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Laboratory Experiments for Understanding Effects of RF Impairments on Received Signal in Satellite Link

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Abstract—Satellite communication becomes a complacent subject for undergraduate students as not many high end equipment or accurate, clear and well interpreted simulated results are available. Given this limitation in the availability of resources, conducting a laboratory becomes a challenging task. Hence, this research has been carried out as an extension of Radiofrequency satellite Link example available in matlab r2016b. The electromagnetic signal carrying information is inflicted upon a lot of impairments such as free space path loss, doppler error, etc. Radio frequency (RF) satellite link documentation of matlab r2016b shows an example wherein these impairments are modeled in the form of respective blocks with the provision of various mask parameters in each of them which allows us to vary those parameters to see the corresponding changes in the nature of the received signal. The primary objective of this paper is to carry out simulation experiments of various RF impairments that the propagating signal goes through in RF satellite communication link. These laboratory experiments are mainly created for students to be performed at undergraduate level. These experiments are then performed on similar lines by transmitting sinusoidal wave, triangular wave, square wave and speech signal from satellite's transmitter and recovering them at ground station downlink receiver. The simulated results, to study the effects of various RF impairments on the received signal, are recorded and analysed in the form of bit error rate (BER) of the system and scatter plot of the received signal. The arrangement of the signal points recorded at the time of its reception denotes the way in which a particular impairment is affecting the signal's quality and power levels.

Keywords—RF Satellite Impairments, Laboratory Experiments, Free Space Path Loss, Receiver Noise, Doppler Error.

I. Introduction

The aim of gaining analytical understanding of transmission and reception of signals via satellite link by undergraduate students remains unaccomplished. Therefore, efforts are being made to conduct some basic experiments on the matlab r2016b in its Simulink feature where RF Satellite link [1] model has already been simulated. All the blocks are modeled as various gain and losses that signal is inflicted upon in the natural phenomena. The overall research objective is to develop Matlab simulation for satellite downlink which has a speech signal or sine waveform as an input and which demonstrates various RF impairments effects on the nature of the propagating signal.

II. Introduction To Satellite Link

Fig.1 shows the general block diagram of a satellite downlink setup for transmission of signals originating from the transmitter located on the satellite, and reaches the satellite downlink receiver located at the earth station while propagating through the earth's atmosphere. In the course of the signal's propagation right from through the transmitter, earth's atmosphere till the ground station receiver, the signal's quality is compromised due to various physical/ real-world phenomena resulting in increased background noise and lesser probability of detecting the signal in its authentic form which is highly undesirable. Therefore, understanding the real nature of these impairments and hence, modeling them in the virtual platform to experiment with them on the signal transmitted digitally aids in a better understanding of these impairments, analysis of their effects on the propagating signal, choosing the best frequency at which signal should be transmitted for minimum BER, estimating the total loss in terms of power that a signal can tolerate while

travelling through the earth's atmosphere whose role surfaces when link power budget of a satellite link is being calculated.

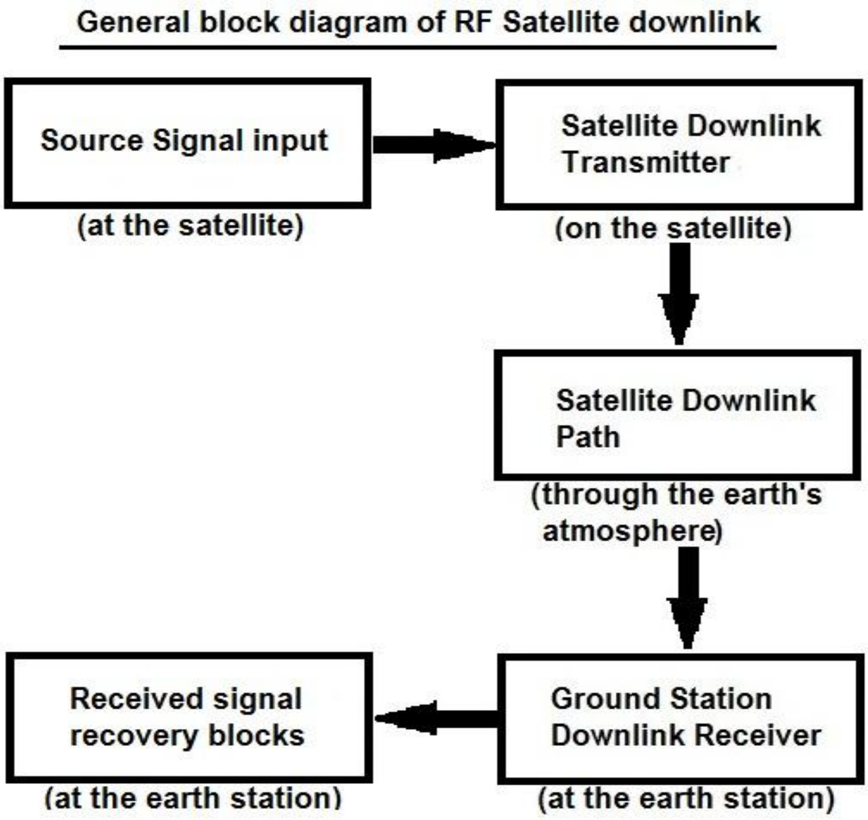

Fig. 1. General block diagram of RF Satellite Downlink.

The types of impairments that are discussed and simulated in this project are as under:

2.1 **Memoryless nonlinearity**: In the communication link, RF devices might get driven into the unwanted nonlinear operating region of their input/output characteristic[2] especially when upsamling and downsampling of the signal is undertaken. This nonlinearity is manifested in simulink RF satellite link example according to the saleh model[3] by inducing gain in the magnitude component of the output signal corresponding to the variations in the amplitude levels of the input (AM/AM conversion). Also phase changes occurring due to amplitude variations of the input signal gets added to the original phase of the signal giving a new phase angle of the output signal (AM/PM conversion). The saleh model provides an independent gain and phase function that has been used to compute output wave-form for given input which is not available in other high power amplifications.

Nonlinearity is applied by multiplying the signal by a gain factor, then split the signal into its magnitude and angle components. Then an AM/AM conversion is applied to the magnitude part of the signal according to the saleh model selected according to the function given as under:

$$F_{AM/AM}(u) = \frac{alpha \times u}{1 + beta \times u^2} \quad (1)$$

Where $alpha$ and $beta$ are the parameters used to compute the amplitude gain of the input signal, u is the magnitude of the scaled signal.

Then an AM/PM conversion to the phase signal is applied according to the saleh model given by the function as under, which adds the result to the angle of the signal to produce the output of the signal.

$$F_{AM/PM}(u) = \frac{alpha \times u^2}{1 + beta \times u^2} \quad (2)$$

Where $alpha$ and $beta$ are the parameters used to compute the phase change in the input signal and u is the magnitude of the scaled signal. This block models memoryless nonlinearity impairment.

The natural/unintentional causes of these amplitude variations are Power supply ripples, Thermal drift, Multipath fading.

2.2 **Free space path loss (FSPL)**: The loss in signal strength of an electromagnetic wave that would result from a line-of-sight path through free space (usually air), with no obstacles nearby to cause reflection or diffraction[4].FSPL is related to the frequency by $(\frac{4\pi df}{c})^2$[5], where d is the distance between transmitter and the receiver (in meters), f is the frequency (in hertz), c is the speed of light (in meters per second), Typically for Geosynchronous Earth Orbit (GEO) satellite of altitude 35600km and frequency of operation 4GHz [6], free space path loss will be 196dB and for Iridium low earth orbit(LEO) satellite whose satellite altitude is 780km [7] and downlink frequency of operation is 18.8GHz and its free space path loss is 156dB.

2.3 **Receiver thermal noise**: Due to random motion of electrons in active and passive RF devices under operation, there will be internal noise produced which gets added to the signal with the rise in the temperature of these devices. Noise temperature provides a way of determining how much thermal noise is generated by active and passive devices in the receiving system. Typically noise temperatures increase with frequency. If GaAsFET amplifiers are used at room temperatures, noise temperature will be 30 deg K at 4GHz and 100 deg K at 11GHz [8].

2.4 **In-phase and Quadrature (I/Q) imbalances**: Because of the differences present in the physical channels of the two components of 16-QAM modulated signal, the gain in amplitude levels as well the changes in their phase happen differently. Therefore, this creates an imbalance while adding back these two components of the signal at the time of demodulation. I/Q imbalance correction [9] is done using a circularity-based blind compensation algorithm. Typically the amplitude level difference between them is 3dB and phase difference is of 20degrees.

2.5 **Phase noise**: It is the noise arising from the short term phase fluctuations that occur in the signal. The fluctuations manifest themselves as sidebands which appear as a noise spreading out on either side of the signal.Faraday rotation is the physical phenomena that is modeled as phase noise impairment. The phase noise block [10] that simulates this impairment applies phase noise by generating additive white Gaussian noise(AWGN) and filters it with a digital filter and then adding the resulting noise to the angle component of the input signal.

2.6 **Doppler error**: For LEO satellites, there is a Doppler shift or change in the frequency at which the signal is transmitted and received at the stationary observer on the earth. If f_T is the transmitter frequency, then f_R, the received frequency is higher than f_T when the transmitter is moving toward the receiver and lower than f_T when transmitter is moving away from the receiver. Mathematically, the relation between the transmitted and received frequencies can be given as

$$\frac{f_R - f_T}{f_T} = \frac{\Delta f}{f_T} = \frac{V_T}{v_p} \quad (3)$$

or

$$\Delta f = \frac{V_T f_T}{c} = \frac{V_T}{\lambda} \quad (4)$$

Where V_T the component of the transmitter velocity is directed toward the receiver, $v_p = c$ is the phase velocity of light $3 \times 10^8 m/s$, and λ is the wavelength of the transmitted signal. This change in frequency is called the *Doppler shift*. Doppler error [11] impairment is simulated by applying phase offset and frequency offset to the incoming signal. Doppler correction block uses carrier synchronization [12], [13].

III. Simulation Of RF Satellite Link

3.1 Introduction

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This section simulates, shown in Fig. 2, the complete model of RF satellite downlink that is available in matlab r2016b with input as Bernoulli binary generator at the transmitter section. The results are recorded in terms of BER, received signal constellation diagram and recovered signal in the case of sinusoidal, triangular, square and speech signal. Further work is done with the aim of building experiments to be performed by undergraduate students by experimenting on different values of RF impairments and comparing the results, thus, obtained for analysis purposes. The parameters set while simulating with all impairments at negligible level are being discussed further. Though the parameters of all the other blocks except those modeling the impairments remain constant at any impairment value. Therefore the paramets set to all these blocks are being shown in the following sections.

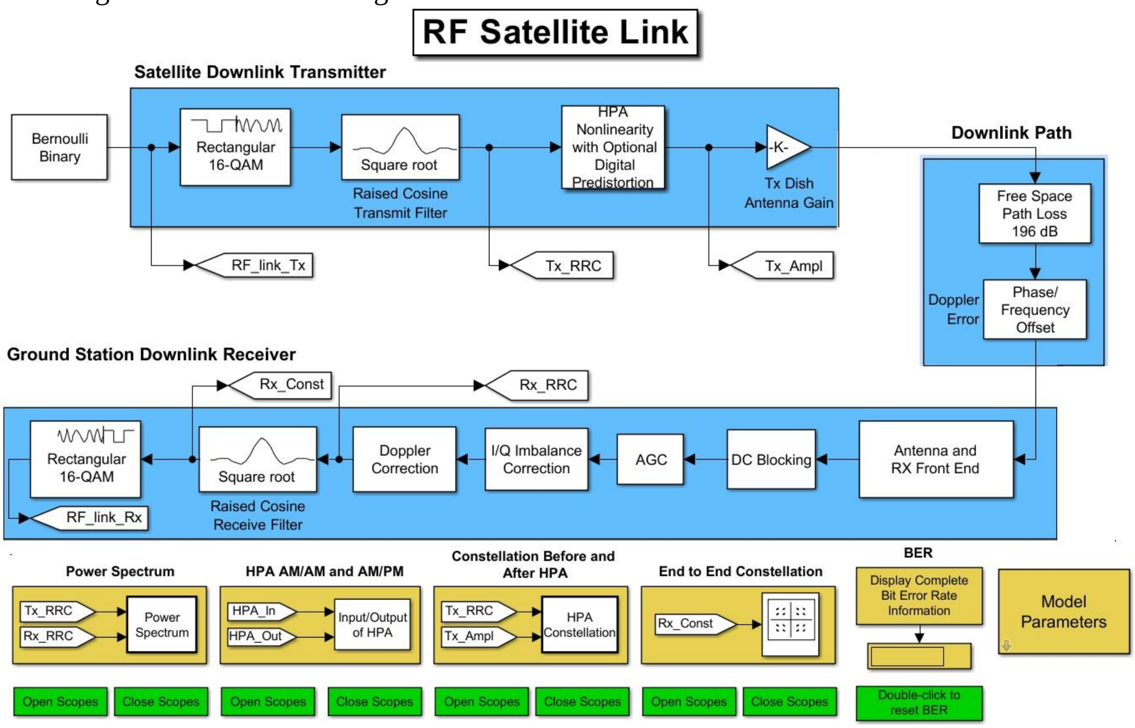

Fig. 2. RF satellite link model in matlab r2016b [1].

