DUAL FREQUENCY BAND ANTENNA FOR INTELSAT EARTH STATIONS

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1. INTRODUCTION

This paper discusses the key technologies used in the development of a dual-frequency band antenna for the new COMSAT Roaring Creek INTELSAT earth station in Pennsylvania. The paper also describes the measured RF performance of this new 32 meter antenna system which began dual band operation in January,1985.

2. ANTENNA CONFIGURATION

The INTELSAT-V system uses both the 6/4 GHz and 14/11 GHz frequency bands simultaneously to achieve a more cost effective communications system. At present, INTELSAT has two separate and independent sets of requirements for the 6/4 GHz Standard A and 14/11 GHz Standard C earth stations. Satellite earth station antennas are designed to satisfy the high efficiency, low noise temperature, high XPD and low sidelobe requirements over their extended frequency bands allocated at WARC-79.

Upto now, the conventional approach has been to build separate 6/4 GHz and 14/11 GHz antennas. However, there are clearly economic and operational advantages in having a common cassegrain antenna mount structure capable of covering both frequency bands and having enhanced gain performance in the 14/11 GHz bands to overcome rain fades. The key technical task needed to design such an antenna was the development of a suitable frequency diplexing system.(1) After careful study of the the INTELSAT requirements and feasibility on the diplexing system, a conclusion was reached that a waveguide type diplexer would be most suitable. A decision was also made to accommodate this waveguide type diplexing system in a 32 meter diameter, beam waveguide, cassegrain antenna system.

3. BEAM WAVEGUIDE AND ANTENNA EFFICIENCY

The broadband beam waveguide design can easily be completed once the broadband corrugated horn has been developed. However, to produce an axially symmetrical beam, with a minimum of XPD from a corrugated horn, there are several technical considerations which need to be resolved.(2)

Two of the major considerations are the dimensions of the corrugated horn and the design of the corrugated waveguide transition. It was established that, in the corrugated horn design, it was necessary to carefully determine the corrugation depth to support the desired fast hybrid modes (HE11 and EH12 modes over the respective C and Ku bands). Under this constraint, it was also necessary to minimize the wall thickness of the corrugation to reduce the undesired EH12 and HE12 higher modes generation. These higher mode are a major cause of beam asymmetry and degraded XPD.

The higher modes generated in the corrugated transition from a circular waveguide are another major cause of performance degradation. In a multi-frequency corrugated horn the corrugated transition is regarded as an overmoded waveguide device. It is, therefore, necessary to gradually transduce the dominant TE11 mode into the dominant hybrid HE11 and EH12 modes, suppressing the generation of undesired higher modes. The new corrugated transition, specifically developed for this purpose, is shown in Fig. 1. Using the newly developed corrugated horn, the 32 meter diameter antenna was designed and the calculated aperture illumination and estimated antenna efficiency are shown in Fig. 2 and Table 1.

4. FEED SYSTEM

An 6 port turnstile orthomode transducer (OMT), with high isolation and low insertion loss, was developed to combine and separate the 6/4 GHz and 14/11 GHz signals. The 6 port turnstile OMT, has 4 GHz and 6 GHz OMTs integrated into a taper waveguide. The 4 GHz signal is partially coupled in quadrature through four slots and then combined to produce the desired orthogonal polarization signals. Another four slots are displaced diagonally to couple the orthogonally polarized 6 GHz signals. The block diagram of the complete feed system is shown in Fig. 3.

5. OVERALL ANTENNA PERFORMANCE

The gain of the 32 meter diameter antenna system was measured by the Y-factor method. The radio star Cas-A (3) (4) was used in the actual measurements and calculations. The measured RF performance is shown in Table 2. The sidelobes were measured using an INTELSAT-V satellite. The 6 GHz and 14 GHz sidelobes along a geostationary arc are shown in Fig. 4 and fully comply with the CCIR recommendation. The XPD measurements were limited due to the poor satellite polarization performance and could only be confirmed indirectly from XPD at the beam waist of the beam waveguide. The 14/11 GHz band cross polarization characteristics are shown in Fig.5.

