OCTAVE COVERAGE LUMPED ELEMENT CIRCULATOR DEVELOPMENT*

by

J. Wolczok and I. Rubinstein

AIL, a division of Cutler-Hammer
Melville, New York 11746

Abstract

A compact broadband 220 to 400 MHz lumped element RF circulator has been developed using novel band-switchable, single-tuned matching networks at each port. Isolations of greater than 15 dB and mid-band insertion losses of 1 dB were obtained.

Extremely broadband circulator operation has been achieved using lumped element matching networks at each circulator port. This paper reports on the analysis and development of compact broadband, lumped element, above-resonance circulators which provide improved performance in the 30 to 450 MHz frequency range, compared to previously available circulators.

A novel analysis of broadband lumped element above-resonance circulators is presented. The analysis is based on optimum impedance matching between the complex impedance of the ferrite junction and the terminating load impedance. This broadband matching technique provides substantially improved circulator characteristics over those previously reported. The measured loaded Q_R of the ferrite junction is used in the analysis to determine the required reactive circuit parameter and to predict the circulator bandwidth.

Based on the analysis, the fractional bandwidth of the lumped element circulator is given by:

$$\frac{\Delta f}{f_o} = \frac{(1 - \rho^2)^{1/2}}{Q_R}$$

where $\rho = (\text{VSWR})^{-1}$ and the optimum circuit elements for the single tuned matching network are given by:

$$L_M = \frac{Q_R R_L}{2\pi f_o \rho} \qquad \text{(Series Inductance)}$$

$$C_M = \frac{1}{(2\pi f_o)^2 L_M} \qquad \text{(Series Capacitance)}$$

where R_L is the terminating load resistance of the circulator.

In the 225 to 400 MHz frequency region, these broadband techniques have been employed to develop circulators having midband insertion losses of 0.8 dB, 20-dB isolation fractional bandwidths of 20 to 25 percent, and 15-dB isolation fractional bandwidths of 25 to 32 percent.

Techniques to extend the isolation bandwidth capability of these broadband circulators while maintaining small size and low insertion loss will be reported. The broadbanding techniques investigated were:
(1) coaxial switching of multiple circulator units, and
(2) nanosecond switching of multiple matching networks in a single circulator structure using pin diode switches.

The measured isolation and insertion loss of two coaxial switched circulators are shown in Figure 1. The resultant 15 dB isolation range extends from 230 MHz to greater than 440 MHz. However, operation below 220 MHz and above 410 MHz is limited by the increased circulator insertion loss.

Measured performance of pin diode switched matching networks in a single circulator unit, operating with a fixed magnetic field, is shown in Figure 2. The measured 15-dB isolation range extended from 210 to 390 MHz, but could be extended further by an improved frequency overlap of the matching networks.

It is believed that these techniques are applicable to circulators having octave and multi-octave frequency coverage. Other circulator considerations such as continuously tunable multi-octave coverage, circulator operation at high power levels (>1 kW), intermodulation distortion, low frequency limitations, out-of-band isolation, and magnetic compensation to minimize effects of ferrite temperature changes have been investigated, measured, and will be discussed.

* This work was supported by USAECOM, Fort Monmouth, New Jersey, under Contract DAAB07-69-C-0380.

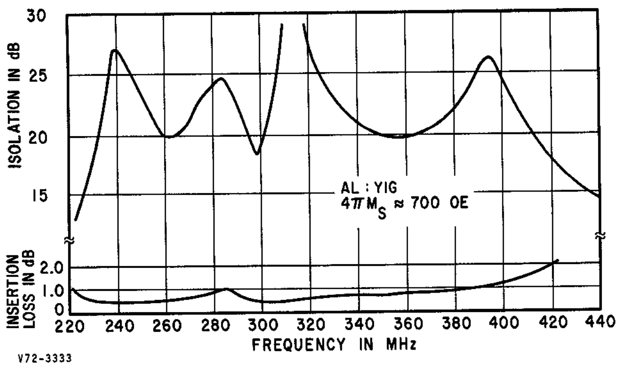

FIG. 1. COMBINED RESPONSE OF TWO COAXIALLY-SWITCHED CIRCULATORS

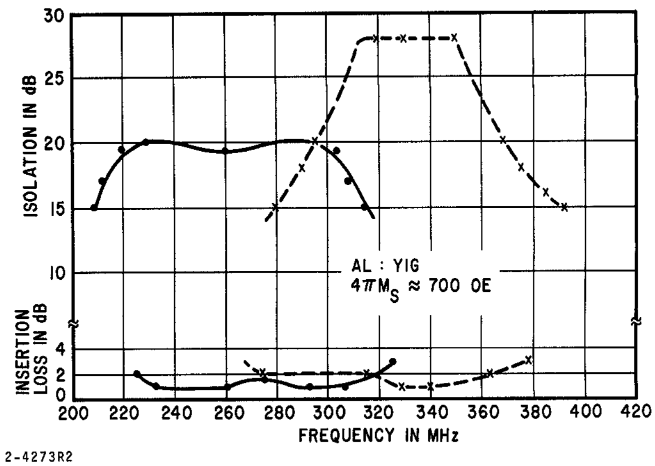

FIG. 2. RESPONSE OF A NETWORK-SWITCHED CIRCULATOR USING PIN DIODE SWITCHES

73-10