THE S-BAND COAXIAL WAVEGUIDE TRACKING FEED FOR ARIA

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ABSTRACT

This paper contains a description of a new technology tracking feed and a discussion of the features which make this feed unique and allow it to perform better than any other comparable feed. Also included in this report are measured primary antenna patterns, measured and estimated phase tracking performance and estimated aperture efficiency. The latter two items were calculated by integrating the measured primary patterns.

KEY WORDS

Tracking Feed, Coaxial Wavguides, High Aperture Efficiency

INTRODUCTION

LJR Inc. has recently completed the design and construction of new tracking feeds that are being used by the USAF in its ARIA aircraft. These prime focus feeds have been designed to meet a comprehensive and difficult set of specifications of which an abbreviated list is shown in Table 1.

The feed is the result of two years of research into the design of tracking feeds using coaxial waveguides. In this time, LJR has developed software which can not only accurately predict the radiation characteristics of the feed but can also optimize its design.

DESCRIPTION

The feed is an example of a rho-theta tracker. Its basis is a set of two concentric coaxial guides and a shaped aperture. The inner guide is used to launch/receive the TE_{11} mode which produces the Σ Channels. The outer guide receives the TE_{21} mode which produces the Δ Channels. Please refer to Figure 1.

The aperture was computer optimized to balance the requirements of

- high efficiency sum and difference patterns,
- good phase tracking between the patterns, and
- good matches of the TE_{11} and TE_{21} modes incident upon the aperture/waveguide interface.

Included in the aperture design, are two outer choke sections, the radome, a shaped inner conductor and two inner inductive choke sections. Please refer to the center drawing in Figure 1.

Four discrete probes are used to generate/receive the two TE_{11} polarizations required.These four probes are fed via coaxial lines which contain an inner conductor which is shaped so as to match the probes into 50 Ω. These lines are connected via cables (item 5 in Figure 2) to two external 180°, 3 dB hybrids. (Item 7 in Figure 3). The outputs of the these hybrids are connected to a 90°, 3 dB hybrid (item 6 in Section A-A of Figure 3) which converts the linear polarizations into LHCP and RHCP Σ channels.

A stripline circuit is used to receive the two TE_{21} polarizations. This is item 24 in Figure 1. The two outputs from this circuit are connected to the 90°, 3 dB hybrid (item 6 in Figure 1 and Section B-B of Figure 3). This converts the linear polarizations into LHCP and RHCP Δ channels.

Item	Specification	Enhanced Performance
Frequency:	2..2-2.4 GHz	range extends past 2.5 GHz
Outputs:	LHCP and RHCP Σ and Δ Channels	
f/D:	Optimized for f/D = 0.433.	range of ratios can be used
Primary ΣChannel Gain	8 dBi	
Primary Δ Channel Gain	5 dBi	
Primary Δ Channel Null Depth	-30 dB Referenced to Σ	
Primary Σ Channel Axial Ratio	< 1 dB at Boresight	
2nd-ary Σ-Δ Phase Tracking	±10° over any 100 MHz band	±5° over whole band
Secondary Δ Null Depth	<-35 dB Referenced to Σ	<-46 dB
Secondary Boresight Shifts	<0.5°	<0.15°
Secondary Σ Channel Gain	>30 dBi in a 7 foot dish	>31.1 dBi
Σ Antenna Temperature	<160 K	<98 K
VSWR:	1.5:1	
Transmit Power:	50 Watts	
Weight:	≤ 8 pounds	actual weight is 7 pounds.
Size:	Diameter: ≤ 8.6 inches. Length: ≤ 8.5 inches.	
Connectors:	N-type.	

Table 1. Abbreviated ARIA Feed Specifications.

