Design of a Linearly Polarized Radial Line MSA Array with Stacked Circular Patch Elements

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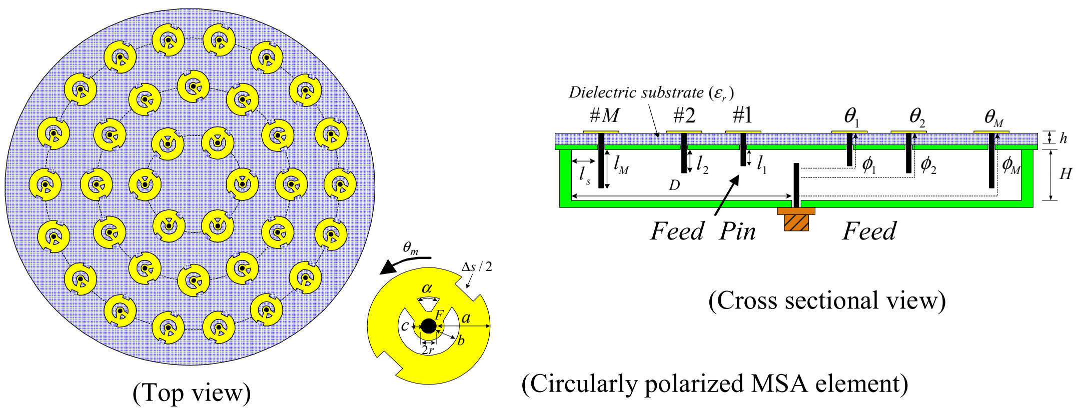
1. Introduction

Microstrip antennas (MSAs) and its arrays are applied to numerous purposes because of their features of small size, low profile, lightweight, and low cost in fabrication [1], [2]. For MSA arrays fed by microstrip lines for high gain use, feeding loss due of the microstrip lines becomes a problem. On the other hand, MSA arrays fed by a radial waveguide (RL-MSAA) are developed for high gain use such as DBS reception because transmission loss of the radial waveguide is very small [3]-[5].

Figure 1 presents a configuration of an RL-MSAA for circular polarization. MSAs are arranged concentrically on a dielectric substrate and are excited by a cylindrical wave propagating in the radial waveguide via a coupling probe. A desired amplitude distribution of the MSA array is designed by tuning a length of the probe. Furthermore, for circularly polarized arrays, radiation phase of the MSA can be controlled by orientation angle of the MSA. However, for linearly polarized arrays, rotation of the MSA cannot be used for design of phase distribution of the array. For this purpose, a stacked MSA with a stub for a linearly polarized RL-MSAA is proposed [6], [7]. Radiation phase of the MSA is controlled by tuning a length of the stub, however, variation range of the phase is limited within around 80 degrees. Another method of phase control for a linearly polarized RL-MSAA is to use a microstrip line between the coupling probe and the MSA [8].

In this paper, a stacked MSA with different radii of circular patches is proposed for a linearly polarized RL-MSAA. Large radiation phase variation as well as wideband impedance matching is achieved by tuning radii of the upper and lower patches. A prototype RL-MSAA with three concentric rows of the stacked MSAs are designed and tested in 12 GHz.



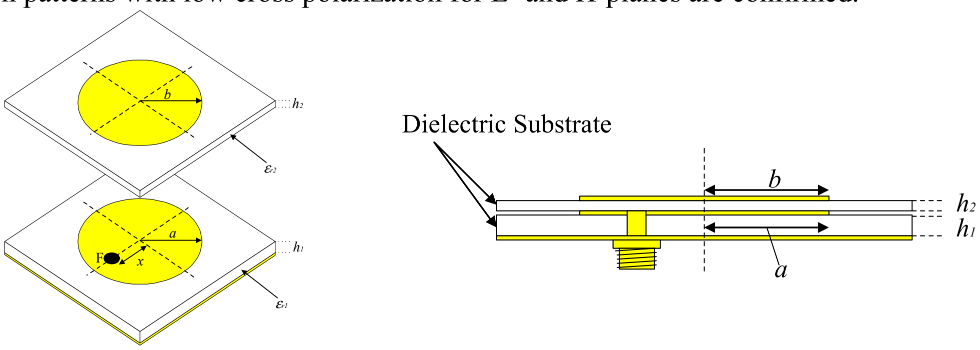
(Top view) (Circularly polarized MSA element) (Cross sectional view)

Figure 1: A configuration of an circularly polarized RL-MSAA.

