IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Design of phased antenna array for UHF RFID applications

To cite this article: I Nachev and P Z Petkov 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **618** 012017

IOP Conf. Series: Materials Science and Engineering **618** (2019) 012017 doi:10.1088/1757-899X/618/1/012017

Design of phased antenna array for UHF RFID applications

I Nachev[1] and P Z Petkov[1]

[1]Technical University of Sofia, Faculty of Telecommunications, RCVT

ivaylonachev@yahoo.com, pjpetkov@tu-sofia.bg

Abstract. The paper present design of low-cost antenna array for RFID indentification in the frequency range 865 to 868 Mhz. The design antenna has enhanced coverage (pattern) and beam-steering capabilities. It can serve as a base element for more sophisticated RFID readers with direction finding capabilities and improved distance of tag reading.

1. Introduction

In the recent years, Radio Frequency Identification (RFID) systems have been gaining strong technological development. RFID technology is a technology that reads remotely (several centimeters to several meters) a tag in order to tracking it, and this tag can be sticked to a person, vehicle, cargo, etc in order to track it. A reader is basically a radio frequency (RF) transceiver, controlled by a microprocessor or another type of a digital controller. An RFID reader emits electromagnetic signals where an RFID tag draws power and retranslate the response. The reader antenna should have a circular polarization (CP) characteristic since the tag antenna can be arbitrarily positioned on the target. In RF design, patch array can be used because of their advantages in this field: such as light weight, small volume, low fabrication cost, high gain, the possibility of integrating a scanning systems, et cetera. In this paper, an improved RFID reader design is demonstrated, with employment of scanning phased antenna array, which will increase reader's technical characteristics [1].

2. Patch array design approach.

The employed substrate for the proposed design is Rogers FR4 with thickness h=2mm and Dissipation factor tanδ = 0.03. In order to improve the bandwidth and efficiency of antennas, a design method called "suspended substrate" is chosen, where the thickness of the gap between ground plane and antenna is Δ=3mm. In this method we use the equivalent Dielectric constant (6). Distribution of the elements of the simulated model, as with radars frequency fc = 866.5MHz. For calculation of antenna dimensions a straightforward basic algorithm is proposed:

Step 1: Calculation of width (W): Width of the Micro strip antenna is given by the common known equation:

$$W = \frac{c}{2fc}\left(\frac{\varepsilon_r + 1}{2}\right)^{-\frac{1}{2}}, \frac{W}{h} > 1 \tag{1}$$

Where c is the speed of the light c=3*10^8, ε_r is the relative dielectric constant of the substrate, f_c is radar frequency and h is substrate thickness.

IOP Conf. Series: Materials Science and Engineering **618** (2019) 012017 doi:10.1088/1757-899X/618/1/012017

Step 2: Calculation of Effective Length (L): Length of the microstrip radiator is given by:

$$L = \frac{c}{2f_c\sqrt{\varepsilon_{reff}}} \tag{2}$$

Where fc is radar frequency and ε_{eff} is effectively dielectric constant of substrate

Step 3. Calculation of the Length extension (L_{ext}): The actual length is obtained by the equation (accounting for the fringing fields):

$$L_{ext} = 0.412h\frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 8)} \tag{3}$$

Follow these instructions as carefully as possible so all articles within a conference have the same style to the title page. This paragraph follows a section title so it should not be indented.

Step 4: Calculation of the actual length of the Patch (L) and the rest of the design parameters: The actual length of the patch is given by:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 10\frac{h}{W}\right)^{0.5} \tag{4}$$

The length of the guided wave and the equivalent permittivity accounted for the air gap:

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_{eff}}} = \frac{c}{fc\sqrt{\varepsilon_{eff}}} \tag{5}$$

$$\varepsilon_{r\,eq} = \frac{\varepsilon_r * (h + \Delta)}{\varepsilon_r + h * \Delta} \tag{6}$$

Where ε_r is a dielectric constant of substrate and Δ is thickness of the air gap. The dielectric constant in accounted for the gap between ground and the suspended substrate is marked with $\varepsilon_r eq$.

