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Design and software implementation of radio frequency satellite link based on SDR under noisy channels

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ABSTRACT

The satellite communication provide a utilization of radio frequency links. Specific frequencies are dedicated for satellite correspondences through global administrative and coordination procedures which keeps impedance among frameworks. Over typical work, the satellite receives uplinked indicator from earth. Progressions its frequency marginally will keep away from self-intervention then re-transmits signal ahead the downlink on the land. Pathloss depicts characteristic Propagate outside the sending signal front as it goes by the space. A software defined radio (SDR) is a flexible technology that aims to replace all hardware by software to enables the design of adaptive communications systems such as changing frequencies, modulation schemes and data rates. Applied to small satellites, some of the implications are increased data throughput when down-linking or up-linking by varying communications parameters and making use of one hardware design and implementation for communicating for many missions, just by updating the software. Therefore, development time for small satellite communication systems can be reduced in the future. This paper analyzes, design and software implementation of radio frequency satellite communications links under noisy channels such as phase/frequency offsets and noise temperature. Modulation schemes such as 64QAM system is used based on Matlab tools to implement the results. Obtained results shows a good response that get the goal from the paper.

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1. INTRODUCTION

Software defined radio (SDR) is a flexible technology which enables the design of an adaptive communications system. This means that a generic hardware design can be used to address various communication needs, with varying frequencies, modulation schemes and data rates [1]. Applying this concept to small satellites can increase data throughput, add the possibility to perform software updates over-the-air and make it possible to reuse the hardware platform for multiple missions with different requirements. Therefore, development time for future small satellite communication systems can be reduced. SDR architecture is shown in Figure 1 that represent the hardware and software parts of SDR [1, 2].

The expanding unpredictability of today's telecommunications satellites is due to the increasing amount of components, coupled with their operators craving to expanded competencies. In the past, traditional payloads had been modelled effectively of radio frequency (RF) terms using utilizing spreadsheet product instruments that permitted predictions will be aggravated with certainty. Nonetheless some calculations for example, such that spurious signs alternately inter-modulation levels also locations, stage noise, touch lapse rate, bit error rate (BER) and impedance need aid a greater amount was troublesome substances to model. It may be a simple process to interface these together under an general frameworks model that joins those get radio wire through the RF intensification Furthermore molding chain of the final transmit radio wire [3]. The spectrum of radio frequency is a segment of the electromagnetic spectrum which is in high needed by the users to communicate with each other. The International Telecommunication Union (ITU) facilitate this coordination, expert proxy of the UN. The use of spectrum is controlled by the National regulations through the borders of a country [4, 5].

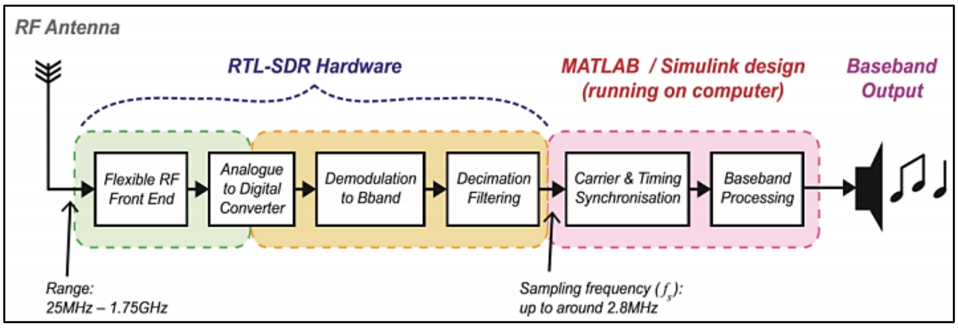


Figure 1. SDR architecture

A correspondences satellite will be an orbiting simulated world satellite that receives an interchanges sign from a the transmitter station, amplifies furthermore potentially procedures it. Interchanges majority of the data not starts or terminates in those satellites. The satellites are a dynamic transmission relay, comparative done capacity will transfer towers utilized within physical microwave correspondences [6]. Figure 2 represents the major usage of satellite and its applications.

