Tangent circles antenna design for RFID applications in ISM 433 MHz

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In this study a low cost and small size antenna has been designed at 433 MHz for RFID applications. While designing the antenna we aimed to keep the antenna geometry as small as possible and the productivity as high as possible without increasing the cost. The operating parameters of the antenna have been simulated with HFSS software. The reflection coefficient of outcome parameters belonging to the antenna has been compared with the reflection coefficient of similar antennas designed in the past.

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1. Introduction

In general terms, RFID represents a way of identifying objects or people using radio waves [1]. RFID tags can be applied in almost every business process and are projected to be applied everywhere to everything that exists in the real world [2]. RFID is fundamentally based on wireless communication, making use of radio waves which form part of the electromagnetic spectrum, and it is not unlike two other wireless technologies, Wi-Fi and Bluetooth [1]. RFID is a multidisciplinary technology that includes RF and microwave engineering, RF and digital integrated circuits, antenna technology, software and computer engineering [2]. An RFID system includes an integrator (reader), a transponder (tag) and antennas [3]. Some criteria for selecting an RFID tag antenna are: frequency band, size and form, read range, EIRP (Effective isotropic radiated power), objects, orientation, mobility, cost, reliability, and power for the tag. On the other hand, the four major considerations when choosing an antenna are as follows: type, impedance, nature of the tagged object and vicinity of structures around the tagged object [1].

RFID applications are used in several frequency bands; these are 125-134 kHz, 13.56 MHz, 433 MHZ [4, 5], 865-954 MHz [6], 2.4-2.5 GHz [7] and 5.7-5.8 GHz. The tags are produced in three cases as: passive tags, semi passive tags and active tags to the tags power state. The advantage of the passive tag is its simplicity and consequent low cost. Semi passive tags can achieve ranges in the tens of meters to as much 100 m. Active tags are fully-fledged radios, with a battery, transmitter, receiver and controller.[3]

It is well-known that the ISM 433.050–434.790 MHz frequency bands are used for low-data-rate applications, such as wireless sensor networks (WSN). Due to the rapid development of wireless communication, the size of the wireless system operating at this frequency band should be small and compact. The free-space wavelength corresponding to 433MHz is 0.692m, and the size of the usual antennas would be too big to integrate in a system as small as a business card. Thus, the volume is the most concerning problem for an antenna design [4, 8]. Therefore, reducing the size of the antenna plays a key role in the design. Thus, several antennas have been proposed for ISM 433 MHz applications [4, 5, 9-11].

Before setting circuits in RF studies, simulation programs are used which work with different methods of calculation [12-15].

A twin-lead transmission line is a symmetrical line whereas a coaxial cable is inherently unbalanced. Devices that can be used to balance systems by cancelling or choking the outside current are known as baluns [16]

In this paper, the performance of two ultra-high-frequency (UHF) shorted planar antennas operating at 433 MHz is examined. In the study, it is important that the recommended antenna should have 433 MHz center frequency and that the reflection coefficient should be at the minimum level. The size of the system is 55 x 45 mm^2.

The Ansoft HFSS [17] is used to perform optimization of the antenna, as well as to design and create certain antenna performance parameters such as return loss.

The recommended antenna has an omni-directional pattern. Omnidirectional patterns can often be approximated by [16]

$$U = \left|\sin^n(\theta)\right|, \quad 0 \le \theta \le \pi, \quad 0 \le \phi \le 2\pi \qquad (1)$$

These settings have been carried out by changing the distance from the antenna's ground and radius. It is observed that the center frequency decreases while the antenna's radius increases. In the same way, the center frequency decreases while the ground plane distance of the antenna increases. The optimal values have been achieved by setting these two parameters.

2. Antenna design

The designed structure is shown in Fig. 1. It is designed on a 1.6 mm thick FR-4 substrate (ε_r=4.4, tanδ=0.02). Compared to the free space wavelength at 433MHz (λ_0=693mm), the ground size has small dimensions: 45mm width and 55mm length.

