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SHORT COMMUNICATION

Design & Development of VSAT Antenna Feed

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ABSTRACT

The paper deals with 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. The VSAT antenna feed is designed, fabricated and tested to operate over a band from 3.7 GHz to 6.5 GHz with good pattern symmetry, low side lobes and low cross-polarisation.

1. INTRODUCTION

Communication satellites were initially used for international telephone and television links. However, due to vast expansion of domestic networks, satellites are now being used for domestic communications also. Typical domestic satellite communication services include TV links, multiplexed telephones, cable television distribution and business communication. With increased satellite output power levels and simplified design of earth station systems, the networks of very small aperture terminals (VSAT) are growing up rapidly, and have an enormous futures. Some countries are now predicting the use of 1,500 to 10,000 terminals for introducing educational TV into various remote areas and providing at least one voice channel for local communication where communication is virtually impossible. In India, the Department of Telecommunications (DoT) has a very optimistic plan of providing STD facility at each village through MCPC (multi channel per carrier) VSAT networking.

Networks using VSATs provide two-way transmission links using antennas with diameters up to 2.4 m. The antenna plays the role of RF interface in the earth/space link. It provides directivity, isolation coverage and connectivity with prime concern on mass, size, cost and its technical and economic viability. In such small aperture antennas, offset feed reflectors are employed to achieve low far off side lobes. These antennas have high efficiency, low side lobe levels and low noise temperatures. Domestic satellite communication systems have an uplink from the earth station to the satellite and a downlink from the satellite to the earth station and are based mainly on 6/4 GHz, 14/11 GHz and 14/12 GHz bands. The design and development of feed systems for multifrequency bands is one of the most important tasks in the antenna design. Since most of the feeds for these antennas are being imported, the total cost of the antenna can be reduced effectively by designing this sub-system indigenously without compromising on electrical performances.

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Under the resource generation programme, the Electronics & Radar Development Establishment (LRDE) took up the task of designing and developing this dual-polarised VSAT antenna feed. In the present paper, the methodology, involving the use of extensive electromagnetic modelling and suitable CAD techniques is presented to design and develop a dual-polarised feed for 2.4 m reflector.

Corrugated conical horns are commonly used as feeds for reflector antennas because of their good pattern symmetry which offers high gain, low spill over and low cross-polarisation, which is essential in dual-polarised systems. Dual polarisation with frequency filter is required because the antenna has to work in two different modes, i.e., uplink and downlink modes. An orthomode transducer (OMT) consisting of a common waveguide that transmits two orthogonal dominate modes for required frequencies and two branch waveguides corresponding to these modes has been used to feed the corrugated horn.

2 SPECIFICATIONS

The design specifications for the feed are:

Frequency		
	Receive port	: 3.70 - 4.20 GHz
	Transmit port	: 5.925 - 6.425 GHz
VSWR (Maximum)		
	Receive port	: 1.3
	Transmit port	: 1.3
Isolation		
	Receive port	: <-60 dB
	Transmit port	<-60 dB
Side lobe level		
	(with reflector)	Better than -30 dB
Cross-polarisation		
	(with reflector)	Better than -28 dB
G/T ratio		
	(with reflector)	>18 dB/K
Port		RxPort - WR 229
		TxPort-N type Jack
Total weight		<3.0 kg
Sealing		Aperture sealed with uniform microwave transparent material

3. DESIGN OF CORRUGATED CONICAL HORN

The design procedure adapted here is similar to that of Clarricoates, *et al*[1] with a new approach to solve the characteristics equations. A simple iterative procedure for evaluating exact Eigen values was obtained using integral representation for associated Legendre functions[2]. A software package has been developed to estimate the Eigen values and thereby the radiation patterns. The detailed analysis is available in literature[3].

The design details concerning optimally flared corrugated conical horn were obtained by suitably selecting its flare angle and axial length to realise the desired beam width. Given the aperture area, the selection of the illumination of a reflector antenna for obtaining the desired amplitude taper at the periphery of the reflector was made possible through a judicious choice of feed dimensions and distance of separation between the apeture of the horn and the reflector antenna. The horn diameter required to produce the desired beam width was obtained using the relation $(R/\lambda) = 2(D/\lambda)$, where R is the distance of separation and D is the aperture diameter of the horn. The selection of the corrugation shape (ratio of corrugation gap width to corrugation period) and number of corrugations was chosen to realise the minimum loss. It was found that corrugation shape of the order of 0.7 to 0. 85 and 6 to 8 corrugations per wavelength leads to minimum VSWR over a wide band of frequency.

