High-Gain Microstrip-Antenna Design Using Sub-Array Method

Adit Kurniawan, Dwi Widodo Heru Kurniawan, and Aghnat Atqiya

***Abstract*— This paper presents microstrip antenna design using sub array technique to produce high gain, compact, and low cost antenna. The working frequency was designed to cover the S-band of 2.520 GHz to 2.670 GHz. The proposed antenna consists of 8 sub-arrays, each of which has 8 identical antenna elements, resulting the total array antenna of 64 elements. The antenna has been implemented on FR4 and produces the bandwidth of 2.48 GHz to 2.6225 GHz, with the resulting average gain of 17 dBi (theoretically was 23.5 dBi). The proposed antenna may be used as substitute of heavy-weight and more costly parabolic TV reception antenna.**

***Index Terms*—Antenna, high-gain, microstrip, sub-array.**

I. Introduction

SATELLITE television receives a very low signal from satellite and therefore requires a high-gain reception antennas. In tropical countries satellite signal also is worsen by high rain percipitation during rainy seasons. Frequencies commonly used in satellite communication systems include: Ku-band (12-18) GHz, C-band (4-8) GHz, and S-band (2-4) GHz. To obtain a good reception, satellite TV commonly employs high-gain and heavy-weight parabolic antenna. The parabolic antenna is made of metal reflector which causes the antenna is expensive, heavy-weight, and can complicate the installation process. In addition, parabolic antennas can not be set to have auto electrically tracking capabilities, so for tracking operation, the parabolic antenna requires expensive and cumbersome mechanical tracking system, since parabolic reflectors antennas are difficult to move either in azimuth or in elevation as they are bulky [1]-[4]. Moreover it requires more time as it is controlled by servo motors and actuators.

Microstrip patch antennas are widely used in today's applications. It is used in satellite communication, military purposes, GPS, mobile, missile systems etc as due to its compact shape and light weight, more compact, and easy to implement. However the most serious drawback of microstrip antennas is low gain. But as we know research on phased array antenna utilizes electronic means to rotate the beam in desired direction has been rapidly growing using todays technology. In this paper, we propose to design, and implement microstrip antenna to produce high-gain antenna using sub-array technique [5]. The proposed antenna is expected to be used as substitute for the heavy-weight parabolic antenna. The sub-array design approach is intended to simplify the feeding network, and also to facilitate phased array research in the future [6]-[8].

The paper is organize as follows, Section 2 presents the antenna design approach. Secton 3 describes the antenna characterization using simulation. Section 4 presents the antenna fabrication and measurements, while Section 5 conclude the results.

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II. Antenna Design

A. Single Element Design

In this work, single antenna element was designed to produce the required bandwith of S-band on FR4 material. The final design of the rectangular patch to produce such the frequency band was shown in Fig. 1, with the dimension of W = 37.01 mm, W_t = 1.7 mm, L = 26.7 mm, L_t = 10.8 mm, L_c = 3.06, W_s = W_g = 46.6 mm, and L_g = L_s = 45.4 mm.

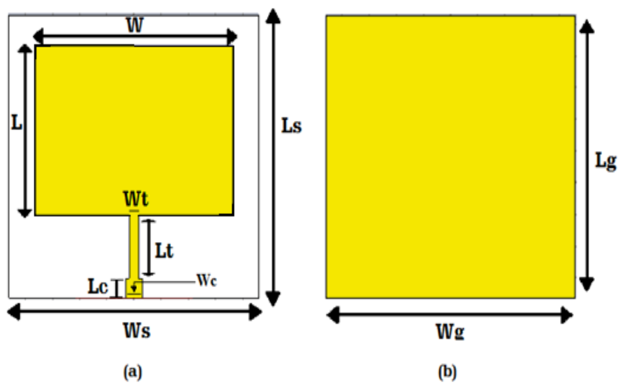

Fig. 1 Rectangular patch microstrip antenna (a) Front view, (b) Back view.

The frequency band that was produced by the proposed patch dimension was from 2,520 GHz to 2,670 GHz, resulting in 150 MHz of bandwidth. While the gain of the patch can achieve approximately 5.5 dB.

