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MODELING AND SIMULATION OF SMALL-SCALE WIRELESS COMMUNICATION SCENARIOS

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*Abstract–***The present work is dedicated to the simulation of several scenarios that they use the wireless channel as a means of transmission, for which MATLAB simulation software, specifically its SIMULINK tool. In order to achieve this objective, a search was made of information on the main characteristics of communication systems, specifically those of wireless communications, and an in-depth study of the Channel models that include the software in their libraries. Modeling and simulation of five scenarios were carried out, three of them used the Rayleigh channel model and two of them the Rician model, once the simulations were analyzed the main results of each variant used and then arrived at conclusions.**

Index Terms–Channel models, wireless communications, Simulink, Rayleigh, Rician fading channels.

I. INTRODUCTION

Since the end of the 80s, the situation of computer networks has changed substantially. There have been constant updates of technology and an increase in the variety of access forms. To the networks that use transmission by wire, those that use means have been added wireless, due to the advantages such as flexibility of operation, low cost and the ease of installation. These transformations have been driven by new commercial circumstances, advanced technological development and the evolution of users' requirements and needs. Currently the development of communication networks and the needs of users demand the support of mobility. It is precisely this requirement that turns out to be one of the greatest challenges in providing interconnectivity support among the users of the data networks. Since the medium that is used is the wireless channel, it is subject to constant variations and multiple effects depending on the type of signal that crosses it [1].

The use of wireless technology makes it possible to eliminate the limitations of space and time, giving the possibility of providing connection to any device anywhere with certain limitations that depend on the conditions of the channel where the connection is established. This trend in communications technologies points to the need to have a secure and stable wireless connection of the devices that make up the digital communication system [3].

There are no detailed simulation studies of the wireless channel using the MATLAB simulation tool. The results can be used as a way to better understand the behavior of the wireless channel and for its use in subsequent studies and investigations.

II. WIRELESS CHANNEL MODELING

The methodology to create scenarios using the models provided by MATLAB depends on the magnitude and dimensions of the system that is to be implemented. Simulink offers the possibility of including all the blocks that are in your library in the same system. Bearing in mind that to make any model it is necessary to know thoroughly all the characteristics and general functioning of a communication system. The blocks are connected through continuous lines and with two clicks you can vary their characteristics and properties. All variables and data types have to be specified within each block [11].

A. Simulation of the scenarios and their characteristics

For the simulation of the scenarios, the combination of several blocks was used. In order to achieve channels that would introduce more influence on the signal transmitted through it. In case of problems in the run of the simulation,

MATLAB provides all the errors with a small explanation with the location of the block and the error it presents. Most of these errors are caused by ignorance in the handling of the data and by problems in the type of signal that each block of the previous one inherits. The type of data that is implemented in each block is double. Figure 9 shows the general model to be simulated.
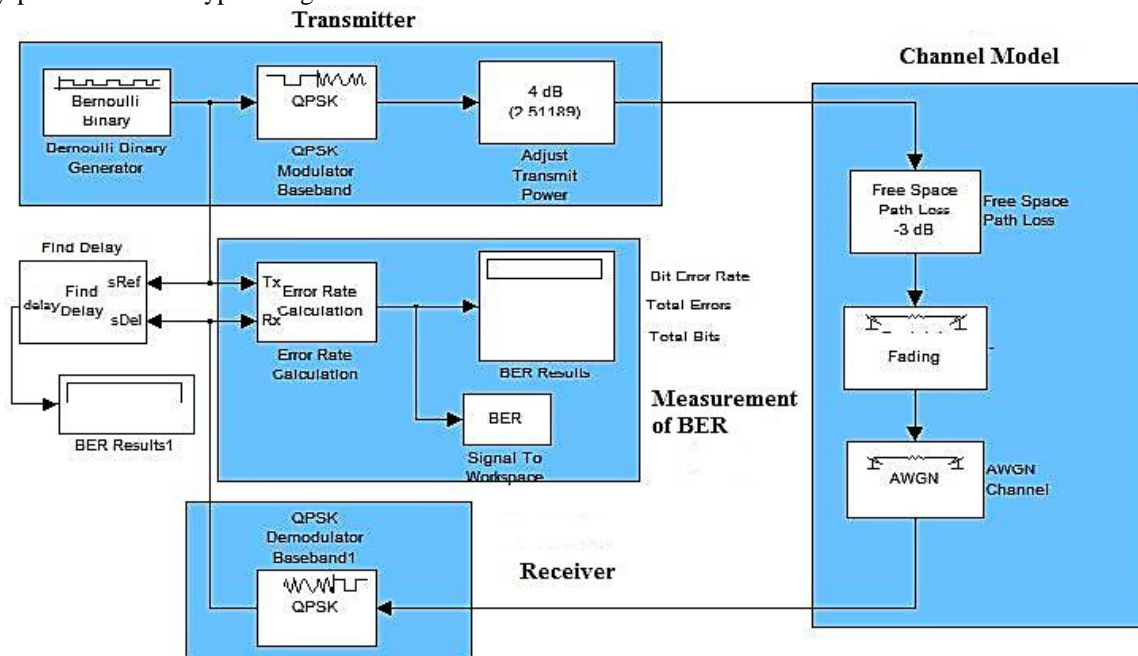

