AGILE CIRCULAR POLARIZATION RECEIVER USING IF PHASE INVERSION SWITCHING

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We present a receiver configuration which is able to distinguish between right hand and left hand circular polarization senses. The circuit discriminates between the polarization senses by switching between low-side and high-side LO injection when mixing down to IF. The prototype receiver shows 20 dB cross-pol rejection with 12 dB conversion loss.

1. Introduction

The main parameters needed to evaluate an antenna's performance include radiation pattern, gain, impedance, and polarization. Polarization describes the vector nature of the radiated electric field. If the electric field vector oscillates along a line, it is called linear polarization. Whereas, the field is said to be circularly polarized if the electric field vector has constant amplitude and rotates around a circular path. Often times, circularly polarized antennas are used in satellite communication to combat Faraday rotation, which is experienced by electromagnetic waves propagating through the ionosphere. Linearly polarized waves will experience random rotation, while circularly polarized waves are immune to this effect. Another benefit is that loss in power reception is independent of the relative tilt mismatch between receive and transmit antennas. On the other hand, if linear polarization is used, receive and transmit antennas should be aligned for maximum power reception.

There are two rotation senses of circular polarization; right hand circular polarized (RHCP) and left hand circular polarized (LHCP). They can be described in an instantaneous form as:

(eq. 1a) RHCP:

$$E = \hat{a}_x \frac{E_o}{\sqrt{2}} \cos(\omega t + kz - \frac{\pi}{2}) + \hat{a}_y \frac{E_o}{\sqrt{2}} \cos(\omega t + kz)$$

(eq. 1b) LHCP:

$$E = \hat{a}_x \frac{E_o}{\sqrt{2}} \cos(\omega t + kz) + \hat{a}_y \frac{E_o}{\sqrt{2}} \cos(\omega t + kz - \frac{\pi}{2})$$

Often times circularly polarized receivers with RHCP/LHCP polarization selectivity, use ferrite polarizers or a 90 degree hybrid coupler and a set of switches [1,2]. A receiver relying on these techniques incurs the disadvantages of added size and weight, increased DC power consumption and switch insertion loss.

In this paper a circularly polarized receiver with polarization selectivity is presented. The receiver's polarization state is toggled from RHCP to LHCP by changing a mixer pair's LO frequency. The receiver selectivity is achieved using the phase inversion effect of switching between high-side injected LO and low-side injected LO mixing [3].

2. Circuit overview

Fig. 1 shows the schematic of the downconversion polarizer. The input signal is fed into the two broadband mixers through a square patch antenna. The IF output of the mixers are then routed into two inputs of a 90 degree hybrid combiner. LO power is supplied in-phase to both mixers using a power divider.

The received circularly polarized signal can be decomposed into two orthogonal linearly polarized waves having a 90 degree relative phase shift, as explained by equation 1. For the RHCP case the RF signal at input I1 leads the RF input at I2 by 90 degrees and similarly, for LHCP I2 leads I1 by 90 degrees. The two LO frequencies, f_{LO1} and f_{LO2} are chosen such that the IF frequency remains constant for both LO frequencies, i.e., $f_{RF} - f_{LO1} = f_{LO2} - f_{RF}$, where $f_{LO1} < f_{LO2}$. When f_{LO2} is applied the phase order of the received RF signal is reversed in the IF signal, by the process of phase conjugation. Phase conjugation simply comes about when the IF signal is the subtraction of the RF signal from the reference LO signal. Phase is subtracted as well as frequency. Therefore, by using this process, the same output port of the hybrid combiner can be used to obtain the combined output of either a RHCP or LHCP signal by changing the LO frequency while the IF frequency is kept the same.

