HBRP PUBLICATION

Journal of Advancement in Communication System
Volume 5 Issue 1

Comparative Study on Various Modulation and Coding Techniques Relevant to Bangabandhu Satellite-2

Zannatul Ferdous[1], Md Kamruzzaman[2], Bobby Barua[1]*,
[1]Ahsanullah University of Science and Technology, Dhaka, Bangladesh
[2]Leading University, Sylhet, Bangladesh
****Corresponding Author***
E-Mail Id: bobby@aust.edu

ABSTRACT
Bangladesh's dream project is the Bangabandhu Satellite 1. Bangladesh Telecommunication Regulatory Commission (BTRC) is implementing the project in collaboration with Space Partnership International, LLC of the United States. This satellite's primary goal is to ensure that telecommunications and internet services in remote areas run smoothly. However, the biggest issue with this benefit is recouping the amount of money that our country has loaned. Because the HSBC bank has loaned roughly $188.7 million. The financing would be extended again if we want to launch Bangabandhu Satellite 2 in 5 years using the same approach. As a result, we must consider how to gain a positive business and technical outcome from this. We may easily employ Bangabandhu Satellite 2 as a good potential for our satellite communication by using private TV channels and lending transponders to other countries sensibly. For the communication window, the modulation and coding technique should be as smooth as feasible. These aspects should be careful because it will be a hybrid satellite. Ground station scheduling is also a challenge for communication. We can dream of launching another satellite in 15 years if we can ensure both the technical and financial aspects of the Bangabandhu satellite. Because, in this technological age, having three satellites floating above our heads without incurring debt is a significant achievement for a developing country like ours. As a result, the theoretical focus of our analysis is on how we might achieve the milestone by examining the aspect of Bangabandhu Satellite 2.

Keywords: *Bangabandhu Satellite-2, BCH code, Bit error rate (BER), Eight Phase Shift Keying (8-PSK), GEO Satellite Networks, Turbo codes*

INTRODUCTION

A satellite is a man-made object that is orbited around the earth or another planet. The communication procedure begins at an earth station. An earth station is a device that sends and receives signals from a satellite in orbit around the planet. Earth stations deliver data to satellites using high-powered, high-frequency signals, which are received and retransmitted back to earth. Other earth stations in the satellite's coverage region then receive the retransmitted signals. The satellite's footprint is the area that receives the signal from the satellite. The uplink is the transmission system that connects the earth station to the satellite, and the downlink is the transmission system that connects the satellite to the earth station. Before developing a satellite communication system, we must pick the orbit in which the satellite will be put [1-5] to minimize confusion.

With the launch of Bangabandhu Satellite 1, Bangladesh has joined the modern era. There is a rule that another satellite must be launched within the following five years. Bangabandhu Satellite 2 is the satellite in question. Bangladesh Telecommunication Regulatory Commission (BTRC) is implementing the project in collaboration with Space Partnership International, LLC of the United States. The satellite will be operated by the government-owned Bangladesh Communication Satellite Company Limited, or BCSCL. It is named after Bangabandhu Sheikh Mujibur Rahman [2], the country's founding father.

The satellite will expand Ku-band (it is the portion of the electromagnetic spectrum in the microwave range of frequencies from 12 to 18 gigahertz (GHz)) coverage as per Fig. 1 over all of Bangladesh and its nearby waters including the Bay of Bengal, Nepal, Bhutan, Sri Lanka, the Philippines, eastern Indian states (West Bengal, Assam, Meghalaya, Mizoram, Tripura, Nagaland (Arunachal Pradesh) and Indonesia [3]. This is coupled with C-band coverage for all aforementioned areas. It will be able to count holdings as well as to measure population density, depending on the natural increase and the natural decrease of birth rates and death rates in a particular country. It scans the number of people per 1,000 km^2 with its advanced, installed technology such as cameras. It is a national pride of Bangladesh. Ensuring smooth telecommunication and internet facilities in rural areas is the most significant benefit of this satellite. Bangladesh has entered into that modern era by launching Bangabandhu Satellite 1.

There is a regulation that there should be a launching of another satellite in next five years. Bangabandhu Satellite 2 is set to be that satellite. We shall make a concept for Bangabandhu Satellite 2 by examining the modulation [5-9] and coding techniques [10-13] of Bangabandhu Satellite 1 and other satellites.

