LOW LOSS, HIGH POWER LATCHING WAVEGUIDE SWITCH

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ABSTRACT

This paper describes a new approach to the design of high power waveguide latching circulating switches featuring simple cylindrical junction parts and exceptional RF performance: typical insertion loss is 0.15 dB at X-band, with a CW power handling capability of 200 W.

Introduction

The development of a low loss, high power waveguide latching ferrite switch is part of a continuing effort to provide methods and designs for producible high performance components in the millimeter wave frequency range. A novel circulator design approach led to a clear advancement in the state-of-the-art in circulator performance in 1976.[1] The development of a switching/latching ferrite junction* extends the earlier fixed magnetic bias circulator effort to provide features permitting optimization of both RF and switching functions independently. As a result, most of the exceptional RF characteristics and well proven structural approach, suitable for space environments, are incorporated in the new design.

Junction Design

The switching/latching junction, depicted in a cross-sectional view in Figure 1, consists of a dielectric tube containing a dielectric spacer separating two RF junction ferrites. This sub-assembly is indexed between two metallic transformers, which are attached to the broad walls of the waveguide housing. The transformers also serve as housings for the driver ferrites. A circular piece of gold foil forms the waveguide wall between the RF junction and driver ferrites. The driver ferrites contain the actuating coils embedded within annular grooves.

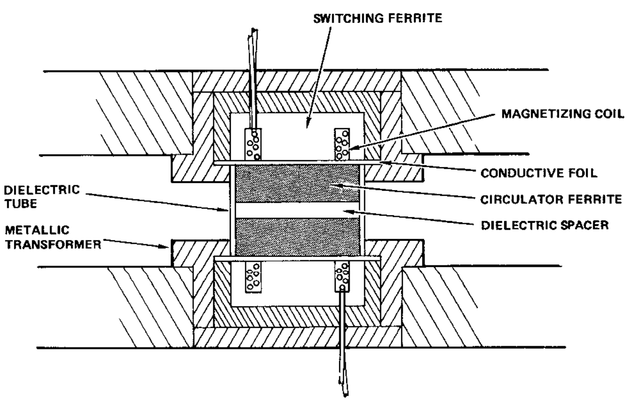

Figure 1. Schematic view of switching junction.

The mechanical design of this junction reflects the efforts and special emphasis on the structural simplicity. The whole assembly consists of simple cylindrical shapes, defined by diameter and length, mechanically interlocked without any need for epoxy or any other lossy bonding materials, self-indexing and easily assembled within the waveguide housing without any locating fixtures. This structural approach offers several important advantages over those using complicated prismatic configurations. Among them:

- the electrical performance is repeatable without any post-assembly corrective trimming
- the switch assembly is shock and vibration proof - tests to spacecraft specification levels never produced a single failure
- the component parts are significantly less expensive considering fabrication and quality control; the assembly of self-indexing and self-locking components is a simple procedure

Electrically the design provides for separation of the RF and switching/latching functions. The RF junction ferrites are selected and optimized for the reuqired performance separately from the switching driver ferrites, which are placed outside the waveguide, and which are selected on the basis of their magnetic characteristics. Consequently, the problems and compromises encountered with an internal actuator coil are eliminated. The presence of the actuating coil in a large waveguide poses a minor problem, but since the switching current is essentially constant and independent of frequency, the same size wire becomes prohibitively large at millimeter wave frequencies. The design approaches where the magnetic switching circuit is outside the waveguide were avoided at lower microwave frequencies in the past because the magnetic circuits usually surrounded the waveguide, and the waveguide, acting as a one turn transformer, increased the switching energy and switching time to unreasonable levels. The present design reduces the undesirable effects of the one turn transformer significantly: the magnetic circuit encloses only a thin gold foil, and as the frequency increases and the skin current depth decreases, the foil thickness is reduced. The compelling reason for the magnetic circuit enclosing the waveguide was the desire to produce axial magnetization within the circulator junction. The present design employs an internal toroidal magnetic field within each junction ferrite and its ferrite driver. The RF junction ferrite and the center core of the ferrite driver are

*Patent applied for

essentially the same size as used in a fixed magnetic bias circulator with axial magnetization. As in all circulators, only the innermost part of the ferrite contributes to circulator action - the excess ferrite to provide for magnetic return of the magnetic field of opposite polarity, to that in the central part of the junction, appears only as dielectric material.