4. DESIGN OF ORTHOMODE TRANSDUCER

The orthomode transducer (OMT) is a key component for various communication systems using dual-polarised transmission. Electrically, an OMT is a four-port device with a common port usually having a square or circular wave guide cross-section which provides two electrical ports with independent orthogonal dominant modes. The other two ports are constructed by using either standard waveguide or coaxial ports which pick up one of the orthogonal modes propagating in the circular/square waveguide.

In the case under consideration, a multiband OMT was developed having a circular waveguide interfaced with the corrugated horn; a rectangular waveguide port to pick up one polarisation and co-axial port to pick up the other polarisation. This OMT uses both a polarisation filter and a frequency filter for the transmit and receive modes. This aids in achieving better isolation between the two ports although the design process becomes much more complex.

The circular waveguide port interfaced with the feed horn has a stepped transformer with a rectangular aperture between two steps in the circular wave guide section to act as a low frequency cut off. A branching ridged rectangular waveguide is introduced in the second step of the transformer to couple the low frequency component. A circular waveguide to co-axial adapter with a suitable aperture to act as a high frequency cut off is introduced in the last circular wave guide section to couple the high frequency component. High frequency structure simulator (HFSS), which is an FEM-based design and analysis package, has been used to design this complex OMT to work in the required frequency bands.

5. FABRICATION & MEASUREMENTS

The fabrication of the horn and the OMT was a complex task and involved extensive machining. Based on the above analysis, a horn and an OMT were made by machining from a single solid block. But this method needed considerable man hours of machining and hence it was neither easy nor cheap to fabricate. An alternative approach which was cheap and simple was machining after casting nearly to the required shape. Casting approach was also used to fabricate the feed. Care was taken to avoid any kind of blow holes during casting which can cause degraded electrical performance. Suitable fixing arrangement was made to cover the horn with microwave transparent material for environmental protection. A photograph of the horn is shown in Fig. 1

The complete assembled horn along with OMT was tested using HP-8510 Network analyser for return loss and isolation. The VSWR less than 1.3 and isolation better than -60 dB were obtained at both receive (3.7-4.2 GHz) and transmit (5.925- 6.125 GHz) ports as shown in Figs 2-5. The far field radiation pattern and cross-polarisation of the horn were measured in an indoor anechoic chamber at LRDE. The length of this chamber was sufficient to make far zone measurements. When, tested with the 2.4 m reflector at LRDE's outdoor test range, the secondary pattern showed SLL of the order of -30 dB (Fig. 6). The side

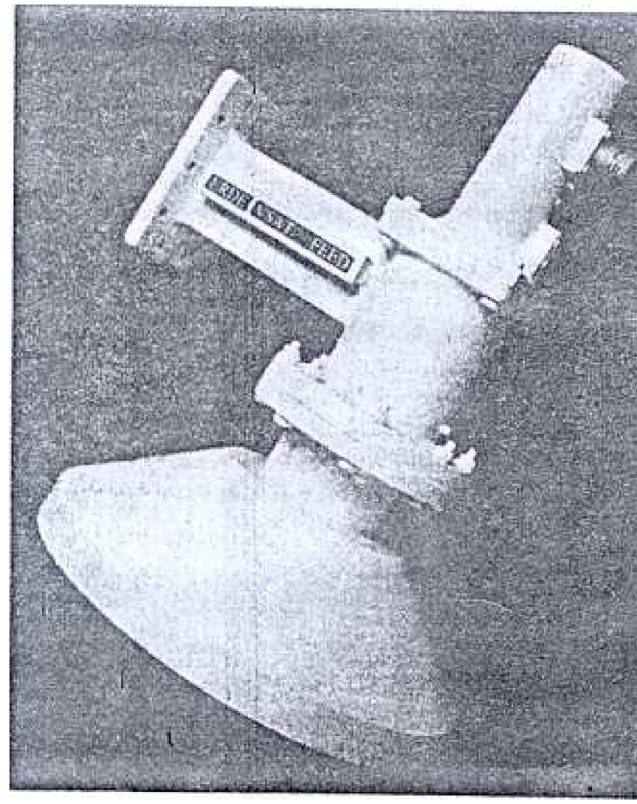

Figure 1. VSAT antenna feed.