In table 1 are presented the values obtained for dimensions of the antenna components. Fig.1 shows simulation model of antenna system - consists of 4 array each one has 4 elements with series fed patch array, which are relevant by using of corporate feed. Using this model, scanning is available only in azimuth. The rounded edges of the square model of patch antenna provides circular polarization.**[2]**[3][4]

Table 1. *Values obtained for dimensions of the antenna components*.

	W, cm	L_{eff} ,mm
Calculated	12.2	13.6
Adjusted after simulation	12.5	13.25

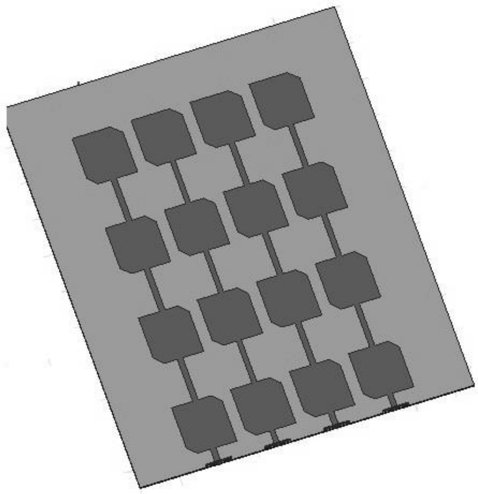

Figure 1. *Patch array – the simulation model*

3. Transmission line phase shifter.

The Butler matrix employed in this designis a type of beam-forming network. Depending on which input is excited, the antenna beam is steered in a specific direction in one plane. It performs a similar function to a Rotman lens and is a simple form of phased array antenna system. The Butler matrix consists N inputs and N output port. The design of Butler matrix is consisted of combination of hybrid couplers, phase shifters and crossovers. Values of the typical Butler matrix is show on table 2.

Described beamformer of the phased antenna array uses a hybrid T junction system that divides the input power in 4 equal parts. In this paper is described how - by changing electric length of microstrip lines (ML), changes the phases of the RF signals, thus steering the beam, for this purpose use the second and third row of Butler matrix (Fig. 2). This arrangement gives the opportunity to steer the beam in three different positions: -45; 0; +45 deg. Similar problems are discussed also in [5],[6],[7].

Table 2. *Values of the Butler Matrix*

Patch array	I	II	III	IV
ectrical length extensions	45^o	90^o	135^o	190^o
electrical length extensions	135^o	0^o	225^o	90^o
electrical length extensions	190^o	135^o	90^o	45^o
electrical length extensions	90^o	225^o	0^o	135^o

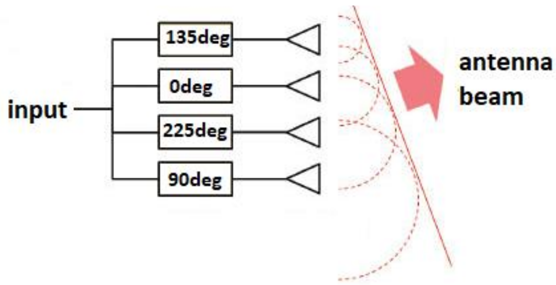

Figure 2. *Switched line phase shifter*

Table 3. Relation between beam steering and radiator's phases

Beam direction	I	II	III	IV
0 deg	0^O	0^O	0^O	0^O
+45 deg	135^O	0^O	225^O	90^O
-45 deg	90^O	225^O	0^O	135^O

4. Phase delay line control system

On Figure 3 a graphical relation between radiating antenna, feed, phase delay lines and hybrid T junctions is shown. Beam steering is accomplished by switching between microstrip lines with different lengths, using PIN diodes or different models RF switches, in this case we can use PE4259, Peregrine Semiconductors. This leads to required beam scanning (Tabl. 3).

