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# A Wideband Dual Polarised Hat Feed-based Ku-Band Reflector Antenna for Man Portable Satcom Application

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**ABSTRACT**

This paper describes the design, simulation, and development of an accustomed 0.76 mtr hat feed-based Ku-band reflector antenna for a man-portable Satcom application. The antenna uses a small f/D ratio of 0.25 for reducing spillover radiation & low far-out sidelobes besides making the antenna compact. This lightweight antenna with a manual pointing system (elevation over azimuth) can operate simultaneously over the complete transmit and receive frequency band of Ku-band Satcom. The designed antenna was simulated in High Frequency Structure Simulator (HFSS) software and results were verified in GRASP (TICRA) software. The measured VSWR of the antenna is 2:1 over the complete receive and transmit frequency band. The achieved gain of the developed antenna is 36.3 dBi @ 11 GHz and 38.4 dBi @ 14 GHz. On-axis cross-polarization of the antenna is better than 30 dB. Carbon Fibre Reinforced Polymer (CFRP) based realized antenna system is in a multi-panel configuration having six symmetrical petals and one central system. The developed antenna shows more than 70 % radiation efficiency at the transmit frequency band of Ku-band satcom. The total weight of the antenna system including the reflector, feed, backup structure, and tripod assembly is less than 11 Kg. The experimental results are quite close to the simulated one in terms of VSWR, gain, cross- polarization, and transmit-receive isolation.

**Keywords:** CFRP; Hat feed; Ku-band; Reflector antenna; Satcom; VSWR

## 1. INTRODUCTION

Nowadays, there is an incremental development and wide applications of satellite communication. Increased satellite output power levels and the simple design of earth stations with Very Small Aperture Terminals (VSAT) pave the way for domestic satellite communication services, including TV links, multiplexed telephones, cable TV distribution, business communication, and DTH services. The design and development of a dual-polarised corrugated conical horn employed as a feed for parabolic reflector antennas used in very small aperture terminal applications was developed[1]. Satcom systems offer wide area coverage, and long-rage service to moving platforms like ships, aircraft, and vehicles. A few years ago, military satcom systems were mainly used as fixed terminals for wideband traffic at high data rates using large antennas[2]. Development of indigenous man-portable systems for tactical military communication that can be quickly shifted and deployed to a new location within a short time under field conditions to provide secure, reliable, and fast communication through satellite is need of time.

Reflector antenna, being a secondary antenna, needs a primary antenna to illuminate it. Conventionally, the feed for the reflector antenna should be a point source placed at the focus of the reflector antenna. The feed/ primary antenna phase centre should coincide with the focus of the reflector for optimum performance. Ring focus type reflector is used to obtain minimum phase error and optimum efficiency. The hat feed has a ring-shaped phase centre that generates an elliptical wave. The hat feed illuminates the reflector, based on radiation from circumferential aperture. In the ring focus reflector system, the ring focus feed should coincide with the ring-shaped phase center of the reflector, to improve the aperture efficiency by almost 1 dB[3].

Man-portable satcom terminal demands low sidelobes and low cross-polarisation. The side lobe level of the reflector antenna is dictated by the ITU envelope. Besides being robust, a hat feed-based reflector antenna has minimum aperture blockage due to self-supported feed geometry without any struts. In this configuration, RF electronics can be integrated behind the antenna reflector and far-out sidelobes can be lowered by selecting a small f/D ratio where f is the focal length and D is the diameter of the reflector.

The idea of designing a reflector antenna using a self-supporting waveguide feed having minimum blockage was proposed in the 1940s[4]. After a long time, hat feed as a new self-supported feed was proposed in 1986-87[5-6]. Since then, several hat feed-based antennas have been developed for several applications[7-17]. The hat feed uses a circular waveguide as the neck which is supported by a dielectric head spacing and a corrugated hat disc to reduce the cross-polarisation level.

