Realization of Ultra-Wideband Bistatic Simultaneous Transmit and Receive Antenna System

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***Abstract*—An ultra-wideband bistatic simultaneous transmit and receive (STAR) antenna system utilizing miniaturized TEM horn arrays is proposed. The TX/RX arrays are fully recessed in a metallic cavity and flush-mounted on a ground plane to reduce the interaction with nearby objects and antennas. Isolation >49dB is measured over the desired bandwidth of operation. Different techniques to improve the isolation at low and mid bands are also discussed.**

Keywords — Cavity-backed antenna, STAR, system isolation, TEM horn array.

I. INTRODUCTION

The co-channel simultaneous transmit and receive (STAR) systems are of great interest for the next-generation wireless networks; since the STAR operation can double the data throughput while efficiently utilizing the available frequency spectrum [1]. The grand challenge to realize STAR systems is the required high isolation level between the co-located transmitter (TX) and receiver (RX) to avoid the self-interference. To achieve sufficient level of isolation, multiple layers of antenna, analog, and digital self-interference cancellation techniques are commonly considered [2]. If a significant portion of the cancellation process is performed at the antenna level the overall system complexity will be significantly reduced. A typical antenna self-cancellation approach relies on the use of multiple apertures (i.e. bistatic approach) where the TX/RX antennas are depolarized [1], or separated by multiple wavelengths [2], or arranged/excited in a specific way to cancel the near-field interaction [3]. However, the same TX/RX polarization is required for many STAR applications. Also, size constraint limits the antenna separation approach. Furthermore, a simple system with minimum number of antenna elements and low-complexity beamforming network is typically desired. Thus, the design of high-isolation bistatic STAR system with specific radiation characteristics/physical constraints is challenging and special design procedures are necessary to achieve the required isolation level.

In this paper, a bistatic STAR system utilizes a miniaturized TEM horn array is designed and characterized computationally and experimentally. The TX and RX TEM horn arrays are fully recessed in a cavity to improve the isolation and reduce the interaction with any nearby antennas and objects. Controlled losses are used at TX/RX sides to improve the radiation performance of the cavity-backed arrays and system isolation. Isolation >49dB is obtained over 3.5:1 bandwidth from 2-7GHz while maintaining good TX/RX radiation characteristics.

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II. TEM HORN ARRAY DESIGN AND PERFORMANCE

The developed array is composed of two combined TEM horn and loop antennas. The combined TEM horn and loop antenna with the crescent slots, shown in Fig. 1(a), is designed using the spherical mode theory to combine the fundamental spherical TM and TE modes of the TEM horn and the loop, respectively in order to simultaneously tune the turn-on frequency and improve the gain at the low end [4]. The antenna dimensions are 2.26cm × 3.5cm × 3.5cm ($\sim\lambda_{2GHz}/6.6 \times \lambda_{2GHz}/4.3 \times \lambda_{2GHz}/4.3$). A 2.5cm-long balun is integrated to feed the parallel-plate transmission line at the input of the TEM horn as shown in Fig. 1(a). The center-to-center spacing between the array's elements is 2.5cm ($\sim\lambda_{7GHz}/1.7$). As discussed, the array is recessed in square cavities as shown in Fig. 1(b). The TX and RX cavities are loaded with ferrite beads and ECCOSORB® MCS absorber (magnetically-loaded silicone rubber material), respectively to reduce currents on the cavity walls and eliminate negative impact of cavity resonances. The total array size including the cavity is 7.2cm × 7.2cm × 6.3cm ($\sim\lambda_{2GHz}/2.1 \times \lambda_{2GHz}/2.1 \times \lambda_{2GHz}/2.4$).

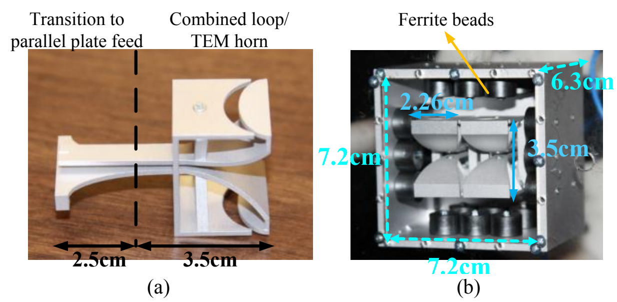

Fig. 1. (a) Geometry of the mintaturized TEM horn and (b) TX TEM horn array fully recessed inside a ferrite-loaded cavity.

The measured and simulated active VSWRs of the designed TX/RX arrays are shown in Fig. 2. As seen, VSWR<1.7 is measured over the designated bandwidth of operation for both arrays. Realized gain >3.8dBi (max. of 10dBi) is measured. Fig. 3 shows that the TX array has higher gain, thus the radiation efficiency over the band. The utilized cavity has a resonance (i.e. strong surface currents/standing waves on the cavity walls) around 4GHz. This explains the drop in the gain around that frequency which is due to the higher power loss at the ferrite/MCS absorber placed at the maximum currents location. High quality radiation patterns with low cross-pol levels and no side lobes are measured over the operating bandwidth as shown in the inset of Fig. 3.