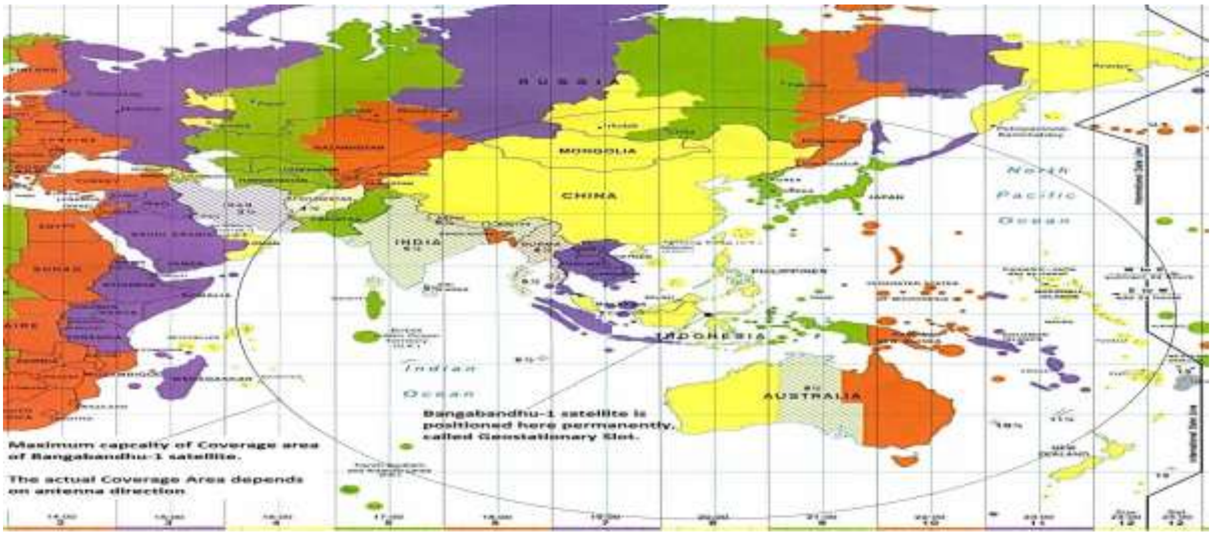

Fig. 1: *Area coverage of Bangabandhu Satellite 1. [3]*

Basic Modulation Scheme Comparison:
Because they reduce the effect of nonlinear amplification in the high-power amplifier, constant envelope modulation methods like FSK and PSK are best suited for satellite communications [6].

Pe of FSK

$$P_e = \frac{1}{2} erfc \sqrt{\frac{E_b}{2N_0}} \qquad (1)$$

Pe of PSK

$$P_e = \frac{1}{2} erfc \sqrt{\frac{E_b}{N_0}} \quad (2)$$

So we can say PSK more efficient. Almost all satellite scientists have employed a PSK variant. They've only used 16QAM a few times, but 32QAM isn't out of the question [7]. Nearly all broadcasting via satellite uses the DVB-S or S2 which is a group of PSK standards and defines beyond modulation to include error correction, error protection and framing. PSK is substantially more efficient than FM, allowing for much better quality for the same capacity, or even many more channels in the same bandwidth.

For 8PSK, M=8, b=3 and

$$P_b = \frac{2}{3} Q \left[\sin\frac{\pi}{8} \sqrt{\frac{6E_b}{N_0}} \right] = \frac{2}{3} Q \left[0.937 \sqrt{\frac{E_b}{N_0}} \right] \quad (3)$$

For 16PSK, M=16, b=4 and

$$P_b = \frac{Q}{2} \left[\sin\frac{\pi}{16} \sqrt{\frac{8E_b}{N_0}} \right] = \frac{Q}{2} \left[0.552 \sqrt{\frac{E_b}{N_0}} \right] \quad (4)$$

Error rate is decreasing in 16psk. So 16psk can be more appropriate for better modulation. As we are assuming to get better performance.

Modulation Techniques for Satellite Communication

Satellite technology is used in almost every communication industry, including broadcasting, navigation, transportation, and cellular. Broadband communications, mobile satellite services, and weather forecasting are examples of satellite communications applications and services.

In-flight connectivity, linked cars, and the 5G New Radio non-terrestrial network are all examples of new satellite communications applications and services. Satellite communications use complicated modulation algorithms to increase their spectrum efficiency in response to high demand for greater data throughput. Not only do satellite modulation techniques necessitate greater data rates, but they also necessitate limiting the influence of nonlinear amplification in the radio-frequency (RF) power amplifier. From signal generation and analysis to the effects of phase noise on modulation quality, this white paper focuses on modulation techniques for current satellite communications [8].

Popular modulation types being used for satellite communications:

- Binary phase-shift keying (BPSK);
- Quadrature phase-shift keying (QPSK);
- Offset quadrature phase-shift keying (OQPSK);
- 8PSK;
- 16PSK
- 16QAM.

Modulation Schemes for Modern Satellite Communications

Basic modulation methods for a carrier signal include amplitude, frequency, and phase. Modulating signals can be expressed as magnitude and phase in polar form (vector). By removing the carrier frequency, digital modulation is commonly described in terms of I (in-phase) and Q (quadrature) components**.** Figure 1 depicts an I/Q diagram on the left side.

I and Q signals are mixed with the same local oscillator (LO), but one of the LO pathways has a 90-degree phase shifter. The fundamental advantage of I/Q modulation is the symmetric ease with which independent signal components may be combined into a single composite signal for transmission and subsequently divided into individual components for reception.

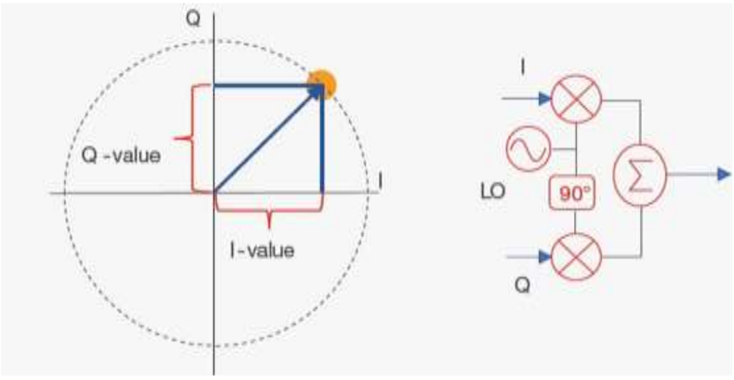

Fig. 2: *I/Q Modulation.*

Constant envelope and non constant envelope modulation systems are the two basic types of modulation schemes. The term "constant envelope" refers to the fact that all constellation points are at the same distance from the center.