Some of the similar types of work[8,12] have been reported by various authors. They use a single reflector antenna configuration which is bulkier and not easily transportable. The

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present work describes a multi-panel CFRP-based antenna for a man-portable satcom terminal where weight and volume should be as low as possible. Accustomed hat feed-based 0.76 m reflector antenna has been designed and developed for Ku-band Satcom, using Carbon Fiber Reinforced Polymer (CFRP) material to meet the 2 Mbps data rate requirement for man portable Satcom terminal. The electrical conductivity of CFRP material is very close to that of metal[18]. There will be negligible effect on the efficiency of the reflector due to the choice of this material because reflectivity due to CFRP is similar to metal. The antenna system has been designed as a detachable multi-panel system with seven segment reflector having six petals and one central feed system. The developed antenna has more than 70 % radiation efficiency at the transmit frequency band of Ku-band Satcom which is higher than a contemporary similar design.

## 2. DESIGN CONSIDERATION

Man portable satcom terminal requires a compact, lightweight, and rigid directional antenna system. To make the system lighter in weight, these type of terminals uses a manual positioning system to point the satellite with the help of GPS, compass, and other sensors. To align with the satellite an orthomode transducer along with high high-performance trans-reject filter is used with the feed system to get 85 dB isolation between the transmit and receive port.

Based on simplicity, ease of fabrication, and fulfilment of all specifications for the present application specifically low sidelobes and low cross-polar levels over wideband for satellite communication, a prime focus hat feed reflector antenna configuration has been chosen. In hat feed- based reflector antenna, the feeding waveguide acts as an axial support also.

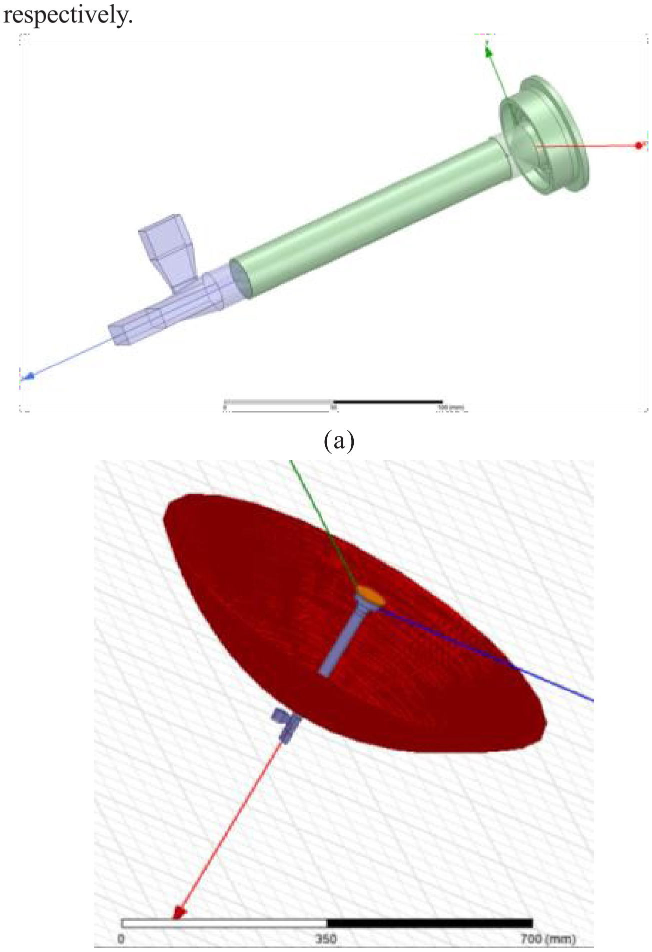
The output of the Orthomode Transducer (OMT) is a circular waveguide that acts as input to the hat feed having $TE_{11}$ fundamental mode. The $TE_{11}$ mode of circular wave guide couples to two different modes in the radial direction, i.e. $\phi$-mode with E-field in both $\phi$ and $\rho$ direction and the z-mode with E- field in the z-direction only. The $\phi$-mode radiates in the H-plane and no radiation along the neck while the radiation of z-mode is mainly in the E-plane and also strongly along the neck in both the E- and H- planes[6]. When the two modes are in the correct phase and amplitude, equal E- and H-plane patterns are created resulting in low cross-polarisation. Generally, the corrugation length of the hat brim is taken as $\lambda/4$ which generates zero current along the brim due to zero normal z-component of the E-field. This creates increased radiation pattern symmetry, reduced cross-polarisation, and low spillover sidelobes.

