PLANNING AND DEVELOPING TECHNIQUES IN WORKING WITH DISTRIBUTED SYSTEMS FOR WIRELESS GATHERING, TRANSFERRING AND MANIPULATION OF INFORMATION STREAMS

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Abstract. The present article contains data for hardware implementation of distributed systems for wireless gathering, transferring and manipulation of information streams, as well as data for building a mathematical model of an electrical analogue filter, described in MATLAB. The diffèrent stages for analysis in the construction of the electrical circuit are described: electrical circuit analysis, frequency analysis, time analysis, modulation of signals, filtering of signals. Furthermore, the results from the calculation of the parameters of the radio-frequency identification antenna are presented.

Keywords: radio-frequency identification, MATrixLABoratory (MATLAB), near-field communication.

1. INTRODUCTION

A system is a set of interworking components that function together with the mutual goal of achieving a task. The information system is a concept that covers all forms of gathering, storing, extracting, manipulating and disseminating information.

Radio-frequency Identification (RFID) systems are information systems built towards wireless gathering of data from transponders (sensors, smart cards, etc.), also known as tags, and toward receiving data from applied systems for satisfying the specific information needs of the system. The RFID systems consist of three main components: a reader device, a transponder and an antenna tuned to the correct frequency in which the data is being transmitted and received. The most commonly used RFID frequencies are 11. From them, the top used ones are 125 kHz, 13.56 MHz and 2.45 GHz. On receiving

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the modulated signal, the reader uses the command protocol to demodulate and decode the incoming data. In the case of more than one transponder signal being received, techniques for identification without conflicts are then used. An example of that is keeping the reading for a small period of time, another one is to concurrently ask every single transponder.

The data in a transponder can identify a certain object in construction, loads in transporting work, cars, animals or humans. RFID devices are used with great success in automated production lines and storage systems as well as for bank transactions – Near Field Communication (NFC). They can store data that can then be read by a base station or by handheld readers. These mobile databases provide personnel with their necessary information, eliminating the need of creating and maintaining a centralized database. In the development process the information stored in the transponders can be actualized, and in this way the database is also actualized with data for the product.

Wireless transfer of data is the transferring of digitally encoded information between two endpoint devices in a certain environment without losing any information. It is done by following the stages:

- Encoding of the data;
- Modulating the data;
- Filtering the signals;
- Wireless transfer of signals (antenna projection);
- Demodulating of the data;
- Digital manipulation of the data (correct choice of a microcontroller with an appropriate firmware).

2. HARDWARE DEVELOPMENT OF AN NFC READER

The digital manipulation of the data inside the reader is done through a previously chosen microcontroller (chosen due to the functional specifications of the system) that does the user application. The microcontroller communicates with a specialized integrated circuit CLRC66302HN via a Serial Peripheral Interface (SPI) [1]. The RFID integrated circuit encodes the data received from the microcontroller by using the SPI and uses them to modulate the carrying frequency – 13.56 MHz. The modulated signal is being transmitted to a filter to remove any high frequency harmonic signals that interfere in the environment and harm the working of other electrical components. After the filter is applied, the modulated signal is being passed through a post-tuning circuit that finalizes the tuning of the frequency of the signal, as well as synchronizes it with an antenna (impedance and frequency).

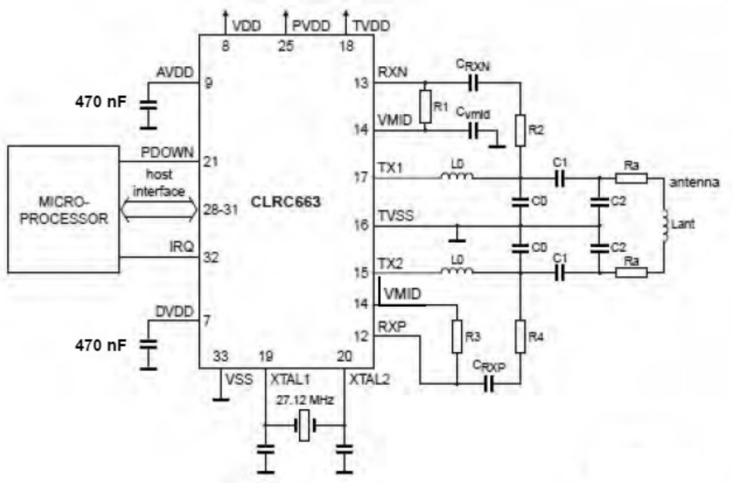

Fig. 1. NFC reader circuit

The circuit for this shown in Fig. 1 is developed with the software product CAD STAR 16. It contains:

1. Microcontroller with a user application;
2. Integral circuit CLRC66302HN [1];
3. An analogue low-pass filter;
4. An analogue circuit for synchronization of the impedance between it and the other part of the system (math circuit) [2].