The rest of this paper are arranged as follow: section 2 represents the detailes of satellite link parameters, section 3 include system design steps, section 4 matlab simulation results and section 5 conclusion. The basic problem to be solved behind the paper is to overcome the acquared noise during receiving the signal and to use higher order modulation teqniques. The results show good response under noisy channels.

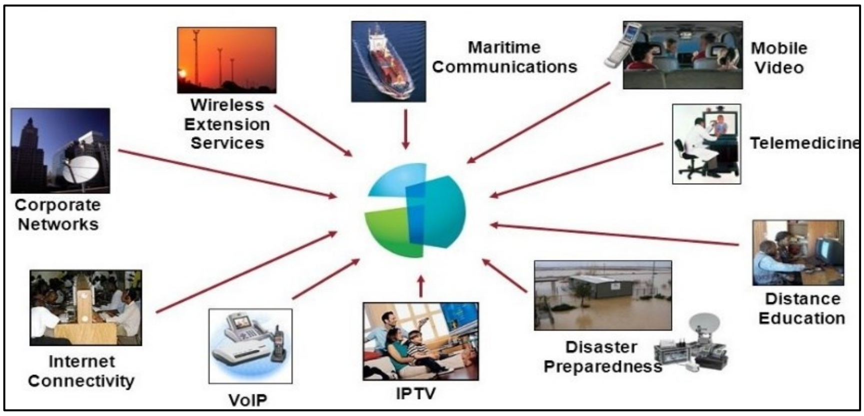


Figure 2. The major applications of satellite

2. SATELLITE LINK PARAMETER

The link budget of communication systems calculates the losing in energy of transmitted signal caused by propagation such as the gain of antenna, feeder and various types of losses [7]. Budget of the link is used to analysis the loss in signal during sending then predict the required power to transmit in order to deal with the noise [7, 8]. Generally, this system compute and supplys information of gains, the losses, transmitted power, gain of antenna and losses caused by noise and natural interference [9]. The primary items that founded in a link budget: transmitted and received power, effective isotropic radiated power (EIRP), gains (transmitter

(TX), receiver (RX)), free space pathloss and effective aperture (η_A) [10, 11]. In [12], estimation of power provided to RX is determined through blur edge, relied upon the limit intensity of transmitter and framework gain and losses. All things considered, the computations in this give just hypothetical estimation and don't represent all the horde useful factors that can and may influence framework execution. In communication, the ratio of carrier to noise frequently composed C/N, is a proportion of the got carrier quality comparative with noise quality. Highest C/N proportion gives good nature of gathering and higher interchanges exactness and unwavering quality when all is said in done. Architects determine the C/N proportion in dB between the force on the transporter of the ideal sign and the all out got commotion power [13, 14]. While the ratio of C/N generally utilized in satellite communication frameworks to point or adjust the destination dish; the good dish position is shown by the most extreme C/N proportion, S/N proportion particular is progressively helpful in real situation [15, 16].

A Doppler offset makes the got signal frequency of a source differs from the sent frequency because of motion that is developed or reduction the isolation between the source and recipient. The system suffer from some type of Doppler at the beneficiary because of the consistent movement of the recipient that either increments or diminishes the separation among collector and the transmitter. The effect of Doppler impacts on the presentation of between satellite connections in LEO has been concentrated in [17-19]

The satellite systems has the ability to deliver tasks around the earth [20, 21]. Generally, the coherent systems like M-ary phase-shift keying (MPSK) and quadrature amplitude modulation (QAM) have advantage of framework affectability, i.e., it need a less measure of power to help the predefined information throughput and the mistake rate. So coherent method is progressively alluring for satellite [22, 23]. This is the cause that why we used the QAM in this paper. The coherent receiver contain phase-locked loop (PLL) to synchronize the transmitter and the automatic gain control (AGC) impacts the noise power as well [24]. The communication system of satellite can be classified to: source earth station, uplink, satellite, down link and destenation earth station. Figure 3 is devoted to show the satellite communication. Number of losses are faced Satellite communication, like freespace loss, atmospheric loss and attenuation due to rain, clouds etc. [25]. Satellite communication has witnessed great researchs interesting due to its effect to increase the rate of transmission and supply seamless connection on a large area [26].

