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A Novel Architecture for M-FSK /DS Spread Spectrum Communication System

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ABSTRACT

The direct sequence (DS) spread spectrum communication technique is widely regarded as one of the most effective methods of mitigating the effects of a repeating jammer in military communications systems. The proposed system coupled DS with multiple frequency shift keying (DS/MFSK). It is comprised of a transmitter and a receiver. Non-coherent demodulation is examined, as are the spreading sequences in question. The effect of AWGN and Rayleigh fading channels on the proposed approach's bit error rate (BER) is examined. The investigation demonstrates that even with an 8 dB signal-to-noise ratio, superior outcomes can be achieved; this study's suggested endeavor is to create a novel transceiver system built on the DS/MFSK modular architecture. MFSK modulation prevents multiple-access interference, while DS is typically employed to boost system efficiency across erratic fading. Test results show that reliability on the AWGN channel decreases a little while reliability is greatly enhanced by Rayleigh fading. Moreover, notable improvements in bandwidth efficiency are achieved.

1. Introduction

As of the 21st century, spread-spectrum communication has become increasingly helpful for military and civilian purposes [1]. Various applications of spread-spectrum approaches have been studied [2], including antijamming, multipath rejection, and efficient range tracking.

The use of jamming can successfully block legitimate users' connections without the provision of highly sophisticated detection and response methods. Due to the unique properties of direct sequence spread spectrum communication systems (DCS) are becoming increasingly important in current communication systems [3]. Since DSSS has a tremendous bandwidth, the fundamental digital code sequences are modulated with pseudo-noise (PN) sequences and spread over a considerable area. A low power-spectrum density is characteristic of DSSS signals, and channel noise frequently obscures them [4]. M-frequency shift keying (MFSK) consumes less energy, resulting in significant quality management, and is highly beneficial in high-

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speed applications. Combining M-FSK and DSSS can eliminate the data rate gap [5]. This modulation technique is highly successful, with increased efficiency and frequency usage (M), but at the expense of increased difficulty and decreased channel capacity [6].

The suggested effort in this study intends to develop a novel transceiver system based on the DS/MFSK modular architecture. DS is usually used to increase system efficiency across jittery fading, while MFSK modulation is used to prevent multiple-access interference. The results of the tests demonstrate that dependability on the AWGN channel deteriorates marginally, whereas Rayleigh fading significantly improves it. Furthermore, significant advances in bandwidth efficiency are realized.

The rest of this paper is structured as follows: Articles in part 2 are comparable works. Definitions and supplies are covered in part 3. Part 4 discusses the DS/MFSK system model. Part 5 contains the results obtained. The conclusion is found in Section 6.

2. Related Works

Because the DS signal detection stage is so important, much study has been done in this area, and several detection algorithms have been developed.

A novel approach to M-FSKIM signal analysis and recognition using the subspectral decomposition method is presented in [7]. [8] Examined the receiver for demodulating M-FSK signals under the effect of Gaussian noise, intersymbol interference, and Rice fading. In diverse acoustic channels, three modulation strategies are examined. At low rates, MFSK is highly resistant to delaying Doppler spreading [9]. Combinations of OFDM, MFSK, and CSS were suggested in [10]. A BER comparison study of Reed-Solomon coded non-coherent M-ary FSK techniques with DSSS is described in [11]. [12] examined the effectiveness of soft decision decoded synchronous FHSS-MA networks over Rayleigh fading channels utilizing turbo and convolutional coded MFSK.

3. Methodology

- *Pseudo-Random Signal Generator (PN)*

PN is a random signal whose attributes must be like those of noise. [13]. A linear feedback shift register (LFSR) is one of the most used methods for generating the pseudo-random pattern. LFSR is considered simple and may be implemented using simple shift registers or a field programmable analog array (FPAA) [14]. Autocorrelation is employed to examine properties [15]. The number of shift registers in the circuit determines the length of the m-sequences [16]. Figure 1 shows the M-sequence code, the Maximal Length Sequence.

