Design and Development of Wide band, High Gain Monopulse Reflector Antenna at Ku-Band for Synthetic Aperture Radar

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Abstract

This paper describes the design and development of a very wide band (> 3GHz), high gain lightweight (< 4kg) parabolic reflector antenna at Ku-band for synthetic aperture radar (SAR) applications. The antenna aperture dimension has been fixed to 0.7m x 0.2m to achieve a 3dB beam width of < 2° in azimuth and < 7° in elevation with a total gain of > 33dB over a 3GHz bandwidth with side lobe levels of -25dB. In order to achieve sum and difference patterns reflector is illuminated with multimode feed horn where feed higher order modes are utilized for producing difference beam.

Keywords : Parabolic Reflector antenna Multimode feed horn Synthetic Aperture Radar (SAR)

1. Introduction

The commonly used antennas for SAR applications are parabolic reflector fed by a horn, slotted array, and patch antenna. Each type of antenna has its own advantages and limitations. The type of antenna is decided based on factors such as bandwidth, efficiency, side lobe levels, weight, size and mounting aspects. Parabolic reflector has large volumetric size as compared to that of the slotted array and patch array. Slotted array is popular because of its high power handling capability, but has limited bandwidth. Microstrip patch antennas are easier to fabricate but have limited power handling capability.

The parabolic reflector antenna illuminated by a multimode feed horn is designed and developed at Ku-band to provide a very high gain (> 33dB) over a wide frequency bandwidth of 3GHz with side lobe levels better that -25dB. The antenna can handle a peak power of 300W and the overall weight is < 4kg. The reflector profile was fabricated using sandwiched fibre reinforced plastic (FRP) material and by pasting a fine metallic mesh on the reflector surface. This paper describes the methodology followed in the design and development of reflector as well as the feed horn. The simulated and measured radiation characteristics of the antenna are also presented.

2. Reflector Design

The parabolic reflector antenna consists of a feed horn placed at its focal point and a reflector shaped in such a way that all the rays being emitted by the feed are collimated and reach the aperture plane in phase [1]. With the antenna aperture size being fixed at 0.7m x 0.2m and the antenna being intended for SAR application, the F/D ratio is the key design parameter. The F/D ratio determines the reflector shape, volumetric space, feed location, and aperture illumination. Based on these factors and available volumetric space for accommodating the antenna, F/D ratio of 0.4 is finalized. The design of the reflector antenna was carried out using TICRA-GRASP9 software. The feed is supported at the focal point position by quadra-pods for achieving rigidity to overcome vibrations. The antenna sketch generated from GRASP9 software and simulated radiation characteristics are shown in Fig. 1.

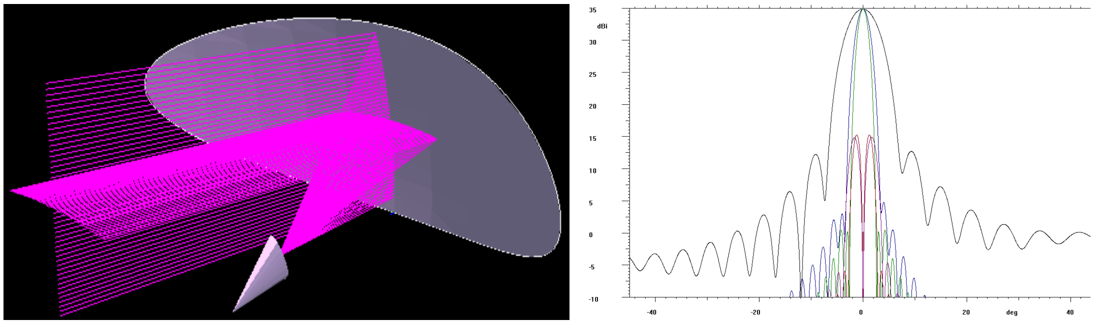

Figure 1: Parabolic reflector antenna and simulated radiation characteristics.