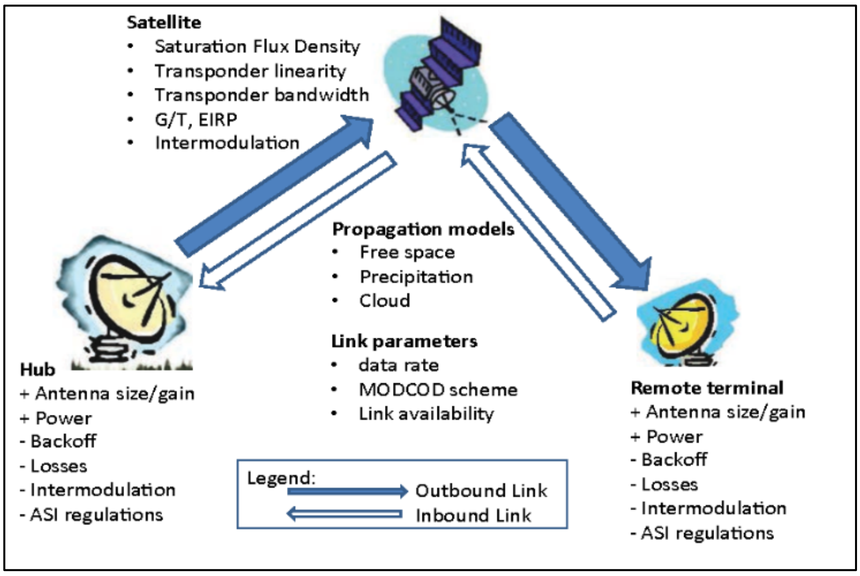


Figure 3. Satellite communication link

3. THE PROPOSED SYSTEM

As mentioned early, this paper aimed to design radio frequency satellite link under noisy environments for 64 QAM modulation system and to solve the major problems during RF satellite system. The proposed system can be summarized in Figure 4 the represent the flowchart of the design steps. The proposed system is seen in Figure 5 that represent the Matlab Simulink which represents the transmitter, noisy channel and the receiver. The system is tested using different cases: the first one when there are no noise (ideal system) and the second one is the noisy case (worst case). In order to check the capability of the system and compare between the transmitted and the received data, the frequency spectrum is plotted between them with calculating the error rate in each case. The parameters are selected according to the design requirements to obtain a good response as seen in Table 1 that represents the design parameters.