5. Simulations results

In this section results obtained by simulation are shown. On Fig. 4 is displayed the return loss of the single segment (vertical seral array) of antenna, with the presence of the adjacent elements. In other words, the coupling between elements is included. Figures 5 and 6 show S_{11} parameters of the entire array with feed network for different scan angles. It is evident, that the operational impedance bandwidth of the array exceeds the required bandwidth for RFID applications with a great margin. The next figures, Fig. 7 and 8 show the antenna radiation pattern in azimuth for 0, +45 and -45deg beam steering. The beam shape is steered according to calculations and performs as described in the theory. The results show that even a small array with significant phase step between elements can bring a satisfactory results for such type of applications.

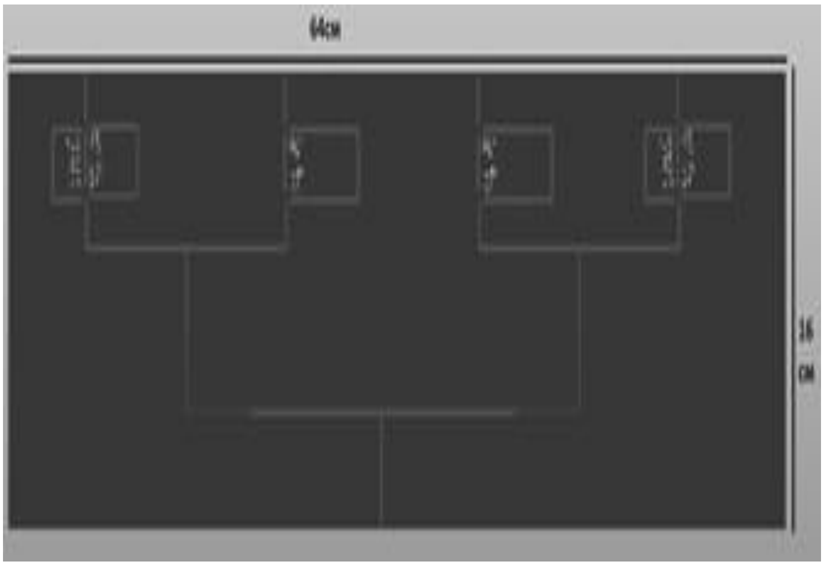

Figure 3. *Design model printed on PCB of antenna phasing section*

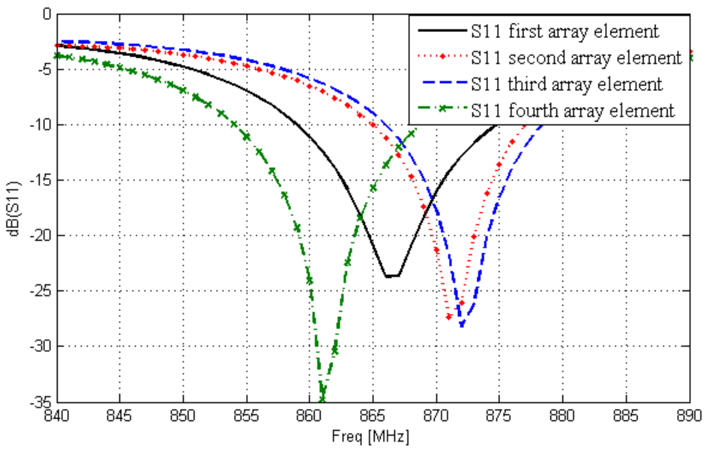

Figure 4. *Antenna array bandwidth (vertical segments), dB*

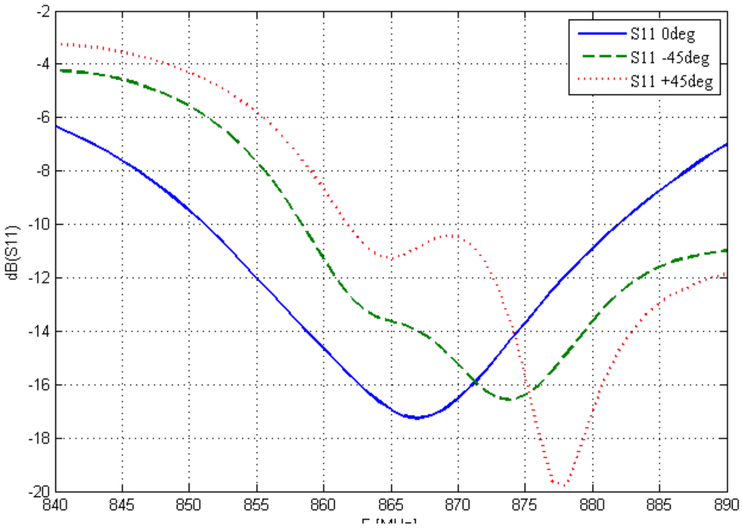

Figure 5. *Frequency bandwidth of the feed network inputs, dB*

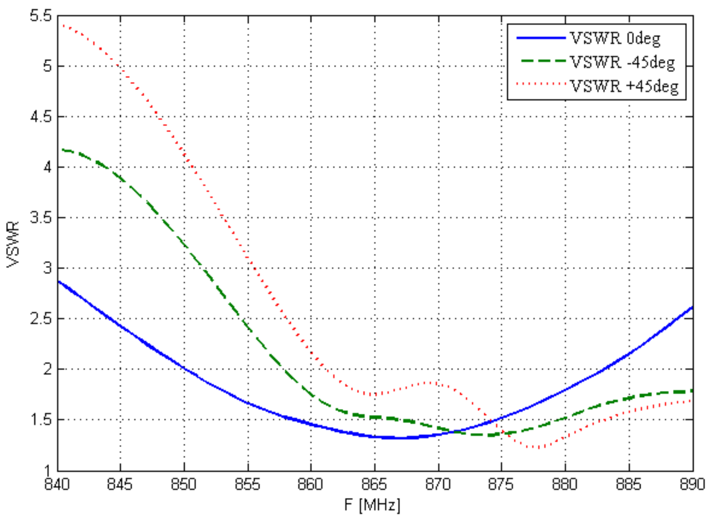

Figure 6. *Antenna array bandwidth for the 3 cases of scan angle*

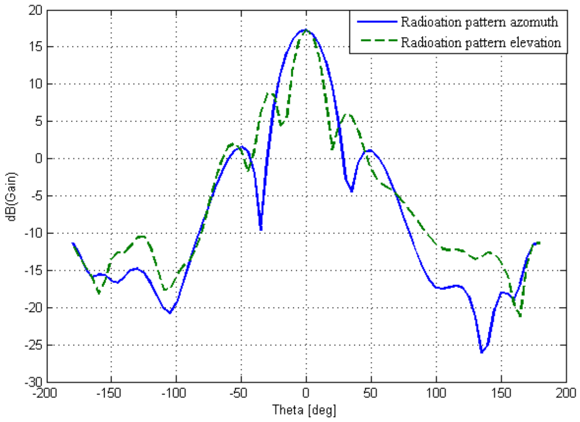

Figure 7. *Radiation Pattern at 0 deg mode*

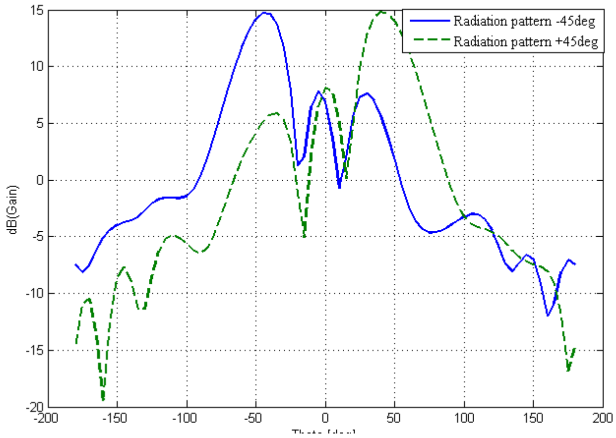

Figure 8. *Radiation Pattern at +-45 deg mode*

In table 4, a comparison of gains in beam`s different state. Figure 10 and 11 shows return loss and VSWR on antenna array inputs, after connecting the array and the fed network, depending on the mode of operation.