6. CONCLUSION

The high efficiency and purity of XPD performance of the newly designed dual frequency band antenna has been demonstrated. The antenna has high tracking accuracy of less than 0.0035 degs.(RSS) under 35 mph average wind speed due primarily to the high rigidity of antenna structure and the monopulse tracking system. The authors would like to express their sincere gratitude to COMSAT and NEC Corporation engineers involved in this development program.

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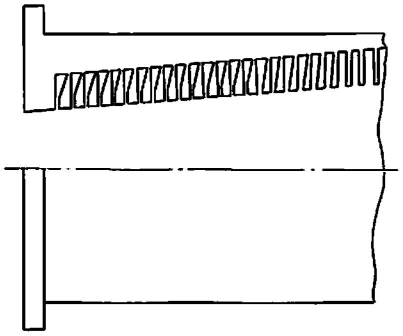

Fig.1 Corrugation Transition

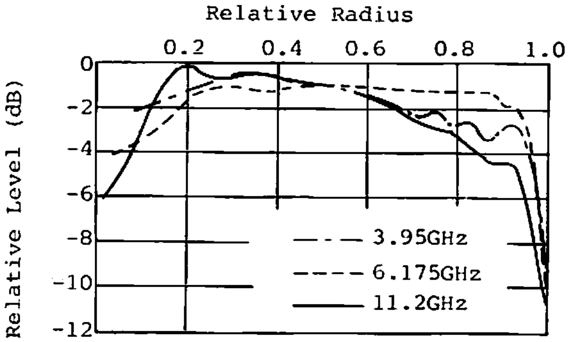

Fig.2 Amplitude Illumination over Aperture

Frequency	3.91GHz	6.14GHz	11.2GHz	14.25GHz
100% Aperture(32mφ) Gain	62.35dB	66.27dB	71.49dB	73.58dB
Efficiency Factors,				
1) Illumination	-0.24dB	-0.19dB	-0.55dB	-0.59dB
2) Spillover f'm Main Reflector	-0.07	-0.03	-0.01	-0.01
3) Spillover f'm Subreflector	-0.03	-0.01	-0.01	-0.01
4) Blockage and Scattering	-0.42	-0.42	-0.42	-0.42
5) Surface Roughness	-0.06	-0.15	-0.47	-0.72
6) Beam Waveguide Loss	-0.21	-0.06	-0.02	-0.02
7) Others (Corrugated Horn, Horn Cover, Reflection)	-0.06	-0.06	-0.08	-0.10
Aperture Efficiency	-1.09dB	-0.92dB	-1.56dB	-1.87dB
Aperture Gain	61.26dB	65.35dB	69.93dB	71.71dB
Feed Insertion Loss	-0.21dB	-0.40dB	-0.53dB	-0.32dB
Effective Antenna Gain	61.05dB	64.95dB	69.40dB	71.39dB