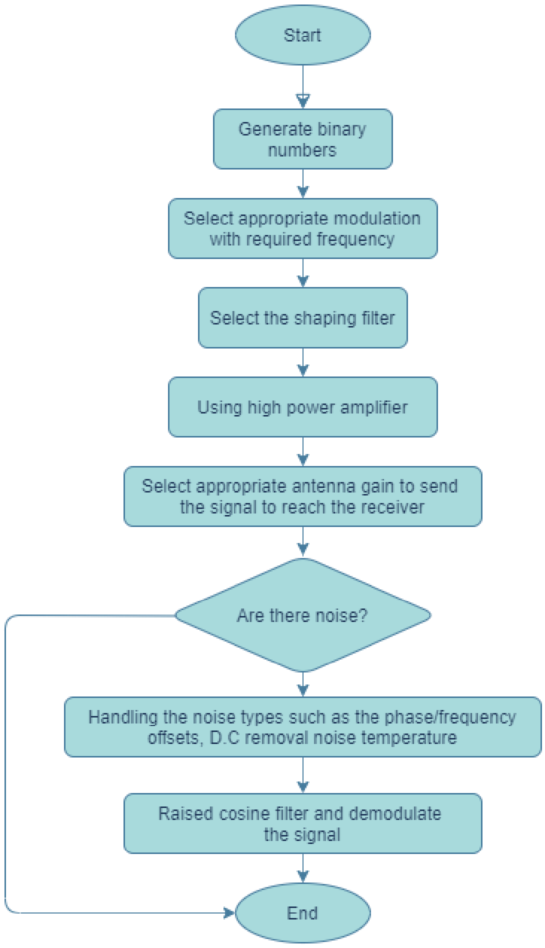


Figure 4. Flowchart of the RF satellite link design system

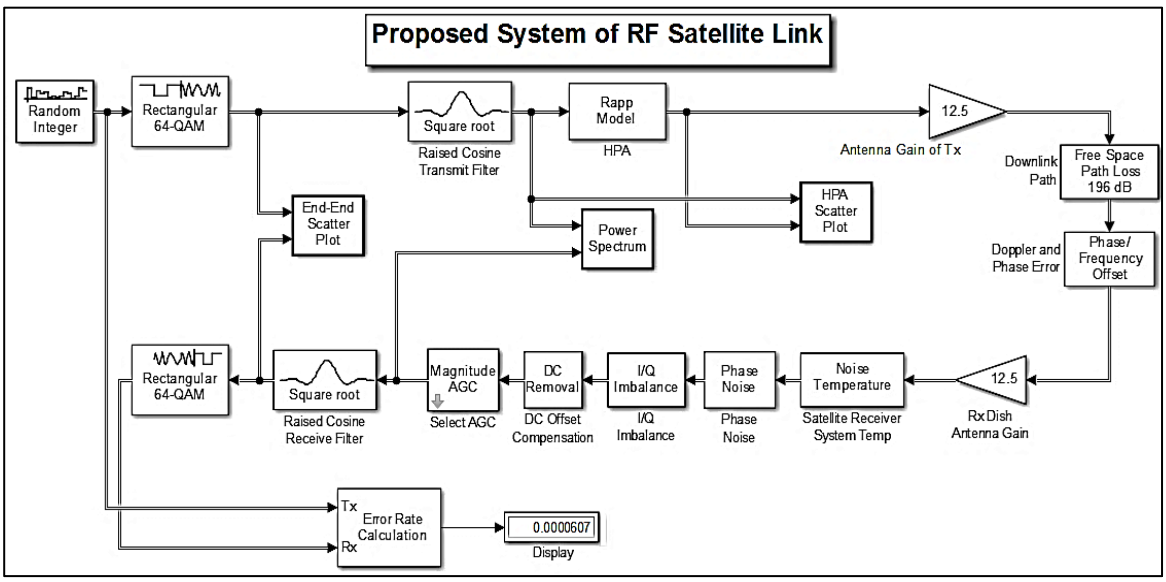


Figure 5. The proposed RF satellite link

Table 1. The design parameters

The parameter	Selected value
The frequency	4 GHz
Modulation	64 QAM
Filter of the transmitter and receiver	Raised cosine filter
Antenna gain of transmitter and receiver	12.5 dB
Diameter of antenna of TX and RX	1 m
Path loss of Free space	195.5 dB
Noise temp.	0, 20, 290 Kilvin
Phase noise	-90 dB/Hz, -100 dB/Hz
Satellite altitude	36000 Km
Phase/ frequency offsets	Various values

As mentioned, Figure 5 represent the Matlab Simulink for the RF satellite link. This diagram is tested with various cases of noise temperature and phase/frequency offsets. From Figure 5 firstly, generate a random data stream using random integer block in order to map the data stream into the constellation of 64QAM as planned in this paper. The sample time used is 6/100000 with 100 sample per frame. Then using shaping filter in order to up the sample rate using the sqrt raised cosine filter. The Rolloff of the filter is 0.3. After that, high power amplifier is used so as to raise the power of the transmitted wave. Then the Gain of the antenna on the satellite is selected according to the following equations:

$$G=10\log\,(109.66 f^2 d^2\, \eta_A) \quad (1)$$

where η_A is the efficiency.