3. THEORETICAL DATA AND EXAMPLES FOR CALCULATING THE PARAMETERS OF RFID DISTRIBUTED SYSTEM FOR WIRELESS GATHERING, TRANSFERRING AND MANAGING OF INFORMATION STREAMS

3.1. Data encoding

The data transfer is susceptible to noise from the environment or the channels, through which the data passes, including air. The electromagnetic noise, the interference and the fluctuations make it necessary the use of defense, one that defends against erroneous data transfer. The transfer process can be synchronous or asynchronous. Structuring the stream of data is known as channel encoding [3–4]. Some methods to do that are shown in Fig. 2.

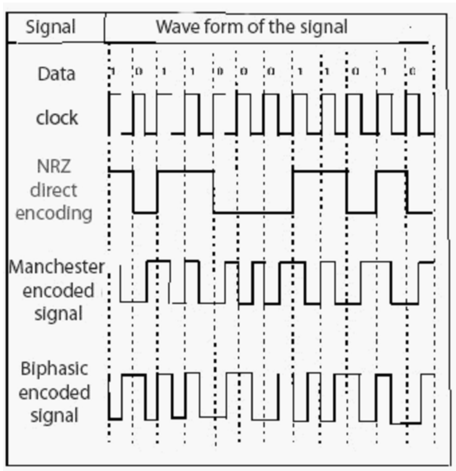

Fig. 2. Methods of signal encoding

- In the case of NZR (direct method), the data is encoded depending on the period of the system clock, where a value of 0 is the low signal mode and a value of 1 translates to the high signal mode.
- In Manchester encoding the change of signal level occurs for every half period of the clock.
- Biphasic encoding method is the same as a Manchester encoding but the phase of the output signal is rotated by 90 degrees.

The data for this operation can be found in the description of integral circuit CLRC66302HN [5].

3.2. Data modulation

The transfer of data in the environment or the space between two components that are exchanging information requires it to be transformed into a fluctuating field or a wave. This transformation is called *modulation* [6].

The modulation is the process of changing the parameters of a signal, called a carrier signal, under the influence of another, called a modulating signal. The carrier signal has a much larger frequency than the modulating one and is usually changed according to the law of sines or cosines. Depending on the parameter that is being modulated, the modulation can be divided into several types – Amplitude Modulation (AM), Frequency Modulation (FM), and Phase Modulation (PM). The latter two are known by their common name – angular modulation. When the carrier signal has rectangular form, an impulse modulation occurs. As with the other type, it can also be divided into Amplitude

Impulse Modulation (AIM), Frequency Impulse Modulation (FIM), Phase Impulse Modulation (PIM) and Wide Impulse Modulation (WIM). When the carrier signal is harmonic, and the modulating one has a rectangular form, the terms of manipulation are similar – amplitude, frequency and phase. The data for this operation can be found in the description of integral circuit CLRC66302HN [5].

3.3. Signal filtering

Development of the technical means of suppressing interference in the radio spectrum is done in this Section. More information can be found in [7–8]. The most common types of filters can be found in the next two Figs 3 and 4.

