Frequency and Polarization Agile RFID Patch Antenna with Reduced Dimensions

(Article begins on next page)

Frequency and Polarization Agile RFID Patch Antenna with Reduced Dimensions

Enrico Tolin, Francesca Vipiana
Dept. of Electronics and Telecommunications
Politecnico di Torino
Torino, Italy
enrico.tolin@polito.it

Achim Bahr, Simona Bruni
Dept. of Antennas and EM modeling
IMST GmbH
Kamp-Lintfort, Germany
achim.bahr@imst.com

***Abstract*— This paper presents a frequency and polarization reconfigurable UHF RFID patch antenna based on a switchable feeding network. For best integration of the antenna, its size and ground plane are much smaller with respect to the canonical patch antenna design, however the proposed design is able to cover the EU and US frequency bands of the RFID standard. State-of-the-art CMOS switches are employed as key element for selecting the desired polarization and proper matching network. The switches provide also a simple solution for high power applications in contrast to concepts based on PIN diodes or varactors. Simulated results have shown good performance. Considering its flexible and inexpensive structure, the proposed system is a promising alternative to aperture tuning and circular polarized antenna approaches.**

Keywords — UHF RFID, frequency agility, polarization agility, reconfigurable feeding network.

I. Introduction

Ultra High Frequency Radio Frequency IDentification (UHF RFID) is used worldwide in a variety of application ranging from identification to tracking, with a specific operating bandwidth for different regions, such as the 865 - 868 MHz band in Europe, the 902 - 928 MHz band in the United States [1]. In this work we propose to employ frequency reconfigurability as a solution for covering the Europe and US standards with just one antenna, instead of two different designs as usually done. Moreover, a critical aspect of the interaction between RFID reader and tags involves the orientation of the electric field between the two elements. In fact, RFID tags are typically linear polarized, while the reader is designed as linear polarized if the position of the tag is fixed, otherwise a circular polarized (CP) antenna is used. However, the use of CP antenna brings to a polarization loss factor (PLF) of 3 dB when receiving linearly polarized waves. In this paper, four linear polarization are used to reduce the PLF. In fact, it is noticed that if the 0° (horizontal), 90° (vertical), 45° and -45° are used, a maximum PLF of 0.7 dB (corresponding to a polarization angle mismatch of 22.5°) is obtained.

II. Design and Simulations

RFID readers are typically integrated in a multitude of devices, and dimensions play a significant role in the design of the antenna. For this reason, the reconfigurable feeding network is applied to a patch antenna with reduced dimensions and including an electrically small ground plane. The antenna is a double pin feeding patch antenna realized in standard FR4 with thickness of 0.5 mm and total size of 60 mm x 60 mm. The feeding pins are inserted along the mid axes. The overall height of the antenna system is 20 mm, while the ground plane is a square metal plate with 95 mm side length, printed on the same substrate material with thickness 1.55 mm. Size reduction is obtained by connecting the patch with four fixed capacitors (all with same capacitance) through metal posts, as is highlighted in Fig. 1.

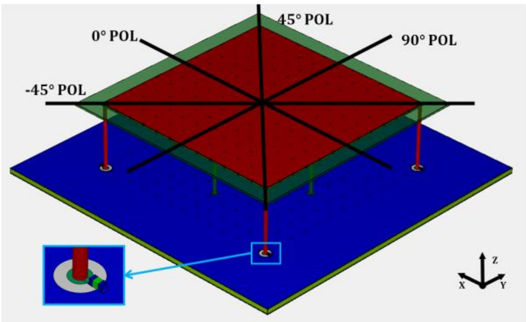

Fig. 1. 3D model of the proposed patch antenna.The detail of the aperture loading capacitor is reported on the bottom left side. The four polarization axes are also displayed.

Unlike many published designs, that place the tuning element directly on the antenna (see e.g. [2] and [3]), in this work the reconfigurable frequency is achieved by mean of a reconfigurable matching network, chosen to be an "L shaped" topology, for avoiding circuit complexity and losses due to number of components. It was decided to use a three state matching network for both input pins in order to cover the EU (one switching state) and the US band (two switching states). It is important to highlight that PIN diodes and varactors are not suitable for this application because of the high power delivered by the UHF RFID front-end. On the contrary, CMOS switches can handle this power and are easier to control. In particular, BGSA13GN10 from Infineon has been selected. In Fig. 2 the reconfigurable feeding network is shown, where switches *SW1* and *SW2* are responsible for selecting among the three matching components. The designed matching networks have a shunt capacitor in common, while the switch is selecting the appropriate series component to match the desired frequency band (one inductor, for matching the EU band, and 2 capacitors used for matching the US sub-bands).

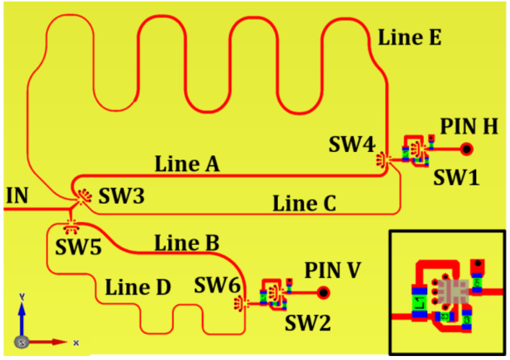

Fig. 2. Modeled reconfigurable feeding network. Main elements and switches used for matching (reported on bottom right side) and polarization agility are named for clarity.

