ULTRA-LOW-COST POWER UWB PULSE STUDY ENVIRONMENT FOR ELECTRICAL ENGINEERING COURSE USING SPREADSHEETS BY CLOUD COMPUTING

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Abstract: *This work presents an ultra-low-cost UWB dynamic Power study and calculation environment for undergraduate and graduate classes on telecommunications of the electrical engineering course which is based on spreadsheet method. This method exploits the familiarity of modern and common spreadsheets programs to a variety of computer users and provides them a friendly and fast environment to study and obtain the power parameters of several classes of radio frequency (RF) ultra wide-band (UWB) pulses. This method is also useful for research and educational purposes, since it does not require the creation of computer programs for processing the UWB pulses extracted from Simulated Program with Integrated Circuits Emphasis (Spice) environments. It is briefly described, and an example is presented illustrating its use to obtain the power parameters of a RF UWB pulse, e.g. seventh order derivative Gaussian pulse, with temporal width of hundreds of picoseconds. In summary, this methodology allows validation of the method and also allows almost explicit analysis of the data throughout the process, in contrast with the black box model system created from programming languages, which in most cases receives data, processes them and displays only the results of the process, which is not always pedagogical, regarding its study as a whole. All this, enjoying the benefits of cloud computing.*

Keywords: *UWB, Power, Dynamic Energy, Gaussian Pulse, Spreadsheets.*

1 INTRODUCTION

Plato (427-347 BC), the great Athenian philosopher always said: “necessity is the mother of invention” (MONBODDO, 1779). The spirit of this quote involves this work, since the proposed method comes from the need to study, teach and research the power parameters of UWB pulses resulting from the Spice simulations of CMOS pulse generators circuits through a quick and friendly method for processing of these data, thereby obtaining these power parameters by using a simple spreadsheet. It takes no more than an hour to be prepared and requires no previous knowledge in any programming language, in contrast to the dozens of hours required to develop the same solution in any programming language (e.g. C++, MathLab, Fortran or Java).

These spreadsheets were initially proposed as electronic tools to solve problems in the areas of accounting and business, however, by great flexibility in solving a variety of problems involving mathematics, familiar interface which eliminates extensive training for its operation and large diffusion amongst computer users, its use was boosted in areas such as physics and engineering, especially (but not only) in educational tasks (MARION, 1987; EL-HAJJ et al. 2003).

Recently, many pedagogical proposals to the use of spreadsheets has been presented, especially in engineering, e.g. automatic control systems (MIRAPALHETA et al. 2013), microwaves (EL-HAJJ et al. 2003), transformed linear (BRONDINO & BRONDINO, 2012) and quantum physics (TAMBADE, 2012).

A new approach is proposed for the spreadsheets use for educational applications through the concept of cloud computing and by using environments like Microsoft SkyDrive or Google Virtual Spreadsheet it was possible to provide remote access to the spreadsheet.

Based on all these advantages presented on the use of spreadsheets, it is proposed a methodology for calculation of power parameters of UWB pulses, namely: Energy and Power consumption, on the order of pico-Joules and milli-Watts respectively. These parameters are calculated as a pulse by pulse repetition rate (PPR), which comes from the cadence at the time of generation.

The study of these parameter settings is very important because one of the great advantages of using RF systems based on UWB pulses is the fact that these are carrier-free, which makes them very efficient systems regarding energy savings, vital for use in devices powered by batteries, which increases their lifetime (PORCINO & HIRT, 2003, HEIDARI, 2008).

To get an idea, according Heidari (2008), an UWB data transmission system, i.e. WiMedia UWB (5mW/Mbps), is five times more efficient than WiFi IEEE 802.11a/b/g (25mW/Mbps) and ten times over Bluetooh (50mW/Mbps).

Therefore, to better present this teaching methodology study of power parameters of UWB pulses, the paper is organized as follows: In Section II is presented the fundamental concepts of UWB pulses, in Section III the proposed methodology, its preparation and some examples application, and finally, in Section IV the conclusions are presented.