Until this point, the signal is ready to transmit. There are impairment effect on the signal such as the path loss of the free space that attenuating the signal by the free space that selected here 196 dB according to the following equation:

$$L_{fs}\,(dB) = 20\log(f) + 20\log(r) + 92.44 \quad (2)$$

where r is the ragne in km.

Also, the synchronization problems (frequency and phase offsets) that change the direction (phase) and Rotates the signal are deal with also. The noise temperature Adds AWGN that figured the effective system temperature of the receiver. Selecting automatic gain control (AGC) to compensates the gain of both I/Q components of the signal, either together or alone. Finally using the demodulator of QAM to demodulate the original data from the 64QAM. The phase noise is filtered according to the specified spectral mask. For a vector frequency offset specification, spectrum mask is inserted across log10*f, and is flat from the largest frequency offset to half the sample rate. The DC removal (DC offset compensation) is selected as recursive filter therefore, IIR fiter is used. In order to test the capability of the system, the frequency spectrum of the receiver and the transmitter is plotted together at different cases to check the closeness between the TX and RX.

4. SIMULATION RESULTS

Matlab simulation is used to simulate the system. Due to the parameters values that selected in Table 1, the first simulation result is seen on Figure 6 that refers to frequency spectrum between the TX and RX when noise temperature is 0K with no phase/frequency offsets at 196dB free space pathloss. It is clearly see the compatible between the TX and RX. Under the same circumstances of Figure 6, Figure 7 stand for transmitted and received samples.

When the noise temperature is increased to 20k, the case will worse than 0k as clearly seen in Figure 8 which represents the power spectrum between TX and RX at 20k noise temperature. Figure 9 stand for the requency spectrum of the TX and RX at noise temp. of 290k that represents the worst case. The selected raised root cosine filter is designed for shaping the signal with roll off of 0.3 as seen in Figure 10 that represents the magnitude response of this filter. Another test is the plotting of the constellation diagram for the receiver at different cases. As shown in Figure 11 when there is no frequency offset but 5^{o} phase offset (part A). While part B is when 10Hz as frequency offsets with 10^{o} phase offset. For the DC removal (DC offset compensation) IIR fiter is used of 3^{rd} order. The impulse response of the filter is shown in Figure 12.

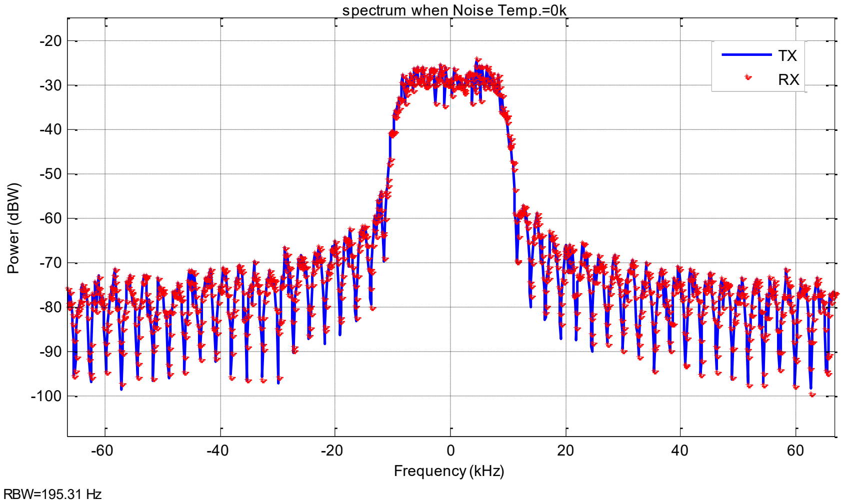


Figure 6. The frequency spectrum between the TX and RX when noise temperature is 0k

