High Isolation Log-Periodic Dipole Array System for Wideband Full-Duplex Applications

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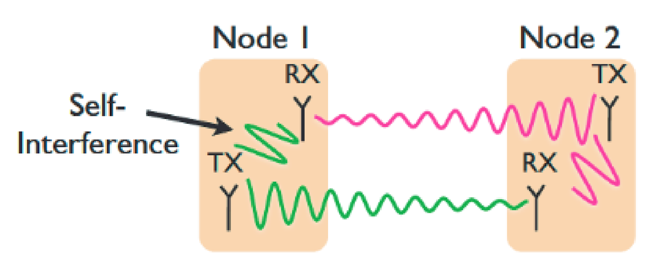
Introduction

As the wireless communication devices are becoming more numerous, researchers are exploring new wireless spectrum standards to address over crowded spectrum. One of these standards is full-duplex communications which allows for transmitting and receiving on the same frequency at the same time. The main challenge in full-duplex operation is high self-interference cancellation in a wide bandwidth. The signals may become unrecognizable and distorted because of the interference between transmission (TX) and reception (RX) antennas.



This project focuses on designing a two-port wideband full-duplex Log-periodic dipole array (LPDA) system that offers a high level of isolation between receive and transmit operations. To maximize the isolation, the orthogonal polarization technique is utilized. The propagating directions of both transmitted and received signals will be offset by 90º about the center of the antenna [1]. The directions of transmitted and received antennas are perpendicular to each other to ensure that both signals will not interfere with one another. Thus, the signals of the system can propagate in 360º direction for both operations. Symmetry manipulation is also employed to attempt to reach a high level of isolation [2]. By attaching both antennas to a single module, a compact planar antenna system can be designed. The antenna system is optimized to sustain a high level of isolation through entire band of interest. The proposed design provides a coverage for X-band spectrum (from 8 GHz to 12 GHz) which has common applications in radar, weather monitoring, or air traffic control.

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Antenna Design Process

In this work, two microstrip LPDA arrays are designed each having two elements. The substrate is FR4 with a thickness, h_1, of 1.5 mm, a dielectric permittivity, ε_r, of 4.4, and dielectric loss tangent, tanδ, of 0.02. LPDA has a desired directivity of 8 dB which has scale factor, τ, of 0.865 and relative spacing, σ, of 0.15. With these parameters, the number of dipoles, N = 8, and aperture angle, 2α = 25.36º, are determined. In addition, by using the lowest frequency operation and the above parameters, the length of the largest dipole is computed. With the 50Ω characteristic impedance, the below expressions are used to find the width of the eighth dipole:

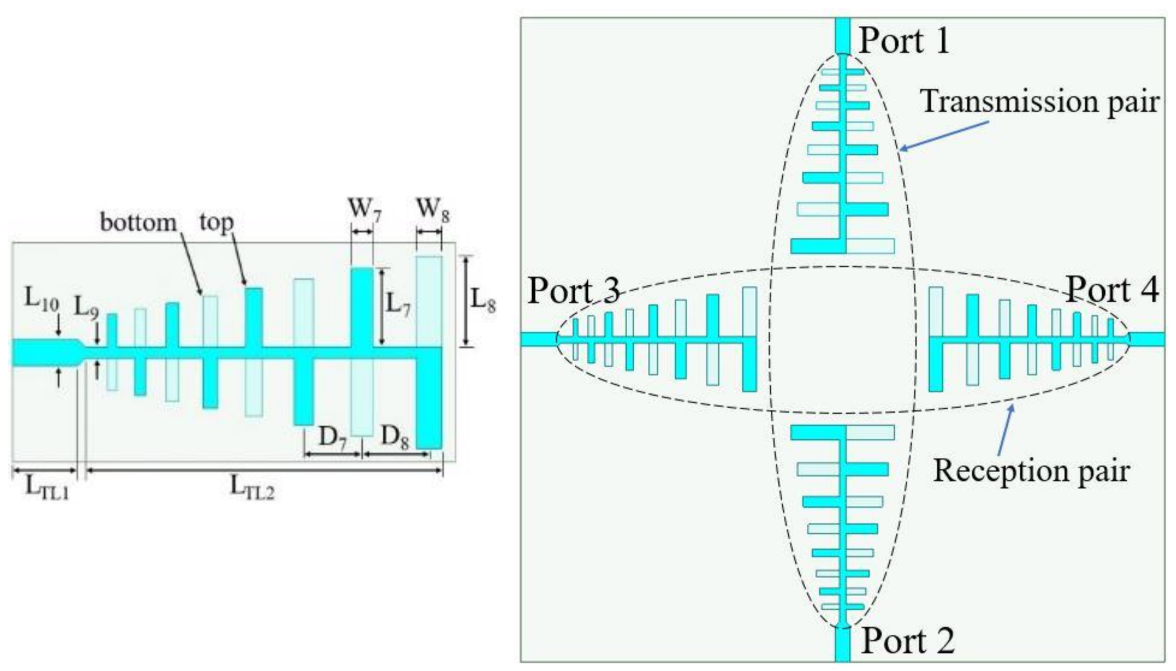
$$Z_n = \frac{\eta_0}{\pi}\left[\ln\left(\frac{L_n}{a_n}\right) - 2.25\right]$$

