Low-cost steerable antenna for satellite applications

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Low-cost steerable antenna for satellite applications

M. Wady*& W. Swelam* & Mohamed H. Adel Azeem*

* Arab Academy for science and technology and maritime transport

Email: mmwady@gmail.com

Abstract. This paper discussed the design of phased array microstrip antenna which has been developed to serve the ground stations of Non geostationary satellites, the antenna array consists of 5*5 elements, the antenna operates in Ka frequency band , the gain reaches 14 dB with steerable beam which can trace the MEO (Medium Earth Orbit) satellites alongside it's visible orbit around the earth, the electronic control of the steerable beam make it possible to use one antenna to trace the MEO and LEO (Low Earth Orbit) satellites series for communication services instead of two mechanical movable antennas, the dimension of each element in the array is (4.6mm * 2.6mm) and the total size of the array antenna ,substrate dimensions, is (30mm * 28mm) which gives the antenna the advantage of small size, low cost, easy to fabricate and also fast and easy to trace the movement of satellites around the earth.

Key Words: Ka-Band, Microstrip array, satellite, Steerable beam

1. Introduction

The huge increase of satellite services like communications, earth exploration and internet caused that many engineers and researchers made a great effort in using the inclined orbit satellites for broadband services like internet and communication so to guarantee the continuity of connection with the inclined orbit satellite we need many satellites in the same orbit to be visible at least one of the series at any time [1].

According to that the ground stations also need to be movable to trace the satellite in orbit[2] and in some cases customers need two movable parabolic antennas[3] to ensure the connectivity which increase the cost and complexity of the antenna,

Our research focused on the design of microstrip phased array antenna with the ability of beam steering to trace the satellite very fast simply by change amplitude and phase of some feeders and very cheap comparing with traditional parabolic antennas[4].

The designed antenna is working in the frequency range of 27-28.8 GHz which uses for METEOROLOGICAL AIDS [5] services according to ITU-RR [6]. It consists of 25-elements of patch radiators with coaxial-probe feeds. The spacing between the patch antenna elements is 5.8 mm in Y-direction and 8.2 mm in X-direction. all simulations done by using CST software [7].

2. Single patch antenna

The antenna consists of single layer with substrate from cheap FR-4 and full ground
The schematic of the single patch antenna fed by coaxial probe is shown in Fig. 1, the single patch antenna dimensions are given in table 1.

Table 1: Single patch dimensions

Ws	**Ls**	**Wp**	**Lp**	**Wf**
30 mm	28 mm	٤,٦ mm	٢,٧ mm	0.8 mm

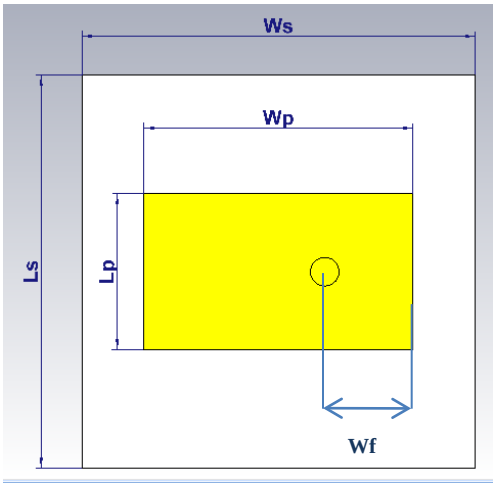


Figure 1 Single Patch antenna

The results of calculated return loss for different patch widths (Wp) are shown in Fig. 2,
We can notice that the center frequency increased as the increasing of patch width,
We optimized the patch width as 4.65 to get the lowest return loss.