2 THEORETICAL FOUNDATION ABOUT UWB RF PULSES, SIMULATION ENVIRONMENT AND CIRCUITS.

This Section presents a brief theoretical background on UWB RF pulses and its regulation by Federal Communications Commission – FCC, as well as the presentation of three UWB pulses and their generating circuits in Spice environment, therefore presenting the scenario where spreadsheet methodology proposed was applied.

2.1 Ultra-wideband RF pulses

Following the liberation of a specific bandwidth (3.1 to 10.6 GHz) for UWB applications by the Federal Communications Commission of the United States - FCC (2002), a growing effort to study this technique has been performed (MOLISCH, 2005).

According to what has been established and is regulated by the FCC for UWB communications applications to receive this designation, the signal must occupy a bandwidth equal to or greater than 500MHz or have a fractional bandwidth (FBW) equal to or greater than 1/5. The FBW can be obtained by the following expression:

$$FBW = 2\frac{f_h - f_l}{f_h + f_l} \qquad (1)$$

where f_h and f_l are the upper and lower limit frequency having a radiated emission at up to 10 dB lower than the highest emission and must be based on measurements with all transmitter system including the antenna (FCC, 2002).

According to Molisch (2005) and Heidari (2008), there are two main areas for applying this technique to the generation and propagation of short-pulse UWB, namely: UWB radars, with main interest focused for military use and UWB communication systems. Both areas benefit from the following features:

- Metric accuracy and high multipath fading due to insignificant fine resolution time;
- Multiple access due to high bandwidth transmission;
- Ultra-high transmission data rate;
- Higher channel capacity and power efficiency;
- Communication link virtually invisible (most receivers practically operates in noise level) due to transmission operation with very low power.
- Allow to penetrate different types of non-metallic materials because of the characteristic of having scattered energy at different frequencies characteristic;

Mobile devices equipped with UWB technology can be operated inside buildings (indoor) with any type of antenna / link and outside of buildings (outdoor), only with omnidirectional antennas type , since emission levels comply with the limit understood in -41.3dBm/MHz band spectrum ranging from 3.1 to 10.6 GHz Further details about the emission limits allowed by the FCC for UWB applications can be observed in Figure 1 and Table 1.

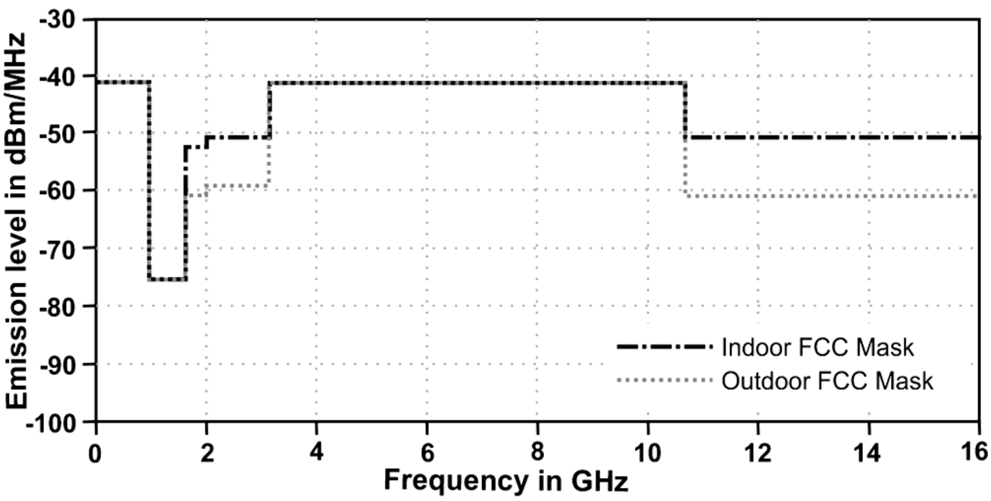


Figure 1 - FCC mask for UWB applications mobile, fixed internal (indoor) and mobile external (outdoor) (FCC, 2002).

Table 1 - Emission limits by the FCC radio frequency for UWB applications embedded in mobile devices (indoor / outdoor) and fixed inside the buildings (FCC, 2002).

