Simultaneous Transmit and Receive with Shared-Aperture Arrays

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***Abstract*—An approach based on shared aperture antenna array is researched for simultaneous transmit and receive (STAR) applications. The proposed configuration is a 10×10 antenna array of circularly-polarized (CP) elements with 50 elements, somewhat sparsely distributed, dedicated for Tx while the remaining elements dedicated for Rx. The high isolation is achieved between Tx and Rx elements at the expense of higher sidelobe levels, which is an inherent property of sparse antenna arrays. To demonstrate the performance of the proposed STAR configuration, numerical modelling is conducted using multilevel fast multipole method (MLFMM) solver in Altair FEKO.**

Keywords—Altair FEKO, dual-pol patch antenna, isolation, self-interference, sparse arrays, STAR.

I. INTRODUCTION

The demand-driven modern wireless RF systems are required to maintain high data transfer rates to meet the increasing need for greater bandwidth and larger data streams. Simultaneous transmit and receive (STAR) is an emerging technology that is capable of transmit and receive with a single RF carrier at the same frequency and time, hence doubling the capacity of wireless network. A major challenge with STAR systems is the strong in-band self-interference (SI) at the receiver(s). Depending on the TX power and bandwidth, a Tx/Rx isolation in order of 110–140 dB is required to cancel the detrimental SI [1]. Several recent studies have demonstrated that >50dB of isolation can be achieved at the aperture layer by re-routing the coupled TX signals away from the RX port in beamformer networks (BFN), near-field cancellation, and modes multiplexing to mention few [2]–[3]. However, most of these approaches are not feasible to large planar arrays due to the complexity of the required BFN. In this paper, a simple bistatic shared-aperture approach relying on uniformly distributing and separating the CP Tx/Rx elements within the array (Fig. 1 (a)) is used to realize a conventional STAR array. Redistribution of Tx/Rx elements of the topologically the same aperture (Fig. 1 (b)) is investigated then and utilized to enhance the system isolation. The unique combination of sparsely and symmetrically distributed Tx and Rx coupling coefficients results in better SI cancelation, hence providing high isolation values compared to the baseline case. By controlling the number of elements, their positions and relevant weights in amplitude and phase, it becomes possible to ensure adequate far-field and isolation performances at the aperture level.

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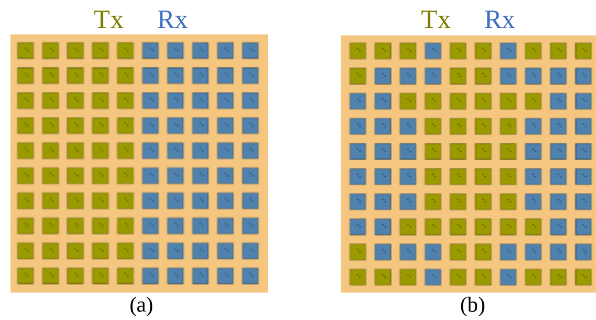

Fig. 1. Array architectures for STAR: (a) conventional bi-static array, and (b) proposed array topology.

To prove the concept, an air-loaded dual-pin-fed circularly polarized patch antenna is used because of its simple design and low computational demand. The 10×10 array consists of 50 elements each for Tx and Rx, distributed in the aperture as shown in Fig. 1. The STAR array is computationally studied using the commercial multilevel fast multipole method (MLFMM) solver in Altair FEKO. The performance of the proposed architecture is compared to that of uniform array.

II. ARRAY ELEMENT

The unit cell element used for the proposed study is a dual-polarized, single layer, air-loaded, dual-pin fed, patch with 90° phasing between the feeds to achieve circular polarization. MLFMM is used to solve the full 10×10 array. To make computational problem reasonable in memory and running time demands [4], the unit cell is designed on an air substrate. Unit cell dimensions are shown in Fig. 2 (a). For demonstration purposes, substrate height is chosen as 0.16mm. To avoid any grating lobes, unit cell size is set to be 0.75 λ (< λ). Unit element is modeled in infinite array setup by applying the 2-D periodic boundary conditions. Fig. 1 (c) shows the impedance match at the input ports in the broadside (i.e., no scan) case. The antenna has VSWR < 2.1 over 27.75–28.25 GHz bandwidth. Embedded element gain for broadside operation is 8.5 dBic and axial ratio is < 0.1 dB at 28 GHz.

