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POLARIZATION SWITCHABLE MICROSTRIP ARRAY ANTENNA BASED ON PROXIMITY FEEDING TECHNIQUE

Manabu Yamamoto*, Taisuke Tokunaga*, Toshio Nojima* and Kiyohiko Itoh**

* Graduate School of Engineering
Hokkaido University
N13, W8, Kita-Ward, Sapporo 060-8628, Japan
E-mail: yamamoto@ice.eng.hokudai.ac.jp

** Tomakomai National College of Technology
Nishikioka 443, Tomakomai,
059-1275, Japan
E-mail: itoh@office.tomakomai-ct.ac.jp

Abstract: A polarization switchable microstrip array antenna is presented. This array consists of square patch antennas coupled in close proximity to a microstrip line. The polarization state can be switched electrically by short- or open-circuiting the end of the feedline using a PIN diode. Fundamental characteristics of the proposed array are investigated by measurements performed at S-band to demonstrate the proposal.

1. Introduction

Microstrip antennas have advantages of lightweight and low profile, and are widely used in many applications, such as satellite and mobile communications. Although many feeding techniques can be utilized to excite microstrip antennas [1], co-planar feeding structures, in which radiating elements and feedlines are arranged on the same plane, are preferable because of its simplicity and ease of fabrication.

One of microstrip antennas employing the co-planar feeding system is a proximity fed microstrip antenna (PMA), in which the radiating patch is coupled in close proximity to a microstrip line [2]. The PMA has the capability to switch the polarization state by short- or open-circuiting the end of the feedline. Thus the PMA is a promising candidate for wireless systems that requires polarization diversity, and for radar polarimetry.

In the past, the performance of the single element PMA has been demonstrated by experiments and analysis [2], [3]. However, PMA arrays with dual polarization have not been studied up to now. Taking these backgrounds into consideration, a microstrip array antenna using proximity feeding is proposed in this paper. Fundamental characteristics of two- and four-element PMA arrays are investigated by measurements at S-band. From the measured results, it is found that polarization state can be switched electrically by short- or open-circuiting the end of the feedline using a PIN diode.

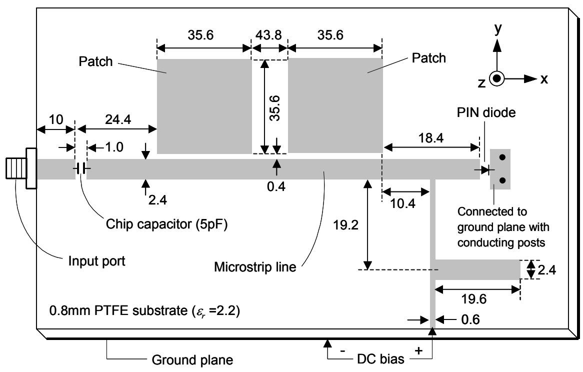

Fig. 1 Two-element PMA array
(All dimensions are shown in millimeters)

2. Two-element PMA array

The configuration of the proposed array antenna is shown in Fig. 1, where all dimensions are indicated in millimeters. As a feedline for the array, a 50Ω microstrip line with a width of

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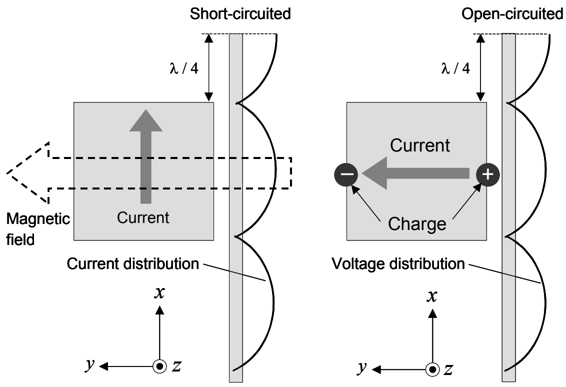
2.4mm is printed on the top plane of a PTFE substrate having a relative permittivity of 2.2 and thickness of 0.8mm. Two radiating patches are arranged in proximity to the feedline, and are excited with electromagnetic coupling through a gap having a width of 0.4mm. The sizes of the patches are fixed at 35.6mm such that they resonate at 2.8GHz. The patch spacing is 79.4mm, which is chosen so that the patches are driven in phase.

The feedline is extended by one-quarter wavelength from the edge of the patch. In order to control the termination of the feedline, a PIN diode is inserted between the end of the feedline and a rectangular pad, which is connected to a ground plane by two conducting posts. A network for supplying DC bias to the PIN diode consists of 100Ω and 50Ω microstrip lines with a length of one-quarter wavelength. In the vicinity of the input port, a 5pF chip capacitor is connected in series with the feedline to isolate the DC bias from the RF signal. The PIN diode employed in the fabricated array is an Agilent Technologies HSMP-489B, which is designed for use at frequencies up to 3GHz [4].