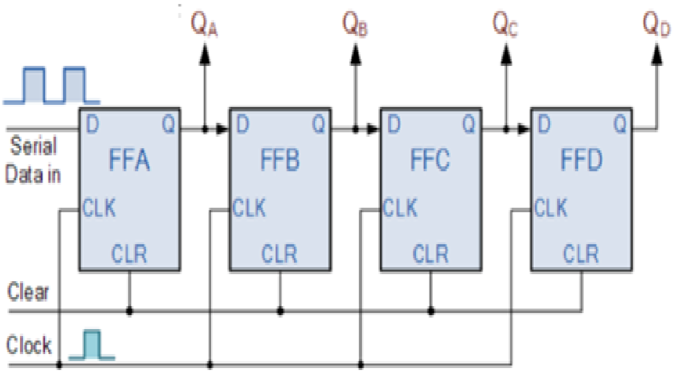


Figure 1. PN sequence Generator

- *M-array FSK*

MFSK is a well-known digital communication modulation method. Information is communicated by selecting one of the M orthogonal signal waves of different frequencies [17]. The MFSK is represented by:

The MFSK is represented by:

$Q_i\ (t) = Acos(w_i t\ +\ \vartheta), 0 \le\ t \le\ T_d$, 0 elsewhere

$$Where\ i = 0, 1.....N - 1\ and\ \ A = \sqrt{\frac{2E_d}{T_d}} \qquad (1)$$

Ed signifies the transmitted signal energy per bit, wi is the transmitted frequency signal, ϑ is the initial phase angle, and Td is the symbol duration. Q1(t) denotes symbol 1 while Q2(t) denotes symbol 0. Q1(t) and Q2(t) are orthogonal signals. Q1(t) and Q2(t) are orthogonal signals.

ϕi(t), the signal's phase is indicated by (Matthias, K. W. 2011).

$$\phi_i(\mathrm{t})\ =\ 2\,T_d \cos \mathrm{w}_i\,\mathrm{t}\,, 0 \le\ \mathrm{t} \le\ \mathrm{T}_d \qquad (2)$$

- *Direct sequence spread spectrum system.*

As wireless communication networks (WCNs) have grown, the necessity for power efficiency in mobile devices and speedy security systems in a dynamic wireless environment has drawn significant attention to physical layer security research. As a result, spread-spectrum technologies (SST) such as DSSS and others were developed. By simulating white noise using PN sequences, DSSS broadens the spectrum of the content signal. This helped to advance DSSS and other SSTs [19]. The data signal combines a spreading signal with a significantly greater DS bandwidth. The resulting modulation signal successfully accommodates the spreading signal's bandwidth. For transmission, this broad modulation is applied to a fixed-frequency carrier signal. The spreading code disseminates data ahead of and independently of the RF modulator. Figure 2 demonstrates the fundamentals of creating a direct sequence spread spectrum and delaying the receiver [20].

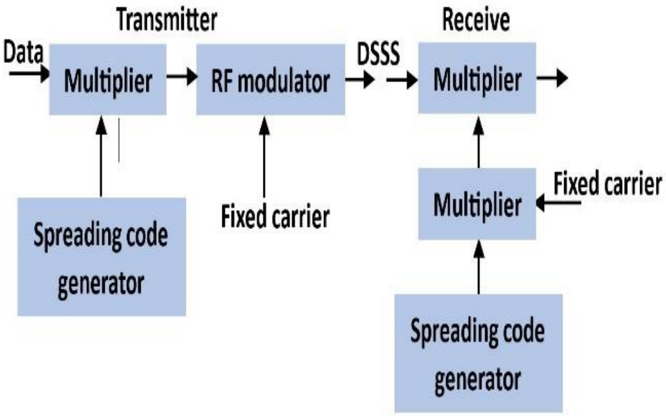


Figure 2 The DSS Transmitter and Receiver

4. System model

Figure 3 shows the DS-MFSK system block diagram. The transmitter integrated an MFSK-modulated signal and DS in a two-step modulation process (Figure 3(a)). The MFSK depicts a system with multiple-access capability, whereas the DS The receiver decodes the received signal (Figure 3-b) and combines it with a locally generated duplicate of the spreading code. The code generated locally must be phase—and frequency-synchronized with the incoming code. The MFSK demodulator employs a series of filters to detect data bits. An integrator element precedes each filter. Finally, a decision circuit is used to declare the original signal.

modulation protects the system against multipath losses.