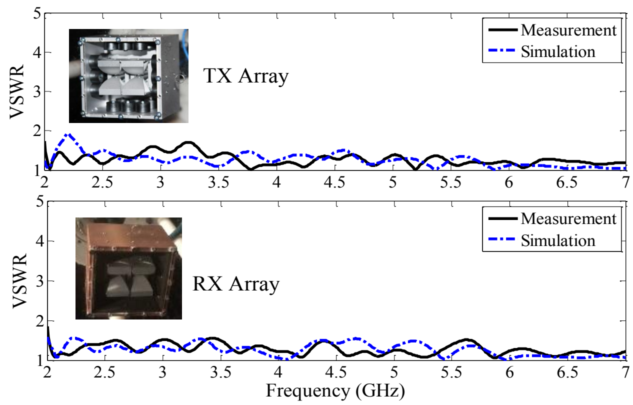

Fig. 2. Measured and simulated active VSWRs of the TX/RX Arrays shown in the inset.

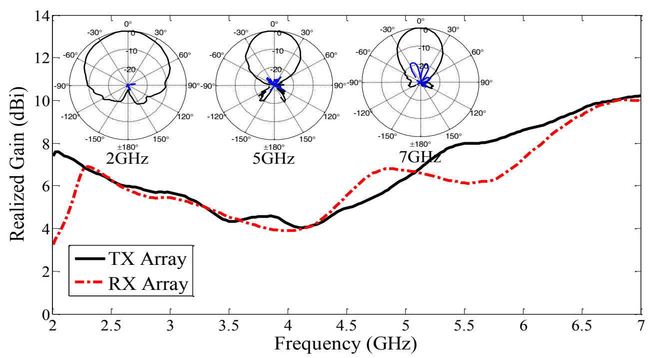

Fig. 3. Measured realized gain of TX/RX Arrays. H-plane TX radiation patterns are also shown in the inset at 2 GHz, 5GHz, and 7GHz.

III. System Isolation

The bistatic antenna system is realized by flush mounting the recessed arrays on a 25cm × 50cm ground plane as shown in the inset of Fig. 4. The center-to-center spacing between the TX and RX arrays is chosen to be 25cm. The TX/RX arrays are oriented in H-plane since the patterns have lower azimuthal gain and narrower beams in this cut. The measured and simulated isolation of the proposed system is shown in Fig. 4. As seen, isolation>49dB (>60dB starting from 4GHz) is measured over the operating bandwidth. Good agreement is obtained between the measured and simulated results. At the low end, the antennas are coupled through radiation. As the frequency increases, the beamwidth and the gain in the direction of the RX antenna decrease, path loss increases and the coupling is predominately through the surface currents and edges diffractions. Thus using approaches such as absorptive paint, edge rolling, and corrugation to suppress the surface currents/diffraction only improves the isolation at the mid and high bands. Analyzing the transmission coefficients of the TX/RX system shows that the TX array elements couple more to the outside RX element (see Fig. 5 for the element's location) at low frequencies. Using this element as dummy element terminated with a 50Ω load leads to 10dB improvement in system isolation over 22% of the bandwidth from 2.9GHz to 4GHz as demonstrated in Fig. 5. Another technique based on inserting a metallic wall or step between the TX/RX antennas, as shown in the inset of Fig. 5, can be combined with the dummy-element approach to further improve the isolation. Isolation >60dB is obtained over the designated bandwidth of operation by combining the two approaches. The inserted wall is 4cm-tall, 18cm-wide, and 1cm-thick. Isolation improves as the wall height/thickness increases at the expense of a beam squint and reduced broadside gain.

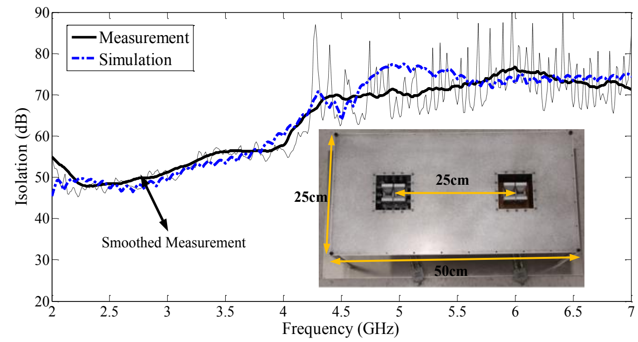

Fig. 4. Measured and simulated isolation of the proposed bistatic STAR system.

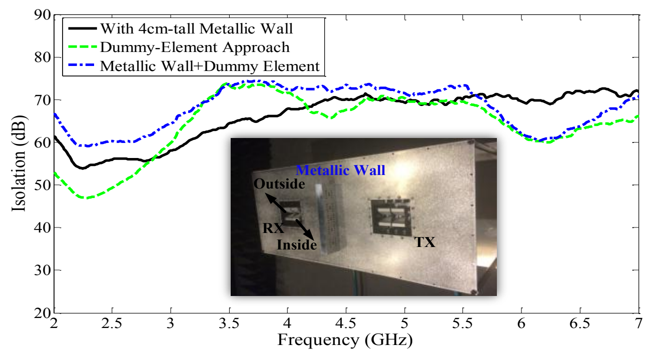

Fig. 5. Measured isolation of the proposed bistatic system with a metallic wall inserted as shown in the inset and with the dummy-element apporach.

IV. Conclusion

An ultra-wideband bistatic STAR antenna system is designed and characterized. The proposed system which utilizes TEM horn arrays recessed in loss-loaded cavity exhibits good radiation characteristics, high isolation, and flush mounting feature which is desired for variety of applications.

References

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