OPEN ACCESS
J. OF ICT, VOL. 4, NO.2, PP.030-037, DES 2022

ISSN : 2686-1089 (ONLINE)
DOI: 10.52661

Journal of Informatics and Communications Technology (JICT)

BER Performance Analysis Over AWGN Channeling For GFSK Modulation To Transmitting Unstructured Data

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Abstract

The first step to enable the optimize the use of information exchange radio-based could be started by providing research on supporting devices. Research on supporting devices and their application, especially in providing service to exchange text-based information is crucial and opens up chances to solve the rest challenges such as signal power, data transfer speed, and security. This research aims to evaluate signal behavior from design information text-based exchange using radio transmission. To achieve the goal, this research adopts a quantitative methodology by comparing theoretical results and simulation results of the design. tuning samples per symbol could give better BER with lower EbNo. The data also demonstrated great results that show using 2 samples per symbol could deliver the best performance that has lower BER and lowest EbNo compared to the rest of the data, including the estimated BER using coherent FSK. It affects the GFSK signal not only very smoothly compared to the FSK signal, but also being able to achieve a minimum BER with the IEEE standard without requiring excessive energy by simply setting samples per symbol at 2. This can be seen from the results of BER 10-3 with energy EbNo was 6.5 dB.

Keywords: GFSK, AWGN Channel, BER, samples per symbol, modulation index

I. INTRODUCTION

The increase of third-party free internet-based services such as cloud storage, messaging apps, and data transfer services could be interpreted as an increase in communication infrastructure. It is helpful and gives easy access and many benefits for everyone to finish their tasks. Besides all of that, there are several risks emerged, and could be a potential privacy invasion related to the data involved in the whole process of the usage of those services. Since the user of those services doesn't have any clue how their data is managed, some possibilities might happen such as Third-party having absolute ownership of the data stored in their server, Misuse of stored data, Data could be gone or corrupted caused to an accident in the server or technical reasons.

Despite the security risks, internet infrastructure is still limited and not evenly distributed in Indonesia. The importance of information exchange becomes the main reason for findings solutions without falling into those previous risks. Exchanging information, especially in the text could be facilitated using a radio frequency in the High-Frequency spectrum[1] could be an answer because transmitting through HF is still considered effective in Indonesia used for both citizens and the government, and then also the cost of building the infrastructure is low. Considered radio infrastructure has advantages such as accessibility of radio coverage could reach the isolated areas, speed because in emergency conditions when there is a blackout or no electricity and internet radio could provide a quick backup plan for exchanging information and communication, and high coverage, especially for areas that are yet covered by internet infrastructure. But considering the equipment specification of the system built in the paper, those components are quite expensive and complicated to use, so they might not suitable for citizens.

In line with these conditions, creating an information exchange radio-based has its challenges such as signal power, data transfer speed especially dealing with large data transmitting, security because it will propagate all over directions and must be complemented by secured protocol and encryption system, cost of frequency licensing, and supporting devices. Examine those challenges, as the first step to enable the optimize the use of information exchange radio-based could be started by providing research in supporting devices. Research on supporting devices and their application, especially in providing service to exchange text-based information is crucial and opens up chances to solve the rest challenges such as signal power, data transfer speed, and security.

For supporting that argument, there is plenty of research related to developing supporting devices such as the use of Radio RIG for long-distance data communication as a carrier wave generator[2], the idea is brilliant but the cost of radio RIG is expensive. Using the availability of devices on the market, there is research that compares and analyze three radio-based devices such as NRF24l01, Xbee, and ESP8266 as data transceiver module[3], the result shows that NRF24L01 outperform Xbee and ESP8266 for sending packets. These interesting findings become the reference of this paper in choosing a device platform to start with. Regardless of the results presented before, most of them refuse to explain their system from the signal behavior instead of providing the device's performance.

Therefore, this article will review our design of a radio-based information exchange system by simulating the signal behavior of BER over AWGN Channel for GFSK modulation by transmitting and receiving unstructured data such as pdf files or docs files.

II. LITERATURE REVIEW

To remain relevant with current technology development, the proposed radio-based information exchange system will reference in alignment with the modulation technology in NRF24L01[4]. Considering its performance compare to the rest of similar technologies, the device is available in the market as a mainstream radio module. NRF24L01 is a 2.4Ghz transceiver or radio module that works in Ultra High Frequency (UHF) which has a band between 300 MHz and 3000 MHz It is designed for sector ISM (Industrial, Scientific, and Medical) frequency band at 2.400 – 2.483 GHz[5].

