Humberto Xavier de Araujo[1] , Antônio Evangelista de Freitas[2], David Nadler Prata[1], Ivan Roberto Santana Casella[3] and Carlos Eduardo Capovilla[3]

Universidade Federal do Tocantins (1), Universidade Federal de São João Del Rei (2), Universidade Federal do ABC (3),

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A Multiband Antenna Design Comprising the Future 5G Mobile Technology

***Abstract**. The pervasiveness of mobile internet, in conjunction to the ubiquitous computing of the internet-of-things has claimed the concept of 5G technology research to allow massive growth of machine communications. One of the main challenges is the scalability problem, which implies issues like small mobile device antennas to fit in the limited amount of space for the smartphone's design, followed by radiation control and low cost. The purpose of this paper is to develop an antenna, which meets the next generation of the mobile technology 5G as well as other resources available and desired in a smartphone (GPS – 1575 MHz, WLAN – 2.4 GHz, 3G – 2.1 GHz, Brazilian 4G – 2.6 GHz e GSM – 900 – 1800 – 1900 – 2100 MHz). The design adopted only one ultra-wideband microstrip antenna that resonates in the frequencies of these technologies. This kind of antenna is thin, has low cost and good radiation control. Besides, this is the most popular type of antenna in mobile devices; the radiant elements use the manufacturing process of printed circuits. It is built in a plate composed by a conductor (the radiant element of the antenna), a substrate, and by another conductor, which is the ground plate. The principal feature of an ultra-wideband antenna is the usage of 1.5 GHz bandwidth or more. The prototype was manufactured and the simulation results for each type of technology resources are compared.*

Streszczenie.** Celem artykułu jest opracowanie mikropaskowej anteny obsługującej technologię 5G. Koszt anteny jest minimal;izowany przez wykorzystanie techniki obwodów drukowanych. Szerokopasmowa antena wykorzystuje pasmo 1.5 GHz oraz inne większe pasma. Testy każdej z anten potwierdziły jej założone parametry.* ***Projekt wielozakresowej anteny szerokopasmowej przeznaczonej do nowych technologii 5G

Keywords: antenna, multiband, smartphone. 5G. UWB.
Słowa kluczowe: antena szerokopasmowa wielozakresowa, technologia 5G.

Introduction

The searching for multifunction devices, such as smartphones, is growing in the mobile devices market. These gadgets have several mobile current technologies, for instance: WiFi, high performance mobile internet (3G and 4G), GPS (Global Positioning System), GSM (Global System Mobile) ou (Global System for Mobile communication)and Bluetooth®. In a globalized world it is a trend that the velocity of the internet maintain increasing over the years in order to, among other functions, perform real-time video calls using, for example, a connection provided by a mobile operator. In addition, the screens of these devices are also increasing in size for a better user experience in video calls with high resolution. However, although the screens are increasing, the consumers are also looking for thinner devices.

Therefore, in order to reduce the dimensions of a smartphone it is necessary to shrink its internal components. So, some techniques are employed, such as the manufacture of integrated circuits, which considerably decreases the circuit size. Supplementary, is necessary to use printed antennas, which has an extremely small thickness.

The necessity of a mobile internet with higher speeds has promoted the research and the constant development of new technologies such as 4G that can reach data rates of 100 Mbps. Despite the fact that this technology was not totally implanted in several places, there is a slightly growing on research and development of the Fifth generation, i.e, 5G of mobile telecommunications, which is capable to operate with extremely high data rates transfer and using the frequency bands of electromagnetic spectrum above 25 GHz [1-3].

In addition, the prospect of growth in the number of devices connected simultaneously after the implementation of the Internet of Things (IoT) has concerned mobile technology companies, who has seek a solution to meet future demand efficiently, highligthing the importance of 5G deployment. [4-5].

In this context, this paper proposes the development of a microstrip antenna capable of meeting all desirable features in a smartphone, including the future 5G technology, using only one antenna in order to reduce the dimensions of the mobile device.

Antenna Design

Antenna is a device that serves as a medium to radiate or receive radio waves, in other words, the medium of transition between the free space and the waveguide, according to IEEE standard definition [6].

The antenna chosen in the project was the microstrip type due to the fact that it has an extremely small thickness. Moreover, this antenna must have the features of an ultra wideband antenna. At first, the microstrip antenna was used in space applications in the 70's decade (although its conception was created in the 50's decade) which made them very popular in this area at that time. Nowadays, this kind of antenna are widely used in civil commercial applications, mainly in mobile devices (such as smartphones). The microstrip antenna basically is composed by three layers: A metallic layer over a substrate over another metallic layer, which is the ground plane. This third layer (ground plane) could have different design formats, named configurations. These are the configurations that will, for instance, define the operation frequency of the device. The circular and rectangular shapes of this kind of antenna are the most used shapes because it is easy to project (when it comes to few resonance bands), to develop and to fabricate. Also, these shapes have an attractive radiation characteristics and low cross polarization.