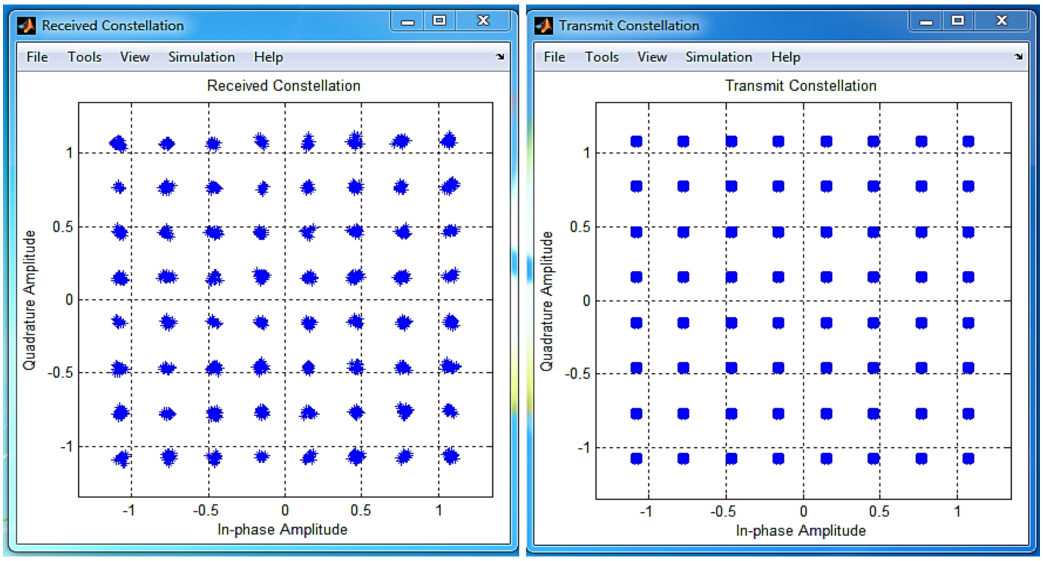


Figure 7. Transmitted and received samples

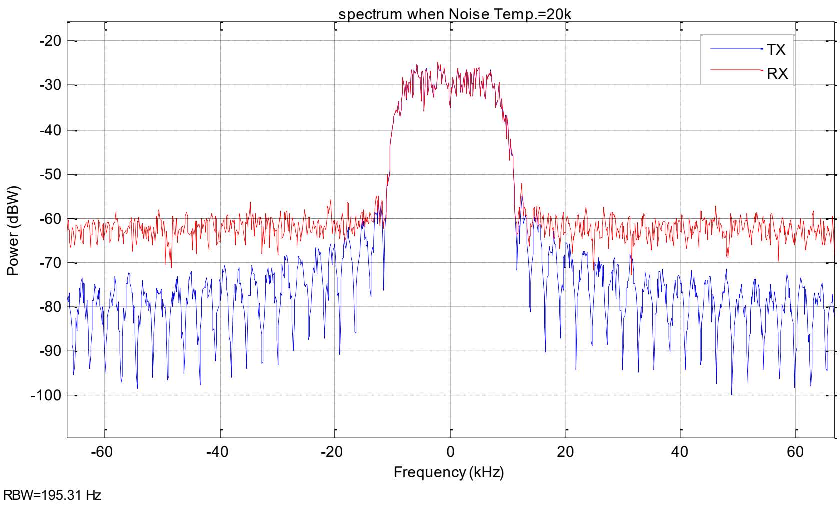


Figure 8. Frequency spectrum between TX and RX at noise temprature 20k