(a)Transmitter

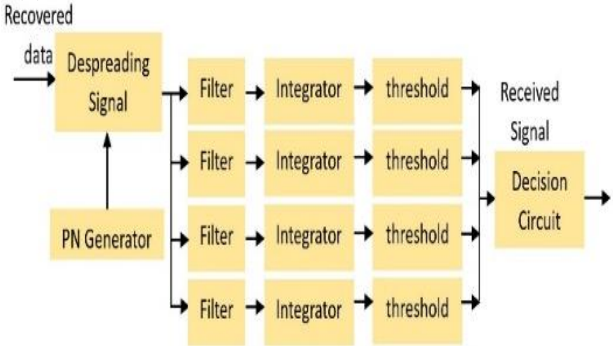


Figure 3.a. Block diagram of MFSK/DS transmitter

The DS modulation protects the system against Block diagram of MFSK/DS transmitter and receiver

(b) Receiver

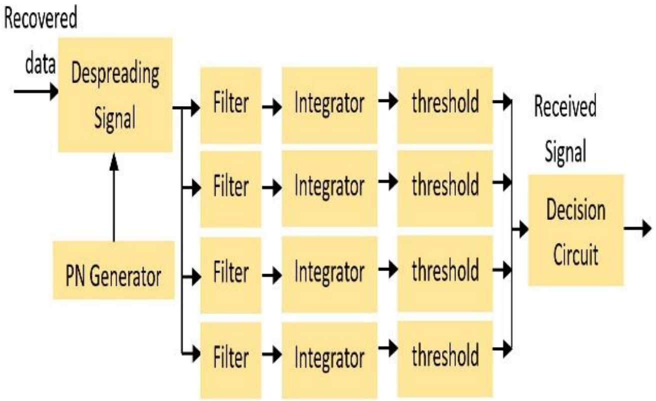


Figure 3. **b** Block diagram of MFSK/DS receiver

5. Hardware implementation of MFSK/DS

The FPAA technique combines trustworthy and robust hardware and software, rapid response, convenience of model construction, relative affordability, and straight design [21].

FPAA is made up of fundamental analog processing units that are grouped into a configurable analog block (CAB) that is linked to other CABs via a routing network. The FPAA includes filter synthesizers, multipliers, and amplifiers. FPAA can be employed to evaluate dynamical swiftly