3. Feed Design

A multimode feed horn is designed to obtain sum and difference in azimuth. As the polarization requirement is vertical, the elevation plane corresponds to E-plane while the azimuth plane corresponds to H-plane. In order to have the first sidelobe level of the order of –25dB, it is required that the edge illumination of the reflector should be 10 to 12 dB below that at the centre. A rectangular aperture horn meeting this criterion was used as a feed for parabolic reflector antenna. Monopulse in azimuth plane is achieved through higher order modes in the feed horn. The feed horn utilizes the TE_{10} mode in a rectangular cross sectional horn for reference (sum) channel operation and the TE_{20} mode to form the monopulse in one plane (H-plane). The radiation patterns of the general TE & TM modes are given by Silver [1]. For the modes used to obtain the sum and difference patterns, these radiation patterns are given by the following, after simplification and dropping constants,

TE_{10} mode :

$$E_\theta \approx (1+\cos\theta)\frac{\sin\frac{u}{2}}{\frac{u}{2}} \qquad \phi = \frac{\pi}{2} \qquad E-Plane \tag{1}$$

$$E_\theta \approx -(1+\cos\theta)\frac{\cos\frac{u}{2}}{\left(\frac{u}{2}\right)^2-\left(\frac{\pi}{2}\right)^2} \qquad \phi = 0 \qquad H-Plane \tag{2}$$

TE_{20} mode :

$$E_\theta \approx (1+\cos\theta)\frac{\sin\frac{u}{2}}{\frac{u}{2}} \qquad \phi = \frac{\pi}{2} \qquad E-Plane \tag{3}$$

$$E_\theta \approx -(1+\cos\theta)\frac{\cos\frac{u}{2}}{\left(\frac{u}{2}\right)^2-(\pi)^2} \qquad \phi = 0 \qquad H-Plane \tag{4}$$

A cross-section of the multimode feed horn and simulated radiation characteristics are shown in Fig. 2. Along with the basic mode of TE_{10}, additional higher order mode of TE_{20} is excited by the linear taper [2] at the input waveguide junction. The feed horn designed and simulated in Ansoft HFSS software.

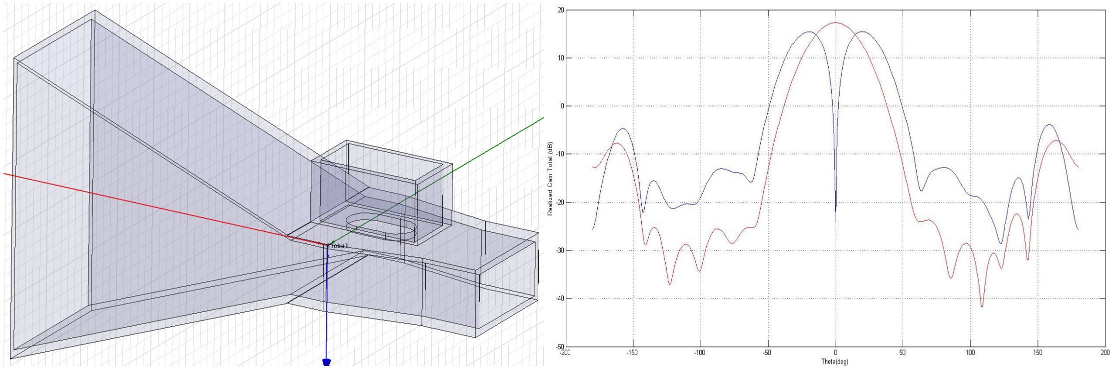

Figure 2: Cross-section of multimode monopulse feed horn and simulated radiation characteristics.

4. Fabrication

As the reflector antenna is designed for SAR applications, it is required to be realized in light weight (< 4kg). The reflector profile and the feed mounting structure was fabricated using foam sandwiched between FRP composite material. The reflecting surface is achieved by pasting a fine metallic mesh. The feed horn was machined out from a single aluminium block of Al - 2024. The fabricated parabolic reflector with multimode feed horn is shown in Fig. 3.

