Polarization Tunable Microstrip Patch Antenna for Polarization Loss Compensation

Jun-Gi Jeong, YoungSub Kim, Young Joong Yoon
Department of Electrical and Electronic Engineering, Yonsei University
50 Yonsei-ro, Seodaemun-gu, Seoul 120-749, Korea
jungi0525@yonsei.ac.kr, yjyoon@yonsei.ac.kr

***Abstract* – Polarization loss of wireless communication system is caused by a mismatch of polarization between incident wave and receiving antenna. In order to compensate a polarization loss of circular polarization system, tunable circular polarization antenna is proposed. The polarization of the proposed antenna is tuned by using a reflection type phase shifter on sequential rotation feed (SRF) microstrip array. The axial ratio of polarization can be converted up to 3.7 dB for two orthogonal tilt angles in 9.5 GHz. Thus, polarization loss factor (PLF) is compensated by polarization matching.**

***Index Terms* — Circular polarization antenna, polarization loss factor (PLF), sequential rotated feed (SRF).**

I. INTRODUCTION

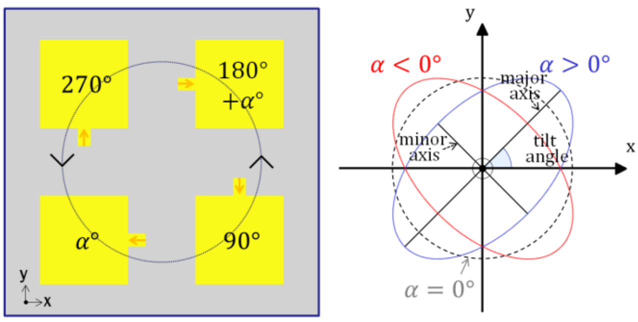
A circular polarization (CP) microwave system is used in various applications because the circular polarization is less sensitive than linear polarization. However, even circular polarization microwave system has a polarization loss due to the propagation environment and antenna misalignment. Thus, the polarization of the incident wave becomes not ideally circular. The polarization mismatch loss is defined by polarization loss factor (PLF). PLF is determined by the difference of the axial ratio and main beam tilt angles between the incident wave and the receiving antenna. In the wireless communication, incident wave and receiving antenna must have same polarization characteristics (including axial ratio and tilt angle of main axis) for maximum power transfer [1]. Thus, it is necessary to compensate the PLF by tuning the axial ratio and tilt angle of the receiving antenna.

In this paper, a polarization tunable microstrip patch antenna is proposed. Using the phase shifter and sequential rotation feed array, the axial ratio and tilt angle of CP are actively tuned to increase the PLF. The axial ratio and tilt angle are tuned by phase shifter designed with varactor diode to control the phase actively.

II. DESIGN OF PROPOSED STRUCTURE

A. Sequential rotation fed microstrip array

Typically, 90 degrees phase difference between two ports is used for circular polarization antenna with single element. In this case, it is required to have a phase shifter for each element in array antenna configuration. On the other hand,



(a) (b)

Fig. 1. (a) Configuration of SRF array (b) Polarization variation according to **α**

SRF array requires only a single phase shifter for each four elements unit. Therefore SRF microstrip array is proper for array in the aspect of space.

SRF array is composed of four elements to obtain circular polarization [2]. Each elements of the SRF array has 90 degree phase difference, and each feeder direction has a difference of 90 degrees, as shown in Fig. 1(a). The type of the circular polarization (RHCP and LHCP) is determined by a direction of phase shifting rotation.

The proposed antenna has two tilt angle conditions which formed orthogonally. Tilt angle of polarization become +45 degrees or -45 degrees depending on sign of α. The axial ratio is only changed by α. Fig. 1(b) represents the variation of the axial ratio by changing α.

B. Phase shifter

Reflection type phase shifter such as 3 dB branch line coupler is used in the proposed antenna [3]. Space for phase shifter in SRF array is limited. Thus, a simple coupled line which is composed of a short section line with chip capacitor to increase the coupling and reduce the size [4] is used in this paper. The designed phase shifter provides the phase range of 70 (-35 ~ +35) degrees by changing of varactor diode capacitance. The insertion loss variation is less than 0.4 dB.

C. Polarization by phase shifting and PLF calculation

The polarization of the proposed antenna is tuned by changing the phase of the phase shifter. The magnitudes of electric fields are the same and their directions are orthogonal

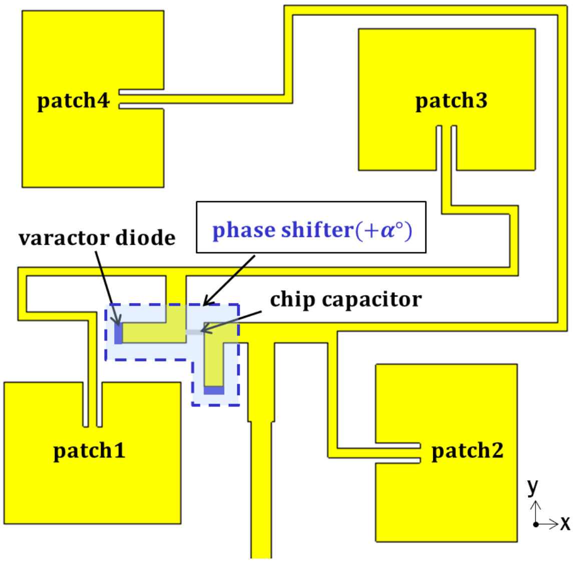


Fig. 2. Designed SRF array antenna

to each other in SRF array. In the Fig. 2, two orthogonal components of electric fields are x-axis (patch2 and patch4) and y-axis (patch1 and patch3). Thus, the wave unit vector of SRF array can be defined as (1)

