IF-Based Polarimetric Receivers

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***Abstract*—A low-cost low-power polarimetric receiver has been developed based on the idea of IF processing. This architecture allows accurate measurement of the incident wave polarization and greatly reduces the cost and size of the receiver. An X-band polarimetric receiver with a dual-polarized microstrip antenna has been designed and tested. The results show a maximum ±5° polarization error using low-cost IF components and demonstrate the feasibility of performing inexpensive polarimetric processing at IF frequencies.**

***Index Terms*— Dual-polarized antenna, IF processor, polarimetric receiver.**

I. Introduction

POLARIMETRIC radars from L-band to W-band are widely used for remote-sensing, tracking, and target discrimination applications [1]. Current polarimetric radars use a dual-polarized antenna (microstrip or waveguide type) connected to a set of local area networks (LAN's), variable attenuators, and phase shifters as shown in Fig. 1(a). The processed H (horizontal polarization) and V (vertical polarization) signals are summed to give a particular polarization state depending on the setting of the variable attenuators and phase shifters. Since the RF polarimetric circuits are expensive, multiple polarization states are not formed simultaneously. This is not acceptable for applications in which a quick measurement of multiple polarizations is required, such as smart munition seekers or advanced automotive radars.

In order to provide low-power multiple polarimetric measurements, the system shown in Fig. 1(b) is proposed as a means of forming many polarization states at the IF frequency. The advantage of this system is that low-cost low-power silicon-based IF circuits can be used to perform most of the processing, and many different polarization states can be formed simultaneously. This architecture also allows the IF frequency, used to perform the polarimetric processing, to be independent of the RF frequency. Thus, the same IF polarimetric processor can be used with different RF front-ends. The disadvantage with this system is the larger fractional bandwidth that the received signal has at IF frequencies compared to RF frequencies. However, it is possible to build an IF network that yields an accurate polarization measurement for a fractional bandwidth of 20%. Since current radars have a bandwidth of 50 to 250 MHz, it is seen that an IF network centered at 2 GHz can process a 400-MHz bandwidth signal.

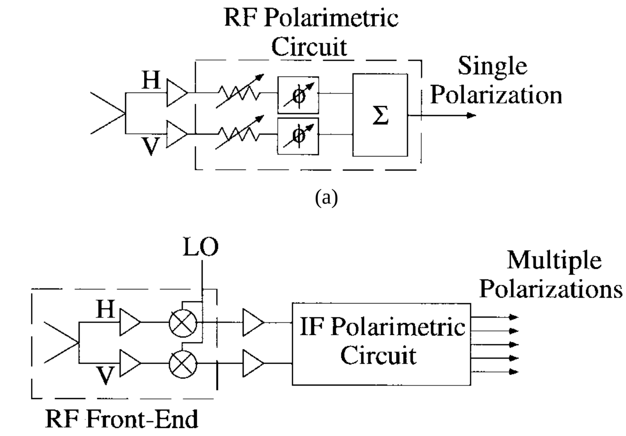

Fig. 1. Architecture of (a) current polarimetric systems and (b) proposed IF-based polarimetric system.

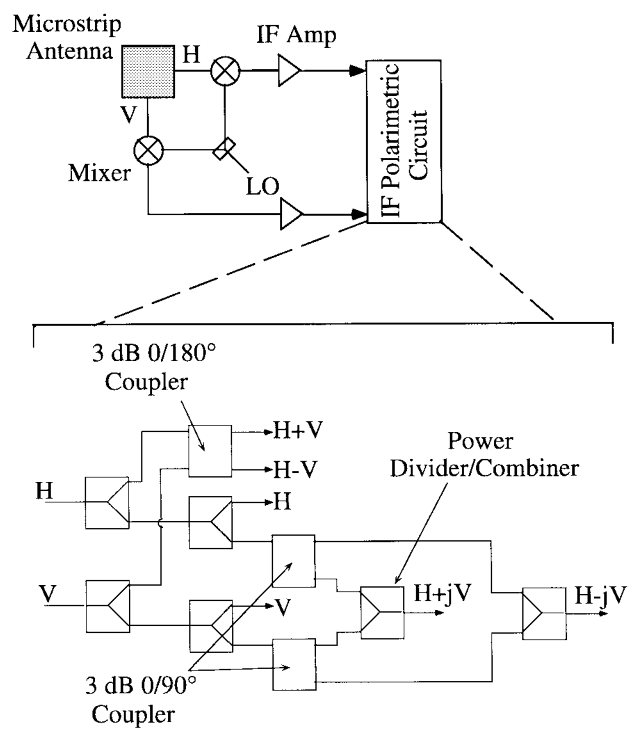

Fig. 2. Schematic of the passive IF polarimetric receiver.

II. Experiment

The polarimetric receiver is composed of a 9.8-GHz dual-polarized microstrip antenna, fabricated on a 0.51-mm-thick