3.2 Parameters of satellite downlink transmitter blocks

Referring to Fig. 1, the satellite downlink transmitter of generalized satellite link is composed of the blocks as shown in Fig. 3

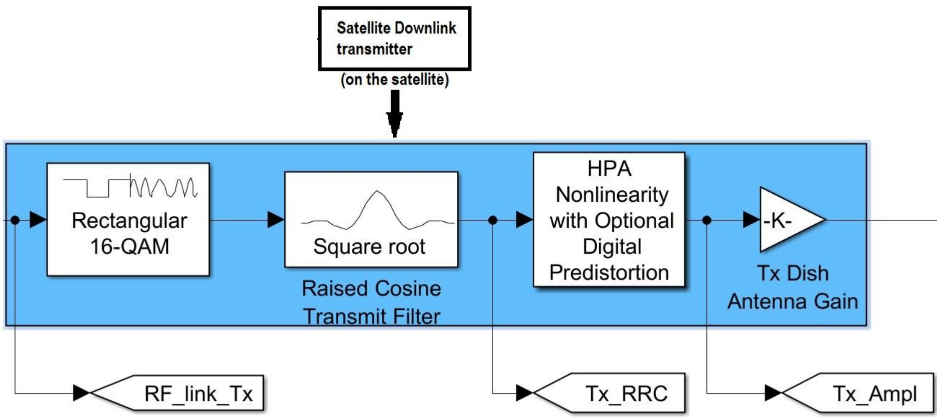

Fig.3. Blocks of Satellite Downlink transmitter.

3.2.1 **Rectangular QAM modulator**: Fig. 4 Shows the parameter of Rectangular QAM modulator

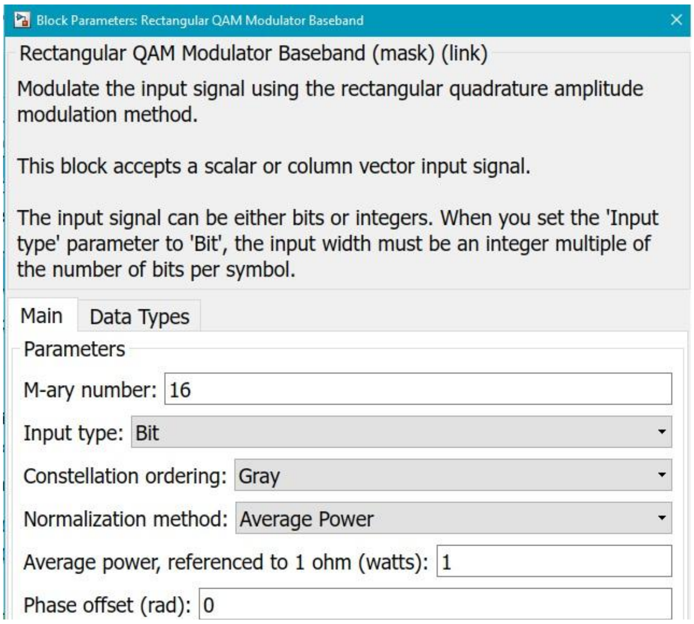

Fig. 4. Parameter values of Rectangular QAM Modulator block

block, which takes input in the form of bit stream which are then grouped into 4 bits denoting as one symbol.There are 16 such symbols arranged according to gray coding in the constellation diagram shown in fig. 5. Normalization method is set to average power referenced to 1 watts with zero radian phase offset.

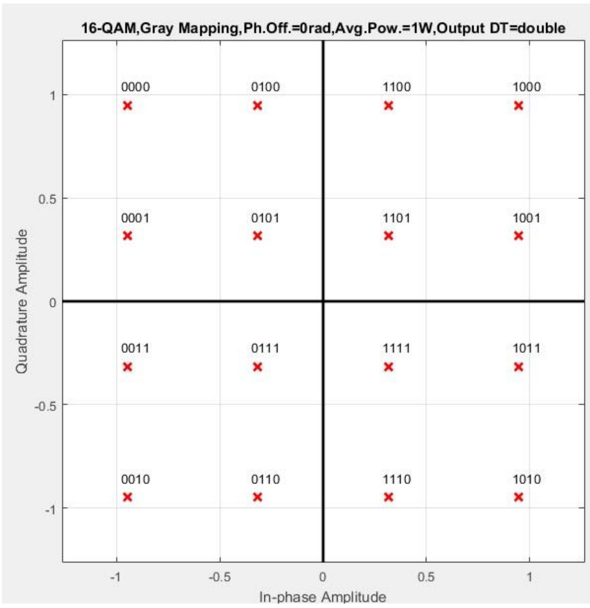

Fig. 5. Reference Constellation diagram of 16 QAM modulated signal points mapped with gray coding and zero phase offset.

3.2.2 **Raised Cosine Transmit filter**: Raised cosine transmit filter upsamples and filters the incoming signal with a square root filter shape whose bandwidth is 1.3 times the input sampling frequency as roll off factor is assigned as 0.3. Referring to Fig. 6, the block truncates the impulse response to 6 number of symbols as fed in the path **paramRFSatLink.FilterSpan** asmentioned in **Filter span in symbols parameter.** The value fed in the path **paramRFSatLink.SamplesPerSymbol** as mentioned in **Output samples per symbol** parameter is 8. **Linear amplitude filter gain**

parameterhas path mentioned as **sqrt(paramRFSatLink.SamplesPerSymbol)** whose value comes out to be as 4 used in scaling the filter coefficients. Each column of the input signal is treated as a separate channel as processing is set as frame based or **Columns as channels**. In this case, only a single channel signal is used as input signal Matrix is [100x1] and output signal matrix is [800x1] keeping the rate of processing same using single-rate processing.

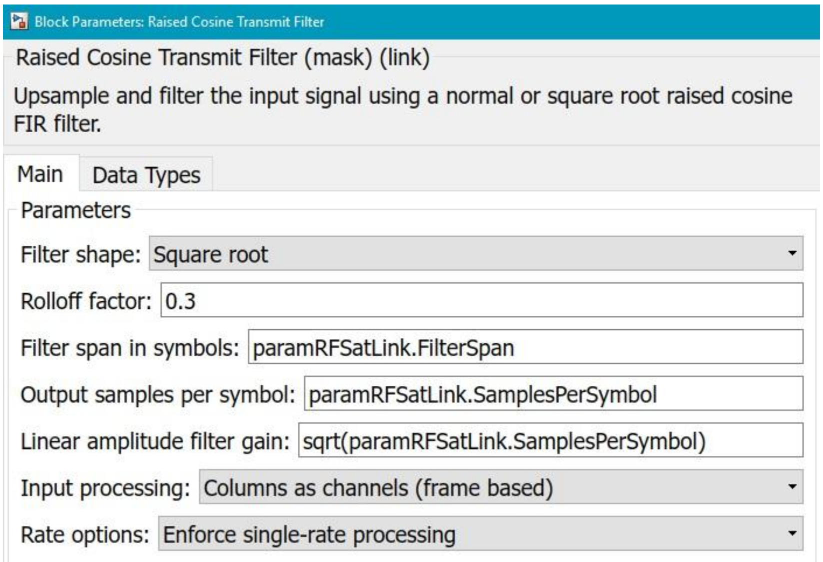

Fig. 6. Parameter values of Raised Cosine Transmit Filter block.

3.2.3 **HPA Nonlinearity with Optional Digital Predistortion (High Power Amplifier)**: Memoryless nonlinearity is applied using saleh model where AM/AM conversion is done with the function given in equation (1), and AM/PM conversion in equation (2). Alpha and beta are the corresponding parameters whose values can be seen in the Fig. 7

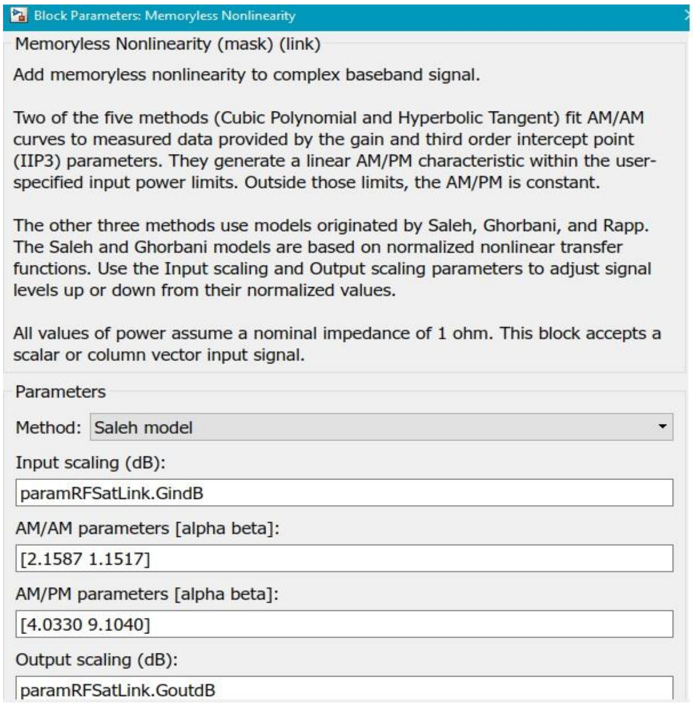

Fig. 7. Parameters of Memoryless nonlinearity block.

3.2.4 **Transmitter Dish Antenna gain**: The Transmitter dish antenna gain block models the gain provided by transmitting dish antenna in **Gain** parameter whose value **12.425959831799187** has been fed in the path mentioned as **paramRFSatLink.TXAntGain** as given in Fig. 8

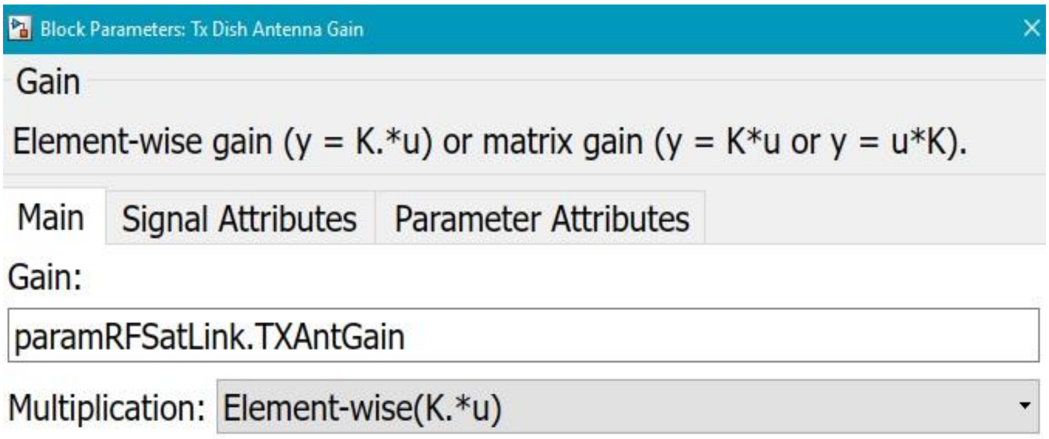

Fig. 8. Parameter of Tx Dish Antenna Gain block.

3.3 Parameters of satellite downlink path blocks.

Referring to Fig. 1, the satellite downlink path of generalized satellite link is composed of the blocks as shown in Fig. 9

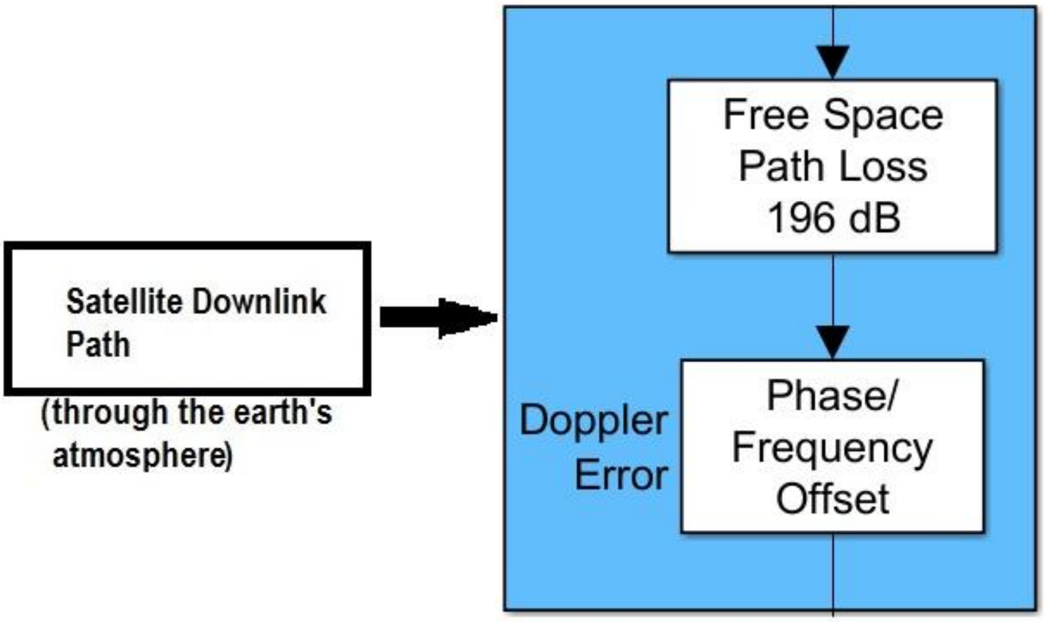

Fig. 9. Blocks of Satellite Downlink path.

3.3.1 **Free Space Path Loss(FSPL)**: In fig.10, Indirect mode of assigning free space path loss value has been adopted where in the path name **paramRFSatLink.Altitude** has been given whose value is fed in “model parameter” block as 35600km (for GEO distance) or 780km(for LEO distance). And corresponding carrier frequency parameter is given a path name as **paramRFSatLink.Frequency** whose value has been fed in “model parameter” block as 4000MHz (for GEO) and 1880MHz (for LEO).

