An Active Integrated Retrodirective Transponder for Remote Information Retrieval

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Abstract

A novel retrodirective transponder is introduced, with potential application in high performance digital communications. Active circuitry is integrated for phase conjugation, giving conversion gain in addition to phase conjugating operation, therefore enabling retrodirectivity. Applying a modulated LO signal, the array can send local information directly back to the base station on demand.

Introduction

A retrodirective array has the unique property that it will send a received signal back to the incoming source without any prior knowledge of its location. This interesting characteristic allows retrodirective arrays to be efficiently used in various communication areas, where high efficiency links are a necessity [1]. One common technique to achieve the retrodirectivity is phase conjugation, which uses microwave mixers [2-4]. The phase conjugation of a RF signal can easily be obtained with heterodyne mixing by applying a LO at twice the frequency of RF, the resulting IF will have the same frequency as the RF, but with conjugate phase. This technique has several advantages. First, it is simple to apply modulation to the signal as it is re-radiated signal. Secondly, signal can be amplified as it is re-transmitted from the array by using active devices as the mixers [5]. Therefore, phase conjugation is one of the most practical and effective methods for achieving retrodirective performance.

In this paper, a novel retrodirective array is introduced, which can be used for high performance digital communication systems. Compact active circuitry is directly integrated for phase conjugation with the added benefit of providing conversion gain in addition to phase conjugating operation. If modulated LO signal is applied, the array will send local information back to the base station on demand. This retrodirective array can therefore be used for remote information retrieval.

Retrodirective RF Tag

The basic idea of the system is shown in Fig. 1. The base station sends a 5.99 GHz signal. A RF tag modulates it with a local information signal and sends the information with the carrier back to the base station by using a retrodirective array.

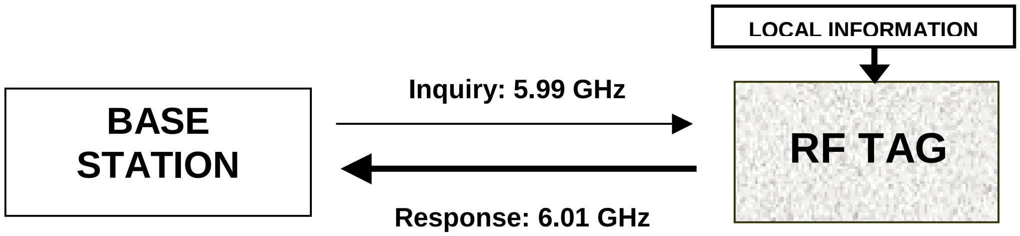

Figure 1 Block diagram of the RF tag system

Figure 2. shows a phase conjugating element of the transponder [6]. The circuit contains two ports, one for the LO which is applied in phase to the two channels and the other port is shared by the incoming RF and outgoing IF. The channels are identical except for a 90° phase delay line at the RF frequency. This delay line causes cancellation of the returned RF signal at the RF/IF port for isolation. Since the LO frequency is twice that of the RF frequency, the LO from the two channels will experience a 180° delay when combined at the RF/IF port, providing good LO isolation. At the same time the IF should be combined in phase due to the phase conjugation. By applying a modulated LO, the information on the LO will be passed to the IF signal through the mixing process. The circuit achieves RF/IF isolation of 20 dB and conversion gain of 3.2 dB at the output port.

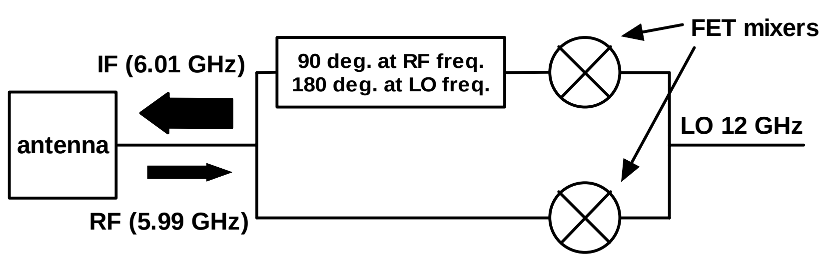

Figure 2 Schematic of the phase conjugating element

Figure 3. shows a 4-element prototype retrodirective array based on the phase conjugating modulator. The array uses 6GHz patch antennas with approximately 0.5λ spacing. The spacing is small enough to avoid grating lobes [4]. The bistatic radar cross section of a retrodirective array is given by the square of its element directivity. Thus, no nulls should be observed in the bistatic RCS pattern. This enables full broadside coverage from –90° to 90°. In this measurement, a LO signal is provided by an external microwave synthesizer.