Constant Envelope Digital Modulation Schemes

Because they reduce the effect of nonlinear amplification in the high power amplifier, constant envelope modulation methods are the best ideal for satellite communications. Frequency-shift keying (FSK) and phase-shift keying are two of these methods (PSK). Higher-order modulation techniques give improved spectral efficiency for larger data rates, but they are more vulnerable to channel defects. The constellation diagrams of binary PSK (BPSK), quadrature PSK (QPSK), and 8PSK are shown in Figure 2. They send 1 bit, 2 bits, and 3 bits each symbol, respectively. The constellation points are closer together in higher-order PSK, hence the system is more susceptible to channel defects [9].

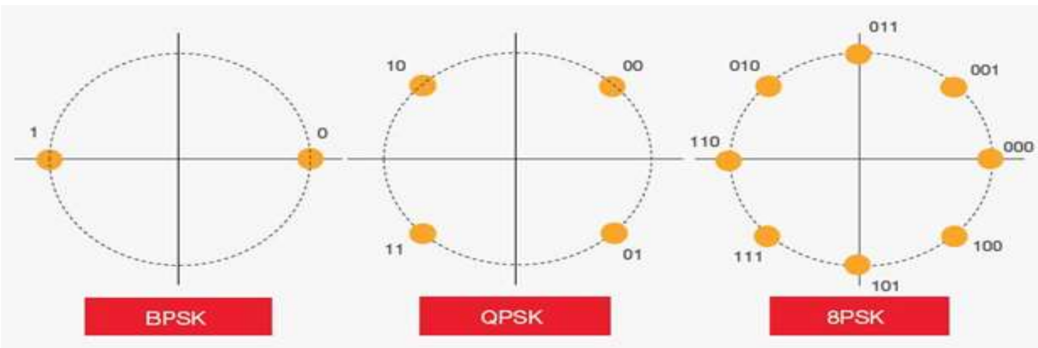

Fig. 3: *Constellation diagram of higher-order modulation schemes*

Non constant Envelope Digital Modulation Schemes:
To improve spectral efficiency, quadrature amplitude modulation (QAM) is a non constant modulation that changes both phase and amplitude. Figure 3 shows the 16PSK and 16QAM constellation diagrams. 16QAM improves the distance between constellation sites while also improving signal resistance. In comparison to 16PSK, 16QAM increases the amplitude levels to three (rings). For non constant modulation, RF power amplifiers require a wider linear range.

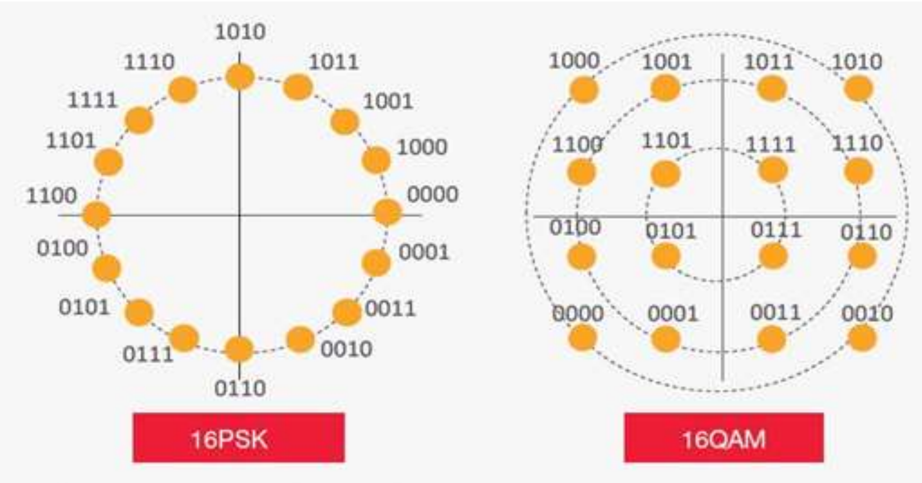

Fig. 4: *Constellation diagram of 16-PSK and 16-QAM.*

To enhance conversion efficiency in satellite transmission, RF power amplifiers are frequently operated at compression settings. AM/AM and AM/AM are caused by operating at compression levels. Figure 4 shows the AM/PM distortion.

The outer points of the I/Q constellation, for example. Have higher output power levels, and the compression is due to the saturated environment the RF power amplifier's output power. As a result, nonlinear amplifiers require a distortion-tolerant modulation system.

Comparative Study and Performance Analysis of Different Modulation Techniques Relevant to Bangabandhu Satellite Communication System
In Bangabandhu Satellite-1, 8-PSK modulation techniques are used (BS-1). Modulation is the process of converting data into electrical signals that are optimal for transmission. Modulation is the process of altering the properties of a signal to be transmitted by superimposing a data signal on a high-recurrence signal in its most basic form.

This approach makes use of video, voice, and other data. The transporter wave signal might be DC, AC, or bit train, depending on the application. A higher frequency sine wave is typically employed as a bearer wave signal. In the beginning, analog modulation techniques were utilized in satellite communication, but now digital modulation is used.

• Basic-Digital Modulation Techniques: We use digital input to generate analog output in this code. The amplitude of ASK varies depending on the digital input. The frequency of FSK fluctuates depending on the digital input. When you get one, the frequency is higher, and when you get zero, the frequency is lower. The phase of PSK changes in response to the input.

