

Performance comparison between an UHF RFID antenna for portable reader and its UHF RFID/WLAN dual-band version

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Abstract

A low-cost single-band circularly polarized antenna for the UHF RFID band and its extended dual-band configuration for UHF RFID/WLAN applications are here compared, in terms of both electromagnetic parameters (reflection coefficient, axial ratio and gain, in the UHF band) and operational performances when used in a commercial RFID reader (Received Signal Strength Indicator, RSSI, and reading range). Thanks to their high compactness and low-profile (60mm×60mm×7mm), both antennas can be easily integrated into a commercial portable UHF RFID reader. An array composed by four inverted-F meandered monopoles appears in both antennas, which covers the 902-928 MHz frequency band. In the dual-band configuration, a miniaturized patch has been added on the same FR4 substrate, in the middle of the four monopoles, so providing the portable reader with an extra wireless functionality, namely a WLAN connectivity (2400-2480 MHz). Results in terms of reflection coefficient, gain, axial ratio, as well as measured RSSI values are shown in this paper. The dual-band antenna performances are comparable with those of the original single-band version, despite of the remarkable mutual coupling between the RFID array and the WLAN patch, which are very close to each other and printed on the same side of the FR4 substrate.

1. Introduction

A number of frequency bands have been assigned to the RFID (Radio Frequency IDentification) technology worldwide: 125 KHz (Low-frequency band, LF), 13.56 MHz (High frequency band, HF), 866-928 MHz (European and FCC Ultra-high frequency bands, UHF), 2400-2485 MHz and 5725-5875 MHz (Microwaves, MW). Therefore, several dual-band antennas have been designed to be implemented in readers operating with different standards or including additional wireless applications: HF/UHF [1], UHF/GPS [2], UHF/MW [3] and MW-2.4GHz/MW-5.8GHz [4]-[5]. Among them, those dual-band antennas that are suitable to operate at both the UHF RFID and 2.4GHz bands are of specific interest for portable readers, as they enable the RFID reader to transmit collected data toward a management data center through a wireless local area network (WLAN).

In this paper, a low-cost version of the single-band circularly polarized antenna presented in [6] for FCC UHF RFID (902-928 MHz) portable readers is compared with its dual-port dual-band extension [7] for FCC UHF RFID (902-928 MHz) and WLAN (2400-2480 MHz) applications. Results in terms of reflection coefficient, gain, axial ratio and received signal strength indicator (RSSI) are shown, demonstrating that the dual-band antenna performances are not reduced with respect to the single-band antenna, despite of the mutual coupling between the closely spaced radiating elements that are printed on the same side of a small FR4 substrate. Moreover, a new functionality has been added to the portable reader without increasing the available volume nor the realization process cost.

2. Antennas design and performance

In Fig.1, the low-cost solution (*single band*) of the antenna proposed in [6] and its [7] *dual-band* version are shown. In both configurations two dielectric substrates (Layer 1 and Layer 2) are separated by a distance H , through 4-pin headers. In Layer 1 top surface, four identical inverted-F meandered monopoles, fed by a microstrip line (Layer 2) that implements the sequential rotation technique [6]-[9], are realized to cover the FCC UHF RFID band. Seven meanders have been introduced to fit the available space (maximum size less than 60mm), reducing the total length (L_t) of 85.6mm to the actual length (L) of 42.6mm (51% reduction) in the *single-band* configuration. The antenna ground plane is in the Layer 2 bottom surface, and the feeding network is realized on the Layer 2 top surface. In the *dual-band* configuration, a W -wide circularly polarized patch antenna [10] has been designed by exploiting the available space in the middle of the four meandered monopoles, without increasing the overall antenna volume. Since the available space was not enough for a conventional patch operating at 2.4GHz, four asymmetrical cuts have been introduced at the patch corners, so reducing

the patch surface area of about 30% with respect to a standard half-wavelength patch. The patch loading effect on the monopoles has been compensated by properly decreasing monopoles length. A trade-off between the *dual-band* meanders miniaturization (28% with respect to the *single-band*) and the achievable maximum gain has been considered in order to guarantee a satisfactory performance for both WLAN connectivity and RFID tag reading range. In Table I, the geometrical parameters of the two antennas are summarized.