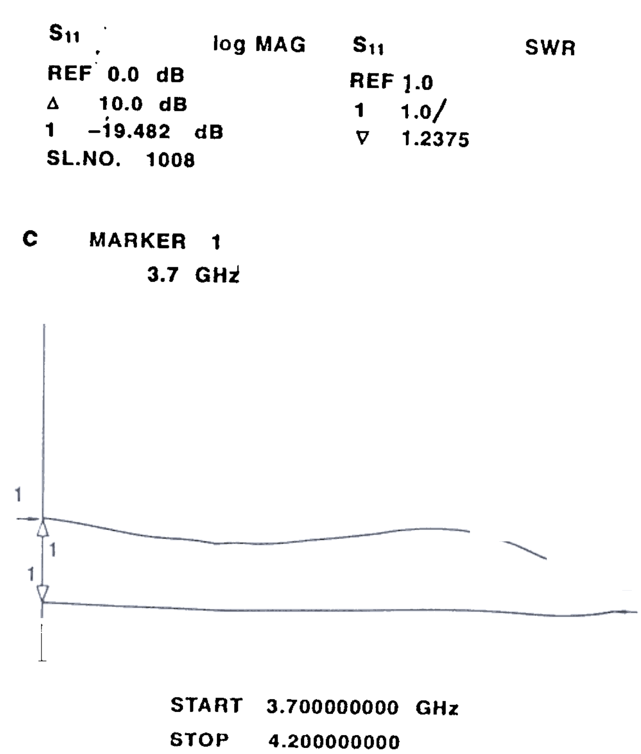

Figure 2. Return loss & VSWR at receive port.

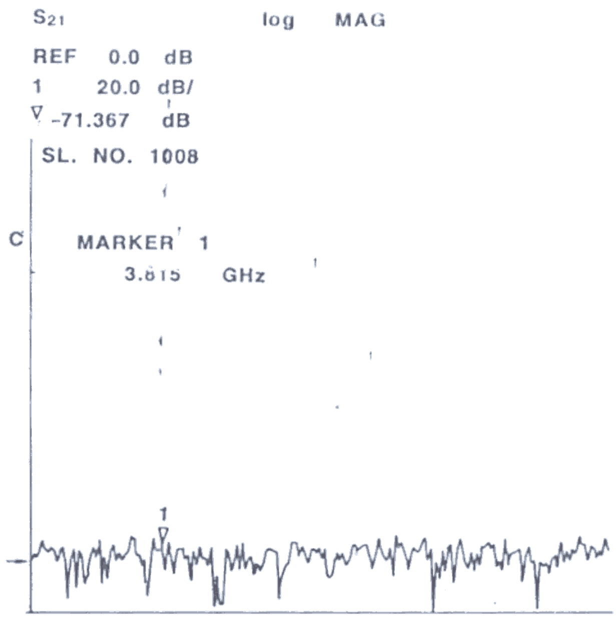

Figure 3. Isolation at receive port.

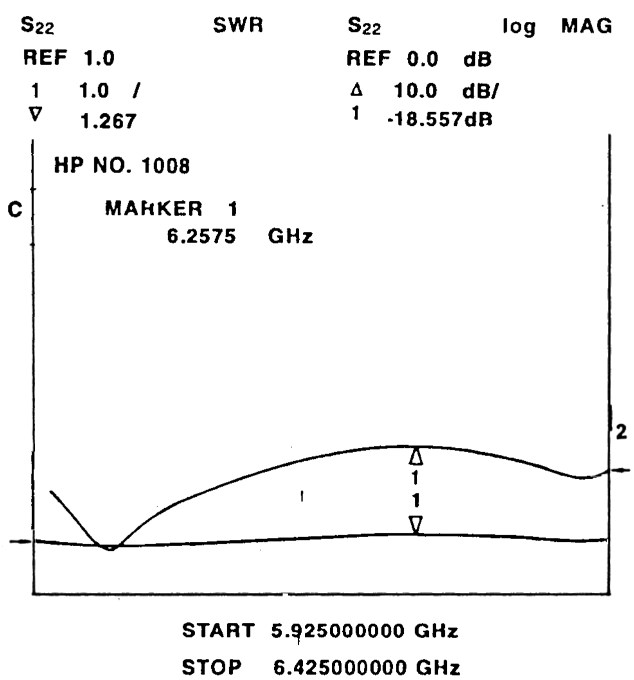

Figure 4. Return loss & VSWR at transmit port.