3. Principle of polarization switching

The principle of polarization switching is depicted in Fig. 2. Consider first the antenna shown in Fig. 2a, in which the feedline is terminated in a short circuit. In this case, the maximum of the current standing wave on the feedline exists at the center of the patch, and the magnetic field due to the standing wave is generated in the y-direction. As a resutlt, a current is induced on the patch along the *x*-direction, and an *x*-polarized wave is radiated from the patch.

Next consider the antenna shown in Fig. 2b, in which the end of the feedline is open-circuited. The maximum of voltage standing wave on the feedline corresponds to the center of the patch, resulting in the generation of electric charges on the left and right edges of the patch. Current due to the charge is induced on the patch in the *y*-direction, and a *y*-polarized wave is radiated from the patch.



(a) Short-circuited (b) Open-circuited

Fig. 2 Principle of polarization switching

4. Performance of two-element PMA array

The two-element PMA array antenna was fabricated on a Diclad 880 substrate (ARLON Inc, Santa Ana, CA), and measured at S-band. To short-circuit the end of the feed line, a bias current of 20mA was supplied to the PIN diode using a constant-current circuit. The reflection coefficients were measured using an HP8510C vector network analyzer, and the radiation patterns and gains were evaluated in an anechoic chamber with an HP8530 microwave receiver.

Fig. 3 shows the frequency dependence of the reflection coefficients measured at the input port of the antenna. It is found that the best match is obtained at 2.782GHz and 2.771GHz when the PIN diode is ON and OFF state, respectively. The return loss at these frequencies is –26dB for bias off and –6dB for bias on.

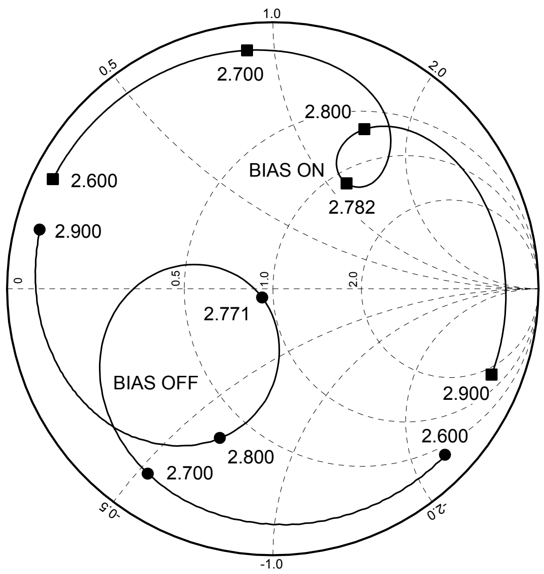


Fig. 3 Frequency dependence of reflection coefficients of two-element PMA array

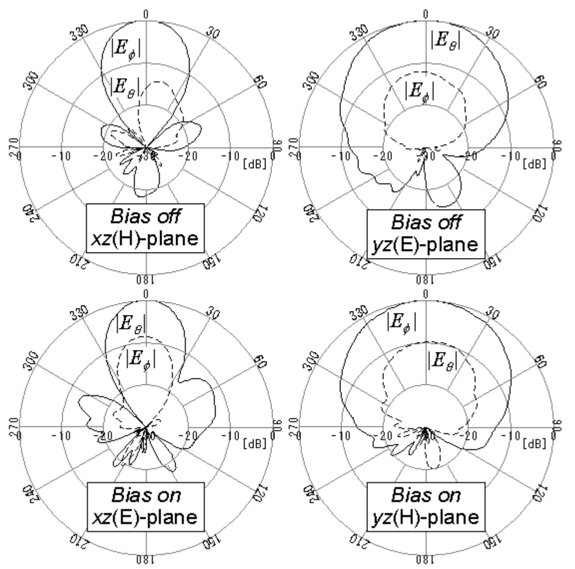


Fig. 4 Radiation patterns of two-element PMA array

At these frequencies, the radiation patterns were measured in two principal planes. The results are shown in Fig. 4, where solid lines indicate co-polarizations, and broken lines are cross-polarizations. Co-polarization components in the *xz*-plane are $|E_\theta|$ and $|E_\phi|$ when the bias is ON and OFF state, respectively. From these results, it is confirmed that the polarization switching technique developed for the single-element PMA can be applied to the array configuration. The half-power beam-widths of the *xz*-plane patterns are 33° for bias ON and 36° for bias OFF, whereas those of *yz*-planes are 77° and 74°. Thus the improvement of the beamwidth due to the array configuration can be confirmed in the *xz*-plane.

Fig. 5 shows the frequency dependence of the actual gains measured in the broadside direction. The maximum gains of the co-polarization components are 10dBi for bias OFF and 8.4dBi for bias ON. The cross polarization levels are found to be –14.3dB for the OFF-state, and –10.2dB for the ON-state.