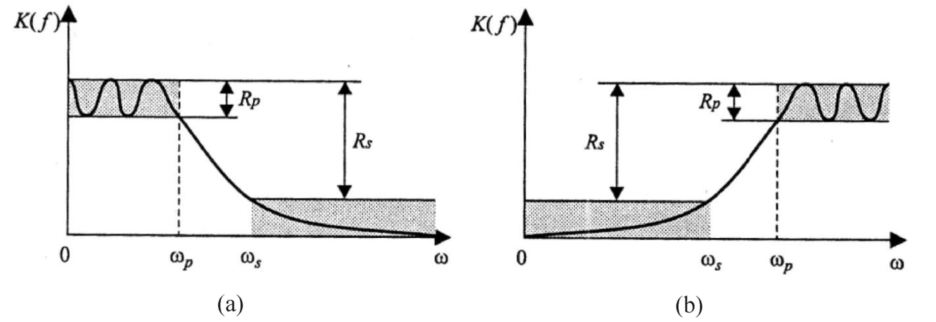

Fig. 3. (a) Low-frequency filter; (b) high-frequency filter

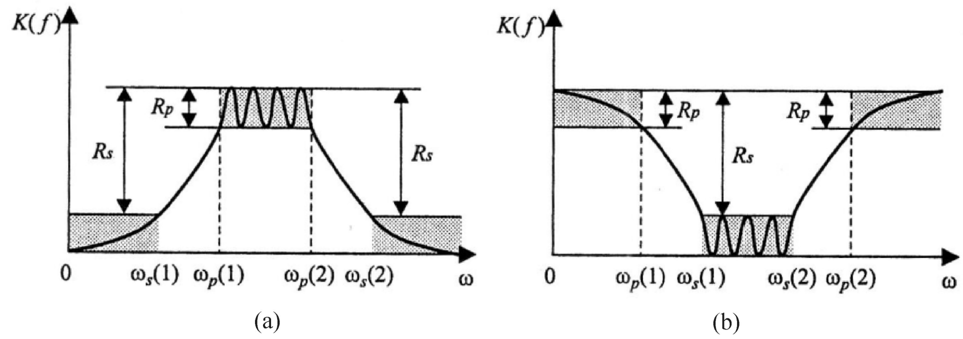

Fig. 4. (a) Line filter; (b) band-stop filter

3.3.1. Method of calculating a low-pass filter

The electrical circuit with passive elements is shown in Fig. 5. Due to the fact that the integral circuit CLRC66302HN allows for transferring data through a carrier frequency of 13.56 MHz, the projection is limited to the development of a filter with passive components. The development of a filter with an operational amplifier is discouraged because the channel capacity is then less than or equal to 1 MHz and the cost of the system rises [7–9].

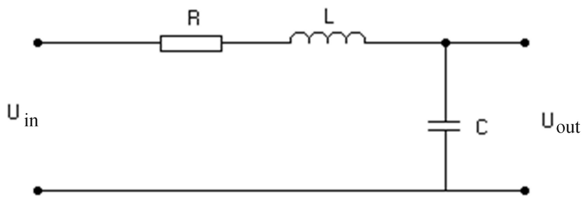

Fig. 5. Electrical circuit with passive elements

The transfer function of the filter is written in the form:

$$W\left(p\right)=\frac{\dfrac{1}{pC}}{\dfrac{1}{pC}+pL+R}=\frac{1}{1+p^{2}CL+pCR}, \tag{1}$$

and the transfer function of a fluctuating track is :

