Low-Noise Receivers: Microwave Maser Development

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A new multijunction, cryogenically coolable, X-band circulator has been developed and tested. Isolation exceeding 20 dB per junction and insertion loss less than 0.2 dB per junction between 8100 and 8800 MHz have been measured at 4.5 K. The new circulator will be used with a maser to provide low noise amplification across a wide instantaneous bandwidth.

I. Introduction

An X-band multijunction, cryogenically coolable circulator has been purchased and tested at 4.5 Kelvins. The circulator will be used with a maser to provide low noise amplification across a wide instantaneous bandwidth. Excellent isolation and low insertion loss have been demonstrated from 8100 to 8800 MHz. Two special refrigerator systems were assembled to enable the development and the testing of the circulator.

II. Application

Isolation required for stable maser amplification can be obtained by using either circulators or resonance isolators. Cavity-type masers built and operated by the Jet Propulsion Laboratory (JPL) from 1960 to 1965 used room temperature circulators; traveling-wave masers used in the Deep Space Network since 1963 had resonance isolators built into the maser structure at 4.5 K (Ref. 1). The requirements of very low noise input temperature (less than 5 K) and wide instantaneous bandwidth (more than 100 MHz) have established the need for improved isolation techniques.

The circulator described here is suitable for use with a very low noise amplifier because it has low insertion loss at 4.5 K. Wide bandwidth operation is possible because high isolation is obtained across a 700 MHz bandwidth.

The use of a traveling wave type of slow-wave structure (without resonance isolators) and line broadened maser material in combination with a circulator results in a reflection-type traveling-wave maser with a bandwidth capability of several hundred MHz. The cryogenically coolable circulator described here has been developed for this purpose.

III. Circulator Development

A special cryogenic system using a Cryogenic Technology, Inc. model 350 refrigerator with four coaxial transmission lines was assembled and supplied to P and H Laboratories (Chatsworth, Calif.) to enable the development of the cryogenically coolable circulator. This refrigerator system is easy to use and is capable of operation at temperatures between 13 and 290 K. The coaxial transmission lines are 0.36 cm. outside diameter with SMA connectors and can be used at any frequency up to 18 GHz.

A second, more complicated 4.5 K cryogenic system was assembled and has been used to test the X-band circulator at JPL.

IV. Circulator Performance Measurements

The circulator, mounted on the 4.5 K station of the refrigerator, is shown in Fig. 1. Mounting brackets for a maser and superconducting magnet are included for future tests. Four coaxial lines are connected so that isolation, loss, and impedance measurements of each circulator port can be made. A schematic diagram of the circulator is shown in Fig. 2. Input, output, and amplifier ports are identified by number (1 through 4). Isolation provided by the first circulator junction (port 2 to port 1) is shown in Fig. 3. Data were recorded at 4.5, 20, 100 and 290 K. Figure 4 shows isolation data for other ports recorded at 4.5 K.

Initial loss measurements show the dissipative loss of the circulator to be less than 0.2 dB per junction. Additional measurements will be made to more accurately determine the match and loss of each individual junction.

V. Conclusion

The new 4-port cryogenically coolable X-band circulator works well at any temperature between 4.5 and 290 K. The internal isolation is adequate to permit stable wideband maser amplification at any frequency between 8100 and 8800 MHz.

Reference

1. Reid, M.S., et al., "Low-Noise Receiving Systems in a Worldwide Network of Large Antennas," *Proceedings of the IEEE*, Vol. 61, No. 9, pp. 1330–1335, September 1973.

