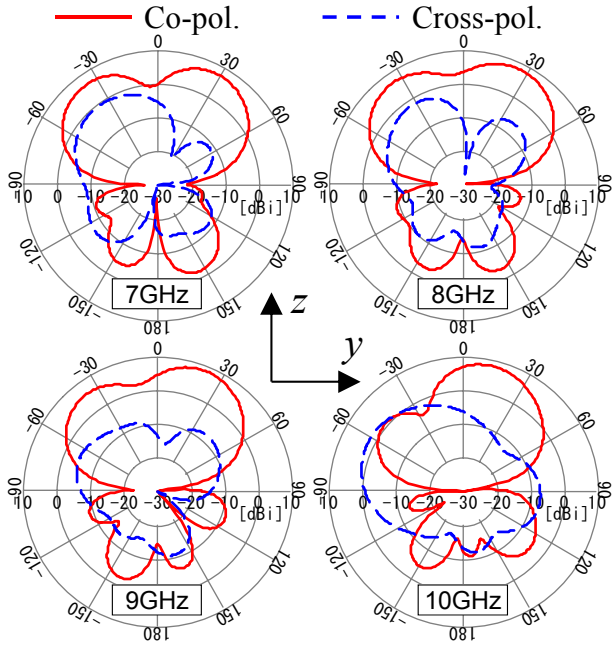
The structural parameters of the antenna assumed in the following investigations are listed in Table 1. The dimensions of the radiating elements are optimized to achieve the operation over the frequency range from 7.25GHz to 10.25GHz, which corresponds to the UWB high band in Japan. In the following considerations, the input terminals for the monopole antennas are designated as port 1 and port 3, and those for the notch antennas are designated as port 2 and port 4, as shown in Fig. 1.

III. NUMERICAL EVALUATION OF ANTENNA PERFORMANCE

Characteristics of the designed MIMO antenna array are evaluated by the FDTD analysis. In the first place, the frequency response of the reflection coefficient is evaluated for the case where the monopole (port 1) and notch (port 2) antennas are excited independently. When the port 1 or port 2 is excited, the other ports are assumed to be terminated with 50Ω loads in the simulation. The simulated results are shown



(a) *xz*-plane (H-plane) patterns

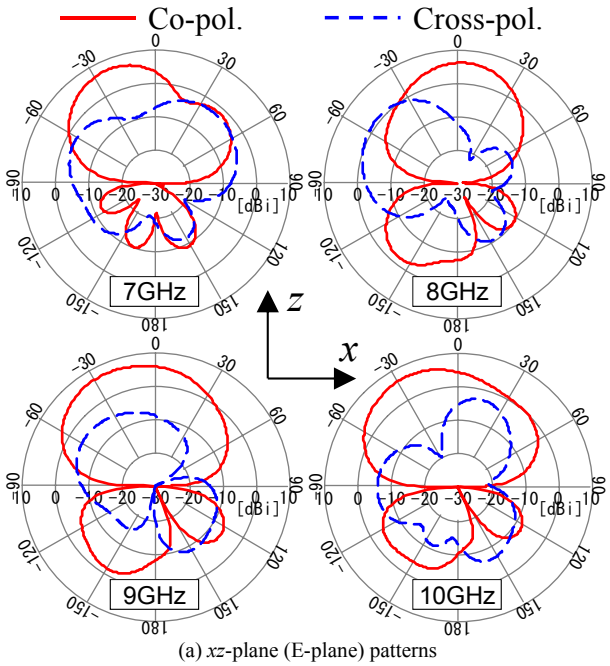


(b) *yz*-plane (E-plane) patterns

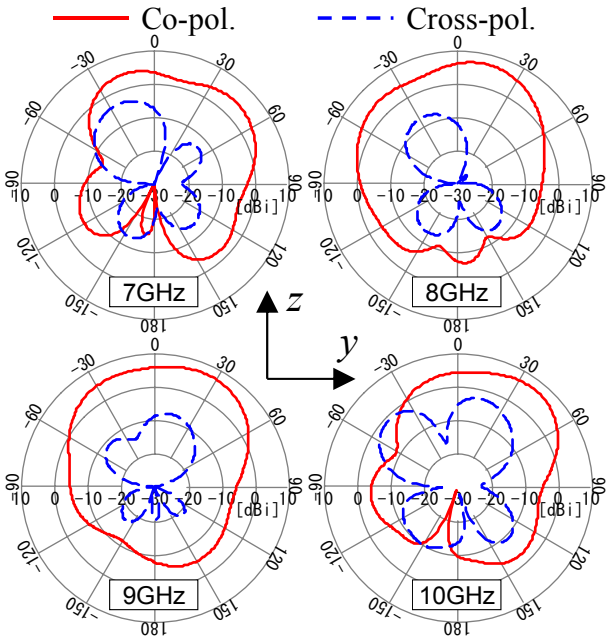
Fig. 4: Radiation patterns when port 1 (monopole antenna) is excited.

in Fig. 2. For both port 1 and port 2, the reflection coefficients are observed to be less than −10dB.