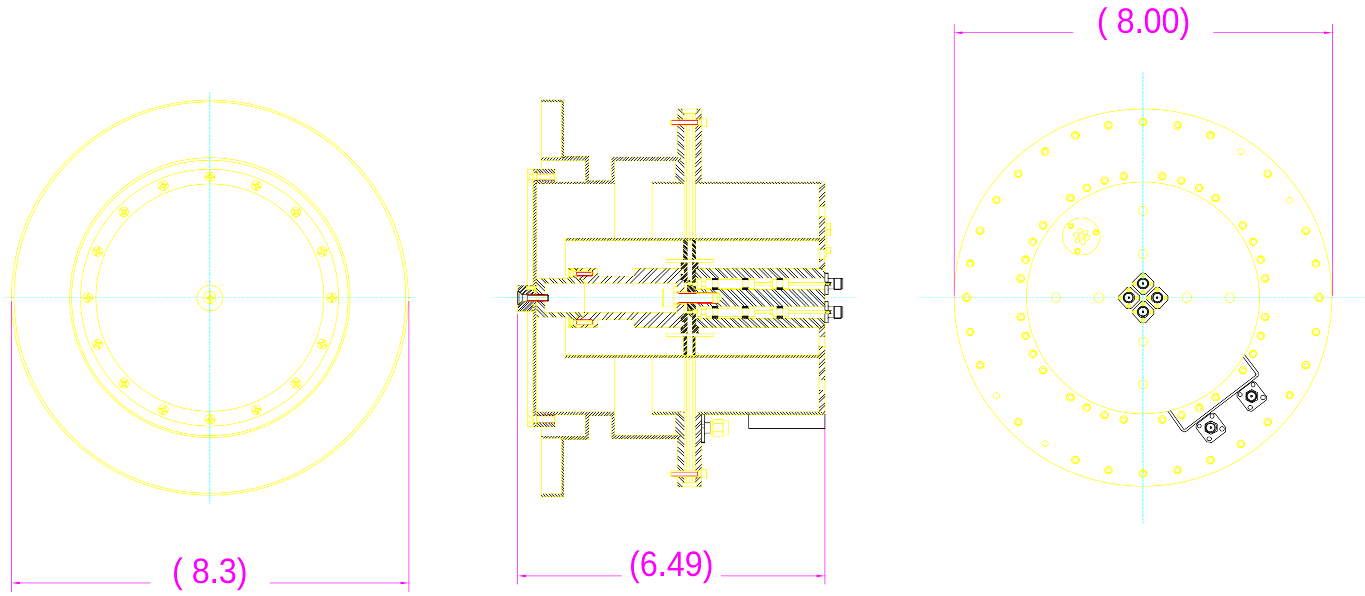

Figure 1: Front, Cross-section and Back Views of the Waveguides.