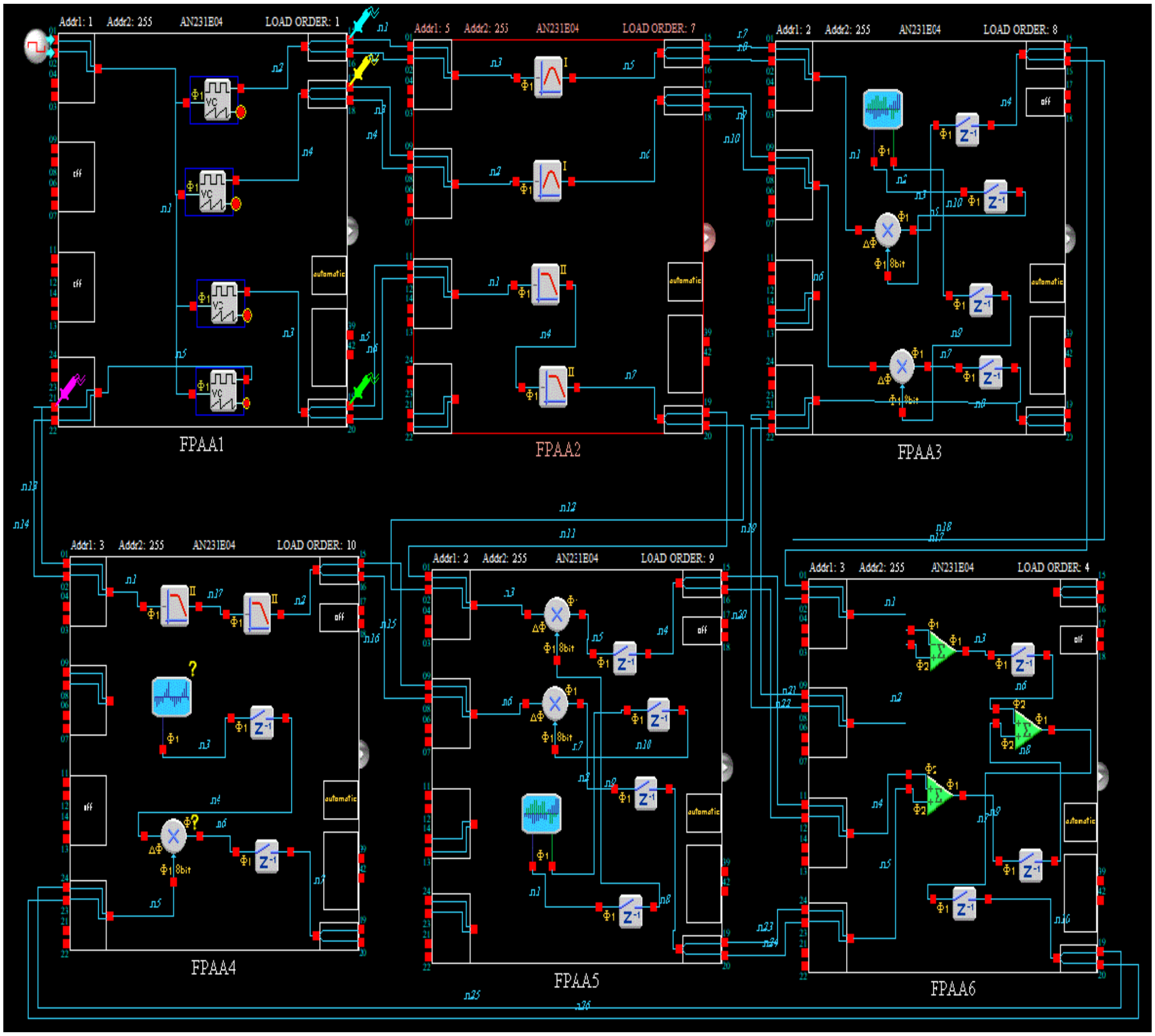


Figure 4 DS/MFSK Transmitter System

Systems and those units can then be built using electronic circuit technology [22]. Because of their low energy usage, FPAA reconfigurable systems have grown in versatility.

Anadigm is one of the firms that make up the FPAA. Anadigm's FPAAs enable designers to transform complex analog circuits into a simple collection of low-level functions, providing the analog counterpart of FPGA [23]. The Anadigm Designer2 program allows users to automatically paradigm and execute a circuit on the FPAA device [24]. Figure 4 depicts an FPAA-based methodology for a DS/MFS transmitter system.

Anadigm Inc.'s FPAA AN2231E04 is used to build the circuit. Based on the block design in Figure (3-a), the DS/MFSK transmitter comprises three shapes created in Anadigm Designer2 2 using configurable analog modules (CAMs). Due to the FPAA board's restricted capacity, six boards are required to achieve the planned system.

A 4-band frequency carrier is formed in the first stage. It comprises four VCOs and four BPFs with the specifications mentioned in Table 1. Four separate data bits are delivered with each chip interval (FPAA1, 2); see figure (5). Each BPF's output will be transmitted directly into the second stage, which consists of four multipliers with two inputs.

FPAA stands for "Field-Programmable Analog Array." Unlike traditional analog circuits, which are fixed-function and designed for specific tasks, FPAA offers programmable analog functionality, similar to how FPGA (Field-Programmable Gate Array) provides programmable digital functionality.

