UWB Antenna for Portable Devices

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Abstract—In this work, a UWB microstrip compact antenna is proposed for operation in the 1.7 GHz and 10.6 GHz frequency band, covering the services UMTS (1.9 and 2.1 GHz), WLAN (2.45 GHz) and UWB (3.1 to 10.6 GHz).

First, an antenna with an input reflection coefficient below -10 dB, in a band between 2 and 10.6 GHz, is designed. Through the application of a material with high dielectric constant on both sides of this antenna, a second structure is obtained with an input reflection coefficient below -7.5 dB, in a band between 1.7 and 10.6 GHz, achieving the goal originally proposed.

The designed antennas, were built and subjected to measurements of the input reflection coefficient, for comparison with results obtained by simulation.

Finally, a study on human influence in the antenna parameters is made. To that end, an homogeneous model of a human hand and forearm is used in simulations, and the results obtained are compared with the ones obtained in measurements made in the presence of human being. It was possible to confirm that being a wideband antenna, the structure has a good robustness to human presence.

Index Terms—patch antennas, Ultra-Wide Band (UWB) antennas, miniaturization, high dielectric material, human interaction.

I. INTRODUCTION

The evolution of communication systems in the last few years, particularly the Internet, has originated the arrival of a great variety of services, each one of them with a specific operating frequency.

Some of these services, like WLAN, WiMAX or UMTS, provide wireless Internet access to portable devices such as notebooks and mobile phones, giving them a mobility that was previously unavailable. There are however, other type of services, like GPS and Bluetooth, that while not directly related to the Internet, are also very interesting for integration in portable devices.

This wide range of different services, is currently being integrated at the same time in all kinds of portable devices. Because every service, has its different requirements in terms of frequency band or even polarization and radiation, it would be necessary to integrate different kinds of antenna structures in the mobile units. However, considering that these units are very limited in terms of space, it becomes clear that having different antennas for each service is impossible. The solution is integrating multiband or wideband antennas, to cover the necessary frequency bands. Wideband antennas have the advantage, over multiband antennas, of covering new services that may appear, because of its wide frequency band coverage.

The objective of this work, is to design and fabricate an antenna for application in portable devices, that covers the services mentioned before, by working in a frequency band, between 1.7 GHz and 10.6 GHz. Two antennas structures that influenced the final antenna design will be studied and presented. The final antenna will be subjected to input reflection coefficient simulations and measurements. Finally, a brief study on the antenna’s performance in the presence of a human being will be made.

All the simulations in this work were made using Computer Simulation Technology (CST) Microwave Studio 2008. The model of the human arm was achieved with the help of Poser and 3D Studio.

II. UWB ANTENNA DESIGN

A. Configuration Study

To reach the final antenna design, two different configurations were initially studied.

The first one, is a patch antenna proposed in [1] which works in a frequency band between 700 MHz and 3000 MHz, referred from now on, by Triangular Wideband Monopole. This antenna consists of a triangular patch printed on FR-4 material, fed by a 50Ω microstrip line. The total dimensions of the antenna are 5.5 cm by 13 cm and the triangular patch is 5.5 cm wide by 4 cm. In Figure 1, a representation of the structure is presented.

Fig. 1: Triangular Wideband Monopole. Front view (a), side view (b) and back view (c).
To achieve the desired frequency band, the triangular metal patch is further sandwiched by two 2 mm thickness of high dielectric constant material, in this case Gallium Arsenide (GaAs), with $\epsilon = 12.9$. The comparison between the input reflection coefficient of the antenna, with and without the "sandwich" of high dielectric material, can be observed in Figure 2. From Figure 2, it’s possible to conclude that the introduction of the high dielectric material, has produced a reduction in the lower resonance frequency. The utilization of this type of material, will be used in the design of the antenna proposed in this work.