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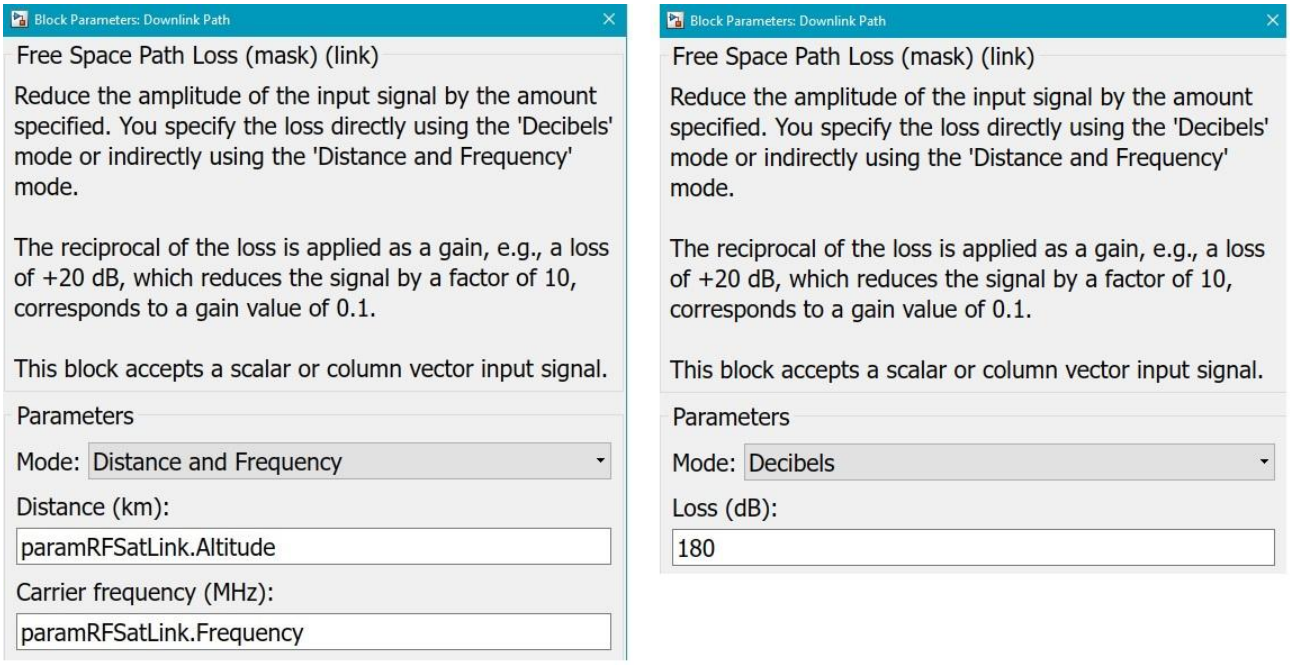

Fig. 10. Parameter of Free Space Path Loss block.

3.3.2 **Phase/Frequency Offset**: Phase offset parameter rotates the grid of the constellation diagram with the value specified in this parameter. Whereas the rate/speed of rotation of the grid from its standard orientation will be decided by the value in the Frequency offset parameter. Whose values have been set to zero as shown in Fig. 11

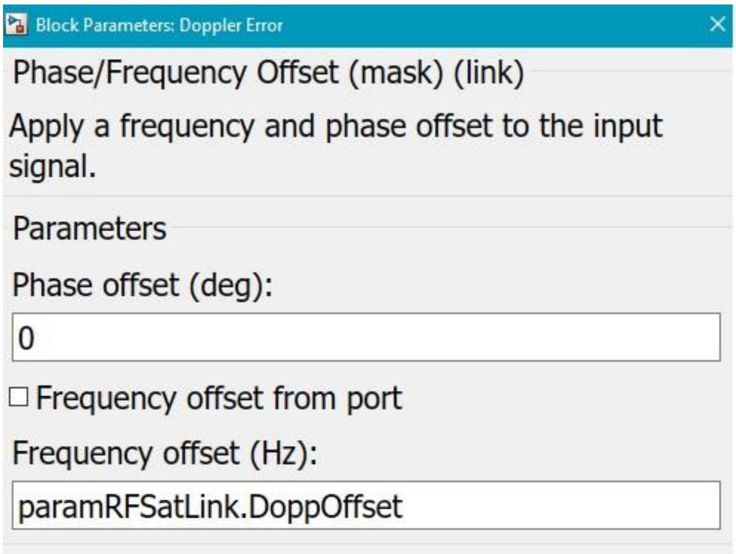

Fig. 11. Parameter of Phase/Frequency Offset block.

3.4 Parameters of satellite downlink receiver blocks.

Referring to Fig.1, the satellite downlink receiver of generalized satellite link is composed of the blocks as shown in Fig. 12

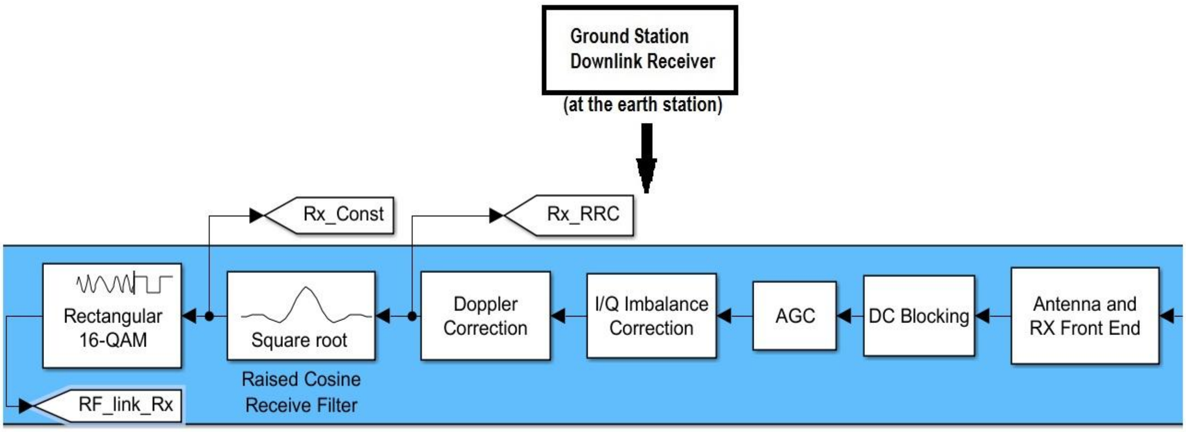

Fig. 12. Blocks of satellite downlink receiver.

3.4.1 **Antenna and Receiver Front end block**: This block has masked blocks which is displayed in Fig. 13

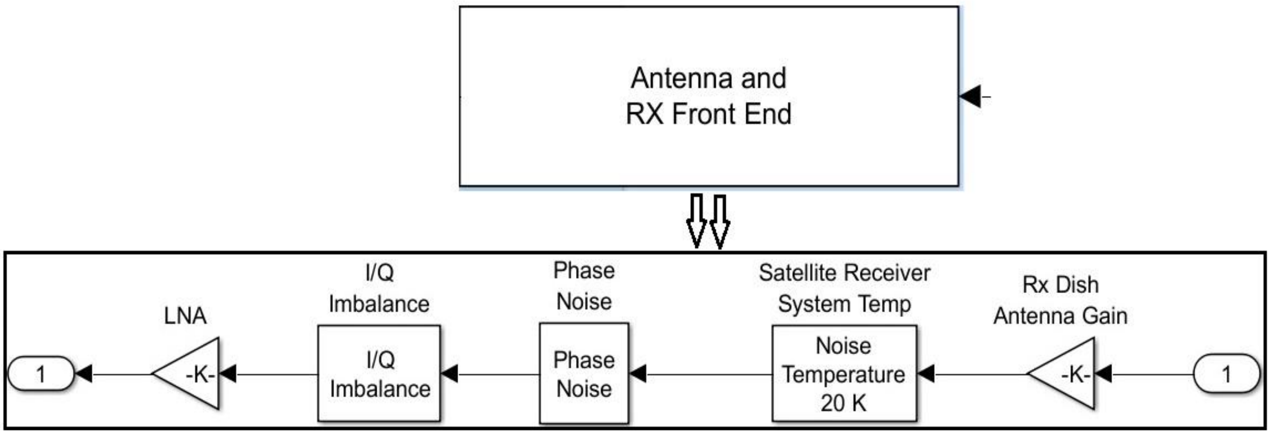

Fig. 13. Masked blocks of Antenna and Receiver front end block.

3.4.1.1 **Receiver Dish Antenna Gain**: The path link mentioned in gain parameter **paramRFSatLink.RXAntGain** is fed as **12.425959831799187** as shown in Fig. 14

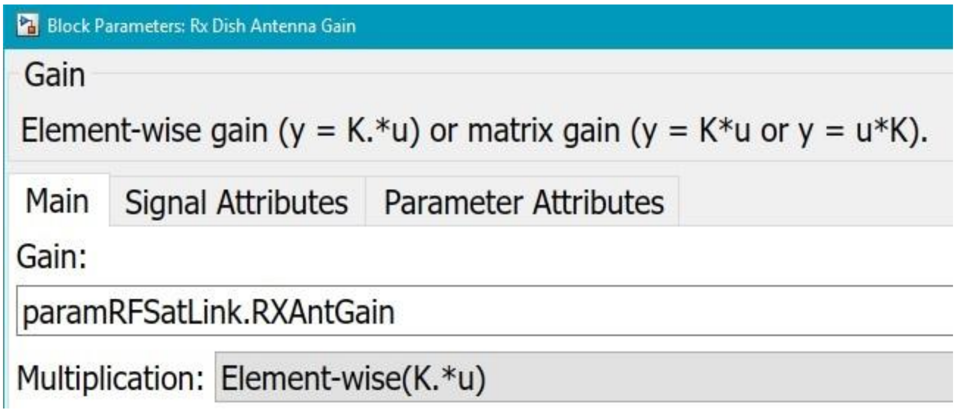

Fig. 14. Parameter of Rx Dish Antenna Gain block.

3.4.1.2 **Receiver Thermal Noise**: In Fig. 15, the specification method is assigned as Noise temperature where the path name mentioned as **paramRFSatLink.RXTemp** which specifies the amount of noise in degrees K. The value in the path name is fed as 20K.

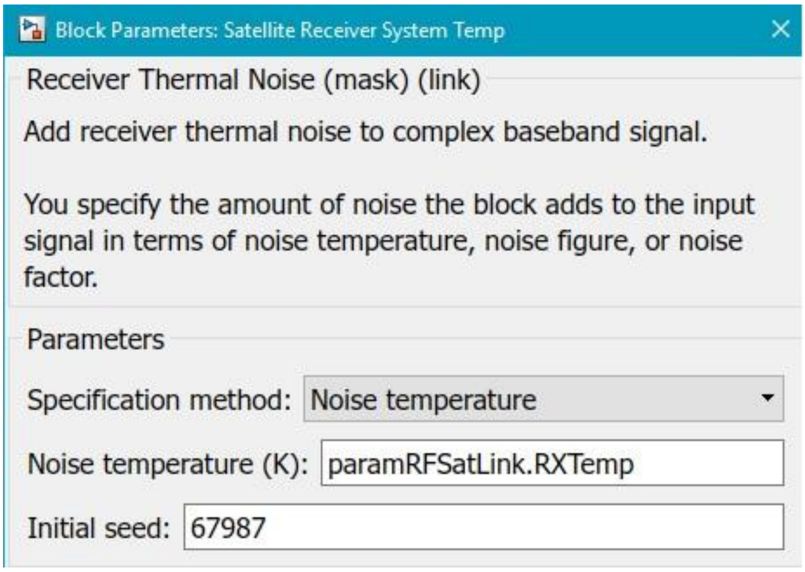

Fig. 15. Parameter of Receiver Thermal Noise block.

3.4.1.3 **Phase Noise**: The Grid of constellation diagram is rotated anticlockwise at **100dB** level with respect to the carrier per hertz as fed in the path name **paramRFSatLink.PhaseNoise** mentioned in **Phase noise level (dBc/Hz)** parameter with speed of rotation at **100Hz** specified in **Frequency offset** parameter which can be seen in Fig.16

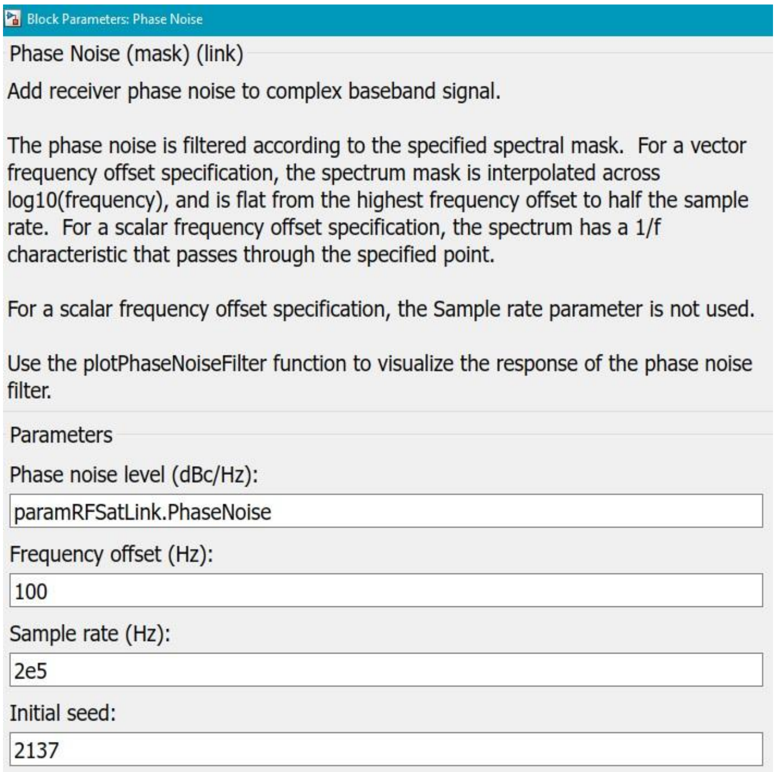

Fig. 16. Parameter of Phase Noise block.

3.4.1.4 **I/QImbalance**: In Fig.17, **paramRFSatLink.IQImbal(1)**, **paramRFSatLink.IQImbal(2)**, **paramRFSatLink.IQImbal(3)**, **paramRFSatLink.IQImbal(4)** path name mentioned in **I/Q amplitude imbalance (dB)**, **I/Q phase imbalance (deg)**, **I dc offset**, **Q dc offset** parameter respectively whose value is fed as 0 in all of them. Though their values can be modified from "model parameters" block displayed in Fig. 2.

