Planar Inverted-F Antenna (PIFA) Array with Circular Polarization for Nano Satellite Application

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***Abstract* – In this paper, a new design of an S-band, self phased, planar inverted-F antenna (PIFA) is proposed for low orbit nano satellite application. The antenna consists of Four PIFAs which are arranged in circular array to generate circular polarization antenna. The antenna operates at 2.35 GHz with 107 MHz bandwidth of Return Loss less than -14 dB. Results show that the antenna has circular polarization properties with 1.21 dB axial ratio and unidirectional radiation pattern. Since the proposed antenna is compact and low cost, it is suitable for nano satellite communication system.**

***Keywords* — Planar Inverted-F Antenna, array, circular polarization, nano satellite communication.**

I. INTRODUCTION

Recently, Telkom University, Indonesia, is developing a low orbit nano satellite with Remote Sensing Payload (RSPL) mission. The satellite has dimension of 10cm×10cm×20cm.

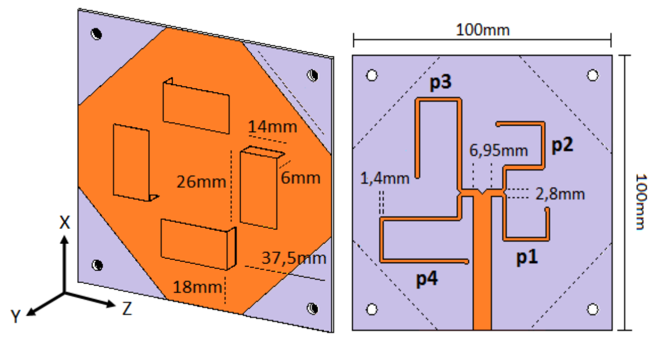
A specific antenna is needed for low orbit nano satellite communications. The expected specifications are: has a minimum 50 MHz bandwidth; has a circular polarization to mitigate Faraday effects that often occur in low orbit satellite communications [1]; return loss < −14dB; and gain min 4 dBi to meet link budget calculation. In addition, the nano satellite standard states that each component should be rugged and reliable for space application and easy to operate during and after launching [2].

Quadrifilar Helix antenna for nano satellites was already made in previous research [3]. However, that helix antenna has 13 cm height which is too long for the nano satellite. Another report was a microstrip antenna with front-end parasitic for nano satellite [4]. This parasitic method cause the antenna becames large to achieve a desired gain.

In this paper, we propose a new antenna S-band design to be used as nano satellite transmitter component. The antenna is designed using PIFA array structure. The PIFA array structure has a compact dimension and a circular polarization characteristic which make this antenna suitable for use as a transmitting antenna on nano satellite.

II. ANTENNA DESIGN

Physical appearance of the proposed antenna design is shown in Fig 1. The antenna structure was created using copper plate with 0.2 mm thickness. It was fabricated on a ground plane with 1.6 mm thick FR-4 substrate. The inverted-F elements which are located on the top of the ground plane are wave radiator and also the part that controls the resonant frequency.



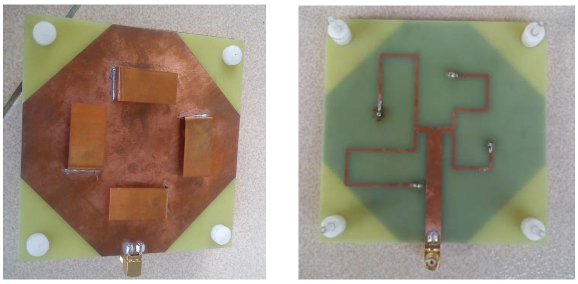
(a) (b)

Fig. 1. Design of Antenna (a) Front View, (b) Back View

Circular polarization can be achieved by arranging the 4 PIFAs in circle and each of the antennas have 90^0 consecutive phase difference. Copper wire was used to connect each of the PIFAs with microstrip feeding network which is located on the bottom of the substrate. This feeding network is the key to divide the phase of each PIFA [5]. Ground plane is square shaped with 4 corner cuts to produce wider beamwidth and smaller axial ratio. As shown on Fig. 1, feeding network that is printed on the bottom of substance has different width according to its designated line impedance. The line width, *sl*, can be determined by following equation [5]:

$$sl = \frac{k}{z} \times \frac{h}{\sqrt{\varepsilon_r}} \quad (1)$$

k is a constant that equals to 120π; z is the desired impedance; h and ε_r are thickness and substrate relative permittivity, respectively. The line feed length difference between each of four feed lines is ¼ λ to create 90^0 phase differences. PIFA length is determined based on antenna's frequency, and it is ¼ λ [6]. Finally, the proposed antenna was fabricated and it is shown in Fig. 2.