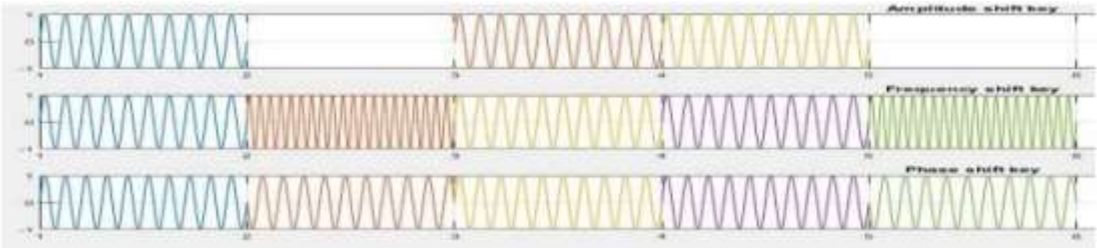

Fig. 5: *Basic digital modulation techniques.*

• As we all know, the eight-phase shift keying (8-PSK) shown in Figure 6 operates in eight stages. This graphic depicts the output of eight phases. Square Pulses, Square Pulses 1, Square Pulses 2, and Square Pulses 3 make up the final 8-PSK. At 0°, 45°, 90°, 135°, 180°, 225°, and 315° degrees, phase changes can be found [8].

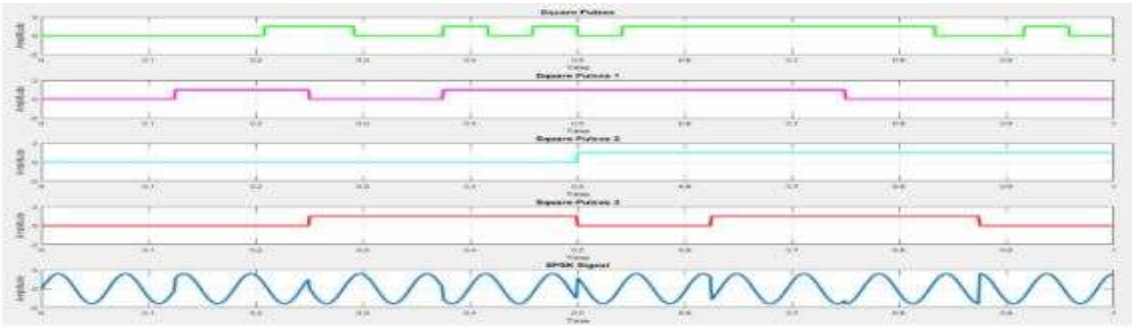

Fig. 6: *8PSK Modulation.*

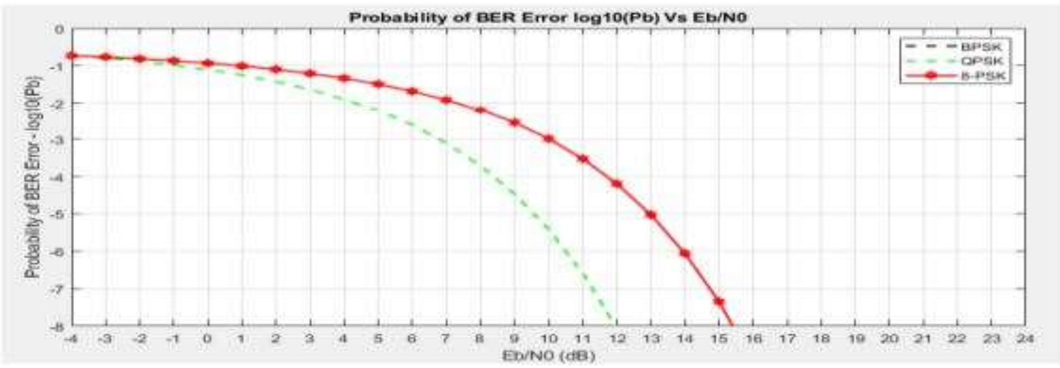

Fig. 7: *Bit Error Rate for BPSK, QPSK, 8PSK.*

With the rising demand for correspondence, it is more important than ever to deliver better and more professional quality service by adopting more effective methods.

Figure 7 shows a BER comparison graph for several modulation techniques. It transfers data more effectively through RF signals than other modulation systems. As a result, compared to ASK and FSK modulation techniques, it consumes less energy. It is less prone to errors than ASK modulation and uses the same amount of bandwidth.

Higher transmission rates will be possible with high-level PSK modulations like QPSK (2 bits per constellation), 16-QAM (4 bits per constellation), and others. PSK has a low error rate and a high level of noise immunity.

Its bandwidth use, on the other hand, is lower. The phase states of the signal are used to demodulate the binary data. These algorithms for verification and retrieval are quite complicated.

Multiple-level PSK modulation schemes (QPSK, 16QAM, and so forth) are more prone to phase shifts. Because this is a kind of FSK modulation, it has a lower bandwidth efficiency than ASK modulation. Because two bits require more power to transmit, PSK is not a very power-efficient modulation approach compared to other modulation types.

CODING TECHNIQUES FOR MODERN SATELLITE COMMUNICATIONS

Turbo Codes

A two-user satellite communication system's performance and design are reviewed here. Each user is encoded with a structured Turbo code that uses the same symbol interleavers.

Turbo decoding may now be done with the combined component code trellises, which gives considerable benefits over separate decoding. The influence of various phase shifts between users is also taken into account, demonstrating the proposed scheme's robustness [10].

Turbo coding is a sort of convolutional code that is unique. Its length has been lengthened. The signal will become more unpredictable and secure as the length of the convolution is increased.

There are two components of a turbo encoding system.

- Interleaver
- Encoder

Turbo encoding is a concatenation of two or more encoders in parallel.

Encoder structure consists of

- Recursive systematic convolutional encoder as constituent encoders in a parallel cancatenation scheme.
- An interleaver rearranges message by changing bit position.