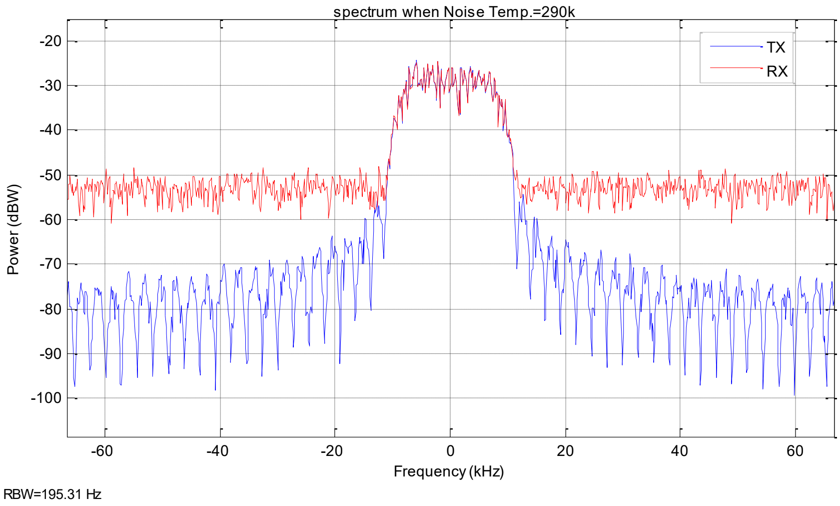


Figure 9. Frequency spectrum of the TX and RX at noise temp. of 290k

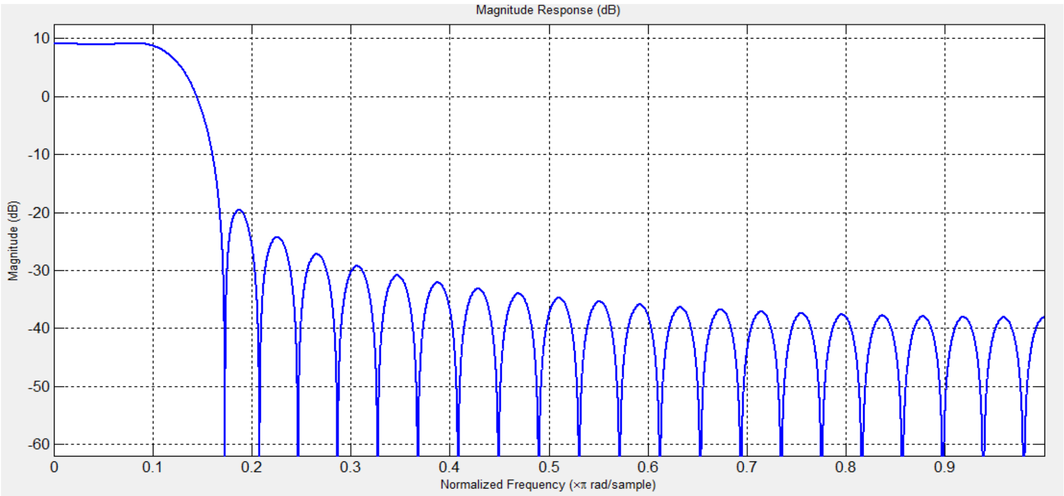
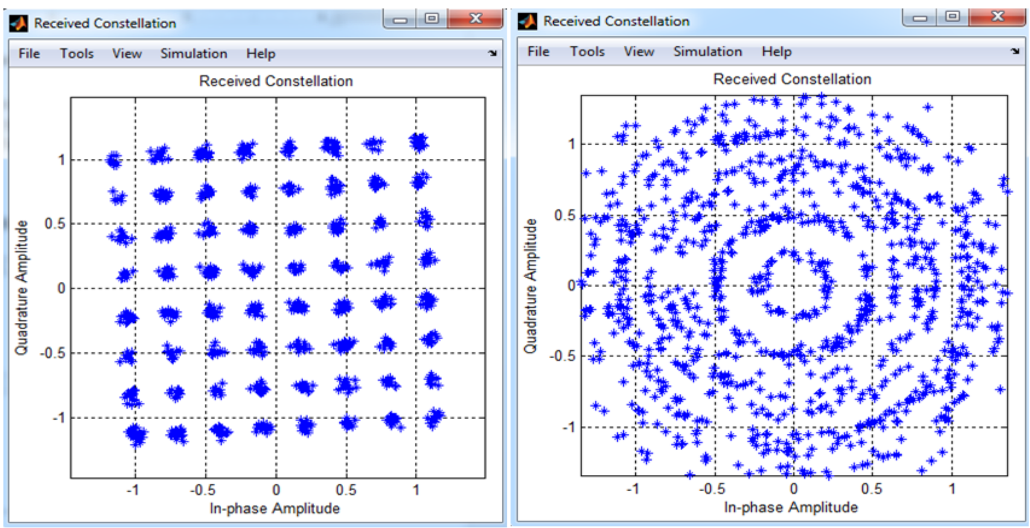


