Tunable Folded-Patch UHF RFID Tag Antenna Design using Theory of Charateristic Modes

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***Abstract*—In this paper, a tunable ultra-high frequency (UHF) radio frequency identification (RFID) tag antenna is proposed by using characteristic modes analysis. The proposed tag consists of a folded-patch and a feeding loop stacked on two substrate layers. The folded patch wrapped around 2 mm thick FR4 substrate and is optimized using characteristic modes to resonate around 915 MHz. The inductive feeding loop provides matching with RFID chip. This tag covers American RFID band form 905 MHz to 928 MHz with 10 dB return loss and can be tunable to European band by adding copper strips. Moreover, the proposed design is low cost, because it does not require any via or shorting pin. Furthermore, the measured read range of this tag is 3.5 m and 5.5 m in free space and above 200x200 m^2 metal plate respectively.**

Keywords—Radio frequency identification; Characteristic modes; Tunable; Impedance matching;

I. Introduction

Radio frequency identification (RFID) in collaboration with Internet of things (IOT) has opened the door to a new paradigm. Both technologies are becoming prevalent in research and have been emerging in numerous industrial applications. The ultra-high frequency (UHF) RFID tags are more attractive to use in plenty of applications because of their simple, low cost structures and long reading range as compared to Low frequency (LF) and High frequency (HF) RFID bands. The widespread use of RFID technology requires tagging of different challenging surfaces such as metal, water food items and other high permittivity dielectrics. However, the tagging of metal based objects are more difficult due to different radiation boundary conditions [1].

There are many designs and techniques have been reported in literature to solve the tagging issues of these problematic surfaces. A small folded patch antenna with serrated edges was proposed in [2] for metallic surfaces. The antenna was fabricated on 3mm thick substrate and RFID chip is mounted on vertical edge, which is more vulnerable to damage and difficult to fabricate. Another dual layer PIFA design was introduced in [3] for platform tolerant applications. However, this design is costly and its performance is highly dependent on position of vias. A single layer loop based RFID tag antenna was designed in [4] for metals and low permittivity dielectrics. Although, this design is compact, the major drawback is the thickness of substrate (3mm). Another solution was proposed [5]in order to design RFID tag antenna using the theory of Characteristic Modes (CM). In [6], a small RFID tag antenna was presented by exploiting the metal object as a radiator and exciting it using inductive load. The use of CM theory was not new in antenna design applications. It was first proposed by Garbacz and later redefine by Harrington and Mautz. However, in recent years, it was revisited and used to get physical insight in antenna designing for modern applications [7].

This paper presents a tunable UHF RFID tag antenna design using Characteristic modes. The proposed design consists of folded-patch and a small inductive feeding loop. The folded-patch is optimized using characteristics modes to resonate around 915 MHz. This tag covers the US RFID band and can be tubule to the European band by adding two copper strips.

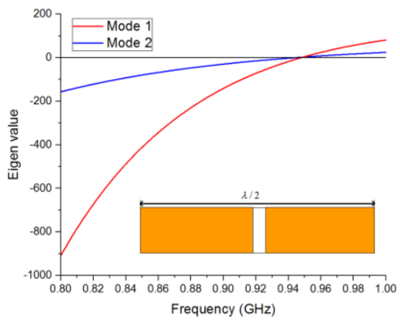
II. Antenna Design Using Chracteritic Modes Analysis

Characteristics modes can be derived by solving eigenvalue equations obtained from Method of Moments (MoM) based impedance matrix as follows:

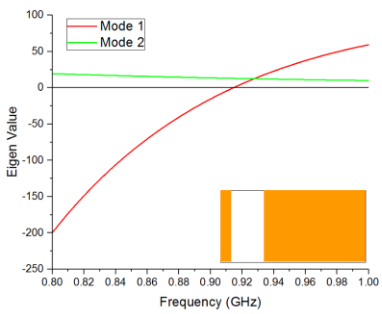
$$[X][J]_n = \lambda_n [R][J]_n$$

Where the R and X are real and imaginary components of MoM impedance matrix, J_n are eigencurrents and λ_n are eigenvalues

