Wideband Leakage Cancellation Network for Monostatic Continuous-Wave Radars

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***Abstract*—For a monostatic stepped-frequency continuous-wave (SFCW) radar operating from 2 GHz to 4 GHz, a wideband passive leakage cancellation network using two circulators and a wideband 180-degree power combiner has been developed. Two similar circulators are utilized to provide two identical leakage signals and then leakage is canceled when both leakage signals are combined by a 180-degree power combiner. The wideband 180-degree power combiner has been implemented using parallel-strip lines. This proposed leakage canceller provides more than 33 dB cancellation over 2 GHz bandwidth, has 27.7 dB cancellation depth, does not require exhaustive adjustments, and is suitable for monostatic radar operation. The successful real-time monitoring of the subject using this monostatic radar indicates that the proposed leakage canceller can be utilized in a monostatic CW radar with a wideband antenna.**

I. Introduction

For compact radars, monostatic architectures are preferred. However, isolation between the transmitter and receiver is a concern, since a relatively low leakage from transmitter to receiver can cause significant interference and dominates the very weak (low-power) signal reflected back from the target.

For UWB impulse radars, monostatic configuration have been developed using high isolation switches. While, for CW, FMCW, or SFCW radars, circulators or couplers are used. However, it is a major challenge to achieve high isolation from transmitter to receiver over a wide frequency range.

There have been several passive leakage cancellation networks for monostatic CW radars [1], [2]. These leakage cancelers however have been designed for narrowband systems. Alternatively, [3], [4] presented monostatic transceivers using relatively high isolation couplers. In [3], for example, a variable gain block amplifier and a variable phase shifter have been used and needed calibration. In [4] a wideband coupler has been designed and led to high insertion loss (> 6 dB). Other methods require use of active elements and complicated calibration methods.

In this paper, we demonstrate a novel passive leakage cancellation network for a wideband monostatic SFCW radar which is easy to implement. The operating bandwidth of the radar system is 2 GHz (from 2 GHz to 4 GHz) and provides adequate isolation between transmitter and receiver, greater than 33 dB over the radar bandwidth.

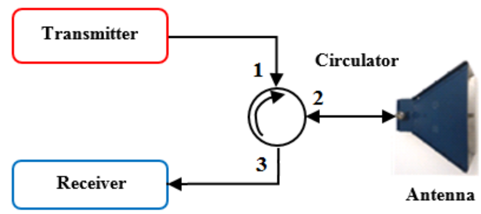

Fig. 1. Block diagram of monostatic radar using circulator.

II. Leakage Cancellation Network

A. *Structure of The Leakage Cancellation Network*

The proposed leakage cancellation network is comprised of two similar circulators (RFLC-301-4S) with relatively poor isolations (18 dB) over 2 GHz, a wideband equal power splitter, a wideband 180-degree phase shifter, and a wideband in-phase equal power combiner as shown in Fig. 2. The transmitted signal from transmitter (Tx) is divided equally using a wideband power splitter (W1). Half of the signal goes through a wideband circulator (C1), and then the forward signal goes to the antenna (Ant.), while the leaked signal is fed to one input of a wideband in-phase combiner (W2). The other half goes through the second circulator (C2), and the leaked part goes through a phase block convertor/ 180-degree phase shifter (PS) and is fed to the second input of W2. Both leakages travel through identical routes. It is anticipated that we have high cancellation over a wide frequency range, and the desired received signal from the antenna will go through C1 in a clockwise direction followed by W2 to the receiver (Rx).

Practically, it is very challenging to design a wideband phase block convertor over a 2 GHz bandwidth, and maintain the amplitude of the two leakage signals equal due to the fact that one of them goes through the phase convertor and suffers from extra loss. Hence, amplitude adjustment would be needed which could make the system very complicated.

To overcome these two problems, we integrated 180-degree phase convertor and equal power divider by designing a wideband equal power combiner with 180° phase difference between its two input ports using parallel-strip transmission lines.

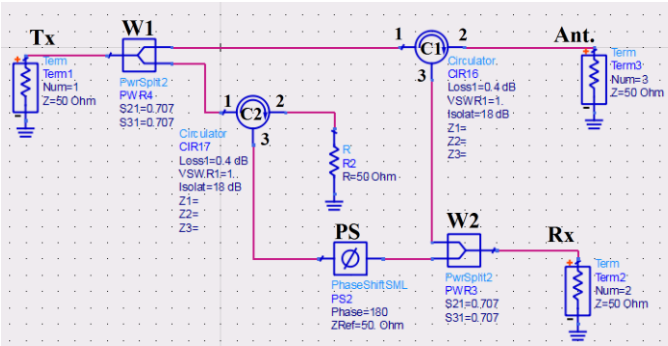

Fig. 2. Architecture of the leakage cancellation network working from 2 GHz to 4 GHz.