Figure 10. The magnitude response of the filter



(a) (b)

Figure 11. Scattering when no frequency offset but 5° as phase offset

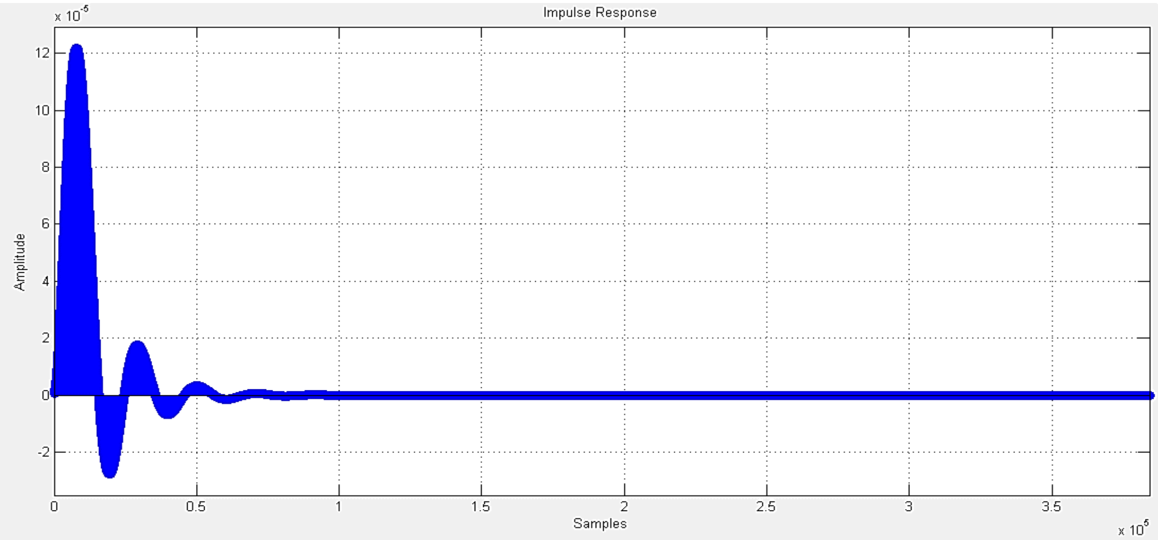


Figure 12. Impulse response of the IIR filter

5. CONCLUSION

As a results, this paper is dedicated to design an RF satellite link under different circumstances such as the noise temperature, the phase and frequency offsets (Doppler phenomena). Also the DC offsets due to the synchronization problems. Good response was obtained from system that is mainally designed to minimize the effect of noise, phase and frequency offset. From the obtained results and the comparison between the transmitted and the received signals, it is easily to note the good capability of the designed system under the different cases of noise temperature and the phase/frequency offsets. The system provide a good response. The bit error rate (BER) is very low equal 0.00006.

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