$$W_n = \pi a_n$$

After computing the dimensions of the largest dipole, the length and width of other dipoles can be determined by using the following well-known expression:

$$\frac{1}{\tau} = \frac{l_{n+1}}{l_n} = \frac{W_{n+1}}{W_n} = \frac{D_{n+1}}{D_n}$$

Fig. 1(a) illustrates the geometry of a single LPDA antenna. The dimensions of the antenna are optimized in order to achieve the best results. Fig. 1(b) depicts the top view of LPDA antenna system. The TX and RX LPDAs are separated by an optimized distance of 0.928λ, where λ is the wavelength of the highest frequency. The spacing between two opposite LPDAs is also important since it affects the mutual coupling and beam direction of the array between TX and RX ports.



(a) (b)

Figure 1. a) The geometry of one LPDA; b) The geometry of LPDA antenna system

Results and Discussion

The antenna system was designed and simulated by using ANSYS HFSS. Fig. 2 presents the top view of the fabricated antenna system with four LPDAs. Each pair of the antenna system is connected to a wideband power divider by using coaxial cables, as shown in Fig. 3. The antenna matching might be degraded because of the use of these cables, especially in the higher frequency bands. Fig. 4 shows the measurement setup for the antenna system.

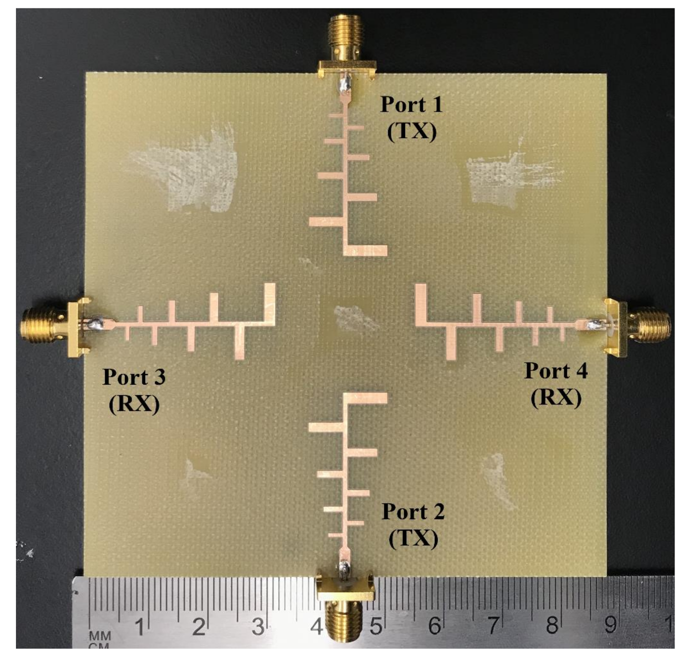


Figure 2. Fabricated antenna system

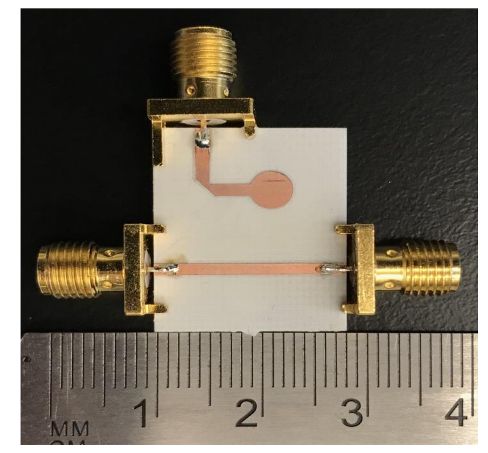


Figure 3. Fabricated power divider

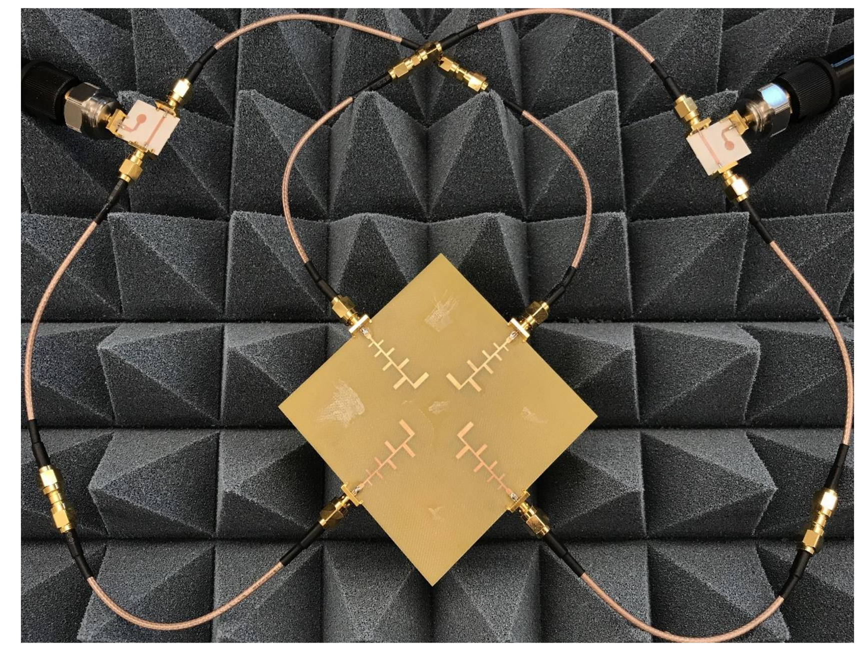


Figure 4. Measurement setup

Fig. 5 illustrates the simulated and measured results of the system. The simulated and measured reflection coefficients show that both TX and RX antennas operate through the entire X-band spectrum. Additionally, the system maintains high simulated isolation, S_{a21} < – 60 dB, attaining -80 dB at the center of the band. The measured results indicate that the system sustains high isolation S_{a21} < – 50 dB reaching as low as – 86 dB. The 3D polar plots, as shown in Fig. 6, depict the radiation direction for both receive and transmit modes. The LPDA antenna system is able to cover entire 360º direction in both modes. Fig. 7 describes the peak gain and the radiation efficiency of the antenna system. The design achieves good efficiency through entire X-band, more than 75 %.