NRF24L01 is designed to be ultra-low power wireless application supported by an embedded baseband protocol engine called Enhanced ShockBurst that enables two-way data packet communication including packet buffering, packet acknowledgment, and automatic retransmission of lost packets. Also, this module uses GFSK Modulation in the radio front end that supports an air data rate of 250 kbps, 1 Mbps, and 2 Mbps [5]. Figure 1 shows the nRF24L01+ diagram block, it contains an integrated frequency synthesizer, amplifier, crystal oscillator, modulator and demodulator, and Enhanced ShockBurst[3].

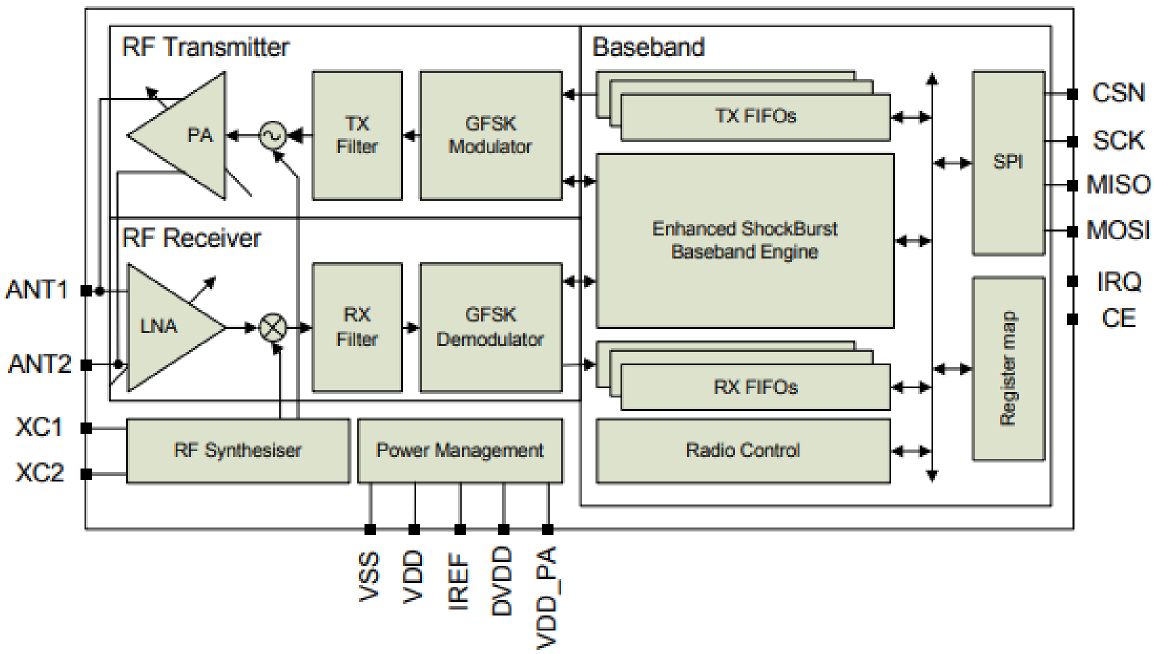

Figure 1 nRF24L01+ block diagram

nRF24L01 use GFSK Modulation, the analysis should start an understanding of the GFSK Modulation itself. *Gaussian frequency shift keying* (GFSK) is a modulation method used for digital modulation that is applied in various wireless technology such as Bluetooth. GFSK is an extension of FSK or Frequency Shift Keying modulation technique. FSK works by decreasing the carrier frequency when the modulated data is 0 symbol and increasing the frequency when it's 1 symbol, applying Gaussian filters to the before the FSK would make the output signal from FSK smoother, as one of the characteristics of GFSK's output signal[6].

Besides smoothing the shape of the frequency pulse, it widens the pulse to one symbol period caused by intersymbol inference. It is intended to prevent high frequencies while switching the logic data. The Gaussian filter is given by:

$$g(t) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{1}{2}(\frac{t}{\sigma})^2}$$

Where σ has a relation with bandwidth B of the 3-dB filter:

$$\sigma = \frac{\sqrt{\ln 2}}{2\pi B}$$

After applying the Gaussian Filter signal will be passed to the transmitter, the transmitted signal called s(t) can be described as a time-dependent phase of cosine signal:

$$s(t) = A\cos(\omega t + \vartheta(t))$$

The phrase itself is derived from the bits that are transmitted, noted as:

$$\vartheta(t) = h\pi \int_{-\infty}^{t} \sum_{i} a_i \gamma(\tau - iT) d\tau$$

h is the modulation index, which affects the wide bandwidth occupied around the carrier. When h is set to 0, means that the carrier is an unmodulated signal. $a_i$is a sequence of numbers, when high (1) is +1 and -1 when low(0). γ is the frequency pulse when no Gaussian Filter is applied it has a rectangular shape that [0, Ts] has $\frac{1}{T_s}$ and 0 outside the interval. Ts is the duration of one symbol. The greater the sampling frequency while converting the signal, the more accurate the result can be[7].