All the dimensions of the hat-fed antenna structure have been calculated and optimised based on the reflector subtended angle at the focus and the required tapering at the edge of the reflector. In the present case, the f/D of the reflector has been taken as 0.25 with the subtended angle of 180° at the focus. -11 dB edge tapering has been taken to minimize the side lobe level of the antenna to less than 15 dB. The hat brim diameter is chosen for minimum aperture blockage due to hat feeding and the satisfactory performance of the antenna system. To support the propagation of $TE_{11}$ mode for cut-off frequency 9.25 GHz, the inner radius of the circular waveguide has been selected as 9.5 mm.

The cross-polarisation of the antenna has been met by selecting the prime focus configuration which is a symmetrical geometry and hence would provide excellent cross-polarisation. A high- performance orthomode transducer has been used to separate the vertically polarized transmit signal and horizontally polarised receive signal with transmit-to-receive isolation of better than 40 dB. A Trans-reject filter (TRF) at the receive port is used to obtain isolation of the order of 85 dB so that transmit power may not saturate the receiver. To rotate the antenna in the required direction (azimuth, elevation, and polarisation), a manual positioning system has been used. Pointing to a satellite is done using a Global Positioning System (GPS) receiver which is attached to the terminal.

Design and simulation of OMT have been carried out using a High Frequency Structure Simulator (HFSS) to meet the transmit-to-receive isolation of 40 dB. Designed OMT has been integrated with the hat feed and the integrated feed system was simulated and optimized in HFSS for the required VSWR within the desired receive and transmit frequency band. After that complete antenna system including the feed and 0.76m reflector has been modelled in HFSS software and simulation and optimization of the same was carried out.

3-D model of hat feed with OMT and complete antenna modelled in HFSS are shown in Fig.1(a) and Fig. 1(b), respectively.




(a)

(b)

**Figure 1. (a) 3-D Model of hat feed with OMT and (b) 3-D model of antenna.**

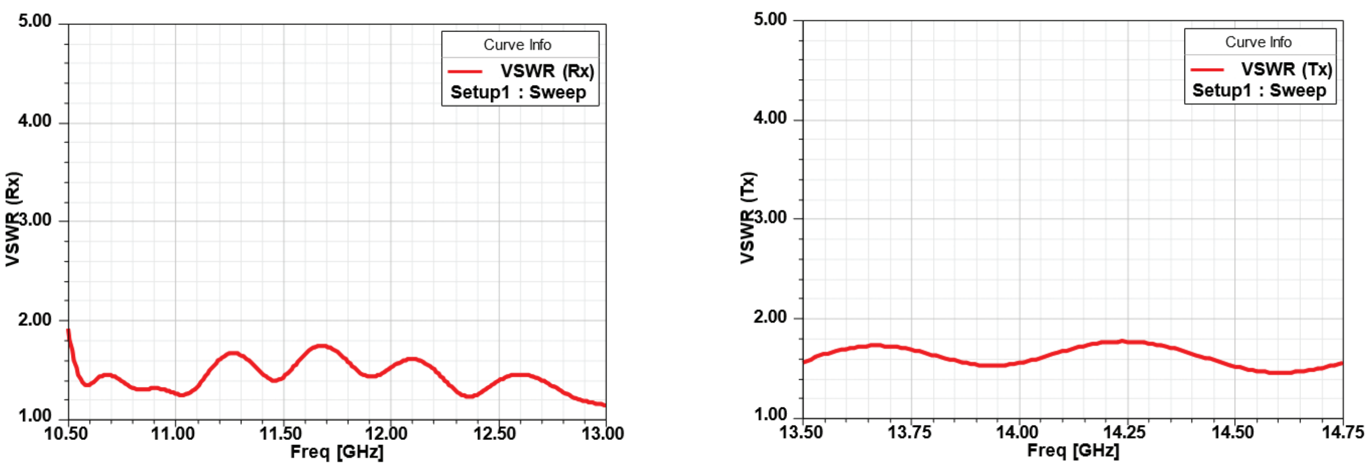
The methodology used for the fabrication of the antenna reflector is CFRP molding and for other major components laser cutting, water-jet machining followed by bending.