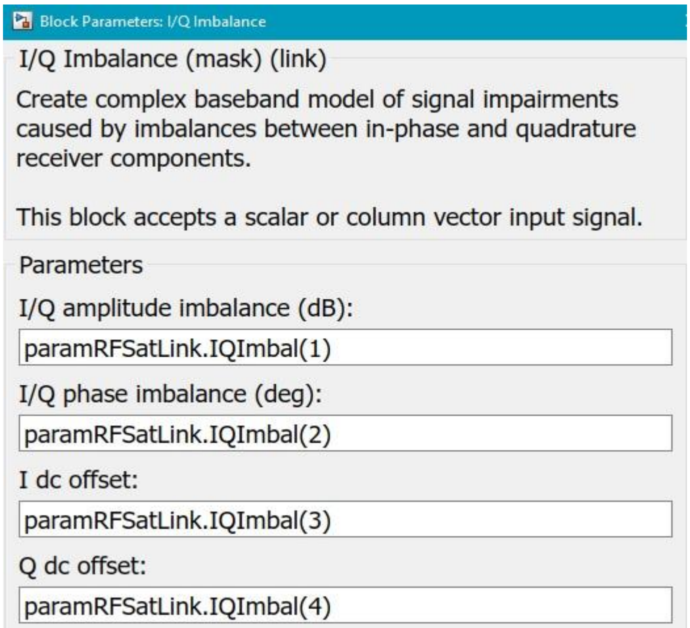

Fig. 17. Parameter of I/Q Imbalance block.

3.4.1.5 **Low Noise Amplifier (LNA)**: Using element wise multiplication of the gain value mentioned in **gain** parameter as seen in Fig. 18

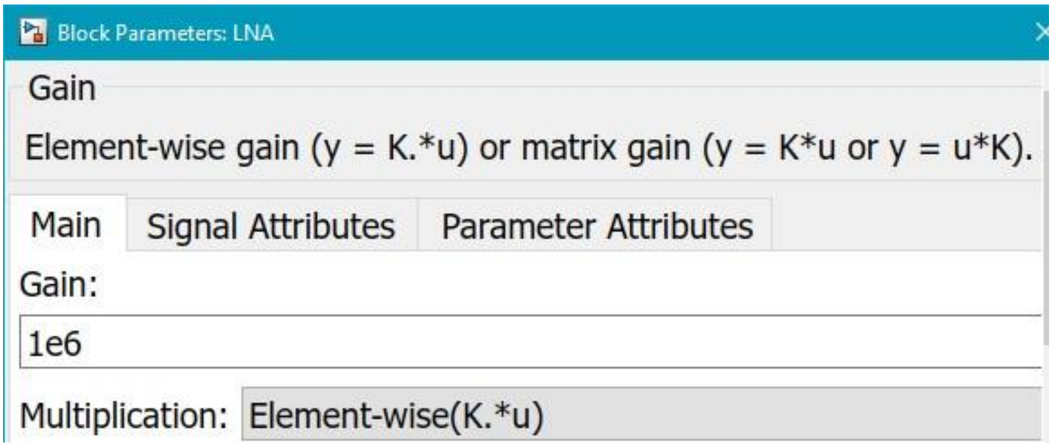

Fig. 18. Parameter of LNA block.

3.4.2 **DC Blocker**: Fig. 19 shows the parameter of **DC blocker** block wherein to estimate the DC offset, Infinite Impulse Response (IIR) algorithm has been selected which uses a recursive estimate based on a narrow, low pass elliptic filter as it uses less memory than Finite Impluse Response (FIR) and is more efficient. The corresponding bandwidth and the order of the IIR filter used for DC blocking is being reflected in Fig. 19.

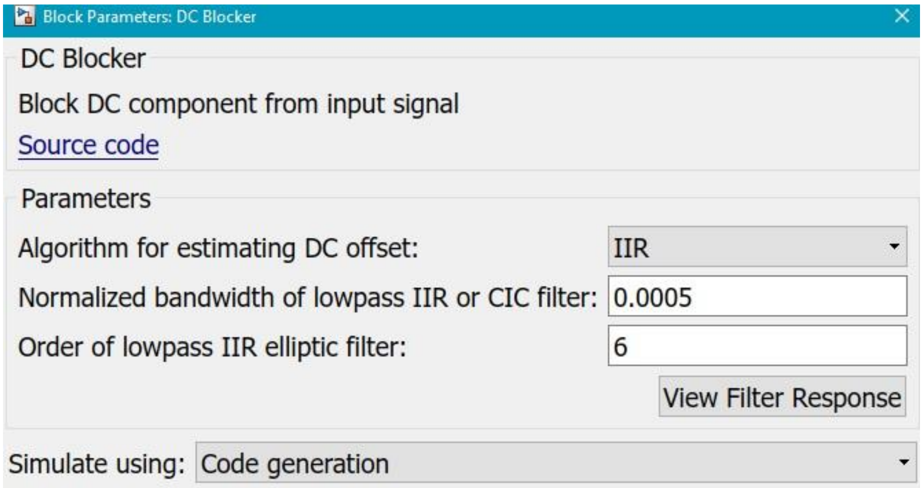

Fig. 19. Parameters of DC Blocker block.

3.4.3 **Automatic Gain Controller (AGC)**: In Fig. 20 shows the parameter of AGC block where in the step size of 0.01 the gain value will get updated with the increase in step size, the response of AGC to the input signal level increases. The desired output power level is set to 1watts. Averaging length with 16 number of symbol points is given as 256. If the AGC input signal level is very small, the AGC gain will be very large. tThis can cause problems when the input signal power suddenly increases. Use **Maximum Power gain (dB)** to avoid this by limiting the gain that the AGC applies to the input signal. As seen in Fig. 20

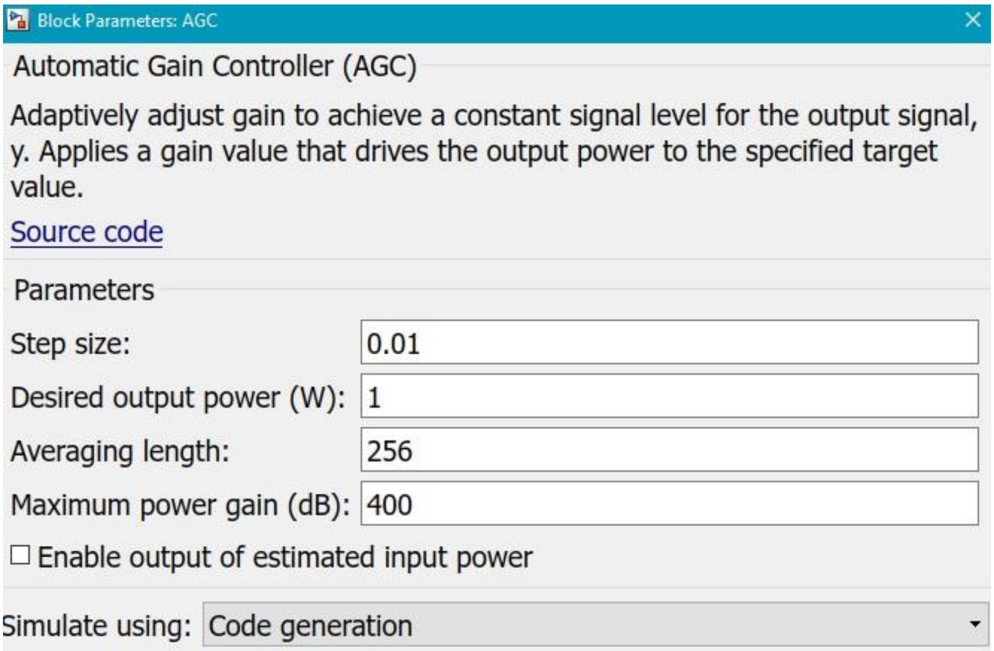

Fig. 20. Parameters of AGC block.

3.4.4 **I/Q Imbalance Correction**: Source of compensator coefficient is estimated form the input signal with initial compensator coefficient set to $0 + 0j$. Adaptation step size is set to 0.00001 as shown in Fig. 21

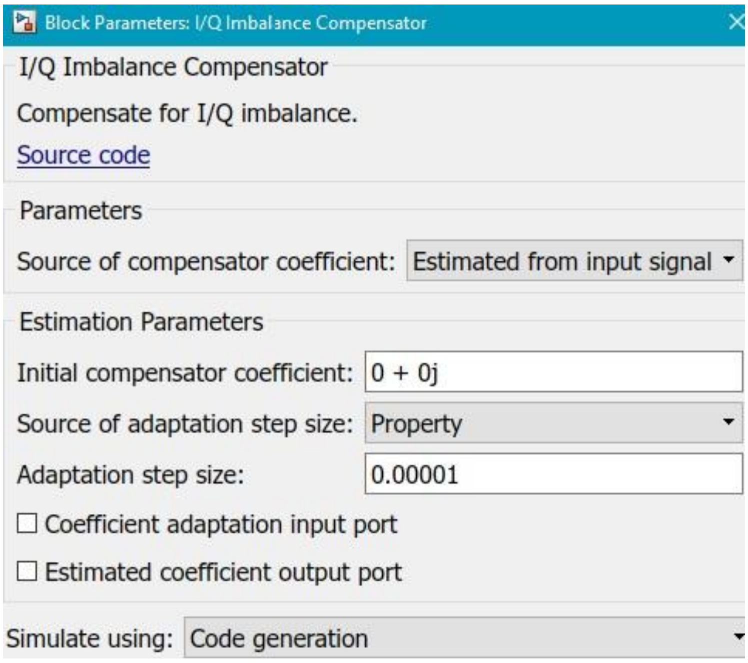

Fig. 21. Parameters of I/Q Imbalance Compensator block.

3.4.5 **Doppler correction**: The path link in **Samples per symbol** parameter has the value 8 feeded in **paramRFSatLink.SamplesPerSymbol**. Closed loop approach for phase and frequency offset is based on Phase Locked Loop PLL-based algorithm. Values of the variables involved in the same are shown in Fig. 22

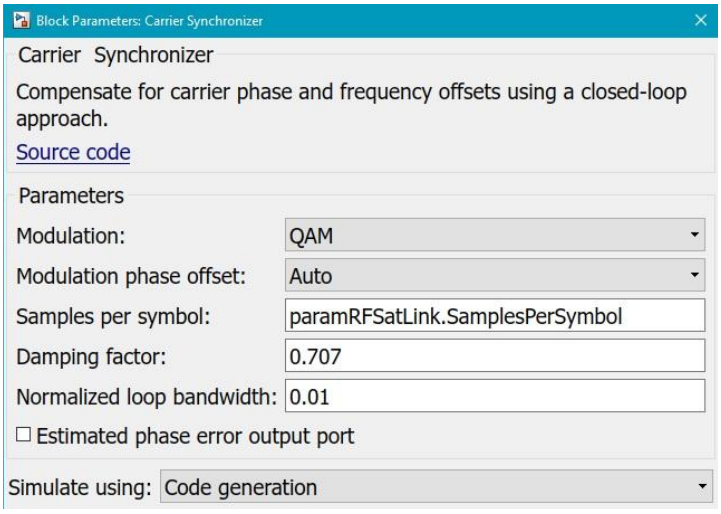

Fig. 22. Parameters of Carrier Synchronizer block

3.4.6 **Raised Cosine Received Filter**: This block does the reverse operation of the raised cosine transmit filter at the transmitter side which does the pulse shaping of the received signal by down sampling the signal.From Fig. 23 the **decimation factor** parameter specifies the decimation factor that the block applies to the input signal. The output samples per symbol equals the value of the input samples per symbol divided by the decimation factor.

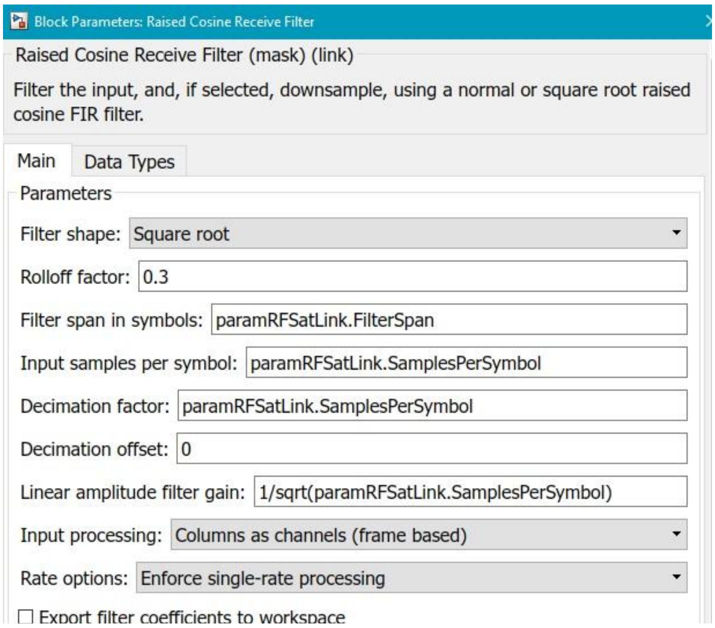

Fig. 23. Parameters of Raised Cosine Receive Filter block.

3.4.7 **Rectangular QAM Demodulator Baseband**: It demodulates the received signal which was modulated using quadrature amplitude modulation. From Fig. 24 the **Hard decision** algorithm of demodulator maps received signal constellation values to M-ary integer I and Q symbol indices between 0 and $\sqrt{M} - 1$ and then maps these demodulated symbol indices to formatted output values, where M is the number of points in the signal constellation which is of the form 2^K for some positive integer K.