2. Phase control of a stacked MSA with different radii

Figure 2 presents a stacked MSA with different radii of circular patches. Circular patches are placed on a top and bottom dielectric substrates. Radiation phase of the MSA can be controlled by changing radii of the upper and lower patches. The stacked configuration is used in order to obtain wideband impedance matching because the resonant frequency of the MSA is varied when the radii are changed.

Figure 3 presents simulated radiation phase of the stacked MSA at 12.0 GHz when the radii of the patches are varied, where a and b are radii of the lower and upper circular patches, respectively, a position of feeding point is $x = 1.1$ mm, thicknesses of the bottom and top dielectric substrates are $h_1 = 1.2$ mm and $h_2 = 0.6$ mm, respectively, and relative dielectric constants of the two substrates are $\varepsilon_{r1} = \varepsilon_{r2} = 2.6$. The simulation is performed by using Zeland IE3D. As the radii are varied in the same values ($a = b$), the radiation phase is changed widely from –80 to –210 degree. When the radius of the upper patch is fixed to $b = 4.2$ mm and the radius of the lower patch a is varied to 4.6 mm, the radiation phase is extended to –250 degree. Totally, almost 180 deg. phase variation is observed. Furthermore, by changing the feeding point to the opposite side of the patch, almost 360 deg. phase variation is achieved. Figure 4 (a) presents simulated return loss characteristics of the stack MSA when the radii of the two patches are varied in the same values ($a = b$). Wideband return loss cartelistic based on the stack configuration as well as the reflection less than –10 dB at 12.0 GHz for the different radii are confirmed. Figure 4 (b) also presents the simulated return loss characteristics when the radius of the upper patch is fixed to $b = 4.2$ mm. The reflection at 12.0 GHz is still below –10 dB for the radius of the lower patch a less than 4.6 mm, although it becomes worse as a is increased. Figure 5 presents the simulated radiation patterns of the MSA, where $a = b = 3.25$ mm, $a = b = 3.8$ mm, and $a = 4.725$ mm and $b = 4.2$ mm, respectively. Good radiation patterns with low cross polarization for E- and H-planes are confirmed.



(a) Perspective view (b) Cross-sectional view

Figure 2: A stacked circular MSA with different radii.

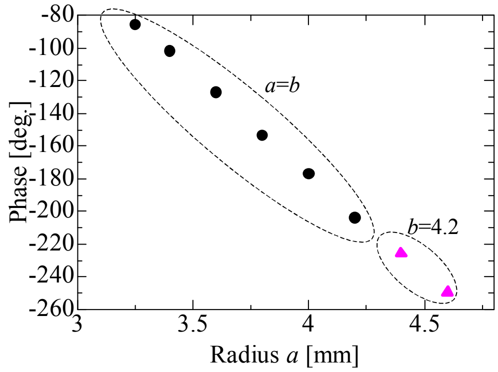
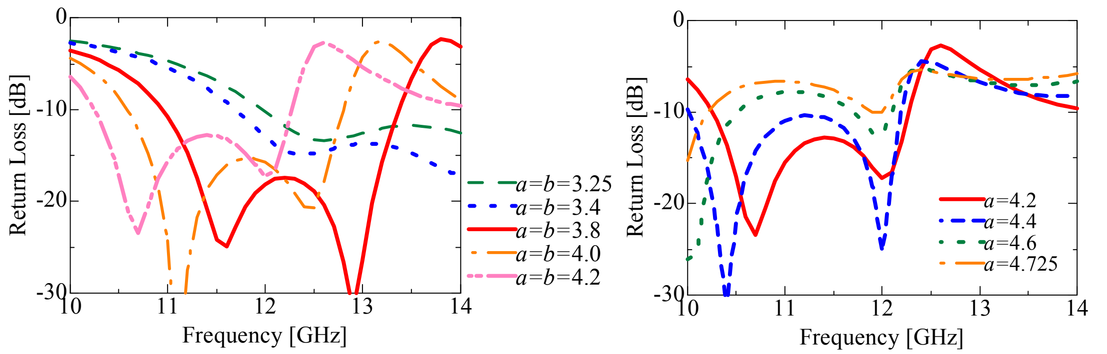
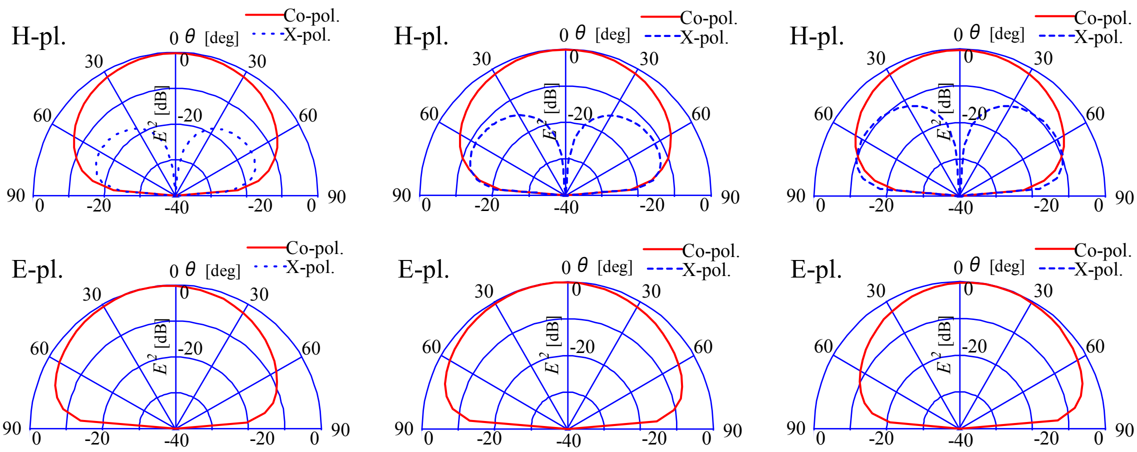


