

TX-RX Isolation Method based on Polarization Diversity, Spatial Diversity and TX Beamforming

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Abstract—In this paper, the feasibility of an antenna isolation technique based on null-steer beamforming, polarization diversity and spatial diversity is investigated. The proposed system consists of six patch antennas which are fed by a feeding network to obtain a null-steer beamformer. To achieve spatial diversity, antenna elements are located on two layers, facing in a different direction. Moreover, the antenna elements in two layers use different polarization. The measured results of the antenna system present a high TX-RX isolation in the order of 70 dB which shows the feasibility of such a system for Full-duplex transmission.

Index Terms—Full-duplex, Antenna Decoupling, Beamforming.

1. Introduction

Full-duplex (FD) wireless communication, in which a radio transmit and receives at the same frequency and time, has the potential to increase the spectral efficiency up to twofold. Optimization of the spectral efficiency with an FD transmission relies highly on the cancellation of a very high powered Self-Interference (SI) leaked from the transmitter. To provide a very high isolation between TX and RX, different stage of SI cancellation, i.e. radio-frequency (RF), analog and digital cancellation is necessary [1]. In order to prevent the receiver Analog-to-Digital Convertor (ADC) from saturation, the SI signal needs to be sufficiently suppressed in RF and analog domain. Many techniques are proposed to suppress the SI in RF and analog domains including, antenna polarization diversity [2], near-field null steer beamforming [3], [4], analog cancellation circuits [5]. The work in [4] presented the concept of null-steer beamforming technique based on differential feeding of two TX antennas located symmetrically from the RX antenna. In this manner, the SI signal is suppressed in the near-field region of the antennas. The authors presented an antenna system in [6] based on null-steering beamforming combined with polarization diversity to achieve an FD-MIMO antenna system. In this work, we apply spatial diversity in addition to null-steer beamforming and polarization diversity to design and evaluate an FD-MIMO antenna system. The antenna system which consists of two TX antenna pairs and two RX antennas was evaluated by simulation and measurement. The results show a maximum TX-RX isolation level of 75 dB over the operating bandwidth in an environment with minimal reflection.

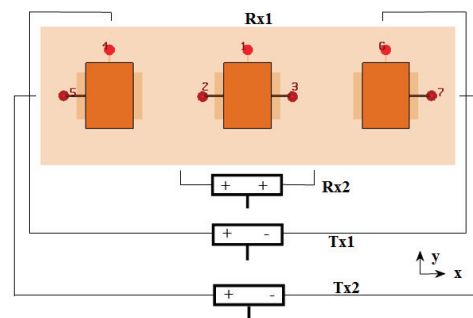


Figure 1: The antenna system setup consist of six dual-polarized patch antennas. Three patch elements are located on the front layer and three elements are located on the back layer. The feeding network is applied to construct a null-steer beamformer.

2. Antenna System

Fig. 1 shows an antenna setup where the transmit antennas are located symmetrically from the RX antennas. In this manner, by differential feeding of the TX antenna elements we can achieve near-field null-steer beamformer and as a result, the transmitted signal can be cancelled at the RX location. In order to achieve polarization diversity, the patch elements on the top layer are located orthogonally to the antenna elements on the bottom layer. To obtain spatial diversity, one pair of TX and RX antennas are located on the top layer and another pair is located on the bottom layer as it is shown in Fig. 1. One can note that in this way, the isolation between the antenna elements can be improved since the patch elements located on top and bottom layer radiate on the opposite directions. The three layers comprising the antenna elements are as follows from top to bottom: 1) top layer consist of three patch elements, 2) the ground plane layer and 3) the bottom layer with the patch elements facing the opposite direction. A rectangular microstrip patch is chosen as the radiation element because of its simple structure and good radiation characteristics of the orthogonal polarization. Fig. 2 shows the dimensions of the patch element used in the antenna setup. Whereas, the total area of the entire antenna system is $240 \times 80 \text{ mm}^2$. Moreover, the patch elements are printed on two FR-4 substrates, each with a thickness of 1 mm. Fig. 3 shows the fabricated antenna prototype.

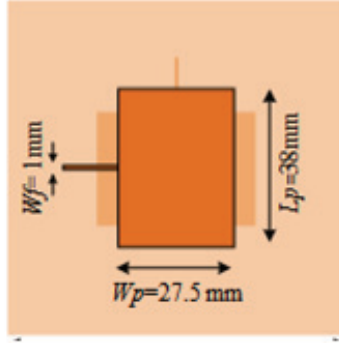


Figure 2: Dimensions (in mm) of one of the 6 patches (top view) comprising the proposed full-duplex MIMO antenna system.