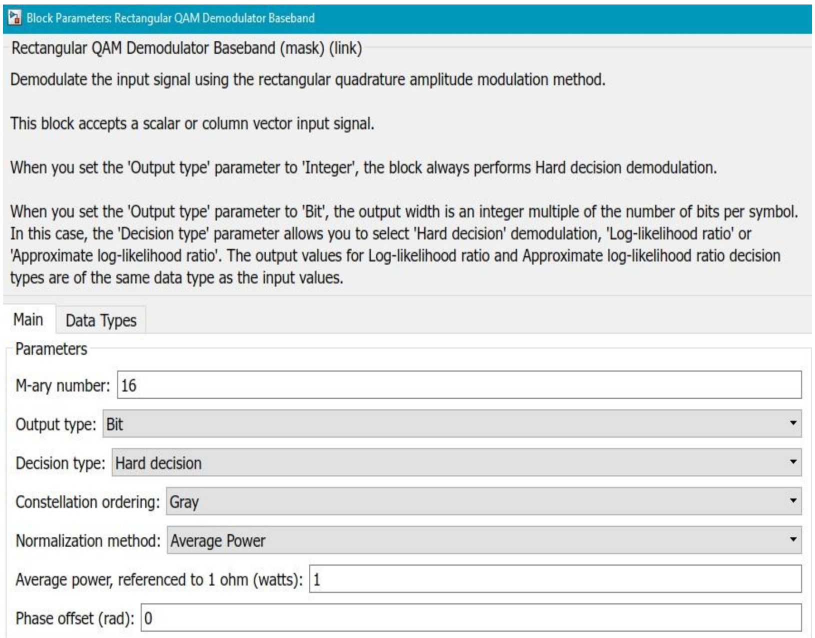

Fig. 24. Parameters of Rectangular QAM Demodulator Baseband block.

3.5 Parameters of signal generator blocks.

3.5.1 **Bernoulli binary generator**: Referring to Fig. 2, the parameters ofbernoulli binary generator block is shown in Fig. 25. **Sample time** parameter has value 0.00001 and **Samples per frame** is set to 400.

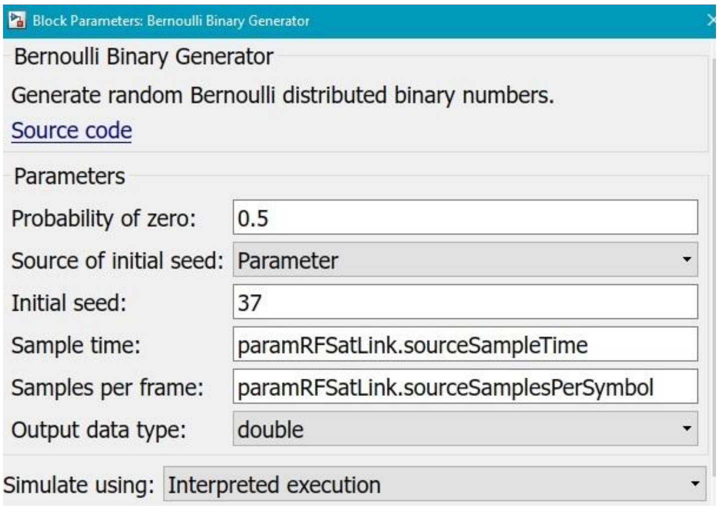

Fig. 25. Parameter of Bernoulli Binary Generator block.

3.5.2 **Sinuosidal Waveform**: Fig. 26 shows the modified RF satellite link as compared to Fig. 2 where several blocks have been added to make the model compatible with the transmission and reception of sine wave.

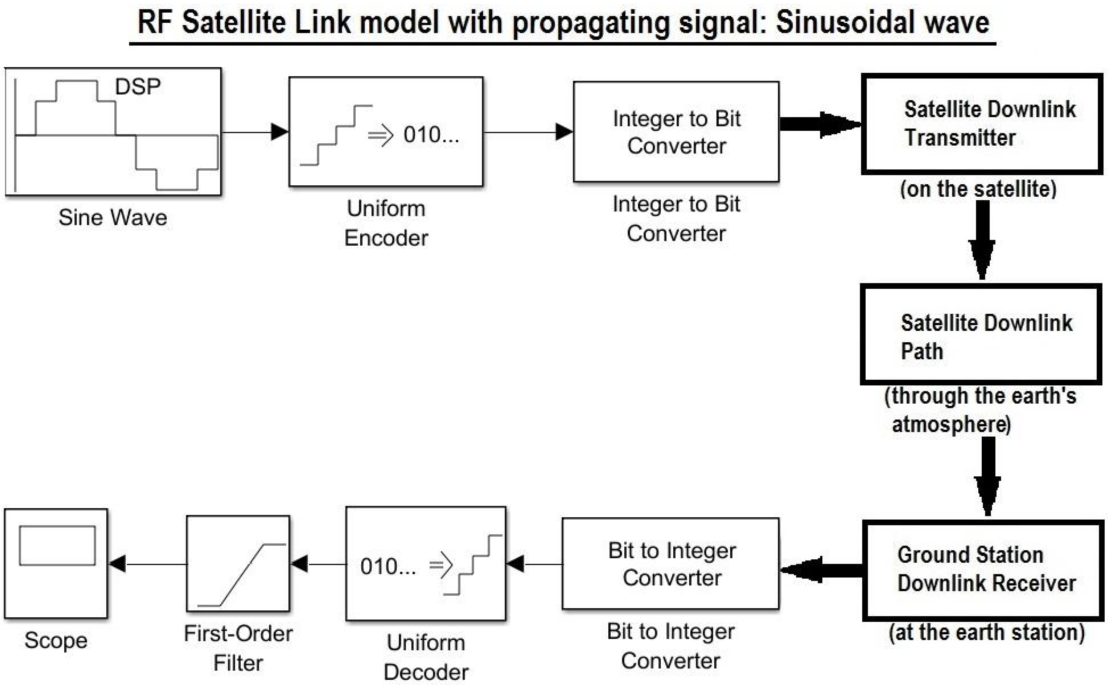

Fig. 26. Modified RF Satellite Link model with Sinusoidal waveform as propagating signal.

The Parameters of sine wave block is shown in Fig. 27 which generates samples of sinusoid with sample time set as 0.00001 and samples per frame set to 400.

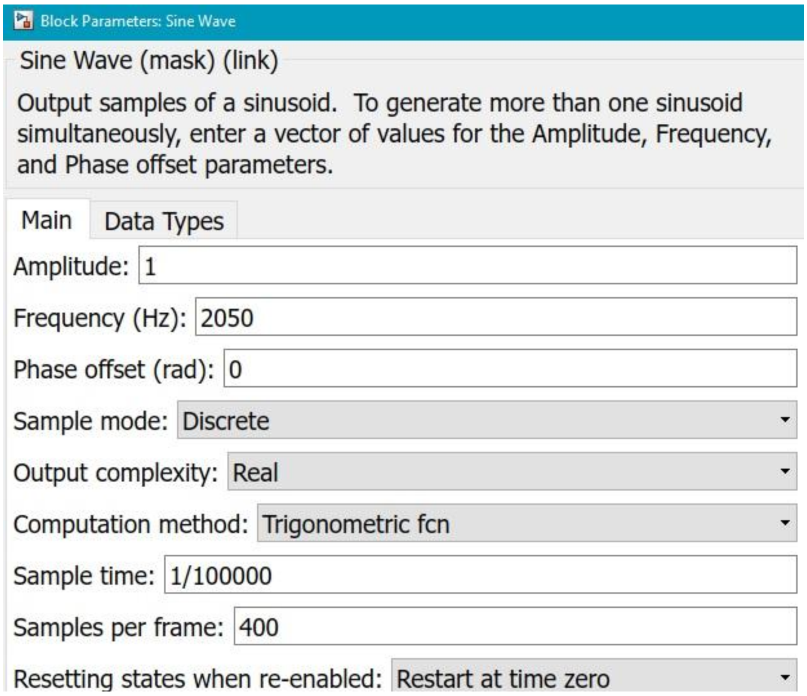

Fig. 27. Parameters of Sine Wave block.

3.5.3 **Triangular waveform**: Fig. 28 shows the modified RF satellite link as compared to Fig. 2 where several blocks have been added to make the model compatible with the transmission and reception of triangular wave.

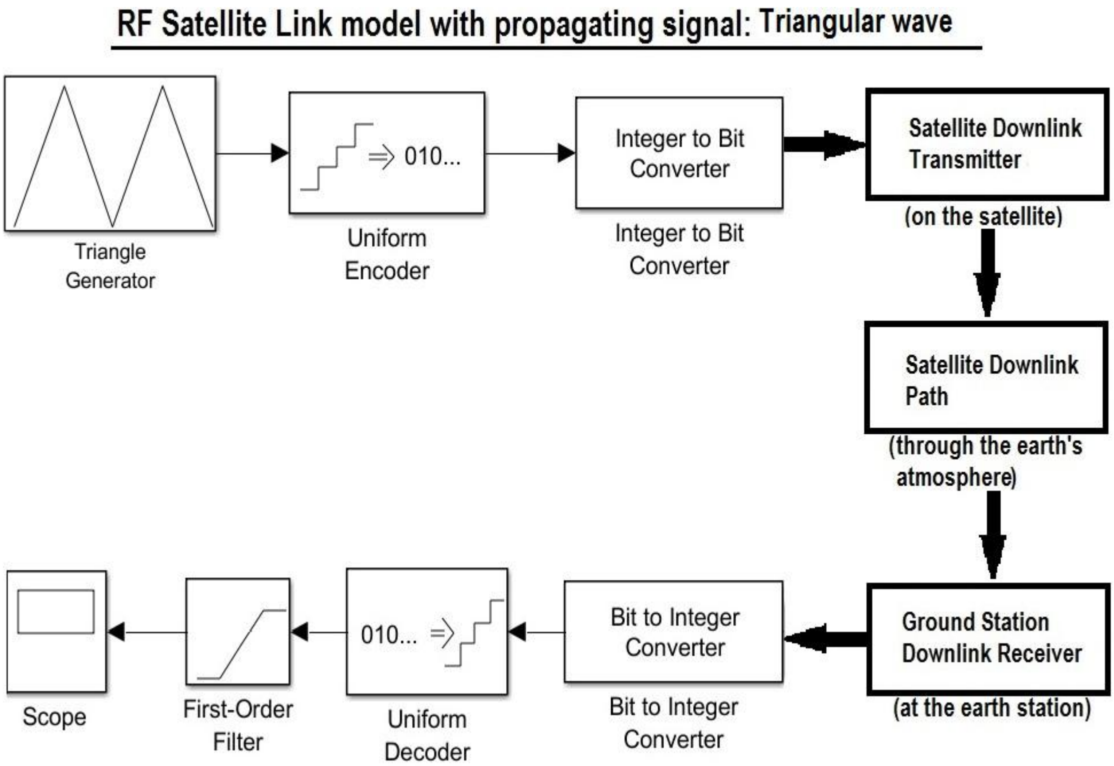

Fig. 28. Modified RF Satellite Link model with Triangular waveform as propagating signal.

The parameters of triangular generator is shown in Fig. 29

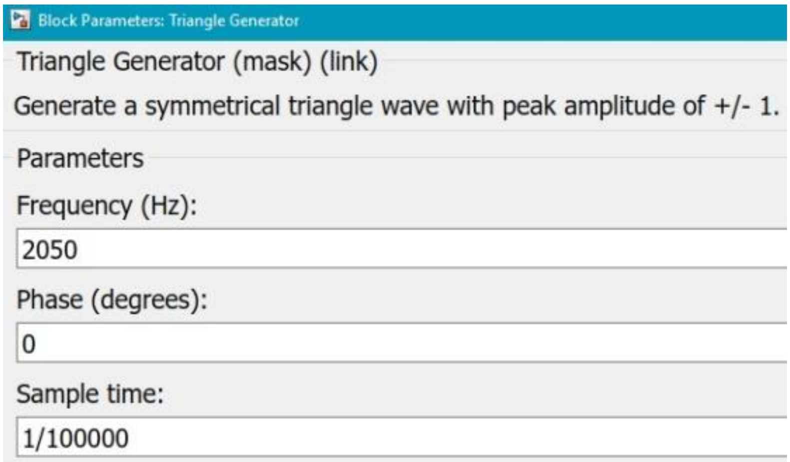

Fig. 29. Parameters of Triangular Generator block.

3.5.4 Square Waveform: Fig. 30 shows the modified RF satellite link as compared to Fig. 2 where several blocks have been added to make the model compatible with the transmission and reception of square wave.

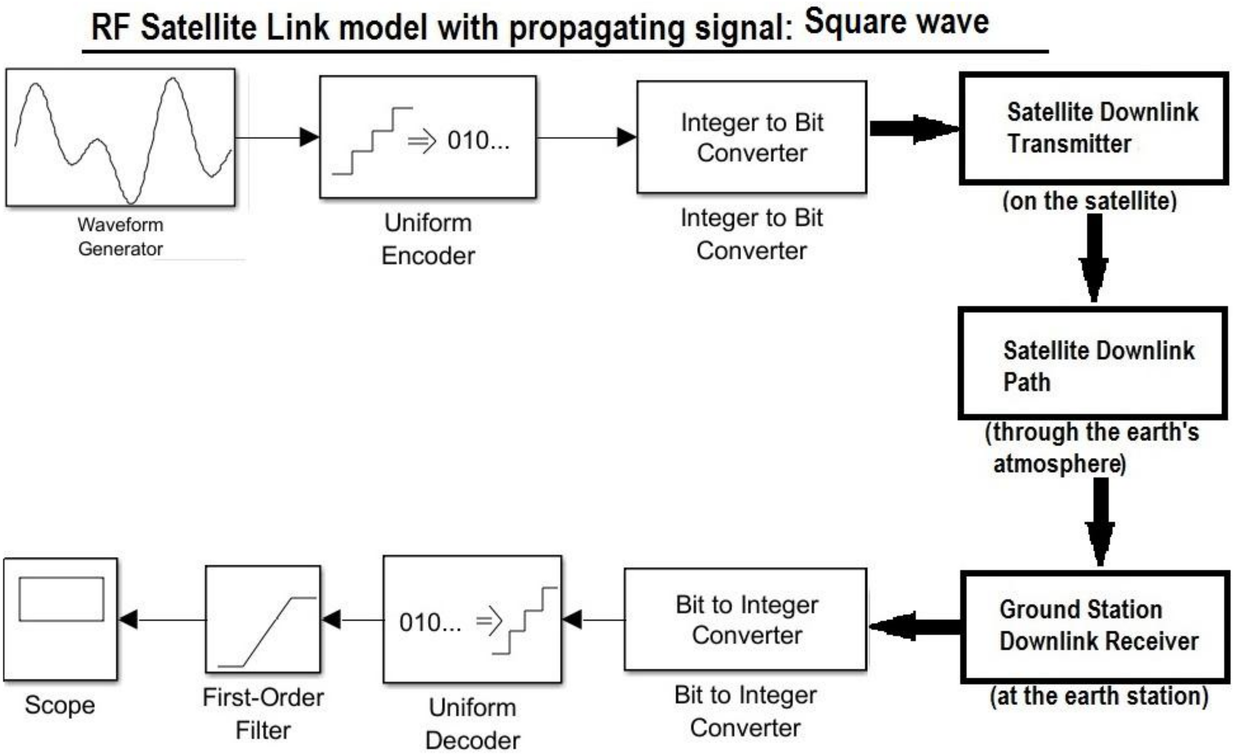

Fig. 30. Modified RF Satellite Link model with Square waveform as propagating signal.