$$W\left(P\right)=\frac{k}{T^{2}p^{2}-2\xi Tp+1}. \tag{2}$$

A mathematical model in the middle of MATLAB

A mathematical model is created in the middle of MATrixLABoratory (MATLAB) for a low-pass second-order filter with Chebyshev approximation. The optimal values are determined for the components of the electrical circuit of the filter. The reaction of the dynamic system to arbitrary inputs is obtained [5, 10–12].

```
A1=5; % amplitude of the periodical sinusoidal signal
N = 1024; % number of points for the signal
Fs =100000000; % frequency for the discretisation in Hz
dt=1/Fs; % step in the moments of discretisation
t = 0:dt:(N-1)*dt; % moment of discretisation
f1=13560000; % frequency in Hz (13.56MHz) of a periodical sinusoidal signal
x1=A1*cos(2*pi*t*f1); % values of a periodical sinusoidal signal
A=3.3; % amplitude for a periodical rectangular signal
f =2000000;% frequency in Hz (2MHz) of a periodical rectangular signal
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x=A*square(2*pi*t*f);% values of a periodical rectangular signal
y=A1*(1+A/A1.*square(2*pi*t*f)).*cos(2*pi*t*f1); % values of a modulated signal
f2=40e6;% frequency in Hz (40MHz) of a sinusoidal signal
x2=1*cos(2*pi*t*f2); % values of a sample function
y1=A1*(1+A/A1.*square(2*pi*t*f)).*cos(2*pi*t*f1)+x2; % value of a modulated signal mixed with other periodical signals

Figure 1; plot(t,x1), title('SINOSIDAL SIGNAL 13.56MHz'),
xlabel('Time[sec]'), ylabel('Amplitude[V]')% graph of the time domain of the signal 'x1'
X1 = fft(x1,N);% function for fast Fourier transform
X1 = X1(1:N/2);% normalization of the stream
mx1= abs(X1)/N; % vector of the module
fx1 = (0:N/2-1).*Fs/N;% vector of the frequency in the domain

Figure 2; stem(fx1, mag2db(mx1)), title('SINOSIDAL SIGNAL FREQUENCY SPECTRUM 13.56MHz'), xlabel('Frequency[Hz]'), ylabel('Power[dB]')% graph of the frequency domain of the signal 'x1'

Figure 3; plot(t,x), title('RECTANGULAR SIGNAL 2MHz '),
xlabel('Time[sec]'), ylabel('Amplitude[V]')%graph of the time domain of the signal 'x'
X = fft(x,N);% function for fast Fourier transform
X = X(1:N/2);% normalization of the stream
mx= abs(X)/N; % vector of the module
fx = (0:N/2-1).*Fs/N;% vector of the frequency in the domain

Figure 4; stem(fx, mag2db(mx)), title('FREQUENCY SPECTRUM OF RECTANGULAR SIGNAL 2MHz'), xlabel('Frequency[Hz] '),
