A K-BAND HIGH POWER LOW LOSS LATCHING SWITCH

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ABSTRACT

A development effort is described that resulted in a rugged 19 GHz ferrite component with 1.4 GHz of bandwidth and 0.25 dB insertion loss and a capability to switch 100W CW power.

Introduction

This development effort was undertaken to provide a rugged high performance waveguide switch for the downlink transmitter of the next generation 20/30 GHz satellite systems. Emphasis was on high power handling capability, low loss and good bandwidth. No switch existed at K-Band with even one of these attributes. The switch described in this paper satisfies all of these objectives.

Design

The specific design of the RF junction is largely based on our cylindrically symmetrical turnstile circulator junction design.[1,2] The latching ferrite switch,[3,4] depicted in Figure 1, features separate structures for the RF and driver ferrites which can be optimized individually for their respective (conflicting) requirements. The RF switching junction differs from the non-switching junction in that it uses larger ferrites to provide an internal return path, as well as chamfering on the interior edge to enhance their magnetic characteristics. High power handling capability is achieved by (1) providing a low loss design, (2) by thermal grounding of the ferrite assembly and the ability to remove heat symmetrically from both ends, and (3) biasing of the RF junction deeply into saturation.

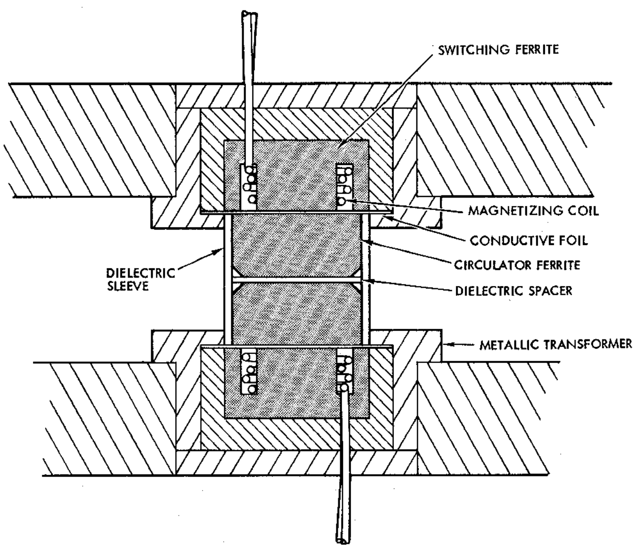

Figure 1. Cross-Section of Switching Junction Showing RF and Driver Ferrite Locations

The low power ferrite junction with an internal toroidal magnetization, enclosed within the waveguide housing, depends upon the remanent magnetization of the RF junction ferrite to satisfy simultaneously the conditions required to obtain the circulator action and latching. Prior efforts with internally activated units have resulted in low bandwidth units with relatively low power operation.[5,6] The single half-wavelength ferrite structure must be also open-circuited and is thermally separated from the conducting waveguide surfaces by the dielectric spacers. This impedes the heat transfer and further reduces the power handling capability.

The problem is solved by providing a well known dual turnstile RF junction with the ferrite drivers, which are placed outside the waveguide, and which are independently optimized to insure latching and sufficient bias magnetization, consistent with high power operation. The two quarter-wave RF junction ferrites are open-circuited at the center of the waveguide height, and in intimate contact with the broad walls of the waveguide, providing a short-circuit to the waveguide as well as enhancing the heat flow from the RF junction to the switch housing.

The switch driver assembly is comprised of three pieces of ferrite, one coaxially located within the other and separated by a small gap, and a cap. The diameter of the center-core of the ferrite driver is determined by the size of the RF junction ferrite, normally used in the standard (non-switching) circulator. For a switch junction this ferrite is doubled in its cross-sectional area, to provide the magnetic return.

The RF junction is impedance matched to the switch housing with a simple step transformer, which also indexes the junction assembly in the geometrical center of the three-port housing. It should be noted that all parts of the RF junction are precisely indexed and mechanically interlocked without the use of any epoxies or bonding materials.

A current pulse through the switching coil induces an internal, toroidal magnetization in the contacting driver ferrite - RF ferrite assemblies. To maintain the switch latched in its last switched state, an intimate contact (except for a thin conductive foil) between the RF ferrites and their driver ferrites is essential. This is insured by a properly designed wavy washer spring, which compresses the entire junction assembly. In this way, thermal expansion, shock and vibration problems are effectively eliminated.