Figure 3: Radiation phase of the stacked circular MSA with different radii. (Sim.)



(a) $a = b$ (b) $b = 4.2$ mm

Figure 4: Return loss characteristics of the stacked circular MSA with different radii. (Sim.)



(a) $a = b = 3.25$ mm (b) $a = b = 3.8$ mm (c) $a = 4.725$ mm and $b = 4.2$ mm

Figure 5: Radiation patterns of the stacked circular MSA with different radii. (Sim.)

3. Design and measurement of an RL-MSAA with stacked elements

Based on the discussion above, a linearly polarized RL-MSAA with 3 concentric rows of the stacked MSAs is designed. A design frequency is 12.0 GHz and a spacing of the MSAs is $0.65\lambda_0$. Figure 6 presents a configuration and parameters of the designed RL-MSAA. In order to realize uniform phase distribution, radii a and b, and a position of feeding point x of each row of the MSAs are varied and optimized by using Ansoft HFSS.

Figure 7 compares simulated and measured radiation patterns of the prototype RL-MSAA at 12.0 GHz. Good agreement between the simulation and the measurement is obtained for the both H- and E-planes. From these patterns, uniform phase distribution over the aperture is confirmed. Figure 8 presents measured reflection of the RL-MSAA. The reflection less than –10 dB is observed at 12.0 GHz. Figure 9 presents simulated and measured gain. Reasonable agreement between the simulation and the measurement are confirmed. The measured gain at 12.0 GHz is 22.3 dBi, which is corresponding to 89% efficiency.