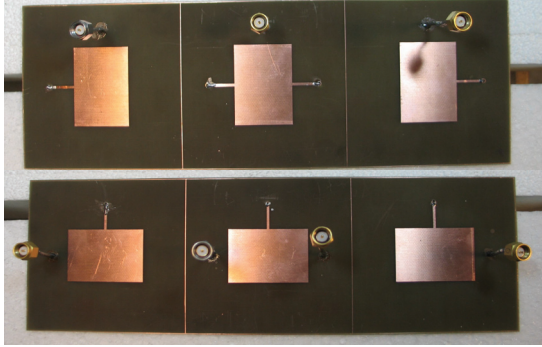


Figure 3: The fabricated prototype, front and back view.

3. Results

The simulated scattering parameters of the seven-port antenna system were obtained using the transient solver in the frequency domain from CST MICROWAVE STUDIO. Fig. 4 shows the simulation and measurement results for the return losses. Measured S-parameters were post-processed with a differential weighting coefficient to construct the null-steer beamformer. The measured antenna prototype is resonating at 2.63 GHz while the simulated resonated frequency is at 2.56 GHz. The difference between the simulation and the measurement comes from the tolerance of the FR-4 permittivity value. Fig. 5 shows the

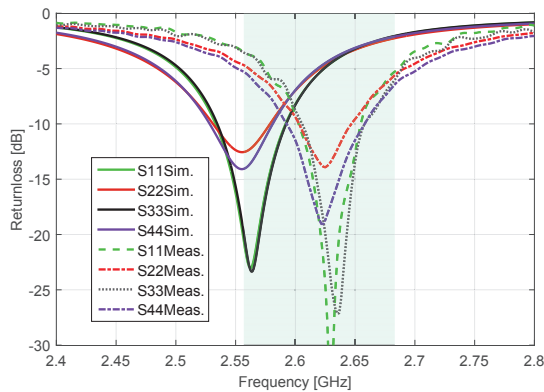


Figure 4: Return losses of the measured and simulated antenna system

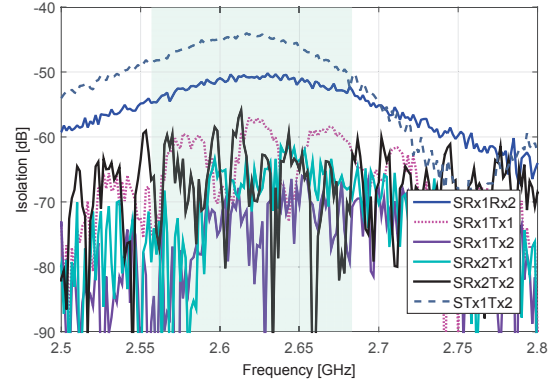


Figure 5: Measured frequency response of the isolation between the 4-port full-duplex MIMO antenna system

results after post-processing the measured S-parameters. It can be seen that the TX-RX isolation is in the range between 60 dB to 75 dB, which indicates a significant amount of self-interference cancellation over 100 MHz bandwidth. The measured MIMO isolation at the center frequency between Tx1 and Tx2, Rx1 and Rx2 are 45 dB and 50 dB, respectively.

4. CONCLUSION

The design and evaluation of an FD-MIMO antenna system based on polarization diversity, spatial diversity and TX beamforming are presented in this work. The patch antenna elements are located on two layers facing in the different direction and are fed in an orthogonal manner. Therefore, spatial diversity and polarization diversity is achieved. Moreover, the TX antenna is located symmetrically from the center patch elements (RX antennas) in order to form a null-steer beamformer. The antenna system was fabricated and measured. The isolation level of 60 to 75 dB between was reported for this particular antenna system. It can be concluded such an antenna system equipped with three different isolation technique can provide a high level of SI cancellation and can be applied in an FD system as the first stage of cancellation.

References

- [1] A. Sabharwal, P. Schniter, D. Guo, D. W. Bliss, S. Rangarajan, and R. Wichman, "In-band full-duplex wireless: Challenges and opportunities," *IEEE Journal on Selected Areas in Communications*, vol. 32, no. 9, pp. 1637–1652, 2014.
- [2] Y. Li, Z. Zhang, J. Zheng, and Z. Feng, "Compact azimuthal omnidirectional dual-polarized antenna using highly isolated collocated slots," *IEEE Transactions on Antennas and Propagation*, vol. 60, no. 9, pp. 4037–4045, 2012.
- [3] A. K. Khandani, "Methods for spatial multiplexing of wireless two-way channels," Oct. 19 2010, uS Patent 7,817,641.
- [4] —, "Two-way (true full-duplex) wireless," in *2013 13th Canadian Workshop on Information Theory (CWIT)*, 2013, pp. 33–38.
- [5] Y. Hua, Y. Ma, A. Gholian, Y. Li, A. C. Cirik, and P. Liang, "Radio self-interference cancellation by transmit beamforming, all-analog cancellation and blind digital tuning," *Signal Processing*, vol. 108, pp. 322–340, 2015.
- [6] E. Foroozanfar, O. Franek, A. Tatomirescu, E. Tsakalaki, E. De Carvalho, and G. F. Pedersen, "Full-duplex mimo system based on antenna cancellation technique," *Electronics Letters*, vol. 50, no. 16, pp. 1116–1117, 2014.