SPACEBORNE HYBRID MIC PIN DIODE RADIOMETER SWITCH*

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Abstract

Using hybrid MIC techniques a new SP5T precision PIN diode radiometer switch has been developed for use in highly accurate spaceborne radiometers. The successful use of hybrid MIC techniques in meeting the unusual and difficult requirements is discussed including the achieving of a precision noise balance and the incorporation of a hybrid MIC matching circuit for precision matching of the switch and receiver combination.

Summary

As modern earthmapping microwave radiometers are capable of sensing hundreths or even thousandths of a dB change in RF level, and as the operating environment is air- or space-borne, the requirements imposed on the necessary RF switches are unusually stringent. In designing a 1.4-GHz spaceborne radiometer with a design accuracy of 1 kelvin (K), commercially available switches were found inadequate. Radiometers of this type require internal noise sources for automatic calibration. It is desirable to incorporate all of the RF switching functions into a single switch. In each switch position, the insertion loss must be small and in some cases balanced to within 0.05 dB. The shot noise generated in the PIN diodes may have to be balanced to a fraction of 1 K and, as there is little information available on shot noise in PIN diodes, experiments were required to study this effect. Significant noise error can result from system interface mismatches and as the RF switch is the critical interface, it is desirable to incorporate matching devices into the switch which match the switch and the receiver.

The use of hybrid MIC techniques allows a reduction in size, provides excellent reliability and ruggedness, allows precision balancing of the parameters, and allows the construction of a highly stable tightly controlled circuit. This paper concentrates on the physical description of the switch and its electrical characteristics. The design theory used for this switch will be given in a more expanded version of this paper.

Description of Switch

Figure 1 shows the top view of the switch with the cover off. The SP5T switches are composed of the following elements:

- Five arms consisting of a series PIN diode and two shunt diodes, approximately an eighth wavelength apart, in a 50-ohm structure.

- Five sets of double-stub tuners. Each tuner consists of two 80-ohm inductive stubs and two capacitive screws separated by an eighth wavelength. Each inner inductive stub supplies the bias for the respective set of PIN diodes.

- A bias circuit consisting of the above mentioned inputs and a dc-floating RF ground to which all the shunt diodes are connected. The RF ground is connected to the common junction of the series diode via a quarter-wavelength high-impedance stub. This arrangement maximizes the efficiency of the driving circuitry.

- Printed capacitive stubs are connected, when necessary, by bridge welding with 20-mil wide gold ribbons, in order to optimize the tuning range of the double stub tuners.

Performance of Switch

The main performance features are:

- A SP5T diode switch with double stub tuners in each arm with an overall size of $2\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{1}{2}$ inches.

- The use of hybrid MIC double-stub tuners in each arm to virtually eliminate the uncertainty in the mismatches between the receiver and the antenna of the various reference noise sources. These tuners are typically capable of matching a 1.2 VSWR of any phase to 1.02 from 1.4 to 1.43 GHz. A maximum VSWR of 1.03 was maintained over a temperature range of 90°C. Figure 2 shows the noise error resulting from the unknown relative phase of the radiometer and antenna VSWR's. A 1.20 antenna VSWR and a system VSWR of 1.02 result in an uncertainty of 0.5 K, underlining the importance of the tuners.

- An insertion loss under 0.6 dB with the capability of matching the losses to within 0.05 dB. This unbalance can result in a 1-K error under special circumstances.

- Matching of the shot noise of the PIN diodes to a fraction of 1 K by series resistance selection and the use of low shot noise PIN diodes. The typical shot noise of the switch being between 1 and 1.5 K.

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- Isolation of about 35 dB, sufficient to reduce the radiometer error due to finite isolation to less than 0.2 K.

- A rugged design capable of withstanding space qualification levels of shock and vibration without effect.

Figure 3 shows the bottom of the substrate and some of the bias circuit details. The MA47054 diodes were used as the series diodes because of their low shot noise. Experiments show that the shot noise of PIN diodes is roughly proportional to the bias current and the minimum series resistance. The classical temperature-limited diode model is unsatisfactory in describing the PIN diode noise characteristics. The shot noise is apparently not a function of the dynamic resistance. The MA47054 with a series resistance of 1.2 ohms at 10 mA resulted in an excess noise of the switch of 1 to 1.5 K. A SP5T diode module with a nominal 1-ohm series resistance at 50 mA and in the same switch configuration has an excess noise varying between 3 to 7 K.

