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# Planar inverted-F antenna for radio frequency identification

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A small and low-cost antenna solution for radio frequency identification (RFID) tags is presented. The impedance of the antenna is designed to match directly to the impedance of the RFID microchip. Also, the impedance of the antenna is immune to the platform. Thus, the antenna is applicable in many different environments. The design and measurement results are reported and discussed.

**Introduction:** Radio frequency identification has lately gained much interest in several service industries. Inductively coupled short-range RFID is already widely used, but demand is growing in the field of long-range identification, where electromagnetic waves and an antenna are used for coupling [1]. However, many challenging features are required from the antenna intended to be used in long-range RFID tags. First, the antenna has to be really small, preferably low-profile, in order to be usable. Secondly, the fabrication has to be inexpensive, since RFID tags are generally designed to be disposable. In passive systems the signal power received by the antenna supplies the microchip. Thus, a perfect impedance match between the antenna and the RFID microchip is essential in order to sustain the power supply of the chip. The impedance level of the chip usually differs from the common 50 Ω case, and the matching has to be direct, since matching networks cannot be used because of the cost and size limitations. More importantly, the matching has to hold in any environment. Since in RFID applications tags are attached directly to different kinds of objects, the impedance tolerance to the platform is a key issue.

Printed dipole antennas may be used in RFID tags, but their performance is highly platform dependent. Conversely, microstrip patch antennas are more tolerant to the effects of the platform, but are very large in size. By using a planar inverted-F antenna (PIFA) structure smaller size may be achieved, but generally at the cost of reduced tolerance to the environment [2]. To meet the challenging demands of long-range RFID, a platform-tolerant design of PIFA is presented in this Letter.

**Antenna design:** The geometry of the developed antenna is presented in Fig. 1. At the operation frequency of 869 MHz the antenna is only 3 mm (0.013λ) high and the patch is 45 mm (0.19λ) wide. The patch and the ground plane are square in shape. The antenna is filled with Teflon in the area under the patch. According to preliminary experiments cheaper polyethylene may also be used.

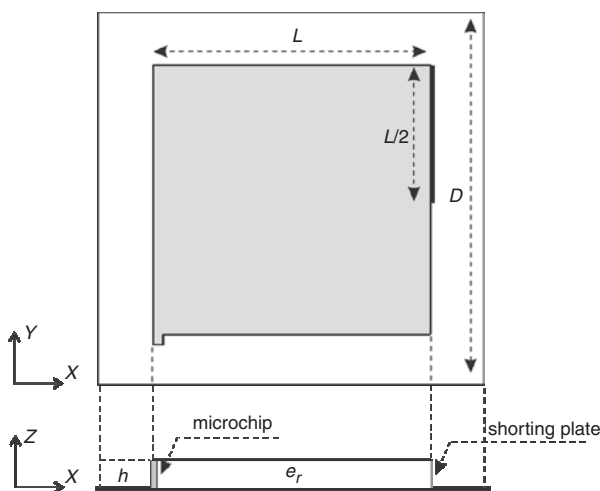


Fig. 1 Antenna design

The microchip feed is placed on one corner and the shorting plate is half the width of the patch edge. In this case the impedance of the antenna is matched to  $(7 - j170) \Omega$ . With this design it is possible to achieve immunity to different platforms. The ground plane is optimised to be as small as possible (59 mm or  $0.25\lambda$ ), while still providing the

impedance tolerance to the platform. However, the antenna is rather narrowband and the radiation is almost omnidirectional. Usually these features lead to platform-sensitive impedance behaviour, but in this case also the right radiation mode plays an important role. The main current flow is directed diagonally from the shorting plate to the feed. The patch is not in resonance and there is no dual-resonance with the ground plane near 869 MHz. In addition, it was discovered that with the presented design the radiation from the shorting plate is reduced, leading to better tolerance to different platforms.

**Experimental results:** The antenna performance was verified with a scattering measurement technique. A microchip with an input impedance of  $(7 - j170) \Omega$  was attached as a feed of the antenna. The chip contains a 200 kHz oscillator which modulates the input reactance of the chip, causing a phase modulation of the backscattered signal. The modulation starts if the chip is fed at least with  $10 \mu\text{W}$  of input RF power. As the limiting power is known, the transmitted power  $P_{tx}$  needed to wake up the chip is measured against the frequency to determine the antenna bandwidth, and against the antenna alignment to determine the antenna radiation pattern, i.e. the effective antenna aperture including mismatch is measured. Both the input impedance and the required power level of the chip are similar to that of the RFID chip in the passive long distance multiple access UHF RFID (PALOMAR) system [3].

