3D Antenna for UHF RFID Tags with Near Omni-direction

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***Abstract* - An improved design of 3D antenna for passive UHF RFID tags is presented. Tags using the proposed near Omni directional antennas are situated in three orthogonal planes. Due to the combined magnitude of the electric field components for two orthogonal polarizations of the designed 3D antenna, the passive tag is invariant to its orientation. The shorted load is introduced to fix the situation of the two arms of the antenna. Through the adjustment of the height of the bifurcation point from the end of the two arms, the fine match of given ASIC and the designed antenna is acquired. The new type is similar to the carrier tape and can be made easily.**

Key words- RFID, Tag antenna, 3D, omni-direction.

I. Introduction

RFID is gaining increasing popularity in the identification of objects in the various supply chain around the world [1] [2]. Since an unread tag may cause significant economic loss or security threat [3], 100% readability is a desiderata for wide practical applications. A tag must be readable in any position though it can be oriented arbitrary with respect to reader antennas. However, today most of the commercial tag antennas are typed with the structure of conventional half-wave length planar dipole or its variations. As we all know, the radiation pattern of a dipole has zeros along its wire axis. Thus, with the zero direction, the tag receives no enough energy to be activated. This problem might be overcome by two ways:

i). Using several reader antenna situated slightly unparallel to each other [4];

ii) Using RFID tags with inconspicuous directivity and read orientations sensitivity, such as a double-dipole tag incorporating two orthogonally placed dipoles [5].

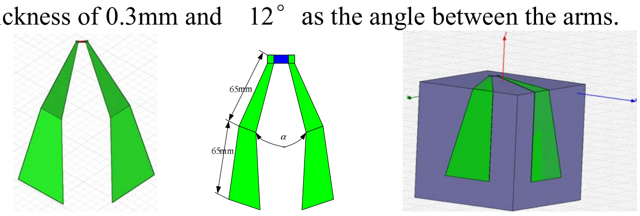
Paper [6] gives a 3D tag antenna deign with near Omni direction, operating within 866-869 MHz. With the adjustment of the angle between the two antenna arms, the tag is reliably identified independently on its orientation under the designed frequency band.

In this paper, an improved antenna type based on paper [5] is presented, but operates within 902-928MHz. Due to the inconvenience of changing the angle in actual application, the introduction of the shorted load fastens the relative position of the two arms. Different from the adjustment of the angle to match with the chip, this paper adopts a bifurcation method. With proper bifurcation height, the work frequency and the pattern conform to the design indicator. Besides the good performance, the design has an outstanding appearance alike the carrier tape, which is available in packing service. The design may integrate the two functions: identification and packing, to widen its practicability and reduce the cost.

II. Antenna Design Process

A. 3D Tag Antenna Design

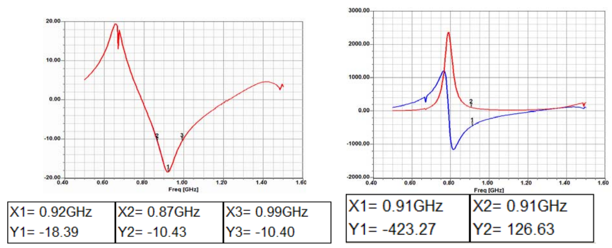
Figure.1 shows the suggested 3D antenna for UHF RFID tags. The two arms are situated on three orthogonal planes, with the thickness of 0.3mm and 12° as the angle between the arms.



(I) (II) (III)

Fig.1.Structure of the designed antenna: the protype (I), dimension (II), and tag placement on a cardboard box corner (III).

The tag antenna under consideration was designed for RFID ASIC in TSSOP-8 package with the input impedance Z_{in}=12-j422 Ohm. The parameters computed with the Finite Element Method (FEM) are shown below.