B. Sub-Array Design

Sub-array design technique was proposed in this work. The proposed sub-array approach was considered, particularly to simplify the feeds network. In addition, sub-array techniques can be designed to facilitate electronic tracking capabilities, such as the use of phased array merhod. Since the target of total gain was 22-24 dBi, theoretically we need to incorporate at least 64 antenna elements. Therefore we construct 8 sub-array, each of which consist of 8 antenna elements using rectangular (4 x 2) elements. With this arrangement, the number of feeds points to feed the sub-array is 8 port, as shown in Fig. 2. In Fig. 2, each port is the feed point to exite each sub-array.

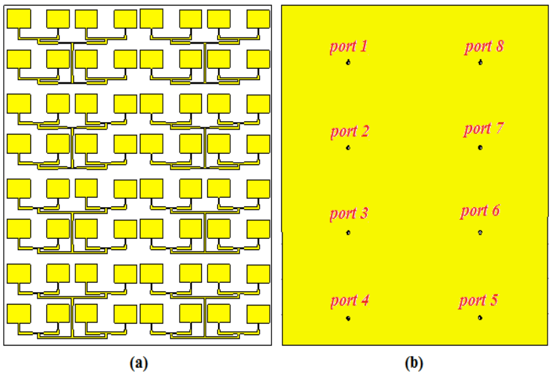

Fig. 2 A 64-element microstrip antenna array with 8 sub-arrays configuration: (a) Front view, (b) Back view.

Within each sub-array, suitable strip lines was developed to combine 8-element patch using T-Junction circuit method. This circuit is used because it has advantages, ie it does not require any other components such as resistors and this circuit can be made easily over substrat. The appearance of the eight ports for each sub-array employs power divider to feed each antenna element, shown in Fig. 3

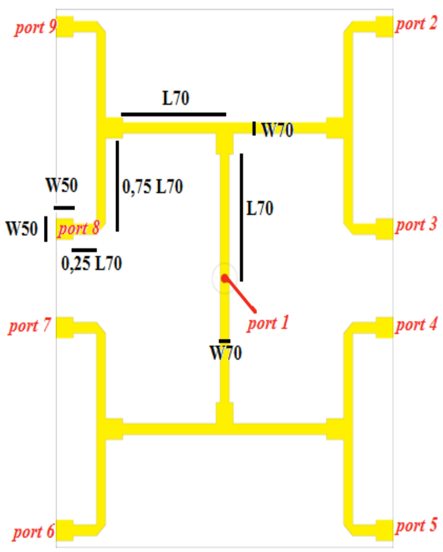

Fig. 3 Power divider for 8-element (4 x 2) sub-array

The design refers to the Wilkinson power divider circuit, to dived power equally to 8 antenna elements. The dimension of Wilkinson power divider is W50 as 50 ohms transmission line, and the W70 to produce 70.71 ohm transmisiion line. L70 is the length of the λg / 4 transmission line as for matching stub requiremens. To produce the power divider network, we compute that the dimension of W50 is 2.99254 mm, W70 is 1.5788 mm, and L70 is 16.2364 mm.

The feed network to excite each sub-array was developed separately. However, since the 8 sub-array was incorporated into a single sheet of microstrip FR4 material, the entire lay out of of proposed antenna resulting in the distance between each sub-array of 4.672 mm to the widht of the (2 x 4) sub array, and 13.44 mm. to the length of the (4 x 2) sub array, to avoid coupling between sub-arrays.

III. Simulation

To see the characteristic of the proposed antenna, simulation was conducted. The final design of the antenna was simulated to determine the gain, return loss and radiation characteristics.

Using the proposed sub-array configuration, the frequency and bandwith characteristic for each sub-array is shown in Fig. 4. In Fig. 4, $S_{1,1}$ represents each sub-array antenna frequency and bandwidth characteristics, and we also found that all sub-array exhibits almost identical frequency characteristics. The working frequency covers the frequency band from 2.4903-2.6647 GHz, with approximately 174.4 MHz of antenna bandwidth.

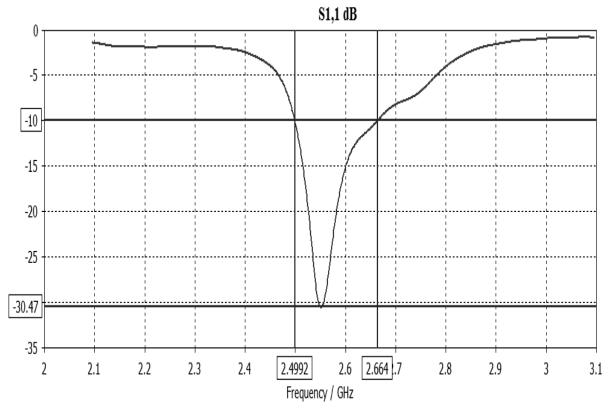

Fig. 4 Antenna frequency characteristics

The proposed antenna gain charactersitic was also obtained from simulation and shown in Fig. 5 an approximately 18 dBi of antenna gain, which is 5.5 dB lower than the 23.5 theoretical gain. This might be as a result of imperfectness of the feeding network due to non zero coupling between striplines.