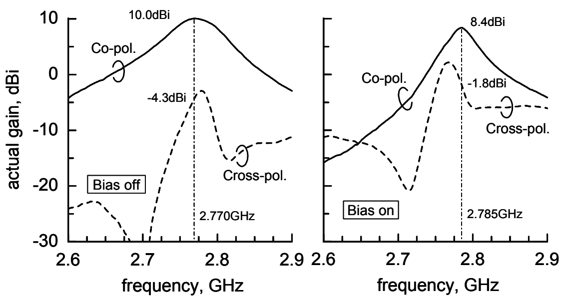


Fig. 5 Frequency dependence of actual gain measured in broadside direction

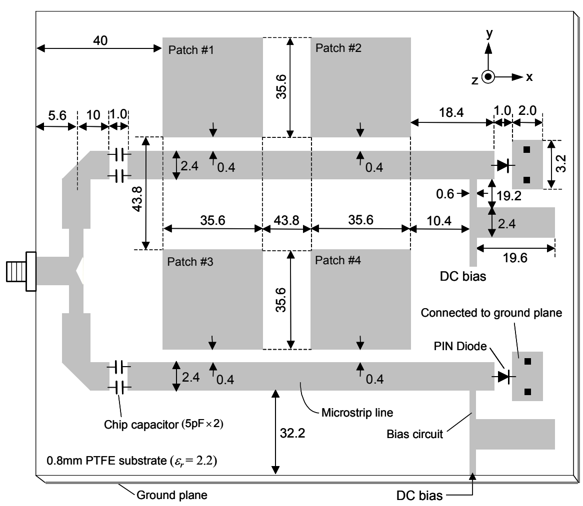


Fig. 6 Two-dimensional PMA array

(All dimensions are shown in millimeters)

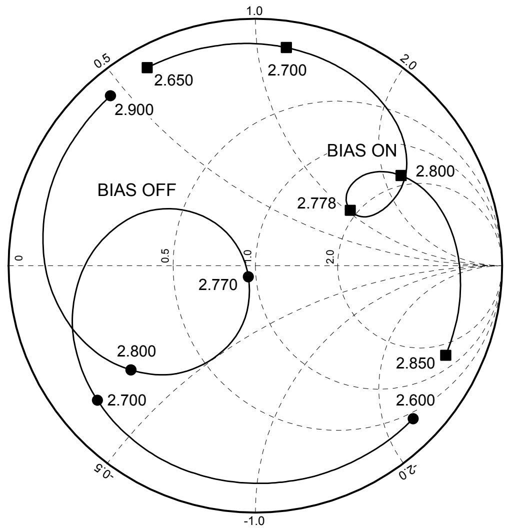


Fig. 7 Frequency dependence of reflection coefficients of two-dimensional PMA array

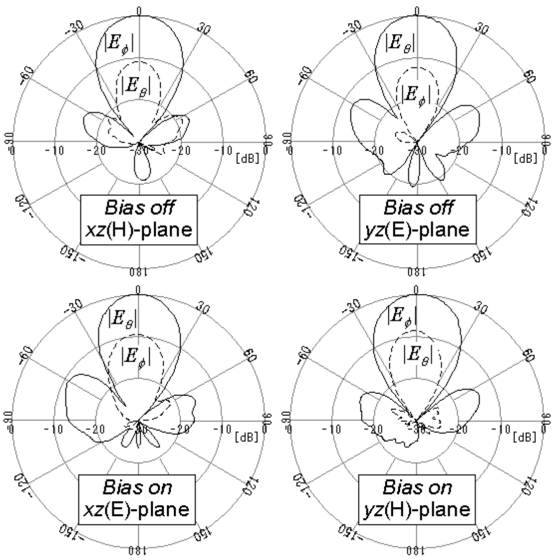


Fig. 8 Radiation patterns of two-dimensional PMA array

5. Two-dimensional PMA array

Fig. 6 shows the configuration of the two-dimensional PMA array. The two-element PMA arrays are arranged on the same substrate in two columns. A corporate feeding circuit consisting of microstrip T-junctions and quarter wavelength transformers is used to excite each two-element array with uniform distribution and equal phase. The spacing between two arrays is 79.4mm, which corresponds to $0.83\lambda_0$ at 2.77GHz (λ_0: free space wavelength).

Fig. 7 shows the frequency dependence of the reflection coefficients measured at the input port. It is observed that the best match is obtained at 2.778GHz and 2.770GHz when the PIN diode is ON and OFF state, respectively.

Fig. 8 shows the radiation patterns measured at above-mentioned frequencies. In both *xz*- and *yz*-planes, it is observed that co-polarization components for bias ON are orthogonal to those of bias OFF. The beamwidths of co-polarization patterns are 33°. In comparison with Fig. 4, *xz*-plane patterns show no significant change, while the beamwidths of *yz*-plane patterns are improved. The maximum gains are 12.5dBi for bias OFF and 11.0dBi for bias ON. These values are 2.5dB higher than those of the two-element array. From these results, it is seen that the polarization switching technique based on the proximity feeding can be applied to two-dimensional array configuration.

6. Conclusions

A polarization switchable microstrip array antenna based on proximity feeding technique has been proposed. Two- and four-element PMA array have been designed, and their characteristics were revealed by measurements at S-band. Measured results demonstrate that the dual-polarization can be obtained by terminating the feedline in open or short circuit using PIN diode.

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