In the next place, all mutual couplings between ports are evaluated. Fig. 3 shows the frequency response of the mutual couplings between ports 1 and 2, ports 1 and 3, ports 1 and 4, ports 2 and 4. For the case between the monopole and notch antennas ($|S_{21}|$ and $|S_{41}|$), the couplings are observed to be less than around −20dB over the frequency range from 7.25GHz to 10.25GHz. The maximum coupling level is observed to be −12dB for the case between the notch antennas ($|S_{42}|$).



(a) *xz*-plane (E-plane) patterns



(b) *yz*-plane (H-plane) patterns

Fig. 5: Radiation patterns when port 2 (notch antenna) is excited.

Radiation patterns for the case where one of ports is excited and the other ports are terminated with 50Ω loads have been evaluated at the frequencies of 7GHz, 8GHz, 9GHz and 10GHz. Fig. 4 and Fig. 5 shows the simulated radiation patterns for the case when port 1 and port 2 are independently excited, respectively. In these figures, solid and broken lines denote radiation patterns for co- and cross-polarization in each planes, respectively. It can be observed that the antenna exhibits quasi-unidirectional at each frequencies for the case when the port 2 excited. When the port 1 is excited, bi-directional radiation is observed in E-plane. This result may be due to the asymmetry of the antenna structure.

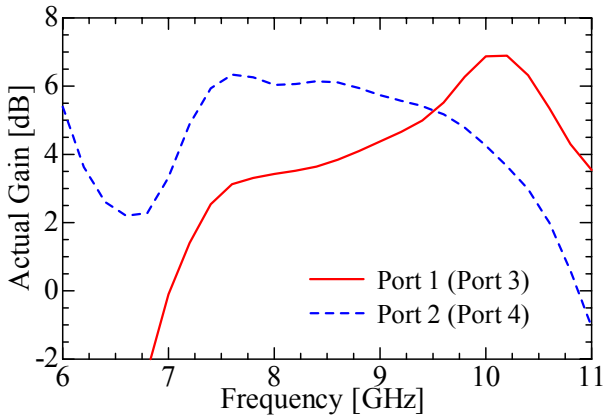


Fig. 6: Frequency response of actual gain in +*z*-direction.

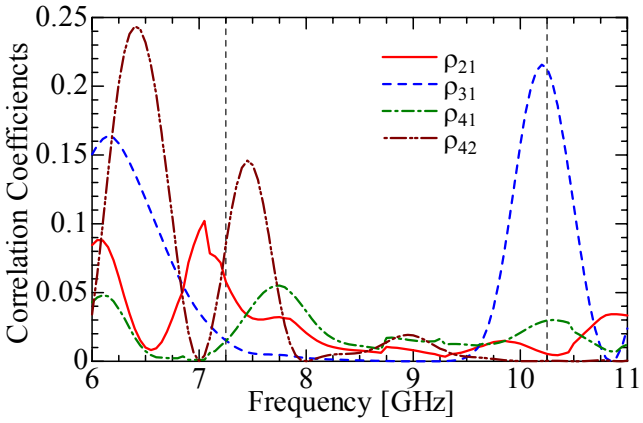


Fig. 7: Frequency response of envelope correlation coefficients.

Fig. 6 shows the frequency response of actual gain observed in +*z*-direction. Over the frequency range from 7.25GHz to 10.25GHz, the actual gain is observed to be 2–6dBi and 3.5-6dBi for the cases when port 1 and port 2 are excited, respectively. As shown in Fig. 4(b), dimples of E-plane patterns are found in +*z*-direction for lower frequencies. These dimples leads to the decrease of the actual gain at lower frequencies when port 1 is excited.

In order to evaluate MIMO performance of the designed antenna array, the envelope correlation coefficient among two antennas is calculated by the use of scattering parameters at each antenna port. The envelope correlation coefficient between *i*-th port and *j*-th port antennas is given by the following expression [6].

$$\rho_{ij} = \frac{|S_{ii}^{*}S_{ij} + S_{ji}^{*}S_{jj}|^2}{(1-|S_{ii}|^2-|S_{ji}|^2)(1-|S_{jj}|^2-|S_{ij}|^2)} \quad (1)$$

Fig. 7 shows the frequency response of envelope correlation coefficients that are evaluated by substituting simulated scattering parameters into the above expression (1). As suggested in [6], a good diversity effect can be obtained when the envelope correlation value is less than 0.5. As can be seen from Fig. 7, the envelope correlation values remain under 0.22 within the frequency band of 7.25-10.25GHz. This leads us to expect good performance of the proposed configuration in terms of diversity.

IV. CONCLUSIONS

A wideband 4-port MIMO antenna array has been presented in this paper. In the designed antenna array that operates over the frequency range from 7.25GHz to 10GHz, a leaf-shaped monopole and notch antennas are used as the array elements. In order to demonstrate the effective performance of the proposed configuration, characteristics of the designed MIMO antenna are evaluated numerically by the FDTD analysis. Over the frequency band of interest, the reflection coefficient is observed to be less than −10 dB and the mutual coupling between ports are less than −12 dB. The antenna port envelope correlation coefficients are observed to be less than 0.22, which are substantially smaller than the value of 0.5 being suggested for realizing the good diversity effect.

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