Encoder

Two convolutional encoders run in parallel in a reduced turbo code. Before entering the second encoder, the information bits are jumbled. In a turbo code, the codeword is made up of the input bits, followed by the parity check bits from the first encoder, and finally the parity bits from the second encoder. There are only two branches in the reduced turbo code block diagram shown in Fig 8. In general, numerous turbo encoders with more than two branches are possible.

The constituent code is the convolutional code at each branch (CC).

The generating functions of the CCs can be similar or distinct. We'll focus on the standard configuration, which has two branches with the identical CC. In the diagram, a PAD is used to append the correct sequence of bits to get all of the encoders to an all-zero state. This is because if we employ starting and tail bits, a convolutional code can be used to construct a block code.

The needed tail is a sequence of zeros with a length equal to the memory order m if we only have one encoder. Because of the interleaver, it appears that stopping both encoders at the same time is problematic. It is, however, still viable to do so using simply m tail bits.

HBRP PUBLICATION

Journal of Advancement in Communication System
Volume 5 Issue 1

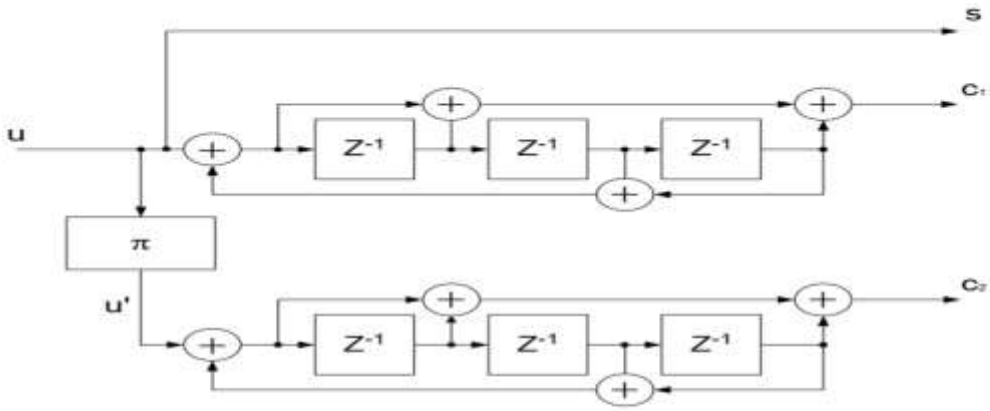

Fig. 8: *Fundamental architecture of turbo coder. [10]*

Decoder

Iterative decoding is used by the decoder. A turbo decoder is depicted in Figure 9 as a block diagram. To distinguish it from the initialization step, the iteration stage is depicted with dotted lines. At any one time, only one loop is executed. In practice, the number of iterations is rarely more than 18, and in many circumstances, 6 iterations are sufficient [4]. Actually, this iterative decoder system is referred known as turbo codes because of the turbo engine principle. The first decoder will decode the sequence before passing the hard decision to the next decoder, along with a reliability estimate for that decision. The second decoder will now have additional information for decoding, such as an a priori value and the sequence.

The interleaver in the middle is responsible for making the two judgments uncorrelated, and interleaving causes the channel between the two decoders to appear memoryless. The specific process for passing information to the next decoder or iteration stage is still under investigation. The modified soft output Viterbi algorithm is described in the next section as a generally accepted decoding algorithm.

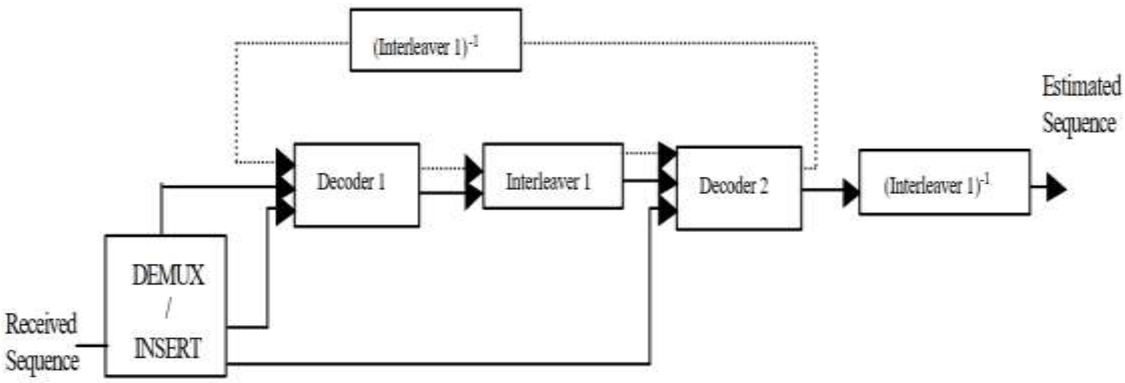

Fig. 9: *Turbo code Decoder block Diagram. [10]*

PERFORMANCE ANALYSIS

With BER values below 10^{-4} at very low energy per 18 information bit values, Turbo code error performance outperforms convolutional and RS codes, as shown in Fig. 10. Table 1 shows the performance of the recommended code rates in terms of Turbo coding error for varied block lengths with 10 decoder iterations in each example. It is clear that codes with greater

coding rates perform better in terms of BER
It's also worth noting that code error performance improves with block length; as a result, Turbo codes can be used to send vast amounts of data.
Complex encoding and decoding processes are common characteristics of turbo codes. However, at a BER of 10^{-6}, the coding gain is inside 0.8dB of the Shannon limit.