## 3. SIMULATION STUDIES & MEASURED RESULTS

Hat feed geometry along with feeding waveguide and orthomode transducer has been modelled and simulated in ANSYS HFSS software. A photograph of the developed antenna system is shown in Fig. 2. The simulated VSWR of the hat feed at transmit and receive frequency bands are shown in Fig. 3 (a) and Fig. 3 (b), respectively. It can be seen from the figures that the simulated VSWR is < 2 over the complete transmit and receive frequency band. Simulated radiation patterns of the feed @11GHz in receiving mode and @14 GHz in transmission mode are shown in Fig.4 (a) and Fig. 4 (b), respectively. Fig. 5 (a) and Fig. 5 (b) show the simulated co- and cross-pol radiation pattern of the antenna at mid-receive and mid-transmit frequency, respectively. The achieved simulated gains are 37.0 dBi (Receive) and 39.3dBi (Transmit). The simulated results of the antenna have been verified in GRASP from TICRA software by exporting the feed patterns from HFSS software. Fig.6(a) and Fig. 6 (b) show the simulated radiation pattern of the antenna @11 GHz and @14 GHz, respectively, using GRASP. The simulated gains through GRASP software are 36.4 dBi and 38.7 dBi at 11 GHz and 14 GHz, respectively.

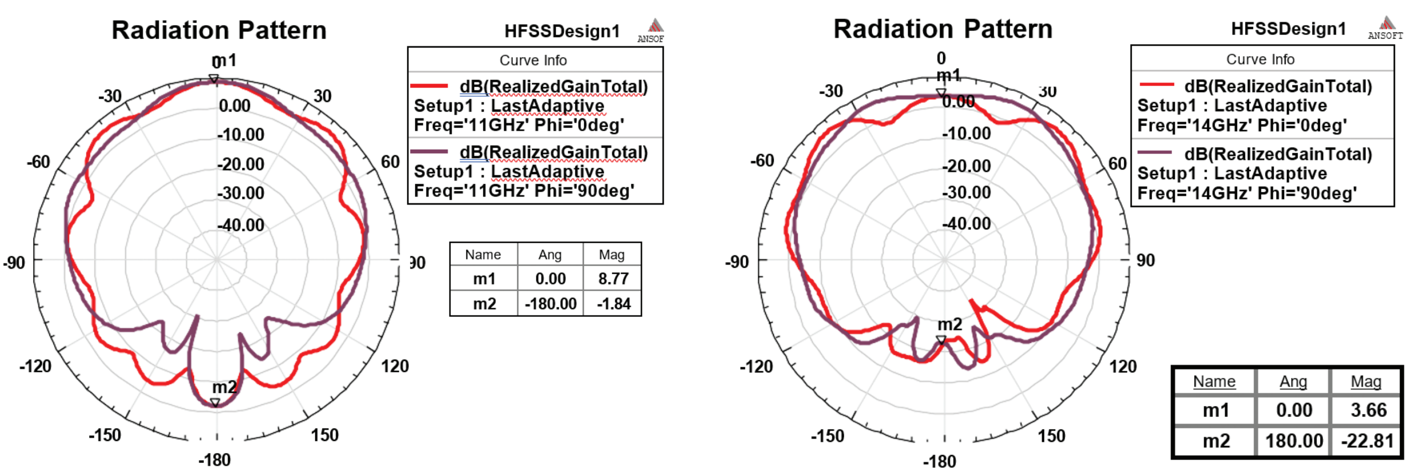
After realizing the antenna using CFRP material, the antenna has been evaluated for its electrical performance in