$$\overrightarrow{\rho_{SRF}} = \frac{1}{\sqrt{2}}(\hat{x}e^{j0} + \hat{y}e^{j\alpha}) = \frac{1}{\sqrt{2}}\{\hat{x} + \hat{y}(\cos\alpha + j\sin\alpha)\} \quad (1)$$

where α is the phase shift of the two diagonal elements. By changing this phase, the polarization can be changed. Practicable tilt angle is ± 45 degrees from x-axis. Therefore, two orthogonal elliptical polarizations can be achieved. The maximum attainable axial ratio of the designed SRF array is 3.7 dB as shown in Fig. 3.

The compensation of PLF is determined by tilt angle and axial ratio of incident wave and receiving antenna. PLF is calculated by using electric field magnitude and phase.

$$10\log_{10}\left\{\frac{1+\tan^2(\gamma_r)\tan^2(\gamma_i)-2\tan(\gamma_r)\tan(\gamma_i)\cos(\delta_r+\delta_i)}{\sec^2(\gamma_r)\sec^2(\gamma_i)}\right\}$$

$$\gamma = \tan^{-1}\left(\frac{y\text{-}axis\ electric\ field_{max}}{x\text{-}axis\ electric\ field_{max}}\right),$$

$$\delta = \text{phase difference between } E_x \text{ and } E_y. \quad (2)$$

By using (2), PLF can be considered in several cases. The proposed antenna can maximally compensate the PLF when the tilt angles between incident wave and receiving antenna are the same. Compensated PLF can be controlled by phase of electric fields (components of x-axis and y-axis) by changing α. It should note that the compensation value of PLF is limited because tunable range of phase shifter is narrow. In other words, the tunable range of phase shifter determines the range of compensated PLF. Table I. Show that some PLF compensated cases for several incident wave cases using proposed receiving antenna. In this case, tilt angle of incident wave is considered only 0 to 45 degrees because tilt angle of receiving antenna has two orthogonal angles.

TABLE I
POLARIZATION COMPENSATION IN SEVERAL CASES OF INCIDENT WAVE

Incident Wave		Proposed Antenna	PLF of Conventional CP Antenna [dB]	PLF of Proposed Antenna [dB]
Axial Ratio	Tilt Angle [degree]	Varactor diode Capacitance [pF] (tuning)		
2	0	0.68	-0.456	-0.455
	15	0.701	-0.460	-0.390
	30	0.832	-0.457	-0.100
	45	0.91	-0.458	-0.010
3	0	0.68	-0.979	-0.981
	15	0.713	-0.972	-0.665
	30	0.857	-0.968	-0.240
	45	0.91	-0.970	-0.108
4	0	0.68	-1.339	-1.341
	15	0.733	-1.341	-0.872
	30	0.875	-1.367	-0.400
	45	0.91	-1.340	-0.243
5	0	0.68	-1.598	-1.596
	15	0.748	-1.595	-1.020
	30	0.892	-1.596	-0.520
	45	0.91	-1.598	-0.352

III. CONCLUSION

The proposed polarization tunable SRF antenna can tune the axial ratio up to 3.7 dB for each orthogonal tilt angle. By controlling the capacitance of varactor diodes, the axial ratio and tilt angle are tuned actively. It is expected that the polarization loss can be compensated (decreased) by tuning the polarization, according to the incident wave.

ACKNOWLEDGEMENT

This research was supported by the MSIP(Ministry of Science, ICT and Future Planning), Korea, under the ITRC(Information Technology Research Center) support program (NIPA-2014-H0301-14-1042) supervised by the NIPA(National IT Industry Promotion Agency).

REFERENCES

[1] Constantine A. Balanis, Antenna Theory, 3rd de, Wiley-Interscience, 2005, pp. 70-80.

[2] Hall, P.S, "Feed Radiation Effect In Sequential Rotated Microstrip Patch Arrays", Electronic Letters, Vol. 23, No. 17, pp. 877-878, August. 1987.

[3] Chien_san Lin, Sheng-Fuh Chang Chia-Chan Chang, Yi-Hao Shu, "Design of a Reflection-Type Phase Shifter With Wide Relative Phase Shift and Constant Insertion Loss", IEEE Transaction on Microwave Theory and Techniques, Vol. 55, No. 9, pp. 1862-1868, September. 2007.

[4] Amin M. Abbosh, "Compact Tunable Reflection Phase Shifters Using Short Section of Coupling Lines", IEEE Transaction on Microwave Theory and Techniques, Vol. 60, No. 8, pp. 2465-2472, August. 2012.