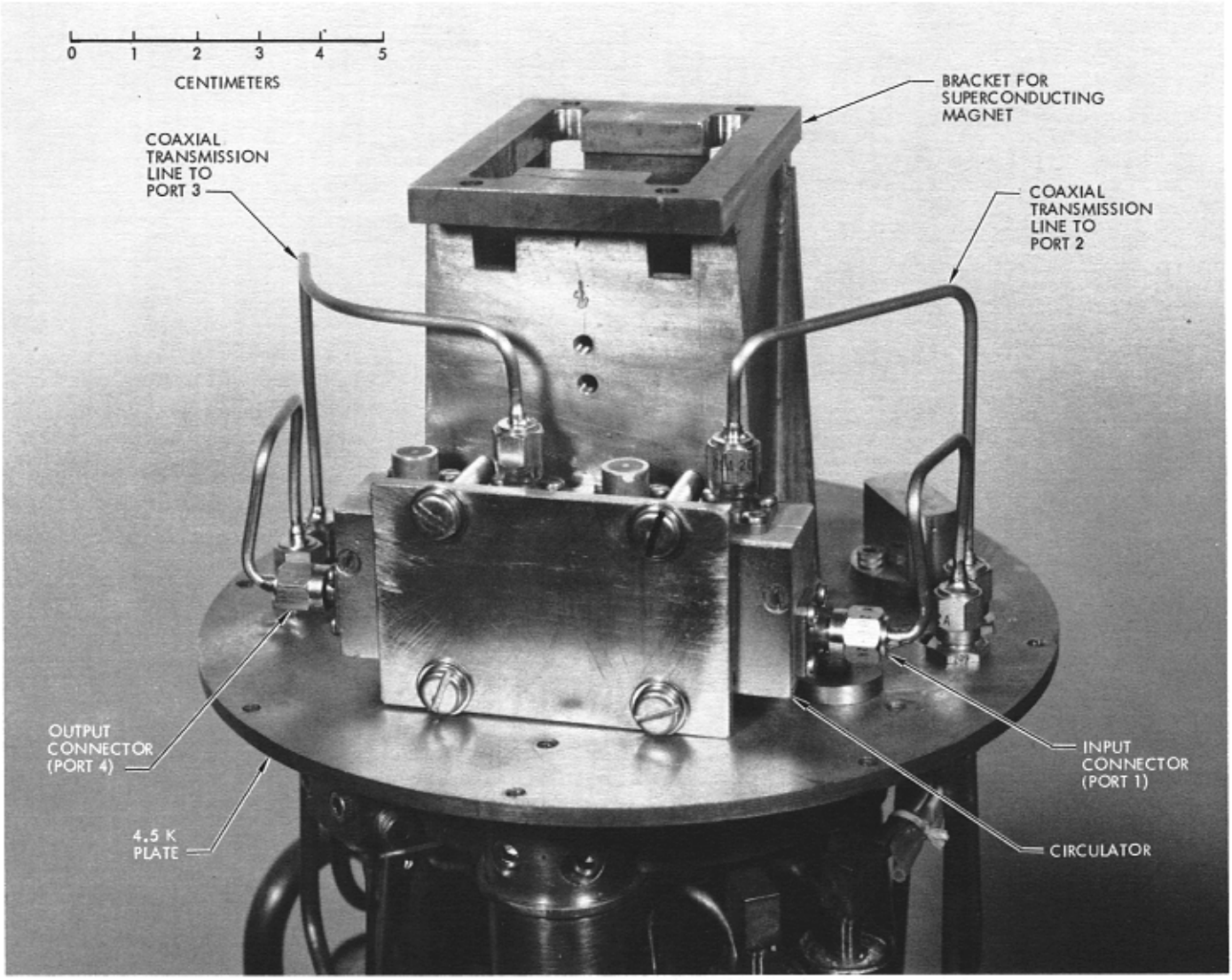

Fig. 1. X-band multijunction cryogenically coolable circulator

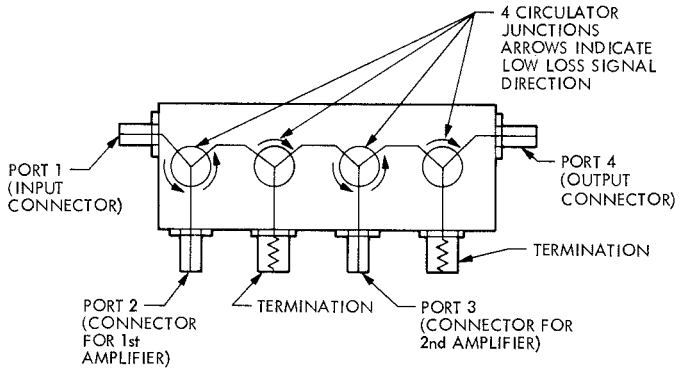

Fig. 2. Schematic diagram of multijunction circulator

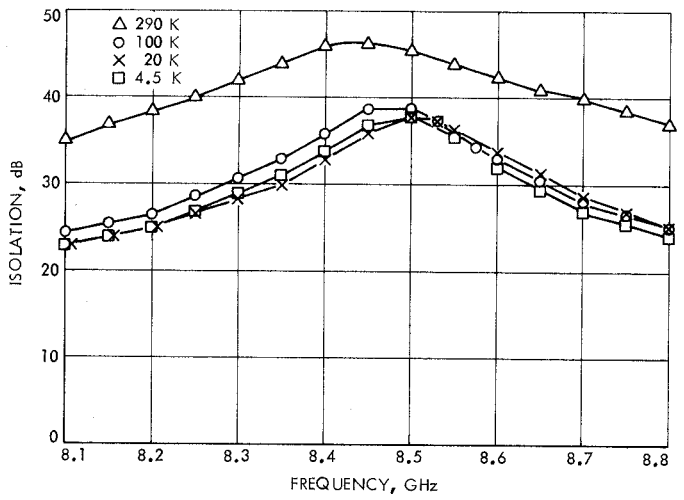

Fig. 3. Isolation of one circulator junction as a function of frequency and temperature (port 2 to port 1)

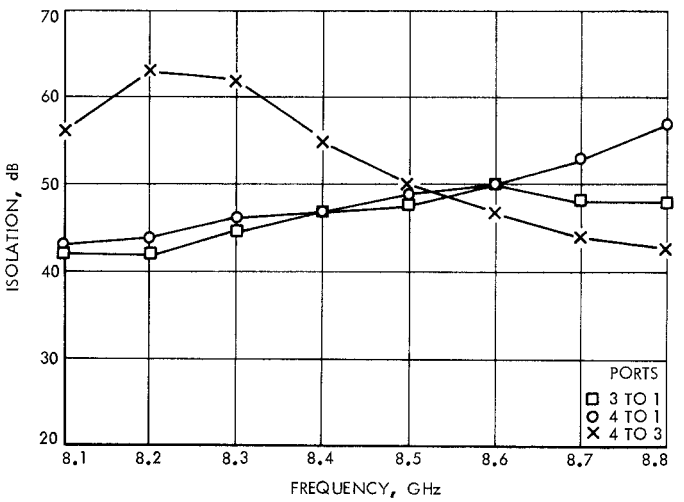

Fig. 4. Isolation of various circulator junction combinations at 4.5 K