Here's how FPAA works and its significance:

Programmable Analog Circuits: FPAA allows users to configure analog circuits dynamically, similar to how FPGA allows for digital circuit configuration. This flexibility enables a wide range of analog signal processing tasks to be implemented on the same hardware platform.

Customization and Flexibility: With FPAA, designers can customize analog signal processing functions according to their application requirements. This flexibility is precious in sensor interfacing, signal conditioning, filtering, and analog-to-digital conversion fields.

Rapid Prototyping and Development: FPAA facilitates rapid prototyping and development of analog systems. Designers can iterate quickly by reprogramming the analog circuitry, allowing for faster testing and refinement of analog signal processing algorithms and architectures.

Reduced Time-to-Market: By leveraging FPAA technology, designers can accelerate the development cycle of analog systems, leading to reduced time-to-market for new products and innovations.

Versatility: FPAA platforms can support various analog functions, including amplifiers, filters, oscillators, and mixers. This versatility makes FPAA suitable for multiple applications across industries such as telecommunications, instrumentation, medical devices, and consumer electronics.

Overall, FPAA represents a powerful tool for implementing custom analog signal processing solutions, offering the flexibility, customization, and rapid development capabilities essential in today's dynamic engineering landscape.

Each multiplier's second input receives a control signal. The signals from each multiplier are combined in the summing units to produce an MFSK signal (FPAA3, 5, 6); see Figure 6.

In the third step, the mixer unit with two inputs is used. The first receives an MFSK signal, while the second gets a spreading signal generated by an arbitrary periodic waveform unit. The mixer outputs a DS/MFSK signal (FPAA4); see Figure 7.a,b.

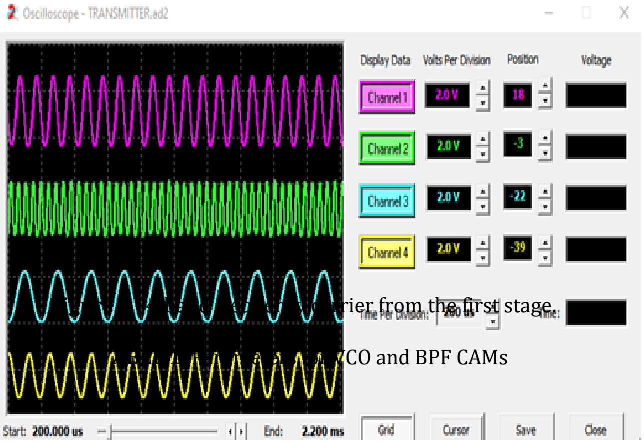
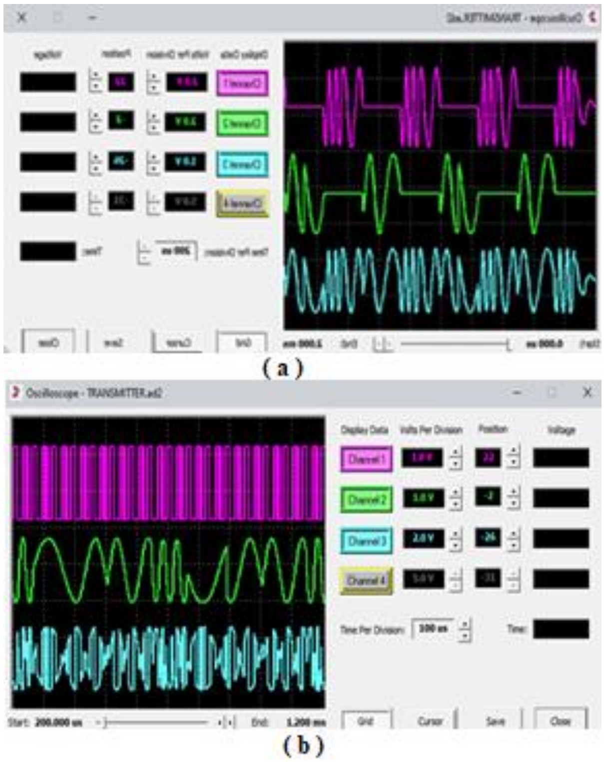


Figure 5 4-band frequency carrier from the first stage.