Figure 9: Proposed model of simulation.

Transmitter:
A Bernuolli binary generator block: binary generator based on Bernoulli tests. It specifies a probability of generating zeros of 0.5, a sampling time of $1/10e+6$ and the number of samples per frame is 200.
A digital modulator block QPSK: It was chosen for presenting similar performance to BPSK. Increasing the order of the PSK decreases the distance between the points of the constellation, increasing the bandwidth of transmission and the signal becomes more susceptible to noise present in the channel. The QPSK is the type of load modulation of many modern communications systems and is used by many current wireless formats. The phase shift is zero, the order of the constellation is ¨Gray¨ and the type of signal at the input is "Bit".
A block to adjust the power of the transmitter: a gain of 4dB in power is specified on the input signal. It can be specified in amplitude or power.

Receiver:
A QPSK digital demodulator: presents a phase shift of zero, the order of the constellation is "Gray", the type of input signal is "Bit", the type of decision used is "Hard decision". It is implemented when the output value is always integer, but by default it handles the same value as the input. This parameter can be chosen "Log-likelihood" or "Approximate log-likelihood" when the value of the output data is the same as the data value to the input and you have to specify the variance of the noise in the input signal.
The BER is measured with:

The Error Rate calculation block: in this block the "Receive delay" is specified to a value that can be found with the block "Find Delay" inside the communications library. This gives the value for this parameter after running the model for the first time. The "Computation delay" is a value that is searched with the block "Final Delay". The "Mode" used is "Entire Frame". The "Output Data" parameter specifies where we will send the output value. It is chosen as "Port" to be able to take it out through the output port to a Display by a three-by-one matrix, to show the total number of bits, the number of wrong bits and the BER. We can also choose the "Workspace" value and give the output variable a name to call the value by entering the variable in the MATLAB workspace. The parameter "Stop simulation" is specified to run only until the block detects a specific number of errors or represents a specific number of comparisons. The first of the two that runs first then the simulation stops.
The "Signal To Workspace" block is used to write the entry of the specified matrix in the main work area of MATLAB. The data is not available until the simulation is paused or stopped. It is used by calling the BER variable from the working area of the MATLAB. It is specified ¨Limits Data Point to Last¨ with a value of one, the parameter "Frames" is chosen as "Concatenate frames (2-D array)" where this value does not specify the end of the first frame and the beginning of the next one. For the value "Concatenate frames (3-D array)" if it easily shows each ordered plot in the MATLAB workspace.
The "Find Delay" block feeds from the two inputs of the "Error Rate Calculation" block and gives the output with the

use of the "Display Rate" block the delay value in the reception. It is a value that expresses the delay in the difference between the number of samples arriving at the receiver. Thus, we can specify this value within the comparisons of the BER.