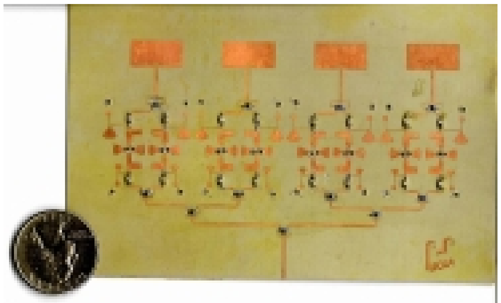

Figure 3 Photo of the 4-element retrodirective array

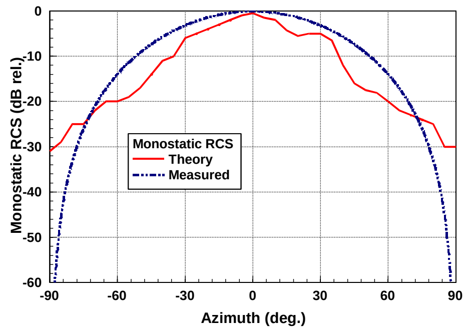

Figure 4 Monostatic RCS of the retrodirective array

Applying a LO with modulation, the transmitted signal is modulated and has certain bandwidth. It is needed to know the pointing error depending on the frequency shift. The beam squint due to the frequency shift is given by this equation

$$\frac{\sin\theta_i}{\sin\theta_s} = \frac{f_{LO} - f_i}{f_i} \quad (1)$$

where: θ_i : Incident angle θ_s : Scattering angle f_{LO} : LO frequency f_i : Incoming RF frequency

The beam squint effect was measured with a source at 30^o as shown in Fig. 5. The beam squint due to the modulation is negligible. The retrodirective array is also suitable for high bit data communications.

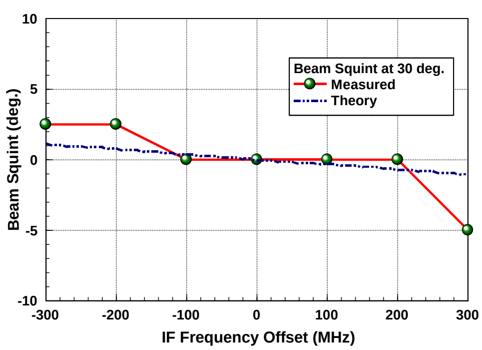

Figure 5 Beam squint effect due to a frequency change

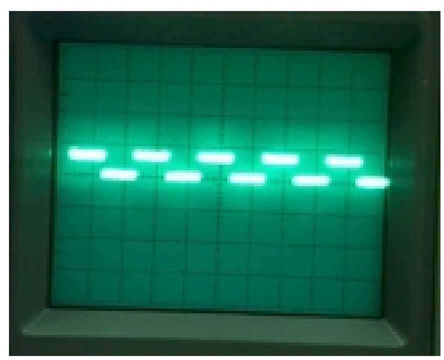

Figure 6 Recovered response from the transponder

Figure 6 shows the demodulated response waveform from the retrodirective array with a LO signal modulated with a simple 1KHz square wave. It was successfully recovered at the source location. By further improvement in modulation schemes, the system should also be useful in advanced applications requiring higher data rate, such as remote information retrieval-on-demand.

Conclusion

A novel retrodirective transponder was introduced. The active integrated circuitry provides conversion gain in addition to phase conjugation. Due to the retrodirectivity the transponder has full broadside coverage. The beam squint caused by the modulation was small enough to neglect. The active retrodirective transponder can also be used for high bit data communications.

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