(a) (b)

Fig. 2. Fabricated antenna (a) Front View, (b) Back View

III. SIMULATION AND MEASUREMENT RESULTS

In order to validate the antenna design, we conducted measurements on several significant antenna parameters and compare it with the simulated results.

The comparison between simulated and measured return loss data is shown in Fig.3. The simulated result show that the return loss and bandwidth at 2.35 GHz are −23.8 dB and 197.4 MHz, respectively. On the other hand, the measured results show −20.7 dB return loss and 107 MHz bandwidth.

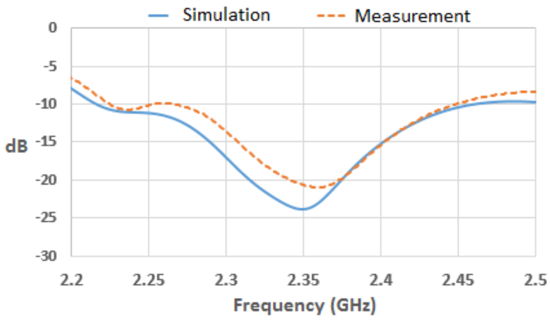


Fig. 3. Simulated and measured Return Loss

Furthermore, at resonant frequency, the antenna has simulated axial ratio of 1.38 dB. Since circular polarization requirement is axial ratio < 3 dB [7], it can be stated that antenna's polarization is circular. Whilst the measured result of the antenna's polarization is depicted in Fig. 4. It can be shown that the antenna has axial ratio of 1.21. Thus, the antenna has circular polarization.

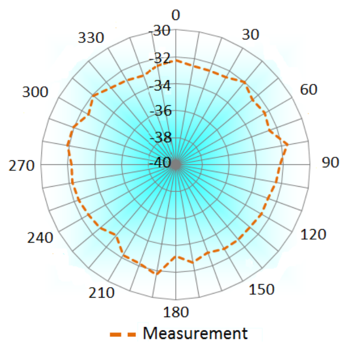


Fig. 4. Measured polarization of the proposed antenna

Next, the azimuth (y-z plane) and the elevation (x-y plane) radiation pattern was measured. The results is shown in Fig. 5. In that figure, 0^o denotes the maximum radiation and it is located in the center of the antenna surface. Moreover as seen in Fig. 5, the antenna has unidirectional radiation pattern.

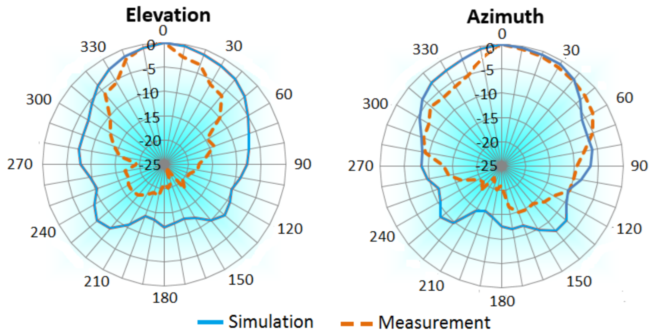


Fig. 5. Simulated and measured Radiation Patern

The simulated antenna gain is 4.56 dBi. By using gain comparison method [8] with horn antenna used as reference, the measured result shows that the antenna has 4.78 dBi gain. This gain meets the requirement for nano satellite link budget.

IV. CONCLUSION

This paper presents a new design of 2.35 GHz PIFA array antenna for low orbit nano satellites application. The measurement and simulation results show that the proposed antenna could meet the specification for nano satellites. The size of the antenna is compact and rigid. Thus the proposed PIFA array is feasible to be applied in nano satellites product.

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