**Figure 2. Developed antenna system.**



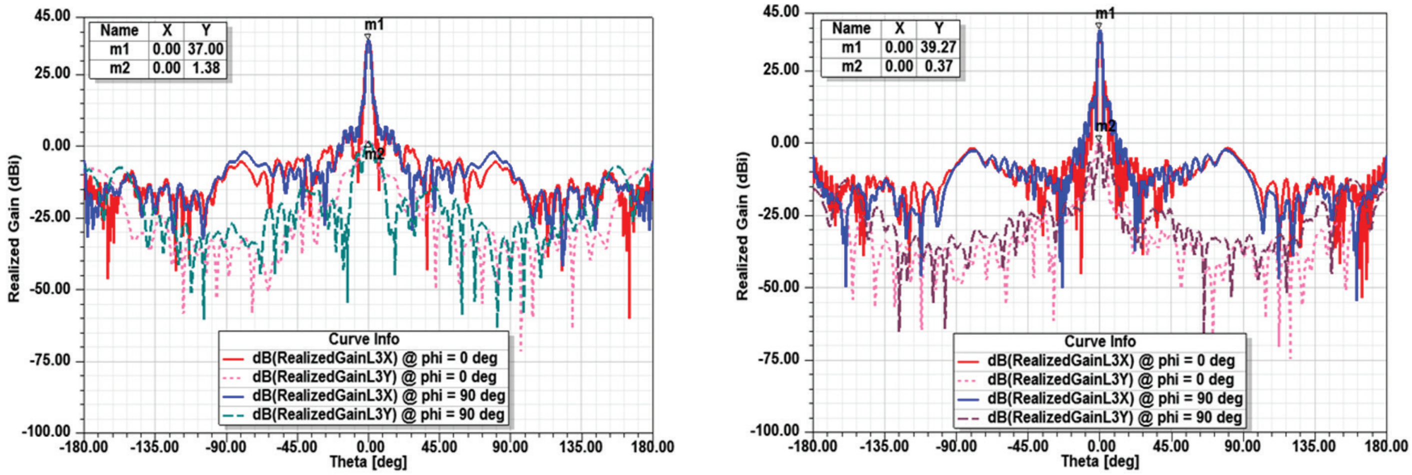

(a) (b)