Wireless Channel:
The channel will be composed of a block to specify the losses by free space, another block that represents the type of multipath to be simulated and a block of AWGN to specify the additive Gaussian white noise. So, varying the parameters to these three blocks we can represent the scenarios that are presented and see their influence on the rate of bit error. In none of the cases is the gain normalized to 0dB within the multipath blocks. Each variant of a scenario modifies the channel conditions by adding attenuation and multipath to model a more critical channel. Figure 10 shows the two channel models.
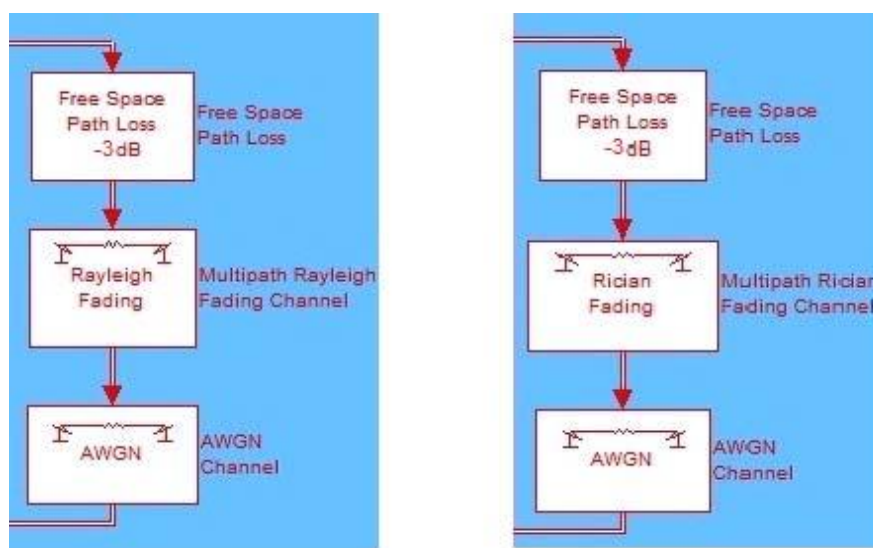

Figure 10: Channel model simulation.

Next, Table 1 and Table 2 show the values that the five variants take for the two Rayleigh and Rician channel scenarios.

Table 1: Variants of the Rayleigh Channel.

Parameter	Variant 1	Variant 2	Variant 3
Free space path loss (dB)	-3	-3	-3
Maximum Doppler Shift (Hz)	20	50	80
Discrete Path Delay Vector (s)	[0 10e-9 50e-9]	[0 80e-9 100e-9 3000e-9]	[0 3e-6 5e-6 10e-6 9e-6]
Average Path Gain Vector (dB)	[0 -2 -5]	[0 -8 -10 -13]	[0 -13 -15 -20 -19]
Mode	Mode Signal to noise ratio	Mode Signal to noise ratio	Mode Signal to noise ratio
SNR (dB)	3	3	3
Input signal power, referred 1ohm (watts)	1	1	1

Table 2 shows the values of the variants for the Rician channel.

Parameter	Variant 1	Variant 2
Free Space Path Loss(dB)	-3	-3
K-Factor	5	2
Doppler shift(s) of line-of-sight components(s) (Hz)	5	10
Maximum Doppler Shift (Hz)	20	50
Discrete Path Delay Vector (s)	[0 20e-9]	[0 20e-9 100e-9 1e-6]
Average Path Gain Vector (dB)	[0 -4]	[0 -4 -4 -10]
Mode	Signal to noise ratio	Signal to noise ratio
SNR (dB)	3	3
Input signal power, referred 1ohm	1	1

B.   Assembly of the Simulink models in the ToolBox of Communications

The tool BER Tool in Figure 11 of the Communications Toolbox can be used in conjunction with the models created in Simulink to generate and analyze the data from a graph of the BER against E_b/N_0 if desired. To access this option just write "Alberto" in the MATLAB workspace. In the figure this tool is shown where entering the value of E_b/N_0, the address where the model is and the name of the variable that contains the data. It also specifies the two conditions to stop the model, by the number of errors found or by the number of bits analyzed. The first condition that comes to be fulfilled.