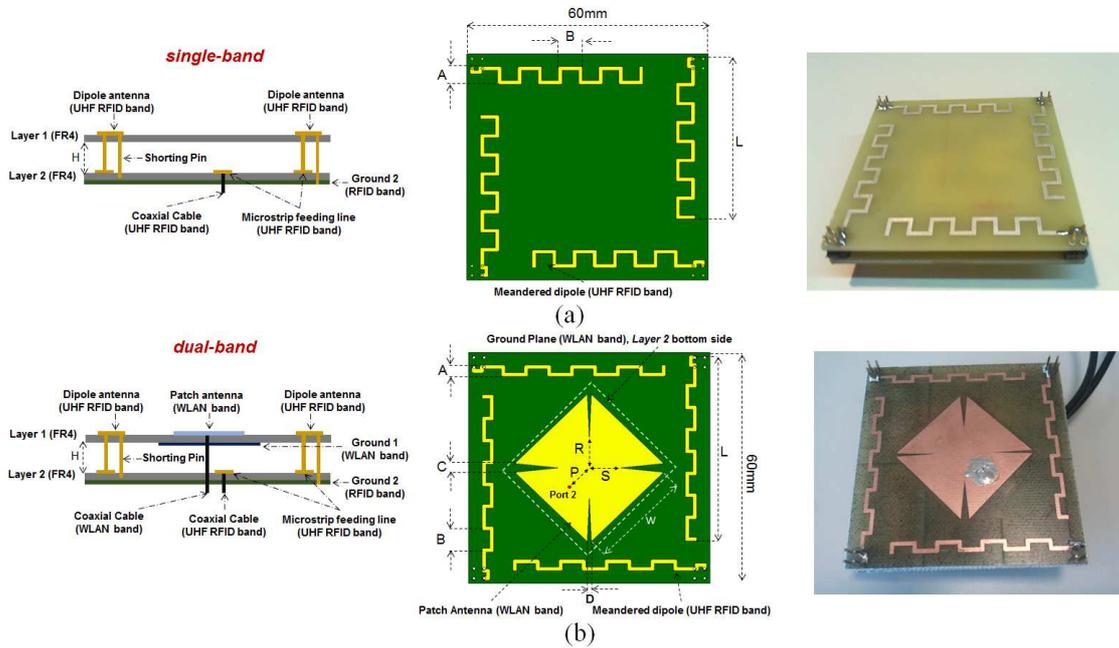


Fig. 1. Stack-ups, top views and prototypes of the proposed circularly polarized (a) *single-band* antenna and its (b) *dual-band* [7] version.

TABLE I
ANTENNAS GEOMETRICAL PARAMETERS (UNITS: mm)

	A	B	C	D	L	L_t	P	R	S	W	H
SINGLE BAND ANTENNA	4.7	6	-	-	42.6	85.6	-	-	-	-	3.8
DUAL BAND ANTENNA	2	5.7	2.3	1	48.2	61.6	7	7.8	7.8	27.7	3.8

In Fig. 2, the reflection coefficient at Port1 (*single-band* antenna and *dual-band* antenna) and Port2 (*dual-band* antenna), and the isolation between the two ports (*dual-band* antenna) are shown, for both the bands of interest. The patch ground plane size and shape have been optimized in order to reduce the mutual coupling between the patch and the monopoles. For the same reason, the patch sides are 45° rotated with respect to the four meandered monopoles (Fig. 1). In the design process, the afore-described patch loading effect (a 30MHz reflection coefficient frequency shift) has been compensated by a fine tuning of the meandered monopoles length. In the *dual-band* antenna, an isolation between the two ports greater than 20dB has been obtained in both the two bands of interest.