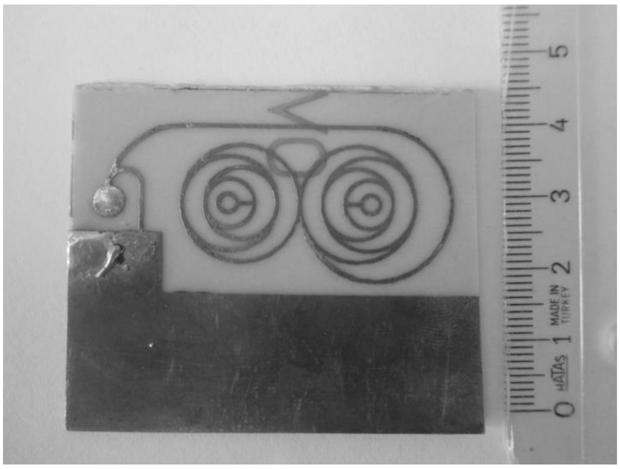

Fig. 1. Designed antenna layout on PCB.

The antenna can be examined in two parts. Fig. 2 shows the radiation part and Fig. 3 shows the feeding part of the proposed antenna.

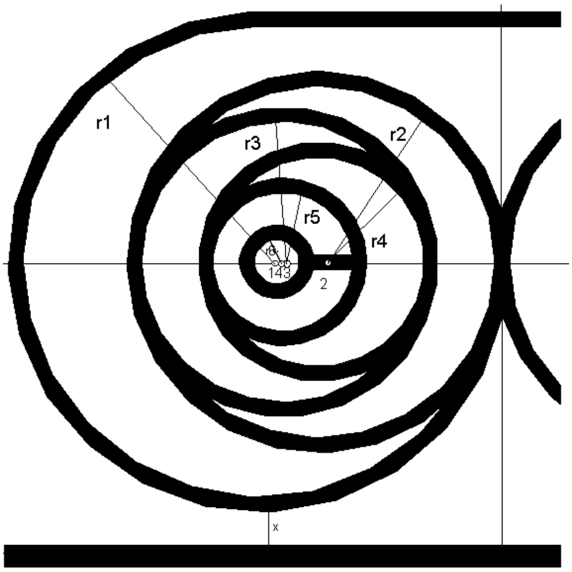

Fig. 2. Detailed geometry of the radiation part.

A circle radius of 2 mm has been used for the feeding of the antenna. The feeding point is connected to the radiation part with a line width of 0.5 mm. In addition, it is necessary to use a balun which matches an impedance to the input of the antenna in order to transfer a minimum loss to the antenna of the unbalanced signal coming from the coaxial cable of 50-ohm. A balun has been created by connecting the 2mm radius semicircle to the ground cable which is drawn by centering the point marked with number 7 in Fig. 3.

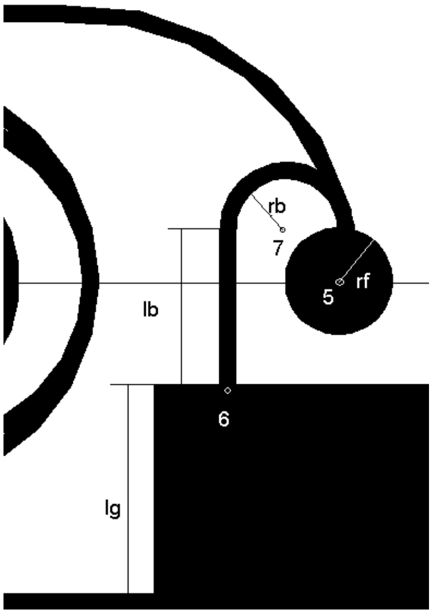

Fig. 3. Detailed geometry of the feeding part.

Table 1 shows the values of the geometrical dimensions and Table 2 shows the coordinate values of the proposed antenna.

Table 1. The physical parameters of the antenna.