ylabel('Power[dB]')graph of the frequency domain of the signal 'x'

Figure 5; plot(t,y), title('AMPLITUDE MODULATED SIGNAL'),
xlabel('Time[sec]'), ylabel('Amplitude[V]')% graph of the time domain of the signal 'y'
Y = fft(y,N);% function for fast Fourier transform
Y = Y(1:N/2);% normalization of the stream
my= abs(Y)/N; % vector of the module
fy = (0:N/2-1).*Fs/N;% vector of the frequency in the domain

Figure 6; stem(fy, mag2db(my)), title('FREQUENCY SPECTRUM OF AMPLITUDE MODULATED SIGNAL'), xlabel('Frequency[Hz]'),
ylabel('Power[dB]')% graph of the frequency domain of the signal 'y'

Figure 7; plot(t,y1), title('AMPLITUDE MODULATED SIGNAL+ 40MHz'), xlabel('Time[sec]'), ylabel('Amplitude[V]')graph of the time domain of the signal 'y1'
Y1 = fft(y1,N);% function for fast Fourier transform
Y1 = Y1(1:N/2);% normalization of the stream
my1= abs(Y1)/N; % vector of the module
fy1 = (0:N/2-1).*Fs/N;% vector of the frequency in the domain

Figure 8; stem(fy1, mag2db(my1)), title('FREQUENCY SPECTRUM OF AMPLITUDE MODULATED SIGNAL +40MHz'), xlabel('Frequency[Hz]'), ylabel('Power[dB]')%graph of the frequency domain of the signal 'y1'
%Lo-pass filter chebyshev
Wp = 2*pi*20e06;% pass-through line
Ws =2*pi*25e06;% suppress line
Rp=10;% permissible unevenness in the frequency response in the suppress line in dB
Rs=13;% minimal necessary damping in the suppression line in dB
[n,Wn] =cheb1ord(Wp, Ws, Rp, Rs,'s')% choosing of the minimal necessary order of magnitude of the filter
[b,a]=cheby1(n,Rp,Wn,'s');% calculating of an analog filter
h=tf(b,a)% transfer function
den2=a/a(3);% equalizing the free coefficient in the characterizing polynomial to 1
num2=b/a(3);
h1=tf(num2,den2)
[H,w] = freqs(num2,den2,4096);

Figure (9); plot(w/(2*pi),mag2db(abs(H))),grid
pol=roots(a)% poles of the signal
nul=roots(b)% zeroes of the signal
w1=sqrt(real(pol(1)) 2+imag(pol(1)) 2)% conjugated frequency in radian/seconds
f_s=w1/(2*pi)% conjugated frequency in Hz
ksi1=abs(real(pol(1)))/w1% damping coefficient
T1=1/w1% time constant
RC1=2*T1*ksi1
LC1=T1^2
L=150e-9; C=LC1/L
R=(2*ksi1*(sqrt(L*C)))/C
y2=lsim(h1,y1,t); % Simulation of the time response of a dynamic system to

a random input
Y2 = fft(y2,N);
Y2= Y2(1:N/2);
my2= abs(Y2)/N;
fy2 = (0:N/2-1).*Fs/N;

Figure (10); stem(fy2, mag2db(my2)), title('FREQUENCY SPECTRUM OF FILTERED SIGNAL'), xlabel('Frequency[Hz]'), ylabel('Power[dB]')