**Figure 3. VSWR Vs. frequency: (a) Receive and (b)Transmit.**



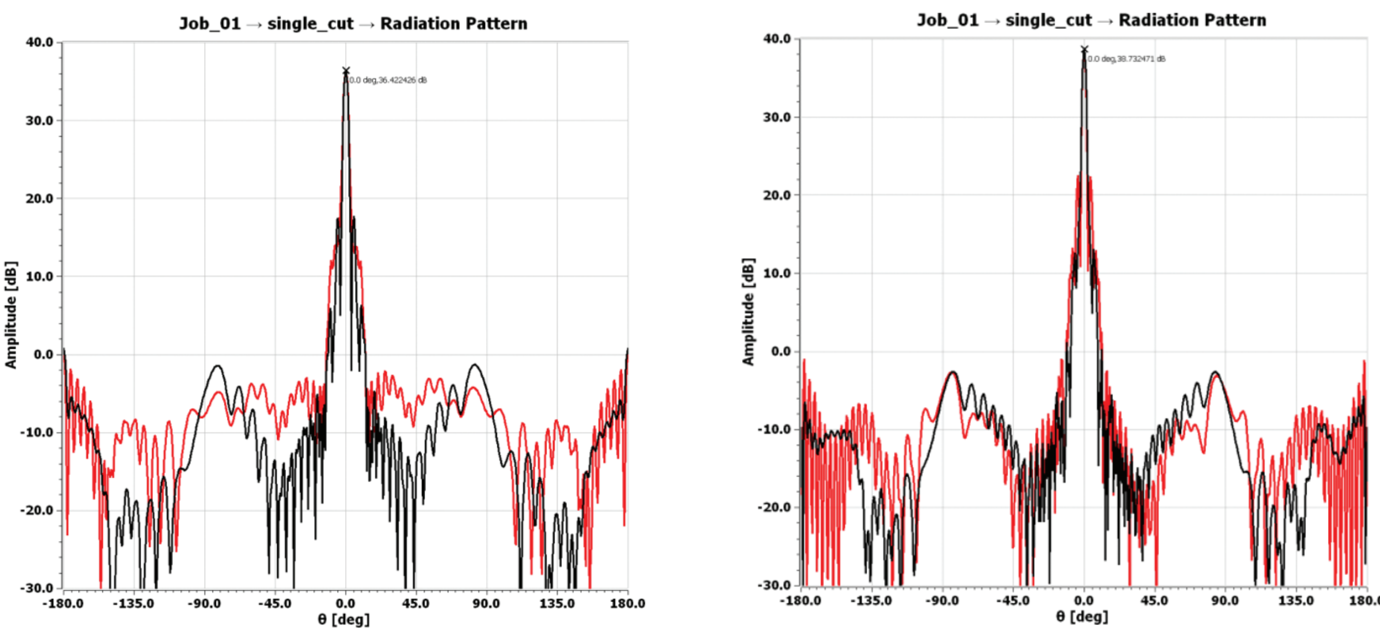

(a) (b)

**Figure 4. Feed pattern with OMT: (a) at 11 GHz and (b) at 14 GHz.**



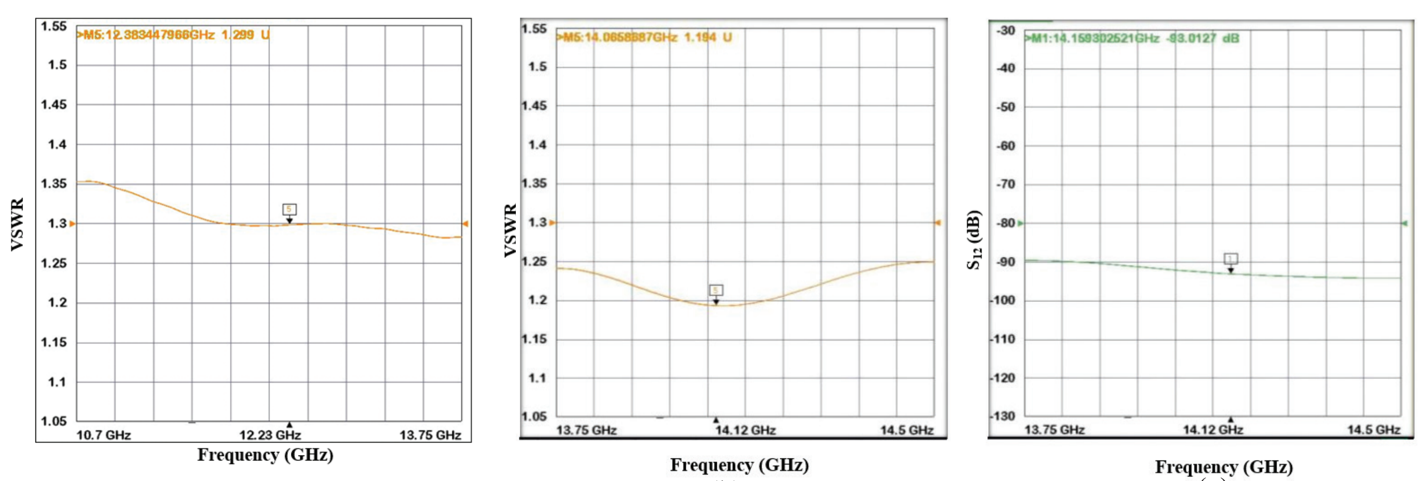

(a) (b)