These antennas are low profile (extremely thin), which makes them fit well to both flat and non-flat surfaces. Also, they have some versatility due to simplicity and economy on its fabrication, similarly to the manufacturing process of printed circuit boards. Furthermore, this antenna is mechanically robust when mounted in solid surfaces. Lastly, some parameters of this antenna are easy to manipulate, such as: resonance frequency, polarization, radiation pattern and impedance [7].

The Federal Communication Commission (FCC) classifies ultra wideband device as any device with a fractional bandwidth greater than 0.25 or occupying 1.5 GHz or more of a spectrum, which is the case of the present project. This class of antennas can be used for military, medical and commercial purposes, also in radars and mobile communications [4]. The FCC also proposed a formula to calculate the fractional bandwidth, given by:

(1) $$BW_{fractional} = \frac{2(f_H - f_L)}{(f_H + f_L)}$$

where f_H is the superior frequency of the emission point and f_L is the inferior frequency of the emission point (-10 dB). The central transmission frequency is given by the average of the -10 dB points [8].

Firstly, it was used the transmission line model equations, which are the basis of the microstrip antenna theory, in order to design a rectangular antenna (due to the simplicity of assembling) which resonates in the central frequency of the 5G technology (26 GHz). Afterwards, the same equations were applied in order to compute the same information for the central frequency of GSM (900 MHz). Then calculations were made to the extremes of the desired resonant frequencies to obtain an estimate of the antenna dimensions.

There are several substrates that can be adopted on the internal layer of the microstrip antenna, generally, their dielectric constant may vary between 2.2 and 12. In this paper, the antenna was built on RT/duroid 5880 substrate, made by Rogers Corporation. The main features of this substrate are the relative permittivity (ε_r) of 2.2 and the thickness of 0.508 mm.

In order to achieve an efficient radiant element, it is possible to calculate a practical value for *W* using the following equation:

(2) $$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

where V_0 is the speed of light in free space, f_r is the desired resonance frequency and ε_r is the substrate permittivity.

After the calculation of *W* it is necessary to acquire the effective parameters of the antenna, starting with the effective permittivity and then determining the length of the antenna due to the effectiveness of permittivity.

(3) $$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2}$$

(4) $$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.258)}\frac{\left(\frac{W}{h} + 0.264\right)}{\left(\frac{W}{h} + 0.8\right)}$$

After the above calculations it can be estimated the length and the effective length of the radiating element of the antenna

(5) $$L = \frac{C_0}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L$$

(6) $$L_{eff} = L + 2\Delta L$$

The result acquired using all above equations is shown on the table I.

The insertion of small rectangular cuts in the ground plane are capable of diminish the values of the S11 parameter (reflection coefficient). This parameter also indicates which are the resonance frequencies of a given antenna and what is its operating range [9-12].

Table I: Values of the extreme frequencies

Dimensions/Frequencies	900 MHz	26 GHz
W (mm)	131.76	4.56
ε_{reff}	2.1866	1.9925
ΔL/h	0.530	0.515
ΔL (mm)	0.269	0.262
L (mm)	112.17	3.56
L_{eff} (mm)	112.71	4.084

The rounding on the edges of the radiating element was made in order to reach the desired resonance frequencies.

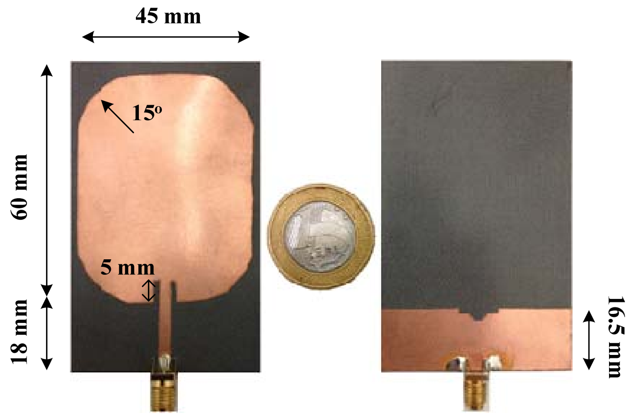

Fig. 1: Built prototype of the multiband antenna.