(I)

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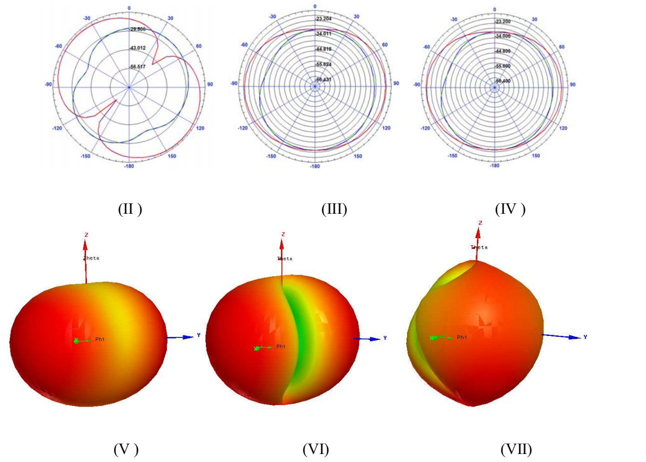


Fig.2 Parameters for the given antenna: Return loss and wave port impedance (I), planar pattern, E_θ, E_φ, θ=90° (II), E_θ, E_φ, φ=90° (III), E_θ, E_φ, φ=0° (IV), and 3D pattern (V), 3D *rETheta* (VI), 3D *rEPhi*(VII).

From Fig.2, we can find the antenna resonates at 920MHz and the -10dB bandwidth is 13.04%, the corresponding wave port impedance at 910MHz is about 126.63+j423.27.

The radiation efficiency can be got from the formula [7] below:

$$P = \frac{4R_a R_c}{(R_a + R_c)^2 + (X_a + X_c)^2} \tag{1}$$

where R_a and R_c separately refer to the resistances of the tag antenna and the ASIC, while X_a and X_c are corresponding reactance.

According to (1), the radiation efficiency of the given antenna at 910MHz is 46.25%. Obviously, the port impedance is a bit large for the match with the ASIC.

B. *Adjustment of the impedance of the antenna designed*

In paper [6], the fine match between tag antenna and the ASIC results from the adjustment of the angle of the two arms. Due to the complex of the 3D structure and the robustness of the antenna integrity, it is not easily controlled for the angle.

According to the transmission line theory, the adding of shorted load may strengthen the self coupling of the antenna arms [8]. Thus, with proper load position, the impedance may efficiently be reduced to the matching dot. Besides, the adding of the shorted load fixes the angle at 12° and reinforces the stability of the antenna structure.

From Fig.3, the loaded antenna resonates at 880MHz and the -10dB bandwidth is from 820MHz to 980MHz. At 920MHz, the port impedance is reduced to 50.04-j310.33. The radiation efficiency is only 6.028%. The radiation pattern varies small.

It is clear that the linkage of the shorted load is approximately equal to improve the effective lengths of the antenna arms. The position and the width of the shorted load have a severe effect on the radiation properties.

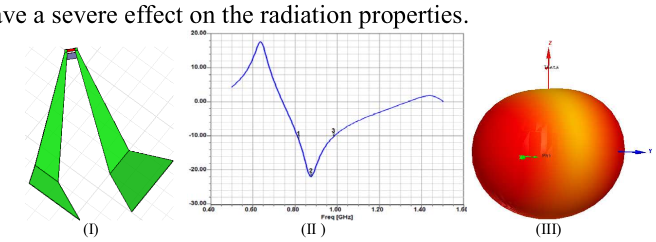


Fig.3 Position of the Adding of the shorted load (gray shadow) (I), Return loss (II) and 3D pattern (III)

It is fussy to definite the perfect position and the width of the shorted load. In this paper, we put focus on the improvement of the antenna arms. Here, we adopt local shorted load form and make it better by the adjustments of the arms.

For convenient design, we provide a bifurcate method from the end of the antenna arms. As shown in Fig.4.