BER Tool:

Use the parameter Eb / No and its characteristics in the AWGN channel block.
Specify within the "Error Rate Calculation" block the values "maxNumerrs" and "maxNumBits".
Use frame-based processing and a large value in the frame length.
Implement the "Signal To Workspace" block to call the data from the MATLAB work environment. Parameters necessary for the assembly of the models in the

This is the fundamental block where the variable is named, in this case it was chosen as the name "BER". The option of

visualization within the fading channel block must be disabled to provide greater speed in the simulation of the data.
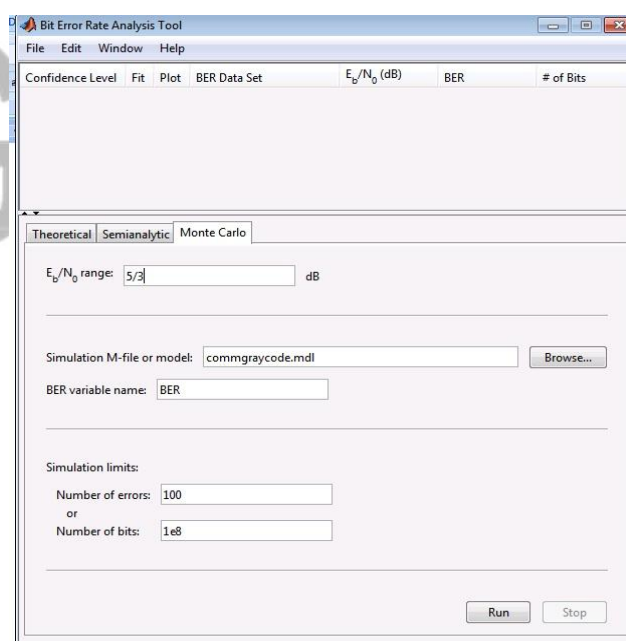

Figure 11: BER calculation block.

This tool performs different simulations of the wireless channel for calculating the BER. It contains three types of models for calculation, "Theoretical", "Semi analytic" and "Monte Carlo". They use different procedures to perform the calculation of the results. With the first one you can simulate

the AWGN or Rayleigh or Rician channel, one of the three channels for any of the digital modulations it offers. With the second one you can only simulate the AWGN channel and in conjunction with the digital simulations. It also contains other features depending on the type of model you want to run. But with the Monte Carlo you can simulate the channel variants created in Simulink and obtain graphs of the BER, differentiating some parameters. This helps to model the results and present them in graphical form.

III. SIMULATION RESULTS

This section analyzes the results of each of the simulated scenarios, results of the combination of the proposed variants for the channel models present in the MATLAB / SIMULINK, in order to show how the signal is affected with the variation of the data within the channel.

A. Analysis of the scenarios with Rayleigh Channel

- **Scenario 1**:

The simulation of this variant one resulted in impulse and frequency responses (IR and FR) that are shown in Figure 13. Its response to impulse (IR) has medium variation, the values of magnitude oscillate between 0.2 to 2. The frequency response (FR) is relatively flat with average values of 10dB to -10dB becoming selective below -11dB at frequencies from 1.5MHz to 2MHz within the entire bandwidth of the 2.5Mhz channel. It contains an average variation of the multipath components from 7dB to -30dB. The multipath gain ranges from -5dB to 5dB with medium variation and narrowband signal behavior. The BER starts at 0.25 and as they are processed, a greater number of bits increases due to the function of the channel response, reaching stabilization at 0.49.