The circuit was fabricated on RT/duroid substrate with 25 mil thickness and $\varepsilon_r = 10.2$ as shown in Fig. 2. The square patch antenna was optimized to have 50Ω input impedance at 5.77 GHz. The pair of Schottky diode mixers consists of RF bandpass filters and lumped element L-C low pass filters to collect the 980 MHz IF signal at the 90 degree hybrid coupler (Anaren). A short circuit stub was used for conversion loss optimization as well as to provide a DC path for the diode. The LO power is fed to both mixers using a Wilkinson power divider. The combined signal output is taken from one of the coupler outputs on the backside of the circuit board, while the other output port is terminated with a 50Ω load.

3. Measurements

3.1. Mixer measurements

The polarization selective mixer was first tested without the antenna by using an external 90 degree coupler to feed the RF signal to the mixer pair. Input test conditions for RHCP and LHCP can be implemented by alternating the feed port of the coupler. For example, to imitate RHCP the circuit is fed such that I1 leads the RF input at I2 by 90 degrees and similarly LHCP is realized when I2 leads I1 by 90 degrees. Fig. 3 shows the mixer pair conversion loss for different input conditions (R/LHCP) and different LO frequency states. When the input was set to imitate an incoming RHCP signal from 5.72 - 5.8 GHz the conversion loss varies from 15 – 12 dB. The LO power was set to 8 dBm at a frequency of 4.79 GHz. Since the signal is first being split and then combined at IF the conversion loss of a single mixer with the same LO frequency has similar conversion loss performance. To switch the circuit into a LHCP input combiner, the LO was switched to 6.75 GHz. The conversion loss varies from 16 – 13 dB over the 80 MHz bandwidth. This result also follows the conversion loss characteristics of the single mixer with LO set at 6.75 GHz.

Fig. 4 shows the isolation between the two polarization senses that the receiver provides. When the LO is set to 4.79 GHz the circuit rejects a LHCP input and is sensitive to RHCP inputs. The peak isolation of 24 dB at 5.77 GHz is measured. In the other state where the LO is set to 6.75 GHz, the circuit rejects RHCP inputs with a peak isolation of 22 dB at 5.775 GHz. Isolation is better than 10 dB from 5.72 – 5.8 GHz for both polarization senses.

3.2. R/LHCP radiation pattern measurements

The radiation patterns of the fabricated receiver directly connected with an orthogonally fed square patch antenna was measured in an anechoic chamber. A circular polarized wave was transmitted using a dual linear horn antenna fed accordingly with a 90 degree coupler at 5.77 GHz. Fig. 5 shows the measurement when RHCP is transmitted. When the LO frequency is set to 4.79 GHz the receiver becomes a RHCP receiver. The radiation pattern compares well with a standard RHCP dual feed patch antenna. When the LO is changed to 6.75 GHz the receiver rejection level is 12 dB compared to the maximum received power in the previous mode. The transmission of a LHCP signal is shown in Fig. 6. Again, the pattern resembles that of a standard circularly polarized patch antenna. The rejection level was measured to be 11 dB. It should be noted that the rejection level is not only dependent on the receiver circuit but also the antenna itself.

4. Conclusions

This paper has presented an alternative technique to design polarization selective receivers. It relies on switching of LO frequency feeding the mixer pair. Low noise amplifiers can be added at the input of the circuit to implement a more functional low noise receiver circuit.

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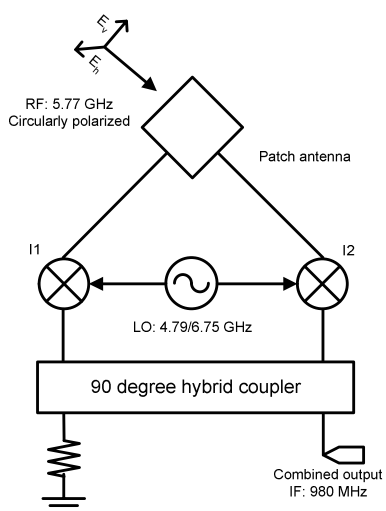

Fig. 1. Schematic of polarization switching receiver.

