Vehicular LF/UHF Antenna Design for PKE System Applications

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1. INTRODUCTION

Passive Keyless Entry (PKE) systems are the next step in automotive security and access. Convenient vehicle security is often a primary consideration for both drivers and the automotive industry. RF identification (RFID) technology has been providing the security aspect with immobilization systems for some time, and now with the latest developments in PKE controller accesses could not be more convenient. The PKE systems allow drivers to enter their vehicles without any explicit action to unlock them, as authorization is granted simply by carrying the appropriate ID device or tag. The PKE in action with two parts: base station (Vehicle) and device (Key), there are two operating band: LF (125 KHz) and UHF (433 MHz) are used [1], as shown in Fig. 1. In the vehicles base station, the unit sends out (LF) to order, periphery search device. Once vehicle owner's responder is searched, this responder automatically responds to base station immediately. The base station after receives the effective confirmation response signal to turn on the vehicle door. In order to examine the low frequency magnetic field, usually must use the harmonious annular antenna. The annular antenna must tight alignment to cause the highest antenna voltage. Regarding to the PKE application, the antenna resonant frequency should be same with carrier frequency of base station. The annular antenna (inductance) and several electric capacities are composed by a constitution parallel L-C acceptor coil. Through increases the ring circuit surface area and the electric circuit quality factor (Q) to cause the antenna voltage to be the biggest [2]. In the long distance application, the responder uses the UHF (433 MHz) transmitter. Generally, the UHF antenna is the wiring metal-line which around the PCB, the transmitting distance increasing with the ring circuit area increasing. But, the physical situation is the space of device in not enough for LF and UHF antenna to be implemented by using three antennas positioned mutual-orthogonal on identical PCB or annular type. In this literature, a compact size spiral antenna with dual operating frequency is presented [3], the slow wave effects were used to reduce the size of the antenna [4-5], a driven spiral monopole and loading components (inductor L paralleled capacitor C), that are located respectively on both sides of the proposed antenna, the relative lower resonant frequency was obvious. This antenna combines omni-directional, simple impedance matching to the feed line and low profile in an easily to fabricated structure. Details of the design considerations of the proposed designs and the experimental results of constructed prototype are presented and discussed.

2. ANTENNA DESIGN

A dual-band antenna consists of a driven spiral monopole and loading components (inductor L paralleled capacitor C), that are located respectively on both sides of the proposed antenna is shown in Fig.2.

In Fig.2, the PCB size: length is 5cm and width is 3cm. The part A is consisted of inductor and capacitor, and connects to ground-plane. The end of spiral antenna is through via to connect to Part A. The figure 2 is the elementary structure of slow wave effect. The main purpose of slow wave is to reduce the phase velocity of wave propagation by increasing the resonant reactance (L and C) of antenna, the relationship as below:

$$V_p = 1/\sqrt{\mu\varepsilon} \quad (1)$$

Increasing L (μ) and C (ε) will reduce the phase velocity. In this literature, the resonant mode of total spiral-length is designed to occur at about 433 MHz. The length of radiating elements can be determined from the quarter-wave length at the resonant frequency. Spiraling the monopole-trace will increase the C of antenna, adding the inductor parallel capacitor on the end of spiral, and that connects to ground-plane, it will cause obviously slow wave effect to introduce lower resonant frequency. The value of inductor and capacitor of extra adding components are depended on the lower frequency 125 KHz, as below:

$$f = 1/(2\pi\sqrt{L^{'}C^{'}}) \quad (2)$$

Based on the Eq. (2), we can get $L^{'}$ and $C^{'}$, therefore the spiral structure has equal value of L and C; so the difference value between $L^{'}-L$ and $C^{'}-C$, we will add extra inductor and capacitor to compensate. The relationship of phase velocity and wavelength as below:

$$V_p = \lambda f \quad (3)$$

If resonant frequency is fixed, then reducing the phase velocity will let the wave-length λ to be decreased. The wavelength is related with antenna size, so reducing phase velocity will decrease antenna size. The slow wave effect can be changed by adjusting the spiral trace-width.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The total spiral-trace length is 13cm, the inductor is 100nH and capacitor is 470uF. Fig. 2 shows the measured VSWR of proposed antenna. For the VSWR of 2:1, the upper operating bandwidth is 28MHz (423-451 MHz) with the center frequency of 433 MHz; the lower operating frequency 125 KHz is difficult to measure by network analyzer, we will direct to setup the transceiver to check the antenna performance.

The radiation pattern of 433 MHz is shown in Fig.4. The radiation in the xy-plane is close to omni-directional, the maximum gain in the xz-plane (E-plane) is 0.19 dBi as shown in Fig. 4(a) and xy-plane (H-plane) is 0.34 dBi as shown in Fig. 4(b). The physical transmitting and receiving distance can over 10m. About the 125 KHz antenna testing, we use the multiplexer to produce ASK modulation signal to input the proposed antenna, and using another proposed antenna connects to MCP2030 (Microprocessor), 3m away to receiving the ASK signal to demodulate, as shown in Fig. 5. The measurement results show the good performance for proposed antenna working in 125 KHz.