Results

The first switching junction, fabricated at Ka-band, confirmed the feasibility of the approach and also disclosed that a dielectric sleeve separating the RF junction ferrite from the magnetic return was not required. The three-piece construction of the RF junction structure was replaced by a single ferrite - a simplification that lead to improvement in performance, producibility and lower cost. The second model, as shown in Figure 1, was fabricated at X_L-band in WR-112 waveguide. The complete performance of this unit is shown in Figure 2. This data is typical of several experimental designs and clearly indicates the high performance of this design. The switching/latching circulator performance is summarized in Table 1. The Ka- and X_L-band circulators are shown in Figure 3.

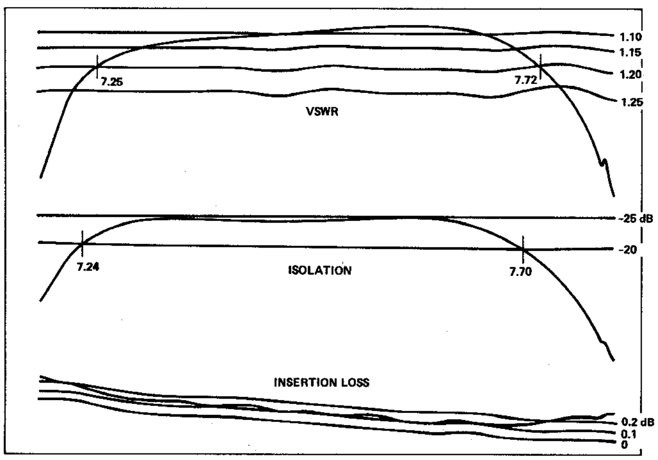

Figure 2. Typical performance of X-band experimental latching circulator.

Table 1. Performance summary of experimental latching circulator switches.

Parameter	Initial Ka-band Switching Circulator	Initial X-band Switching Circulator Wideband	Initial X-band Switching Circulator Low Loss
Center Frequency	27.2 GHz	8.1 GHz	7.5 GHz
Bandwidth	1.5%	9.5%	6.0%
Isolation	20 dB	20 dB	24 dB
Insertion Loss	0.5 dB	0.3 dB	0.15 dB
VSWR	1.5:1	1.2:1	1.15:1
Power Rating (Average)	25 W	200 W	200 W

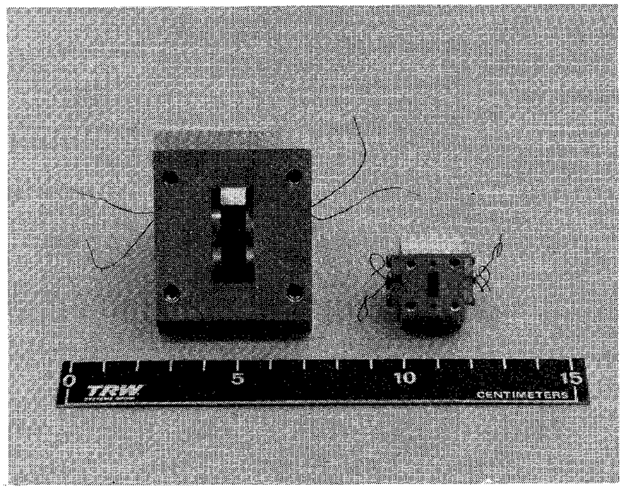

Figure 3. Ka-band (right) and X-band experimental latching waveguide switch.

Conclusions

A new approach to the design of switching/latching junctions offers excellent RF performance, structural simplicity and reliability for millimeter wave applications. Its usefulness can also be appreciated at lower frequencies, provided slower switching speeds (about 100 microseconds at X-band) are acceptable. Several switching units, featuring outstanding temperature, power, VSWR and insertion loss characteristics, are currently undergoing qualification testing for near term space applications.

Acknowledgement

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Reference

1. W. S. Piotrowski and J. E. Raue, "Low-Loss Broad-Band EHF Circulator", IEEE Trans. Microwave Theory and Tech., Vol. MTT-24, pp. 863-866, November 1976.