Progress In Electromagnetics Research Letters, Vol. 3, 95–103, 2008

NOVEL Ku BAND FAN BEAM REFLECTOR BACK ARRAY ANTENNA

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Abstract—In this paper, a Ku band fan beam reflector back array antenna is introduced. This is made up of two main parts that are planar array and main reflector. The proposed antenna has dimensions of $103.3 \times 27.5 \times 12\,\text{mm}^3$ including the reflector. This antenna with high gain for incorporating in Ku band radars at 13.4–14 GHz is described. The fan beam radiation patterns with monopolar characteristics i.e., the cross-polarization is at least 10 dB lower than the co-polarization and are obtained in the frequency band of interest. The maximum gain for proposed antenna is 16.6 dBi at 13.75 GHz and the peak gain generally >16 dBi throughout the frequency band of interest.

1. INTRODUCTION

In recent years, the demand for wireless communication services has advanced from fixed narrow bands to radar and mobile broadband services. The capability of a mobile antenna system should provide wireless internet services, wireless LAN and multimedia services, as well as high quality broadcasting services simultaneously on moving vehicles via Ku-band geo-stationary satellites. Reflector antennas with mechanical beam steering occupy an important place in the area of mobile and radar communication systems [1–10]. They make possible high gain and an admissible side lobe level at minimum cost and light weight. Recently, a shaped array antenna with an elongated main reflector and a sub-radiator was utilized in several projects (for example in [1–3]). It has a low profile design along with a high gain fan beam. Also, due to an almost reflector aperture, a feed with axial symmetry operating at both a linear and a circular polarization and providing a low cross-polarization can be used. At the same time, the aforementioned antennas have a sub-array located in the central part of the main reflector aperture that creates a blockage effect.

In this paper, a Ku band fan beam reflector back array antenna is introduced. This is made up of two main parts that are planar array and main reflector. The proposed antenna has dimensions of $103.3 \times 27.5 \times 12\,\mathrm{mm}^3$ including the reflector. This antenna has high gain suitable for incorporating Ku band radars in 13.4–14 GHz (This is one of the two frequency band that International Telecommunications Union (ITU) allocated to radars in Ku band [11]) is described. In advance, results including return losses, radiation patterns and gain variations are presented and discussed.

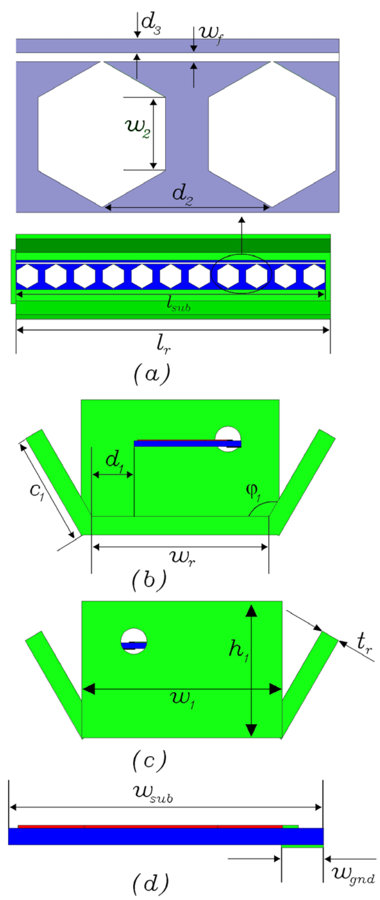

Figure 1. Geometrical parameters of antenna with band notch characteristics.