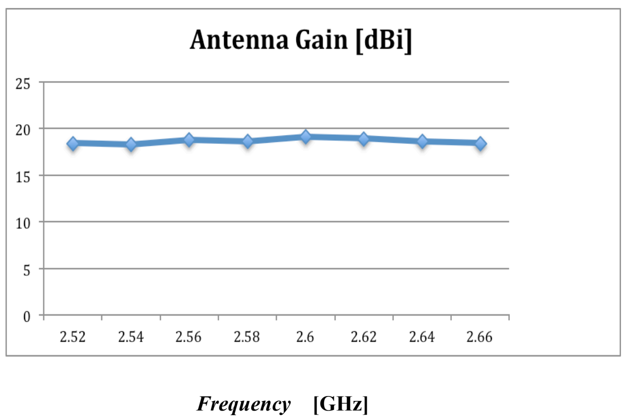

Fig. 5 Antenna gain characteristic

For the radiation pattern, the simulation was conducted at the middle frequency of 2.595 GHz. The resulting radiation pattern of the proposed antenna was shown in Fig. 6

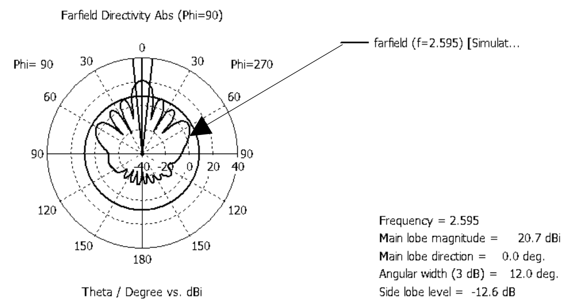

Fig. 6 Antenna radiation pattern (simulation)

From Fig. 6 we can see that the proposed antenna can produce major lobe as well as silelobes, however the ratio of the major to sidelobes was no less than approximately 20 dB.

IV. Antenna Fabrication and Measurement

Once the antenna design and simulation satisfy the required specisfication, the proposed antenna design was then implemented. Fig. 7 shows the fabrucated antenna,

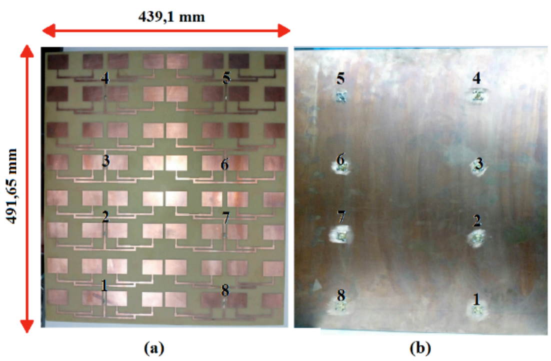

Fig. 7 Fabricated antenna : (a) Front view, (b) Back view

As shown in the design process, the proposed antenna was fabricated on FR4 material. To feed the antenna, which has 8 ports to excite each sub-array, we develop a separate uniform feed network as shown in Fig. 8.

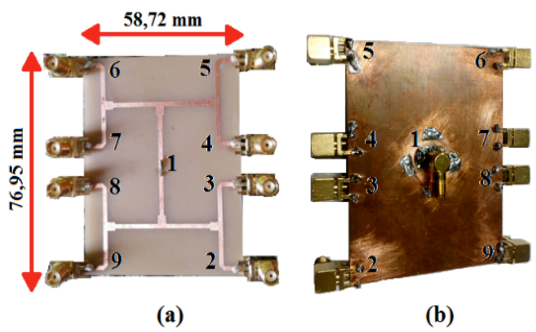

Fig. 8 Antenna feed network ; (a) Front view, (b) Back view

At this stage, the proposed antenna usning sub-arrah technique was intended to obtain high gain. For the sake of simplicity, we also feed the sub-arrayusing uniform distribution . In further study, we can feed the antenna using other more more complec and sophisticated feeding techniques to obtain different antenna characteristics, such as Tchebyscheff distribution to obtain optimum antenna characteristics. For uniform distribution, we use 8 50-ohm cables with equal length, as shown in Fig 9.

