A Quasi-Optical Isolator

Stein Hollung, Wayne Shiroma, Milica Marković, and Zoya B. Popović

Abstract— **A nonferrite X-band quasi-optical isolator is presented. The isolator consists of six cascaded printed gratings loaded with lumped elements and exhibits less than 2-dB insertion loss. The isolator is designed for protection and stabilization of quasi-optical amplifiers. A linearly polarized output wave from a quasi-optical amplifier becomes circularly polarized in the isolator, which in this case serves as a linear-to-circular polarization converter as well. Isolation of 9 and 19 dB was measured for the co- and cross-polarized waves, respectively.**

I. Introduction

A variety of quasi-optical grid components have been demonstrated in recent years: oscillators and amplifiers [1], mixers [2], phase shifters [3], multipliers [4], and switches [5]. Quasi-optical active grids for power combining were developed with high-power millimeter-wave solid-state transmitters in mind. In a quasi-optical transmitter, the output is a quasi-optical power amplifier. Most quasi-optical amplifiers to date are linearly polarized, with the input and output antennas polarized orthogonally to each other to provide isolation. To protect the amplifier against high-level reflections, an external isolator can be used. Here we present for the first time a quasi-optical isolator. The isolator is designed to improve the isolation and stability of a quasi-optical amplifier and provide additional functions such as tuning and linear-to-circular polarization conversion. The isolator, shown in Fig. 1, consists of multiple loaded gratings and is cascadable with a quasi-optical amplifier. A system based on the same principle of operation, consisting of a meander-line polarizer backed by a metallic ground plane, was designed for reducing radar cross section (RCS) [6]. A similar quasi-optical circular polarization duplexer was presented in [7].

In Fig. 1, the vertically polarized output wave from a quasi-optical amplifier is first incident on a pair of grids, which do not introduce any significant transmission loss. Both grids consists of horizontal printed strips, and the second one is in addition loaded with 390-Ω resistors. The vertically polarized wave then passes through a linear-to-circular polarization converter and is right-hand circularly polarized at the output. In the event of a reflection, e.g., the transmitter facing a large conductive object, the right-hand circularly polarized wave reflects back toward the transmitter as a left-hand circularly polarized wave. The left-hand circularly polarized wave becomes

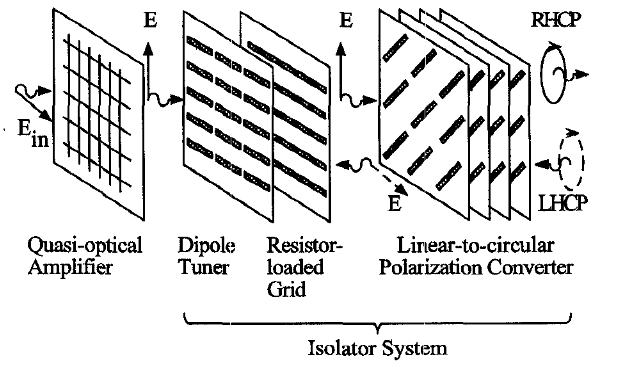

Fig. 1. The isolator system consists of a linear-to-circular polarization converter and an absorbing surface. Transmitted waves are given by solid lines and reflected waves by dashed lines.

horizontally polarized upon passing through the polarization converter and is then absorbed in the resistor-loaded grid.

It is possible to view the linear-to-circular polarization converter as a four-port device by considering the horizontal and vertical polarizations as separate ports at the input and output. In this case, since the horizontally and vertically polarized waves have half the power of the input wave and are 90° out of phase, this device can technically be considered a 3-dB 90° hybrid coupler. However, the ports at the output are actually coupled together to form a circularly polarized wave, and the horizontally polarized port at the input is terminated by the absorbing surface, so this device effectively has only one input and one output port. With the above properties in mind, in this letter we call the device in Fig. 1 an isolator.

II. Design

The linear-to-circular polarization converter demonstrated in [8] operates at around 9 GHz, so the isolator is designed for that range. A full-wave analysis program developed at the University of Colorado was used for the design [8]. The absorbing surface consists of a resistively loaded grid and a dipole tuner grid separated by $\lambda/4$ of air. The resistive grid has a period of 10 mm and consists of 9-mm-long thin metallic strips separated by 1-mm gaps. Lumped 390-Ω chip resistors are soldered across the gaps. The dipole tuner grid consists of 15-mm-long dipoles separated by 7 mm and periodically spaced 15 mm apart. Both grids are fabricated on 0.79-mm-thick substrates with $\epsilon_r = 2.17$.