2. ANTENNA DESIGN

The antenna geometry is shown in Figs. 1(a)–(d). This antenna is made up of two main parts that are planar array and main reflector. The array part of this antenna is constructed on Rogers TMM 10i substrate with thickness ∼508 mm (20 mil), relative dielectric constant ε_r of 9.8 and $\tan\delta = 0.0020$ which has a dimension of $9.5 \times 100\,\text{mm}^2$ ($W_{sub} \times L_{sub}$). This is array of conventional hexagonal planar monopole antenna. Also, the feedline length and L_{gnd} are equal to L_{sub}. The width of transmission line, $W_f = 0.48\,\text{mm}$ has been designed for approximately $50\,\Omega$ characteristic impedance and W_f has been calculated from (1) and (2) [12] for $\varepsilon_r = 9.8$, $h = 0.508\,\text{mm}$ and $Z_0 = 50\,\text{ohm}$. The remaining parameters of planar array are: $W_2 = 4.01\,\text{mm}$, $W_{gnd} = 1.28\,\text{mm}$, $d_1 = 3.71\,\text{mm}$, $d_2 = 9.275\,\text{mm}$ and $d_3 = 0.76\,\text{mm}$. The reflector part is made from aluminum conductor with thickness $t_r = 1.65\,\text{mm}$. The ground of array is connected perpendicularly to reflector part (Fig. 2) and this means the reflector isn't parasitic element. The remaining parameters of planar array are: $L_r = 101.65\,\text{mm}$, $W_1 = 17.55\,\text{mm}$, $h_1 = 12\,\text{mm}$ and $W_r = 15.67\,\text{mm}$, $C_1 = 9.87\,\text{mm}$ and $\varphi_1 = 150\,\text{deg}$.

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12\dfrac{h}{w}}} \tag{1}$$

$$Z_0 = \frac{120\pi}{\sqrt{\varepsilon_{eff}}\left[\dfrac{w}{h} + 1.393 + 0.667 \ln\left(\dfrac{w}{h} + 1.444\right)\right]} \quad \text{for} \quad \frac{w}{h} \geq 1 \tag{2}$$

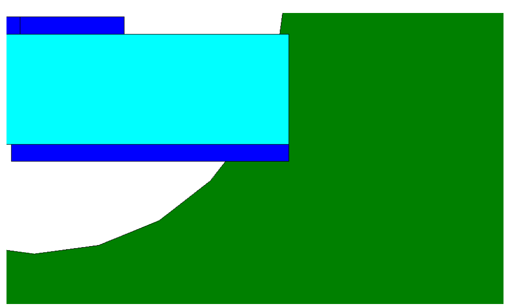

Figure 2. The ground of array is connected perpendicularly to reflector to reflector part.

3. RESULTS

The comparison between magnitude of s-parameters simulation results with Ansoft HFSSv.10 [13] and CST MICROWAVE STUDIO [14] for proposed antenna is shown in Fig. 3. Plot shows the good match between two simulation results with different commercial software for proposed antenna. Start frequency for Ansoft HFSS results is 13.25 GHz while for CST MICROWAVE results is 12.85 GHz in measurements. Both results show good impedance match ref to VSWR < 2 throughout the 13.4–14 GHz (ITU Radar Ku Band Nomenclature) passband.

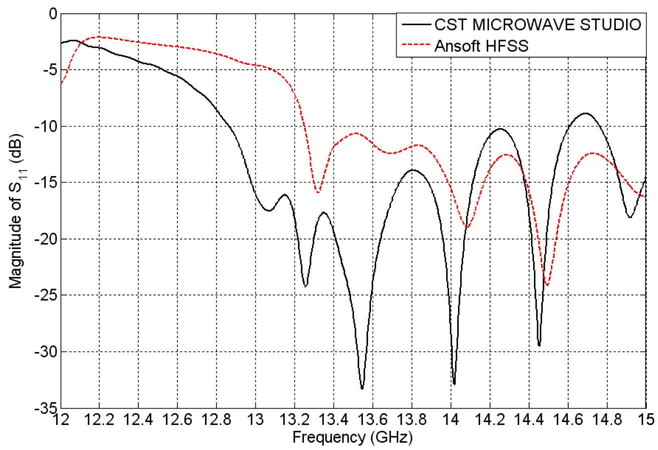

Figure 3. Magnitude of S_{11} for proposed antenna in dB.

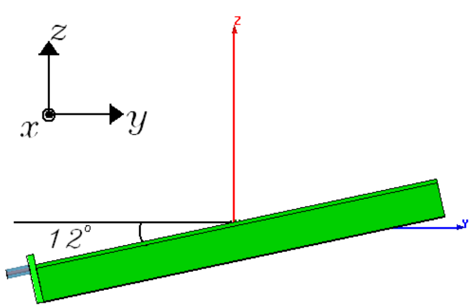

Figure 4. The deviation of antenna from Y-axis.

