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QPSK and 32-APSK Based Non-Linear Distortion Cancellation in Satellite Forward Link

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Abstract: - **The extension of second generation Digital Video Broadcasting (DVB-S2X) standard for the satellite broadcasting and unicasting that performs non-linear distortion cancellation for the application at the user terminal based on QPSK and 32-APSK is designed using low complexity equalizer in satellite forward link. The system is designed using MATLAB communication toolbox and built-in Simulink of version 17. The channel is designed using non-linear characteristics of TWTA, filter responses of input-multiplexing (IMUX) and output-multiplexing (OMUX) at the satellite transponder and the introduction of phase noise at the user terminal mainly focused for the applications like High Throughput-Satellite (HTS) systems. The requirements of satellite communication can make 32-APSK more suitable modulation scheme than QPSK with high quality end-to-end-transmission. Their performance is analyzed through a constellation diagram. These advances enable the shift towards more bandwidth-demanding applications and services, the adaptation to traffic demand across the coverage area, and the decrease of the cost per transmitted bit.**

***Key words*: DVB-S2X; QPSK; 32-APSK; HTS; IMUX; OMUX; TWTA.**

I. INTRODUCTION

The initiation of the first stages of standardizing the digital TV broadcasting started in early 90's due to digital multimedia broadcasting evolution over broadband communication. The project named Digital Video Broadcasting (DVB) was started by European Telecommunication Standards Institute (ETSI) in the year of 1990. Its main objective is to introduce a standard for digital multimedia service. The first standard for satellite video broadcasting over GEO satellite was DVB-S which uses Forward Error Correction (FEC) technique. Then ETSI introduce new standard called DVB-RCS (Return Channel Satellite). It provides option for using same antenna for return link at receiver via satellites. In the mean time, another project specification called DVB_S2 for second generation satellite broadcasting was introduced by ETSI. It uses new Forward Error Correction (FEC) technique with higher order modulation scheme, dynamic selection of coding with channel state information [1]. It can utilize 30% of channel efficiency with same bandwidth coverage and power when compared with previous DVB-S. The S2X is the extension of DVB-S2 standard having wideband operation which can be used for the application of Ka band with finer SNR threshold in higher order modulation scheme and to cover emerging markets such as mobile and professional applications as well as core markets (DTH, VSAT) with low roll off factor [2]. Due to its co-channel interference mitigation, it can be used in DTH receiver and on HTS satellite service with broadband benefits. Due to increased granularity, DVB-S2X can reduce unnecessary margin in modulation and coding for DTH [3]. The DVB-S2X is best suitable for single carrier scenario for the satellite forward link with compensation of adjacent channel interference, co-channel interference are modeled using low complexity symbol based equalizer. It is proposed based on detection of symbol at receiver in [4], which can perform non-linear distortion cancellation. An iterative receiver that performs non-linear distortion noise cancellation and the performance is accessed for single carrier time division multiplexing which are comprehensively modeled using TWTA, IMUX, and OMUX filter response characteristics in [5]. A powerful compensation technique to mitigate the effect of non-linear distortion is modeled in [6]. In this multicarrier pre-distortion technique is used to handle the adjustment of transmitted symbol for driving the distortion vector toward zero. This methodology gives pre-distorted symbols that contain past and future impacts for each carrier within a certain memory span. One of the advanced linearization techniques is Digital Pre-distortion that makes the system to be operated at higher level in which band-limiting function is included into volterra operators, without sacrificing linearity [7]. The correction of non-linear distortion performed in a turbo equalization framework by the soft interference canceller is explained in [8]. In this minimization of mean square error is carried out between output of canceller and transmitted symbol. In general, the distortion reduces energy efficiency as well as spectral efficiency with tighter roll-off factor for the application. On considering all these information into an account, satellite forward link is designed for Non-linear distortion cancellation with low implementation complexity using TWTA, IMUX, and OMUX with different modulation schemes of QPSK and 32-APSK.Then comparison is done between these modulation schemes and their performance is analyzed through received constellation diagram. So the quality of end-to-end transmission can be analyzed.

II. SATELLITE SYSTEM MODEL

The construction of satellite forward link includes modeling of gateway transmitter, satellite and user terminal receiver with channel compensation technique. The figure1 shows the block diagram for the satellite transmission chain in the forward link.