- **Scenario 2**:

The simulation of this variant two resulted in the impulse and frequency responses (IR and FR) shown in Figure 14. The IR graph shows a slow variation with values of magnitude from 0.5 to 2. The frequency response is also slow with a difference of values of 2dB for the best behavior up to -10dB

where it affects the 2.5MHz bandwidth of the signal with deep fades of -40dB. The components multipath contain relative variations of attenuation between -5dB to -20dB up to -30dB. The signal follows a narrow band behavior with gains of up to 7dB. The BER starts at 0.30 and as they are processed, a larger number of bits increases as a function of the response of the channel, reaching stabilization at 0.49.
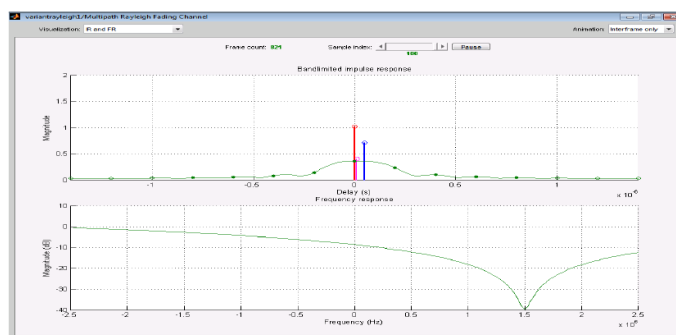

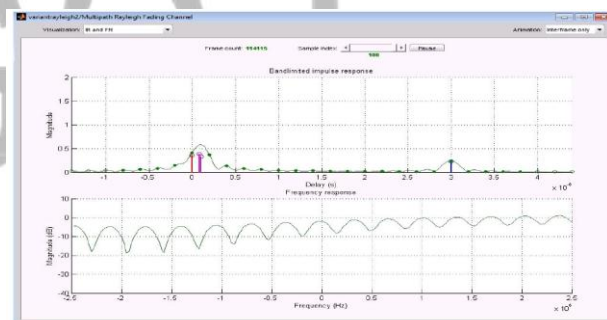Figure 13: IR and FR with variant one.

Figure 14: IR and FR with variant two.

- **Scenario 3**:

In this variant, whose IR and RF responses are observed in Figure 15, the response to the impulse has a slow variation with values of magnitude from 0.6 to 2. The frequency response is very selective with a difference of values of 2dB for the best behavior. There is also a critical behavior of -30dB that affects the 2.5MHz bandwidth of the signal with very deep fades of more than -40dB. Very selectively affecting the entire bandwidth of the channel. The multipath components contain relative variations of attenuation between -5dB to -30dB up to -40dB for some components. It contains a path

gain of 5dB to -20dB with broadband signal behavior. The BER starts at 0.40 and as they are processed, a greater number of bits increases as a function of the response of the channel, reaching stabilization at 0.5.
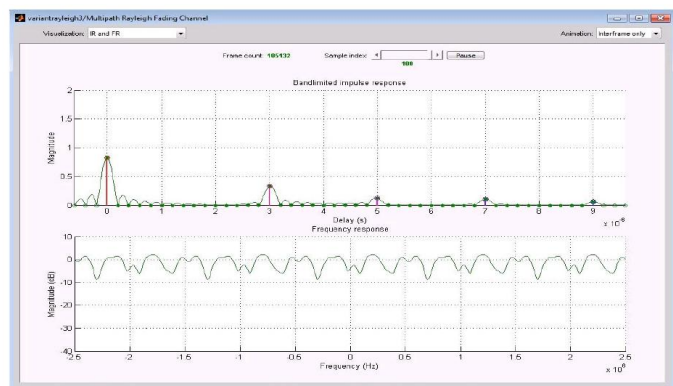
with relative values of -5dB to -40dB is also observed. It has a gain up to 8dB with narrow band behavior. The BER starts at 0.49 and stays that way throughout the simulation.
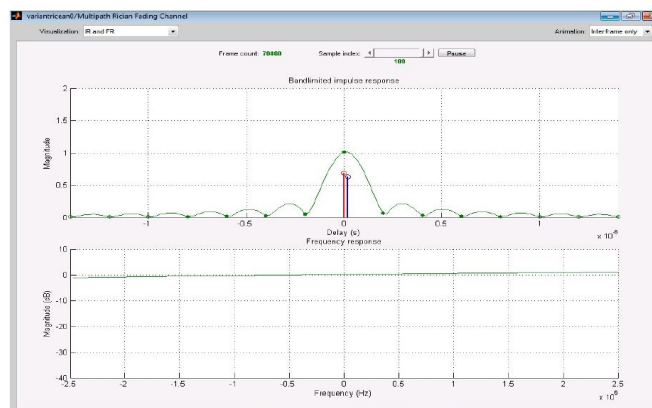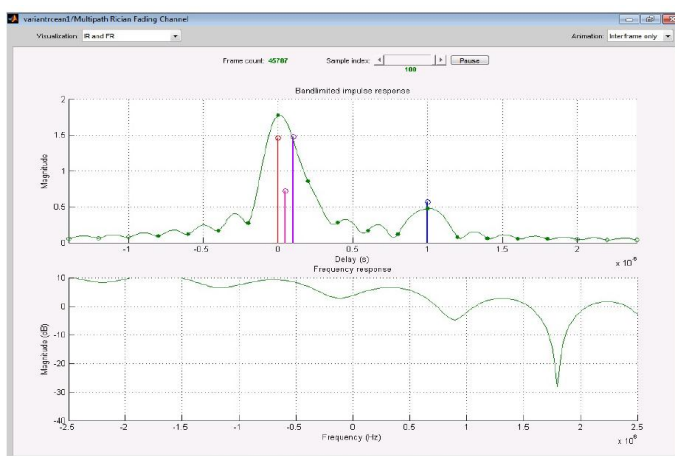

