A Novel Technique of Broadband Circularly Polarized Microstrip Antenna Development with Square Ring Slot for SAR Application

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***Abstract*—This paper presents a novel technique to develop a broadband circularly polarized microstrip antenna by using square ring slot (SRS) for SAR application. The minimum requirements of proposed antenna are 800MHz bandwidth with the resonant frequency at 9.4GHz and workable in circular polarization. To satisfy a broadband bandwidth characteristic, a novel technique, called as SRS technique, is implemented upon the patch radiator. The proposed antenna is designed to produce the left-handed circular polarization (LHCP). It is etched on double layer of NPC-H22A dielectric substrate with the dielectric constant of 2.17 and the thickness of 1.6mm. By implementing SRS technique on the proposed antenna, the bandwidth of axial ratio achieved of 12.7% (8.7GHz–9.9GHz), the impedance bandwidth of 36% (8.5GHz–11.9GHz), and the gain achievement up to 6dBic.**

***Keywords*—Broadband; microstrip antenna; LHCP; Synthetic Aperture Radar (SAR); spaceborne SAR.**

I. INTRODUCTION

At this time, Synthetic Aperture Radar (SAR) system has become very popular due to its reliability and very immune to various circumstances and weather [1]–[2]. Along with it, some researchers have made various breakthroughs to create a reliable system, one of them is SAR sensor referred as the antenna. Furthermore, microstrip antenna becomes favourite as SAR sensor as it has properties such as highly compatible, rigid, easy to fabricate and lightweight [3]–[6]. However, the microstrip antenna has some drawback, e.g, low efficiency, low gain, low power, narrow bandwidth [7].

The proposed SAR sensor design will implemented to unmanned aerial vehicle and micro-satellite [8]. Todays, JMRSL has planed several SAR sensor, e.g. L-band, C-band, X-band to be implemented in UAV, aircraft or microsatellite. This main propose of this project is to provide the remote sensing data with high accuracy and high standard resolution on environmental field, for example as disaster monitoring, farming monitoring, mining project, military and so on. This year, JMRSL and Center for Environmental Remote Sensing, Chiba University has completed performing the field test of C-band SAR system in Makassar, Indonesia by using CN235 under the project name of Hinotori-C2 [9].

The goal of required bandwidth for the system is quite width, it can be called broadband bandwidth, much be up to 800MHz. The lower frequency will be set at 9.0GHz then the higher frequency set at 9.8GHz. It is already mention in first paragraph that microstrip antenna has several disadvantages, on of which is narrow bandwidth and low efficiency. There are many efforts have been performed by many researchers in terms of bandwidth and efficiency enhancement. Some of them have employed an air gap as effort to enhance the bandwidth [10], which was implemented between the substrates, reflector patch and groundplane. This method has proven very effective to enhance the reflection coefficient bandwidth of antenna. Nevertheless this technique makes the antenna structure to be weaken and not quite rigid since the gap itself makes a space and being fragile. So, it is not suitable to be implemented on UAV, aircraft, or microsatellite.

In [11], a method to enhance the bandwidth by using one layer of substrate has been proposed. This technique is effective to increase the return loss bandwidth, axial ratio, and gain. Despite of the fact, this technique produced low gain. A single dielectric superstrate has also been introduced to increase the bandwidth. In this method, the structure design of antenna architecture was similar with the air gap method. This model was developed with three stages; a substrate, a foam and a superstrate [12]. The foam was set on the patch area, while the superstrate was laid on the foam. The antenna design was quite corpulent. However, this is incompatible to be set for vehicles with high speed movement.

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Another method is by implementing slot on the patch radiator which is very effective and efficient. The design is kept rigid and compact with a simple structure. In this paper, a broadband circularly polarized microstrip antenna by using square ring slot (SRS) is presented. The novel SRS technique is implemented in the middle of radiation patch. The proposed antenna has good performance in reflection coefficient (S_{11}), circular polarization characteristic, and gain. The reflection coefficient bandwidth achieved of 36% with the low frequency at 8.5GHz and the high frequency at 11.9GHz. Whilst the axial ratio bandwidth achieved of 12.7% with the low frequency at 8.7GHz and the high frequency at 9.9GHz. The gain of antenna attained up to 6dBic.

II. Design and Configuration

The proposed antenna is etched on double layer dielectric substrates in which the upper dielectric substrate is set for placing a radiator patch with SRS, then back-side of the upper dielectric substrate is laid down a feed line, while the groundplane is set on the back-side of second dielectric substrate. In the realization, to unite the double layer of dielectric substrates 4 plastic screws are placed in every corner of proposed antenna. It has been confirmed that the plastic screws have no effect to the antenna performances. The dielectric material used for designing and realizing the proposed antenna is a NPC-H220A material which has the dielectric constant of 2.17 and the thickness of 1.6mm. The dielectric material has a cooper thickness on its surface of 0.035mm and the dissipation factor of 0.0005. Fig. 1 represents the geometry of proposed antenna with SRS.

The total size of proposed antenna is 31.2mm, the radiation patch is formed by a truncated-circular-shape antenna with the diameter R_p = 9.6mm in which the truncation factor is set in -45^o of y-axis and 45^o of x-axis. The SRS is set in the middle of patch radiator which has the wide of 0.5mm and W_{sq} = 2mm as the inner square, while the outer square is 2.5mm. The truncation shape is formed by a pair of rectangular shapes. Both of the truncation factors have different dimension, the upper part has the size of W_t = 2mm and L_t = 1.75mm, whereas the under part (45^o of x-axis) is represented by W_{t2} = 2mm and L_{t2} = 3.75mm.