Figure (11); plot(t,y2), title(' FILTERED SIGNAL'), xlabel('Time[sec] '), ylabel('Amplitude[V]')

The mathematical equation of the filter is:

$$H = \frac{0.3162}{1.202e - 16s^2 + 3.512e - 0.9s + 1}\ . \tag{3}$$

The optimal values of components in the electrical circuit are calculated. The poles of a characteristic polynomial are determined (the denominator of the transfer function). For a fluctuating track from the second order of magnitude there are two complex solutions with a real RE and imaginary IM part. Results for the values of the passive elements included in the electrical circuit of filter are given in Table 1.

Simulation graphs are shown in Figs 6–14. The periodic rectangular signal of 2 MHz can be seen in Fig. 6, and the frequency spectrum of rectangular signal of 2 MHz, in Fig. 7.

Table 1. Results for the values of the passive elements included in the electrical circuit of filter

n	f_s	T [s]	$Ksi - \xi$	*pol*	k	R [Ω]	L[nH]	C[pF]
2	14.520 MHz	1.0961e-08	0.1602	Complex conjugate -1.4613 ± 9.0051i	0.3162	4	150	800

The periodic sinusoidal signal of 13.56 MHz and the frequency spectrum of the sinusoidal signal of 13.56 MHz are depicted in Figs 8 and 9, respectively. Figures 10 and 11 show an amplitude-modulated signal and a frequency spectrum of amplitude-modulated signal, respectively. An amplitude-modulated signal of +40 MHz and a frequency spectrum of an amplitude-modulated signal of +40 MHz can be seen in Figs 12 and 13, respectively. The response of the filter to the input amplitude-modulated signal summed with a periodic sinusoidal signal of 40 MHz is shown in Fig. 14.

The present article, synthesized in such way, gives clear insight into the work of passive filters visualized in the frequency and time domain simulated

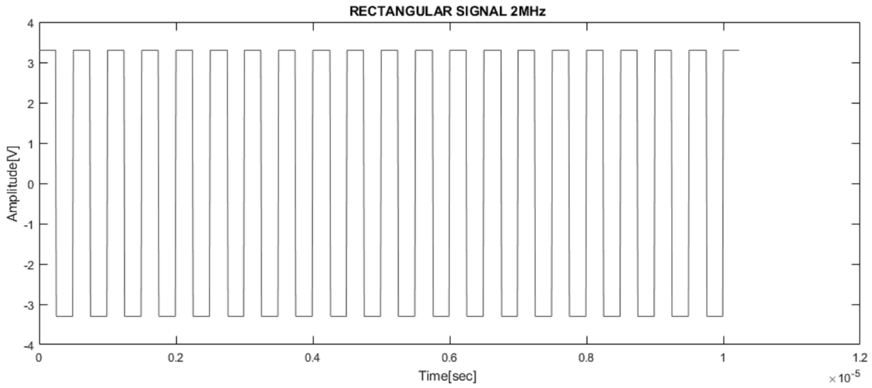

Fig. 6. Time domain

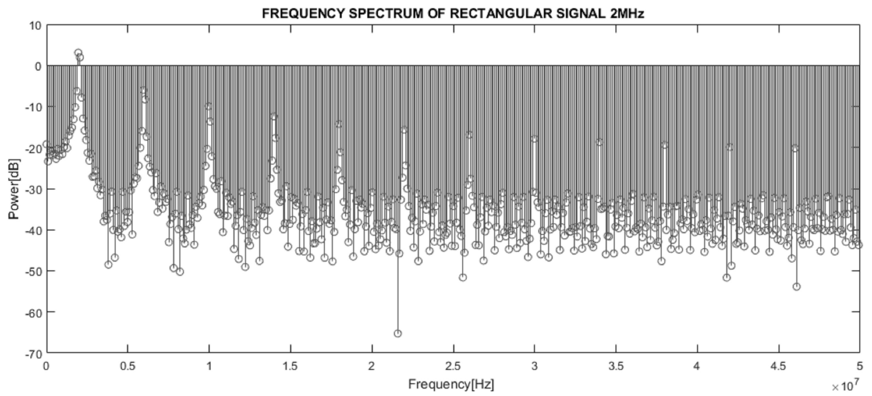

Fig. 7. Frequency domain

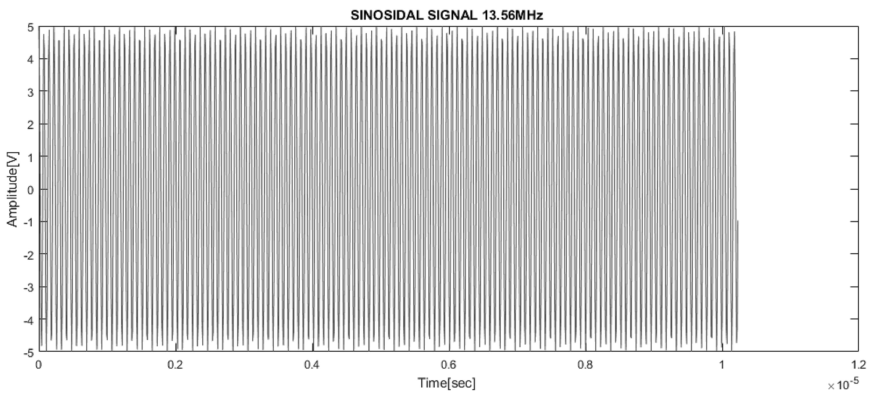

Fig. 8. Time domain

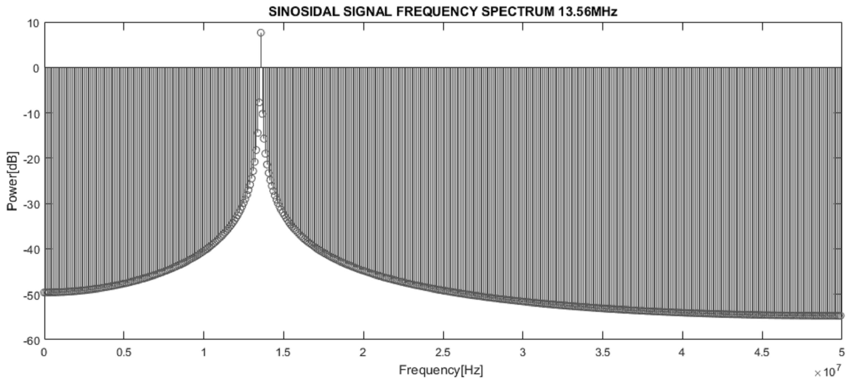

Fig. 9. Frequency domain

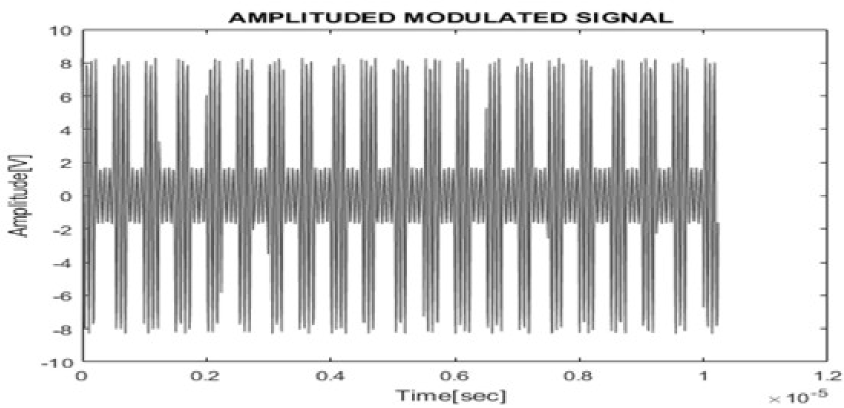

Fig. 10. Time domain

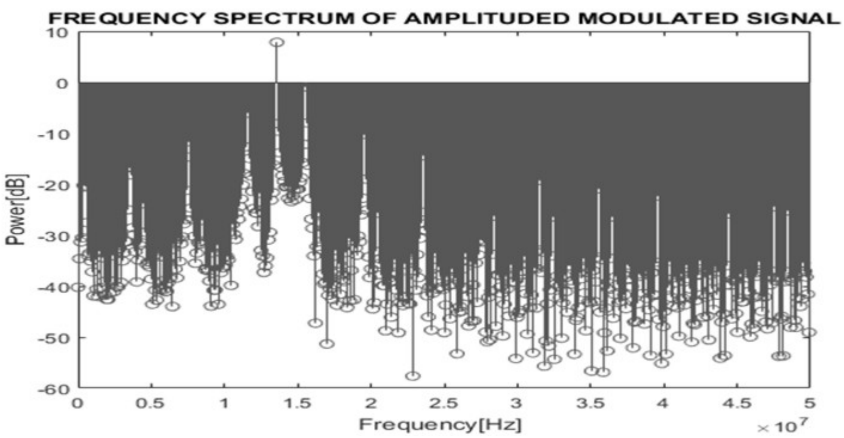

Fig. 11. Frequency domain

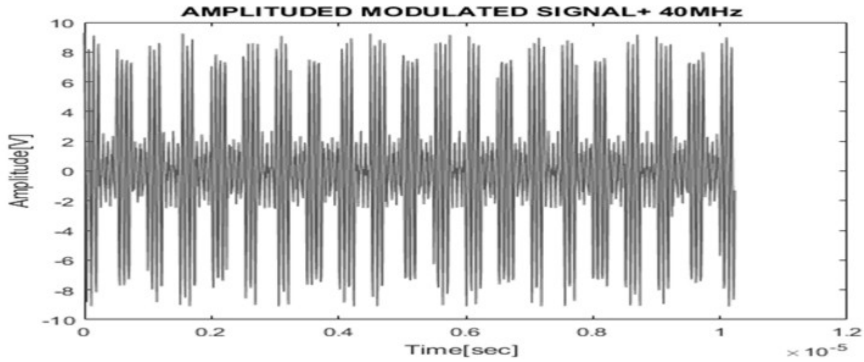

Fig. 12. Time domain

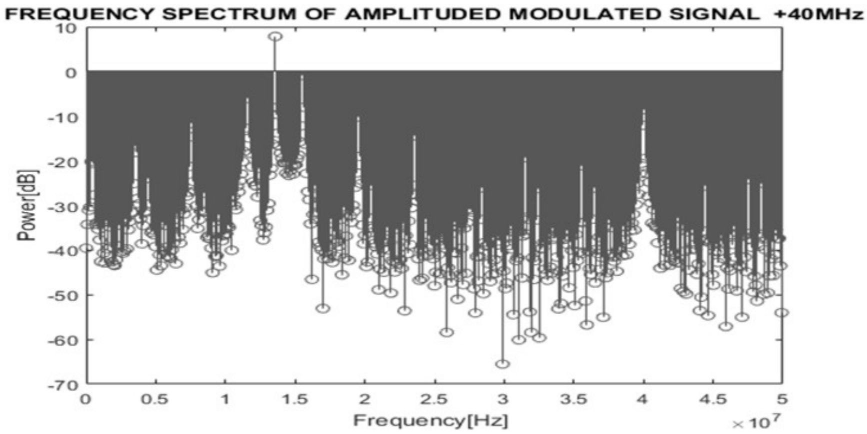

Fig. 13. Frequency domain

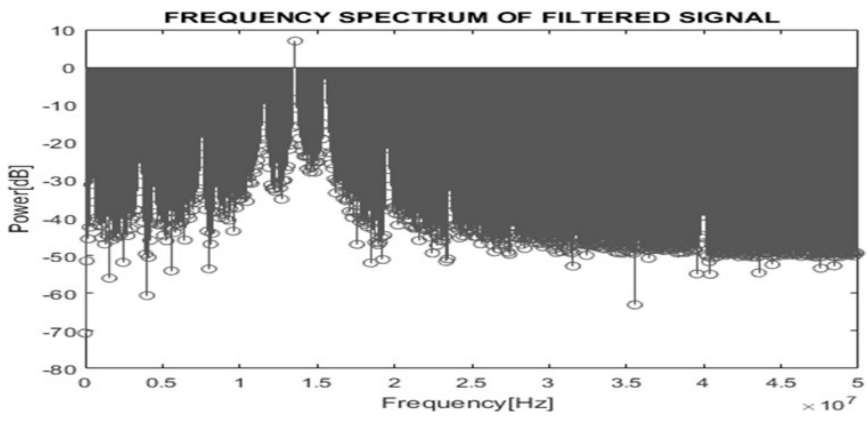

Fig. 14. Frequency domain