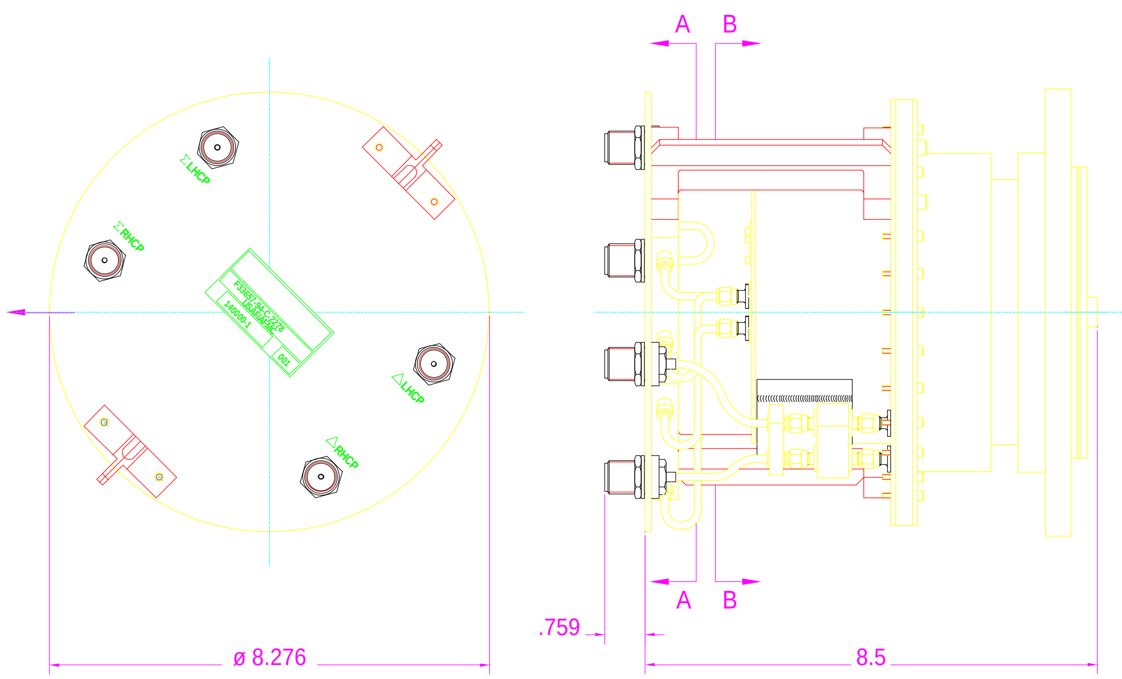

Figure 2: Back and Side Views of the Feed.

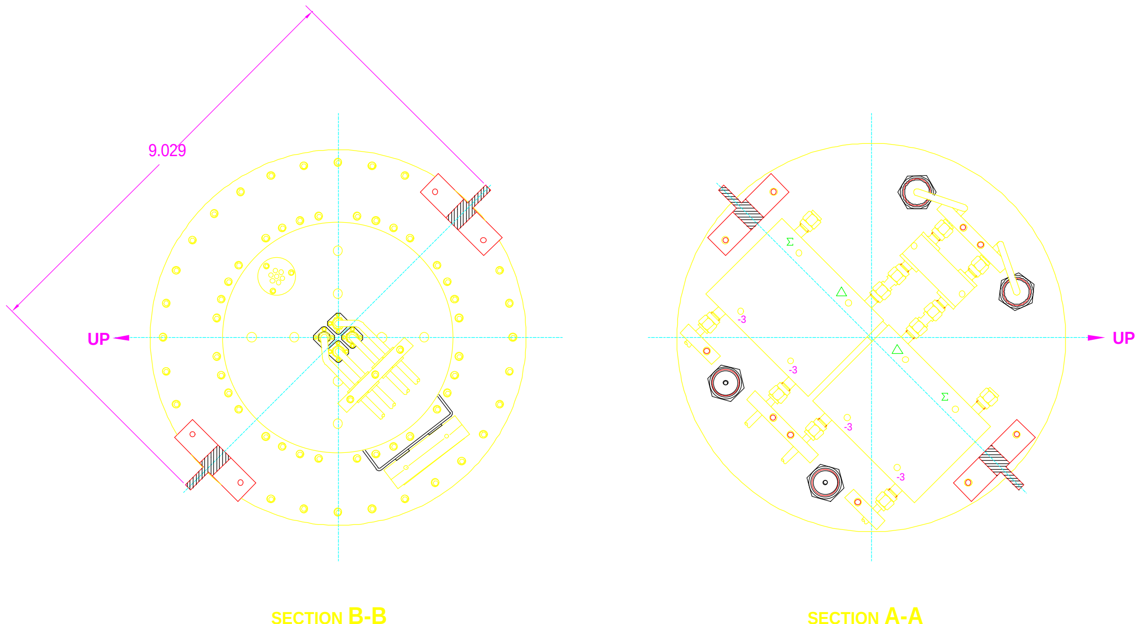

Figure 3: Two Section Views showing the External Hybrids and Their Connections.

DESIGN FEATURES

The ARIA feed has many special features. A list of the important ones is given below.