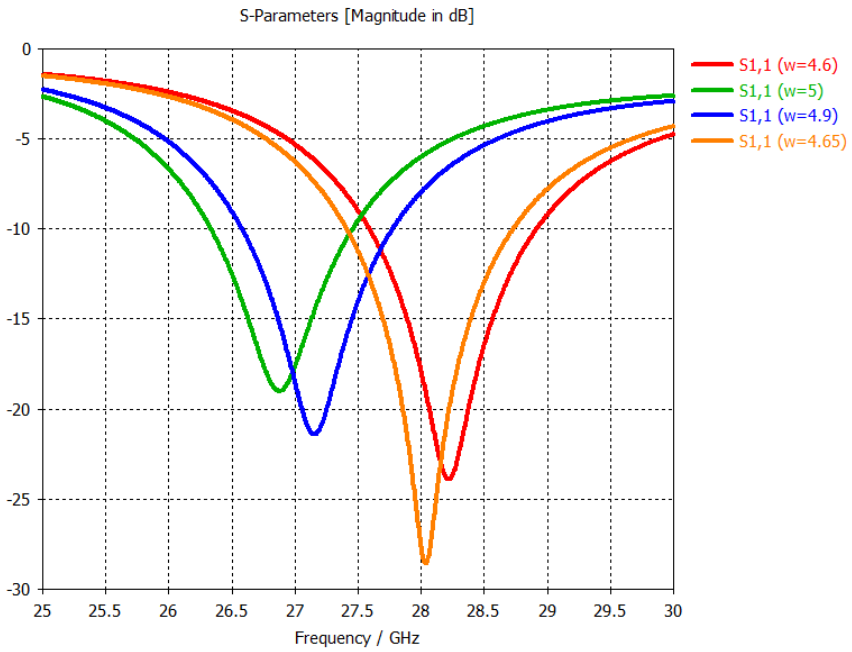
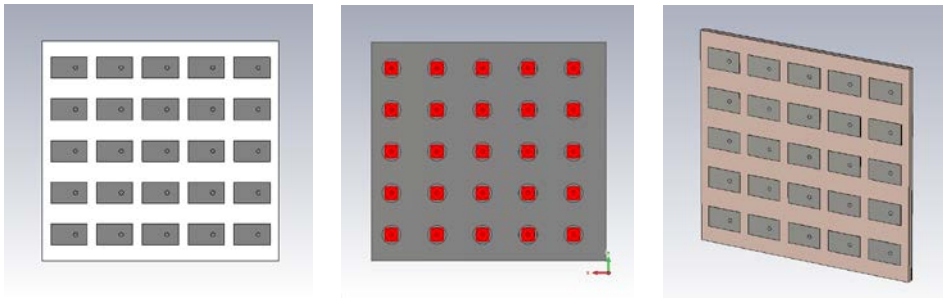


Figure 2 Return loss for different patch widths

3. Array antenna design

The array antenna is designed from 25 elements the spacing between each element is 5.8 mm in Y-direction and 8.2 mm in X-direction with separate feeding port for each element as shown in fig3



perspective front Rear

As shown in figure-4 we can notice that with some fine tuning in the spacing between elements we can shift the transmission band of the antenna to fit our needs,

In order to increase bandwidth of the antenna we choose the 8.2mm spacing between each element in X-direction which results maximum bandwidth and lowest return loss.

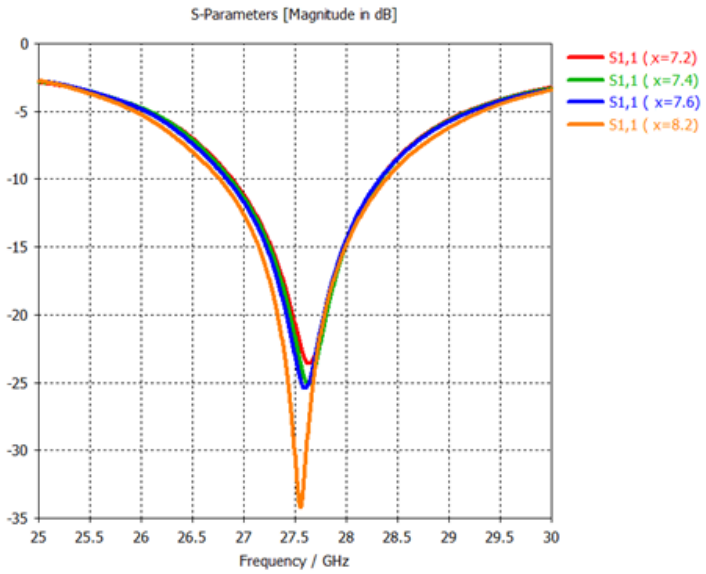


Figure 4 Return loss for different spacing between array elements

The gain of the 5*5 array antenna reaches 14dBi with the ability to point the main lobe direction by changing the phase shift between the feeders of elements according to [eq-1] described below, the half power beam width is 21º in Y-direction and 12 º in X-direction.

