Reduced Coupling for Through Wall Radars Using Orthogonal Circular Polarized Antennas

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***Abstract*—In this work, we propose using orthogonal circularly polarized quadrifilar helical antennas for the transmitter and receiver of a through-wall radar system. The objective of this configuration is to achieve low coupling between the transmitter and receiver antennas. The quadrifilar helix antennas were chosen because of their high gain, wide bandwidth and compact size. Experimental validations have been performed in line-of-sight conditions with and without a target.**

I. Introduction

Through-the-wall radars (TWR) have been researched and developed over the last two decades for law enforcement, security and biomedical applications for tracking humans in urban environments. These systems typically require antennas that support wide bandwidths - for obtaining good range resolution - wide field-of-views and compact sizes to enable portability [1]. The choice of the carrier frequency, for TWR systems, is dictated by the trade-off between the attenuation of the radar signal through walls and the desired resolution (in range, Doppler or direction-of-arrival). Several antennas have been investigated for TWR systems such as the Vivaldi antennas proposed by [2], [3]. These antennas are simple to fabricate, have high gain, wide bandwidth and low side lobes. Alternately, rectangular patch, bow tie, log periodic array, ridge horn antennas have also been investigated. All of these antennas support linear polarization of the electromagnetic waves. One of the challenges, however, with using linearly polarized antennas is the high coupling between the transmitter and receiver elements especially in bistatic scenarios. In TWR systems, the signal reflected off the target is often very weak at the receiver - when compared to the direct signal from the transmitter - due to the attenuation introduced by building walls during the two-way wave propagation between the radar and target. The objective of this work is to demonstrate a method to reduce the direct coupling between the transmitter and receiver by using orthogonal circularly polarized antennas. The first bounce reflection off the target undergoes a polarization reversal (in the case of circular polarization) and hence is picked up by the receiver. We hypothesize that the proposed antenna configuration will enable the detection of the weak targets despite the strong signal from the transmitter.

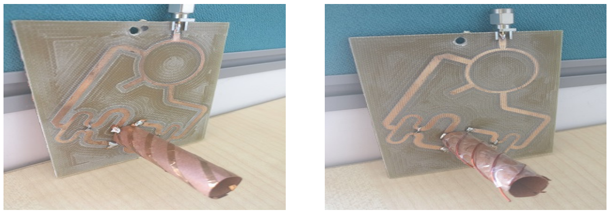
One of the most commonly used circularly polarized antennas is the helix antenna. It is easy to fabricate and has a high bandwidth and gain. In this work, we realize circular polarization using the quadrifilar helix antenna (QHA), a compact alternative to the conventional helical antenna [4]. The QHA consists of four helical windings over a common core. The wires are fed by a quadrature feeding structure. The transmitter and receiver antennas are designed so as to have opposite polarization in order to minimized the direct coupling between them. The sense of the polarization is determined by the direction of the winding. Experimental validation of the coupling is carried out in line-of-sight conditions both in the presence and absence of a planar target. The paper is organized as follows. In the following section, we discuss the design principles of the system. In section III, we present the measurement results and conclude in section IV.

II. System Design and Implementation

Two types of QHA were developed as shown in Figure.1. The printed quadrifilar helix antenna (PQHA) is used as the transmitter due to its large field-of-view while the wire wound QHA is used as the receiver [4]. We consider two types of PQHA - one of left hand circular polarization (LHCP) and the other of right hand circular polarization (RHCP). The wire wound QHA is designed to be LHCP. Both the QHAs are fed by a quadrature feeding network to provide constant magnitude and progressive 90° phase shift to each of the four helical windings. A custom feeding network has been proposed in this work as shown in Figure.2(a). The feed network consists of a rat race coupler to obtain a 180° hybrid followed by a Wilkinson power divider for an additional 90° phase shift. The four feeds collectively provide phase shifts of 10°, 94°, 157° and 273° to the signals at 3.4 GHz as shown in Figure.2(b). The feeding circuit is designed upon an FR4 substrate. The S_{11} plots measured in vector network analyzer (VNA) for the transmitter and the receiver antennas are shown in Figure.3. Both the antennas radiate at approximately 3.4 GHz having wide bandwidths of approximately 600 MHz.