The Implementation of Turbo Codes Introduces Advantages and Disadvantages as Listed Below

- Turbo codes are appropriate for low power communications over long distances because they exhibit low BER at low SNR, which means that transmission can be close to error-free even with very low energy signals;
- The code requires a complex decoder as a result of the multiple encoder components;
- The decoder calculations required for error correction require knowledge of the channel characteristics;
- the decoding process is iterative and, therefore, the memory requirement is very large;
- Turbo encoding introduces latency, since an entire length of information must be read before encoding begins; and
- The decoder also processes an entire block before giving an output, which introduces decoding latency.

Turbo decoder BER performance approximation results for various block lengths, 10 iterations, compiled from (CCSDS, 2012).

Table 1: *Turbo Decoder BER Performance Approximation Results.*

Block Length	Rate	SNR(dB) at BER 10^{-4}
1784	1/2	1.3
	1/3	0.66
	1/4	0.43
	1/6	0.14
3568	1/2	1.11
	1/3	0.47
	1/4	0.25
	1/6	-0.17
7136	1/2	0.97
	1/3	0.34
	1/4	0.135
	1/6	-0.25
8920	1/2	0.9
	1/3	0.3
	1/4	0.1
	1/6	-0.8
16384	1/2	0.875
	1/3	0.25
	1/4	0.02
	1/6	-0.036

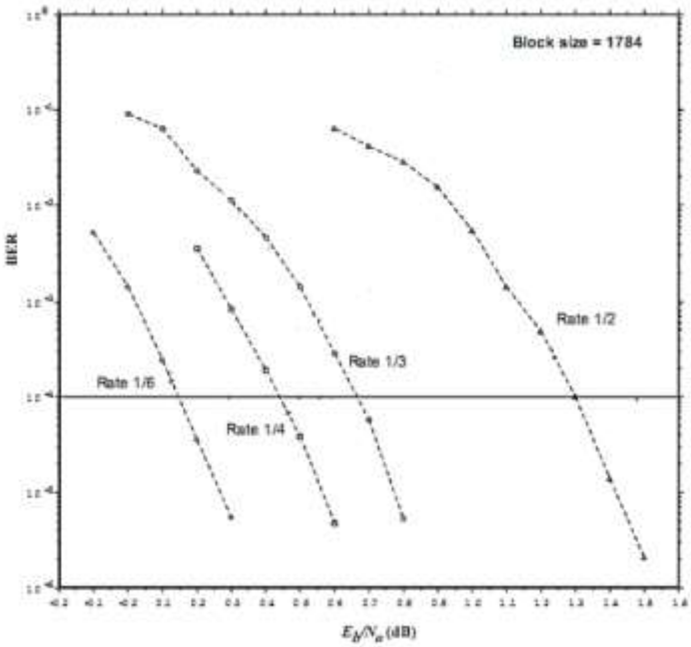

Fig. 10: *Turbo code BER performance, Block Size 1784 Bits, Measured from JPL DSN Turbo Decoder, 10 iterations Adapted from (CCSDS, 2012).*

BCH Code

There are a variety of error-correcting algorithms available, one of which is direct block coding, and the simplest block codes are Hamming codes. They're only good for dealing with glaring irregular errors, therefore they're not very useful unless a basic error control circuit is required. The Bose, Chaudhuri, and Hocquenghem (BCH) codes, which are a speculation of the Hamming codes for various mistake rectifications [12-13], are more advanced error remedying codes. The BCH codes (Bose-Chaudhuri-Hocquenghem) are a large class of capable irregular error-correcting cyclic codes that are suitable for a variety of error revisions. BCH codes function on limited fields or Galois fields, and their use on parallel Galois fields is possible (2m). Because technology is rapidly evolving and information transmission is becoming increasingly digitized, a single data exchange error can degrade the entire secure data, just as it can at a bank. It is critical to notice and write such faults in order to obtain unique data at the receiver.

Encodingof BCH Code

These codes are summed up types of Hamming codes that permit various error redresses. They shape a class ofeffective arbitrary error redressing cyclic codes which gives a determination of bigger block lengths, code rates and error revising capacity [12]. BCH codes are characterized by the following parameters:

For any positive integer’s m where m ≥ 3 and t where t <2^m -1; there exist a binary BCH code where:

Block Length: n=2^m-1;Number of Parity-Check digits:r =n-k ≤ mt;
Minimum distance: dmin ≥2t+1.

The Alphabet of a BCH code for n=2^m-1 is represented as the set of elements of an appropriate Galois field, GF(2m) where the primitive element is α.

The generator polynomial of the t error correcting BCH code is the Least Common Multiple of M1 (x), M2 (x), … ,

M2t(x) i.e., g(x) = LCM{M1 (x), M2 (x), … , M2t(x)} (5)

Where, M(x) Minimal polynomial ofα^i , i=1,2,…2t (6)

Since the minimal polynomials for even power of α are same as for the odd power of α, then the generator matrix reduces to;
g(x) = LCM{M1 (x), M3 (x), … , M2t−1 (x)} (7)

Then for a given message m(x) the code polynomial is given by

In non-systematic form: C(x) = g(x)m(x) (8)

In systematic form: C(x) = P(x) + X^{n-k} m(x) (9)

Where ,P(x) = modulo of ($\frac{X^{n-k} \quad m(x)}{g(x)}$) (10)

Decoding of BCH Code
Berlekamp algorithm

- Find out the syndrome S=(S1,S2<… ..S2t) from the received polynomial r(x)
- Compute the error Location polynomial σ(x) from the syndrome segments S1,S2,… … .S2t utilizing the iterative method.
- Focus on the error area numbers.
- At that point focus the error polynomial e(x).
- Add e(x) to the received polynomial r(x) to get the codeword.