in the middle of MATLAB. From Figs 8 and 10 it is clearly apparent that the power of the useless signal to us is 40 MHz and it has diminished by approximately 30 [Db], which means that the used passive filter is effective in removing high-frequency signals from the spectrum of the useful signal.

3.4. Sample designing and tuning of the NFC antenna

3.4.1. Tuning of the NFC antenna

In this Section of the article, an object of interest is a circular NFC antenna, made as a flexible circuit board. The copper layer is placed between two layers of polyamide isolation, such as to stay in the neutral line of bending of the PCB. The measurements and the construction of the base of the antenna have been presented below, on the basis of which the technical and electrical means are being calculated. The configuration method is also presented. It is used for wireless RFID communication. The initial values of the parameters of a circular NFC antenna are: $N = 2$ is the number of coils; $r = 5$ cm – distance that we want to transmit to $a = \sqrt{2}r = 7$ cm, optimal coil radius; $b = 0.5$ cm – thickness of the coil; $h = 0.5$ cm, height of the coil.

The inductivity of the antenna is calculated by means of the formula:

$$L_{pa} = (a.N)^2 \frac{0.31}{6a + 9h + 10b} = 1.2\,\mu\text{H}, \tag{4}$$

where $X_L = 2\pi f_0.L = 100\ \Omega$ is the induction resistance, $f_0 = 13.56$ MHz is the resonant frequency, $f_{\text{natural}} = 520$ MHz is calculated by using an LC meter or a Vector-Impedance Analyzer.

The condenser C_{pa} is calculated by means of the formula:

$$C_{pa} = \frac{1}{(2.\pi.f_{\text{natural}})^2 .L_{pa}}. \tag{5}$$

The condition in which there is resonance in the circle is:

$$X_L = X_C. \tag{6}$$

From condition (6) for the value of the adjusting capacitor we get:

$$C = \frac{1}{2\pi f_0 XL} = 117\ [\text{pF}]. \tag{7}$$

The quality factor Q describes the energy stored in the antenna. When the Q-factor is high, the antenna needs more time to react to the modulation but it is emitting more energy:

$$Q \geq 13.56\ \ \text{MHz*}3\,\mu\text{s} = 40.68, \tag{8}$$

$Q = 25$ is the standard value for NFC antenna.

The active resistance for the antenna R is calculated by using the formula:

$$R = \frac{XL}{Q} = 4\ \Omega. \tag{9}$$

The gathered data from the analysis are summarized in Table 2.

Table 2

a	b	h	r	Q	N	L	C	R	f_0
cm	cm	cm	cm	–	no	µH	pF	Ω	MHz