Staring from a metal plate ($\lambda/2$) above a grounded substrate resonate around 2 GHz. After creating a small slot, it acts like a $\lambda/2$ dipole. The resonating modes of $\lambda/2$-patch are shown in Fig. 1a. The two modes are resonating near 920 and 940 MHz respectively. However, the length of this patch is more to use it as RFID tag. Therefore, a patch is folded and wrapped around 2 mm thick FR4 substrate in order to make a small RFID tag and offset slot (similar to offset feed) approach is exploited to further shorten the length of tag antenna.



(a)



(b)

Fig. 1. (a) Eignvalue plot of $\lambda/2$ patch on a finite ground plane (b) Eignvalue plot of proposed folded patch on a finite ground plane

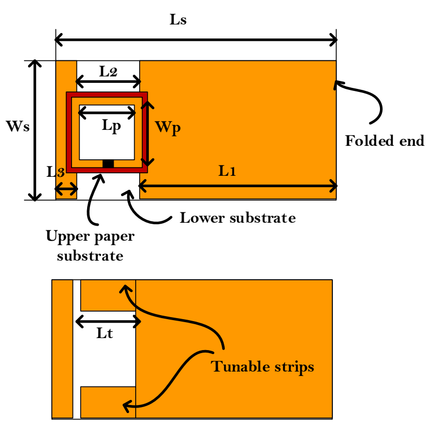


Fig. 2. Diemsions (mm) of Proposed tag antenna ($Ls=50, Ws=25, L_1=38.5, L_2=8.5, L_3=, Lp=18, Wp=12, Lt=8$)

Furthermore, the folded patch is optimized to resonate around 915 MHz using Multilayer solver of CST Microwave Studio. As it can be seen from Fig. 1b, the two modes for this folded patch, one mode is resonating near 915 MHz (Eigen value zero) and the other mode is an inductive mode. In order to excite these modes, the tag is loaded with an inductive feeding loop placed above the slot on a 0.25 mm thick paper substrate. The antenna is simulated and optimized further to tune at 915 MHz. The dimensions of proposed antenna are shown in Fig. 3. Furthermore, this antenna can be tunable to European RFID band by adding two copper strips as illustrated in Fig. 2.

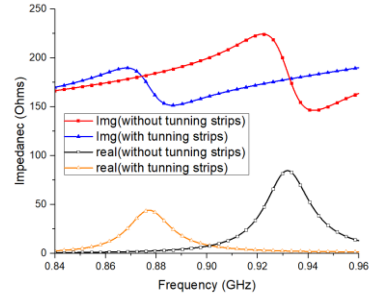


Fig. 3. Simulated impednace of Proposed RFID tag antenna

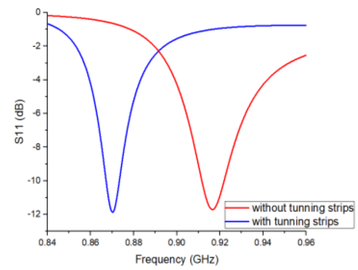


Fig. 4. Simulated S11 plot of Proposed tag

Fig. 3 shows the simulated impedance of proposed tag with and without tuning strips. It is clear that antenna has good impedance match with the Alien Higgs-3 RFID chip (27-205j). The simulated return loss of RFID tag antenna is illustrated in Fig. 4.The antenna is work in US RFID band without tuning strip and tuned to European band with tuning strips.

III. Conclusion

In this paper, a tunable folded patch UHF RFID tag antenna design is proposed using Characteristic mode (CM) analysis. This tag antenna able to cover both American and European RFID band by tuning strips. Moreover, the measured read range of fabricated RFID tag is 3.5m and 5.5 m in free space and above 200x200 m^2 metal plate.

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