Figure 15: IR and FR with variant three.

Figure 16: IR and FR with variant four.

B. Analysis of the Scenarios with Rician fading channel

- **Scenario 4**:

Within the Rician channel, specifically this variant is obtained as a result of the simulation of its response IR and FR shown in Figure 16. The response to the impulse presents a slow variation within magnitudes of 0.7 to 2dB.

The frequency response has a slow variation with a flat behavior reaching values of 7dB. It begins to lose this characteristic as the impulse response decreases, reaching a wave-shaped drop of -25dB that gradually crosses the 2.5×10^6 Hz bandwidth of the channel. The multipath component has a slow variation with values ranging from -5dB to -20dB.

It has a gain up to 5dB with narrow band behavior. The BER starts at 0.32 and as they are processed, a larger number of bits increases depending on the response of the channel, reaching stabilization at 0.49.

- **Scenario 5**:

From this variant its response IR and FR is shown in Figure 17. The impulse response has an average variation with relative values from 0.2 to 1.5. The frequency response is oscillatory with values from 3dB to 5dB. This becomes selective with deep falls at relative frequencies of 2.2×10^6 Hz at 1×10^6 Hz. A slow variation of the multitrack components

Figure 17: IR and FR with variant five.

C. Change in transmission rate scenarios three and five.

By reducing the transmission rate from 10×10^6Hz to 10×10^4Hz in scenarios three and five which are the most critical scenarios of each channel model due to the greater number of routes and greater attenuation, the IR and RF responses They change significantly:

- **Scenario III**:

The responses of the Rayleigh channel shown in Figure 18 show a significant variation since it is possible to obtain a flat frequency response for values of 10dB to -10dB.
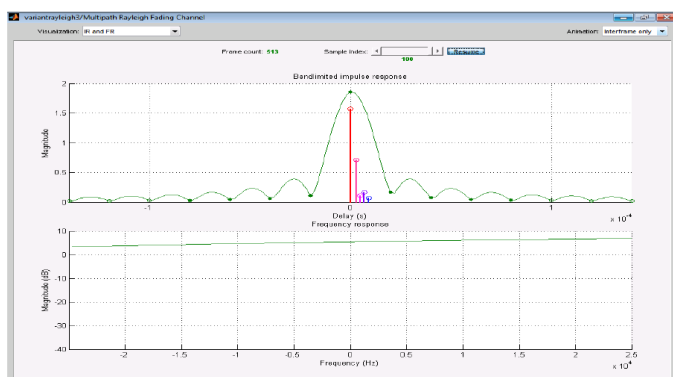
Fig. 18: Improvement of the FR and IR of variant three of the Rayleigh channel.