Table 1 Estimated Antenna Efficiency and Gain

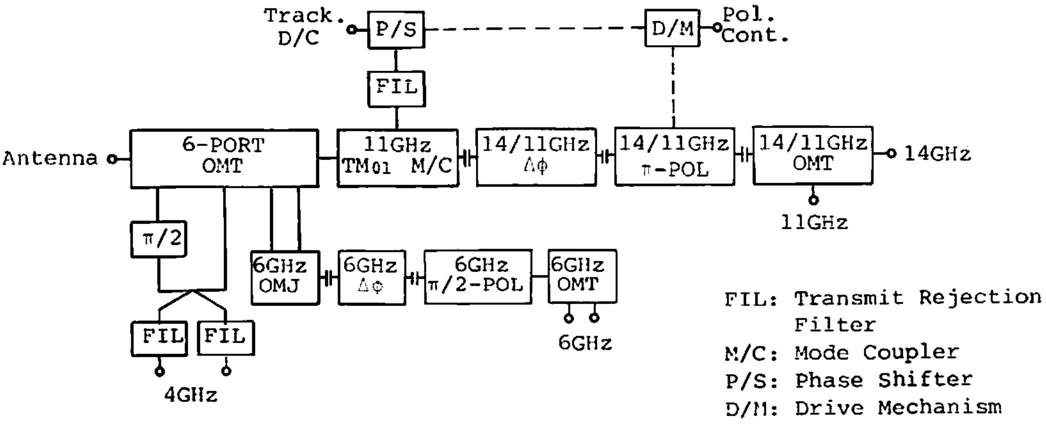

Fig.3 Feed System Blockdiagram

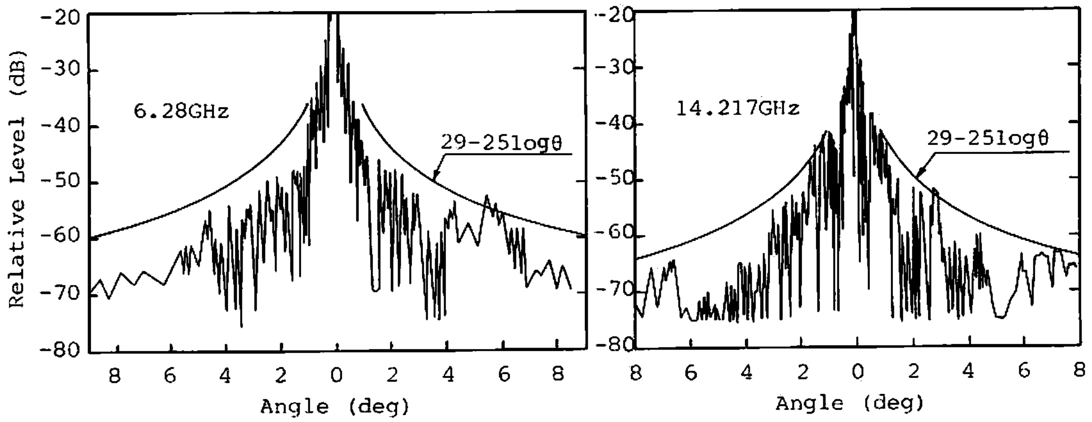

Fig.4 Antenna Sidelobe Pattern along Geostationary Arc

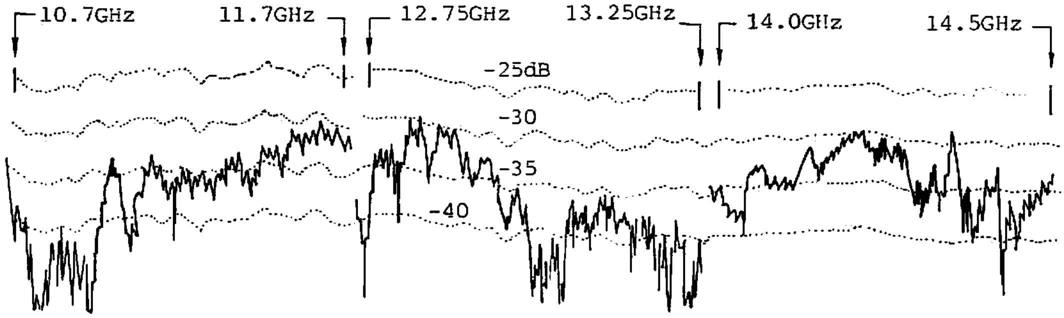

Fig.5 Measured Cross Polarization Discrimination in Ku-Band

Frequency Band	C - Band		Ku - Band	
	Reception	Transmission	Reception	Transmission
Bandwidth	3.62∿4.2GHz	5.845∿6.425GHz	10.7∿11.7GHz	14.0∿14.5 and 12.75∿13.25GHz
Polarization	Dual Circular (RHCP/LHCP)	Dual Circular (LHCP/RHCP)	Single Linear*	Single Linear*
Antenna Gain**	61.1dB	64.9dB	69.0dB	70.7dB and 69.9dB
Antenna Noise*** Temp. (10°EL)	48K max.	————	69K max.	————
Voltage Axial RAtio	Less than 1.06	Less than 1.06	more than 31.6	more than 31.6
VSWR	1.25 : 1 max.	1.15 : 1 max.	1.25 : 1 max.	1.25 : 1 max.
Port Isolation	18dB min.	18dB min.	————	————
Feed Loss	0.29dB max.	0.33dB max.	0.47dB max.	0.36dB max.
3 dB Beam Width	0.147°	0.098°	0.052°	0.042°

* Polarizations between reception and transmission are orthogonal.

** at center frequency (Reception:at LNA Input, Transmission:at Feed Input)

*** Contributions of connecting waveguide to LNA are included.

Table 2 Measured Antenna RF Performances