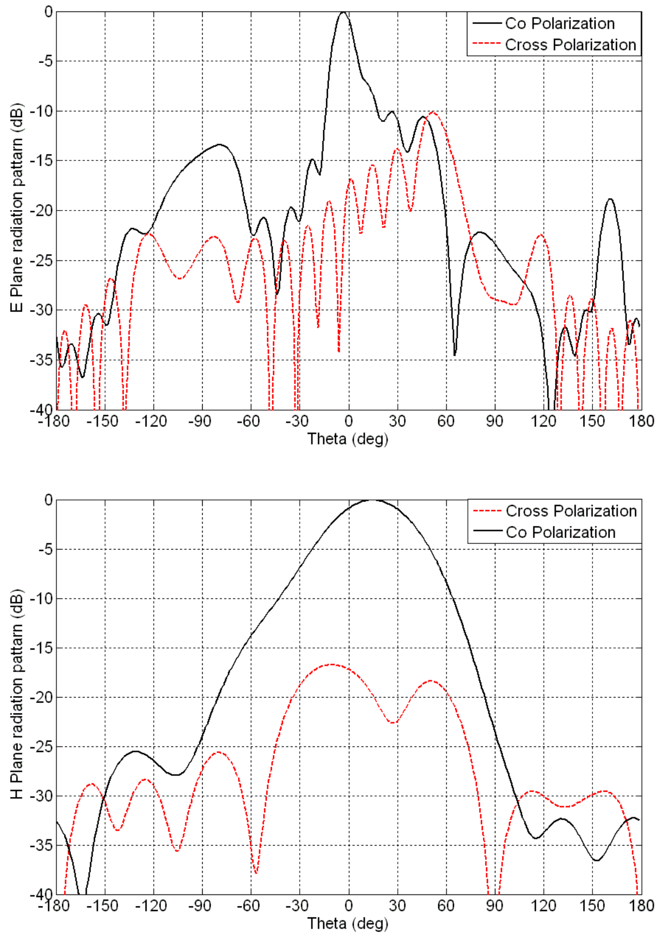

Figure 5. Radiation patterns simulated in $f = 13.4\,\mathrm{GHz}$, top is $\varphi = 90^\circ$ cut and bottom is $\varphi = 0^\circ$ cut.

The radiation pattern is achieved by Ansoft HFSS and antenna had 12 deg deviations from Y-axis (Fig. 4). The plots correspond to operating bands of 13.4, 13.7 and 14 GHz are shown in Figs. 5–7 respectively.
The top row of each figure shows the $\varphi = 90^\circ$ cut radiation while the bottom row shows the $\varphi = 0^\circ$ cut radiation patterns. The radiation plots display very good monopolar mode radiation and at least, the cross-polarization is 10 dB lower than the co-polarization in all frequency. Table 1 shows main electrical performances of the

Table 1. Main electrical performances of the radiation patterns.

Frequency band	3 dB Beam width	Side-lobe Level	Cross polarization
13.4 GHz	$13^\circ \times 57^\circ$	10.06 dBc	10 dBc
13.7 GHz	$11.25^\circ \times 49^\circ$	10.55 dBc	18.5 dBc
14.0 GHz	$10.2^\circ \times 40^\circ$	9.9 dBc	17.26 dBc