A. Gateway Transmitter

Bernoulli sequence generator is the very first block responsible for generating random binary sequence. The output of this block is frame which contains 1504 bits. The output from this Bernoulli generator is buffered to make BBFRAME (Base Band Frame). The size will be equal to the input size of BCH (Bose-Chaudhuri-Hocquenghem) encoder, which is related to coding rate. The usage of forward error correction is to reduce the bit error rate in transmission. It is constructed using polynomials which results in cyclic error correcting codes. The output of BCH encoder will be equal to the input of LDPC encoder. It is considered to be linear error control code [9]. Resulting FEC frame is having the length up to 64800 bits. This block is followed by bit interleaver. It creates rows in metric format from the output of the LDPC encoder. The interleaved vector is processed by the modulation block. In this paper, QPSK and 32-APSK schemes are used for modulation. The raised cosine filter block is used to maximize the data rate transmission and to minimize the transmission errors within the allocated bandwidth. It is then followed by Digital to analog Converter (DAC). After DAC, the baseband signal is up-converted to carrier frequency. Then the signal gets amplified at High Power Amplifier (HPA).

B. Satellite Channel

At satellite portion, there will be linear distortion as well as non-linear distortion. The imperfect magnitude and group delay response of OMUX and IMUX filter will introduce linear distortion in the form of Inter Symbol Interference (ISI). The equalization process will handle the ISI. This is done by channel estimation based on the knowledge obtained from the channel. In the form of constellation warping and clustering, the non-linear distortion is introduced by Travelling Wave Tube Amplifier (TWTA) [3].

C. User terminal receiver

At the receiver side, the output from the downlink module is given to LNA. After that the Additive White Gaussian Noise (AWGN) block will add noise to the signal which is being sent from the modulator. It is based on the parameter setup. The noise variance value is calculated by this block and noise with zero mean value is added to signal. Then the signal is down converted. Due to local oscillator instability, the signal gets distorted by the phase noise. Next to ADC, matched SRRCF is applied. In order to handle linear distortion, the symbols are allowed to pass through linear equalizer. This can be done after the timing and frame synchronization. Soft demapper generates log-likelihood ratios. After deinterleaving process, it is provided as input to the decoding stage. The deinterleaver block will receive the output of demodulator block as input. Then it performs reverse process to create a serial output for the LDPC decoder. It is then followed by BCH decoder.

D. Channel Compensation Technique

Pre-distortion will compensate the effect of spectral regrowth [9], [10]. Data pre-distortion will preserve the signal spectrum and applied to the constellation symbol prior to pulse shaping. Static data pre-distortion accounts for static non-linearity in the channel. The pre-distorted constellation points are stored in the lookup table. Dynamic data pre-distortion compensates memory effects in the channel.

III. QPSK and 32-APSK CHARACTERISTICS

The process of varying the properties of a carrier signal with a modulating signal which contains the information to be transmitted, called as modulation. QPSK (Quadrature Phase Shift keying) is a type of modulation scheme which can transmit two bits per symbol. In this modulation, the variation of carrier signal is not in terms of frequency but it

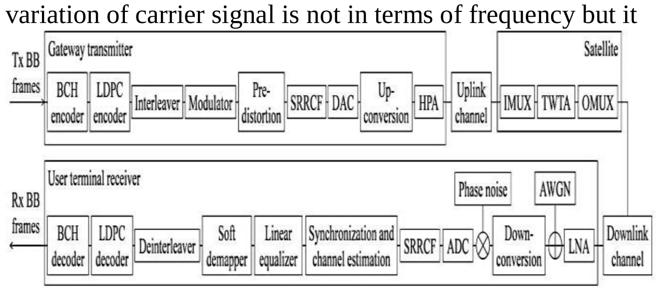

Figure 1: Satellite Transmission Chain Forward Link

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is in terms of phase shift. In APSK (Amplitude Phase Shift Keying), both amplitude and phase of the carrier signal is varied. For any kind of modulated communication signal, how the data to be transmitted over the channel has to be considered. APSK modulation becomes a more suitable scheme than QPSK due to the requirements of satellite communications. The construction of 32-APSK is explained in figure 3. It is designed using QPSK and BPSK. Then it is allowed to pass through the high power amplifier.