Table 1. Parameters for VCO and BPF CAMs

VCO Parameters			Filter Parameters			
	Center frequency	%Frequency Variation		Center frequency	Quality factor	Gain
VCO$_1$	KHz 10	5	BPF$_1$	10	6	0.7
VCO$_2$	KHz 22	5	BPF$_2$	17	12	0.7
VCO$_3$	KHz 5	5	BPF$_{3,4}$	3	0.9	0.7
VCO$_4$	KHz 8	5	BPF$_{5,6}$	12	0.9	0.7

Figure 6 Output signal from the second stage.

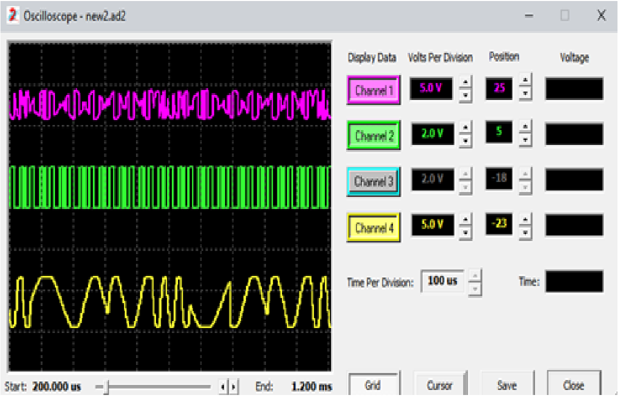


Start: 200.000 us End: 1.200 ms

Figure 7.a,b. DS/MFSK Output signal

Figure 9 depicts the receiver system based on FPAA technology. The PN generator in the receiver creates the replica spreading pattern as the one in the transmitter to recover the MFSK (FPAA7); see Figure (8).

The MFSK demodulator uses four-band pass-tuned filters to separate chip bits from one another. Following each filter is an integrator and a threshold determination unit (FPAA 8, 9, 10, 11). Next, a decision matrix is employed to announce the signal's appearance (FPAA12).



Channel 1 5.0 V 25
Channel 2 2.0 V 5
Channel 3 2.0 V -18
Channel 4 5.0 V -23
Time Per Division: 100 us
Time:
Start: 200.000 us End: 1.200 ms

