# FEED DEVELOPMENT FOR ADVANCED SATCOM RX-ANTENNA APPLICATION

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## ABSTRACT

The paper presents the results of the feed development for the Advanced Satcom Rx-antenna. Two design variants have been developed and described in this paper. The first feed design was used to illuminate a dielectric lens antenna , whereas the second is compatible with a multiple reflector antenna system. Both antenna concepts require the use of a feed cluster. A 19-element feed cluster was designed, built and tested for the dielectric lens. A single feed chain was developed for the reflector system. The feed design issues, as well as the measured results are presented in the paper. Excellent feed performance is demonstrated .

## I. INTRODUCTION

Advanced Satcom project at Spar Aerospace , Spar Space Systems, is a technology development program for space borne multimedia service. The Advanced Satcom system requires the use of Ka-band spectrum with the Tx-frequency allocated between 19.5 and 20.0 GHz, and the Rx frequency allocated between 29.5 and 30.0 GHz. The system operates in both LHCP and RHCP polarization.

One of the critical subsystems on the Advanced Satcom payload is the Ka-band antenna A comprehensive trade-off study was performed on the Ka-band antenna options [1], leading to the selection of a dielectric lens as one of the prime candidates for the Rx antenna. Since the Advanced Satcom is a multiple beam system , a feed cluster is required to illuminate the lens antenna. The design of the feed cluster was one of the major tasks in the Advanced Satcom technology development. The development has targeted a 19-element cluster with a single active element connected to a feed chain consisting of a bandpass filter, polarizer and a circular-to-rectangular waveguide interface. The paper describes the design methods and measured results for each of the feed chain components.

More recently, the Advanced Satcom technology development has evolved towards inclusion of several potential frequency allocations leading to an extended Rx and Tx bandwidth. For the Rx antenna the frequency specification is 28.35-30.0 GHz. This new system requires a filter to provide rejection over several frequency bands extending from 18.5 Ghz to 64 Ghz. As a consequence, the feed chain used for the dielectric lens had to be re-designed. The development results of the second design variant are also presented in the paper.

## II. DESIGN METHODOLOGY

For the Advanced Satcom feed development, an advanced , full-wave design software was developed, [2]. The software is based on the Mode-Matching method, as applied to circular waveguide discontinuities. The customized Mode

Matching software was used in the design of the bandpass filter, septum polarizer and stepped transformer (for the feed design variant I) and for the septum polarizer in the design variant II. The Mode Matching analysis of the septum polarizer approximates the septum with a bowtie shape in order to maintain the polar coordinate system for the ridged and bifurcated part of the polarizer. Consequently, the modal spectra consist of TEνn and TM νn modes, or combinations thereof, where ν is related to fractional-order Bessel functions of the first kind, Jν (x), and the second kind Nν (x) .

A commercial software package from TICRA (Denmark) "CHAMP" was used in the design of Dual-Mode horn for both variants of the feed chain. Mode Matching method was also applied to the design of the corrugated waveguide low-pass filter [4] used in the second design variant of the feed chain. $TE_{mn}$- $TM_{mn}$ mode matching formulation was used for the solution of double plane step-discontinuity in a rectangular waveguide. For the circular-to rectangular waveguide transformer (which involves discontinuities with non-orthogonal edges ) the finite element based software - " HFSS " was used. All software packages used in the design process are coupled to powerful optimizers (such as MiniMax).

## III. FEED CHAIN DESIGN FOR THE DIELECTRIC LENS ANTENNA

A 19-element horn cluster (see Figure 1.) was designed to illuminate the bread-board lens. The lens focal distance and the 0.65-degree systems specification for the separation between secondary beams, determined the horn aperture diameter as 1.49λ. For such feed element aperture size, a dual-mode horn design is feasible.

Because of superior beam symmetry and crosspolar isolation a dual-mode horn was chosen over the conical horn. The horn was optimized to provide minimum 30 dB crosspolar suppression within the lens semi-flare angle and return loss of minimum 30 dB.