**Figure 5. Radiation pattern of the antenna: (a) At mid-receive frequency and (b) At mid-transmit frequency.**



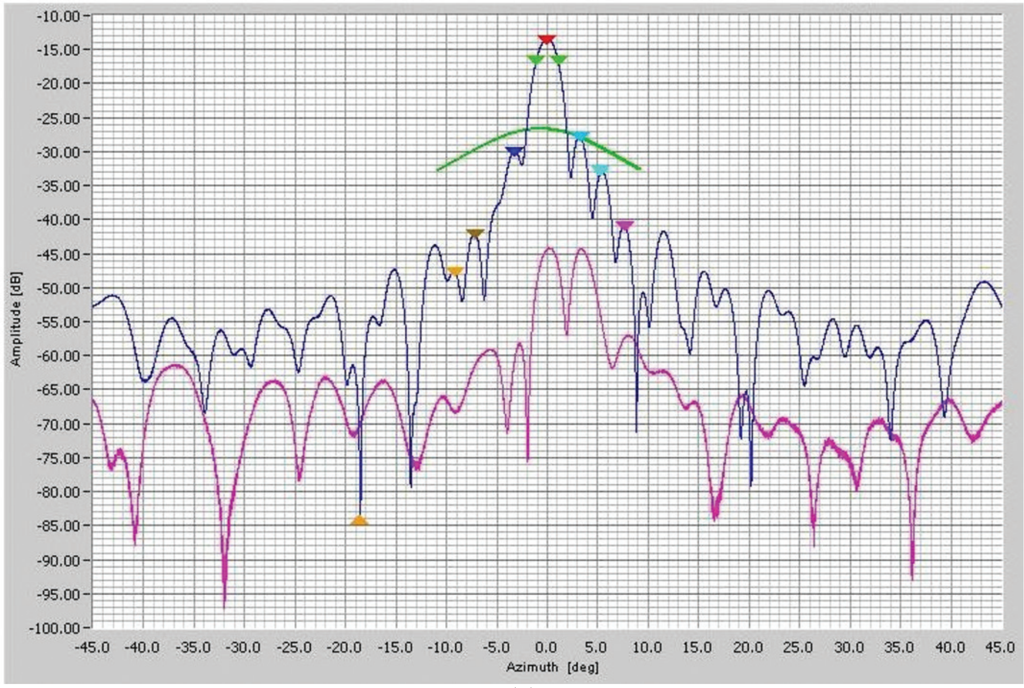

(a) (b)