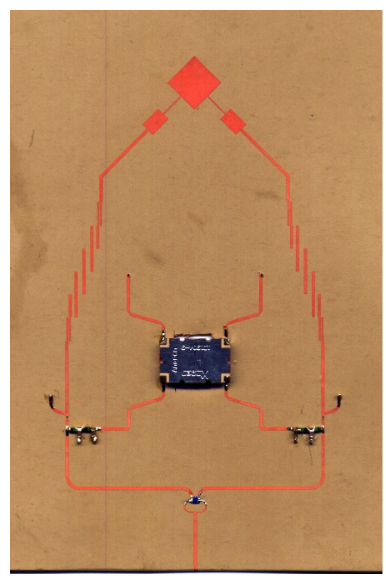

Fig. 2. Fabricated polarization switching receiver.

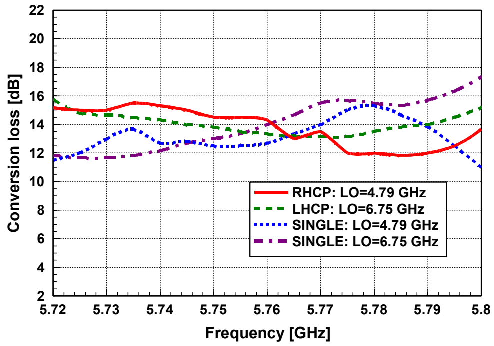

Fig. 3. Mixer conversion loss.

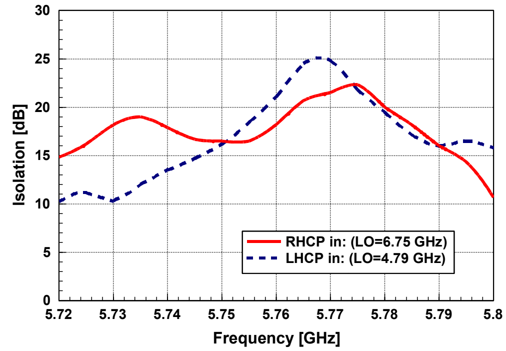

Fig. 4. Circuit polarization isolation.

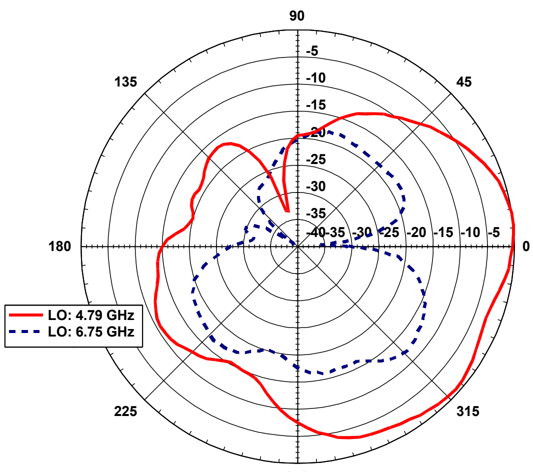

Fig. 5. Transmit RHCP at 5.77 GHz

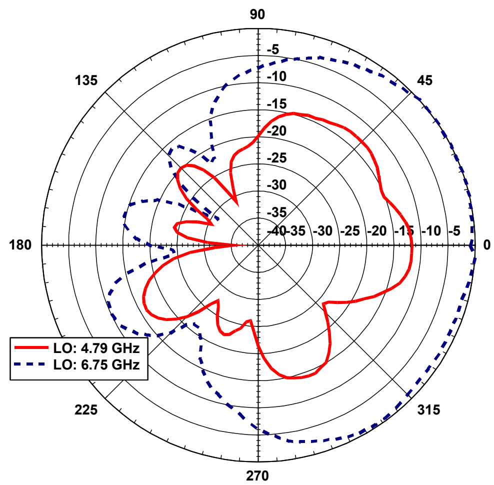

Fig. 6. Transmit LHCP at 5.77 GHz.