Results

The proposed antenna was designed on Rogers RT/duroid 5880 substrate, with relative permittivity of 2.2 and thickness of 0.508 mm. All the simulations were performed by CST Studio design tool, which is based on Finite Integration Technique (FIT).

In Fig. 2, the return loss parameter is shown, with the comparison of simulated and measured results. Based on this, it is possible to observe all ranges and applications that the proposed antenna can correctly work.

According to Fig. 2, it can be stated that the antenna has a resonance band between 970 MHz and 2.71 GHz, which meets the requirements of GSM, GPS, 3G, 4G and WiFi (2.4 GHz). It also resonates around 15 GHz, an unwanted frequency that may be useful for future applications in mobile devices, including satellites systems. Lastly, the antenna has another resonance band between 24.8 GHz and 27.5 GHz, which meets the requirements of 5G technology.

As soon as the S11 parameter meets values lower than -10 dB, a bandwidth is established. Another parameter used to evaluate the quality of antenna is the VSWR (Voltage Standing Wave Ratio), which is a function of the reflection coefficient, and is given by:

(7) $$VSWR = \frac{1 + |S_{11}|}{1 - |S_{11}|}$$

The VSWR indicates how much of an RF (Radio Frequency) signal was reflected to the transmitter. It has high values if the impedances are not very well-matched. The VSWR response of the antenna is resumed in Table II.

It can be seen that in the majority of the desired frequencies the VSWR has values lower than 2, which indicates that a small part of the wave, in the desired frequency becomes standing.

In Figs. 3-5, the radiation pattern of each technology is shown, regarding a normalized gain. All these results are summarized in Table II.

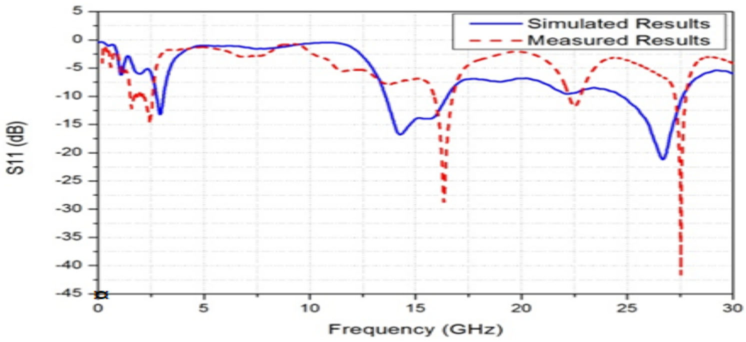

Fig. 2: The S11 parameter of the proposed antenna.

a) b)

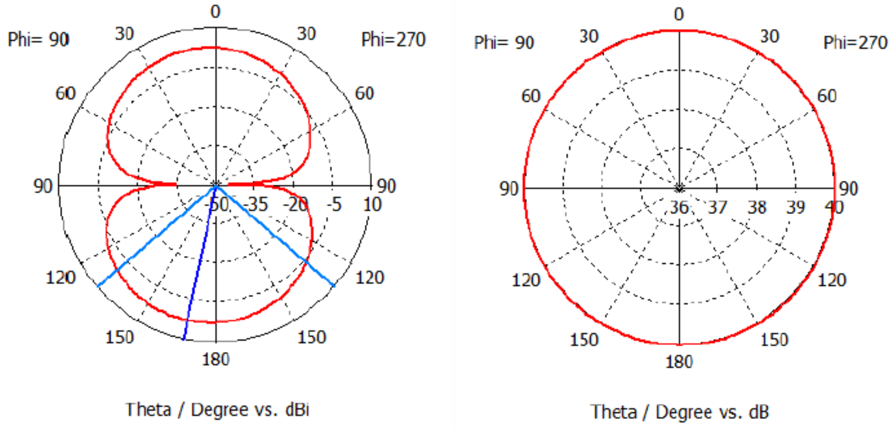

Fig. 3: 1575 MHz (GPS) radiation diagram. (a) E Plan, (b) H Plan

a) b)