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The TT71-4000 lithium ferrite was selected for the switch driver. It has a high ratio of remanent to maximum magnetization (Br/Bm), indicating an acceptable squareness of the hysteresis loop, and its remanent magnetization is adequate to magnetically bias the RF junction for stable high power operation.

The material selected for the RF junction was TT2-4000 nickel ferrite. This material has good power handling capability, good magnetic and dielectric properties, and acceptable loss tangent.

An extensive algorithm has been developed that calculates all required design parameters and the resulting component dimensions.

Results

A photograph of the final K-Band switch, together with a box containing two SPST switches, is shown in Figure 2. The actuating circuitry is contained within the K-Band switch housing shown in the foreground. All that is required to operate the switch is an external 24 volt power supply. Designed for application in space, the switch weighs only 355 g and is 9.53 cm. x 3.18 cm. x 5 cm. in size. The outstanding performance of the complete unit is summarized in Table 1, with one set of detailed RF performance data included as Figure 3.

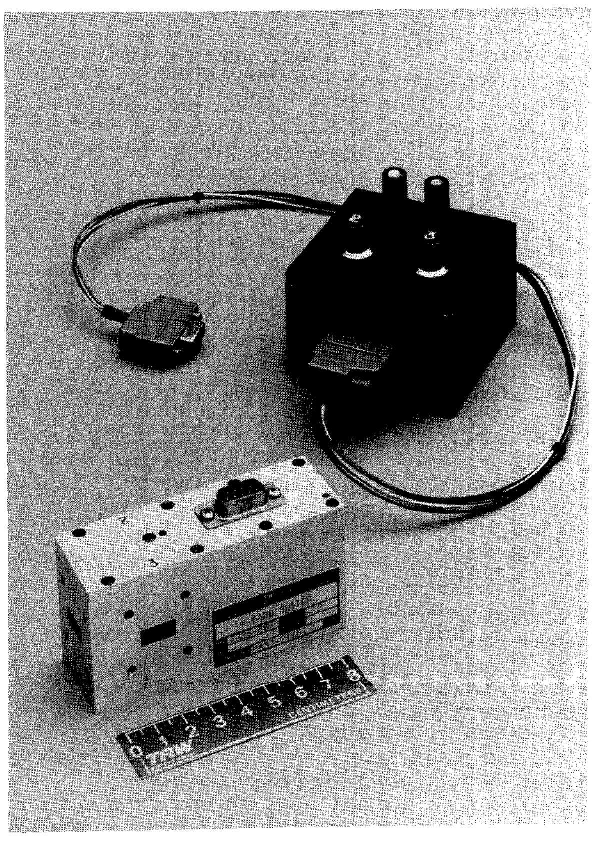

Figure 2. K-Band Latching Switch

Table 1. K-Band Switch Performance

PARAMETER	PERFORMANCE SPECIFICATIONS	ACTUAL
CENTER OPERATING FREQUENCY	18.95 GHz	19.1 GHz
BANDWIDTH	1.4 GHz	1.4 GHz
INSERTION LOSS	0.25 dB	0.25 dB
INSERTION LOSS FLATNESS	$\pm$0.05 dB	$\pm$0.05 dB
ISOLATION	25 dB	25 dB
INPUT VSWR	1.2:1	1.2:1
INPUT VSWR WITH 1.15:1 LOAD	1.3:1	1.15 TYP. OVER BAND 1.2 ON EDGE
PHASE LINEARITY	$\pm 5^{\circ}$ OVER ANY 300 MHz PASSBAND SEGMENT	NEGLIGIBLE DEVIATION
SWITCHING TIME	80 μsec	50 μsec
MAX OPERATING TEMPERATURE	+56°C	+56°C
MINIMUM NON OPERATING TEMPERATURE	-40°C	-44°C (OPERATING)

In addition to complete temperature tests (negligible performance changes over the +10 to +58°C temperature range), the switch was subjected to complete shock and random vibration tests, both performed for all three axes. Detailed switch performance was recorded after all environmental tests indicating no changes in latching and electrical performance and confirming the structural integrity of the design.