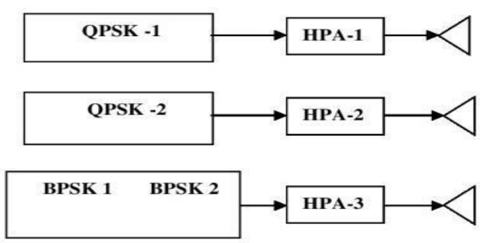

Figure2: Construction of 32-APSK

IV. RESUTS AND DISCUSSIONS

The initial steps involved in researches mainly concerning with satellite systems are often taken in simulation environments in order to minimize the design time as well as implementation costs. The figure 3 and figure 4 shows the design of 32-APSK and QPSK using simulink.

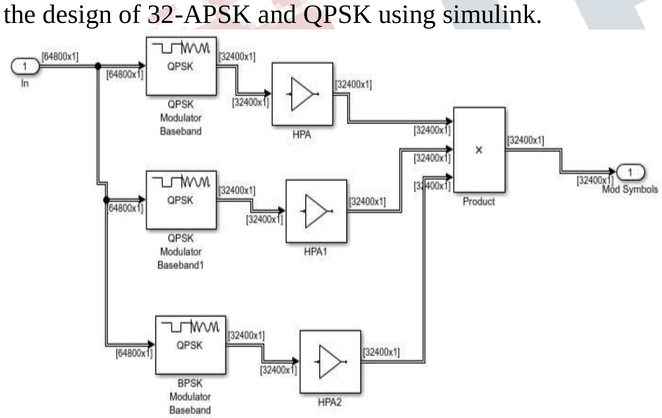

Fig 3: Design of 32-APSK using BPSK and QPSK in Simulink

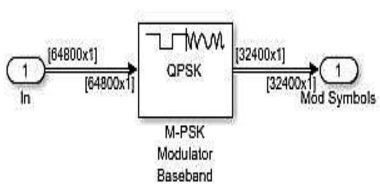

Fig 4: QPSK design using simulink

The satellite transmission chain forward link using QPSK and 32-APSK as modulator designed with Simulink is shown in the figure 5 and 6.