The performance of the antenna has been studied with different platforms. The results of the bandwidth measurements are presented in Fig. 2 and in Table 1. In Fig. 2 all the peaks have been scaled to 0 dB. The bandwidth is defined as the half-power bandwidth of the antenna aperture, which is equivalent to +3 dB in required transmitted power  $P_{tx}$ . As seen from Fig. 2 and Table 1, the centre frequency varies only  $\pm 1$  MHz around the operation frequency of 869 MHz. Also, the bandwidth varies only from 15 to 17 MHz. It is clear that the impedance and bandwidth variance against different platforms is minimal, indicating very good tolerance to different platforms.

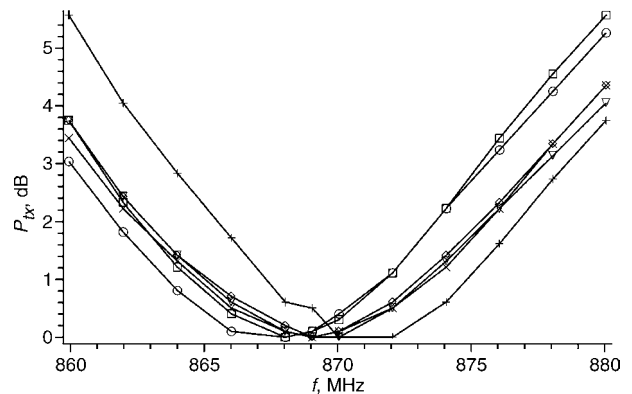


Fig. 2 Results of bandwidth measurement

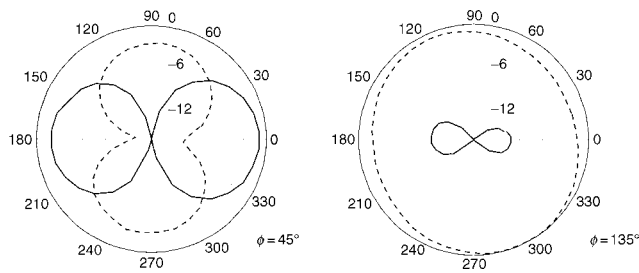
- + — free-space
- ◊ — metal 150 × 150 mm
- ▽ — metal 600 × 600 mm
- ○ — wood
- □ — PVC plastic
- × — water canister

Table 1: Measured centre frequencies and bandwidths

Platform	Centre frequency [MHz]	Half-power bandwidth [MHz]
Free-space	870	15
Metal 150 × 150 mm	869	17
Metal 600 × 600 mm	869	17
Wood	868	16
PVC plastic	868	15
Water canister	869	17

The co- and cross-polarisation radiation patterns measured with the scattering technique are presented in Fig. 3. It is evident that the antenna is rather omnidirectional with a simulated directivity of only 1.5 dBi. Also, the antenna has a rather high cross-polarisation level, which has to be considered in developing the reader device. Otherwise the orientation of the tag may have a major impact on the reading

reliability. Also, the three-dimensional radiation patterns were measured with a traditional far-field measurement system. From these results the radiation efficiency could be calculated exploiting the spherical wave expansion. The radiation efficiency of the antenna varied between 50 and 60% depending on the platform.



**Fig. 3** Measured radiation patterns

—  $E_\phi$   
 - - -  $E_\theta$

**Table 2:** Maximum reading distances

Platform	Maximum reading distance, m
Free-space	2.0
Metal 150 × 150 mm	5.1
Metal 600 × 600 mm	4.3
Wood	3.9
PVC plastic	3.2
Water canister	2.0

The maximum reading distances were studied with the PALOMAR system, using the maximum allowed transmission power of 0.5 W ERP. The reading distances of the antenna on different platforms are

presented in Table 2. Because of different directivity values on different platforms, the reading distances vary between 2 and 5 m. It is clear that the antenna operates satisfactorily on every tested platform, but the best performance is achieved on metal.

**Conclusions:** A compact and low-cost antenna applicable to RFID tags has been developed. By using a certain design an RFID microchip may be directly matched to the antenna. More importantly, a platform-independent impedance behaviour can be achieved. Also, the antenna has adequate bandwidth and radiation characteristics. Because of these features, the antenna is applicable in several RFID environments, e.g. on metal, wood and plastic surfaces or even on a water canister.

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### References

- 1 Finkenzeller, K.: 'RFID handbook' (John Wiley & Sons, Chichester, UK, 2003)
- 2 Huynh, M.C., and Stutzman, W.: 'Ground plane effects on planar inverted-F antenna (PIFA) performance', *IEE Proc., Microw. Antennas Propag.*, 2003, **140**, (4), pp. 209–213
- 3 The Palomar project: 'Passive long distance multiple access UHF RFID system', European Commission, Public Report, Project Number IST1999-10339, November 2002