2-Port Antenna with Matching Network for Dual-band IoT Terminal

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***Abstract*—In this paper, a design methodology for multiple access antenna operating at different frequency bands is presented. The single antenna structure is successfully designed to efficiently radiate at both LoRa 863 MHz - 870 MHz and GPS L1 1563 MHz - 1587 MHz bands by exciting 2 different ports with the help of a suitable matching circuit. The study shows that by adjusting the antenna geometry, it is possible to achieve the desired total efficiency over multiple bands.**

I. Introduction

Multi-standard communication devices come in response to the need of integrating multiple services in a single device. A good example is the Internet of Things (IoT) idea of realizing a pervasive network of connected objects. As future IoT will offer a broad range of very different services, multifunction devices will coexist in an heterogeneous environment of things that differ in technology and scope of use. Additionally, most IoT applications have several standards with different frequency allocations. The ability to handle more than one communication protocol allows the terminal to be used for various applications. From the antenna point of view different approaches to address multi-standard have been proposed. Firstly, the use of multiband antennas is redundant in literature [1]. However, this approach increases the complexity of the circuitry on the Printed Circuit Board (PCB), since switching or duplexing mechanisms must be introduced to use the antenna with multiple transceivers. A second solution is to have multiple separated antennas [2], which is not optimal for a miniature device due to the effective volume needed by each antenna to properly radiate.

By combining the previously mentioned solutions, the proposed design methodology is based on the use of multi-access single structure antenna. With the help of matching circuits, a simple antenna having two ports, each one generating a different resonance is designed. This solution avoids using switches or diplexers in the PCB to connect different transceivers and enables the simultaneous signal reception on different bands. A practical example can be found in an IoT terminal using wireless positioning services (e.g., based on GPS standard) and low-power connectivity for long-distance communication (e.g. LoRa) [3].

In this paper, a methodology to design multiband multi-access single structure antenna suitable for small size IoT terminals is presented. The method is applied to design a dual-port single antenna that covers both Lora at 868 MHz and GPS L1 at 1575 MHz bands.

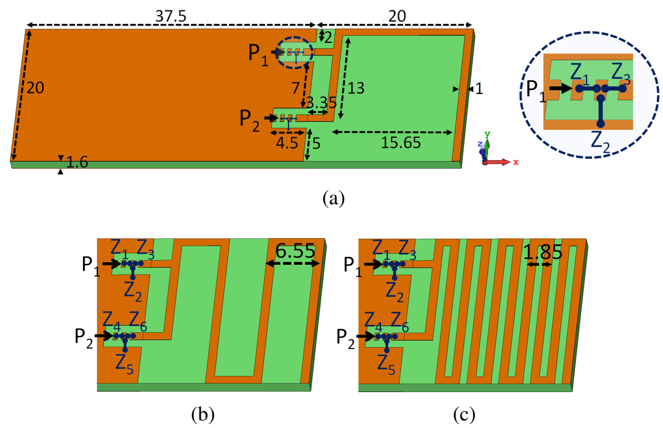

Fig. 1. (a) 2-port antenna geometry for N_1 configuration with T-type matching networks. (b) N_3 antenna configuration. (c) N_9 antenna configuration.

II. Design Methodology

The principle of the proposed approach is using multi-access on a single antenna to excite different frequencies. However, matching circuits are required to enhance isolation among ports and equally improve the matching properties. The Inverted-F Antenna (IFA) is a well-known single band resonator. It represents a good initial design choice by making use of the shorting point as an additional port.

The design procedure can be divided into the following steps:

(a) A single port IFA is first designed and matched at a specific frequency band.

(b) The shorting point of the antenna is replaced by the second excitation port.

(c) Each port of the antenna is matched by using lumped circuits at the desired frequency band.

These steps can be repeated for different geometries matched at different bands of interest. The next section will show that the designer can optimize the radiation performance on each band by properly choosing the initial structure and therefore resonant frequency.

III. Results

The effectiveness of the proposed approach is evaluated in designing an antenna for LoRa and GPS standards. Three

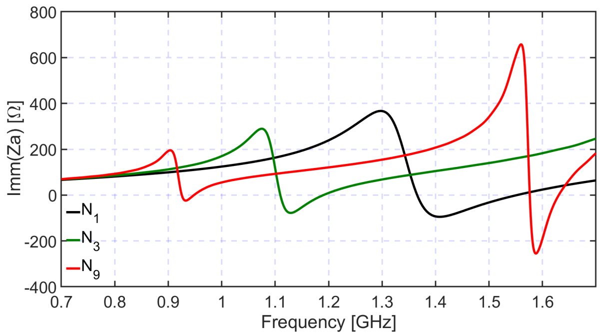

Fig. 2. Imaginary part of antenna impedance of the single port IFA for (a) low band (N_1), middle band (N_3) and high band (N_9) antenna configurations.