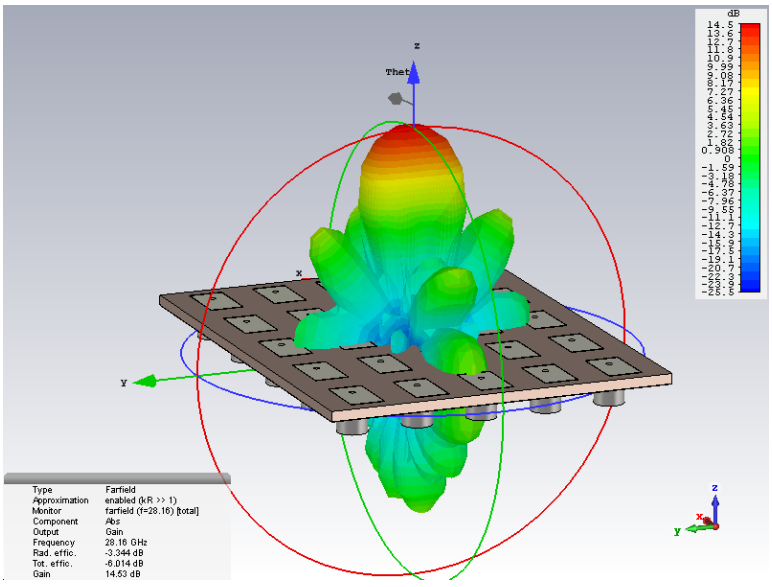


Figure 5 3-D Gain of 5*5 array antenna

The main beam angle shift $\Delta\delta(\theta_o)$ can calculated using this eq-1[8]:

$$\Delta\delta(\theta_o) = -K \bullet d \bullet \sin(\theta_o) \quad (1)$$

$K = 2 * \pi / \gamma$

γ : wave length.

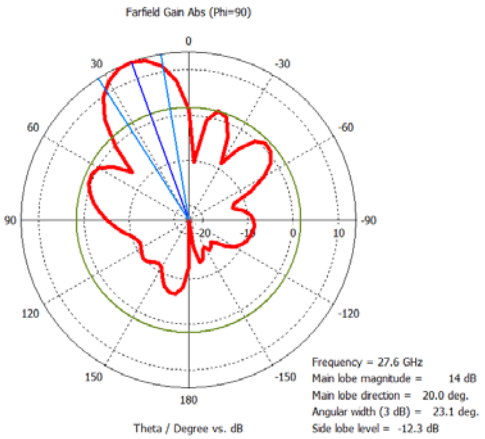
d: spacing between array elements.

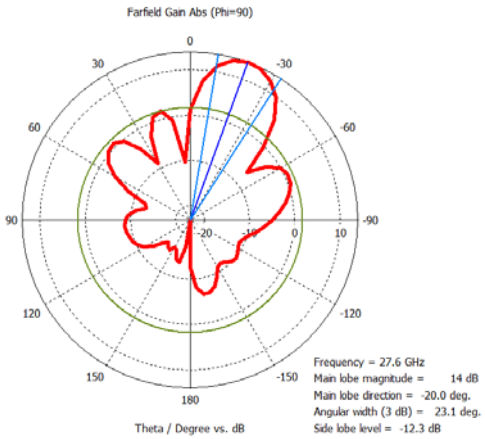
θ o : phase shift between the adjacent antenna elements

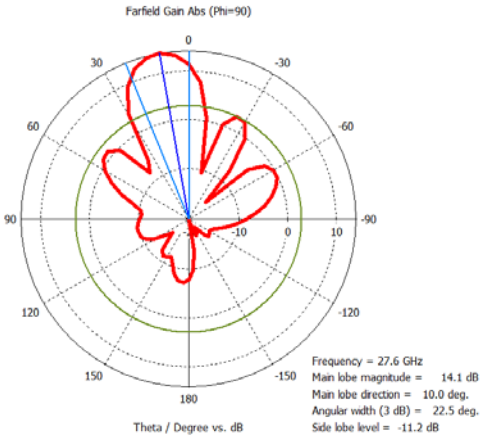
Table 2 shows the needed phase shift between the array elements to get the main lobe gain at different angles.

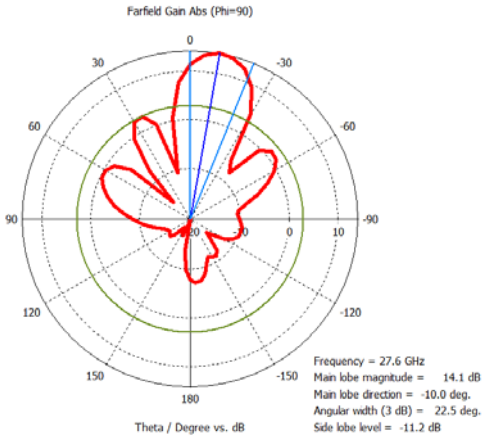
Table 2: control steerable beam using different phase shifts