In summary, a rugged, producible microwave component was developed that clearly advances the state-of-the-art in ferrite switches by simultaneously achieving high power handling, very low insertion loss and good bandwidth.

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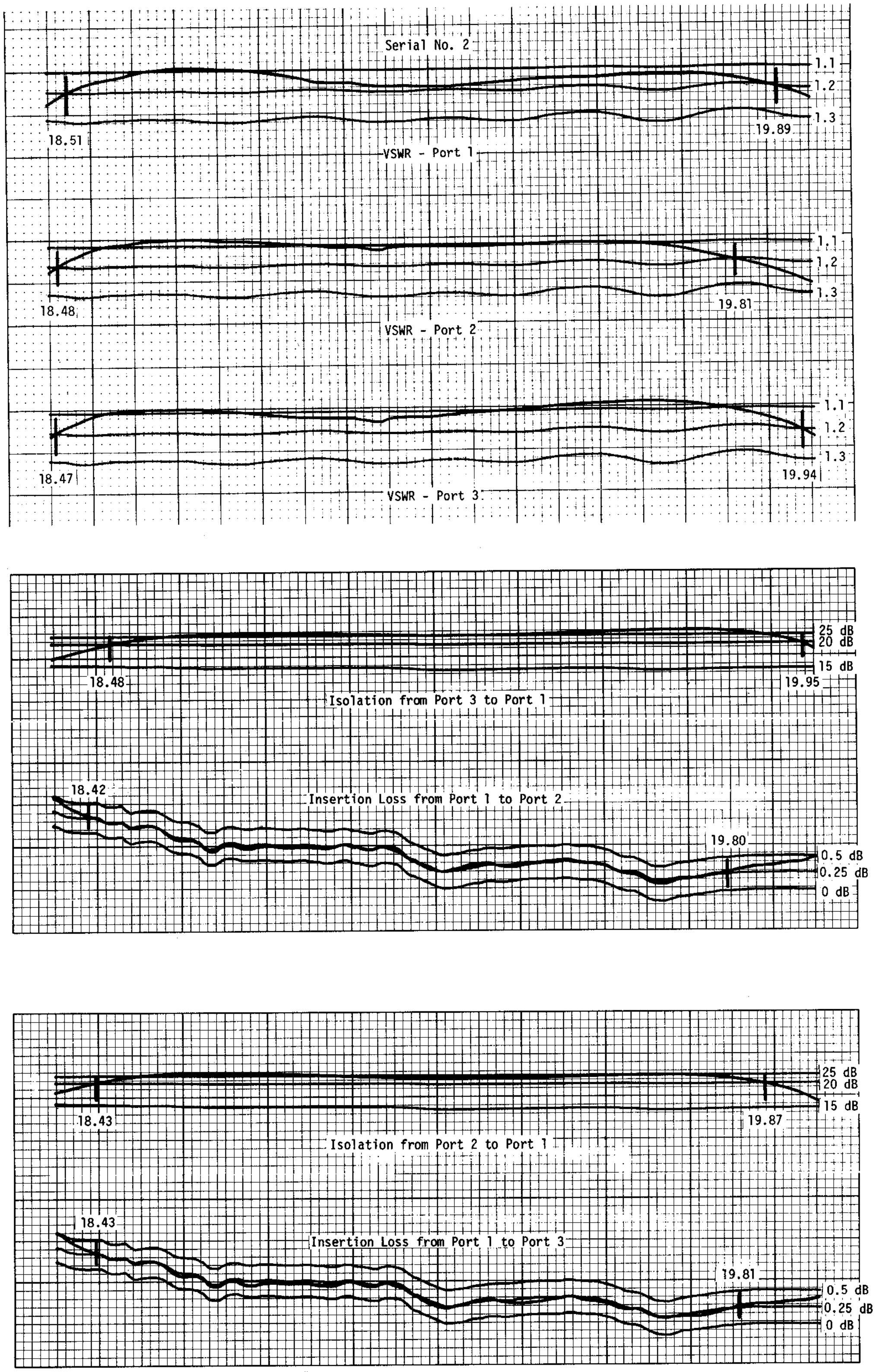

Figure 3. Final Performance of K-Band Latching Switch