For effortlessness it has been utilized thin sense BCH code with settled code rate (0.7) and variable codeword length (n) and variable message length (k) to assess the execution of such code to see the dynamic parameters. Fig. 11 represents the aftereffect of BER(Bit Error Rate) when utilizing just BCH codes.

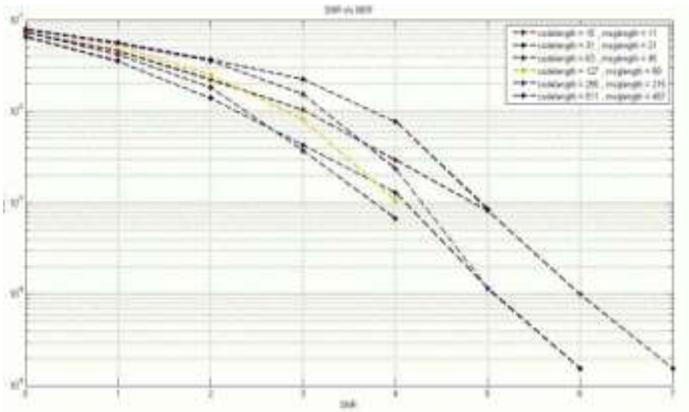

Fig. 11: *BCH encoding and decoding for Different code words.*

Transmission Scheme
The proposed coding scheme is depicted in Fig. 12. The satellite image is decomposed to 3 dyadic scales using a wavelet transform, this yields 10 sub-bands images. Each source word$\underline{i}$, issued from a sub-band ***(k*** samples) is first encoded using a real BCH coder that produces a codeword $\underline{c}$on *n* samples, which is then quantized onb_i bits per sample using a Lloyd-Max quantizer.

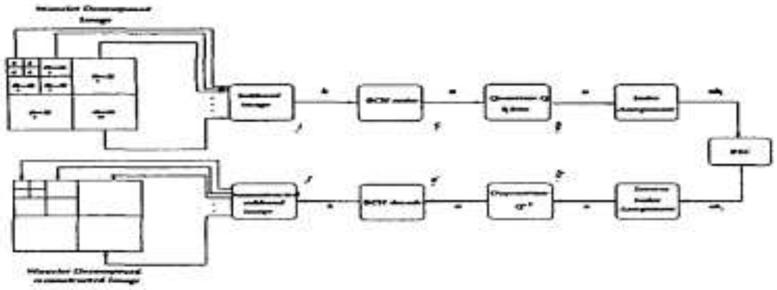

Fig. 12: *Real BCH code Scheme.*

BCH Encoder on the Real Number
We describe these codes in the framework of BCH codes**,** whose definition and properties can be investigated using the Discrete Fourier Transform (DFT).

The BCH coder diagram is shown in Fig. 13. **A** block $\underline{I}$ of k spectral components is computed from the original data block $\underline{i} = (i_0, i_1, \ldots, i_{k-1})$by applying a length-k DFT.

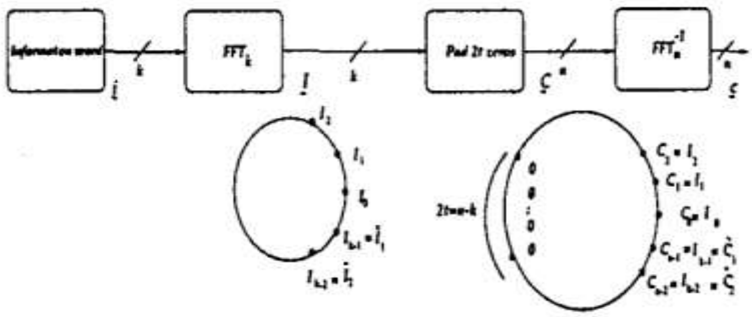

Fig. 13: *BCH coding from the information word to the expanded BCH encoder signal.*

This block is then padded with n - k consecutive zeros in such a way that Hermitian symmetry is preserved (see fig. 2), and a length-n inverse DFT is applied, resulting in a real encoded signal , $\underline{c} = (c_0, c_1, \ldots, c_{n-1})$. This codeword is normalized so that energy is preserved: $||\underline{c}||^2 = ||\underline{i}||^2$.Compared to a classical systematic BCH coding scheme as described by Blahut, this encoding procedure has the nice feature that it roughly preserves the amplitude range of data samples.In fact, a very simple loop procedure is used to achieve decoding: A first pass is made on the lines of the matrix, a second pass is then performed on the columns. Next iteration the same procedure is repeated.

Even when only a few impulses are suitably corrected in the beginning of the algorithm, such correction greatly reduces the task of the following step, which is performed in the other direction in the sub-band matrix.