B. *Wideband 180-Degree Equal Power Combiner*

Fig. 3 shows the wideband equal power combiner with 180° phase difference between ports 2 and 3. The concept of designing this component is to use parallel-strip transmission lines instead of microstrip lines [5]. In Parallel-strip lines, a substrate is sandwiched between two strip conductor lines and therefore, the signals flowing on the upper and lower lines always have equal magnitudes but are 180° out-of-phase. With this approach, we can obtain a frequency-independent 180° differential phase between ports 2 and 3. This is achieved by step transitioning the parallel-strip lines to microstrip lines while connecting the inner conductor of SMA connectors to the lower line in port 2 and to the upper line in port 3 as shown in Fig. 3. Measured results show 180° ± 2° phase difference between output ports. To make the combiner wideband we used a two-stage Wilkinson with a center frequency of 3 GHz.

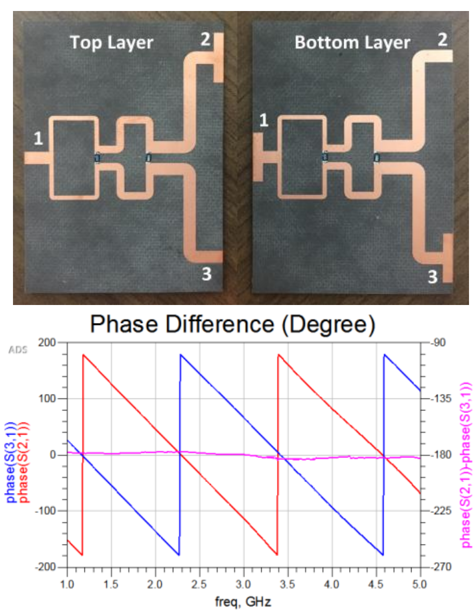

Fig. 3. The wideband 180-degree equal power combiner using parallel-strip lines (top layer (left) and bottom layer (right)), and phase response measurements.

III. Measurement Results

All components in the designed leakage cancellation network were assembled, and the measured isolation from the transmitter to the receiver is shown in Fig. 4, while the insertion loss from the antenna to the receiver is less than 4.05 dB over the entire bandwidth. The results demonstrate that this cancellation network reduces the leakage signal by more than 33 dB through the whole 2 GHz operating bandwidth, while it passes the received backscattered signal from the target to the receiver. Thus this network provides a full duplex operation over a wide frequency range.

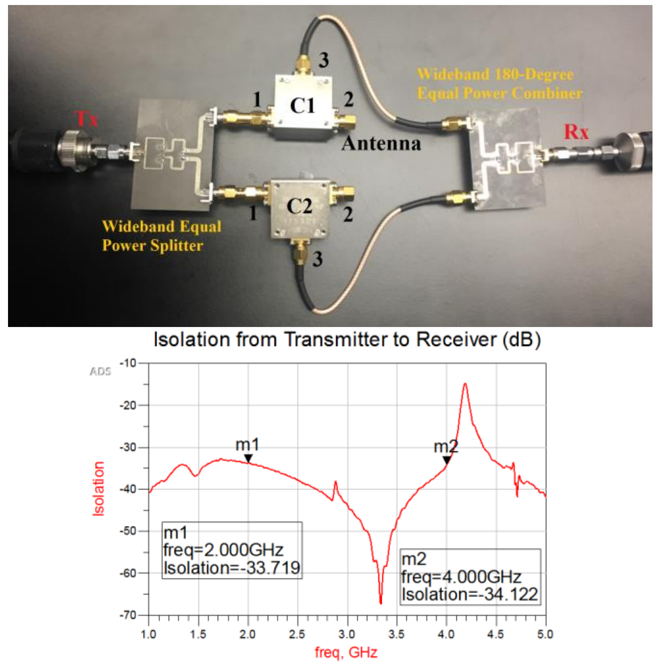

Fig. 4. The leakage cancellation network; measuring the isolation from the transmitter to the receiver.

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