The second antenna studied, is a Wideband Microstrip Fed Monopole, proposed in [2] for UWB operation. This structure is very appealing due to its small size and simple design. In Figure 3 the antenna structure is presented while its input reflection coefficient can be observed in Figure 4. This antenna covers the UWB frequency band, as shown in Figure 4, and demonstrates that with a very simple design and small size it’s possible to achieve a UWB working antenna.

B. Design and Simulation

As mentioned before, the purpose of this work is to design an antenna capable of operating in the UWB frequency, but that also can cover a band starting in 1.7 GHz to 3.1 GHz. To achieve this goal, a basic rectangular patch antenna, similar to the Wideband Microstrip Fed Monopole without the slit, was taken as a starting point. This initial structure, had a patch with 15 mm by 15 mm on top of Rogers RT5880 material with $\epsilon = 2.2$ and 25 mm by 35 mm by 1.57 mm. A reference structure with the variables that were adjusted can be seen in Figure 5.

The initial structure, was subjected to a series of simulations, where the variables $l$, $h$, $lp$, $hp$ and $hc$ were adjusted in order to achieve an input reflection coefficient below -10 dB for the proposed frequency band; 1.7 GHz to 10.6 GHz. The final dimensions obtained for the antenna are presented in Table I, and the results for the input reflection coefficient can be observed in Figure 6. At this stage, its important to point, that the structure has a feed gap, with the ground plain having a length of 15 mm and the line a length of 16.5 mm. It has been demonstrated in [3], that the feed gap has the effect of decreasing the input reflection coefficient, in all the band, especially at higher frequencies. From Figure 6, we can see that the antenna has input reflection coefficient lower than -10 dB, from 2 GHz to 10.6 GHz. The cuts made in the transition from the line to the patch, contributed to the decrease in the input reflection coefficient, has expected from [4]. In order to further reduce the lower resonant frequency, the technic
used in the Triangular Wideband Monopole, of applying a high dielectric material to both sides of the antenna will be used. In Figure 7 a comparison of the effect of three different high dielectric materials is presented. The materials tested are Gallium Arsenide ($\epsilon = 12.9$), Rogers RO3006 ($\epsilon = 6.15$) and Rogers RT6010 ($\epsilon = 10.7$).

By observing the effect of the three different materials, it can be confirmed, has expected from [1] and [5] that the higher the dielectric constant is, the lower the frequency resonance is. In this case, the material chosen will be Rogers RT6010 with $\epsilon = 10.7$ and a thickness of 1.27 mm, because its the material that has a good compromise between lower frequency achieved and increase in input reflection coefficient for the higher frequencies.

The final antenna structure can be seen in Figure 8, and a comparison between the input reflection coefficient with and without the dielectric “sandwich” is presented in Figure 9. The structure without the dielectric “sandwich” will be referred to as Bevelled Monopole (BM) and the structure with the dielectric “sandwich” as Dielectric Loaded Bevelled Monopole (DLBM). In Figure 9, it’s noticeable the influence of the high dielectric material, where the lower resonant frequency, drops from 2 GHz to 1.78 GHz. However there is also a degradation in the input reflection coefficient for the higher frequencies, but still below -7.5 dB in all the band between 1.78 GHz and 10.6 GHz.

In the Figures 10, 11, 12, 13 and 14, the radiation patterns with and without the high dielectric material, are presented for the central frequencies corresponding to some of the most used services, like UMTS (1.9 GHz), WLAN (2.45 GHz and 5.45 GHz), Bluetooth (2.45), WiMAX (3.5 GHz) and Wireless USB (7 GHz).

The radiation patterns show that the antenna as monopole like behavior, with two radiation lobes, for all the simulated frequencies, except for 5.45 GHz and 7 GHz where the appearance of other small lobes becomes noticeable.

C. Measurements

In order to evaluate the results obtained in simulations, the antennas were fabricated and subjected to input reflection coefficient measurements. In Figure 15 both prototypes are presented. The results obtained for both prototypes can be seen in Figures 16 and 17. The results shown in Figures 16 and 17, demonstrate a good match between the measured and simulated results.

