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Multi-arm Dipole for Compact Wearable Antennas

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***Abstract*— Non-resonant antenna configurations are investigated to provide compact radiators suitable to be adopted in wearable electronics. The non-resonant radiator exhibiting a capacitive reactance and a non-negligible radiation resistance can be matched by using a suitable underneath surface which is also able to prevent the radiation toward human body. High Impedance Surface (HIS) have been proved to be a suitable configuration to provide these two features. The focus of this paper is on the selection of a suitable primary radiating element. A novel element based on a CPW-fed version of a multiple-arm dipole is proposed and compared with the standard CPW-fed monopole previously employed in similar designs.**

Keywords—Electrically Small Antenna (ESA), Multiple Arm Dipole.

I. INTRODUCTION

Designing wearable antennas has been a challenge that started almost 20 years ago, and it is an even more important task nowadays with the request of increased connectivity, ubiquitous devices and interconnected people. Several areas of applications can benefit from the integration of wearable antennas such as protective clothing for professional workers for short range communications in operative environmental conditions [1] or the health monitoring of elderly [2].

A relatively unexplored area is represented by electrically small antennas (ESA) that can be employed at sub-GHz frequencies, where the size of resonant antennas becomes cumbersome for the integration in wearables. It is well known that an antenna can be considered electrically small if it is entirely included within a sphere of radius less than $\lambda/4\pi$ [3]. A self-resonant antenna in a small electrical volume can be obtained by resorting to folded elements or by exploiting dielectric loading [4]. Concerning safety issues, it is also desirable that the antenna placed on the garment does not radiate too much power toward the body, especially in case of prolonged device operation. Clearly, this unwanted interaction may also affect the antenna with detuning effects and efficiency degradation. A possible solution to these drawbacks can be represented by adopting resonant radiators designs with a metallic ground plane which acts as a shielding or by using a High Impedance Surface (HIS) [5]. Although effective, the adoption of a HIS usually increases the antenna footprint. Recently, a design based on a non-resonant antenna matched by using a compact Artificial Magnetic Conductor (AMC) has been proposed to benefit from both the matching and shielding feature of the HIS [6], [7]. To be successful, this approach requires the non-resonant antenna to exhibit a negative reactance and a not negligible radiation resistance since the matching is provided by the inductive impedance of an AMC substrate [8]. The aim of this study is to investigate compact antennas that can satisfy this requirement and tailor their properties to be suitably integrated on a HIS for innovative compact wearable radiators.

II. COMPACT CPW ANTENNA

An interesting candidate for the design of an antenna that can be easily integrated is a coplanar waveguide (CPW)- fed antenna since it offers several degrees of freedom and does not require any via or thick substrate to be implemented [9]. However, the requirement imposed to the real part of the input impedance of the desired non-resonant radiator was only mildly satisfied by the design presented in [10] which relied on a CPW-fed monopole and new solutions must be investigated. An antenna that provides a considerably high radiation resistance is represented by the multiple-arm folded dipole [11] which can be placed close to a metallic ground without suffering the degradation of its performance. A compact version of this element, which has been successfully employed for designing a compact on-metal UHF RFID tag [12], suggested the CPW-fed version of the multiple-arm dipole represented in Fig.1a. As it is apparent, the ground plane that was previously located in the lower side of the supporting dielectric slab has been placed around the antenna on the top face of the substrate.

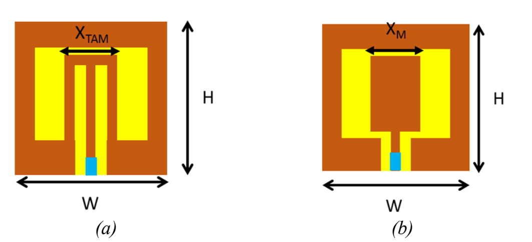
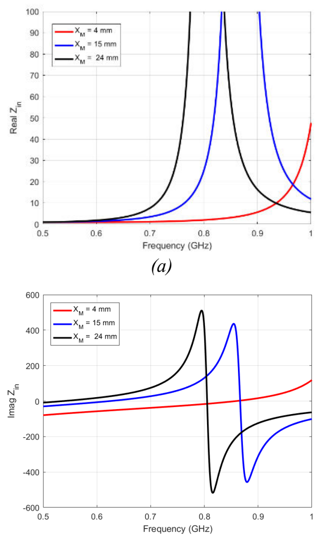


Fig. 1 Investigated CPW-fed antennas: *(a)* Three-arm dipole and *(b)* monopole. The blue rectangle represents the input port.

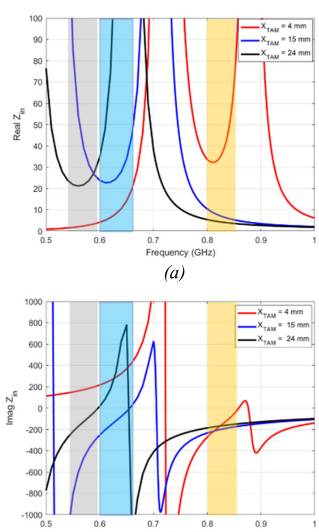
The input impedances of this structure and of a standard CPW-fed monopole (Fig.1b) have been investigated. The overall dimensions are the same for both structures (W = 55mm, H = 55mm) and their input impedance is evaluated for different values of the monopole width (X_M) and distance between the outermost arms of the three-arm dipole (X_{TAM}). It is important to underline that no HIS surface has been placed close to the antennas for this analysis and that the HIS effect will be considered once the most promising design has been found. Let us observe the impedance of each antenna for frequencies below their resonance. It is apparent from Fig. 2b that within the considered bandwidth (550 MHz-1.0 GHz) the monopole exhibits a capacitive impedance only for $X_M = 4$mm and then, for further increase of the parameter, the behavior is inductive. However, within the frequency range where the impedance is capacitive, the configuration with $X_M = 4$mm provides a low radiation resistance.



(a)

(b)

Fig. 2 Input impedance of the CPW-fed monopole antenna as a function of parameter X_M : real part *(a)*, imaginary part *(b)*.



(a)

(b)

Fig. 3 Input impedance of the CPW-fed three-arm dipole X_{TAM}: real part *(a)*, imaginary part *(b)*.

The CPW-fed three arm dipole offers an inductive impedance at low frequencies but its impedance becomes capacitive after the resonance. The impedance of the CPW three arm dipole is shown in Fig. 3. For the considered X_{TAM} values, the frequency band where the impedance remains capacitive spans approximately from 850 MHz down to 550 MHz. More importantly, in correspondence of these frequency intervals, the radiation resistance is significantly higher than that guaranteed by the investigated monopole. These results suggest employing this latter design in combination with the HIS to achieve the desired performance.

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