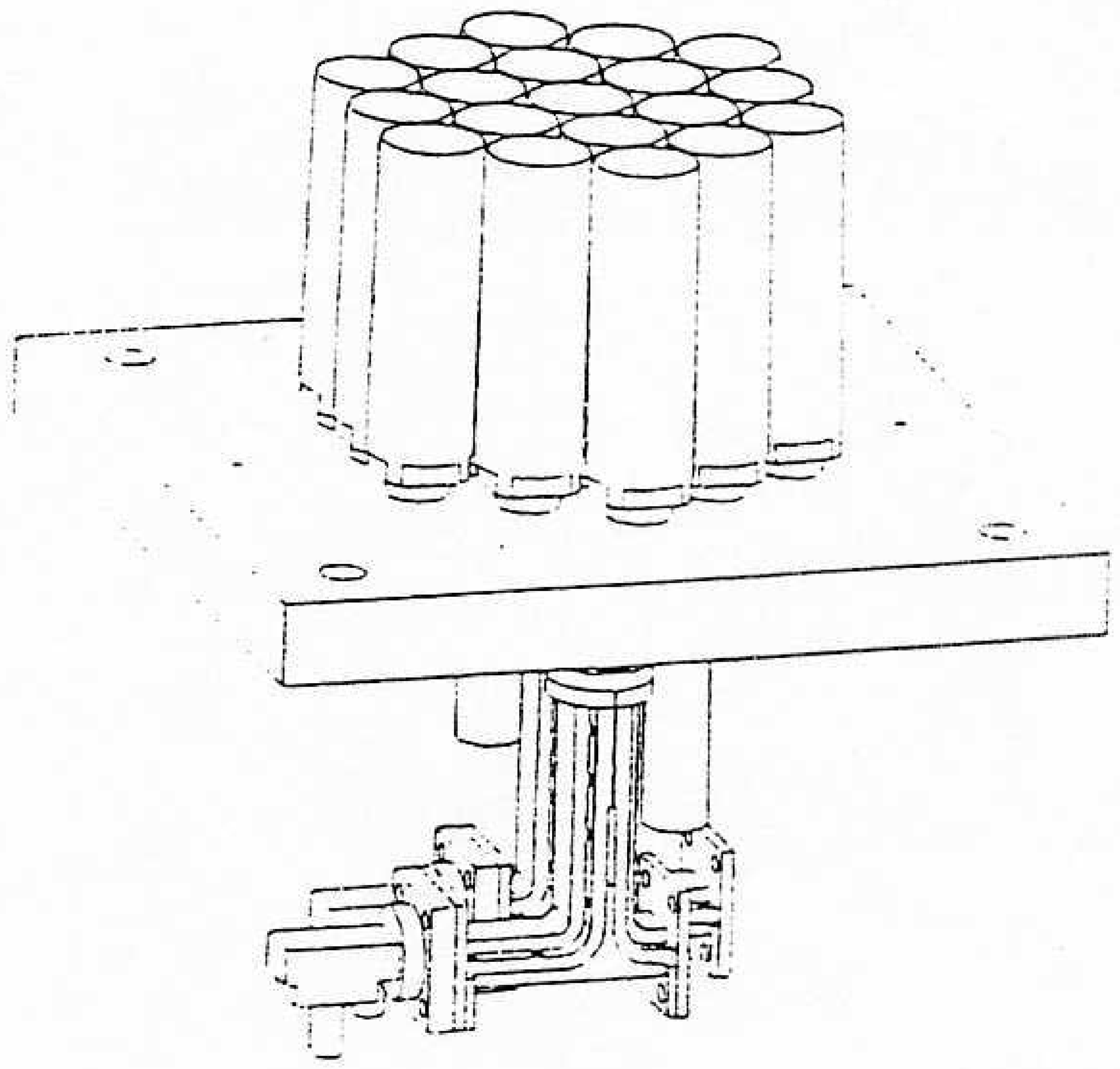

Figure 1: 19-element feed horn cluster

The bandpass filter is a 3-pole Tchebyschev, resonant iris type in circular waveguide. The filter is used to reject signal at 25.0 GHz and to improve the isolation over Tx band. The polarizer is of septum type with 4-steps. The polarizer is connected to a rectangular waveguide interface via an semi-octagonal impedance transformer.

Figure 2 shows the measured return loss of the complete feed chain, whereas Figure 3 presents the measured feed radiation patterns (LP probe cuts) in the diagonal plane.

