Ultra-wideband Antenna with Metamaterial and Periodic Structure

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Abstract— In this article a compact ultra-wideband (UWB) microstrip antenna basing on the planar patterned array metamaterial concept has been presented. This latter consists of loading the ordinary rectangular microstrip antenna on its metallic parts with periodic shaped patterns. The antenna is $27.48 \times 31.74 \times 0.787\,\mathrm{mm}^3$ dimensions. The antenna patch is etched out simply with an array of crosses, and the ground plane consists of small square patches separated by slots and loaded with slits on their angles. The substrate of the antenna is Rogers RT 5880 with $\varepsilon_r = 2.2$ and 0.787 mm thickness. This antenna after being designed, simulated and fabricated, showed enhancement in bandwidth. The measured bandwidth at the -10 dB return loss is 13.985 GHz, ranging from 4.389 GHz to 17.581 GHz, which represents 120% fractional bandwidth.

1. INTRODUCTION

Nowadays many applications due to their working environment, require integrated and miniaturized systems where the antenna should coexist with the transmitting and receiving modules. These latter have even seen their construction being miniaturized thanks to the recent development in solid state devices and MEMS. It remains only to the antenna to follow and render the system complete.

Among the antenna that received the greatest interest during the last decades we find the microstrip antenna. The microstrip antenna benefits from several advantages like simple structure, small size, low cost conformality and easy fabrication by means of lithographic technique. But suffers from a major handicap of narrow bandwidth. Several studies and tests were conducted to improve the bandwidth and the literature is prolific in this topic. Among the techniques used to overcome this obstacle we can find increasing the height of the substrate and/or decreasing its dielectric constant, dielectric substrates layering or stacking with different dielectric permittivity values, different feeding and coupling techniques, etc. [1–4, 20–24]. Unfortunately these ways were limited and achieved only small bandwidth enhancement and could not realize miniaturization.

Especially with the advent of the ultra-wideband technology, which the communication systems adopt more and more because of its many advantages like high bandwidth, high data rates, security, jamming and interference robustness, coexistence with other radio systems, thus avoiding more spectrum scarcity, etc. [5, 7–15]. Consequently this technology is found in many areas and found applications in vehicles and traffic regulation, ground penetrating radar and mine detection, "see through the wall" applications among which we find medical imaging, localization and detection of persons [16–18]. So the microstrip antenna has to be adapted to follow these developments and meet the requirements of the time to keep its place in the concert.

During the last decade new materials appeared, known as metamaterials because of their properties not found in nature like negative refractive index (NRI) implied by both negative permittivity and permeability, thus due to these characteristic they are also called left hand materials (LHM). The metamaterials are human engineered materials and were theoretically predicted forty years ago by Veselago [19]. Their properties were verified experimentally by many ways and gave rise to two main categories, the resonant and the non-resonant types. The resonant type is a composite of a meta-structure of electric and magnetic plasma like particles made by means of split ring resonators and metallic wires put on opposite sides. But this type as its name suggest is a resonating structure and seems of less practice interest because it shows low bandwidth and high losses. On the other side the non-resonant type, which is preferred in an application point of view because it can be engineered in planar configurations compatible with modern microwave integrated circuits, could be designed to exhibit low loss and high bandwidth. A similar structure was proposed in [6], it is a planar patterned configuration, which consists of arrays of different patterned cells arranged on both metallic sides of a substrate. This configuration was used and applied directly on an ordinary microstrip patch antenna in [27]. The antenna has the following dimensions $28 \times 32 \times 0.794\,\mathrm{mm}^3$, with a feeding line of $8 \times 2.46\,\mathrm{mm}^2$ dimensions, it achieved a -10 dB bandwidth of 3.2 GHz starting from 5.3 GHz to 8.5 GHz.

In this paper we propose a new antenna following the same philosophy basing on different patterns to enhance much further the bandwidth. The shapes of the patterns consist of simple crosses put in a 3×4 array on the patch, and on the ground plane, they are small patches separated by crossing slots, the patches are forming a 7×6 cells array and loaded with small slits on their angles.

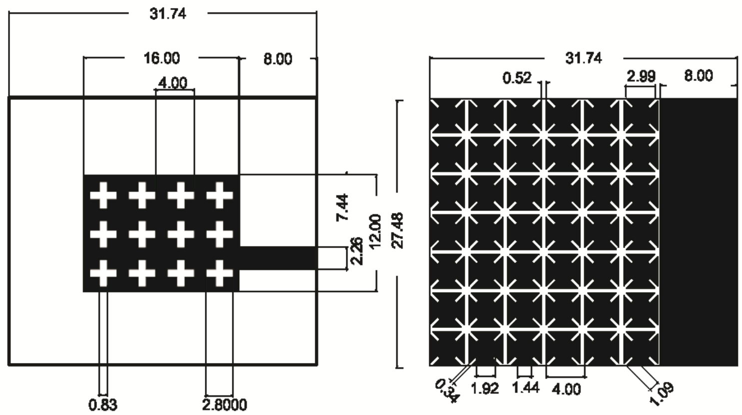

Figure 1: The antenna configuration.