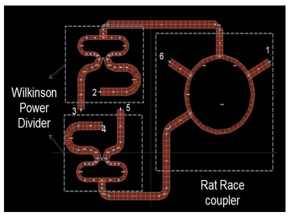
III. Results

In order to study the coupling between the transmitter and receiver antennas, we mount them on stands as shown in Figure.4. and perform indoor line-of-sight S_{21} measurements using a two port vector network analyzer (VNA). The first

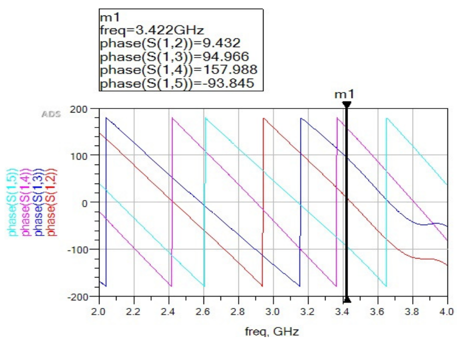


(a) (b)

Fig. 1. Quadrifilar helix antennas (a) printed (transmitter) (b) Wire wound (receiver)



(a)



(b)

Fig. 2. (a) Quadrature feed network for QHA (b) Phase plot from feed network

port of the VNA is connected to the transmitter PQHA while the second port is connected to the receiver antenna. In our experimental study, we consider four cases. In the first case, we consider the transmitter and receiver, of opposite polarization (RHCP and LHCP respectively), placed $0.15m$ apart, in the absence of a target. For comparison's sake, we consider a second case, where the transmitter antenna is of an identical polarization to the receiver. The results, presented in Table.I, show that the direct coupling between the transmitter and receiver when they are of the same polarization is approximately $8dB$ greater than when the antennas are of opposite polarization. Next, the S_{21} measurements are made in the presence of a square metallic target of $1m^2$ cross-sectional area. The target is placed in the far-field of the radar. Our measurements show that the S_{21} for the case when antennas of opposite polarization are used is $15dB$ greater than when compared to the case when antennas of same polarization are deployed. This is because when the planar target is introduced, the radar signal undergoes a polarization reversal off the first bounce reflection. Naturally, this advantage would be lost if we considered other types of targets such as dihedral corner reflectors where the signal will undergo even number

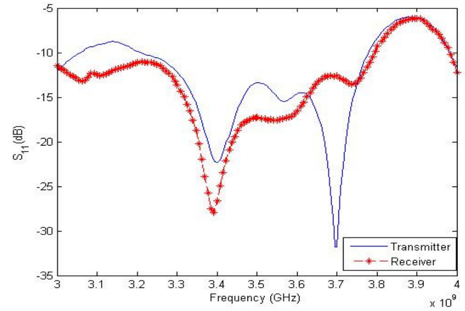


Fig. 3. S_{11} Plots for the printed (transmitter) and wire wound (receiver) quadrifilar helical antennas

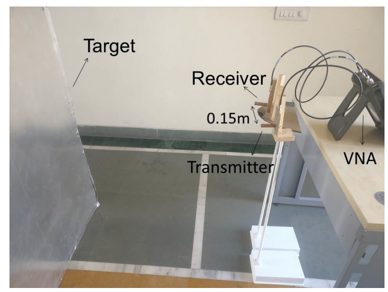


Fig. 4. Experimental set up

of reflections.

TABLE I
S_{21} VALUES AT 3.4 GHZ

Without Target	
	Rx (LHCP)
Tx (RHCP)	-62.78
Tx (LHCP)	-55.95
With Target	
Tx (RHCP)	-51.52
Tx (LHCP)	-67.62

IV. CONCLUSION

From the measurement results, we demonstrate that when orthogonal circular polarized antennas are used as transmitter and receiver, the direct coupling between the antennas is reduced while the reflected signal off a planar target is picked up. Such a configuration would be especially useful for bistatic through-wall radar systems.

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