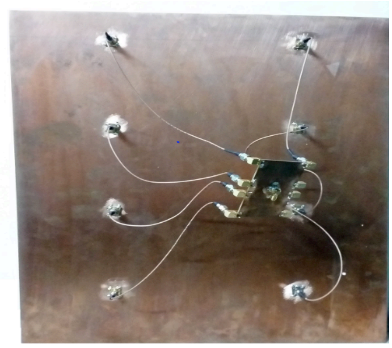

Fig. 9. Uniform feeding network of 8 sub-array antenna

Antenna measurements were then carried out to verify the antenna characteristics, i.e the antennna return loss, gain and the radiation pattern, obtained from the design and simulation, by measurements. Fig. 10 show the proposed antenna return loss characteristic, in that the measurement bandwidth was approximately 190 MHz (from 2.48-2.67 GHz), while the simulated bandwidth was approxumately 200 MHz (from 2.48-2.68 GHz)

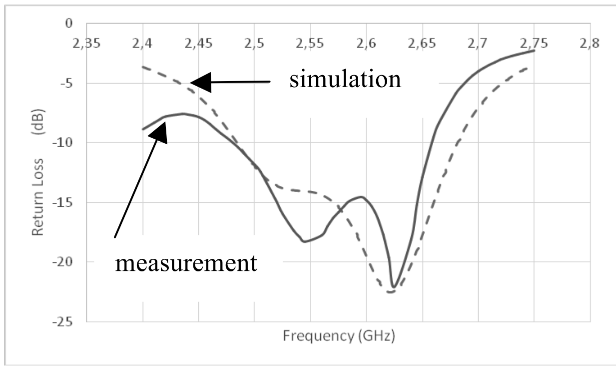

Fig. 10 Antenna Return loss characteristic

The antenna gain charactersitic, as presented in Fig. 11 shows a good agreement between simulation and measurement, which the measured gain is more frequency dependent than that obtained from simulation.

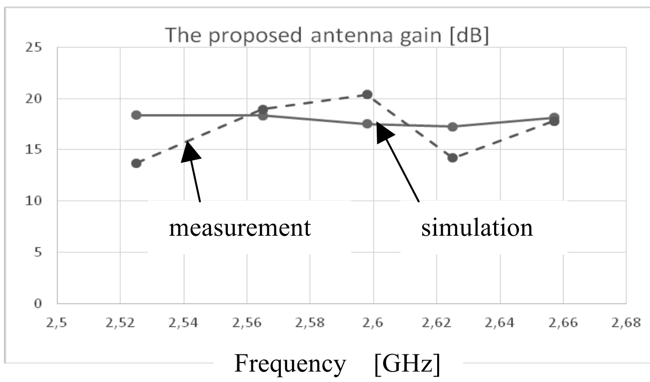

Fig. 11 Antenna gain characteristic

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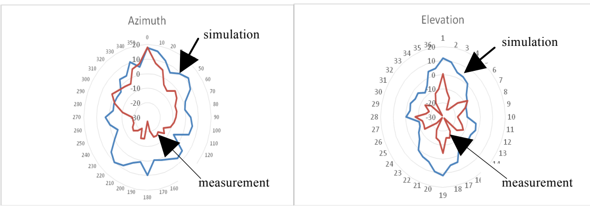

Fig. 12 Antena radiation pattern (Azimuth and Elevation).

From Fig. 12 we can see that the antenna radiation pattern has a major lobe for both azimuth and elevation angles, with many sidelobes.

V. Conclusion

The high-gain low-cost microstrip antenna has been designed using sub-array technique, and has been fabricated on FR4 substrate material. The antenna consist of 8 sb-array, each of which has 8 patch antenna elements. The fabricated antenna can operate at a frequency range of 2.4875-2.6225 GHz (covering the S-band satellite TV frequency band). The proposed antenna has gain of between 14 dB and 21 dB for the range of frequency under consideration).

In this work the sub-array construction was considered to produce high gain antenna by using uniform distribution of feeding network However, the sub-array technique can also be considered to allow flexibility of other feeding methods, so as to facilitate phased-array or other more sophisticated feeding distribution schemes to produce different antenna characteristics and requirements.

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