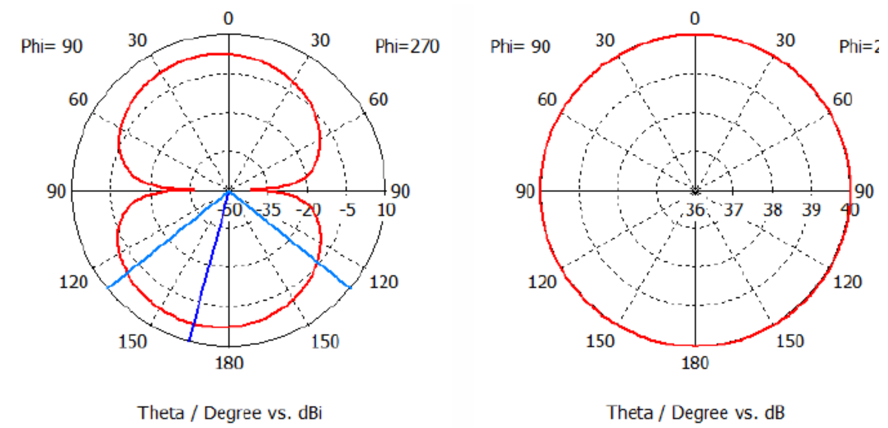

Fig. 4: 1800 MHz (GSM) radiation diagram. (a) E Plan, (b) H Plan

a) b)

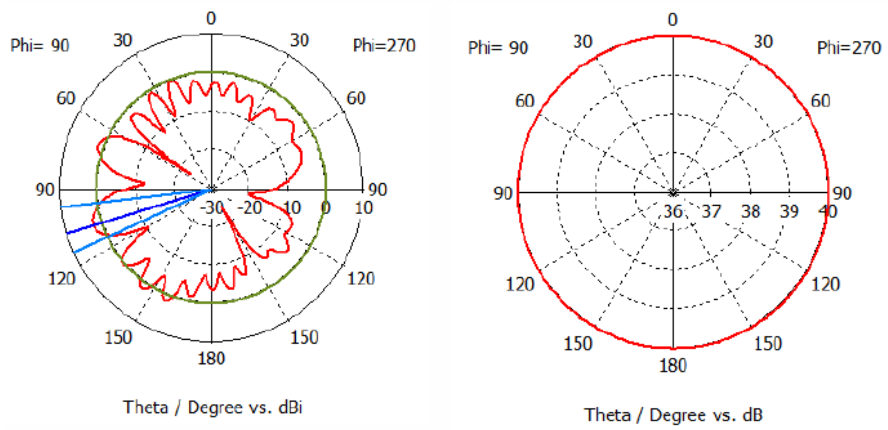

Fig. 5: 26 GHz (5G) Radiation Diagram. (a) E Plan, (b) H Plan.

The obtained results (the return loss, gain and VSWR) of for each technology (feature) of the smartphone is shown on Table II. The impedance matching is analyzed by S11, which may be lower or equal to -10dB in the operation band, due to 90% of the antenna input power to be radiated in this case [13].

Table II: Simulation Results

Technology	Frequency (GHz)	S11 (dB)	Gain (dBi)	VSWR
GPS	1.575	-15	2.8	1.48
GSM	1.8	-12.5	3.1	1.63
3G	2.1	-14.2	3.6	1.49
WLAN	2.4	-18.8	4.2	1.26
4G	2.6	-13.3	4.7	1.56
5G	26	-16.5	2.4	1.37

Conclusions

In this paper, a multi-band microstrip antenna that can be used in a smartphone was proposed, to attend its main wireless applications, including 3G, 4G, Bluetooth and also the next 5G mobile telecommunications systems.

As soon as the consumers are always looking for thinner and compact devices, but at the same time, with high data speed, the design of a compact antenna is imperative. Therefore, the proposed antenna can attend the applications and yet still thin and compact due the characteristics of the substrate. Finally, experimental and simulated results were compared, showing the good agreement of the proposed antenna.

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***Authors**: Prof. H. X. Araujo, Faculdade de Engenharia Elétrica, Universidade Federal Tocantins, Av: NS 15 ALC NO 14, 109 Norte - 77001-090, Palmas - TO, Brazil email: hxaraujo@uft.edu.com*

Prof. A. E Freitas, Departamento de Mecatrônica e Telecomunicações, Universidade Federal de São João Del Rei,Campus Alto Paraopeba, Congonhas - MG, 36415-000, Brazil email: aefreitasacad@yahoo.com.br

Prof. D. N.Prata, Faculdade de Ciências da Computação, Universidade Federal Tocantins, Av: NS 15 ALC NO 14, 109 Norte - 77001-090, Palmas - TO, Brazil email: ddnprata@gmail.com

Prof. I. R. S. Casella, Universidade Federal do ABC, Av. dos Estados, 5001 - Santo André - SP, 09210-580, Brazil email: ivan.casella@ufabc.edu.br

Prof. C. E. Capovilla, Universidade Federal do ABC, ABC, Av. dos Estados, 5001 - Santo André - SP, 09210-580, Brazil email: carlos.capovilla@ufabc.edu.br

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