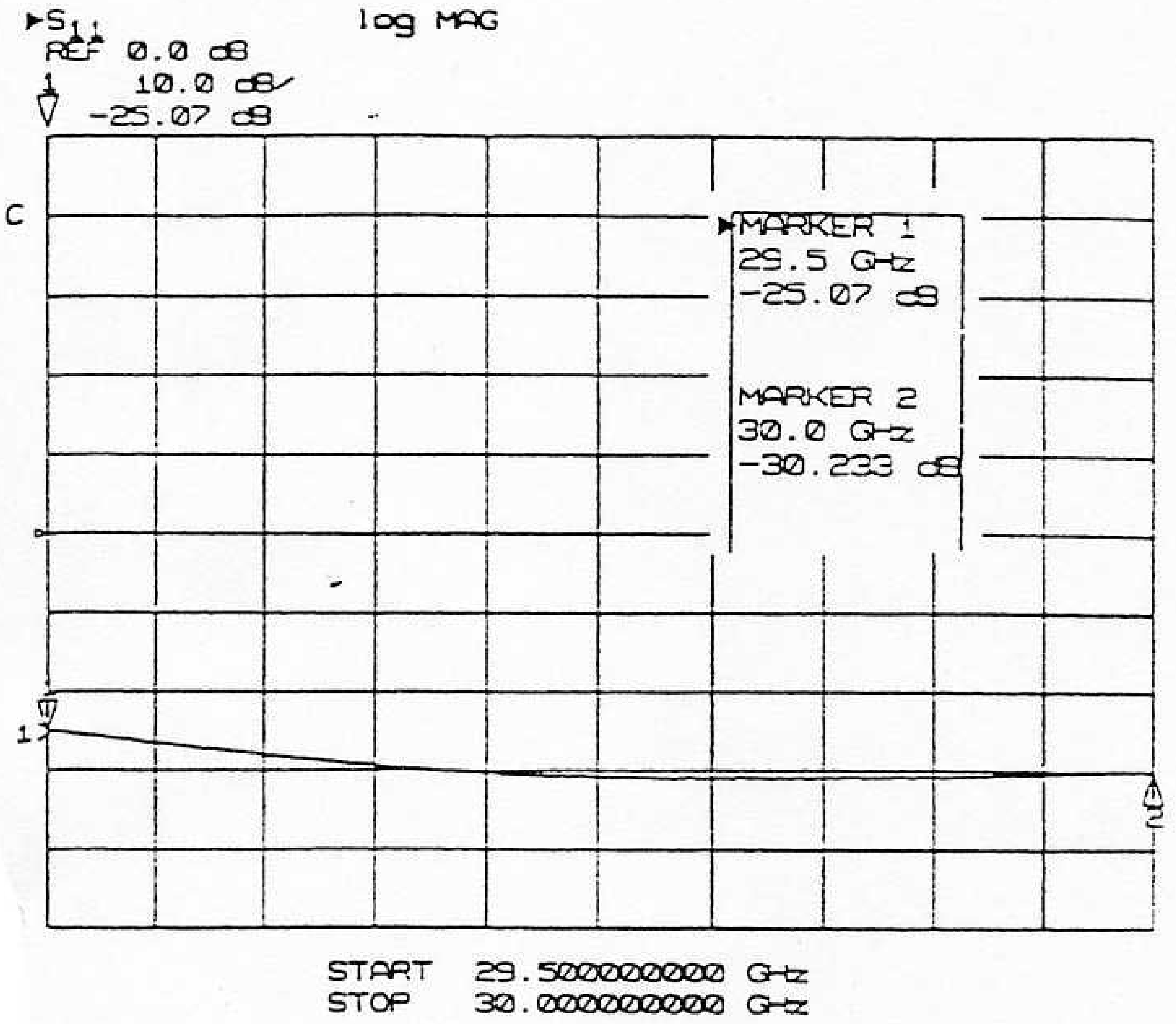


Figure 2: Return loss of the entire feed chain (design variant 1)