**Figure 6. Radiation pattern of antenna in GRASP: (a) At 11 GHz and (b) at 14 GHz.**

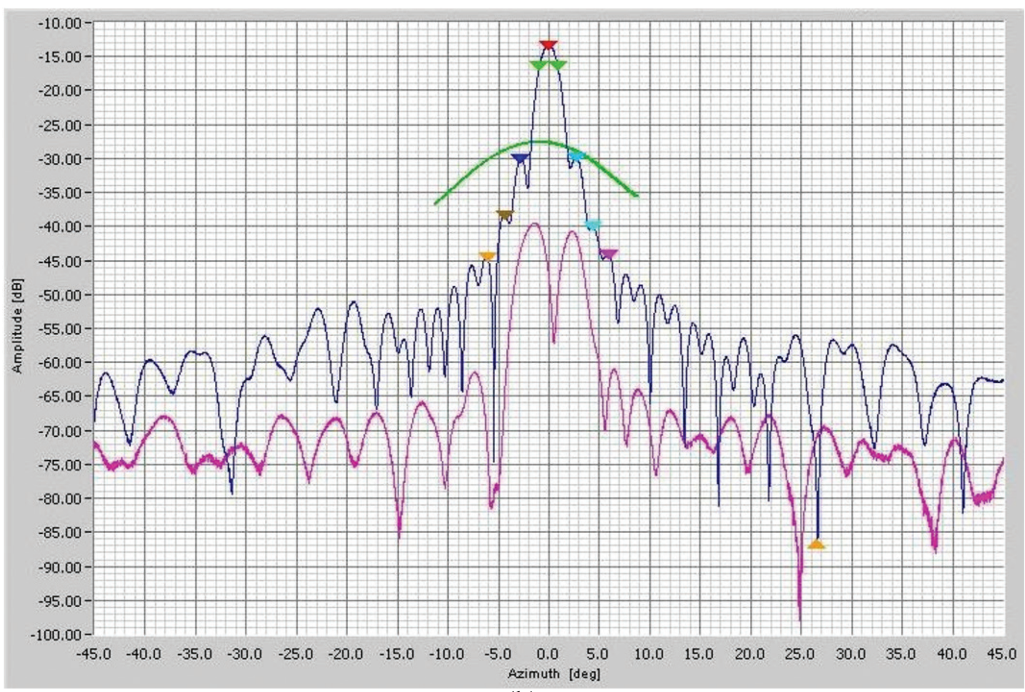



(a) (b) (c)

**Figure 7. Measured VSWR Vs. frequency: (a) Receive, (b) Transmit and (c) Trans-receive rejection (Receive port).**




(a)




(b)

**Figure 8. Measured radiation pattern: (a) At 11 GHz and (b) At 14 GHz.**

the Compact Antenna Test Facility. Measured results have been shown in Fig. 7 and Fig. 8. Measured VSWR of the designed antenna is less than 1.5 over the complete receive and transmit band of operation as shown in Fig. 7(a) and Fig. 7 (b). It is seen that transmit-to-receive port isolation with OMT and trans-reject filter is better than 90 dB at receiving port, as shown in Fig. 7(c). Measured radiation patterns of the antenna at receive and transmit frequency bands are shown in Fig. 8(a) and Fig. 8(b), respectively.

The measured gains of the realized antenna are 36.3 dBi and 38.4 dBi at 11 GHz and 14 GHz, respectively. In the present developed hat feed-based antenna, we have achieved radiation efficiency of more than 70 % @Ku-band Satcom transmit frequency as compared to 60 % radiation efficiency achieved in recent contemporary similar design[12] @ Ku-band Satcom transmit frequency. Table 1 compares the present work with the recently published work.

It can be seen from Table 1 that in the published work[8,12] a single reflector-based antenna has been developed, while in the present work, CFRP-based detachable multi-panel lightweight reflector antenna has been developed which was a stringent requirement for man-portable Satcom terminal so that the

**Table 1. Comparison of the developed antenna with recently published work**

| Antenna type | Feed | Frequency range (GHz) | Per cent bandwidth | Antenna size | Polarisation | Reference |
|---|---|---|---|---|---|---|
| Single reflector | Hat | 10.75-14.5 | 30 | 0.53 meter | Orthogonal | 8 |
| Single reflector | Hat | 10.95-14.50 | 28 | 0.8 meter | Orthogonal | 12 |
| CFRP detachable multi-panel system | Hat | 10.50-14.50 | 32 | 0.76 meter | Orthogonal | Developed |

whole system should be lightweight and can be dismantled and easily carried from one place to other in a carry box or rucksack. The table also shows that the percentage bandwidth of the presently developed antenna is 2 % higher than the published one. The novelty of the developed system is CFRP based detachable multi-panel reflector, a 0.76-meter antenna size to achieve radiation efficiency of more than 70% @Ku-band Satcom transmit frequency and a weight of less than 11 kg with a manual positioning mechanism.

## 4. CONCLUSION

Accustomed 0.76-meter hat feed-based Ku-band reflector antenna has been designed, simulated, optimized, and developed using carbon fibre-reinforced polymer (CFRP) material as a multi-panel solution, which is not available indigenously. The antenna uses an f/D ratio of 0.25 which decreases spillover radiation and far-out sidelobes besides making it compact. Realized gains of the antenna are 36.3 dBi @11 GHz and 38.4 dBi @14 GHz. The achieved radiation efficiency of the developed antenna at the transmit frequency of Ku-band satcom is 70 % which is better than a contemporary similar design. More than 90 dB transmit to receive isolation at the receive port of the designed antenna has been achieved. The measured results of the antenna are quite close to the simulated values. The designed lightweight antenna system (weight < 11 Kg) with the manual pointing system is most suitable for the Ku-band man-portable satcom system.

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In the current study, he contributed in design review of the antenna.