Beam angle (degree)	5	10	15	20	25	30	35	40
phase shift (degree)	-15.3	-30.5	-45.4	-60	-74.2	-87.8	-100.7	-113
Beam angle (degree)	-5	-10	-15	-20	-25	-30	-35	-40
phase shift (degree)	15.3	30.5	45.4	60	74.2	87.8	-100.7	113









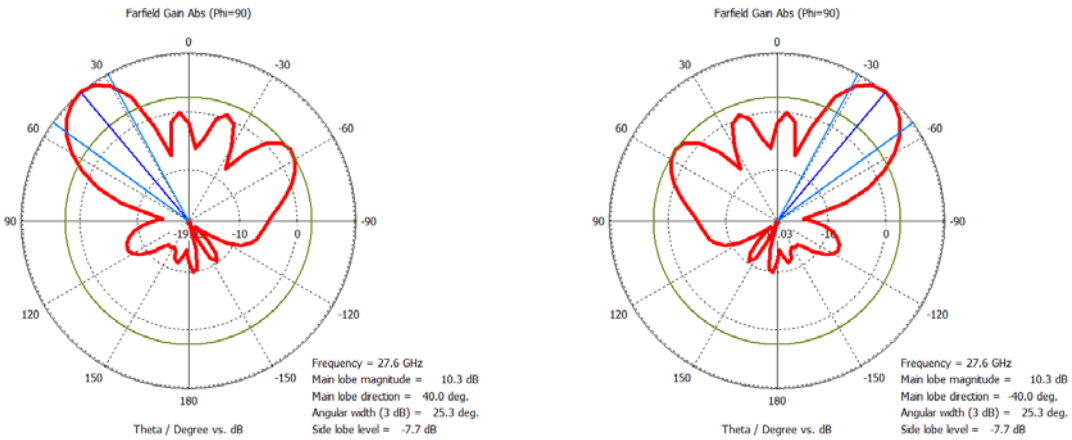


Figure 6 Steerable beam of the antenna array

4. Conclusion

The designed 5*5 array antenna can achieve maximum gain at main lobe 14 dBi each patch has it's own feeder from phase shifter to control electronically the direction of main beam to track the non-geostationary satellites in orbit by change the phase shift of each feeder,

You can notice that the maximum gain decreases with the increase of offset angle so the limits of the angle is 40o $< \theta o <$ -40o when the first side lobe power is half power of the main lobe.

References

[1] MEOLink VA-45-KA 4.5 Meter Ka-band Antenna.
[2] A. Krauss, H. Bayer, R. Stephan, and M.A. Hein *Low-Profile Tracking Antenna for Ka-Band Satellite Communications*.
[3] VA-45-KA 4.5 Meter Ka-band Antenna.
[4] Naser Ojaroudiparchin, Student Member, IEEE, Ming Shen, Member, IEEE, and Gert Frølund Pedersen, Senior Member, IEEE. *Low-Cost Planar MM-Wave Phased Array Antenna for Use in Mobile Satellite (MSAT) Platforms*, Serbia, Belgrade, November 24-26, 2015.
[5] *Earth Exploration-Satellite Service* – Handbook - Radicommunication Bureau - E n g l i s h E d i t i o n 2 0 1 1
[6] ITU-RR ARTICLE 4: *Assignment and use of frequencies.*
[7] https://www.cst.com/academia.
[8] Vasujadevi Midasala, Dr. P. Siddaiah *Microstrip Patch Antenna Array Design to Improve Better Gains* (International Conference on Computational Modeling and Security (CMS 2016)).
[9] M. Vasujadevi, Dr. P. Siddaiah and S Nagakishore Bhavanam *Rectangular Patch Antenna Array Design at 13GHz Frequency Using HFSS 14.0.* (Springer India : Advancements of Medical Electronics, Chapter : 24, ISSN : 2195-2728, ISBN : 978-81-322-2255-2, ISBN : 978-81- 322-2256-9 (eBook), Springer Book Publications, January 2015, pp.263-270).
[10] Ms.Varsharani Mokal, Prof S.R.Gagare, Dr.R.P.Labade *Analysis of Micro strip patch Antenna Using Coaxial feed and Micro strip line feed for Wireless Application* (IOSR Journal of Electronics and Communication Engineering (IOSR-JECE) e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 12, Issue 3, Ver. III (May - June 2017), PP 36-41)
[11] V. Rabinovich and N. Alexandrov, Antenna Arrays and Automotive Applications,