The transmitted signal is demodulated by shifting the signal to the baseband to reduce the carrier frequency to zero. Applying delay and multiply transformation is done after filtering the signal with a low-pass filter.

$$d(t) = q_1(t). t_1(t - \Delta T). q_1(t - \Delta T)$$

The modulation method could affect data transmission by determining the number of bits per symbol that will be transmitted[7], another factor that could affect data transmission is the communication channel. The connection between the transmitter and receiver is the communication channel. Distortion of the signal is needed to represent the condition real world that could affect the quality of the received signal. Contemplative design models used additive white Gaussian noise (AWGN) as the source of distortion[6]. It represented as:

$$s_n(t) = s(t) + n(t)$$

The effect of the distortion would give information in finding Bit Error Rate (BER) as the ratio of the different bits between data and the demodulated data received on the other side. According to IEEE 802.11, BER values can't exceed 10-3[8].

III. RESEARCH METHOD

This research aims to evaluate signal behavior from design information text-based exchange using radio transmission. To achieve the goal, this research adopts a quantitative methodology by comparing theoretical results and simulation results of the design. The method used in this research showed in Figure 2.

The method in this research consists of five main steps, there are: 1) a literature review that started with the main reference paper, and after finding the analysis gap in this step also conducted keyword search for finding similar research as it is. Those papers would be based on a foundation in explaining the state of the art of the topic and the chance for improvements. 2) Determining specifications and requirements conducted after developing an analytical concept based on the previous steps, in this step, the goal should be achievable. 3) Design and simulation, which are more practical and programming activities from proving the concept and preparing source code for the simulation bug-free. 4) Parameter testing aims to observe the signal behavior based on the requirements that have been determined before. 5) Analyze the system performance based on the result of the previous step, and match the result with the findings from the literature review and theoretical explanation.

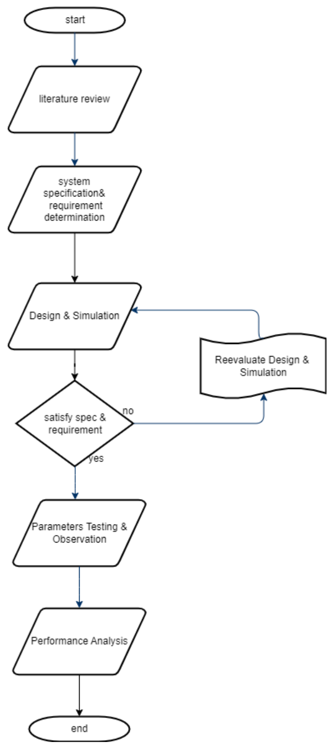

Figure 2 Resarch Method

As a result, the following are the result of the determination of specifications and requirements for this research shown in Figure 3.