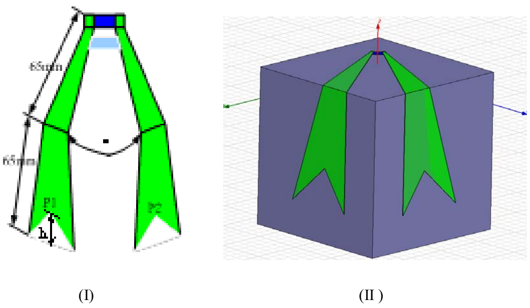


Fig.4 Structure of the bifurcate antenna (I) and the tag placement on a cardboard box corner (II)

In Fig.4 (I), h is the height of the triangles cut from the end of the arms. The two arms have symmetrical structure and are situated on the adjacent planes of the cardboard box. The angle between the two arms is fixed at 12° for the existence of the shorted load.

The performance parameters of the provided antenna change along with h. Table 1 and Fig.5 lists the tendency of different h with resonate frequency, -10dB bandwidth and port impedance.

As shown in Table.1 and Fig.5, we can see that the tendencies for resonate frequency, impedance and bandwidth with the mutative height of the triangle cut from the antenna arm' end, are almost accordant.

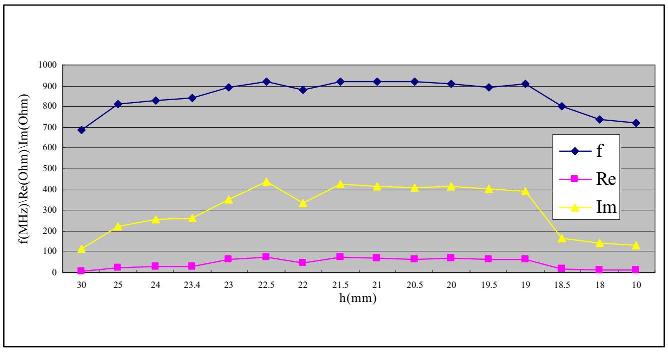
For the fine matching of the antenna under design and the ASIC and the consideration of work frequency, 19mm was chosen as the value of h.

In this case, the results from FEM calculation show in Fig.6.

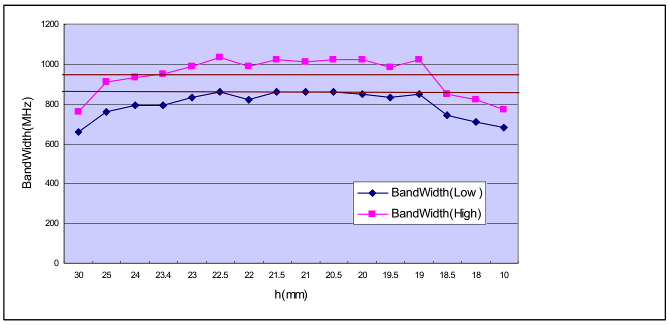
When 19mm height triangles were cut from dipole arms of the 3D tag antenna, just like the structure in Fig.4, the resonate frequency appears at 910MHz, besides a wide work frequency band from 850MHz to 1.02GHz. At 910MHz, the antenna owns wonderful radiation efficiency at 99.62%. The patterns reveal no

Table.1 List of variable antenna properties along with spur heights

h（mm）	f（MHz）	Bandwidth （MHZ）	Z (910MHz) (Ohm)
30	690	660~760	7.51+j111.19
25	810	760～910	24.63+j219.9
24	830	790～930	28.79+j256.54
23.4	840	790～950	29.17+j260.5
23	890	830～990	60.83+j354.52
22.5	920	860～1030	76+j438.88
22	880	820～990	45.61+j332.48
21.5	920	860～1020	72.59+j426.06
21	920	860～1010	70.16+j415.96
20.5	920	860～1020	63.31+j407.08
20	910	850～1020	69.36+j414.70
19.5	890	830～980	61.29+j401.25
19	910	850～1020	60.02+j392.01
18.5	800	740～850	14.36+j164.58
18	740	710～820	11.36+j144
10	720	680～770	10.06+j129.86



(I)



(II)

Fig.5 Tendency of variable antenna properties along with spur heights: resonate frequency, impedance (I), bandwidth (II), in which the upper garnet line refers to 960MHz scale, while the lower, 860MHz.