Frequency Range in GHz	Indoor emission in dBm/MHz	Outdoor emission in dBm/MHz
0.96 a 1.61	-75.3	-75.3
1.61 a 1.9	-53.3	-63.3
1.9 a 3.1	-51.3	-61.3
3.1 a 10.6	-41.3	-41.3
After 10.6	-51.3	-61.3

If these emission limitations imposed by the FCC mask for UWB applications are met, there are small chances of interference with other existing systems, such as mobile phones, GPS, Bluetooth and W-LAN IEEE 802.11 (HÄMÄLÄINEN et al., 2002; LIANG, 2006; ARAÚJO, 2011).

2.2 The UWB radio impulse

Wentzloff (2007) analyzed several pulses that would be potential candidates for UWB applications: The sync pulse, illustrated in Figure 2 (a), has higher spectral efficiency regarding little or no side emissions. However, this requires a pulse transmitter with electronic circuit complexity. In contrast, the square wave pulse (Figure 2 (b)) generator circuit is one of the simplest. When analyzing the pulse in the frequency domain, Wentzloff (2007) noted that it has the highest emission side though. The best relationship between spectral efficiency versus degree of simplicity pulse generator circuit may be found in the Gaussian pulse, illustrated in Figure 2 (c), which has the lowest rate, product of time for bandwidth (Btω), low emission side, and electronic circuit with moderate complexity. For these reasons, the Gaussian pulse is regarded as one of the most suitable candidates for UWB applications (WENTZLOFF, 2007).

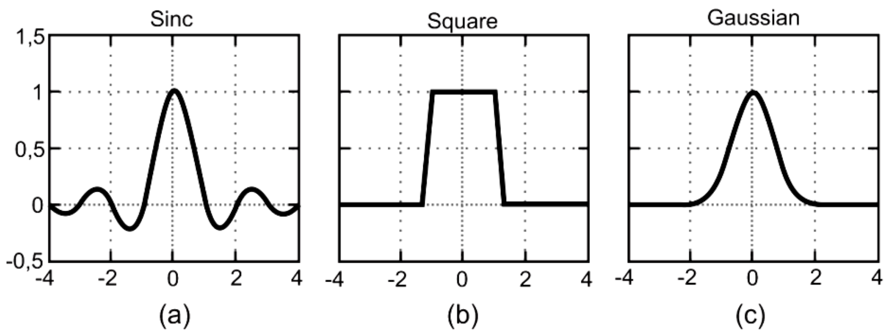


Figure 2 - Three candidates for pulse UWB applications. (a) Pulse Sync, (b) square wave pulse, (c) Gaussian Pulse (WENTZLOFF, 2007).

Another important aspect that should be noted is that both the pulse square waveform as the Gaussian pulse feature DC component (zero frequency or DC), which makes it less efficient radiation (ZHUANG et al., 2003; TOYA et al., 2011; DE OLIVEIRA, 2012). To solve the problem of the DC component, Toya et al. (2011), De Oliveira (2012), as well as several other studies (e.g. ZHUANG et al., 2003; KIM, et al., 2010) choose to work with a derived version of the Gaussian pulse that, besides not presenting DC component (the promoting efficient radiation) can be synthesized by circuits order of low to moderate complexity.

De Oliveira (2012) conducted a comparative study between the Gaussian pulse and its first seven forms derived and came to the conclusion that the Gaussian pulse in the fifth, sixth and seventh order of derivation has no DC component and meets FCC requirements.

For the reasons above, the pulse Gaussian derivative is studied for developing UWB applications.

2.3 UWB pulse and its generating circuit in Spice environment

As discussed earlier, one of the advantages of the application of UWB pulses is its extreme energy efficiency which makes it a great choice when this is the main design parameter (MOLISCH, 2005), so the study of the pulse energy is very important, therefore, a circuit will be presented in the literature and its UWB pulse which was used to test the proposed method. Table 2 shows the parameters of the UWB generator circuit, where the synthesized pulse was used to validate the proposed method in this paper.

Table 2 - UWB pulse generator parameters.