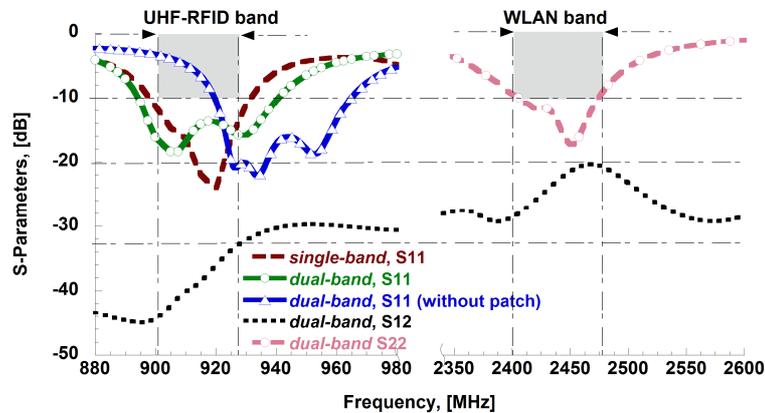


Fig. 2. Measured reflection coefficient for the proposed antennas (*single-band* antenna and *dual-band* antenna) and port isolation (*dual-band* antenna). The patch effect on the *dual-band* antenna reflection coefficient is also shown.

The simulated gain (obtained by using the CST software package) in the broadside direction is about -0.5 dBic for the *dual-band* antenna, which is only 1dB less with respect to the simpler *single-band* antenna; as far as the dual-band antenna is concerned, it exhibits a 1.5dBic gain at the WLAN frequency band. Axial ratio in the broadside direction is below 3dB at the central frequency, for both configurations in a beam of at least 60° around the broadside direction.

As a further comparison between *single-band* and *dual-band* antennas, some antenna prototypes have been constructed and used to perform RSSI measurements. The measurement setup for the RSSI evaluation test is shown in Fig.3a. The frequency hopping has been enabled in the FCC UHF (902-928 MHz) band. A number of microwave absorbers have been used to mitigate the reflection from the ground. RSSI measurements have been performed by feeding the antenna with the C.A.E.N. UHF Long Range Reader (R4300P ION) with an input power of 150mW, which represents a typical value for portable readers. The Alien 9640 and UH414 (Lab ID) tags have been attached on a thin wood pole, as shown in Fig. 3a. Both reader antenna and tag are placed at 1 meter above the ground level. The reader antenna performance (shown in Fig 3b and Fig 3c) have been evaluated with both vertical and horizontal tag orientations.

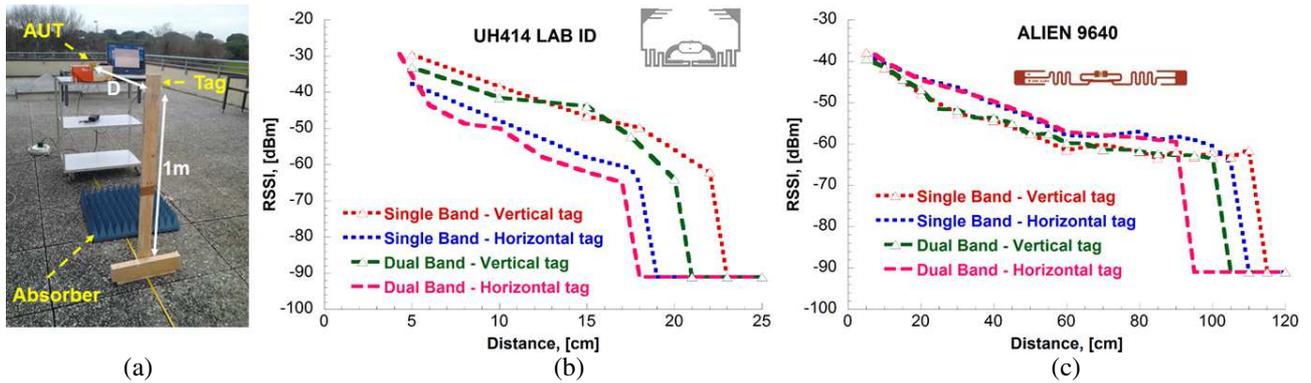


Fig. 3. (a) measurement setup for the tag reading tests, (b) RSSI for the proposed *single-band antenna* and *dual-band antenna* with a UH414 LAB ID tag, by varying the tag-antenna distance from 5cm to 25cm, and (c) RSSI for the proposed *single-band* and *dual-band* antennas, with an ALIEN 9640 tag, by varying the tag-antenna distance from 5cm to 120cm. The reader input power is set to 150mW.