- The waveguides have been designed so that the phase velocity of the TE_{11} mode in the inner guide is the same as that of the TE_{21} mode in the outer guide. Due to this and the alignment of the TE_{11} probes with the TE_{21} stripline circuit, the waveguide dispersion does not harm the phase tracking of the Σ and Δ antenna patterns.
- The use of the TE_{21} mode naturally gives deep, symmetric and stationary nulls on the boresight of the feed. All that is required is that the feed be made circularly symmetric and that the mode be launched cleanly.
- The Σ and Δ feed circuits are completely separated. In other feed systems (e.g. cross dipoles) each radiator receives/transmits both the track and sum signals. Thus a complicated comparator network is required to separate the track signal from the sum signal. This incurs added resistive losses. The separate circuits of the ARIA feed avoids this.
- The TE_{21} stripline circuit containing 8 voltage probes is placed a quarter of a TE_{21} guide wavelength away from the back short (i.e. at a voltage maximum). The waveguides have been designed so that this is also a half TE_{11} guide wavelength from the backshort (i.e. at a voltage minimum). Thus the stripline circuit does not interfere with the TE_{11} operation. Also the TE_{21} mode is cut-off in the inner tube and does not

reach the TE_{11} probes. As a result of these design features, the two circuits are completely isolated at the mid-frequency and have very little coupling at the frequency band edges.

- The outer choke rings perform in the same way as those in high efficiency (non-tracking) ring feeds. Thus, this tracking feed gives almost as much aperture efficiency as a ring feed.
- The TE_{11} combining circuits are made from external off the shelf hybrids. These are the cause of ≈ 75% of the loss in the sum channel. These also limit the amount of power that can be transmitted by the feed. Better noise temperatures or power handling capability can be attained by simply replacing this "off the shelf" outer circuit without changing any of the internal circuit.

PRIMARY PATTERNS

Figure 4 contains Σ and Δ, E and H plane antenna patterns of the feed at four frequencies within the band. Please note both the Σ and Δ channels have almost equal E and H patterns in the range of the dish (± 60^{o} for f/D=0.433). This is desirable for high aperture efficiency. Please note also the deep nulls and co-alignment of the nulls in the Δ patterns.

ESTIMATED APERTURE EFFICIENCY AND PHASE TRACKING

It is possible to produce a good estimate for the feed's performance within a dish by knowing the amplitude and phase of its primary patterns. Thus these were measured at 72 angles and 101 frequencies within the 2.2 to 2.5 GHz band. This data was then used in appropriate formulae to calculate the aperture efficiency and the phase tracking of the Σ and Δ secondary patterns. The results of this analysis are shown in Figures 5and 6. Included in Figure 6 are phase errors directly measured during the testing of the secondary patterns inside the ARIA frequency band.

The aperture efficiency does not include any resistive or VSWR losses. It merely represents the efficiency of the primary pattern illuminating the dish. It includes the effects of spillover and aperture tapering. Note the sum pattern's estimated efficiency is very high when one compares it to what can be expected from a ring feed comprised of a circular waveguide with three rings. This would typically have an optimum aperture efficiency of 77%.

