Microstrip Patch Antenna Array for Range Extension of RFID Applications

Mehmet ABBAK*, Ibrahim TEKIN
Faculty of Engineering and Natural Science, Sabanci University
34956, Istanbul, Turkey

E-mail: tekin@sabanciuniv.edu

In this paper, an UHF band 2X2 microstrip phased antenna array is designed for extending the range of an RFID reader system. The phased antenna array operates at the frequency of 867 MHz, as specified in Gen2 protocol European standards. The phased antenna array has four microstrip patch antennas, three Wilkinson power dividers and a transmission line phase shifter printed on the same Arlon AD450 substrate with a dielectric constant of 4.5 with dimensions of 34x45 cm. The phased array antenna has a measured directivity of 9.5 dB and the main beam direction can be switched between the angles of ± 40 degrees with a 3dB beamwidth of 90 degrees. The phased antenna array can be used to extend the RFID system working range.

Introduction

This paper presents the design of an UHF microstrip patch antenna array RFID based monitoring and analysis system. In order to extend the coverage area of the RFID system, one may implement many readers and antennas with small reading ranges to cover the monitoring area, or use high gain phased array antenna system for extended reading range of an RFID reader for a smaller number of total reader deployments. In this paper, a phased antenna array system is proposed for extending coverage range of an RFID system.

For passive RFID systems in EPCglobal Class1 Gen2 RFID standard working at UHF, the working range of the RFID System is limited compared to active systems [1]. General purpose application RFID systems use antennas with wide beam widths and hence small gains to receive and transmit the RFID signals. Consequently, to overcome short range limitations of RFID systems, both due to passive tags and wide beam widths; a novel phased array antenna system with higher gain will be used for beam forming for increased directivity and hence increased range.

Phased Antenna Array System

A schematic view of the proposed antenna array is plotted in Figure 1. The phased array will be consisting of four (2x2) patch antenna elements, Wilkinson power dividers, phase shifters enabled by SPDT switches. By using transmission line based phase shifters, the main beam of the array can be steered to two main directions as shown in Figure 2 as State1 and 2. The main purpose of steering the main beam of the array is to extend the coverage while increasing the gain of the antenna. A typical radiation pattern of a microstrip patch antenna is shown as in Figure 2 radiating into the half space, and also shown in the figure a more directive beam of a phased antenna array with two different pointing directions.

Antenna feed network is designed to steer the beam in two directions in H-plane (±40°) and this necessitates a phase difference of 120 degree between the antenna sets (1,2) and (3,4) for 0.4 λ_o spacing between the antennas as shown in Figure 1. There is no phase shift between antennas 1 and 2, 3 and 4, and the spacing in x-direction is set to 0.3 λ_o to obtain the optimum gain and mutual coupling, where ADS Momentum 2.5D EM software is used.

Implementation and Results

Each component in the antenna array system, microstrip patch antenna, phase shifter and Wilkinson power divider is first designed using ADS Momentum, and than, implemented, and finally measured, using Agilent 8270ES S-Parameter Network Analyzer. For the design of microstrip patch antenna, various geometry parameters and material parameter have to be determined. With the use of equations for patch antenna from Balanis [2], initial values are resolved. For substrate material with a relative electric permittivity of 4.55 (ε_r) and thickness of 1.55mm, the fabricated microstrip patch antenna is shown in Figure 3. Measured input return loss of patch antenna is given in Figure 4, where 10dB return loss bandwidth is about 15MHz, and the antenna radiates at 867MHz, with a return loss of 22dB. Radiation pattern of the patch antenna is measured in compact test range. Broadside direction pattern has better than 15dB cross polarization at E and H planes, and 3dB bandwidth is 70° at H plane, and 80° in the E plane, with a directivity of 7.5dB as shown in Figure 5.

For the phase shifter implementation, delay arm should provide additional 120° phase difference according to reference arm, because 240° phase difference between left and right arm is needed which requires ±120 phase differences. The implemented phase shifter on FR4 substrate is shown in Figure 6. Measurement results are given in Figure 7. Insertion loss of 1.1dB and return loss of 50dB are measured for 120° phase difference (Figure 7). MA/COM High power SPDT switch chip is used to switch between the two branches of the transmission line. As a last block of the array system, Wilkinson power divider circuit is realized and measured as shown in Figures 8 and 9. According to measurement results, power is delivered equally with an insertion loss of 0.1dB (S12≈S13≈ -3.1dB), with an isolation of 40dB at 867 MHz. (Figure 9).

