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Compact antenna for wearable applications

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Abstract

Compact radiators are particularly appealing in all applications involving wearable devices. The body effects on the antenna performance suggest design approaches that provide isolation between human tissues and the radiator without seriously affecting its radiation capability. A novel element based on a CPW-fed version of a multiple-arm dipole is investigated with the aim of exploiting its features with properly-designed reactive surfaces.

1. Introduction

Wearable devices are of great importance in the ICT arena for on-body applications as well as for the spreading of the Internet of Things and Wireless Sensor Networks. Wearable devices must be small, low-powered and able to connect to a hub or gateway device for access to internet or cloud. Many new antenna technological designs have to be exploited and tested to satisfy the many requirements of wearables (flexible, conformal, integrable with clothes or accessories, small, low profile, cost). Rigid dielectric substrates commonly employed in standard PCB lithographic processes do not provide the necessary degrees of freedom in terms of integration and wearability therefore organic and polymer substrates are promising candidates for realizing light and flexible radiators.

One of the most challenging aspects of designing wearable antennas is avoiding as much as possible the negative effect of the interaction between the antenna and the dissipative biological tissue. The human body detunes the antenna and may absorb a large amount of the radiated power, thus reducing the gain and changing the radiation pattern. It is therefore necessary to isolate the antenna in order to preserve its radiation characteristic as much as possible and to prevent hazardous biological effects.

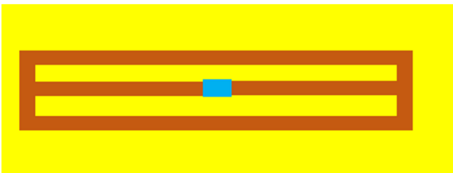
The IEEE 802.15 has recently regulated the various paradigms of on body, off body and in body communications. Within this framework, several technological solutions have been proposed in order to fabricate antennas that can fit on a human body.

In particular, IEEE 802.15.4 Standard for Low-Rate Wireless Personal Area Networks (LR-WPANs) is focused on enabling very low-cost communication of nearby devices with little to no underlying infrastructure and is particularly suited for near data transfer to handheld wireless devices and RFID applications in the 868/915/2450 MHz frequency bands. At the same time, the IEEE 802.15.6 Standard for Wireless Body Area Network (WBAN) provides an international standard for for broader wearable applications (health monitoring and consumer electronics).

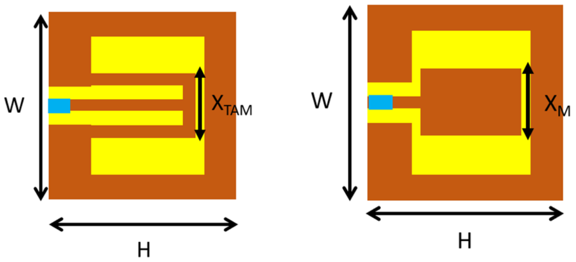
In this scenario, it is interesting to explore innovative approaches for antenna design for coping with all the aforementioned challenges.

2. Multiple-arm CPW antenna

Few of the antennas proposed in the literature for wearable applications work at frequencies lower than 1 GHz. This is probably due to the cumbersome dimensions of an antenna working in the sub-GHz region. A possible solution is offered by adopting resonant radiators designs with a metallic ground plane which acts as a shielding or by using non-resonant elements close to an High Impedance Surface (HIS) [1] [2]. An interesting opportunity is represented by coplanar waveguide (CPW)-fed antennas since they do not require any via or thick substrate to be implemented. Since the antenna has to be placed close to an electric ground plane or a magnetic one, it is very important to be able to achieve a good impedance matching even in these conditions. More in particular, such an antenna should exhibit a considerably high radiation resistance [3], [4] if placed close to a conductive ground. A possible solution is represented by the multiple-arm folded dipole. An example of a three-arm dipole is shown in Fig. 1a, whereas a compact version of this element, is represented in Fig. 1b. To adhere to the CPW structure the ground plane is placed around the antenna on the top face of the substrate. The input impedances of this structure and of a CPW-fed monopole have been investigated. The overall dimensions are the same for both structures ($W = 55$mm, $H = 55$mm) 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}).



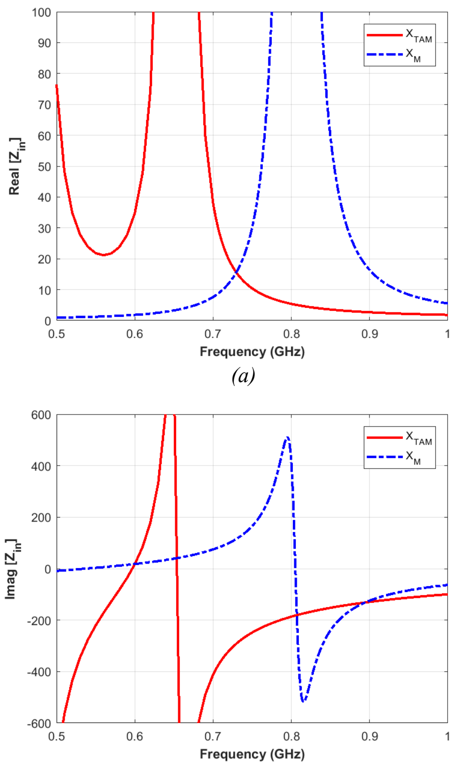
(a)



(b) *(c)*

Fig. 1 Example of a printed standard multiple-arm dipole (a) its CPW-fed implementation (b) and coplanar monopole (c). The blue rectangle represents the input port.