Variable	Length(mm)
r1	10
r2	7.5
r3	6
r4	4.5
r5	3
r6	1
rf	2
lg	8
lb	6
rb	2
x	1.65

Table 2. The coordinates of the antenna.

point	Coordinate(x,y)(mm)
1	(0,10.25)
2	(0,7.75)
3	(0,9.25)
4	(0,9.5)
5	(0,25)
6	(-4,-21)
7	(2,-23)

3. Measurements and simulated results

The simulated return loss of the antenna is shown in Fig. 4. The antenna was fabricated and returns loss of the antenna was measured using Spectrum analyzer (FSH6, ROHDE&SCHWARZ) and shown in Fig. 5.

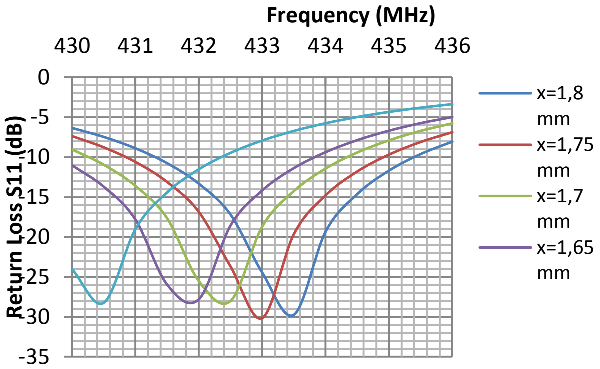

Fig. 4. Simulated return loss at 433 MHz for different x values.

The antenna is simulated for 5 other values for antenna and ground plane distance. Fig. 4 shows the return losses of the proposed antenna for different antenna and ground plane distance. The ideal value is seen as 16.65 mm in Fig. 4. The -10 dB bandwidth in simulation of the proposed antenna is from 431 MHz to 434.5 MHz, 3.5 MHz.

The simulated radiation patterns of the proposed antenna are shown in Fig. 6, Fig. 7 and Fig. 8 respectively. The 3-D radiation pattern of the antenna is doughnut-shaped as expected for the general radiation pattern for a half-wavelength dipole.

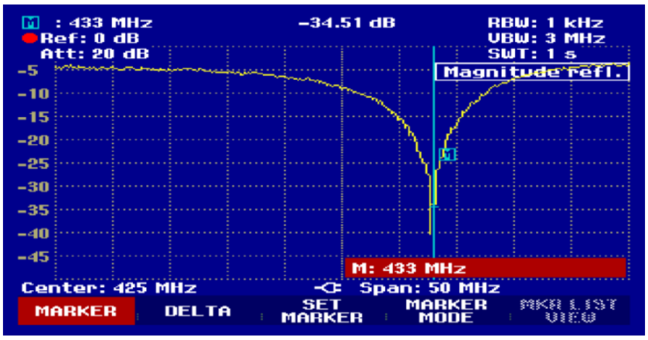

Fig. 5. Measured return loss of proposed antenna.

Fig. 6 shows 2-D polar plot which illustrates the radiation for the φ=90 degrees with angle θ that varies from 0 to 180 degrees. Also Fig. 7 shows the 2-D polar plot which illustrates the radiation for the θ=90 degrees with angle φ that varies from 0 to 360 degrees. The pattern is almost omnidirectional with two nulls in the whole 360 degree coverage.

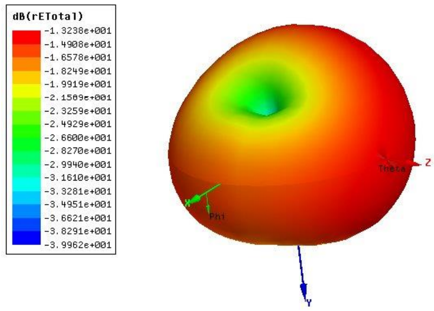

Fig. 6. 3-D radiation pattern for proposed antenna.

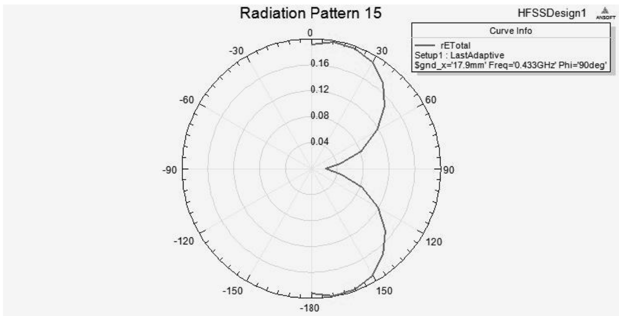

Fig. 7. Polar radiation pattern for φ=90°.