This becomes selective below the previous value and the BW decreases with the change in the bit rate. The impulse response becomes more impulsive, and it seems more like a sync pulse. The ISI is also reduced in number and time. The coherence time of the channel becomes smaller with the reduction in the transmission rate. Figure 19 shows how the signal follows a narrow band behavior and the variation of the components is very fast, achieving rapid changes between the attenuation and gain values. The value of the BER does not make any change remaining with the average value of 0.5.
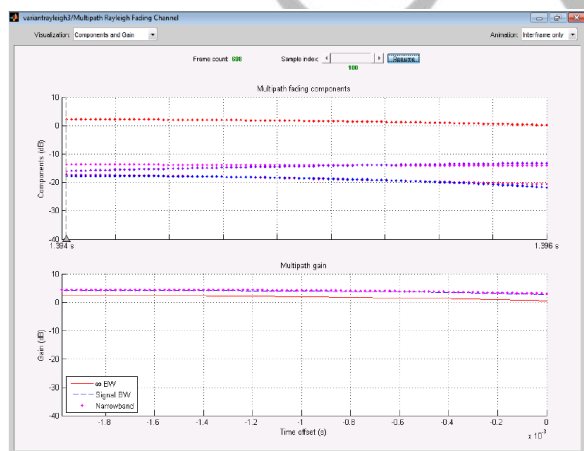

Figure 19: Improvement of the multipath of the Rayleigh channel.

- **Scenario IV**:

With the reduction of the transmission rate from 10x106Hz to 10x104Hz in scenario VI corresponding to the second variant of the Rician channel, the IR and RF responses vary considerably. In Figure 18 we can see a flat frequency

response throughout the BW of the signal and an impulsive response with less temporal dispersion than that corresponding to the same scenario when the transmission ratio of 10x106Hz was used. The changes in the multipath gain follow a narrowband behavior as seen in Figure 20.
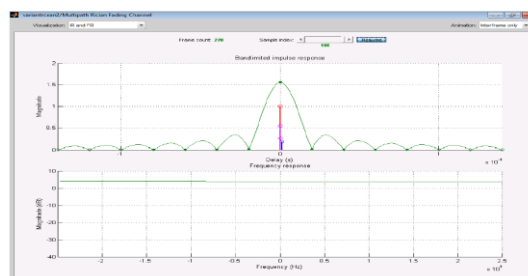

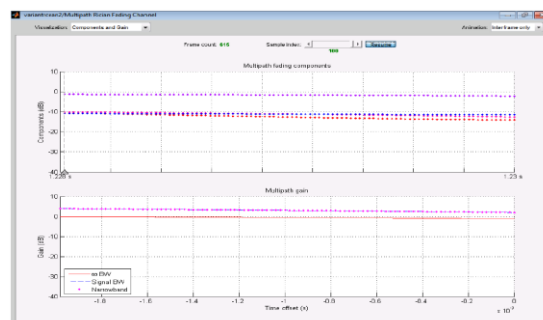Figure 18: Improvement of IR and FR of the Rician channel.

Figure 20: Improvement of the multipath gain of the Rician channel.

IV. CONCLUSIONS AND RECOMMENDATIONS

The following conclusion was reached based on the results obtained. A study was carried out on the main characteristics of the channel models included in the MATLAB/SIMULINK software, emphasizing the Rayleigh and Rician wireless channel blocks. The QPSK digital modulation was chosen to be used in the scenarios of the simulations. Modelling and simulation of three variants of Rayleigh wireless channel and two variants of Rician wireless channel were achieved, simulating five different scenarios. The main results of each of the simulated scenarios were analysed. The following aspects are recommended. Deepen the study of modelling and simulation of communication systems in SIMULINK. Expand the investigation of the wireless channel simulation using SIMULINK including several additional blocks provided by the software such as channel coding and equalization blocks.

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