The parameters of Waveform generator block Fig. 31 mentions the syntax of square wave which is given as square(amplitude,frequency,phase_delay,duty_cycle). The parameter amplitude gives the amplitude of the signal. Frequency parameter gives the waveform frequency in rad/s. phase_delay parameter means a horizontal signal shift based on elapsed simulation time, in seconds. duty_cycle parameter gives the percentage of signal that remains high per period.

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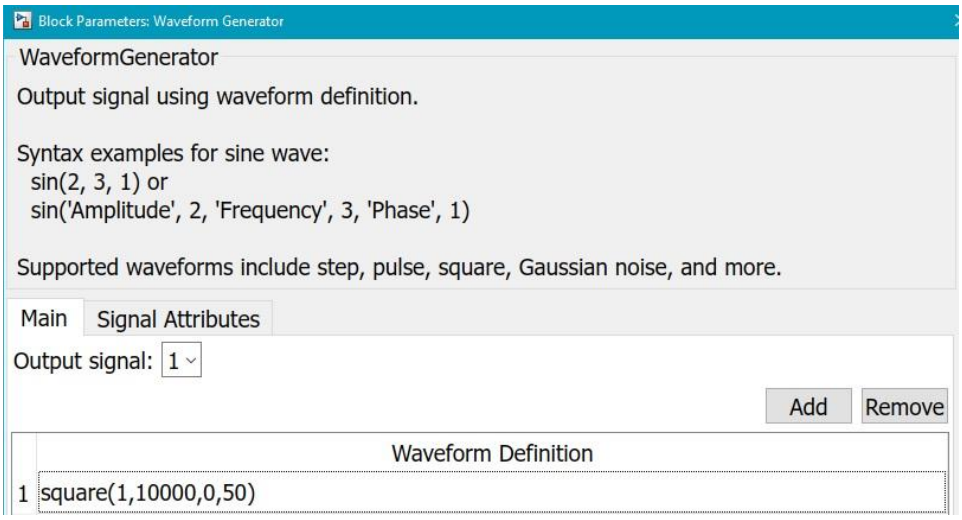

Fig. 31. Parameters of (Square) Waveform generator block.

3.5.5 Speech signal: Fig. 32 shows the modified RF satellite link as compared to Fig. 2 where several blocks have been added to make the model compatible with the transmission and reception of speech signal.

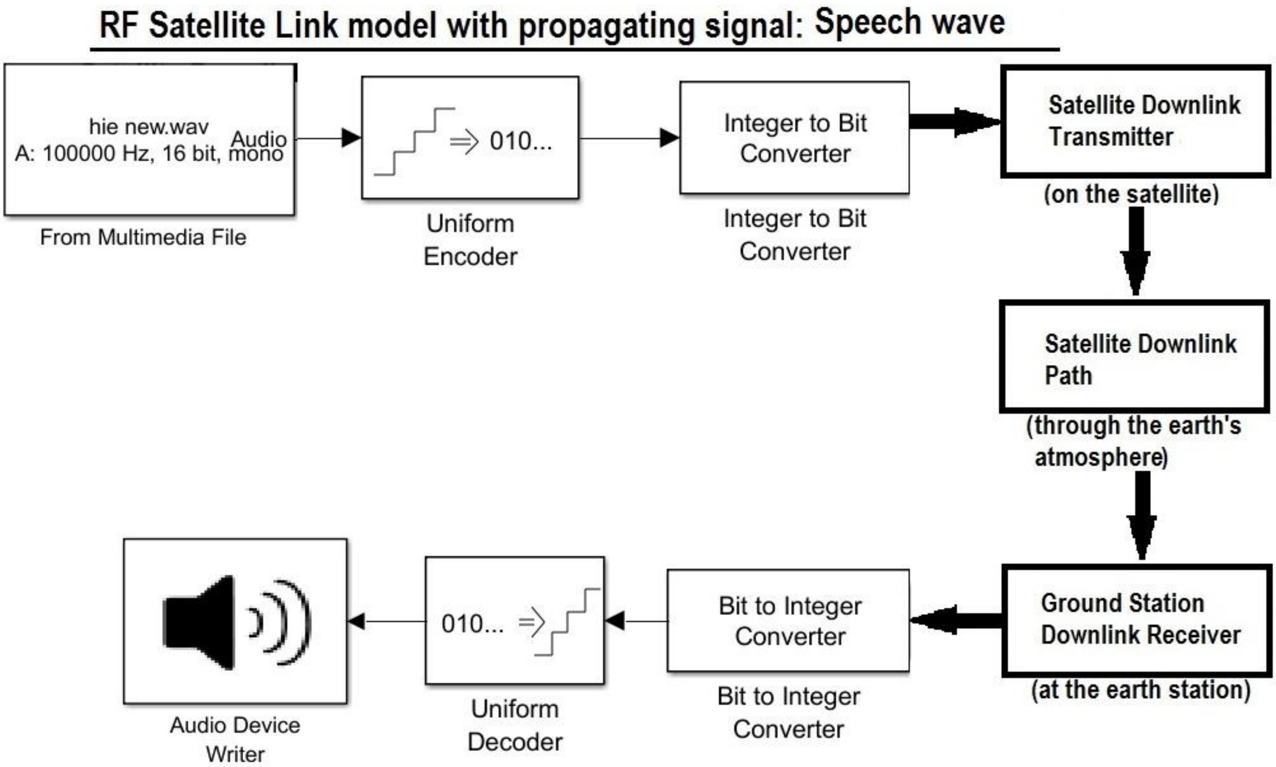

Fig. 32. Modified RF Satellite Link model with Speech waveform as propagating signal.

The Parameter of From Multimedia File block in Fig. 33 shows the path name where the audi0 file is located. Audio is recorded at 100000Hz to obtain the sample time as 0.00001 in a monochannel. Samples per audio channel remains 400.

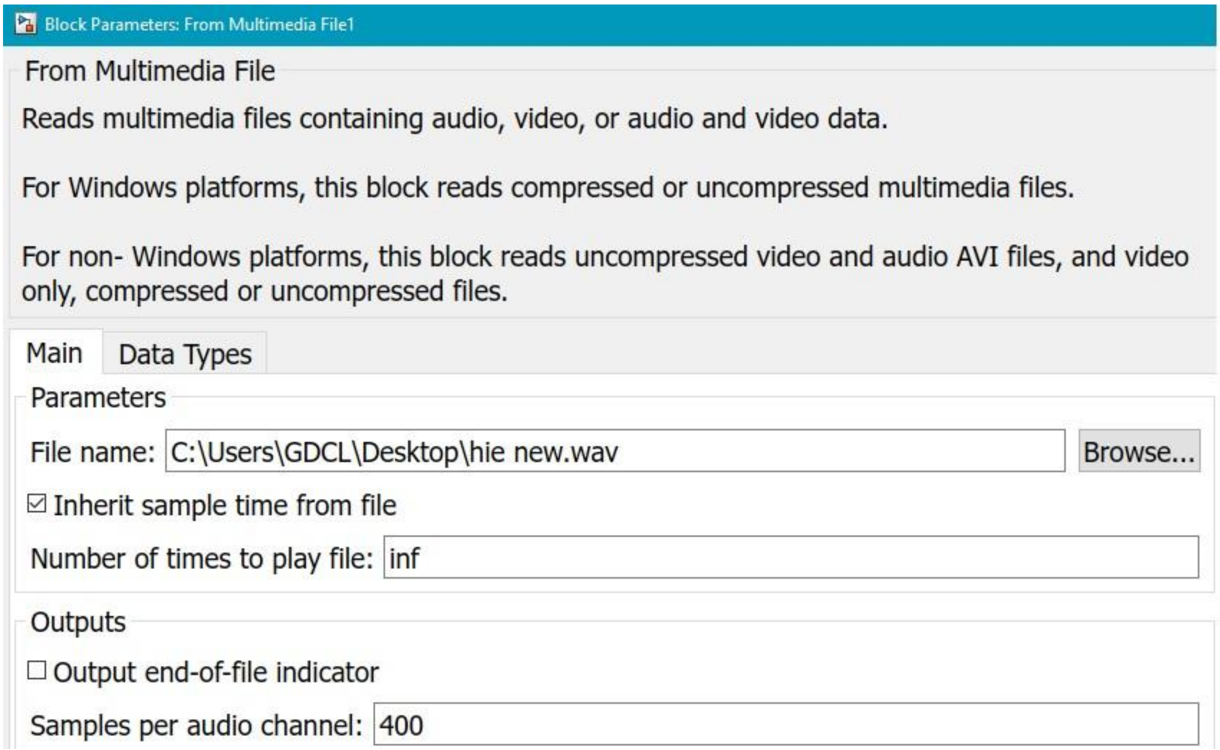

Fig. 33. Parameters of From Multimedia File.

Uniform encoder blocks uniformly quantize and encode the input into 4 number of bits and uniform decoder block decode the input with positive and negative peak value. The number of bits parameter in uniform decoder block is kept same as uniform encoder block, that is, 4.

Data type converter blocks such as Integer to Bit after uniform encoder block because the input data type of Rectangular 16-QAM block is of set to bit. Low pass filter type is selected of first order to recover obtain signal at the scope display whose sample time is 0.00001. In Fig. 32, Audio device writer writes the incoming data with sample time same as the audio file, which enables to hear the audio received.

IV. Results and Discussion

Since rectangular 16-QAM binary signal generator is used as source input, its constellation diagram will consists of 16 different states of the signal usually in a square grid form. The location of those constellation points are of utmost significance and becomes the basis of analysis and conclusion as any deviation from its usual position reveals both amplitude and phase variation at the same time, unlike other forms of phase shift keying (PSK), hence the need of using 16-QAM is justified. Raised cosine transmit/receive filter of square root with roll off factor 0.3 helps in band limiting and pulse shaping of the signal. Transmit/Receive antenna has a gain of 1dBi.The Constellation diagram displays the received signal points that are yellow and spread as compared to the dotted - red star points which is the reference signal points (that is, those are the standard location of the 16 points of 16-QAM modulated signal).

The Error rate calculation block calculates the error rate as a running statistic, by dividing the total number of unequal pairs of data elements by the total number of input data elements from one source. This block produces a vector of length three, whose entries correspond to:

- The error rate
- The total number of errors, that is, the number of instances that an received element does not match the corresponding transmitted element.
- The total number of comparisons that the block made.

In this paper results are displayed only for Bernoulli binary numbers as input and sinusoidal waveform as input in terms of their BER and Received signal scatter plot at different values of various RF impairments. To notice the effect of a particular impairment on the propagating signal, then all the impairments except the one which is under consideration should be kept at negligible.

Experiment 1: **Memoryless nonlinearity**: Referring to Fig. 34, at severe nonlinearity, that is, at 1dB,the outer constellation points seem to have displaced inwards. Because the outer signal points are higher in amplitude and power levels, they become more susceptible to any small increase in the noise power as the operating point of high power amplifier might go into the saturation region of its input-output characteristic, thus leading to reduction in the signal power. The circular shape of the diagram indicates the phase shifting of signal points due to AM/PM conversion. BER is seen to be increased with the corresponding increase in the level of impairment introduced.