Final layout of the RFID array antenna is shown in Figure 10 where AD450 (ε_r=4.5, $\tan\delta$=0.002@ 2GHz with 1.52 mm thickness) substrate is used. Overall response of the phased array antenna can be seen for two different positions of the switches, in Fig.11, the return loss of 21dB and 30dB obtained at the resonance frequency of 845 MHz for two different main beam positions. The simulated radiation patterns of the array are shown in Figure 12. Directivity of 9.5dB and 30dB difference co and cross polar level is obtained from the simulations. Early measured results show that antenna can be steered ±40 degrees, and, as a future work anechoic chamber measurement will be performed for the gain measurements.

Conclusion and Future Work

2x2 UHF RFID antenna array system at 867 MHz, which consists of phase shifter, power dividers and microstrip patch antenna is designed, implemented and measured. The main beam of the antenna array can be switched between two directions which are designed to be 80 degrees apart. The measured input impedance is well matched with two different beam pointing directions with return losses of 20dB and 30dB. Directivity of the array is simulated to be 9.5 dB, which is also confirmed by early measurement. As a future work, the array antenna gain will be measured in compact range.

References:

[1] K. Finkenzeller, RFID Handbook, 2nd edition, John Wiley & Sons, England, 2003.
[2] Balanis, Constantine A. Antenna Theory, John Wiley & Sons, Inc.