Figure 3: Realized reflector assembled with multimode feed horn.

5. Results and Conclusions

The realized light weight (< 4kg) parabolic reflector antenna integrated with multimode feed horn is measured for its return loss which is better than -15dB (for sum as well as difference ports) throughout the required 3GHz frequency band of operation is shown in figure 4. The radiation pattern measurement was carried out in compact antenna test range (CATR) at SAMEER Kolkata. The measured radiation patterns at centre frequency are shown in Fig. 5. SLL of the order of -22dB and a total gain of reflector antenna > 33dB over a wide frequency bandwidth of 3GHz is achieved. The deterioration of SLL in azimuth is attributed to the surface roughness of 80 microns practically achieved by the use of metallic mesh for the reflector surface. The null depth of better than –20dB is achieved in azimuth difference port with the multimode feed horn.

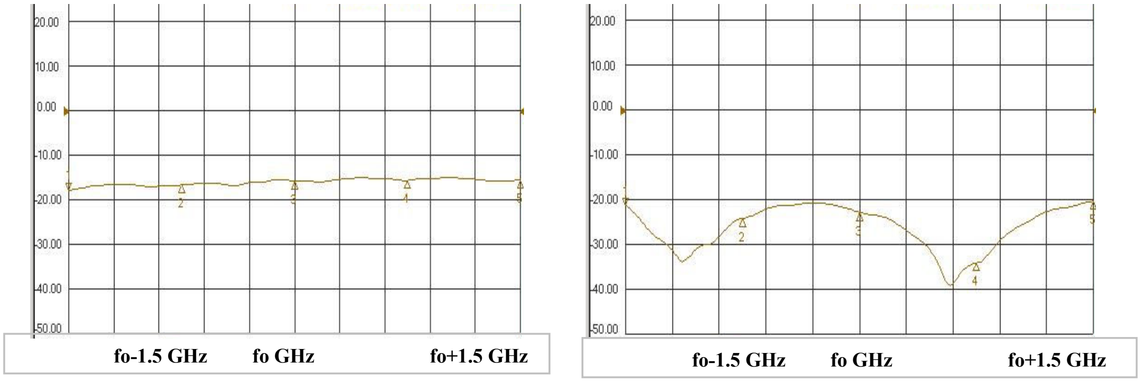

Figure 4: Measured return loss of sum and difference ports of parabolic reflector antenna.

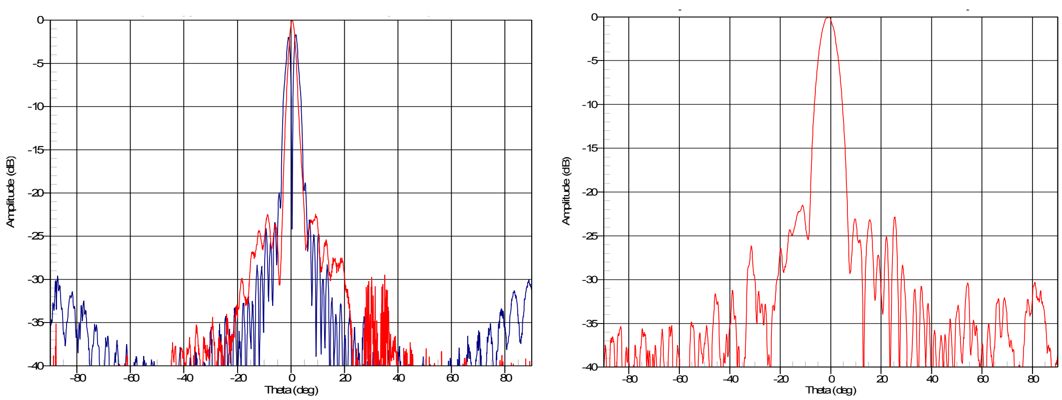

Figure 5: Measured radiation characteristics of parabolic reflector antenna fed by multimode horn.

References

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