III. HUMAN INTERACTION

During the design of an antenna, its characterization is made considering the antenna is in free space, i.e., with no objects in its vicinity. Although this approach is necessary in the development of an antenna, it’s also important to consider the influence that nearby objects can have in its performance. Considering that the type of antennas presented in this work, is used in the proximity of a human being, it’s relevant to characterize its influence in the parameters of the antenna.

Simulations were made with the antenna presented previously, involved in a human hand with forearm. Two tests were made, one with a left hand, with the antenna patch turned to the inside of the hand, and another with a right hand, with the antenna in the opposite direction, both for two users. A correspondence between the human model used in simulations and in measurements is presented in Figure 19. In Figure 18, a comparison between the simulated input reflection coefficient
Fig. 10: Representation of the radiation pattern (total gain), in the planes XY (a) and YZ (b) for the final structure, with and without the high dielectric material, at 1.9 GHz.

Fig. 11: Representation of the radiation pattern (total gain), in the planes XY (a) and YZ (b) for the final structure, with and without the high dielectric material, at 2.45 GHz.

Fig. 12: Representation of the radiation pattern (total gain), in the planes XY (a) and YZ (b) for the final structure, with and without the high dielectric material, at 3.5 GHz.

Fig. 13: Representation of the radiation pattern (total gain), in the planes XY (a) and YZ (b) for the final structure, with and without the high dielectric material, at 5.45 GHz.

Fig. 14: Representation of the radiation pattern (total gain), in the planes XY (a) and YZ (b) for the final structure, with and without the high dielectric material, at 7 GHz.

Fig. 15: Fabricated antenna, Dielectric Loaded Bevelled Monopole (a) and Bevelled Monopole (b).
with the isolated antenna and in the presence of the human hand model is presented. The model used in simulations is homogenous, with $\epsilon = 49.54$, $\tan(\gamma) = 0.29353$ and a density of $1000\, Kg/m^3$. The results shown in Figure 18, demonstrate that the presence of the human hand, doesn’t have a significant effect in the input reflection coefficient. In Figure Figure 19, the results obtained in measurements are compared with the ones obtained in the simulations, for the left hand. It is possible to confirm, that there is a good agreement between measurements and simulations. However, its important to emphasize, the difference between the results obtained for the User A and User B. It is quite clear that the exact reproduction of the conditions of measurement is very difficult, as is the replication of the simulation environment.

IV. CONCLUSIONS

In this work the design of a compact UWB antenna was presented.

Two antenna configurations were achieved. One with an input reflection coefficient below -10 dB, in a band ranging from 2 GHz to 10.6 GHz, and another, below -7.5 dB in band between 1.78 GHz and 10.6 GHz. The second antenna consisted in the application of a high dielectric material in both faces of the first antenna. It was possible to confirm that this technique produces a decrease in the lower resonant frequency, but can introduce a degradation in the input reflection coefficient for the higher frequencies. The application of the high dielectric material, must take into consideration the application of the antenna, because sometimes a degradation in the input reflection coefficient, may compromise the operation of the antenna, for certain frequencies.

Input reflection coefficient measurements were made, that confirmed the results obtained in the simulations.

A study on the impact of the presence of a human being in the vicinity of the antenna was also made. The measurements that were made, confirmed the simulations, and demonstrated that the antenna has a good robustness, in terms of input reflection coefficient, to the presence of the human being.

ACKNOWLEDGEMENTS

Nuno Serro would like to thank Professor António Alves Moreira for his guidance and support during this work; to Mr. Carlos Brito and Mr. Vasco Fred for their commitment and effort to make the antenna prototype possible; to Mr. António Almeida for is patience and support in the measurements in the laboratory; to Dr. Jerzy Guterman for his tips and availability in the clarification of simulation software doubts.

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