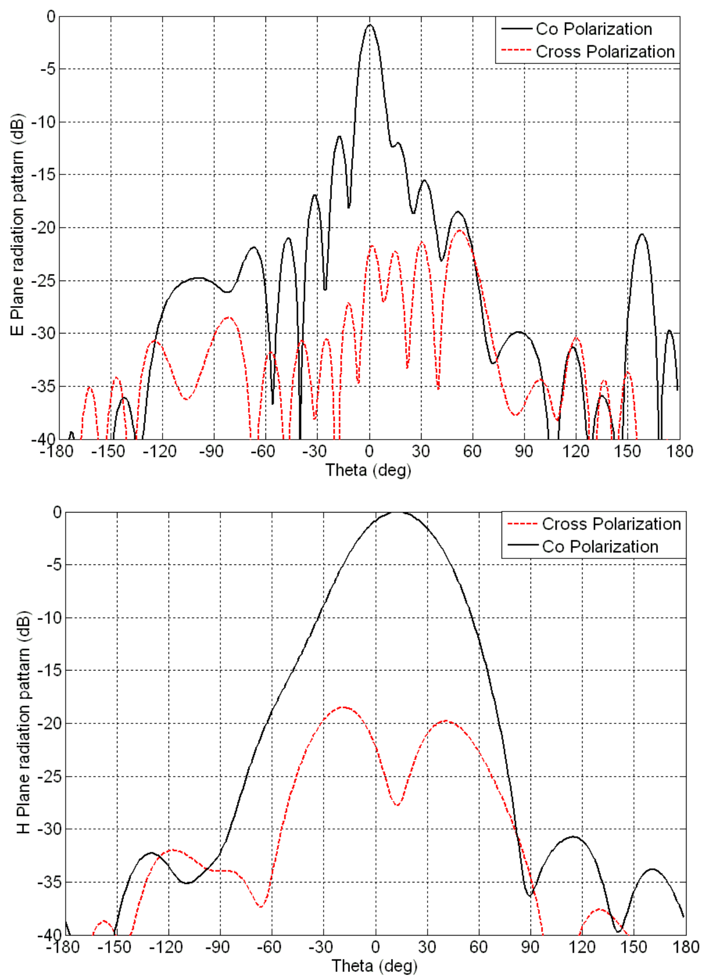

Figure 6. Radiation patterns simulated in $f = 13.7$ GHz, top is $\varphi = 90^\circ$ cut and bottom is $\varphi = 0^\circ$ cut.

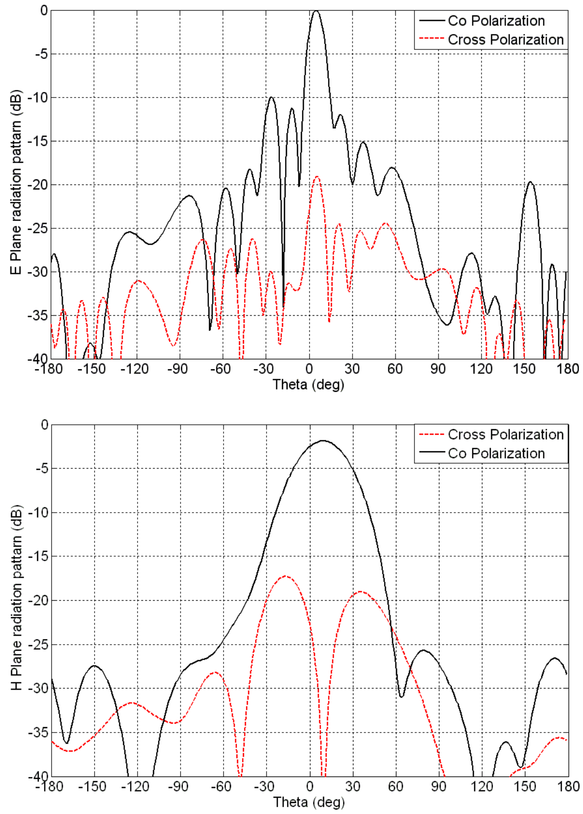

Figure 7. Radiation patterns simulated in $f = 14.0\,\mathrm{GHz}$, top is $\varphi = 90°$ cut and bottom is $\varphi = 0°$ cut.

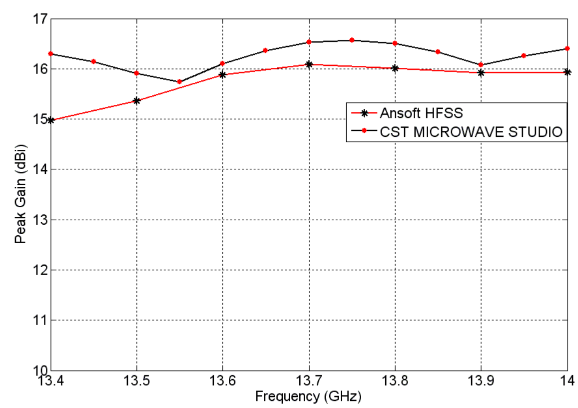

Figure 8. Peak gain of proposed antenna in (dBi).

radiation patterns results.