4. CONCLUSION

A spiral monopole antenna with loading component (inductor is parallel capacitor) for vehicle application in passive keyless entry (PKE) system is proposed. The frequency range of proposed antenna can cover LF (125 KHz) and UHF (433 MHz) bands. The slow wave effects were used to reduce the size of the antenna, if varying the width of spiral resonator where has the large current density, the relative lower resonant frequency was obvious. Experimental results of the constructed prototype had been presented to illustrate novelty of antenna characteristics. The omni-directional effects on the operating bands of the proposed antenna had also been addressed.

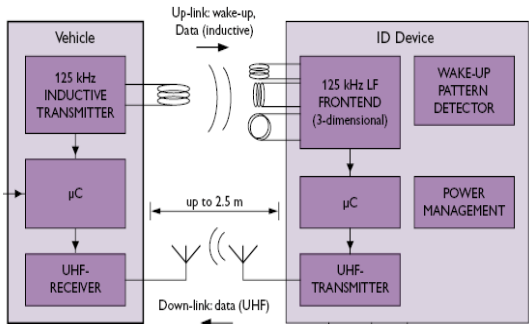


Fig. 1. Bi-directional PKE system.

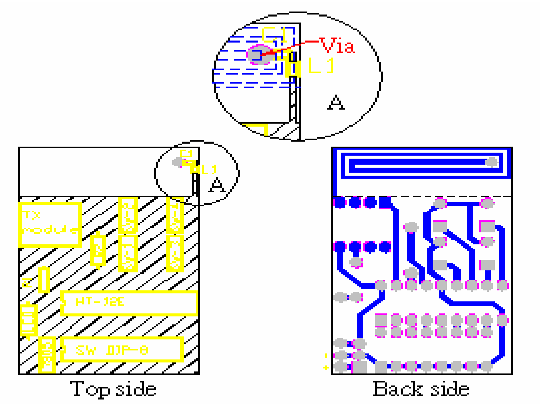


Fig. 2 The proposed antenna for PKE device.

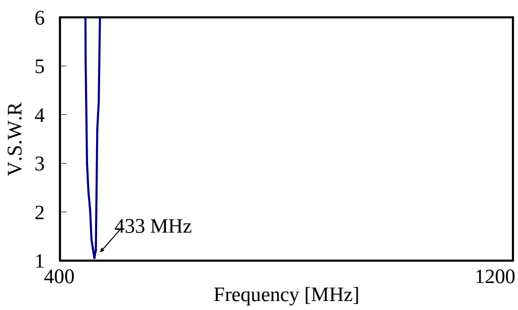
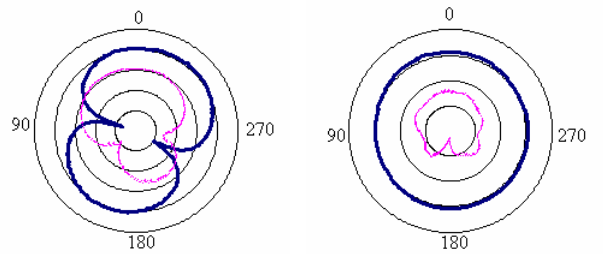
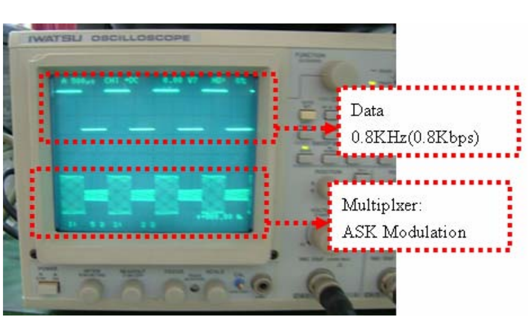


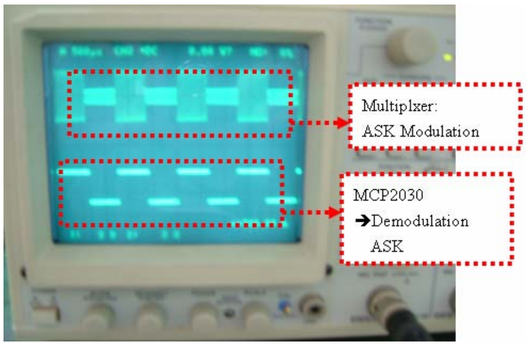
Fig. 3. Measured V.S.W.R of proposed antenna.



(a) (b)

Fig. 4. Measured radiation patterns for the proposed Antenna at 433 MHz."—co-pol.""... cross-pol."
(a) E-plane (xy-plane) pattern. (b) H-plane (xz-plane) pattern.





(a) (b)

Fig.5. The testing method for verifying 125 KHz antenna performance.

(a) ASK modulation signal.

(b) Demoulation ASK signal.

Acknowledgements

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