The selection among the four linear polarizations (0°, 45°, 90° and -45°) is made by using two SP3T and two SP2T (Infineon BGSA12GN10) switches, for choosing the appropriate line, as illustrated in Fig. 2. Referring to the figure, 0° polarization is active when *line A* is enabled (through *SW3* and *SW4*), while *SW2*, *SW5* and *SW6* in "all-OFF" state disable the connection with other lines and feeding pin on the other branch. Vice versa, 90° polarization is achieved by selecting *line B* in a similar way (*SW2*, *SW5* and *SW6* are active, while the others are set to "all-OFF"). The 45° linear polarization is active, when *line C* and *line D* are selected. These two lines are quarter wave transformers @ 900 MHz (characteristic impedance 70.7 Ω), for ensuring 50 Ω at input. Finally, -45° polarization is achieved in a similar way as the case 45°, by selecting *line C* and *line E*, that is a 270° line composed by a quarter wave transformer and a 180° delay line.

III. Results and Discussion

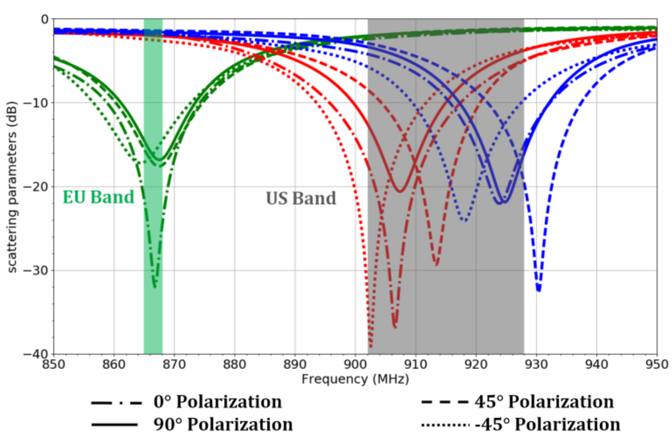

Fig. 3. Simulated reflection coefficients in the EU and US band for the four operative polarization states, corresponding to different linestyles. Different colors refers to different matchings.

Fig. 3 presents EMPIRE XPU simulated return loss for the complete frequency agile patch including the switchable matching network and feeding, in the four considered polarization states. It is recognized that the EU band is well matched in all cases (better than -14.5 dB), and the US band is almost completely covered by the two matching states. The loading effect of the disabled lines caused by the finite isolation of the switches have an impact especially on the 45° and 90° polarizations, leading to a minimum of -9 dB at 916 MHz in the first case and -8.4 dB at 902 MHz in the latter case. It is interesting to see that the shift in frequency is almost constant in this band for the different polarization states. Antenna gain has also been simulated in the four polarizations. In Fig. 4 the results are reported for 868 MHz, where the measured planes are consistent with the specified polarization. The gain of the patch antenna is limited by the electrically small ground plane and by the cascade of three switches, whose insertion loss is found to be 0.4 dB at 900 MHz.

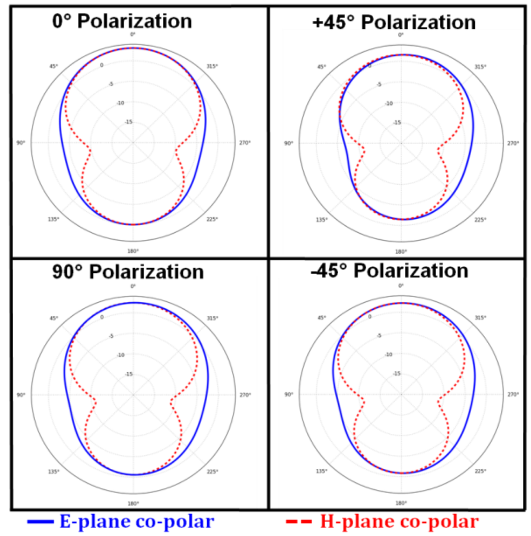

Fig. 4. Simulated antenna gain at 868 MHz in the four polarization states.

IV. Conclusion and Perspectives

In this paper, the design of a frequency and polarization agile UHF RFID antenna system has been presented. The described system allows to cover the EU and US frequency bands with a single antenna design, and the selectable polarization strongly reduces the losses given by polarization mismatch, with respect to a CP antenna approach. Moreover, the antenna is considerably smaller than standard designs, thus simplifying the integration. In particular, the switching feeding network is a flexible and cost effective solution for narrowband and high power applications, where reconfigurability is the best solution for improving system performance and integration. Finally, it is noticed that by using switches with high isolation, or by employing a more complex matching structure, better results can be obtained in the US bands for 45° and 90° polarization. A prototype will be manufactured and measured, for validation of the proposed concept.

References

[1] Finkenzeller, K., RFID Handbook: Fundamentals and Applications in Contactless Smart Cards, Radio Frequency Identitcation and Near-Feld Communication, John wiley & Sons, 2010

[2] Jeen-Sheen Row and Jia-Fu Tsai, "Circularly Polarized Microstrip Antennas with Tunable Frequency", in IEEE Int. Symp. Antennas Propag., Vancouver, Canada, 19-24 July 2015, pp. 2256-2259

[3] Nghia Nguyen-Trong, Leonard Hall, and Christophe Fumeaux, "A Frequency and Polarization-Reconfigurable Stub-Loaded Microstrip Patch Antenna", IEEE Trans. Antennas Propag., Vol. 63, No. 11, November 2015