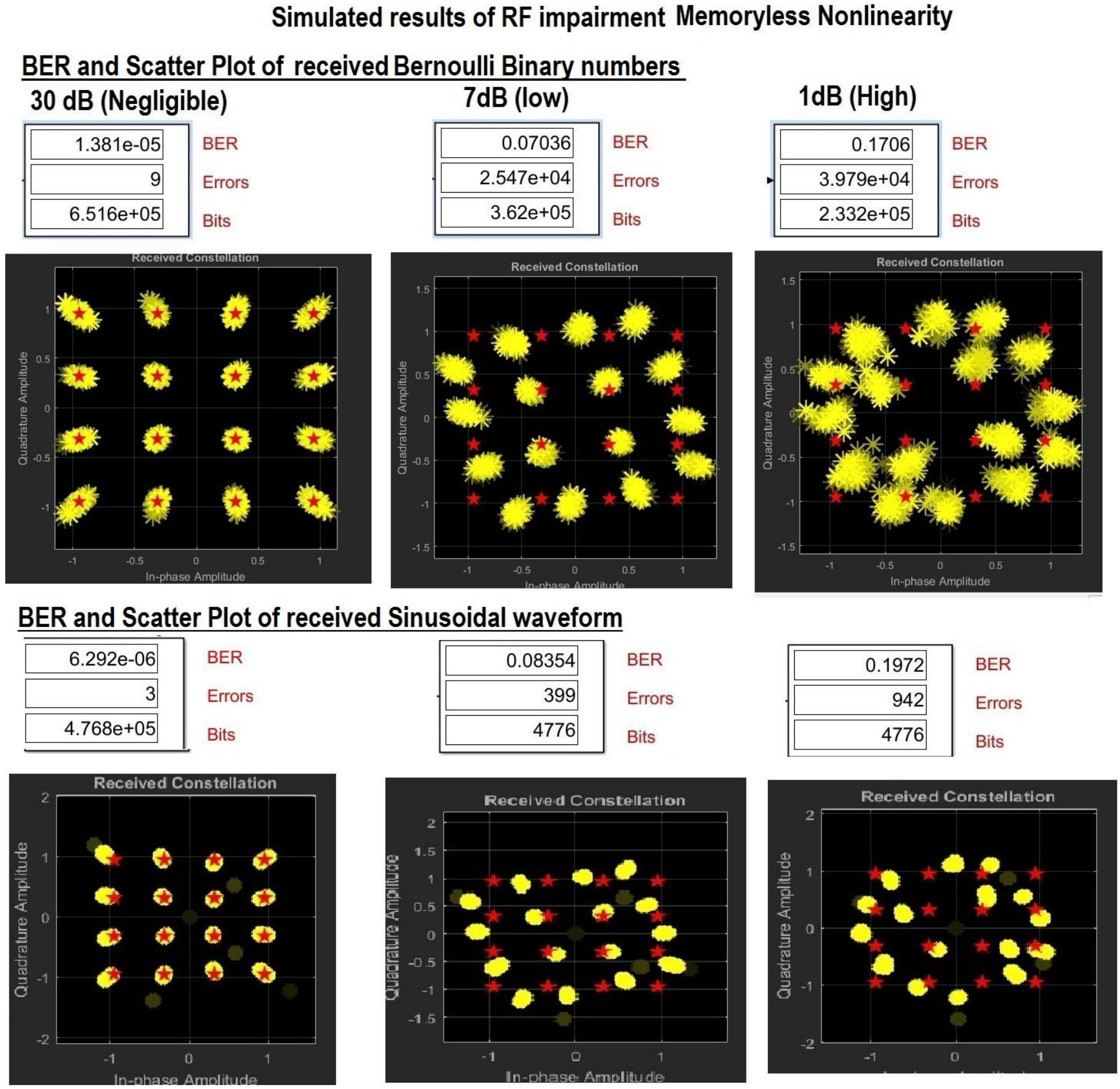

Fig. 34.Scatter plot of the received signal with Memoryless Nonlinearity impairment.

Experiment 2: **Free space path loss (FSPL)**:Free Space Path Loss at 156dB, in Fig. 35, shows that all the received signal points are at their standard locations with a little spreading across them while maintaining the shape of the constellation grid. At 560dB for bernoulli binary numbers and at 550dB for sinusoidal received signal points approaches nearer to each other in the signifying the loss in the power of the received signal while its phase remaining the same as it was at the transmission. At 570dB for Bernoulli and at 575dB for sinusoidal received signal, all the signal points have come together implying that the signal cannot be distinctly recovered due to heavy loss in the power, resulting in increased BER and depleted quality of the received signal with heavy background noise.

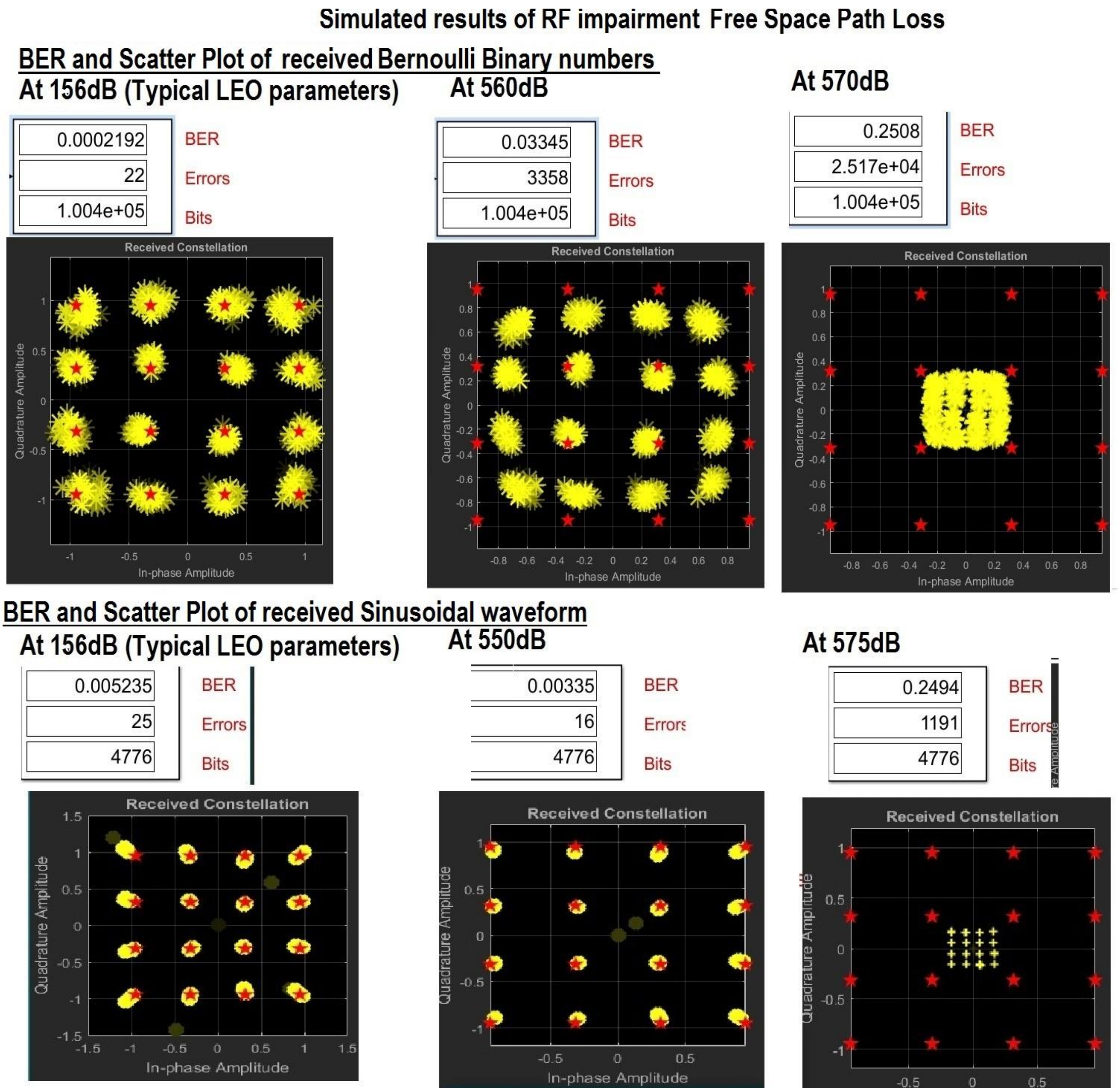

Fig. 35. Scatter plot of the received signal with Free Space Path Loss impairment.

Experiment 3: **Receiver Thermal noise**: Referring to Fig. 36, the constellation diagram of received signal retains its grid shape while the points are spreaded across their standard positions at 290 degrees K. Upon increasing the temperature to 500K, the points seem to have positioned themselves all over the space. This implies that the quality levels of the received signal is been hugely depleted with the increased noise power. The corresponding increase in the number of errors are also marked.

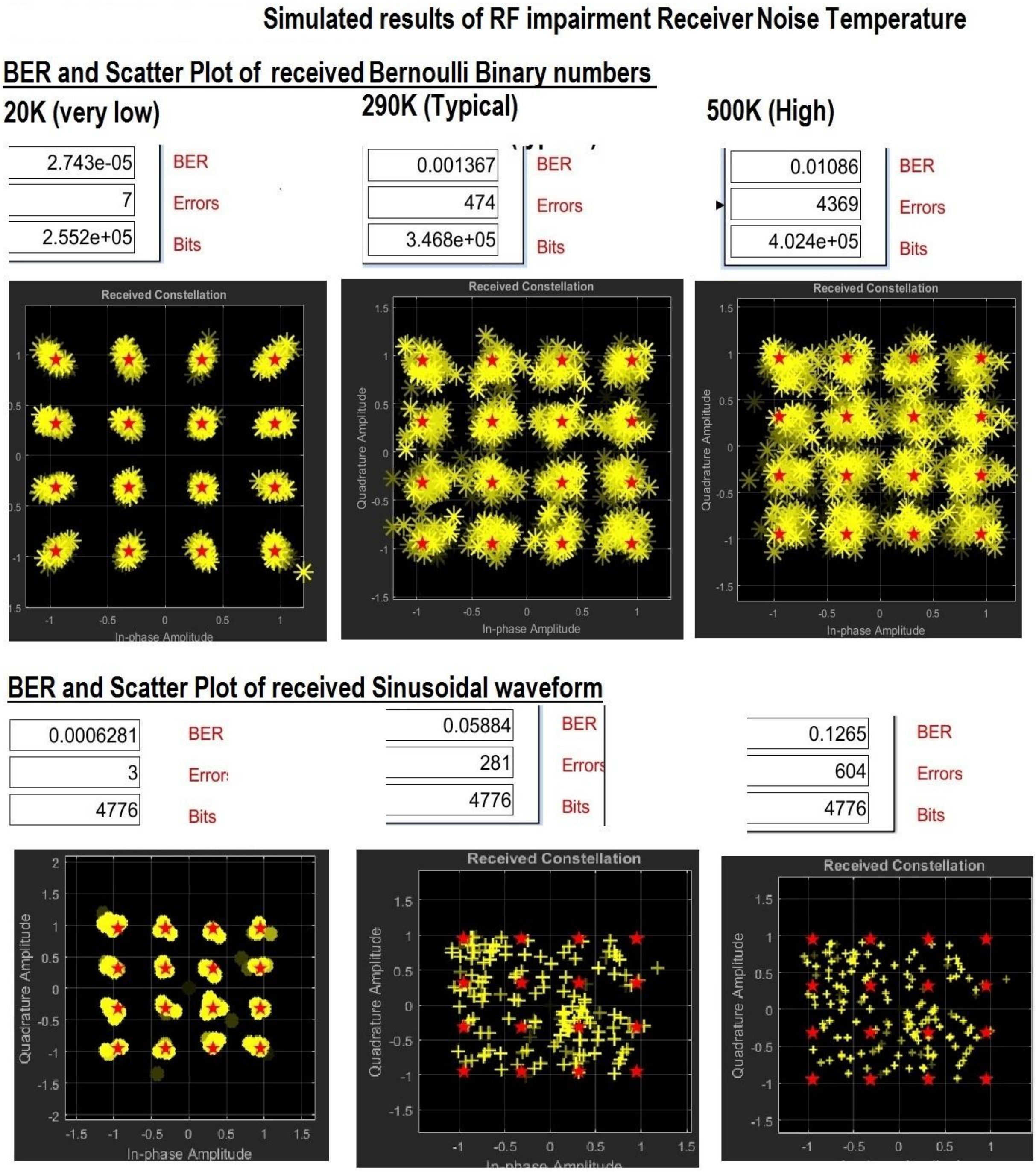

Fig. 36. Scatter plot of the received signal with Receiver Noise Temperature impairment.

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Experiment 4: **I/Q imbalances**: Referring to Fig. 37, both the scatter plots are oscillating towards In-phase amplitude axis and quadrature phase amplitude axis. Imbalance indicates the difference in amplitude levels in I and Q component of the signal which is of 3dB typically. Again the inner constellation points are less spread than outer ones because higher the amplitude, more is effect given the sameimbalance, resulting in larger displacement from their usual location. Automatic Gain Controller helps in balancing off these variations to get a stable output signal level hence, we get the scatter plot after I/Q imbalance correction is applied.

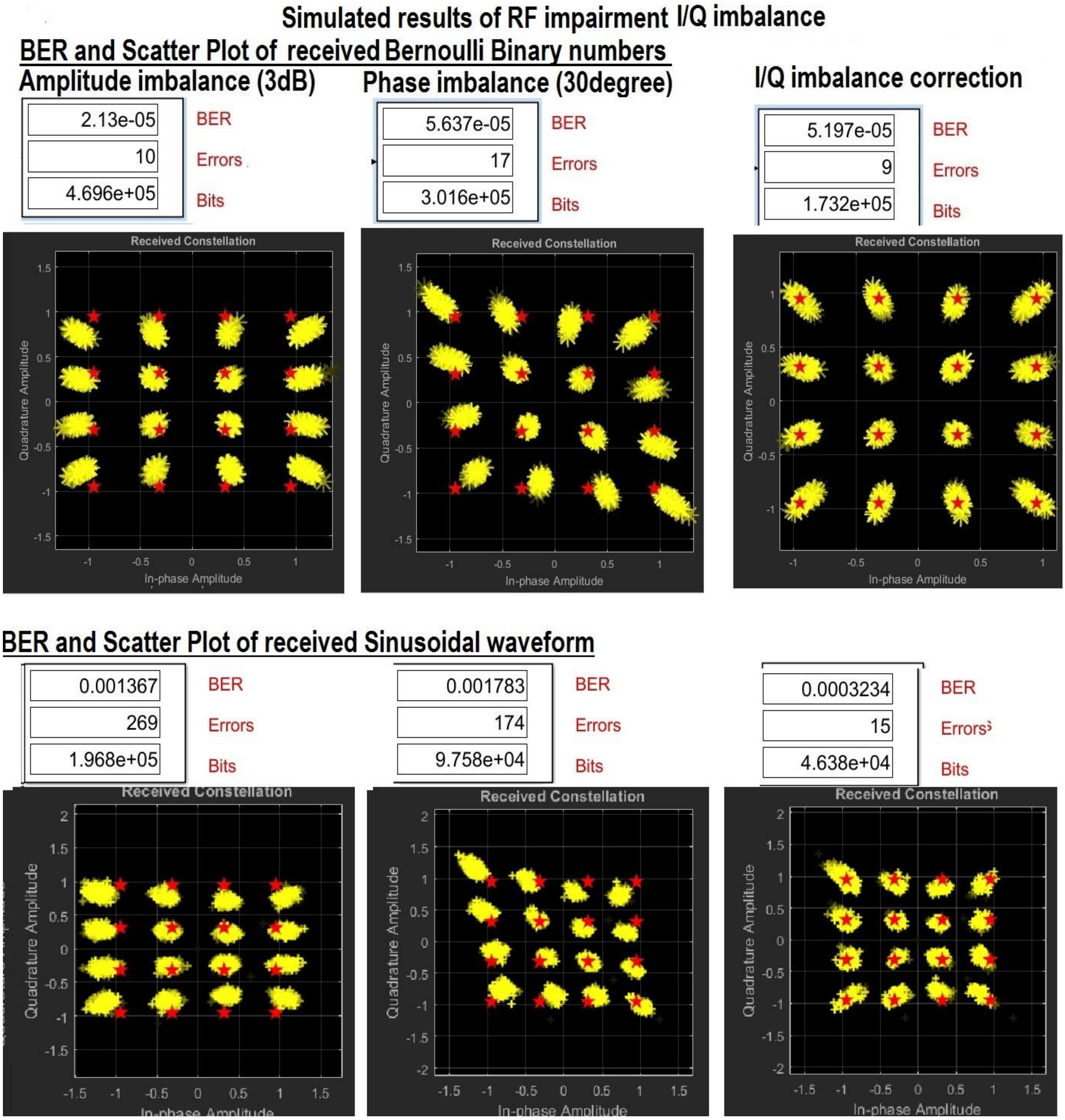

Fig. 37. Scatter plot of the received signal with I/Q Imbalances and correction.