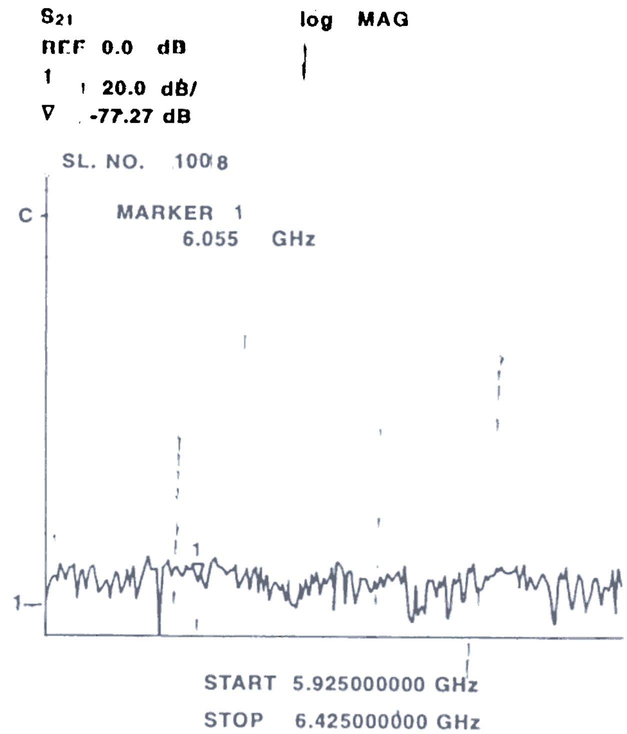

Figure 5. Isolation at transmit port.

lobes were found to be well within the side lobe envelop calculated using the relation E = 29-25 $\log_{10} \varphi$ dBi, where, E is the gain of the side lobe envelop and φ is the off-bore sight angle. A test was also conducted for G/T ratio and this was found to be better than 19 dB/K in the present case.

6. CONCLUSION

The design, fabrication and testing of a corrugated conical horn along with an OMT has been presented. The total process involved design of the components using software based on FEM techniques, fabrication, assembly and finally tuning and testing of each piece. Testing involved Network analyser testing for VSWR and isolation, primary pattern of the feed in an anechoic chamber, secondary pattern with 2.4 m reflector at out door test range facility, and finally G/T ratio. Both the components of the feed were tested successfully, and were able to meet all technical requirements as shown in Section 2.

This is an indigenous effort in the country to design and develop a feed for VSAT antennas meeting all the desired specification. LRDE has sold a number of these VSAT feeds to other organisations on commercial basis. These feeds have got considerable

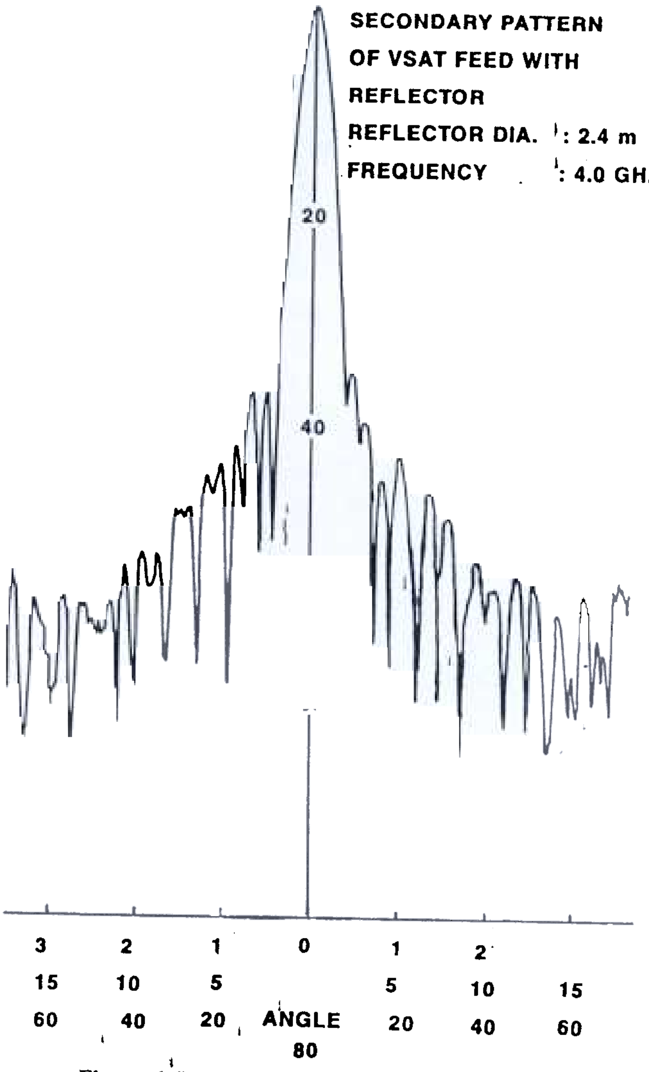

Figure 6. Radiation pattern of the reflector.

market potential in terms of generating resource for the organisation and to save foreign exchange for the country.

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