14.14	0.5	0.5	50	25	2	1.2	117	4	13.56

3.4.2. NFC antenna adjustment

Smith's diagram is meant to help with finding the solution to the problem of carrying lines and identical circuits [2]. The diagram in essence is a graphical method to displaying the impedance of an antenna as a function of the frequency, Fig. 15. It shows the complex coefficient of reflection in a polar form for certain impedance. This means that we want to minimize the reflection coefficient, to minimize the reflected power from the load (the antenna) and to maximize the power that is received by the antenna. In order to reach the perfect balance of these three, we want the impedance of the load to be equivalent to the impedance of the carrying line. In the context of Smith's diagram we wish to shift this impedance of the load towards the center where the reflection coefficient tends towards zero, Fig. 15.

The circles describe the active (real) part of the impedance and the arcs – the reactive (imaginary). The method of calculating a concurrence block is described in Fig. 16:

$$Z_{tr} = R_{tr} + j.X_{tr},$$

where

$$R_{tr} = \frac{Z_{match}}{\left(1-\omega^2.L_0.C_0\right)^2 + \left(\omega.\frac{Z_{match}}{2}.C_0\right)^2}, \tag{10}$$

$$X_{tr} = 2\omega.\frac{L_0.\left(1-\omega^2.L_0.C_0\right) - \frac{Z_{match}^2}{4}.C_0}{\left(1-\omega^2.L_0.C_0\right)^2 + \left(\omega.\frac{Z_{match}}{2}.C_0\right)^2}. \tag{11}$$

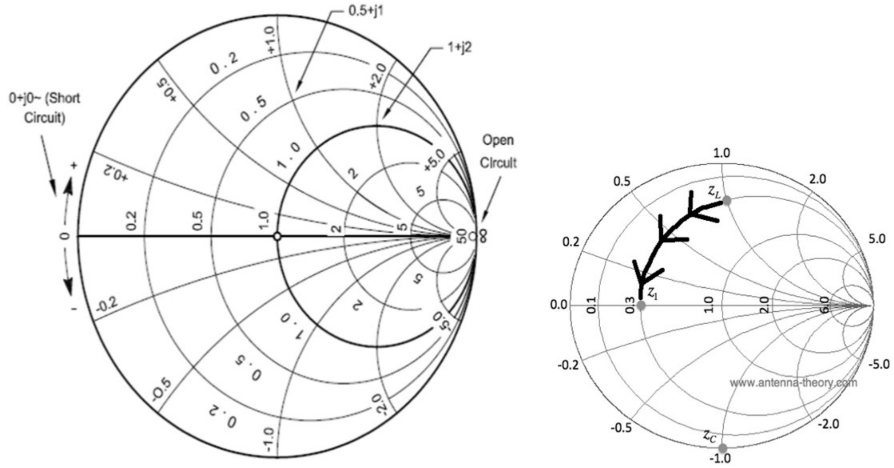

Fig. 15. Smith's diagram and the reflection coefficient

The value of capacitor C_1 correcting coefficient of reflection towards zero is calculated by using the formula:

$$C_1 = \frac{1}{\omega.\left(\sqrt{\frac{R_{tr}.R_{coil}}{4}} + \frac{X_{tr}}{2}\right)}. \tag{12}$$

The value of capacitor C_2 tuning the resonant frequency of the antenna is

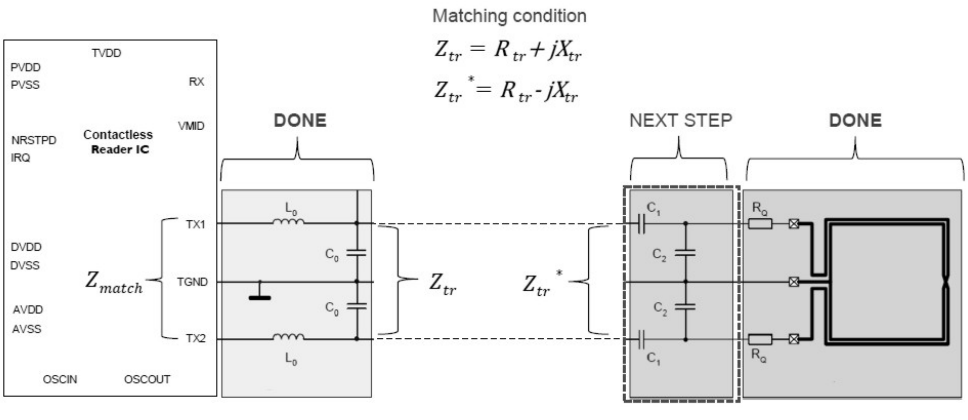

Fig. 16. Method of calculating a concurrence block

calculated by means of the formula:

$$C_2 = \frac{1}{\omega^2 . \dfrac{L_a}{2}} - \frac{1}{\omega . \sqrt{\dfrac{R_{tr} . R_{coil}}{4}}} - 2.C_{pa}. \tag{13}$$

4. CONCLUSION

In the present article, the results from the process of design and development of technical resources in the implementation of distributed systems are described for wirelessly gathering, transferring and managing information streams.

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