2. ANTENNA CONSTRUCTION

For purposes of comparison, a conventional microstrip antenna was designed and simulated, and will hence serve as a reference. This antenna has the following overall dimensions $28 \times 32 \times 0.787\,\mathrm{mm}^3$, a patch with $12 \times 16\,\mathrm{mm}^2$ and a feeding line of $2.46 \times 8\,\mathrm{mm}^2$. Our proposed antenna originates from the conventional antenna with slightly reduced dimensions of $27.48 \times 31.74 \times 0.787\,\mathrm{mm}^3$, with the same patch dimensions and a reduced coupling line of $2.26 \times 8\,\mathrm{mm}^2$. The substrate is the RT 5880 with 2.2 permittivity and 0.787 mm thickness. The metallic parts of the antenna were repetitively etched out with different patterns in such way they construct planar arrays respectively on both sides of the substrate. So on the patch, an array of 12 crosses arranged in 3×4 configuration. On the other side, i.e., the ground plane, the patterns are formed by small patches separated by crossing slots, the patches are loaded with small radial slits on their angles. The area in the ground plane under the feeding line was not etched out The antenna configuration is shown in Figure 1.

The whole structure made of planar patterns on both sides of the substrate incites the left handed characteristic by driving a coupling between the patch and the ground plane. Thus the characteristics of the antenna are enhanced. The design and the simulations were carried out in the CST MWS 2011 environment. The final configuration of antenna was obtained after a parameter sweeping of the dimensions of the main shapes for optimization and better enhancement of the characteristics.

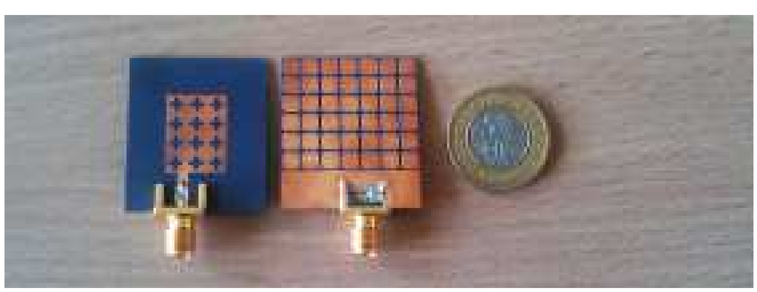

Figure 2: Picture of the fabricated antenna.

3. RESULTS AND DISCUSSION

As stated above in order to verify our approach, both antennas, after being designed and simulated, were fabricated, and their characteristics measured The picture of the proposed antenna is depicted in Figure 2. The dimensions of the antenna were continuously studied and submitted to parameter sweeping with the aim of obtaining better results. As we can notice that some dimensions in the antenna were slightly reduced, like the overall dimensions of the antenna and those of the feeding line. In both antennas we observe, as shown in Figures 3 and 4, a good agreement between the results of the simulations and the measurements. Also the proposed antenna achieved a −10 dB bandwidth of 13.192 GHz, ranging from 4.389 GHz to 17.581 GHz, it is 58 times larger than that of the conventional antenna, which is 0.225 GHz only, so a 120% fractional bandwidth is realized. And it is more than 4 times larger than in the antenna in [14].

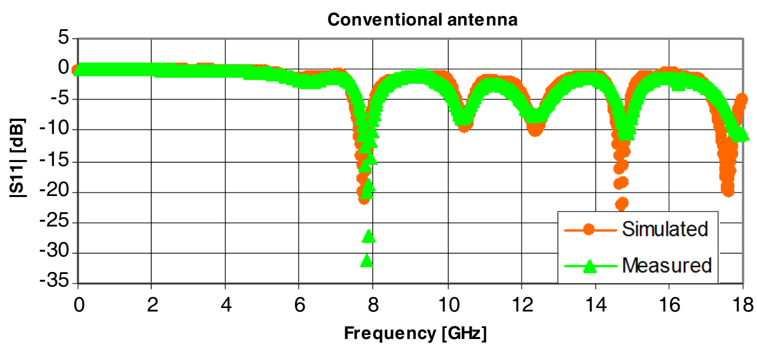

Figure 3: The results of simulation and measurement of the conventional antenna.

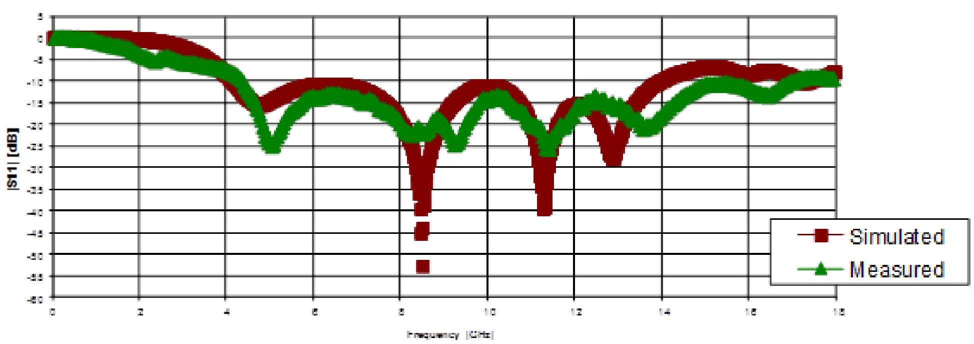

Figure 4: The results of simulation and measurement of the proposed antenna.

4. CONCLUSION

In this paper a compact ultra-wideband microstrip antenna is realized basing on the principle of planar patterned metamaterial. The metamaterials draw their properties rather from the structure than the contents, and confer special characteristics not found in natural materials. As it is noticed in the experiment shown in this paper, the structure applied here to the ordinary microstrip antenna has enhanced significantly its bandwidth, and transformed it from simple narrow bandwidth to an ultra-wideband antenna just by loading simply shaped patterns on its metallic parts.

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