Author	Technology	Type	Amplitude	Width
(DE OLIVEIRA, et al. 2012)	CMOS 0.18μm	7^{th} der. Gaussian	136mVpp	350ps

The circuit architecture (Figure 3) consists of a serial line with four delay elements (Delay 1, 2, 3, and 4), where each input and output of the delay elements is connected to the inputs of a triangular pulse generator (PG 1, 2, 3, and 4). The output of the four triangular pulse generators are connected to an output block (+) which generates the UWB Gaussian pulse of 7^{th} derivative order (Figure 4). This pulse feeds the antenna load with 50Ω of impedance.

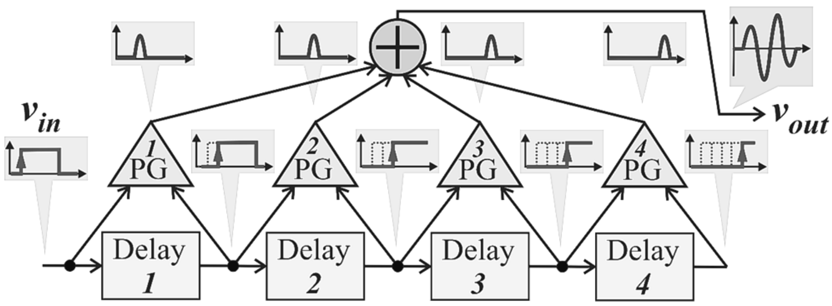


Figure 3 – Circuit architecture of 7^{th} derivative Gaussian pulse generators (DE OLIVEIRA et al., 2012).

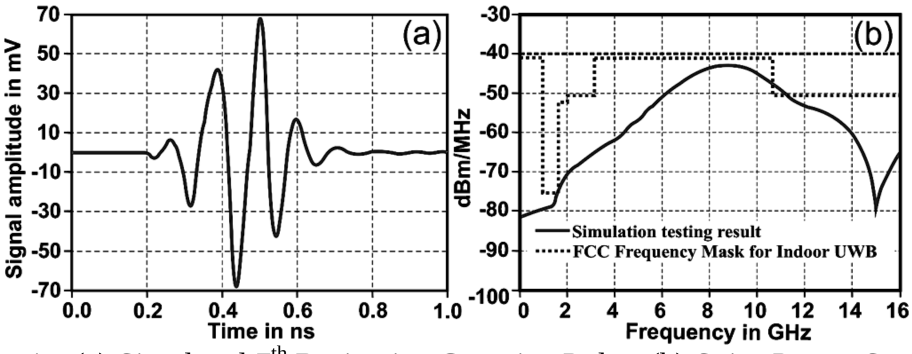


Figure 4 – (a) Simulated 7^{th} Derivative Gaussian Pulse, (b) Spice Power Spectral Density of output pulse (DE OLIVEIRA et al., 2012).

The pulses illustrated in Figure 4 were synthesized by their respective circuit in the Spice environment (*LTSpice IV and MicroWind 3.5*).

In order to analyze the power of this pulse, it should export the simulation data relating to current and voltage as a function of time through a text file and then these data are imported (or copied and pasted) in the spreadsheet as shown in Figure 5.