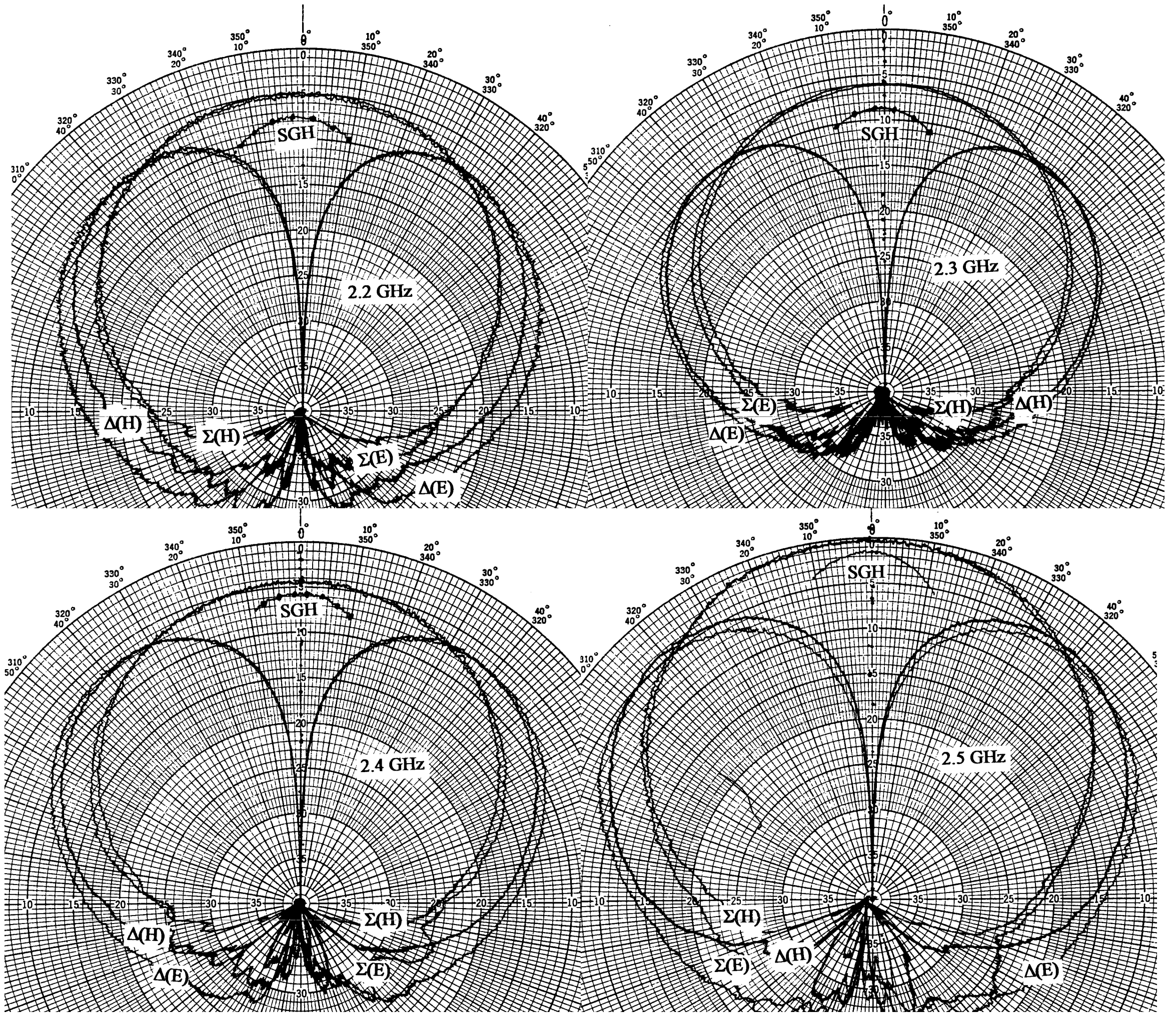

Figure 4: Primary patterns.

Errors in the phase tracking between the Σand Δ patterns directly cause angle errors in the detected target's position. The relationship is one to one, i.e. every degree of tracking error causes a degree error in the target's position. Thus, it is important to minimize this error. It is generally accepted that a tracking system with a 10% cross-talk is a good tracker. This amount of cross talk corresponds to a phase tracking error of 5.7^{o}. Thus the estimated phase tracking error of ±4^{o} means that the ARIA feed will provide excellent tracking performance.