The antenna peak gain (dBi) is depicted in Fig. 8. It reveals that the peak gain is very stable over the frequency band of interest and in both simulations results, the gain is about 16 dBi.

4. CONCLUSION

Fan beam antenna is made up of two main parts that are sub array and main reflector is introduced. The proposed antenna has dimensions of $103.3 \times 27.5 \times 12\,\mathrm{mm}^3$ including the reflector. This antenna has high gain suitable for incorporating Ku band radars in 13.4–14 GHz is described. The fan beam radiation patterns with monopolar characteristics are obtained over the frequency band of interest. The maximum gain for proposed antenna is in 13.75 GHz and this was equal to 16.6 dBi. These results shown that the sub-array is located in the central part of the main aperture can improve the radiation performance of antenna very well.

Since the proposed antenna technology permits the provision of diverse radar applications inculduding low profile portable radar systems.

ACKNOWLEDGMENT

The author would like to thank Framoj-Pejouh-engineering Company in Iran, for their invaluable assistance and funding for this research and this is small part of RPAH project and also, would like to thank Abbas Akbarzadeh-Jahromi and Hamid-Reza Behjou.

REFERENCES

1. Schena, V. and F. Ceprani, "FIFTH project solutions demonstrating new satellite broadband communication system for high speed train," *Vehicular Technology Conf.*, Vol. 5, 2831–2835, May 2004.
2. Monk, A., et al., "An ultra-low profile airborne reflector antenna subsystem for broadband satellite communications," presented at *21st AIAA Int. Communications Satellite Systems Conf. and Exhibit AIAA*, 2003–2316, Yokohama, Japan, Apr. 15–19, 2003.
3. Eom, S. Y., S. H. Son, Y. B. Jung, S. I. Jeon, S. A. Ganin, A. G. Shubov, A. K. Tobolev, and A. V. Shishlov, "Design and test of a mobile antenna system with tri-band operation for broadband satellite communications and DBS reception," *IEEE*

Transactions on Antennas and Propagation, Vol. 55, No. 11, 3123–3133, November 2007.

4. Densmore, A. and V. Jamnejad, "A satellite-tracking K- and Ka-band mobile vehicle antenna system," *IEEE Trans. Veh. Technol.*, Vol. 42, No. 4, 502–513, Nov. 1993.
5. Inasawa, Y., S. Kuroda, K. Kusakabe, I. Naito, and Y. Konishi, "Aeronautical ultra-low-profile reflector antenna designed by physical optics shaping technique," *IEICE Society Conf., C-1-5*, Tokushima, Japan, Sep. 21–24, 2004 (in Japanese).
6. Wakana, H., et al., "COMETS for Ka-band and millimeter-wave advanced mobile satellite communications and 21 GHz advanced satellite broadcasting experiments," *Proc. IEEE Int. Conf. on Communications*, Vol. 1, 79–83, Jun. 1998.
7. Lee, H., Y. H. Kim, V. A. Volkov, R. V. Kozhin, D. M. Vavriv, and T. S. Kim, "35 GHz compact radar using fan beam antenna array for obstacle detection," *Electronics Letters*, Vol. 43, No. 25, December 6, 2007.
8. Young, J. and L. Peter, "A brief history of GPR fundamentals and applications," *Proc. 6th Int. Conf. Ground Penetrating Radar*, 5–14, 1996.
9. Kim, I. K., K. S. Yang, S. Pinel, and J. Laskar, "Slot array antennas fed by integrated wave guide on liquid crystal polymer for V-band wireless LAN application," *Proceedings of Asia-Pacific Microwave Conference*, 2006.
10. Daniels, D. J., "Surface-penetrating radar," *IEE Radar Sonar Navigation Avionics*, Series 6, 72–93, IEEE Press, 1996.
11. Skolnik, M. I., *Introduction to Radar Systems*, New York, McGraw-Hill, 1980.
12. Jameses, J. R. and P. S. Hall, *Handbook of Microstrip Antennas*, Vol. 1, Peter Peregrinus & IEEE, London, 1989.
13. Ansoft High Frequency Structure Simulation (Ansoft HFSS$^{\text{TM}}$ V 10.0), Ansoft Corporation, 2005.
14. CST MICROWAVE STUDIO v5.0, Computer Simulation Technology, 2003.