Table 4. Simulated Antenna array gain

Beam direction	Antenna array gain, dBi
0 deg	16.23
+45deg.	14.83
-45deg	14.86

6. Sample algorithm for beamforming control code

As addition to the beam steering antenna array, authors propose a simple algorithm for programmable microprocessors/controllers to perform scanning for RFID tags (targets) and control the phase shifters. Fig. 9 shows algorithm block diagram of the code for beamforming control.

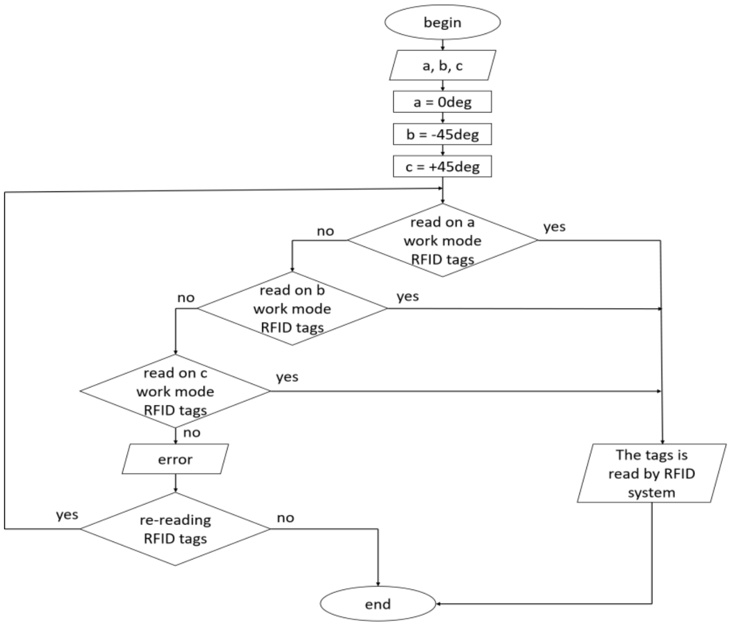

Figure 9. *Proposed aalgorithm for beamforming control.*

7. Conclusion

A simulation design RFID antenna array can be integrated into advanced, controllable RFID reader system, which work on EU-UHF license for Radio-frequency identification. The proposed antenna array has many advantages over typical antennas for that technology – simplicity, cost effectiveness and beam steering capability, as a disadvantage it can be pointed out the increased size of the entire antenna array.

Acknowledgments

This material is based upon work supported by the Bulgarian Science Fund under Grant No DN07/19/15.12.2016

References

[1] Klaus Finkenzeller, ”RFID HANDBOOK”, *Wiley*, 2010
[2] Chang, Kai; "RF and Microwave Wireless Systems",*Wiley*, 2000
[3] FR4 specification: www.rogerscorp.com
[4] J R James & P S Hall, “Handbook of microstrip antennas ”, *Peregrinus*, 1993
[5] Akhtar A., Mateen Alahi H., Sehnan M., "Simulation of Phased A rrays with Rectangular Microstrip Patches on Photonic Crystal Substrates", MSc thesis, *Linaeus University*
[6] J. Ehmouda, Z. Briqech, and A. Amer, "Steered Microstrip Phased Array Antennas", *World Academy of Science, Engineering and Technology*, issue: 49, 2009, p. 321 - p. 323
[7] Ilia Iliev, Stanio Kolev, Stoicho Manev „ Reduction of the frequency offset influence in OFDM using an optimal PRS coding and MLSD „ *Internat Journal of Research in Computer and Communication Technology*, Vol 3, Issue 1