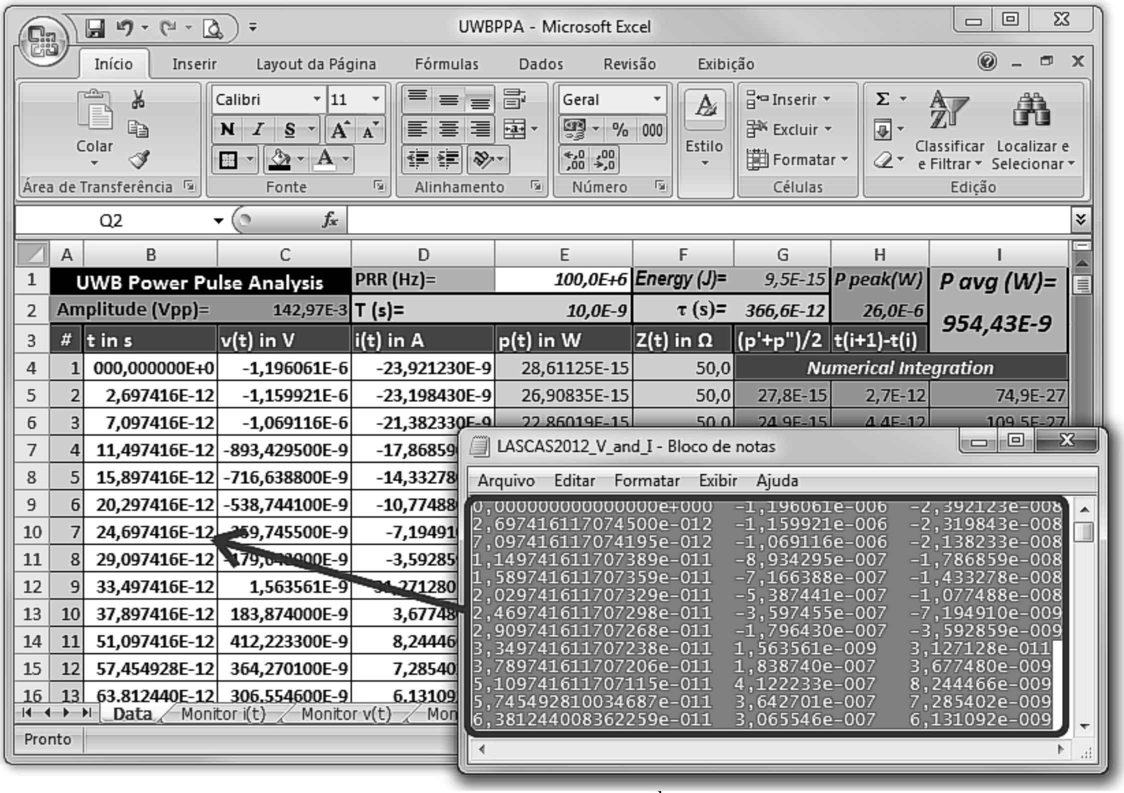


Figure 5 – Notepad with synthesizing text data of 7th derivative Gaussian pulse simulated, of De Oliveira, et al. (2012), in Spice environment and imported to spreadsheet proposal (background).

Text file containing a simulation data of a discretized UWB pulse as a time function, where the first column (***B4..B282 at spreadsheet***) refers to the time in seconds, the second column (***C4..C282 at spreadsheet***) refers to voltage, and the third column (***D4..D282 at spreadsheet***) refers to the current in a period ***T*** (***E2 at spreadsheet, which is obtained by the formula =1/E1***) of 10ns in function of PRR (***E1 at spreadsheet***).

From this point on begins the use of the spreadsheet methodology proposed in this paper, to perform the power analysis of pulse synthesized.

3 PRESENTATION OF THE SPREADSHEETS UWB PULSES POWER ANALYSIS METHOD

As seen in Section 2, one of the main characteristics of UWB pulse is its energy efficiency. In this way, it is extremely important to study the parameters of power and energy of a UWB pulse, therefore, the power must be defined and its various analysis parameters (instantaneous power, average power, pulse amplitude, and pulse energy).

To better understand the concepts of UWB pulse power shown in this Section, one should consider a regularly repeating pulse train with a PRR (***E2 at spreadsheet***) as shown in Figure 6, where τ is the pulse width, and ***T***, the period of the cadence of pulses.

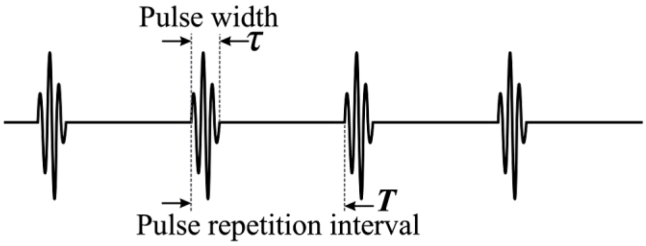


Figure 6 – Representation of the pulse width and pulse repetition interval in UWB signals (NEKOOGAR & DOWLA, 2012).

3.1 Power pulse

In the study of UWB pulse, power may be defined as: The rate at which energy is transferred from a transmitter system for transmission medium and/or the reverse, by time unit, with your unit [J/s] or [W].