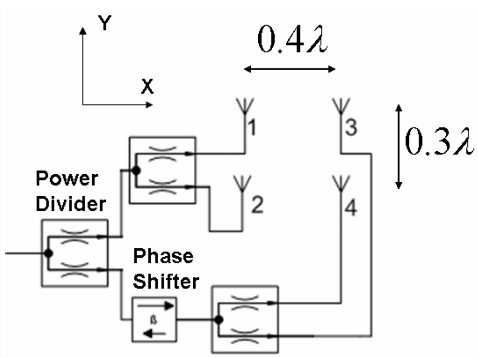

Fig. 1 Diagram of Antenna Array

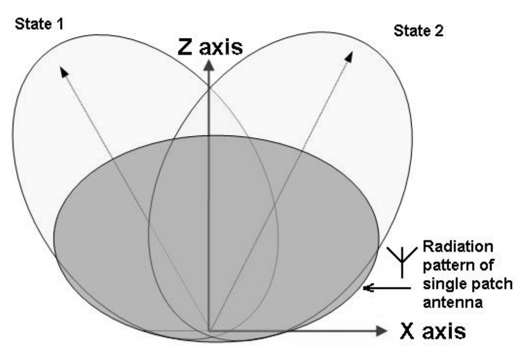

Fig. 2 Extending Coverage Area

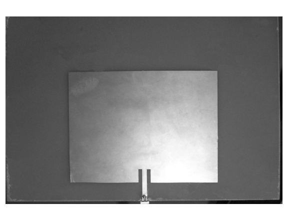

Fig3. Microstrip Patch Antenna

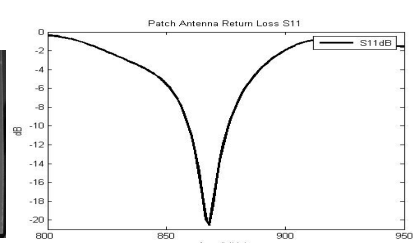

Fig4. Return Loss of Patch Antenna

Fig6. Phase Shifter

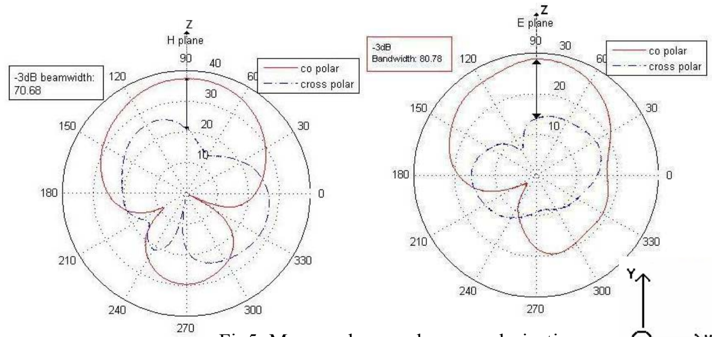

Fig5. Measured co- and cross-polarization

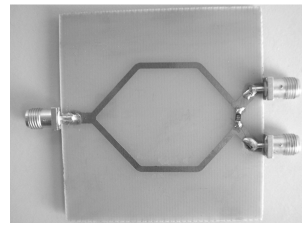

Fig8. Power Divider

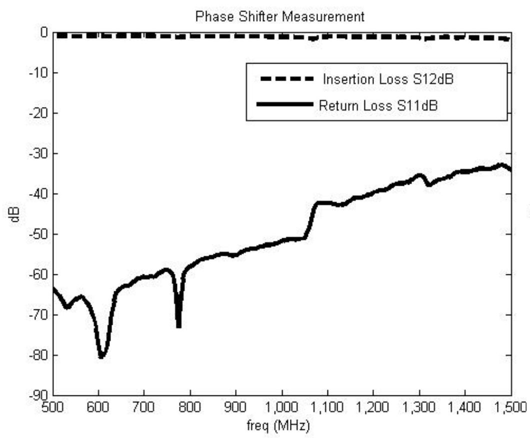

Fig7. Phase Shifter S-Parameters

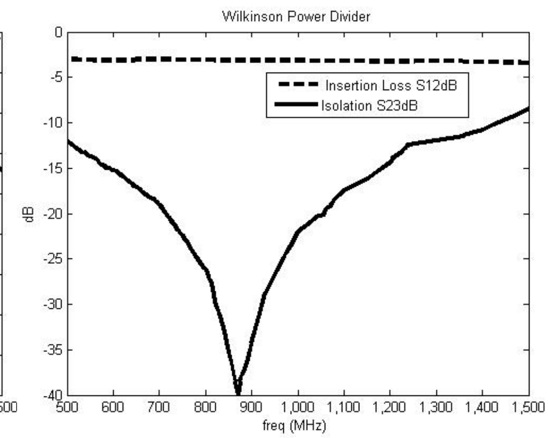

Fig9. Power Divider S-Parameters

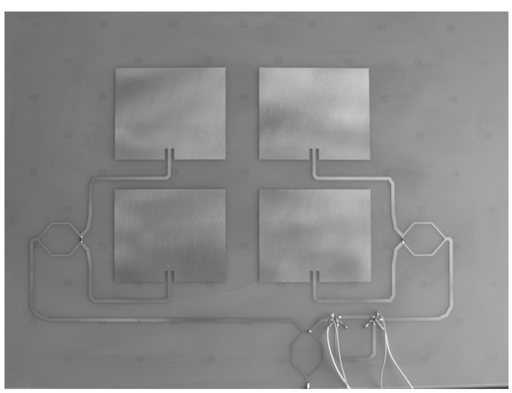

Fig10. Array Antenna

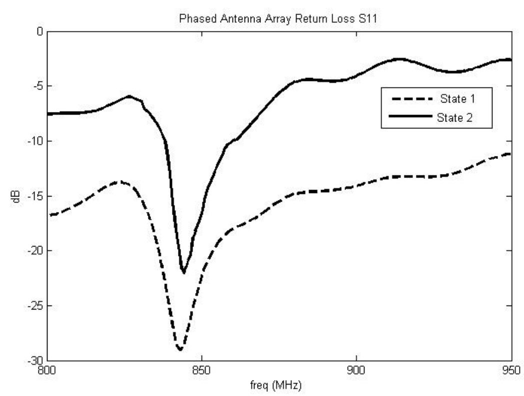

Fig11. S11 of the array antenna

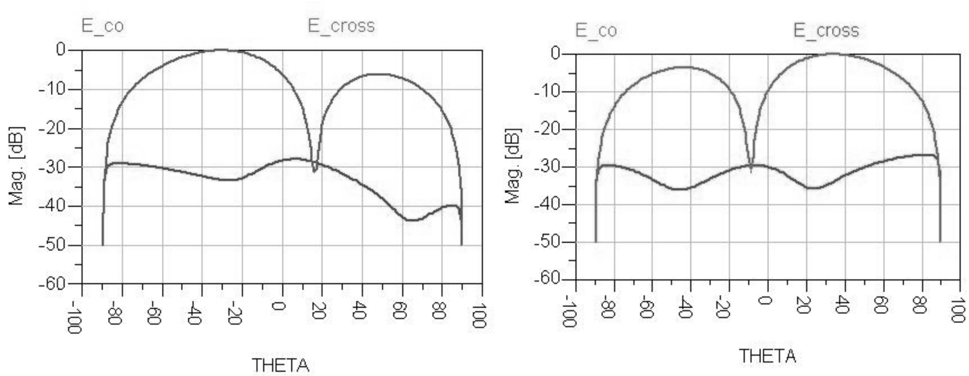

Fig. 12 E Co-cross ϕ plane radiation pattern for state 1 and state 2 respectively.