

# High Performance Dual Circularly Polarized S- Band Feed

**Praveen Kumar, V Senthil Kumar, AVG Subramanyam, VV Srinivasan, VK Lakshmeesha,  
S Pal FIEEE**

[pkumar@isac.ernet.in](mailto:pkumar@isac.ernet.in), [senthil@isac.ernet.in](mailto:senthil@isac.ernet.in),

*Communication Systems Group, ISRO Satellite Centre, Bangalore-560017*

## ABSTRACT

A high performance feed for 11 meters dual shaped reflector system is designed, developed and tested. It is a dual circularly polarized monopulse tracking feed with a measured axial ratio of 0.5dB over the required frequency band of 2GHz to 2.3GHz (Uplink: 2.02GHz -2.12GHz, Downlink: 2.2GHz-2.3GHz). This feed consists of four high performance Teflon dielectric radiating elements. Each dielectric element has a gain of 16.5dBi and are placed  $1.57 \lambda_0$  apart in 2x2 configuration to obtain the amplitude taper for the sub reflector. The feed level measurement was done in compact antenna test facility of ISAC, Bangalore. Total antenna system with 11 meters reflector was characterized in outdoor test range at Sohna. Measured difference pattern null depth is -40dB, measured gain is 46dBi and sum pattern peak to difference pattern peak difference is 7dB. The measured G/T of the antenna system is 25dB/K<sup>0</sup> and the cross-polar levels are better than -30dB. In this paper design of the feed system and the measured results are presented.

## INTRODUCTION

With the availability of microwave receivers using low noise amplifiers such as parametric and maser amplifiers, the main factor limiting the antenna performance is antenna feed system. Dual polarized broadband (covering uplink & downlink frequencies) feeds are very important for satellite applications since they allow realizing several missions with the same antenna involving mass and volume reduction. These feeds require high performance radiating elements, polarizers (septum polarizers in this case) and diplexer to ensure satisfactory performance for the polarization over the required frequency band.

## DESIGN

In the following sub-headings design of the feed system (radiating element, septum polarizer, diplexer) is discussed in detail.

### Radiating Elements

In this feed system Teflon dielectric elements are used as radiators. The diameter of the element is equal to that of feed waveguide so close spacing between elements is possible e.g. 2x2 array for monopulse tracking feed system. This advantage with the high gain of the element generates an optimum illumination of the sub-reflector with low spill over resulting in high efficiency of the earth station antenna. These dielectric radiating elements in the form of dielectric cone/cylinder enable directivity enhancement by increase of only axial dimension. Computer aided design techniques have been adopted for the optimum design of such structure. New design has resulted in dielectric (Teflon) elements having directivity of the order of 17 dBi with sidelobes of the order of -19 dB, whereas earlier development efforts have shown limitations in the realization of such properties. In the present developed element there is a full control over the radiation properties of the antenna i.e. it is possible to get required directivity with the desired level of side lobes. These elements are fabricated from commercially available Teflon rods. The simulated (using CST Microwave studio Software Package) radiation pattern of a single element, used in this feed, is shown in fig. 1.

In contrast to the ordinary waveguide, the metal walls of which fully screen the internal field from external space, the wave propagating over the dielectric rod is only partially reflected from the boundary separating the dielectric and the external medium (air), while partially, it emerges along the points of the surface to outside. This phenomenon excites hybrid (HE<sub>11</sub>) mode in the antenna. As a result of these conditions the directional pattern of the external electromagnetic field formed by the dielectric antenna differs from that of an open waveguide, being more directional. By controlling the radiation at the metal waveguide to dielectric transition, and diameter of the dielectric cylinder, sidelobes and the directivity of the dielectric antenna can be controlled. In the newly developed antenna, this is done by giving multiple tapers in the dielectric. The choice of the dielectric material depends on the bandwidth required. If higher dielectric constant material is chosen, element will have higher taper angles which will reduce the bandwidth of the structure. The dielectric is tapered to a point inside the metal waveguide carrying the dominant TE<sub>11</sub> mode for the purpose of matching.

## Septum Polarizers

To make the feed a dual circularly polarised, it is required to identify the polarization of the received signal and route it into appropriate circuitry for further processing. Apart from this, we should be able to change the input linear polarisation to LHCP, RHCP, VP or HP at the output depending on the requirement. To fulfil this, it is thought of using a septum polarizer that can convert linear polarized signal into circularly polarized signal and also acts as an orthogonal mode transducer (OMT). It is a three port device with two rectangular ports that are dedicated to the waves of one circular polarization (LHCP/RHCP), and the common square waveguide port that serves the common circularly polarized waves. It is this characteristic of the device that makes the overall feed into a dual circularly polarized, without using much of the complex switching circuitry.

The septum polarizer was designed and simulated for a return loss of better than -25dB and axial ratio was better than -0.3dB. The septum thickness is 2.0 mm with four steps inserted in a square waveguide of 85x85mm dimension. The overall length is around 160mm. A 90° waveguide e-plane mitred bend for use at one of the output ports and a transition between septum polariser output (85x41.5mm) and standard WR430 guide (109.2x54.6mm) were also designed and optimised. The design and analysis was carried out using MM (Mode matching) technique based WASP-NET software package. The measured results show axial ratios better than -0.4dB and return loss better than -21dB.

