Measurement of 15 GHz beam adjustable microstrip antenna arrays with a variable short stub and with a varactor diode

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Abstract - **This paper presents measured performance of 15 GHz beam adjustable microstrip antenna arrays (BA-MSAAs). The BA-MSAA consists of a central patch element fed by a feeding line and two parasitic patches with a variable reactance circuit (VRC) adjacent to the center patch. Radiation pattern of the BA-MSAA is controlled by reactance values of the VRCs. In order to evaluate beam-shaping performance of the BA-MSAA in 15 GHz, the BA-MSAA with square patch elements and two types of the VRCs, with a variable short stub (VSS) and with a varactor diode, are designed and fabricated. In this paper, performances of the VRCs with the VSS and the varactor are measured. Then, beam-shaping performance of the BA-MSAAs with the two types of the VRCs using the VSS and the varactor diode is presented in 15 GHz.**

Index Terms — **Microstirp antenna, Patch array, Beam adjustable array, Pattern reconfigurable antenna, Variable reactance circuit.**

1.   Introduction

Beam adjustable antennas or pattern reconfigurable antennas have been demanded attractively for microwave and millimeter wave applications such as future mobile communication systems and high-speed wireless LAN systems. Beam adjustable microstrip antenna arrays (BA-MSAAs) have been proposed for the beam adjustable antennas or pattern reconfigurable planar antenna [1], [2]. The BA-MSAA consist of a center MSA fed by a feeding line and two parasitic MSA with variable reactance circuits (VRCs) adjacent to the center MSA. Because a reactance of the VRC with a varactor diode can be controlled by a DC bias voltage applied to the varactor, radiation pattern or beam direction of the BA-MSAA can be varied by changing the reactance of the VRCs. Therefore, electronic beam-shaping or beam scanning of the BA-MSAA is realized [2].

In [2], a basic design of the BA-MSAA in which almost square MSAs are arranged at an interval of $0.4\lambda_0$ (wavelength in free space at design frequency) is presented. From a viewpoint of practical use, miniaturization of the BA-MSAA is preferable. For this purpose, BA-MSAAs using bow-tie element [3] and with H-shaped element [4] have been proposed. Other miniaturization designs of the BA-MSAA, a combination of a narrow-width center rectangular MSA and wide-width both-side parasitic rectangular MSAs [5], three- and seven-element BA-MSAAs with all narrow-width elements [6]-[9], and BA-MSAAs with square ring

patch elements [10] and with slitted patch elements [11], are reported. All these BA-MSAAs are designed in 5 GHz.

In order to apply the BA-MSAA to higher frequency, the BA-MSAA is designed and fabricated in 15 GHz [12]. Three square MSAs are arranged at an interval of $0.4\lambda_0$ on a dielectric substrate with a relative dielectric constant of 2.6 and a thickness of 0.6 mm, as shown Fig. 1. Furthermore, two types of the VRCs, with a variable short stub (VSS) and with a varactor diode, are designed for the BA-MSAA. In this paper, performances of the VRCs with the VSS and the varactor are measured. Then, beam-shaping performance of the BA-MSAAs with the two types of the VRCs using the VSS and the varactor diode is presented in 15 GHz.
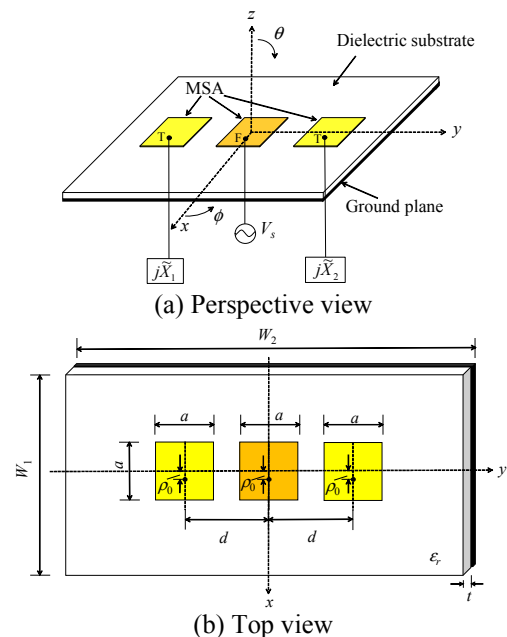

(a) Perspective view

(b) Top view

$$\begin{bmatrix} a = 5.8, \, d = 0.4\lambda_0, \, \rho_0 = 0.812, \, W_1 = 20.0, \, W_2 = 36.0, \\ t = 0.6, \, \text{unit:[mm]}, \, \varepsilon_r = 2.6, \, \tan\delta = 1.8 \times 10^{-3} \end{bmatrix}$$

Fig. 1. Configuration of the 15 GHz BA-MSAA.

2.   A BA-MSAA with a Variable Short Stub (VSS)

Figure 1 shows a configuration of the BA-MSAA designed for 15 GHz. Three square MSAs are arranged at a spacing of $0.4\lambda_0$. The center MSA is fed by a feeding line and the VRCs are connected to the both sides of the parasitic MSAs from the backside of the ground plane. H-plane pattern of the

BA-MSAA is controlled by the reactance values of the VRCs (jX_1 and jX_2). A dielectric substrate with a relative dielectric constant of 2.6 and a thickness of 0.6 mm is used.