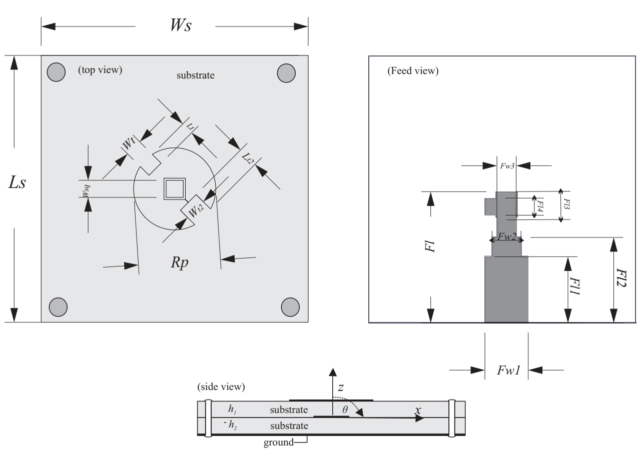

Fig. 1. Configuration of proposed LHCP truncated-circular-shape microstrip antenna with SRS.

The three stages of feeding line is implemented to feed the antenna. The design of feeding line is equipped with a kind of head/bulb at the edge of the line. The first stage is represented with F_{w1} = 4.75mm and $F(l1)$ = 7.75mm. In the second stage, F_{w2} = 3.375mm as the width and F_{l2} = 10mm as the length. Then, the third stage is represented with F_{w3} = 2.25mm and F_{l3} = 14mm. Finally, two rectangular shapes are set as a head of feeding line with the dimension of 2.5mm × 3mm and 2mm × 3mm, respectively. A 50Ω SMA connector is connected in another edge of the feeding line.

III. Result and Discussion

Fabrication of the proposed antenna and its experimental measurement are conducted at JMRSL, Chiba University. The comparison result of measured and simulated return losses is plotted in Fig. 2. The fabricated antenna is performed as a decent result of reflection coefficient. In the simulation, the reflection coefficient (S_{11}) is performed in a broadband bandwidth working at the low frequency of 8.61GHz and the high frequency of 11.9GHz. The simulated bandwidth is 3.29GHz or 36% in which the bottomless curve stands at 9.3GHz achieved of 24.95dB, and the mid-band frequency at 9.4GHz obtained of 23.79dB.

Furthermore, the measured result evidently meet the agreement with the minimum requirement. Nevertheless, the measured result is worse compared to the simulated one. In

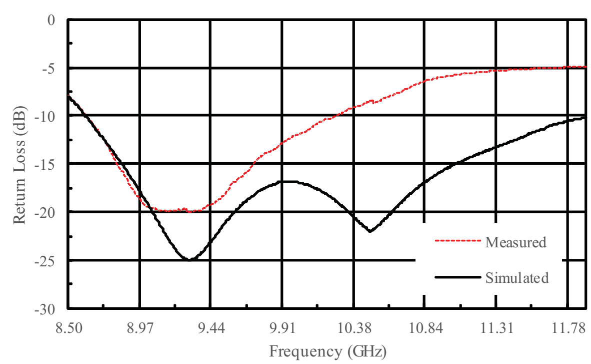

Fig. 2. Comparison result of simulated and measured return losses.

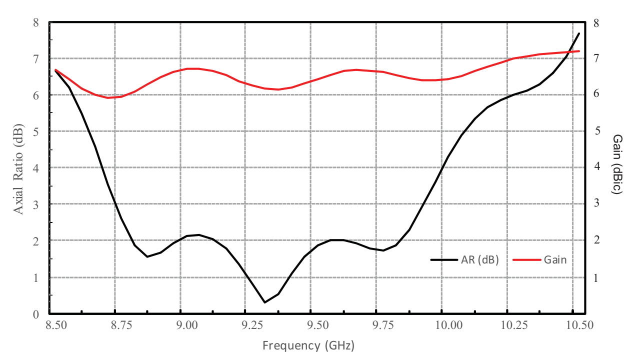

Fig. 3. Simulated results of gain and axial ratio.

Fig. 2, it shows that the measured bandwidth is 1.64GHz or 17% with the low frequency of measured result stands at 8.62GHz and the high frequency stands at 10.26GHz. It is noticeable that the measured result is 50% decreased to the simulated one. The deepest point of measured result stands at 9.29GHz achieved of 20.01dB.

The simulated result for gain and polarization characteristics is highlighted in Fig. 3. It shows that the gain tends to be static up to 6dBic. This indicates that the proposed antenna has a decent output power and high efficiency. The gain in the resonant frequency stands at 6.19dBic, while in the low and high frequencies stand at 6.71dBic and 6.53dBic, respectively. Furthermore, the circular polarization result also shows a satisfied product with the bandwidth axial ratio of 12% (8.75GHz–9.90GHz) and at the resonant frequency of 1.09dBic. Evidently, the proposed antenna has shown a decent performance. The results obtained from simulation and measurement has indicated suitability of the proposed antenna to satisfy the requirement with good performance.

IV. Conclusion

A novel technique of broadband circularly polarized microstrip antenna development has been presented. The proposed antenna designed to resonate at the X-band frequency of 9.4GHz for SAR application was developed by implementing a novel SRS technique to gain the broadband bandwidth characteristic. The simulated result has demonstrated the broadband bandwidth of proposed antenna about 36% (8.5GHz–11.9GHz) for return loss, 12.7% (8.7GHz–9.9GHz) for axial ratio, and up to 6dBic for gain. Meanwhile, the measured result for bandwidth return loss was 17% (8.62GHz–10.26GHz). In general, the proposed antenna has demonstrated a good performance satisfiable for SAR application.

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