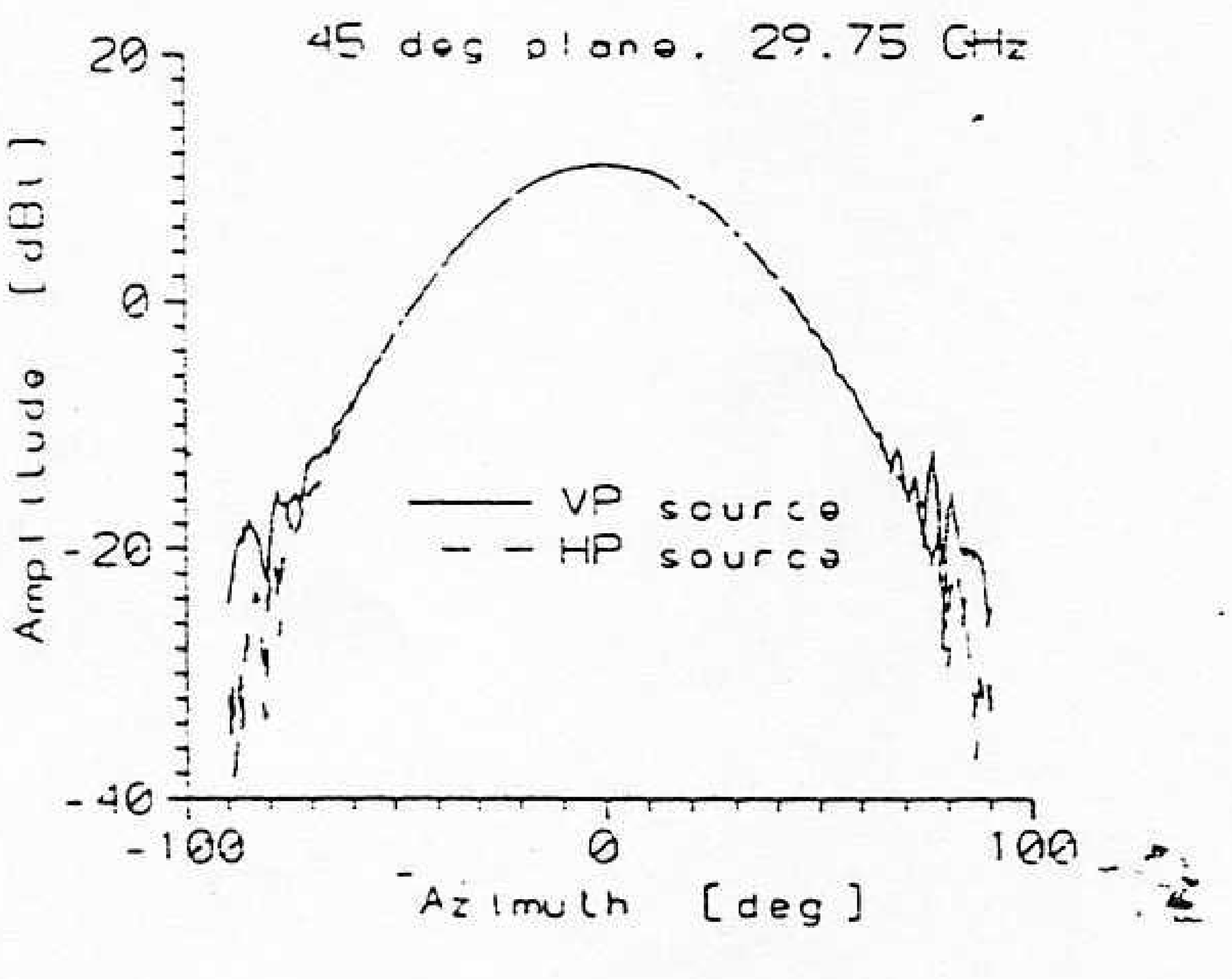


Figure 3: Radiation pattern of the feed variant 1.

The measurements show that the worst case feed chain return loss (including test set-up bend) is better than 25 dB. The measured patterns exhibit good rotational symmetry. The reconstructed circularly polarized patterns demonstrate on axis axial ratio better than 0.5 dB.

## IV FEED CHAIN DESIGN VARIANT II

For the extended Rx-band (28.35-30.0 GHz) and the modified out-of-band signal rejection requirement a new feed chain design was necessary. The feed horn design was modified as to provide compatibility with an offset fed reflector system generating multiple beams. For this system the horn aperture size was increased to 2.4 $\lambda$. The septum polarizer was also re-designed to provide good axial ratio performance over 7% bandwidth. The bandpass filter was replaced by a quasi-lowpass filter which combines functions of the lower band rejection due to the reduced width waveguide cut-off and higher band rejection due to corrugated waveguide low-pass response. The measured return loss of the complete feed chain and the axial ratio response of the overall feed is shown in figures 4 and 5, respectively.