III. ARRAY ARCHITECTURE AND PERFORMANCE

Full 10×10 antenna array antenna system is modeled in FEKO as shown in Fig. 1. For baseline (conventional) case, half of the elements are used as transmitting elements and the other half as receiving. The isolation between Tx/Rx in above antenna array system can be calculated using (1),

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$$\begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_{200} \end{bmatrix} = \begin{bmatrix} S_{1,1} & \cdots & S_{1,200} \\ \vdots & \ddots & \vdots \\ S_{N,1} & \cdots & S_{200,200} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_{200} \end{bmatrix}, \quad (1)$$

where $a_i = a_1, a_2, \ldots a_{200}$ are the input signals phased with $e^{i\cdot 0°}$ and $e^{i\cdot 90°}$ to form desired CP, $b_i = b_1, b_2, \ldots b_{200}$ are the output signals, and $[S]$ is the S-matrix of the proposed array. Total input power is normalized to 1 W. Total received power in Rx ports can be calculated using (2),

$$SI = \frac{1}{\sqrt{N}} \sum_{1}^{N} b_i \cdot C_i \cdot P_i, \quad (2)$$

where N is total number of elements, C_i is phasing factor for circular polarization ($C_i = e^{i\cdot 0°}$ when i is odd, $C_i = e^{i\cdot 90°}$ when i is even), and P_i indicates Tx/Rx elements ($0 = Tx, 1 = Rx$). To determine which elements should be used for Tx and Rx, a random-search is performed on P_i with the goal to minimize SI over the frequency band. Values chosen for P_i are constrained to ensure symmetry across principle planes to preserve beam symmetry and low axial ratio. Fig. 1 (b) shows the configuration that provides significant improvement in isolation over desired bandwidth. As seen in Fig. 3, isolation > 63 dB is obtained over the band with average isolation improvement of 20 dB compared to the baseline case. Co-pol Tx/Rx far-field patterns of the proposed array configuration is compared to the uniform array performance in Fig. 4. Cross-pol level remains > 30 dB below Co-pol. The peak directivity of both Tx and Rx beams in the proposed array configuration remains similar to the uniform array (25.53 dBic and 25.51 dBic, respectively). However, the side lobe level (SLL) increases particularly in the Rx case. Since the peak directivity remains the same as that of the uniform array, there is no degradation in the aperture efficiency of Tx and Rx. Reducing SLL in the proposed STAR array along with realizing a scan operation is currently being researched.

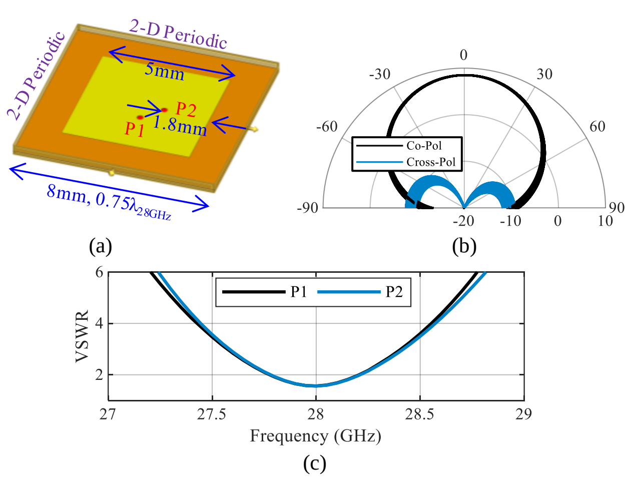

Fig. 2. Unit cell used in proposed array architecture. (a) Unit cell dimensions, (b) far-field radiation patterns, and (c) VSWRs at ports P1, P2.

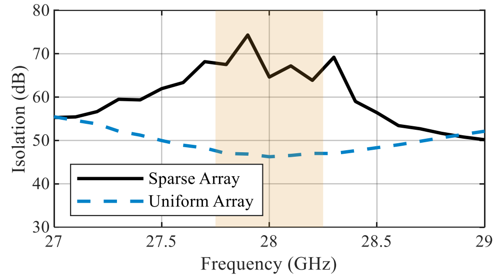

Fig. 3. Simulated isolation between Tx and Rx elements for uniform and proposed array configurations.

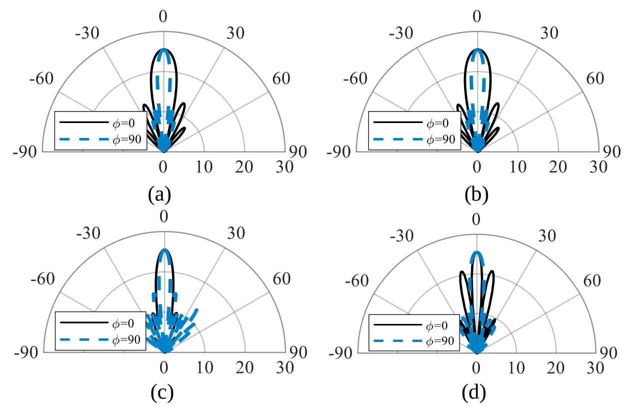

Fig. 4. Co-pol gain pattern of the conventional STAR array along with that of the proposed architecture. (a) Uniform array (Tx), (b) uniform array (Rx), (c) proposed array (Tx), and (d) proposed array (Rx).

IV. Conclusion

A STAR antenna array configuration with isolation > 63 dB for broadside beam is proposed. The proposed array shows an isolation improvement of 20dB and more when compared to the conventional configuration. High isolation values are realized at the cost of higher SLLs, which is an inherent property of similar arrays. No degradation in aperture efficiency is observed for both Tx and Rx beams. High isolation characteristics and adequate far-field performances make shared aperture sparse antenna arrays a feasible candidate for full-duplex applications that require high gain and multifunctional operation.

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