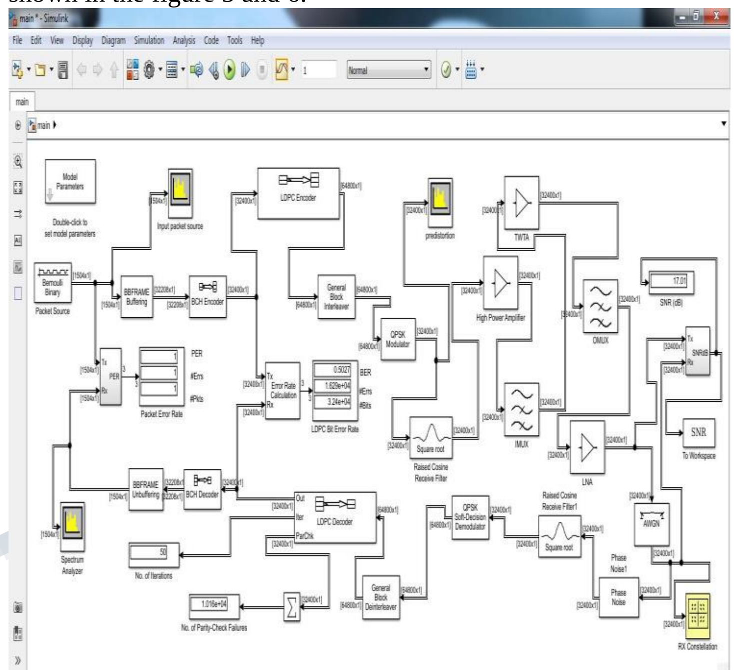

Figure 5: Satellite Transmission Chain Forward Link using QPSK as modulator

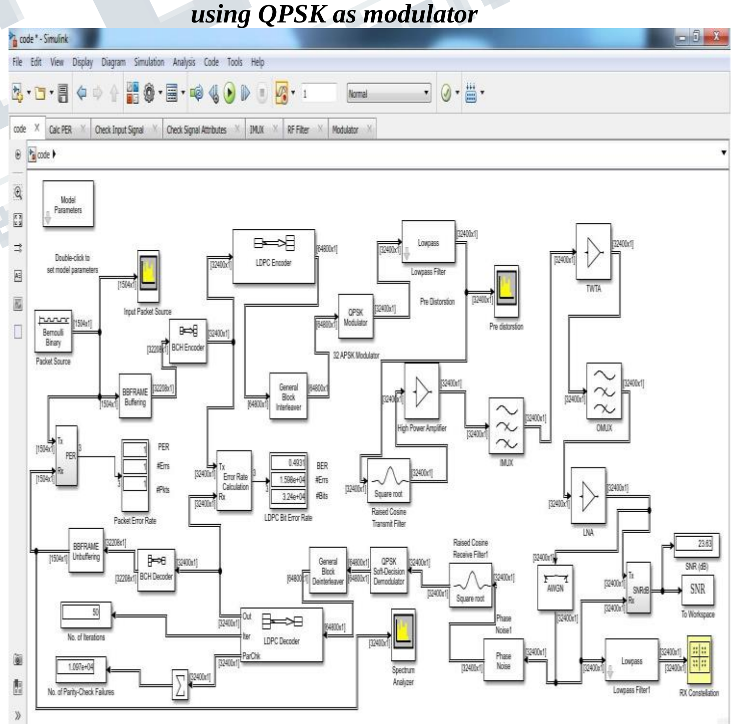

Figure 6: Satellite Transmission Chain Forward Link using 32-APSK as modulator

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More bits per symbol can be transmitted by APSK when compared with QPSK. So that large amount of data can be sent using same bandwidth. This is having two positive benefits. There is less effect on the spacing between states due to compression of signals. During demodulation process, the states can be easily distinguished from each other. It is possible to pre-distort the signal by varying the space between rings before transmission. So the effects of transmission distortion can be eliminated. It leads to get a better output. This is the main advantage of using APSK in transmission chain. The signal received should be monitored and measured for dynamic pre-distortion then the results are fed back to the pre-distortion circuitry. Better resistance to the distortion can be achieved in APSK scheme. The fewer retransmissions and higher data rate is achieved, if the SNR value is high it leads to better throughput. From the figures 5 and 6, it is clear that the SNR value for the satellite transmission chain with 32-APSK modulation is 23.63 dB. But the transmission chain with QPSK modulation is having 17.01 dB. So 32-APSK is having less retransmission and more data can be sent when compared to QPSK. The performance of transmitter, receiver and the medium are accessed by BER value. It should be kept as low as possible. The BER value for 32-APSK is 0.4931 and for QPSK, it is about 0.5027. The high-power Travelling Wave Tube Amplifier (TWTA) and solid-state power amplifiers used in satellite transmission, helps to maximize the energy as well as spectral efficiency by transmitting the signal often used at or beyond their compression levels.So high output power can be achieved within the limited power available on the satellite. Table I describes the some of the parameters involved in designing satellite forward link.

TABLE I: DESIGN PARAMETERS

Parameters	Values
ESN0	1
Number of bytes per packet	188
Number of bits per packet	1504
BCH code word length	32400
BCH Message Length	32208
Number of packets Per BBFRAME	21
BCH Generator Polynomial	[1 * 193 double]
Interleaver order	[64800 * 1 double]
Number of LDPC Iterations	50
LDPC parity check matrix	[32400 * 64800 logical]
Bits per symbol	2
Sequence Index	2
Noise Variance	0.7943
IMUX filter	7th order Chebyshev Type II filter
OMUX filter	5th order Chebyshev Type II filter
LDPC Parity Check Matrix	[32400 * 64800 logical]
Symbol Mapping	[0 2 3 1]
Number of Frames	20

Frequency spectra of signals can be analyzed with the help of spectrum analyzer block where frequency, power, distortion, harmonics, bandwidth can be observed by analyzing the spectra of electrical signals which are not easily detectable in time domain waveforms. Here, the spectrum analyzer scope which showing the signal spectrum of input packet source, Pre-distortion and final response for satellite transmission chain block having 32-APSK and QPSK are shown in the figures 7,8,9,10,11,12.