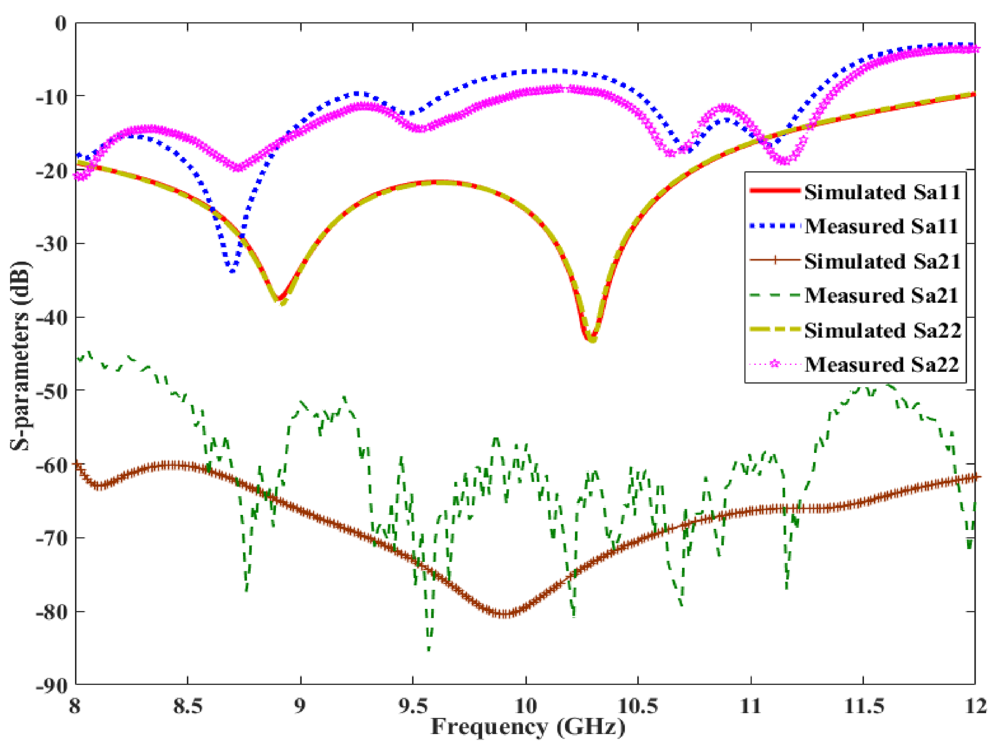


Figure 5. Simulated and measured return losses and isolation

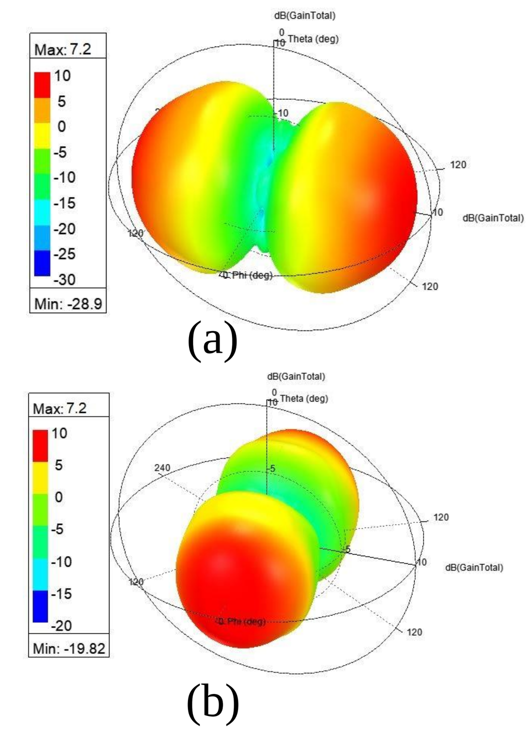


Figure 6. 3D gain polar plot: a) reception mode, b) transmission mode

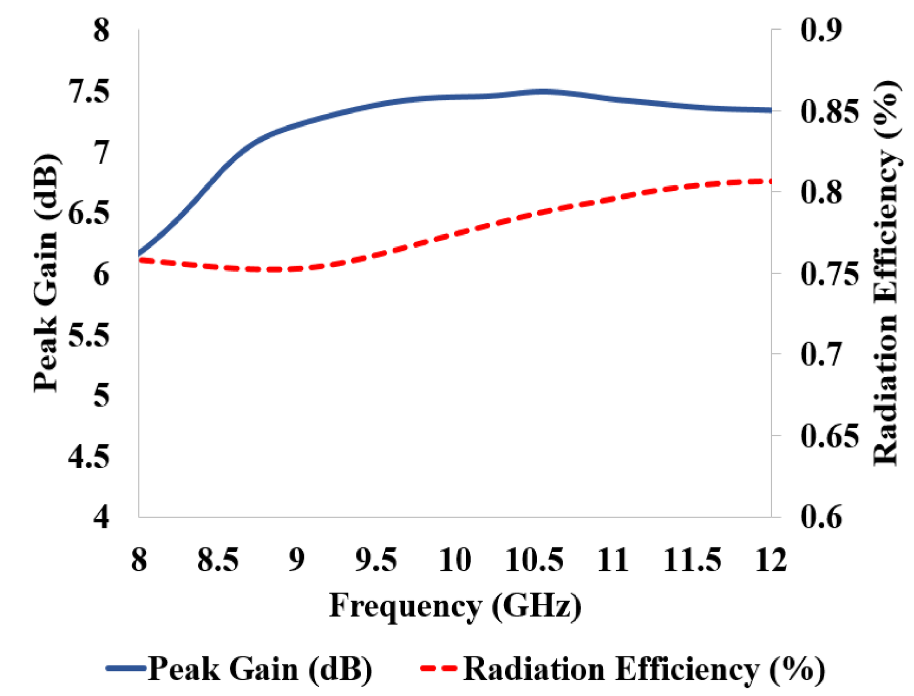


Figure 7. Peak gain and radiation efficiency of the system

Conclusion

This project presents a high isolation antenna system for X-band full-duplex applications. The proposed design has two differentially-fed LPDA pairs for RX and TX operation. The structure maintains the isolation greater than 50 dB through the entire band of interest in a highly reflective environment. Good radiation patterns with low cross-polarization values are observed and cover 360º direction for both RX and TX modes. This compact antenna system with its high isolation and good gain values can be used within small size wideband full-duplex systems.

References

[1] T. Nguyen and T. Karacolak, "Planar patch antenna system with high isolation for full-duplex applications," *Electronics Letters*, vol. 55, no. 25, pp. 1326-1329, Dec. 2019.

[2] G. Makar, D. Kim, N. Tran, and T. Karacolak, "Compact Antennas with Reduced Self Interference for Simultaneous Transmit and Receive," *Progress in Electromagnetics Research C*, vol. 78, pp. 19-31, 2017.

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