## Diplexer

Since the common antenna is being used for both the transmission and reception simultaneously, it is required to safe-guard the receiver from saturation or damage. To provide the good isolation between high transmission power and high receiver sensitivity, by atleast 120dB, it is decided to put a diplexer. To fulfil this, an E-plane waveguide diplexer using two H-plane iris filters, for up and down link frequencies each with 100MHz bandwidth was designed and simulated using WASP-NET. The measured insertion loss was better than -0.3dB, return loss better than -20dB and an isolation of about -125dB. The beauty of this waveguide diplexer is that it offers low loss, high power-handling capability, ease of fabrication and all this without the use of any tuning screws.

## Feed Performance

Reflector antenna's performance depend mainly on the feed performance in terms of losses and radiation pattern. Feed photograph is shown in Fig.2. Because of dual polarization operation monopulse comparator is very complex but special care is taken to reduce the numbers of bends and total waveguide lengths. Monopulse comparator is an eight-port network consists of four magic tees and relevant waveguide bends to obtain the sum, azimuth and elevation error signal from four equal amplitude and phase signals. The feed level measurement was done in compact antenna test facility (CATF) of ISAC, Bangalore. Measured

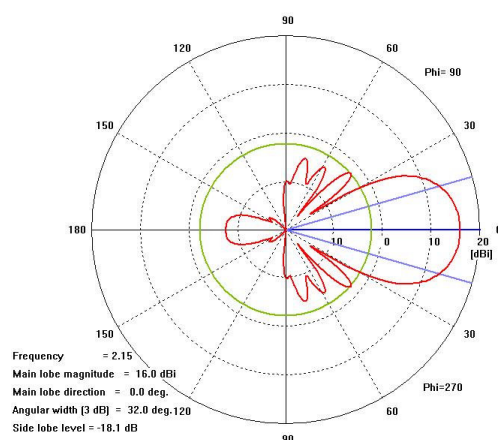


Fig. 1. Simulated radiation pattern of single radiating element

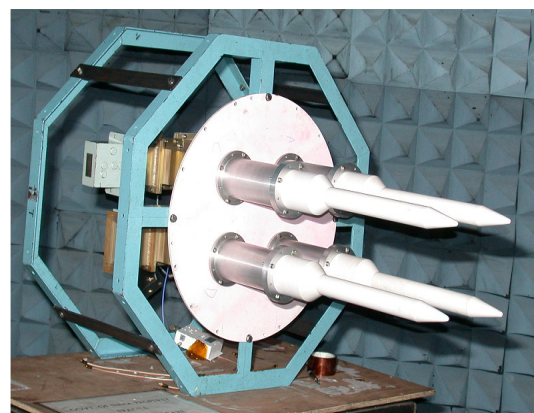


Fig. 2. Feed in anechoic chamber

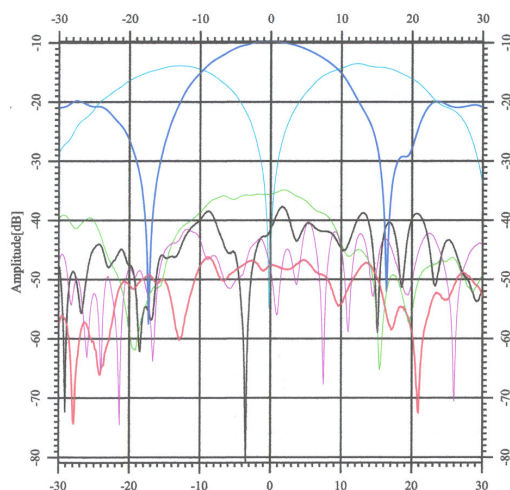


Fig. 3. Sum and difference pattern of feed

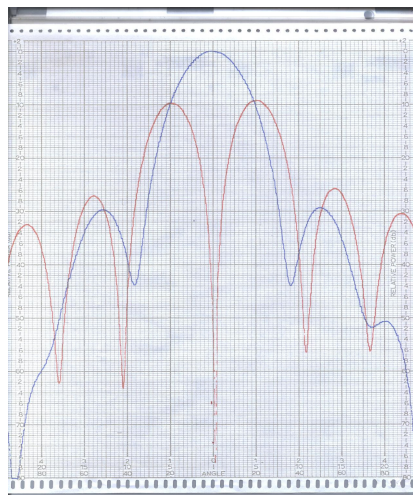


Fig. 4. Sum and difference pattern of reflector system

radiation pattern of the feed is shown in fig. 3. The measured performance exhibits the required illumination and the cross-polar levels are better than -30dB. The null depth measured at the feed level is -45 dB. The power handling requirement of the feed is 3 KW. Individual elements were tested for 3.5 KW of continuous radiation for 2 hours. The insertion loss of monopulse comparator is 0.15dB and the overall loss of the feed system is 0.3 dB and hence higher EIRP and G/T is achieved.

## Conclusion

Performance of the full reflector system is measured, fig. 5, at Sohna test facility (BEL), Haryana and the measured pattern is shown in fig. 4. Measured G/T of the total reflector antenna system is 25dB/K<sup>0</sup>. this confirm the superior performance of the complex feed circuitry and radiating elements. This antenna is installed at Lucknow Ground station.

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Fig. 5. Reflector antenna measurement at Sohna test range