3.2 Instantaneous Power pulse

It can be defined as the instantaneous power (***E4..E282 at spreadsheet***) supplied (or absorbed) by the antenna, through the product of instantaneous electric potential difference at its terminals (***C4..C282 at spreadsheet***) and the instantaneous current (***D4..D282 at spreadsheet***) through this, as illustrated in Figure 7 (RIZZONI, 2009; IRWIN, 2003).

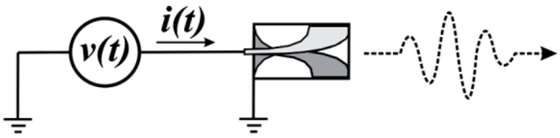
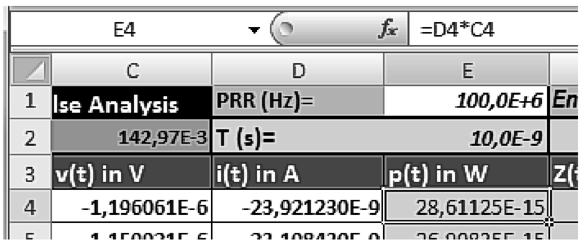


Figure 7 – Simple UWB transmitter circuit network.

Based on the circuit shown in Figure 7, it is possible to obtain the general expression of the instantaneous power pulse as:

$$p(t) = v(t)\, i(t)[W] \quad (2)$$

in general, e.g. ***E4*** cell is equivalent to the product of cell ***D4*** and ***C4*** as shown in Figure 8.


E4 =D4*C4

	C	D	E	
1	lse Analysis	PRR (Hz)=	100,0E+6	En
2	142,97E-3	T (s)=	10,0E-9	
3	v(t) in V	i(t) in A	p(t) in W	Z(
4	-1,196061E-6	-23,921230E-9	28,61125E-15	

Figure 8 – Part of the spreadsheet, with emphasis in cell ***E4***.

3.3 Pulse Energy

The pulse energy (***G1 at spreadsheet***) can be defined in a simplified way and mathematics as the integration function of the instantaneous electric power in the range from ***0*** to ***T*** as seen in the expression:

$$E_{pulse} = \int_0^T p(t)dt\ [J] \tag{3}$$

To accomplish the integration of the function ***p(t)*** between ***0*** and ***T***, we used the technique of numerical integration by the Riemann sum, which according Stewart (2007), can be defined as approximation of calculating a definite integral $\int_b^a f$ by summing several rectangles that divide the region formed, superiorly by the function, inferiorly by the horizontal axis (***t*** in this case) and laterally by ***a*** and ***b*** (***0*** and ***T*** respectively).

The Riemann sum uses only rectangles. To get the rectangles, one must subdivide the interval [***0***, ***T***] into ***n*** sub-intervals (in this case was adopted **277** intervals, which represents the rows ***5*** to ***282***). The subdivisions do not need to be irregular; they can be the nodes of an uniform partition and, therefore, satisfy an arithmetic progression of reason $\Delta t = T/n$. With the arithmetic progression obtained with this reason Δt in the range ***0*** to ***T*** it is possible to write the Riemann sum for this case as:

$$E_{pulse} = \sum_{i=1}^{n} p(i\Delta t)\Delta t[J] \tag{4}$$

Which in the spreadsheet corresponds to cell ***G1***, that equals the sum of cells ***I5*** to ***I282***, in this case, ***=SOMA(I5:I282)***. These cells, in turn, store the general formula $\boldsymbol{H_m * G_m}$, where ***m*** is the number of row of the spreadsheet, then $\boldsymbol{H_m}$ has the Δt ($\boldsymbol{B_m - B_{m-1}}$) and ***Gm*** has the arithmetic average between ***p(t)*** and ***p(t-i)***, or ($\boldsymbol{E_m + E_{m-1}}$)/2.

3.4 Average power pulse

The average power (***I2 and I3 at spreadsheet***) of any UWB pulse (e.g., 7th derivative Gaussian pulse) can be computed by integrating the instantaneous power pulse over a complete period (***T***) dividing this result by ***T***, and can be represented by:

$$P_{avg} = \frac{E_{pulse}}{T}[W] \tag{5}$$

Substituting the expression (4) to (5) have:

$$P_{avg} = \frac{1}{T}\int_0^T p(t)dt\ [W] \tag{6}$$

what the spreadsheet is representing in the merged cells ***I2*** and ***I3***, the formula **= *G1/E2***.