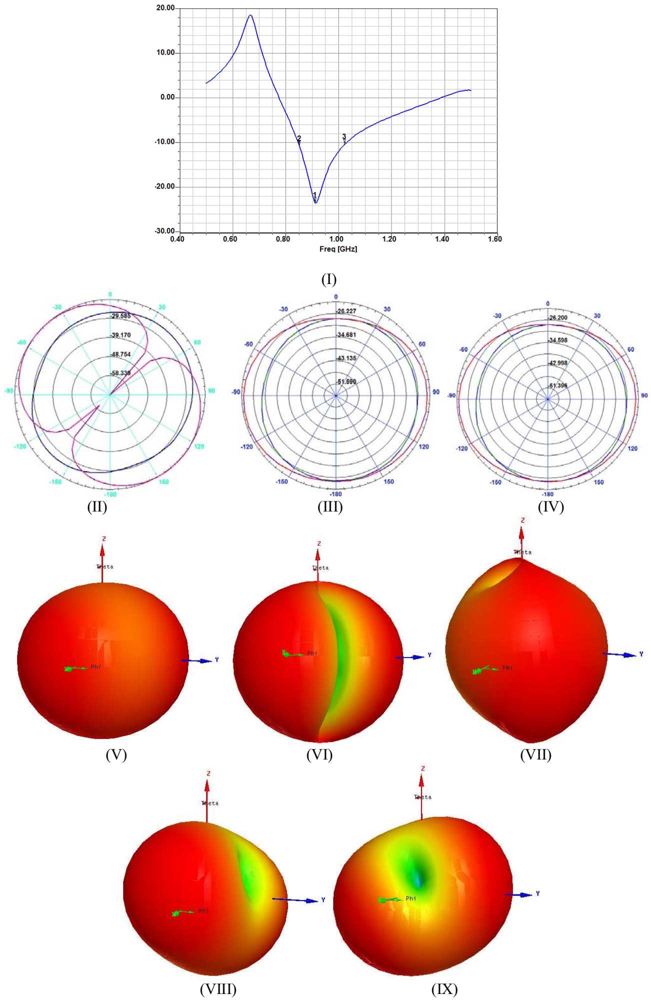


Fig.6 Properties for antenna under designed with triangles cut from dipole arms at a height of 19mm: return loss (I); Plane pattern, *Theta*=90° (II), *phi*=90° (III) and *phi*=0° (IV); Solid pattern (V), 3D *rETheta* (VI), 3D *rEPhi* (VII) and Polarization Ratio Circular LHCP (VIII), Polarization Ratio Circular RHCP (IX).

distinct disparity in all directions. The field intensity well distributes around the spheroid space.

III. Theory Analysis of Near Omni-direction for the Proposed 3D Antenna

Different from the traditional planar dipole antennas, the 3D antenna, whose arms were situated in three orthogonal planes, possesses two orthogonal polarizations. The minima for one polarization correspond to the maxima for the orthogonal polarization. Due to the equivalent length at the bent point, which in this paper is 65mm to 65mm, the distribution of the electric field evenly occupies the space around. Furthermore, the solid structure of the tag antenna can be activated by reader antennas with two orthogonal polarizations, linear or circular.

Thus, the 3D antenna with near omni-directiona coverage by the combined magnitude of the electric field components for two orthogonal polarizations is insensitive to direction when it is put on a cardboard box corner. In addition, the attributes of the cardboard box has a severe effect on the antenna performances. In this paper, the cardboard box with 2.0 as its permittivity is considered.

IV. CONCLUSION

A new kind of 3D RFID tag antenna is given in this paper. The single arm is just like a bent machete. A shorted load is introduced to fix the integral to strengthen its robustness. In order to fine match the designed antenna and ASIC, a triangle is cut from the end of each arm. The height of the triangle plays a key part in the performances of the antenna under designed. The solid structure of the antenna with near omni-direction eliminates read-orientation sensitivity. The 3D tag antenna can be read independently on their orientation. With the shape alike a carrier tape, the tag looks pleasing, economical and practical. This may come true in gift-wrap or analogous fields.

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