It is worth noting that the *single band* antenna performs little better than *dual band* version, but both meet the typical read-range requirements for portable reader antennas [11]. For a vertical tag, satisfactory (higher than -65dBm) RSSI performances for the *dual band* antenna are obtained up to a distance of 20cm and 100cm with a UH414 or ALIEN 9640 tag, respectively. These results are comparable with those obtained with the *dual band* antenna: RSSI higher than -65dBm up to a distance of 23cm and 110cm with a UH414 or ALIEN 9640 tag, respectively. Lower performance, still equally satisfactory, were obtained when the tags are placed horizontally, confirming the good axial ratio performance.

In order to evaluate the reader antenna performance in terms of tag detection in a multi-tag scenario, nine tags (ALIEN 9640) have been attached on a thin foam slab, in a 3by3 grid configuration, as shown in Figs. 4-5. The distance between nearby tags centers is 15 cm and the tag-reader distance has been varied from 20cm up to 160cm.

The reader antenna tag detection performances as a function of the distance between the reader and the tags plane has been evaluated by considering both vertical (Fig. 4) and horizontal (Fig. 5) tag orientations, with a reader output power of 150mW. When the successful reading percentage (number of useful readings with respect to the total interrogation number) is greater than 10%, for a specific tag position, the test has been considered fulfilled and a light color (green) has been assigned (the total number of reader interrogations is provided by the reader management SW).

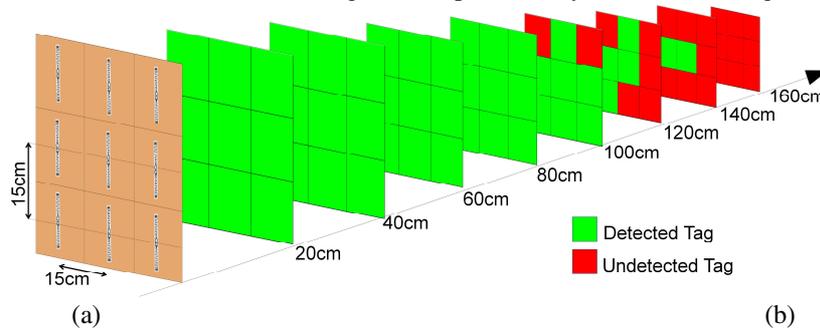


Fig.4. Results of the tag reading test by varying the distance of a grid of 3by3 ALIEN 9640 long-range tags from the reader antenna, for the vertical tag orientation. The dark color (red) denotes a test case where the tag has been detected less than 10% in a time interval of 10sec.

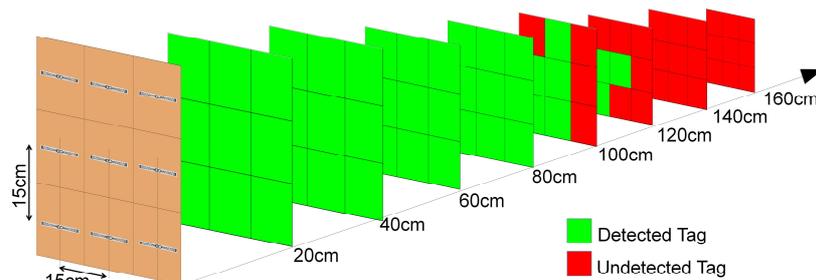


Fig.5. Results of the tag reading test by varying the distance of a grid of 3by3 ALIEN 9640 long-range tags from the reader antenna, for the horizontal tag orientation. The dark color (red) denotes a test case where the tag has been detected less than 10% in a time interval of 10sec.

Such a test confirms that a tag can be properly detected within 120cm, independently from its particular orientation, even in presence of other nearby tags. It is worth noting that the presence of various tags close to each other leads to an overall performance improvement in terms of tag detection with respect to the single tag scenario, due to apparently favorable mutual coupling effects.

3. Conclusion

A compact, low-profile, dual-band circularly polarized antenna for UHF RFID/WLAN applications has been compared against its simpler single-band version, in terms of reflection coefficient, gain, axial ratio. Moreover, RSSI measurements have been performed by using two different tags (Alien 9640 and UH414 Lab ID) and a commercial reader, by considering both single-tag and multi-tag scenarios (the latter being a typical situation when using a portable reader in a warehouse or retail environment).

4. References

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