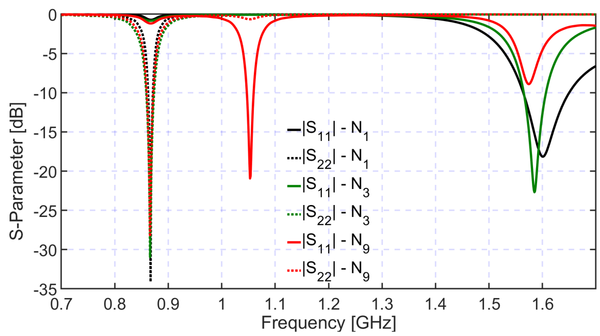

Fig. 3. S-parameter for the three tested 2-port antenna configurations N_1, N_3, N_9.

IFA-like radiating elements are used as initial geometries for the matching network optimization. These three configurations differ only for the number of meanders, shown in Fig. 1. They have been selected as following: the first one (N_1) and second one (N_9) are the ones exhibiting the resonances closest to the LoRa-868 MHz and GPS-1.575 GHz bands, respectively. The third antenna (N_3) resonates at 1.10 GHz which is an intermediate frequency between the two desired bands as illustrated in Fig. 2. N_k represents the antenna with k meanders. The terminal size is 20×57.5 mm^2 with the ground plane occupying 20×37.5 mm^2. All the free-ground area is used for the antenna. The substrate is a 1.6mm thick Epoxy FR-4 with a permittivity of 4.4.

To match the two antenna ports, namely P_1 and P_2 respectively, T-type matching (blue circle in Fig. 1a) circuits are utilized. This type of matching circuit could be modified to work as different types of filters [4]. The obtained results are shown in Fig. 3. All three antennas have been matched for LoRa band with a -10 dB criteria. Due to different matching properties in GPS band, N_1 and N_3 antennas both achieve -10 dB reflection coefficient, while the N_9 configuration is only matched at -6 dB level.

In Table I, the minimum values of $|\Gamma|$ and the total efficiency in both bands of the three antenna are reported. A trade-off is observed on the radiation efficiency at 868 MHz and 1575 MHz. As the number of meanders increases, the total efficiency improves in LoRa band, from -3.8 dB to -2.42 dB, while it decreases in the GPS band. The designer decision

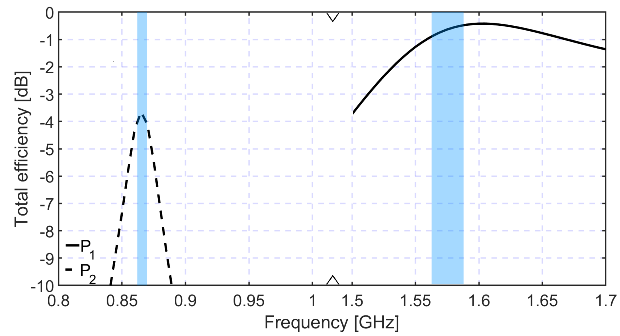

Fig. 4. Total efficiency of the 2-port antenna configuration $N = 1$.

is based on specification of the system. Fig. 4 shows that if the device is designed to maximize GPS performance, the N_1 design is the best option as it obtains highest performance in terms of total efficiency for GPS, and LoRa has a total efficiency higher than -4 dB, which is sufficient for LP-WAN communication.

TABLE I
TOTAL EFFICIENCY AND REFLECTION COEFFICIENTS FOR THE 2-PORT ANTENNA CONFIGURATIONS N_1, N_3, N_9.

Freq. (GHz)	$N = 1$		$N = 3$		$N = 9$	
	$\|\Gamma\|$ (dB)	Tot. Eff. (dB)	$\|\Gamma\|$ (dB)	Tot. Eff. (dB)	$\|\Gamma\|$ (dB)	Tot. Eff. (dB)
0.868 (P_2)	-21	-3.8	-21.75	-2.47	-19	-2.42
1.575 (P_1)	-12.52	-0.64	-15.15	-2.09	-8.87	-7.7

IV. Conclusion

By following the proposed design procedure, a miniature antenna configuration with a single radiating element and 2 feeding ports has been designed and simulated. The proposed N_3 design, matched at 868 MHz and 1.575 GHz with efficiency higher than 50%, validates the proposed methodology. The simulated performance indicate that the antenna is a good solution for multi-standard devices. Future work will include dissipative loss from real lumped components as well as experimental results.

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