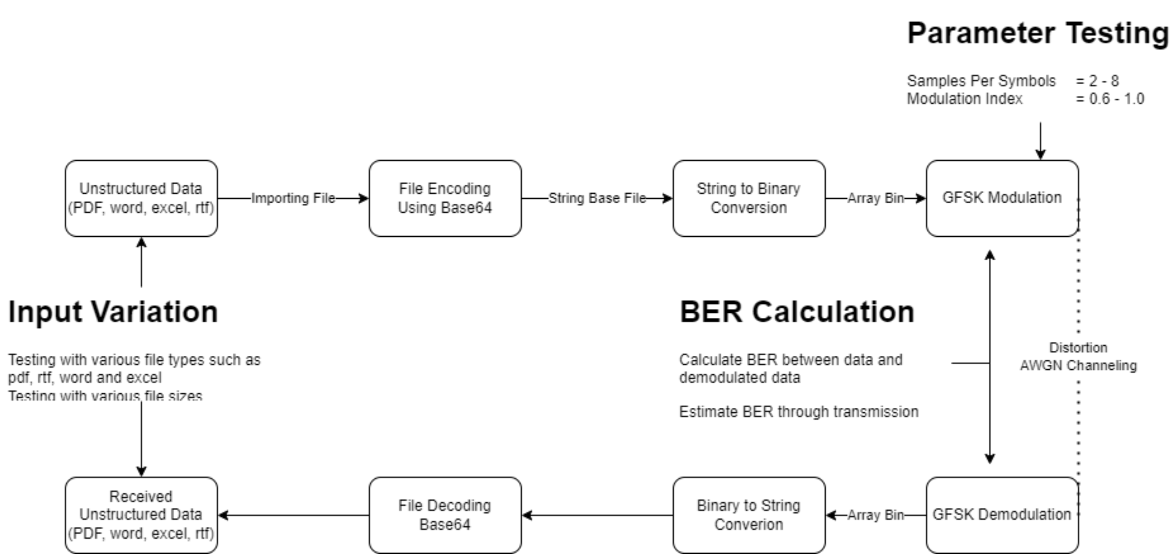

Figure 3 Research Points and System Diagram Block

IV. SIMULATION RESULTS AND DISCUSSION

Following are list of input variations that were determined for this research shown in Table 1.

Table 1 Input Variations

No	File	Type	Size	Value	Data Type	Total Bits	Total Errors Determined (bits)
1	Tabel Data	XLSX	8,94 KB	85540x1	Double	85540	8554
2	Docs with a math equation	Docs	55 KB	519456x1	Double	519456	51946
3	PDF contains table, image, string	PDF	169 KB	1618652x1	Double	1618652	161865
4	Converted PDF to RTF	RTF	1711 KB	16351496x1	Double	16351496	1635150
5	PDF of a scientific paper	PDF	1777 KB	16979088x1	Double	16979088	1697909

Those inputs will be used for transmission simulation using GFSK Modulation. As shown above, the size of bits generated in each file varies from the smallest around 85000 bits to the largest that about 17 million bits. Those files are already encoded in Base64 as input for the string-to-binary conversion.

Table 2 Communication Channel Distortion

Distortion	Modulation Type	Modulation Order	BER	EbNo (dB)
AWGN Channel	Coherent FSK	4	1.00E-03	7.5

After we got the binary array, first we experiment with changing the parameter of its samples per symbol that is used in GFSK Modulation and Demodulation. The value varies from 2, 4, 6, and 8. For calculating the BER performance, the process can be done by iterating each EbNo (dB) that is already between 0 to 15 dB. Following are the result of the experiments shown in Table 3. On the other side, the Bit error rate for AWGN Theoretical is estimated using mathematical functions the same as for FSK Modulation shown in Table 2..

Table 3 BER and EbNo Comparison On Tuned Parameter

Modulation	Independent Parameter	Tuned Parameter	BER	EbNo (dB)
GFSK	modulation index = 1	Samples per symbol = 2	1.00E-03	6.5
GFSK	modulation index = 1	Samples per symbol = 4	1.00E-03	9
GFSK	modulation index = 1	Samples per symbol = 6	1.00E-03	10
GFSK	modulation index = 1	Samples per symbol = 8	1.00E-03	10.5

From the data above, experimenting with various values for samples per symbol could lead to significant changes for each ratio of BER and EbNo. Based on data obtained in

Table 2 used an estimated BER over AWGN using FSK Modulation. It will be the comparator for the simulation result that showed in Table 3. It shows that GFSK Modulation BER performance could be accepted for IEEE 802.11 BER standard.