The impedances of the two antennas are reported in Fig. 2. It is apparent that the CPW-fed three-arm dipole exhibits a lower resonance and a quite high value of the real part of the input impedance. This seems particularly suitable for the placement of this antenna near a ground plane or a reactive surface for obtaining a compact antenna.



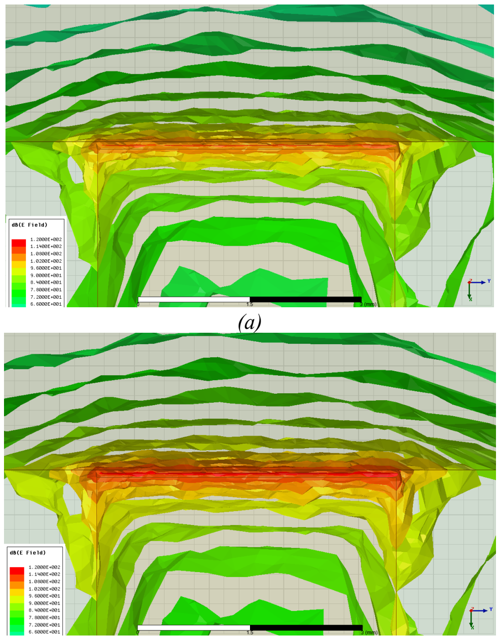
(a)

(b)

Fig. 2 Comparison between the input impedances of the CPW multiple arm dipole and the monopole: real part (a) and imaginary part (b).

3. Antenna Tunability

The proposed CPW design also allows obtaining a reconfigurable antenna by simply adding variable loads that are realizable by using integrated resistive or functional materials. By inspecting the level of the field at the top of the monopole antenna, it is apparent that a strong electric field is present at 800 MHz for the case of X_M = 4mm (Fig. 3).

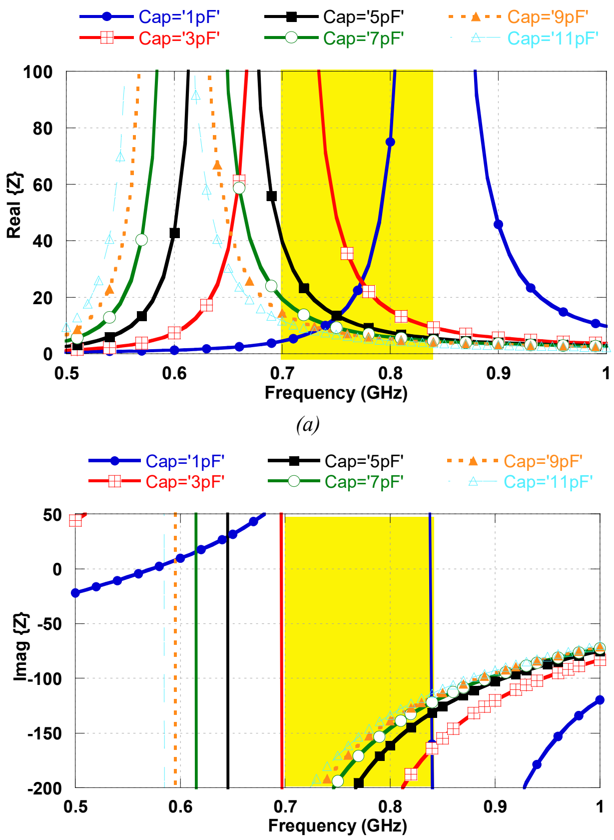


(a)

(b)

Fig. 3 Plot of the electric field at 500 MHz (a) and 800 MHz (b). The dB scale is the same in both plots.

By adding a capacitor of value C_{ap}, it is apparent from Fig. 4 that the antenna provides a capacitive impedance in the range 700 MHz-800 MHz.



(a)

(b)

Fig. 4 Input impedance of the CPW-fed monopole antenna as a function of parameter C_{ap}.

Moreover, by realizing the antenna on a chemical interactive material, such as a suitable coated paper [5], it could be possible to relate the shift of the working frequency to a variation of a physical parameter (*e.g* relative humidity) thus opening the possibility to realize a sensor. The effect of placing the CPW-fed three-arm dipole on a HIS [6] or close to a PEC ground will be part of the ongoing activity as well as the analysis of further antenna configuration that will be presented at the conference.

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