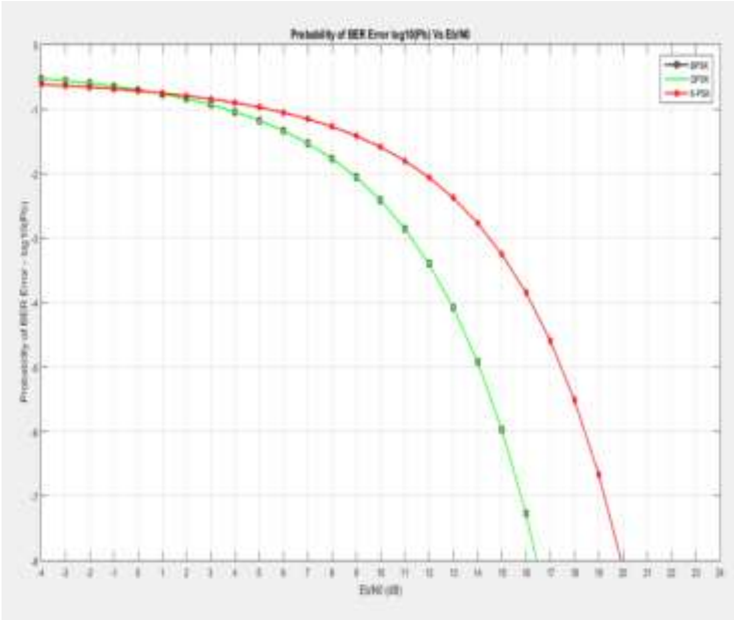

Fig.14: *SNR ratio (coded).*

These codes can correct up to *t* errors, and where *m* is any positive integer, the permissible values are *n*=2^*m*-1 and *k*>=*n*-*mt*.The integers *m* and *t* are arbitrary, which gives the code designer considerable flexibility in choice. Proakis and Salehi (1994) give an extensive listing of the parameters for BCH codes, from which the values in Table 11.3 have been obtained. As usual, the code rate is *rc*=*k*/*n*.

Codeword, n	Message bit, k	Error bit limit, t
7	4	1
15	11	1
15	7	2
15	5	3
31	26	1
31	21	2
31	16	3
31	11	5
31	6	7

CONCLUSION

The feasibility study of Bangabandhu satellite-2 is predicted in this study. We discussed both analytical and business purposes when launching a new satellite. With the launch of Bangabandhu Satellite-2, the country would become self-sufficient in earth observation with optical and radar images and applications. We're looking into how we might study the use of other spacecraft and build the Bangabandhu Satellite 2. We have to figure out how to make the second Bangabandhu Satellite more useful for our economy and communication infrastructure. Modulation is one of the most important techniques for transmitting signals from one location to another. In satellite communication, modulation is used to send signals from Earth to space;

for example, in our most recent project, the Bangabandhu Satellite -1 (Geo synchronous) 8psk modulation was utilized. In order to assess the viability of Bangabandhu Satellite-2, we should use more convenient modulation technology and analyze mathematical expressions such as BER, SNR, and so on.

After all of this thought, we've theoretically decided that 8PSK should be replaced by 16PSK because 16PSK has a higher SNR and better BER. Some coding techniques are required in a satellite communication system. We chose two sorts of coding for this: BCH code and Turbo code. In most satellites, BCH codes are utilized instead of convolutional codes (since BCH is a block error correcting code). It has a simple hardware system and a large bandwidth when compared to other coding schemes. Some coding techniques are required for modulation in Bangabandhu satellite 1. We examine BCH coding for better modulation both theoretically and practically in this research for Bangabandhu satellite-2.

REFERENCES

1. Bangabandhu-1 (BD-1) Communication Satellite, (2021), Aerospace Technology.
2. Asaduzzaman, M. (2017). The Impact of Bangabandhu Satellite on Telecom Sector in Bangladesh.
3. Barua, B., Pandit, D. K., Golam-Mostafa, M., Turjo, T. A., Rahman, I., & Aktheruzzaman, K. M. (2022). Feasibility Study of Bangabandhu Satellite–2. *Recent Trends in Information Technology and its Application, 4*(3).
4. Hashim, A. H., Mahad, F. D., Idrus, S. M., & Supa'at, A. S. M. (2010, July). Modeling and performance study of inter-satellite optical wireless communication system. In *International Conference on Photonics* (pp. 1-4). IEEE.
5. Sharma, V., & Kumar, N. (2013). Modeling of 2.5 Gbps-intersatellite link (ISL) in inter-satellite optical wireless communication (IsOWC) system. *Optik*, *124*(23), 6182-6185.
6. Feng, T. Y., & Yang, J. W. (2005). Study of application of 8 PSK modulation demodulation technology. *Chongqing Youdian Xueyuan Xuebao (Journal of Chongqing University of Posts and Telecommunications), 17*(4), 440-443.
7. Song, X., Hassan, M. Z., & Cheng, J. (2012). Subcarrier DQPSK modulated optical wireless communications in atmospheric turbulence. *Electronics letters, 48*(19), 1224-1225.
8. Miah, M. S., Rahman, M. A., Ahmed, Z., Kim, Y., & Kim, J. (2020). Comparative Study and Performance Analysis of Different Modulation Techniques Relevant to Bangabandhu Satellite Communication System. *The Journal of Contents Computing, 2*(1), 113-126.
9. Kumar, N. (2014). 2.50 Gbit/s optical wireless communication system using PPM modulation schemes in HAP-to-satellite links. *Optik, 125*(14), 3401-3404.
10. MacKay, D. J. (1999). Good error-correcting codes based on very sparse matrices. *IEEE transactions on Information Theory, 45*(2), 399-431.
11. MacKay, D. J., & Neal, R. M. (1996). Near Shannon limit performance of low density parity check codes. *Electronics letters, 32*(18), 1645.
12. Xie, N., Xu, W., Zhang, T., Haratsch, E. F., & Moon, J. (2008). Concatenated low-density parity-check and BCH coding system for magnetic recording read channel with 4 kb sector format. *IEEE Transactions on Magnetics, 44*(12), 4784-4789.

13. Kumar, N. G., & Raju, M. R. (2015). Design and Performance Evaluation of Error Detection and Correction Using Concatenated BCH and LDPC Coding Scheme for Data Streams in Satellite Communication. *International Journal of Engineering and Research Technology (IJERT),* 234-238.