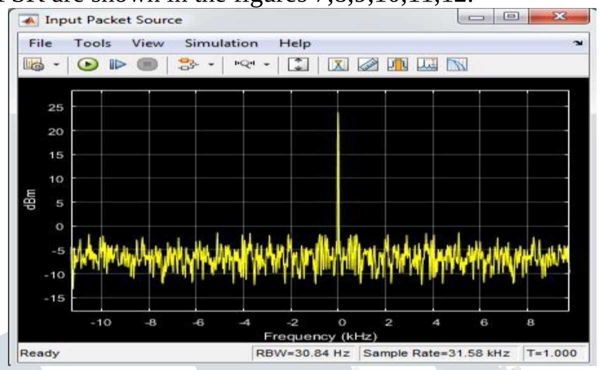

Figure 7: Spectrum at input packet source for 32-APSK as modulator.

By expanding the signal peaks at transmission stage, pre-distortion compensates the waveform at uplink.

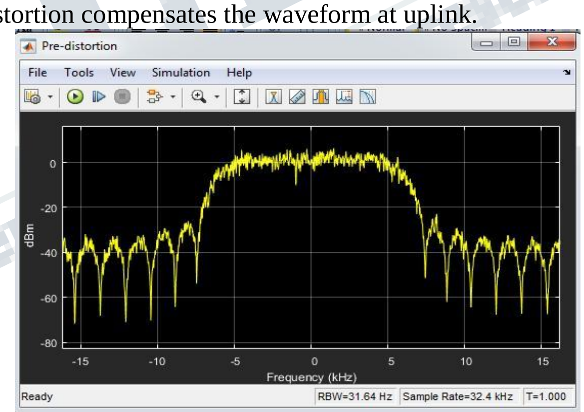

Figure 8: Spectrum at pre-distortion stage for 32-APSK as modulator.

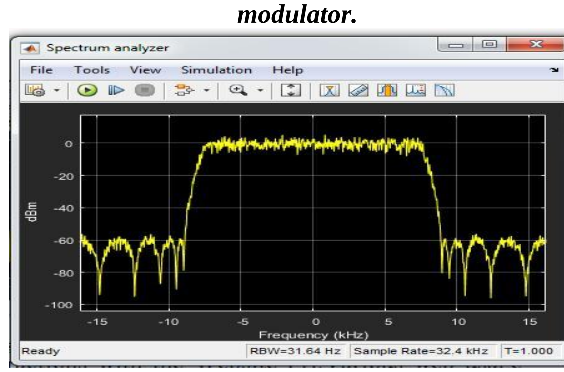

Figure 9: Final system response for 32-APSK as modulator.

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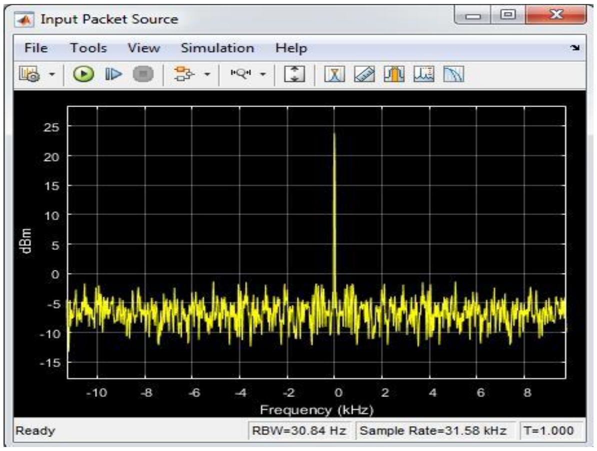

Figure 10: Spectrum at input packet source for QPSK as modulator.