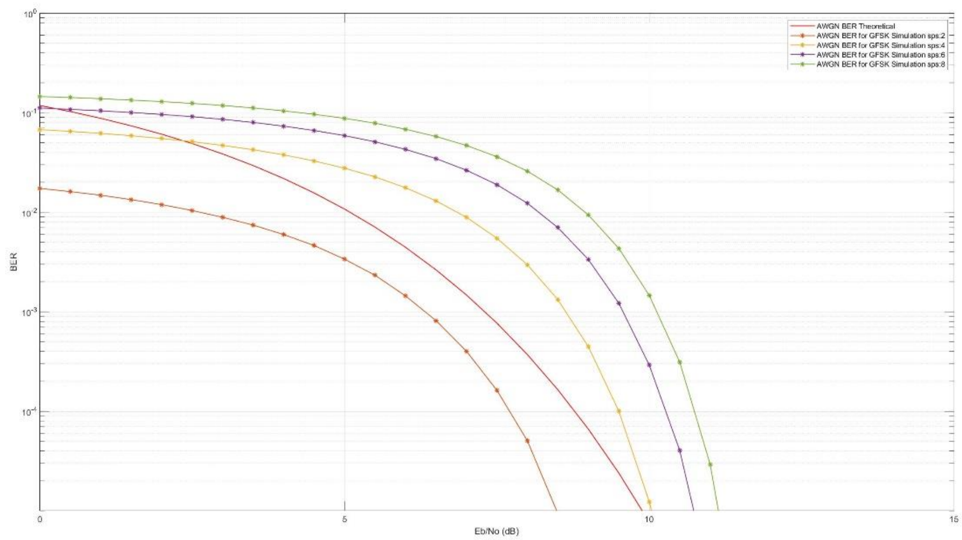

Figure 4 Performance From File 5

Table 3 also found that tuning samples per symbol could give better BER with lower EbNo. The data also demonstrated great results that show using 2 samples per symbol could deliver the best performance that has lower BER and lowest EbNo compared to the rest of the data, including the estimated BER using coherent FSK. Figure 4 shows the semilog y of BER and EbNo comparing all of the data obtained in this experiment. This happened because there is a Gaussian Filter that is applied before FSK modulation thus making the symbol transition time less and minimizing the occurrence of errors due to noise.

After experimenting with samples per symbol, the next is to observe the influence of the modulation index that is included in GFSK modulation. The result is shown in Table 4

Table 4 BER and EbNo Comparison On Tuned Parameter

Modulation	Independent Parameter	Tuned Parameter	BER	EbNo (dB)
GFSK	Samples per symbol = 2	modulation index = 0.6	1.00E-03	6.5
GFSK	Samples per symbol = 2	modulation index = 0.7	1.00E-03	6.5
GFSK	Samples per symbol = 2	modulation index = 0.8	1.00E-03	6.5
GFSK	Samples per symbol = 2	modulation index = 0.9	1.00E-03	6.5
GFSK	Samples per symbol = 2	modulation index = 1	1.00E-03	6.5

Based on data shown in Table 4, differences with samples per symbol tuning modulation index don’t affect the EbNo significantly. Figure 5Figure 4 shows the semilog y of BER and EbNo comparing all of the data obtained from tuning modulation index in GFSK modulation.

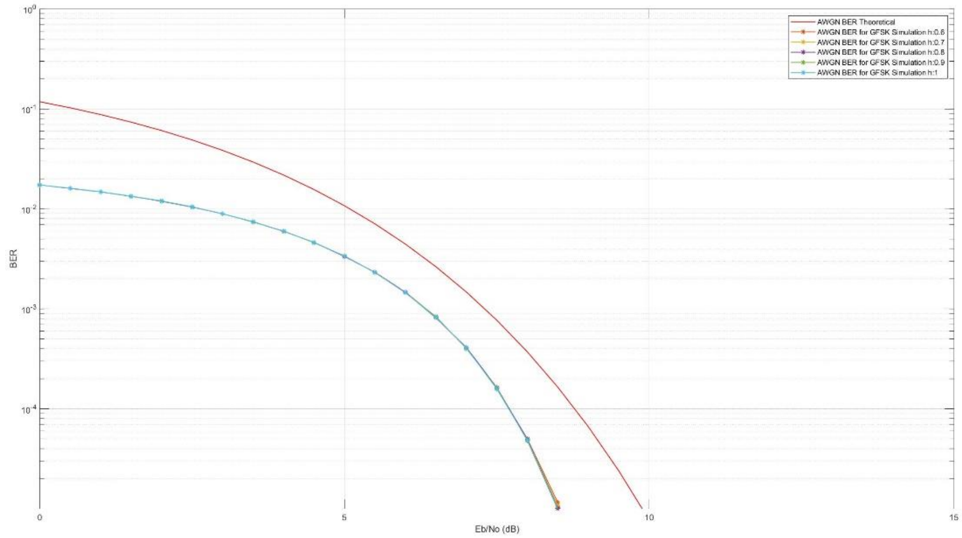

Figure 5 Performance From File 5

V. Conclusion

Considering the results of the experiments, GFSK signal characteristics could be determined. Two of the GFSK modulation parameters are samples per symbol and modulation index. If referring to the performance of the BER on EbNo, the samples per symbol gives a significant influence compared to other parameters. It affects the GFSK signal not only very smoothly compared to the FSK signal, but also being able to achieve a minimum BER with the IEEE standard without requiring excessive energy by simply setting samples per symbol at 2. This can be seen from the results of BER 10-3 with energy EbNo was 6.5 dB.

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