Figure 2 presents measured reactance of the VRC with a VSS at 14.9 GHz. The reactance is varied by changing a length of the coax phase shifter with a short termination mechanically. As shown in Fig. 3, the reactance normalized by 50Ω can be shifted from −2.0 to 2.0. The variation range of the reactance is the same as the VRC of 5 GHz. A real part of impedance of the VRC with the VSS is varied from 4 to 20Ω, which is a larger result than that of VRC of 5 GHz.

Figure 3 presents measured radiation patterns of the BA-MSAA with the VSS in H-plane at 14.9 GHz when the normalized reactance is $\widetilde{X}_1 = -\widetilde{X}_2$. As shown in Fig. 3, the main beam is tilted from the broadside to around 40 deg. when $\widetilde{X}_1$ is varied from 0 to 2.0, which is similar tendency to the BA-MSAA of 5 GHz.
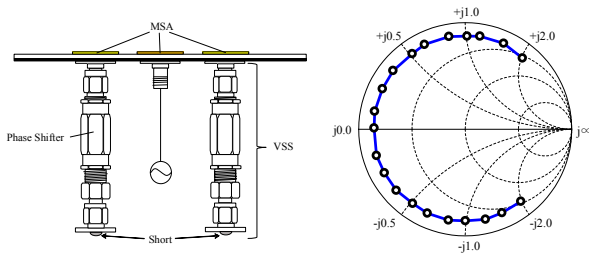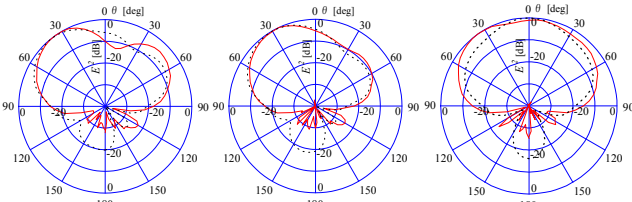

Fig. 2. Reactance of the VRC with the VSS.

$\widetilde{X}_1 = 2.0, \widetilde{X}_2 = -2.0$ $\widetilde{X}_1 = 1.0, \widetilde{X}_2 = -1.0$ $\widetilde{X}_1 = 0, \widetilde{X}_2 = 0$

Fig. 3. Radiation pattern of the BA-MSAA with the VSS.

— Exp.(VSS)
--- Sim.

3. A BA-MSAA with a Varactor Diode

Figure 4 presents measured reactance of the VRC with a varactor diode at 14.9 GHz. The reactance is varied by changing a DC bias voltage applied to the varactor electronically. As shown in Fig. 4, the reactance of the VRC with the varactor is limited from −0.5 to 0.5 when the DC voltage is set to 0 to 12V. The variation range of the reactance is much smaller that that of 5 GHz. A large real part of impedance of the VRC with the varactor is observed from 12 to 18Ω.

Figure 5 presents measured radiation patterns of the BA-MSAA with the varactor in H-plane at 14.9 GHz when the normalized reactance is $\widetilde{X}_1 = -\widetilde{X}_2$. As shown in Fig. 5, the main beam is tilted to around ± 25 deg. when $\widetilde{X}_1 = \pm 0.5$, respectively. The measured sidelobe level of the BA-MSAA with the varactor becomes larger than those with the VSS and of simulation IE3D due to effects of the real part of the impedance of the VRC of the varactor.

4. Conclusion

In this paper, the BA-MSAAs with the variable short stub and with the varctor diode are designed and tested in 15GHz. The BA-MSAA with the VSS exhibits almost similar beam shaping performance to that of 5 GHz. The beam scanning angle of the BA-MSAA with the varactor becomes smaller because the variable range of normalized reactance of the VRC with the varactor is limited within −0.5 to 0.5.
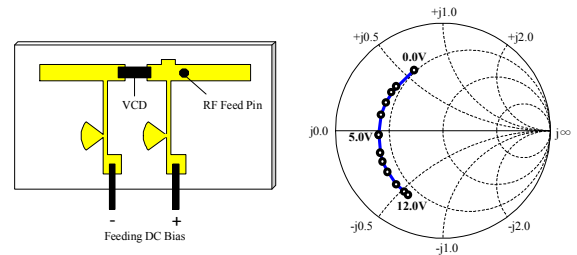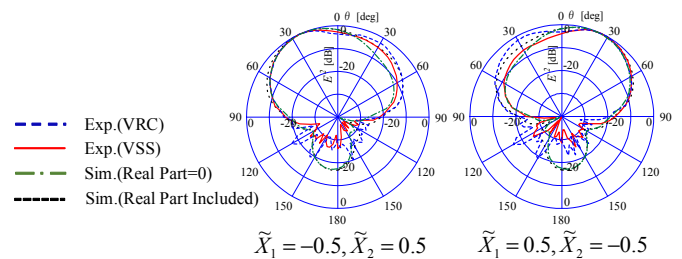

Fig. 4. Reactance of the VRC with the varactor.

- - - Exp.(VRC)
— Exp.(VSS)
-·-·- Sim.(Real Part=0)
----- Sim.(Real Part Included)

$\widetilde{X}_1 = -0.5, \widetilde{X}_2 = 0.5$ $\widetilde{X}_1 = 0.5, \widetilde{X}_2 = -0.5$

Fig. 5. Radiation pattern of the BA-MSAA with the varactor.

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