3.5 Result of the application of the spreadsheet

As a result of the methodology application of UWB pulse analysis by spreadsheet, the data from the simulation of the circuit proposed by De Oliveira, et al. (2012) are presented in Table 3:

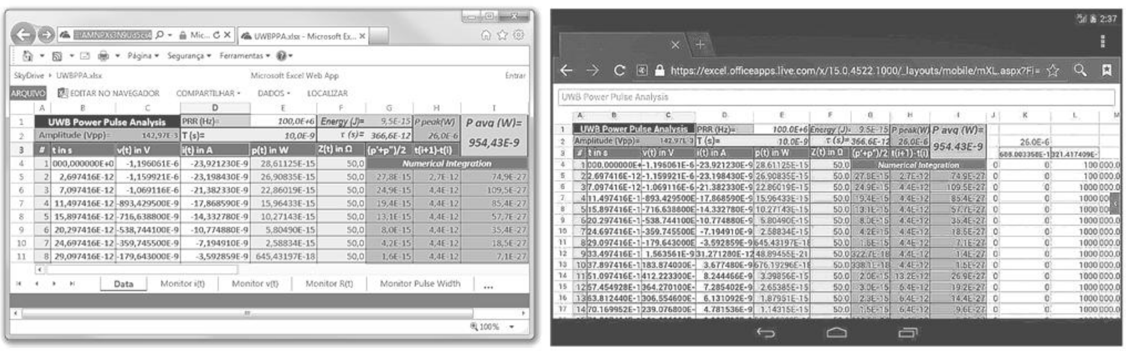
Table 3 – De Oliveira, et al., (2012), calculated UWB pulse generator parameters.

Parameter	***Value***
T	10ns
τ	366ps
E_{pulse}	9.5fJ
P_{avg}	1µW
Amplitude	142.97 mVpp

3.6 Cloud Computing

With the advent of cloud computing, an extremely versatile tool that increases the flexibility of the electronic spreadsheet methodology proposed in this paper, is the use of the virtual environment, e.g. Microsoft SkyDrive, or Virtual Spreadsheet of Google.

Figure 9 shows the spreadsheet being accessed in two different environments: the first one traditional Windows OS with Internet Explorer (Figure 9 (a)) and the second the Android 4 OS from mobile world of tablets (Figure 9 (b)).



(a) (b)

Figure 9 – Screenshot of the browser accessing the spreadsheet proposal. (a) Windows environment using Internet Explorer; (b) Android 4 OS at a Tablet using a browser.

This flexibility is of great interest when they want to interact with students of distance education and / or research partners remotely.

To access the spreadsheet, go to: https://skydrive.live.com/view.aspx?resid=E7811F195A6E364A!397&app=Excel&authkey=!AMNPXs3N9Ud5cs4

4 CONCLUSIONS

In this paper a new and ultra-low-cost method for the study of power parameters of a UWB pulse using modern spreadsheet programs is presented. This method considerably reduces the time and effort needed to create and write computer programs and does not require access to advanced or additional packages. It is extremely useful for educational and scientifically purposes, where the budget is limited, and the focal point is to study the properties and performance of the different types of UWB transmitter circuits. This particular methodology, allows the use of the concepts of cloud computing, by sharing the spreadsheet in a virtual environment such as Microsoft Virtual SkyDrive or Google Spreadsheet that allows greater interaction with students and researchers from distance. In the pedagogical field, this methodology was used to present the study of power parameters of UWB pulses in a didactic manner, since the data are all explicit. In the research field, this methodology proved to be very effective when applied in the study of Gaussian pulse and its first seven orders of derivation performed by De Oliveira (2012). Finally, by applying the methodology proposed in this paper in a seventh order derivation pulse proposed by De Oliveira et al. (2012), parameters of pulse energy were rapidly obtained, with a period of 10ns, a pulse width of 366ps, an energy pulse of 9.5fJ, an average power of 1µW, and amplitude of 142.97mVpp.

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