Figure 8 De-spreading signal

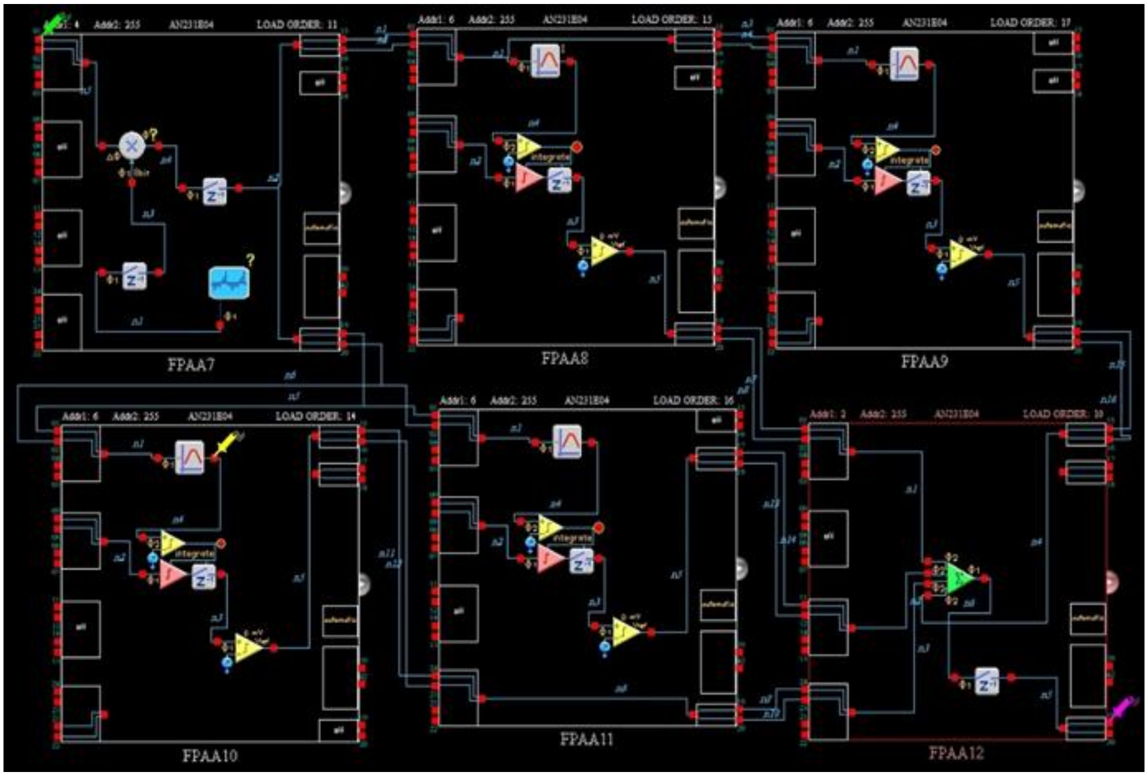


Figure 9 DS/MFSK Receiver

6. Results and Discussion

Field-programmable analog array (FPAA) technologies are ideal for countless analog signal processing implementations. This technology contains components for each chip, such as integrators, multipliers, summing, gain, filters, and other blocks. Compared to DSP processors, it provides high accuracy, electronic efficiency, and ease of implementation. FPAAs can change specifications designed in real time to meet the system's variable demand requirements. FPAA reconfigurable technologies have shown increased.

Figure 10 compares the system's efficiency for AWGN and Rayleigh fading. Under Rayleigh's influence, the proposed system performs much worse than an AWGN channel, with a linear decline in symbol error probability. Based on the results, an adequate signal-to-noise ratio of 6 dB may be achieved with AWGN and Rayleigh interferer signals. The analysis shows that employing a 4-FSK orthogonal modulation signal improved the effectiveness of the proposed system.

BER results show high reliability even with AWGN and Rayleigh interferers and a signal-to-noise ratio of 6 dB.

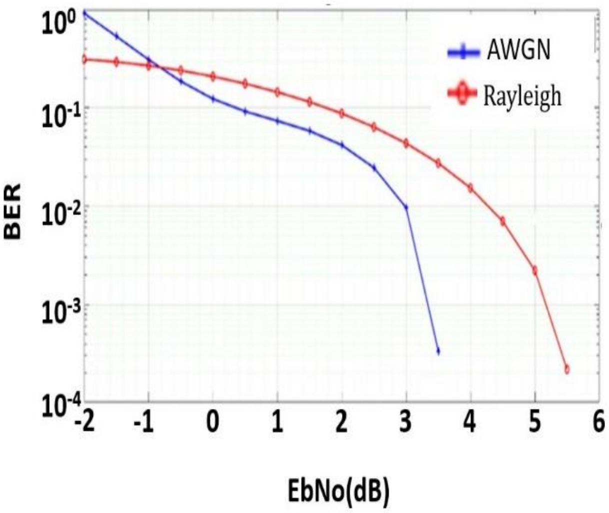


Figure 10 BER Performance of 4-FSK/DS system

7. Conclusions

This paper suggests a novel modulator and demodulator that employs DS/MFSK modulation techniques, developed and implemented using the FPAA method, and then evaluated on AWGN and Rayleigh fading channels. This concept was centered on using DS and MFSK modulation schemes, which are efficient and low in noise and interference. All communication systems are experiencing an improvement in data rates and bandwidth consumption, both of which benefit the system. However, error correction accuracy is also increasing, which is undesirable in any communication system.

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Conflicts of Interest

The author declares that there are no conflicts of interest.

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