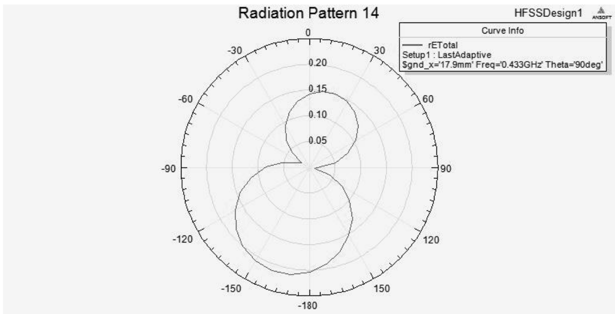

Fig. 8. Polar radiation pattern for θ=90°.

Fig. 9 shows the simulated electric current flow and distribution on the Tangent Circles antenna.

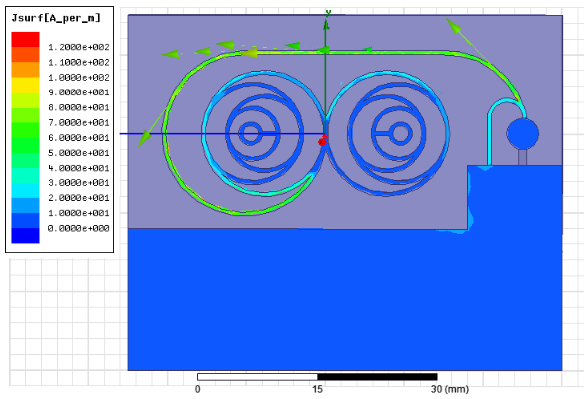

Fig. 9. Simulated current flow and distribution of the proposed antenna at 433 MHz.

Fig. 10 shows the gain pattern of the antennas. The achieved max gain from the antenna was around -12 dBi.

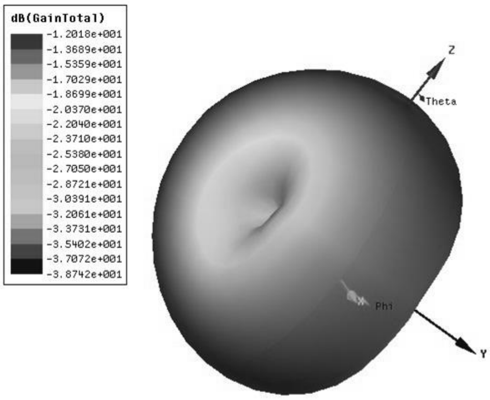

Fig. 10. Gain pattern of the antenna.

Table 3 gives performance comparison between proposed antenna and some other antennas reported recently.

Table 3. Comparison of Antennas performance.

	Width (mm)	Length (mm) (ground plane included)	Min S_{11} (dB)	Gain (dBi)
This work	45	55	-34.51	-12
Ref. [4]	51	82	-18	-4.3
Ref. [5]	37	50	-23	-6.1
Ref. [10]	55	103	-23	-2.5
Ref. [11]	30	80	-18	-15

4. Conclusions

In this study, an antenna has been designed at 433 MHz for RFID applications. It has been observed that the operating frequency can be adjusted through changing the ground plane of the designed antenna and the distance. According to the simulation results which were made at different distances, 17.85 mm was chose for the designed antenna.

The advantage of using this kind of an antenna is that it does not use any lumped component to match the antenna at the operating frequency.

The -10 dB bandwidth of the proposed antenna is from 427 MHz to 437 MHz, 10 MHz. This value covered the corresponding ISM Band.

The S_{11} value belonging to the antenna prepared by Babar and his colleagues has been used for simulation -15 dB, and -15 dB for the measurement [11]. It is observed that the value of S_{11} is about -34 dB when the recommended antenna is measured in the same frequency. Also, the dimensions of the proposed antenna are smaller than the antenna prepared by Liu and his colleagues [4].

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