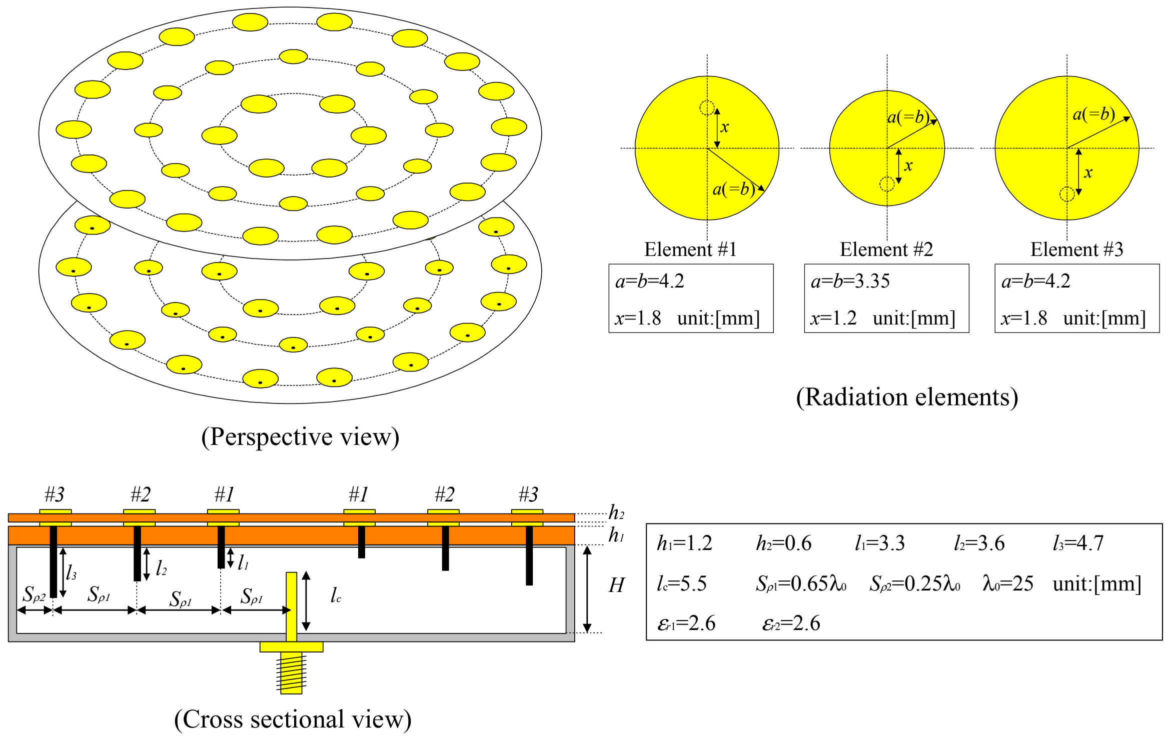


Figure 6: The designed RL-MSAA with 3 rows.

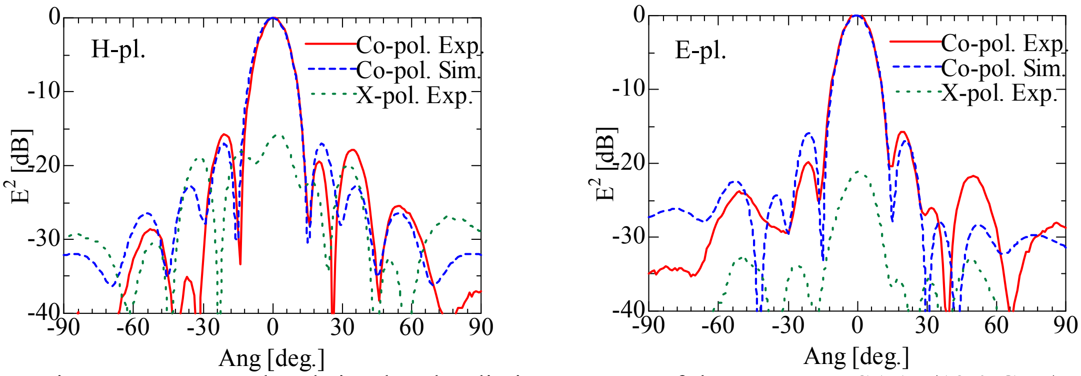


Figure 7: Measured and simulated radiation patterns of the test RL-MSAA. (12.0 GHz)

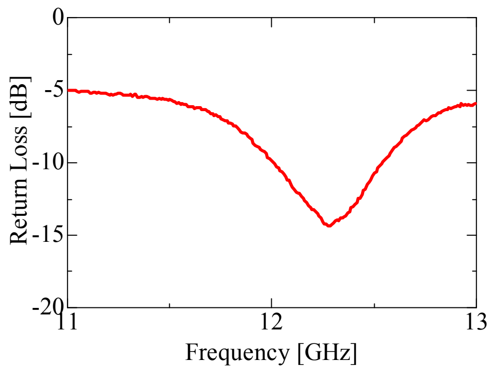


Figure 8: Measured return loss.

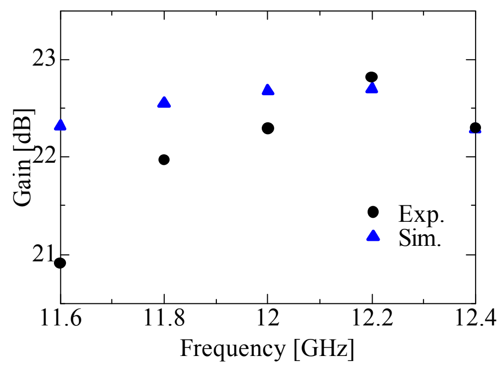


Figure 9: Measured and simulated gain.

4. Conclusions

This paper presents design of a linearly polarized RL-MSAA. A stacked circular MSA is with different radii of upper and lower patches is introduced for the RL-MSAA. It is confirmed that the radiation phase can be controlled by the radii of the patches in the range of around 180 degrees by simulation. A prototype RL-MSAA with three concentric rows of the stacked MSAs arranged at a spacing of $0.65\lambda_0$ is designed at 12 GHz and uniform phase distribution is measured at the design frequency. The experimental results reveal that a validity of the stacked MSA with different radii for a linearly polarized RL-MSAA is demonstrated.

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