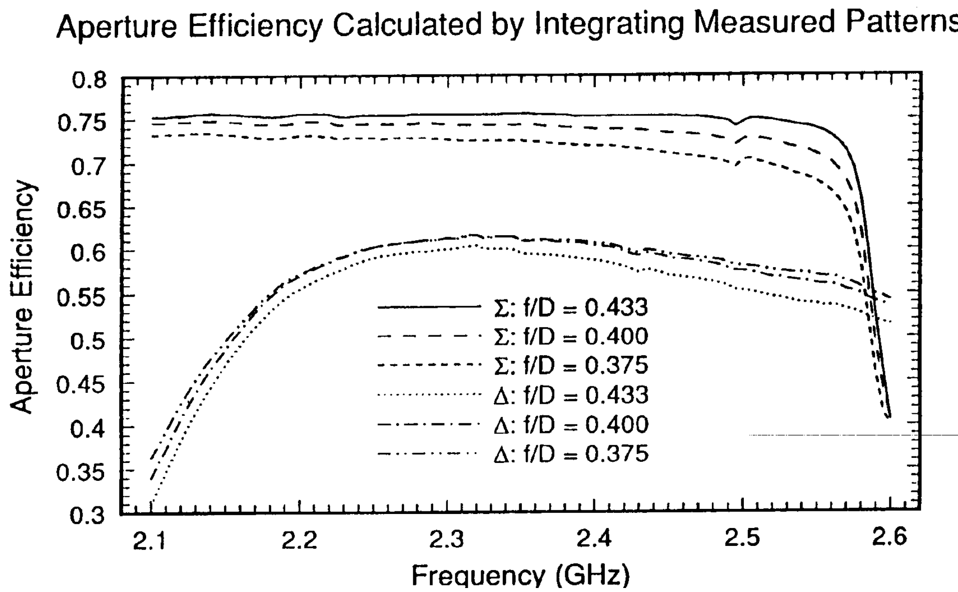

Figure 5: Estimated Aperture Efficiency.

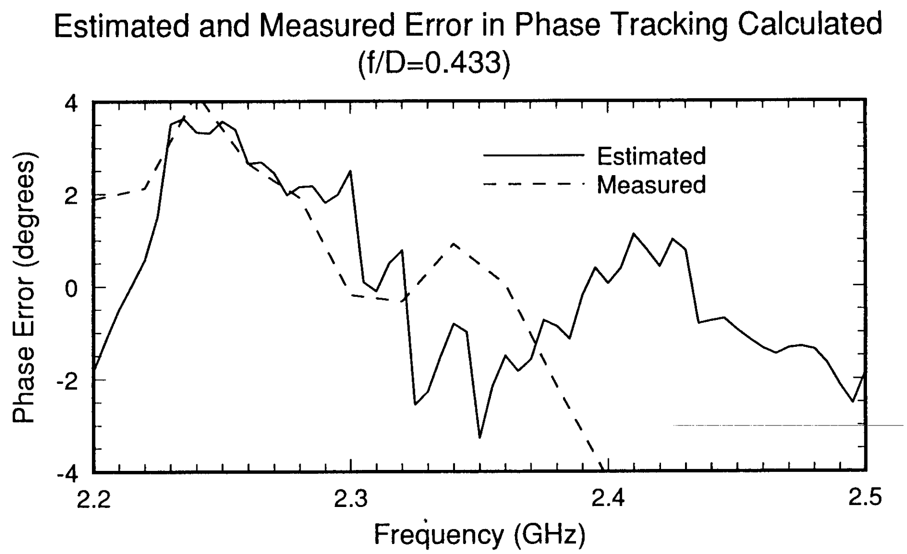

Figure 6: Estimated Phase Tracking Error.

CONCLUSION

LJR Inc has developed a new type of tracking feed with many advantages over other available feed technologies. The feed was developed by first developing software tools that could accurately predict its performance and could be used to optimize the feed's design. The result of this research is a highly reliable and easy to construct feed which meets a tough set of specifications and in many cases greatly exceeds the requirements.