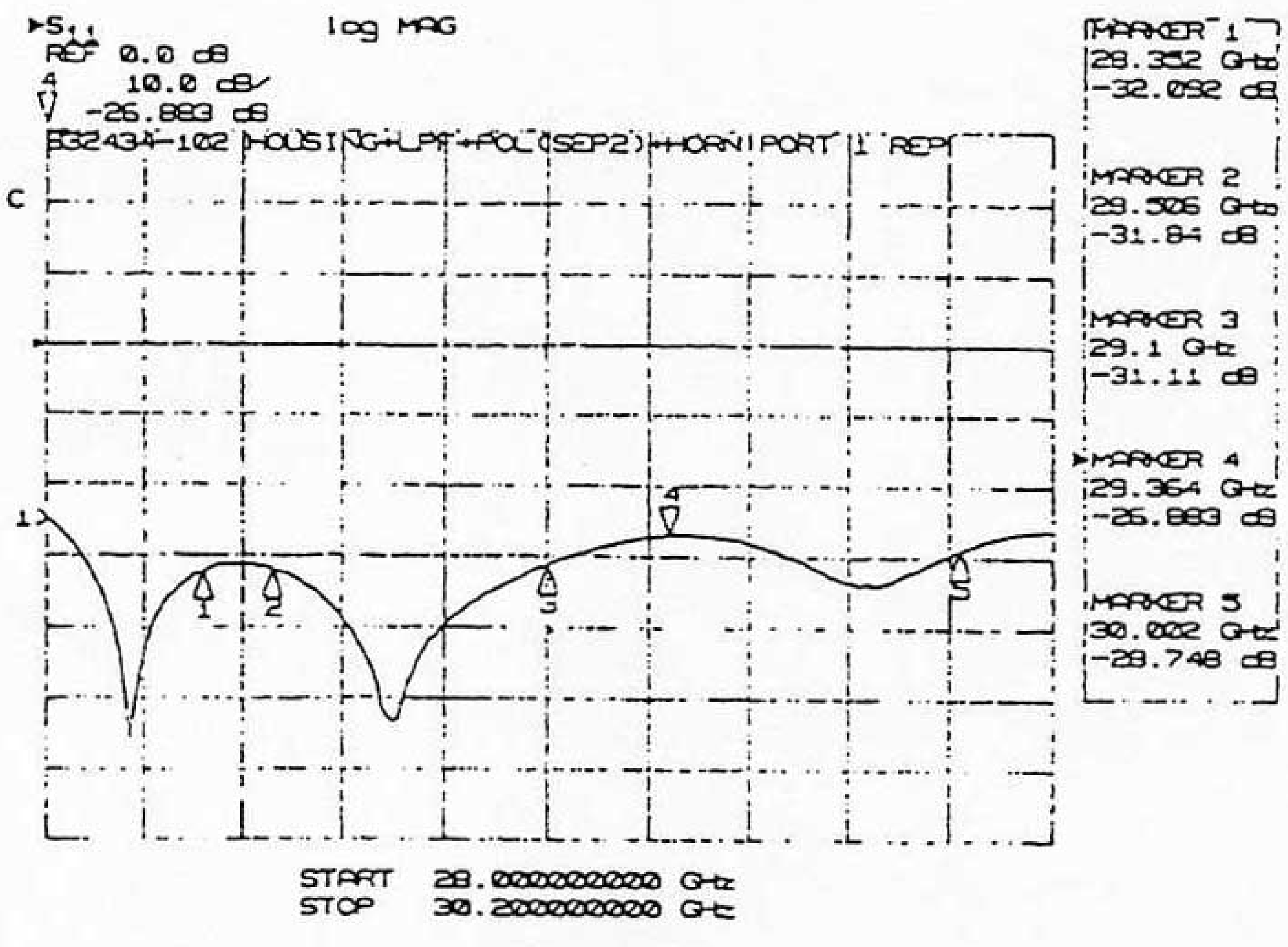


Figure 4: Return loss of the overall feed chain

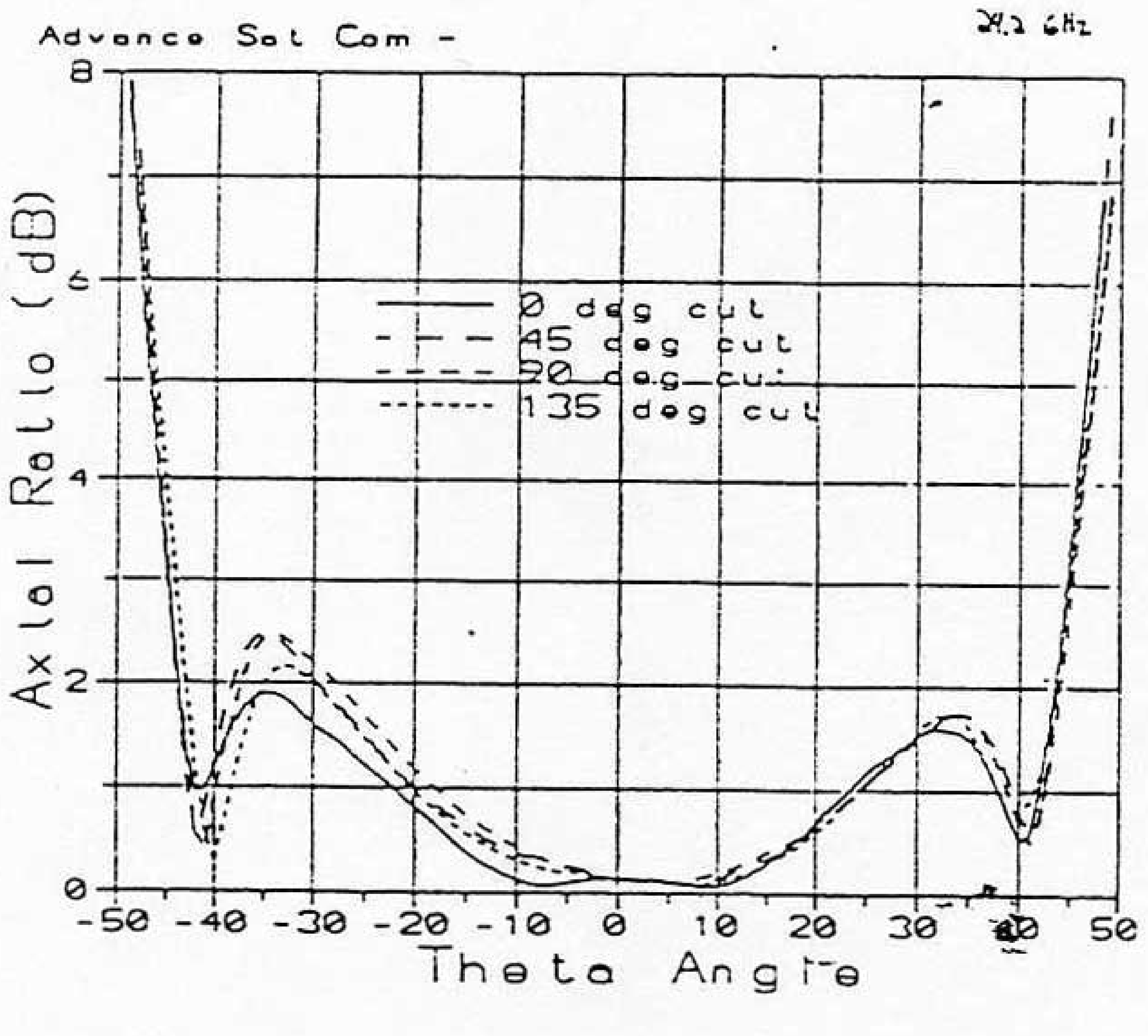


Figure 5: Measured axial ratio of the complete feed

## V CONCLUSIONS

Two variants of feeds have been developed for the Advanced Satcom Rx-antenna. The first design variant (with 2.5% bandwidth) was used to illuminate a dielectric lens antenna, whereas the second (with 7.5 % bandwidth) was developed for a reflector system. The feed chains have been designed using advanced full wave analysis software combined with efficient optimization methods. Because of a high design precision no experimental development was necessary. Excellent measured performance of the feeds was measured meeting all performance requirements.

## ACKNOWLEDGEMENT

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