The use of alumina dielectric with descrete components is particularly useful when a unit is to operate over a large temperature range. This is due to the close match of the coefficient of expansion of alumina and the materials used to package the semiconductors typically alumina, glass, and Kovar. Attempting to build this circuit on nonceramic dielectric substrates would result in poor reliability with temperature, due to the relatively large thermal coefficient of expansion of fiberglass epoxy and other similar types of substrates. The dimensional stability of the substrate is also important to the thermal stability of the double stub tuner circuits.

The use of the conventionally packaged series diodes, as were used in the SP5T RF switch, should be possible into S-band. Beam lead or chip diodes can be used at much higher frequencies; however, the low noise PIN diodes are only available in chip form, which makes their measurement, and therefore their matching, difficult. Circulator switches have been the preferred RF switch used in radiometers, because of their low loss; however, where multiple switching functions are involved, the PIN diode switch described herein should have lower overall loss into S-band.

The MIC double stub tuner should be feasible to at least X-band, and with the use of varactors as the variable capacitors, tuning screws can be eliminated and the entire switch can be made completely MIC.

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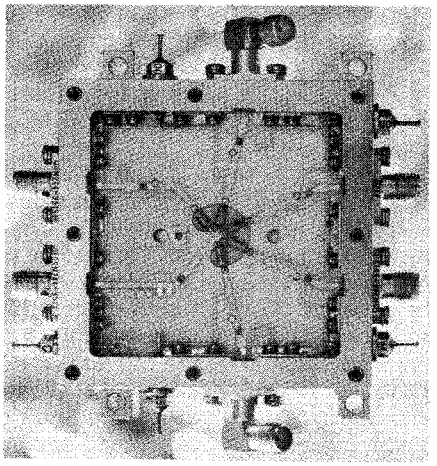

FIGURE 1. TOP VIEW OF SP5T SWITCH

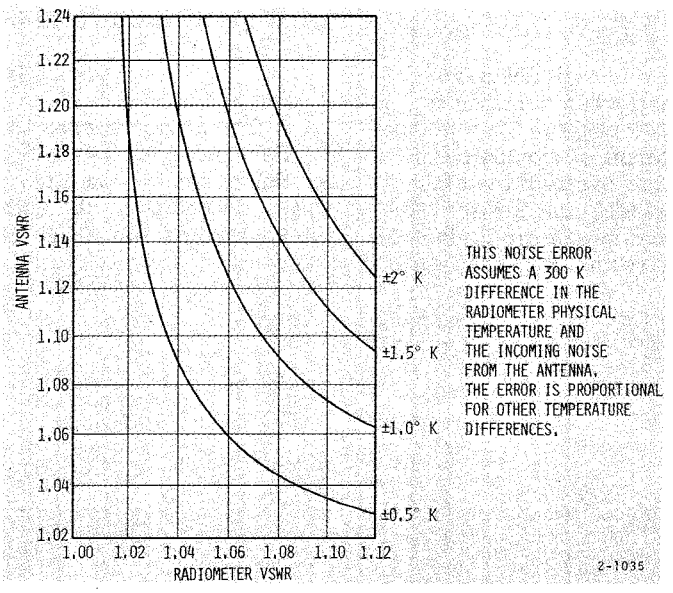

FIGURE 2. EQUIVALENT NOISE UNCERTAINTY DUE TO UNKNOWN RELATIVE PHASE BETWEEN ANTENNA AND RADIOMETER MISMATCHES

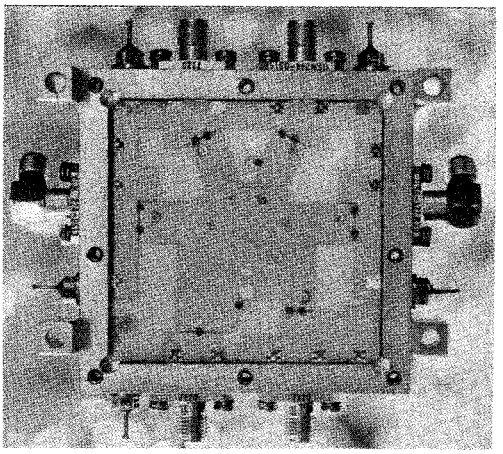

FIGURE 3. BOTTOM VIEW OF SP5T SWITCH