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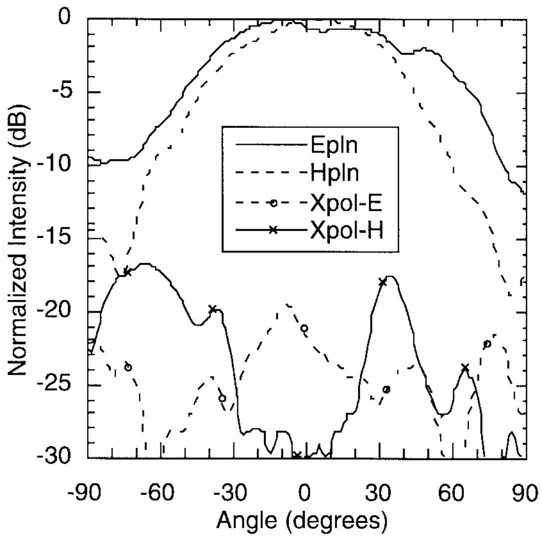
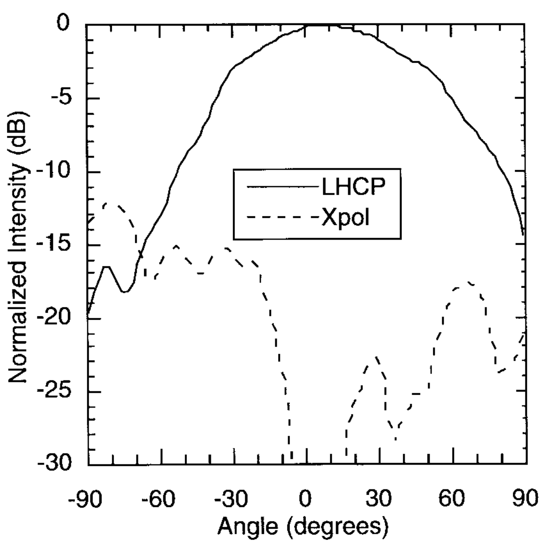


(a)



(b)

Fig. 3. Response of polarimetric receiver for (a) horizontally polarized wave and (b) left-hand circularly polarized wave.

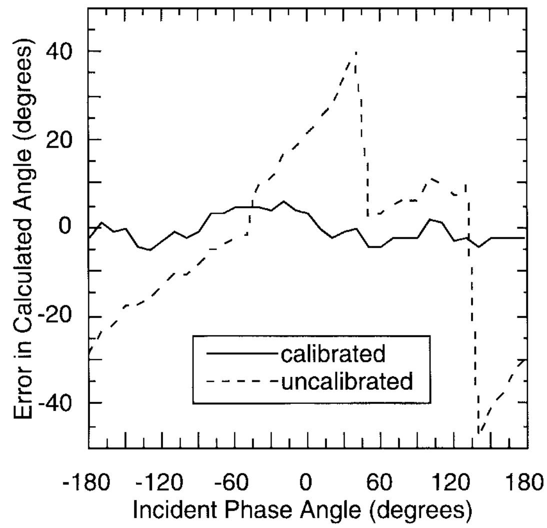


Fig. 4. Measured phase error for X-band receiver.

$\epsilon_r = 2.2$ Duroid substrate,[1] followed by two balanced mixers with a measured SSB conversion loss of 6 dB. The mixers are fed with an local oscillator (LO) frequency of 9.6 GHz, resulting in an IF frequency of 200 MHz. All of the IF couplers, amplifiers, and switches used for the IF circuitry are low-cost components purchased from Mini-Circuits.[2] The IF polarimetric processor can be completely integrated on silicon, including all necessary amplifiers and switches up to 1–2 GHz [2]. This will reduce the cost even further and also increase the available bandwidth of the system.

The IF polarimetric circuit that has been tested is shown in Fig. 2. It is based on the concept of a six-port junction in which the relative phase and amplitude between the two input signals can be determined from four different amplitude measurements [3]. In this case, six different measurements have been used in order to decrease the error in the polarization measurement.

To verify the operation of the polarimetric receiver, two tests are performed. The first measures various antenna patterns where the measurements are taken from the output ports of the IF polarimetric circuit. The second test transmits many different polarizations and measures the error in the incident polarization calculated from the amplitude measurements taken at the IF output ports. For both of these tests, an X-band quad-ridged horn is used as the transmitting antenna. The transmitted polarization is set by adjusting low-loss coaxial line stretchers placed in the feed-lines of the quad-ridged horn. The coaxial line stretcher physically changes the length of the line and is therefore equivalent to a monolitihc microwave integrated circuit (MMIC) phase shifter in the sense that it adjusts the phase of the signal.

III. Results

The received patterns for a horizontally polarized transmitted wave and a left-hand circularly polarized transmitted wave measured at the IF ports are shown in Fig. 3(a) and (b), respectively. The measured patterns show the typical traits of a microstrip antenna. For the linearly polarized wave the E-plane pattern falls to −10 dB at 90°, and the H-plane pattern is −15 dB at 90°. The cross-polarization for the microstrip antenna was measured to be −23 dB, and so the increased cross-polarization seen here is due to the presence of the RF and IF circuitry around the antenna. For the circularly polarized wave, the cross-pol. increases significantly near ±90° (as expected) due to the difference between the E- and H-plane patterns.

To obtain accurate polarization measurements, the system is calibrated to eliminate phase and amplitude imbalances in the IF couplers. The calibration is performed by transmitting six different known polarizations and then calculating the necessary calibration coefficients from the measured response. Fig. 4 shows the results of the calibrated and uncalibrated measurements. As can be seen, the calibrated system works well and gives a ±5° error in the measured polarization at

[1] Rogers Corp., 100 S. Roosevelt Ave., Chandler, AZ 85226 USA.

[2] Mini-Circuits, P.O. Box 350166, Brooklyn, NY 11235-0003 USA.

the IF ports. This error is limited by the accuracy of the transmitting system. The jumps in the uncalibrated curve are due to using different output ports of the IF polarization circuit to find the incident polarization.

IV. Conclusion

The idea of using IF based polarimetry for applications in which a quick polarization measurement is needed while maintaining low power consumption has been proposed. The advantage of this architecture is that low-cost low-power silicon-based IF circuits can be used to implement the polarimetric processing. Bandwidth should not be a problem since the IF circuits can be designed to operate at 1–2 GHz. This idea has been successfully demonstrated with an X-band system, and can be implemented with any RF frequency.

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