Experiment: 5**: Phase noise**: Changes in the phase component of the signal results in phase noise which is quite evident from Fig. 38which shows that for negligible phase noise, the constellation points are at their standard locations. But as the phase noise increases to –55dBc/Hz, that is, the received signal is rotated anti-clockwise 55degress with respect to the carrier, this change in the phase carries noise information which is unwanted or redundant. The amplitude part of the signal remains unaffected. As the phase noise increases up to –48dBc/Hz, the constellation points start to form concentric circles, that is, they spread across their usual points such that their amplitude tends to get equal, hence the circular pattern signifying only the phase change.

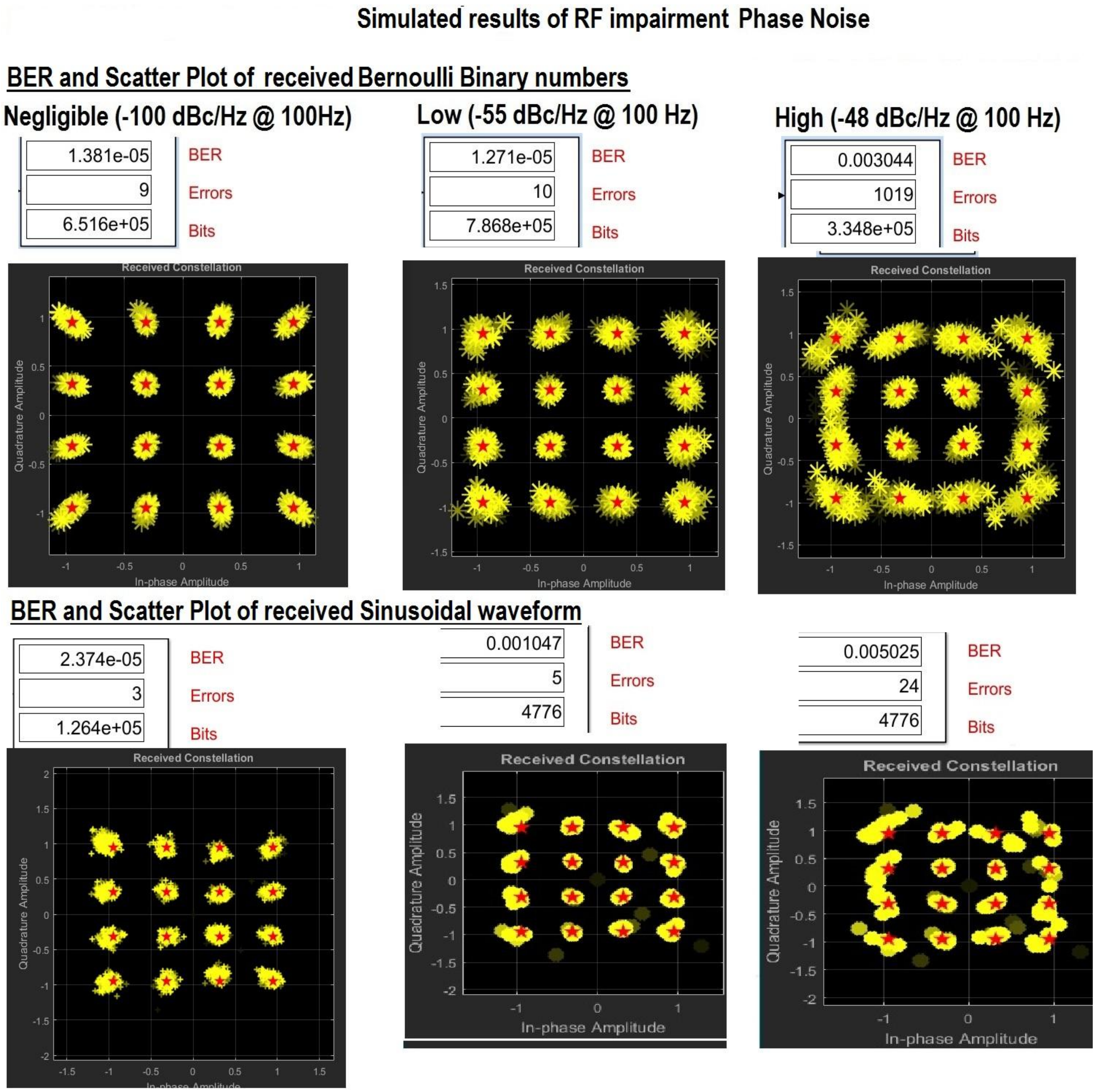

Fig. 38. Scatter plot of the received signal with Phase Noise impairment.

Experiment 6: **Doppler error**: Referring to Fig. 39, The scatter plot of the received signal without any Doppler correction reveals that there is noise in the background since a few points are

scattered in the outermost region as well as across their usual locations forming a circular pattern, which means along with noise, phase shifting effect is also prominent. At LEO, the satellite and earth station relative speed of motion is different. Hence, the signal transmitted from satellite to earth station will arrive at different times resulting in phase/frequency shift/offset. This phenomena is modeled in Phase/frequency offset block. Through carrier synchronization techniques using Phase locked loop system, modeled by carrier synchronization block, this carrier frequency offset can be corrected.

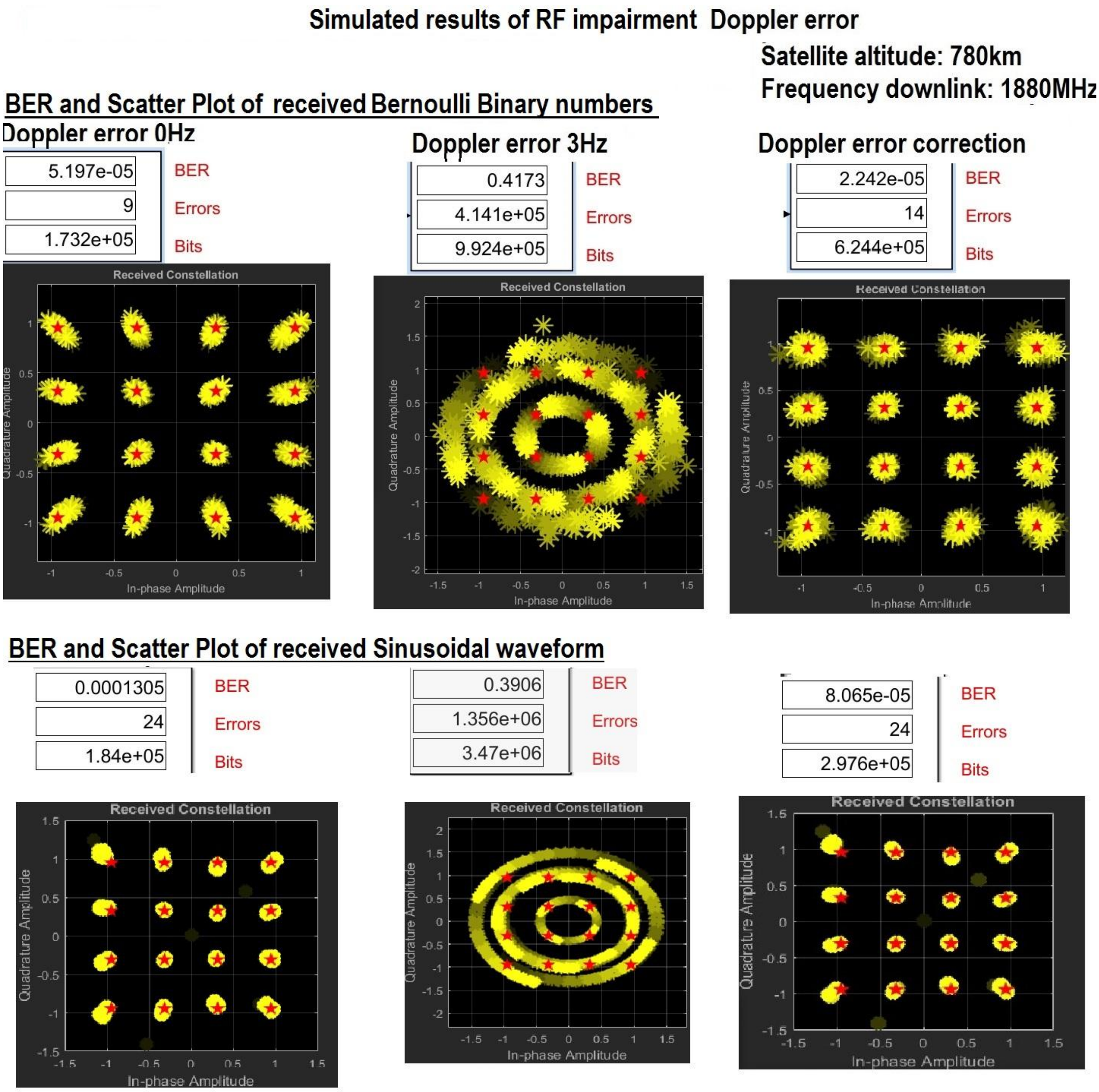

Fig. 39.Scatter plot of the received signal with Doppler Error impairment.

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V. Conclusion

Experiment 1: Memoryless Nonlinearity: From Fig. 34,BER increases with the corresponding increase in the level of nonlinearity introduced to the signal. Outer signal points traversed inwards as they are more susceptible to noise power.

Experiment 2: Free space path loss: From Fig. 35, the shape of the constellation grid is retained at different values of FSPL. Hence, change in the amplitude levels and power levels are witnessed.

Experiment 3: Receiver thermal noise: From Fig. 36, the constellation grid loses its shape as points scatter themselves in the area enclosed implying increased noise power levels with degraded quality of received signal.

Experiment 4: I/Q imbalance: amplitude and phase imbalance is seen with signal points coming nearer though in rectangular form and circular shape of the signal points respectively.

Experiment 5: Phase noise: The circular shape of the scatter plot clearly conveys that the change is only in the phase component of the signal whereas amplitude remains constant. A sudden increase in BER when phase noise was increased from low to high.

Experiment 6: Doppler error: The constellation grid continuously rotates during simulation time indicating thatthe signal transmitted at LEO parameters has a different carrier frequency when received at the earth station As well as phase with which the signal was transmitted is not the same at the time of its reception.

References

[1] Available: http://in.mathworks.com/help/comm/examples/rf-satellite-link.html

[2]T.Keller and L. Hanzo,"Adaptive multicarrier modulation: A convenient framework for time-frequency processing in wireless communications," *Proc. IEEE,* vol.88, pp. 611-640, May 2000.

[3] Availble: https://in.mathworks.com/help/comm/ref/memorylessnonlinearity.html

[4] Available: http://www.idc-online.com/technical_references/pdfs/electronic_engineering/Free_Space_Loss.pdf

[5]A. A. Atayero, M. K. Luka and A. A. Alatishe,"satellite Link Design: a tutorial", International Journal of Electrical & Computer Sciences IJECS-IJENS Vol: 11 No: 04.

[6] T. Pratt, C. Bostian, J. Allnutt,"Satellite Communications",2nd ed. Published by john Wiley & Sons, INC.pp. 114

[7] T. Pratt, C. Bostian, J. Allnutt,"Satellite Communications",2nd ed. Published by john Wiley & Sons, INC. pp. 411.

[8] T. Pratt, C. Bostian, J. Allnutt,"Satellite Communications",2nd ed. Published by john Wiley & Sons, INC. pp. 105-106

[9]Available: https://in.mathworks.com/help/comm/ref/ qimbalancecompensator.html

[10]Available: https://in.mathworks. com/help /comm/ref/phasenoise.html? searchHighlight=phase%20 noise&s_tid=doc_srchtitle

[11] Available: https://in.mathworks .com/help/comm/ref/ phasefrequency offset.html? searchHighlight=phase%20offset&s_tid=doc_srchtitle

[12] Available: https://in.mathworks.com/help/ comm/ref/carriersynchronizer.html?searchHighlight= carrier%20synchronizer&s_tid=doc_srchtitle

[13] E. Vilar and J. Austin, "Analysis and correction techniques of Doppler shift for nongeosynchronous communication satellites," *Int. J. SatelliteCommun.*, vol. 9, pp. 123–136, 1991