For the horizontal polarization, the dipole tuner grid can be interpreted as a transmission-line short at the design frequency. Because the two grids are separated by $\lambda/4$, the short can be represented as an open circuit at the plane of the resistive grid. The resistive grid can then be matched to the free-space

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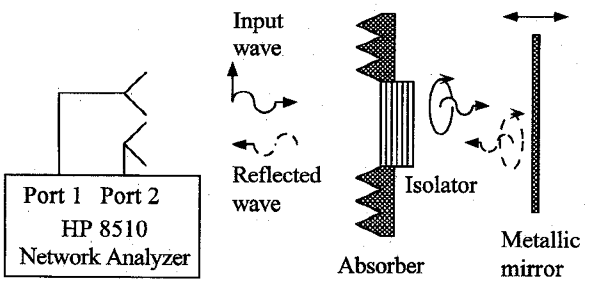

Fig. 2. Experimental setup of the isolator system. Two X-band horns are connected to ports 1 and 2 of a network analyzer. The isolator system is placed in the far field of the horns in the plane of an absorbing aperture. A metallic mirror is used as a variable load behind the isolator system.

impedance of 377 Ω, minimizing transmission and reflection of the horizontally polarized wave at the design frequency.

The linear-to-circular polarization converter consists of four capacitively loaded dipole grids, as shown in Fig. 1. The dipoles are 10 mm long and periodically spaced 13 mm apart. A 100-pF chip capacitor is soldered across each of the 1-mm gaps. Each grid contains an array of dipoles oriented 45° with respect to a vertically polarized incident plane wave. The field component parallel to the dipoles is phase-shifted 90° relative to the orthogonal component, resulting in a circularly polarized transmitted wave. To achieve low transmission loss for both field components, four identical grids spaced 5.5 mm apart are used. This linear-to-circular polarization converter has a measured axial ratio of 1.3 dB and a 1.1 dB transmission loss at 8.4 GHz [8].

III. Experiment

To characterize the isolator performance, two X-band horns are placed side-by-side as shown in Fig. 2. One of the horns provides the incident vertically polarized wave from port 1 of an HP 8510 network analyzer. The other horn is connected to port 2 and is used to measure either the co- or cross-polarized signal reflected through the isolator. The isolator system is inserted at the plane of an absorbing aperture in the far field of the horn antennas. A metallic mirror is used as a variable load behind the linear-to-circular polarization converter. Measurements of S_{21} are made for a range of mirror positions.

First, both the transmit and receive antennas were vertically polarized and the metallic mirror was located at the plane of the absorber. Measurements of S_{21} were obtained as the mirror was translated. The isolator system was then inserted and S_{21} measured for a range of mirror positions. Finally, the receive horn was horizontally polarized, and the isolator measurement was repeated for the same range of mirror positions. The maximum reflected powers were compared for a range of frequencies.

The best isolation was found at 8.83 GHz, where the linear-to-circular polarization converter has a measured axial ratio of 2.5 dB and a transmission loss of 1.1 dB. The co- and cross-polarized reflected signals, normalized to the maximum

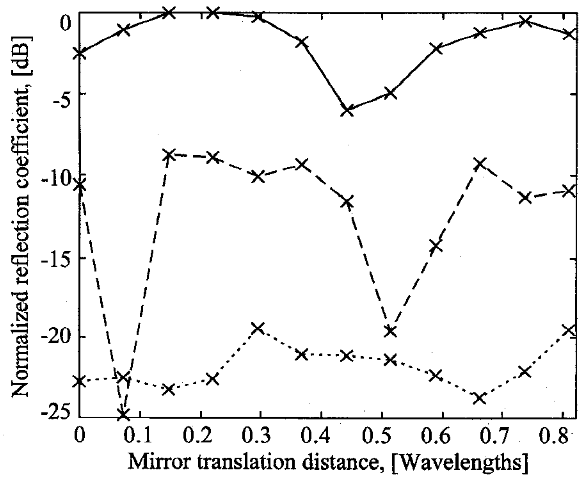

Fig. 3. Measurement of the quasi-optical isolator at 8.83 GHz, normalized to the reflection from a metallic mirror as the mirror is translated. Co-polarized reflected signal (dashed line), cross-polarized signal (dotted line), and co-polarized signal with mirror only (solid line) are plotted.

reflected signal when the isolator is replaced by a mirror, are plotted in Fig. 3. At 8.83 GHz, the co- and cross-polarized isolation for the maximum reflected signal are 9 and 19 dB, respectively.

IV. Conclusion

This is the first demonstration of a nonferrite quasi-optical isolator. The X-band isolator consists of cascaded printed gratings loaded with lumped resistors and capacitors. The isolator exhibits low insertion loss and good isolation. Such a component is useful for stabilizing and protecting linearly polarized quasi-optical amplifiers, while simultaneously providing circular polarization.

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