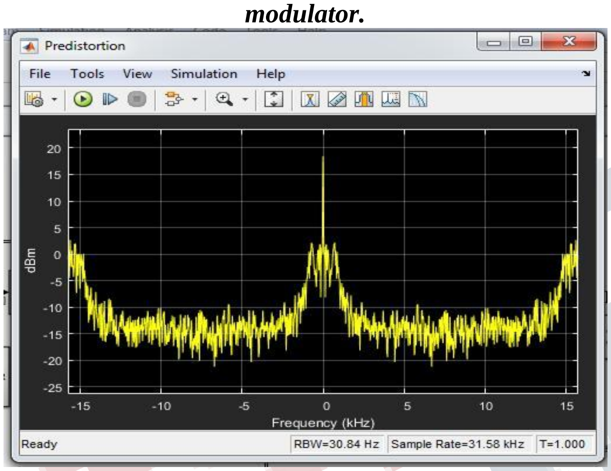

Figure 11: Spectrum at pre-distortion stage for QPSK as modulator

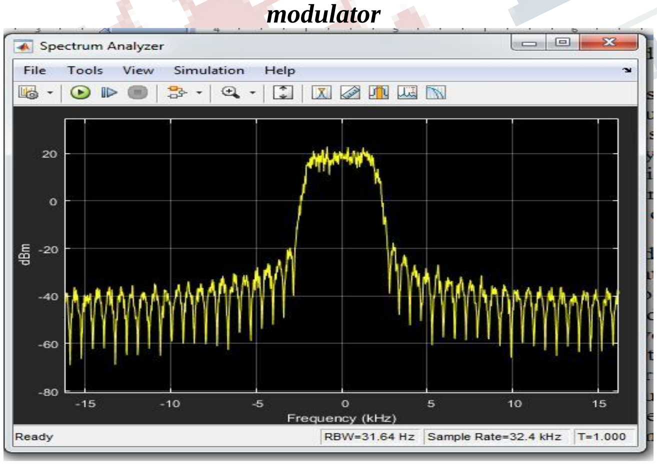

Figure 12: Final system response for QPSK as modulator.

From the figure 9 and 12, it is clear that distortion level is reduced in 32-APSK when compared with QPSK. The distortion in the signal can be recognized by the constellation diagram. In general the signal gets corrupted between transmission and reception points. Constellation map helps to design the transmission system with less prone to error thereby developing error detection and error correction schemes to detect the transmission problem. Figure 13 and 14 shows the distortion level of signal. The distortion get reduced in 32-APSK when compared to QPSK.

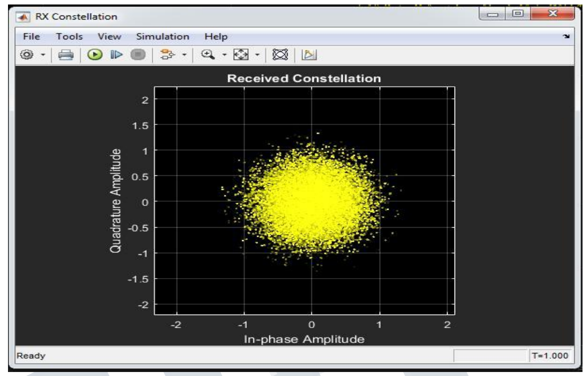

Figure 13: Received Constellation for 32-APSK as modulator

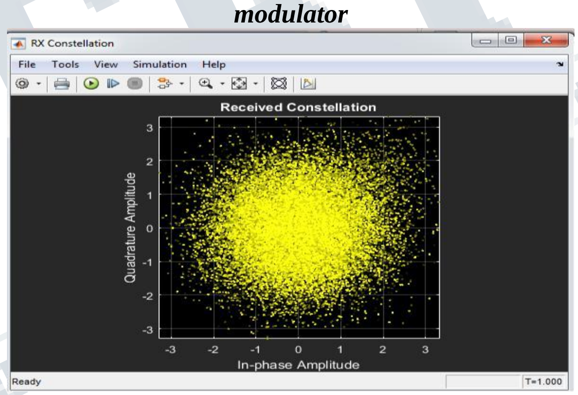

Figure 14: Received Constellation for QPSK as modulator

V. CONCLUSION

Thus non-linear distortion cancellation for the application at the user terminal based on QPSK and 32-APSK is designed using low complexity equalizer in satellite forward link. Since the satellite transmission chain with 32-APSK is having SNR value 23.63 dB, less retransmission occurs when compared with transmission chain model having QPSK modulation having SNR value 17.01 dB. The BER value of 32-APSK is 0.4931, which is less when compared to system model with QPSK having the BER value 0.5027. More bits per symbol can be transmitted with less distortion in 32-APSK when compared with QPSK. More data can be sent using same bandwidth for 32-APSK when compared with QPSK modulation scheme in satellite system model.

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