BER Analysis of FSK Transceiver for Cognitive Radio Applications

Nagarathna N, Preeti.G.Biradar, Himanshi Budhiraja, Susham K.Rao

Abstract— In modern wireless communication, the radio spectrum is the most vital resource for a mobile operator. Most of the prime spectrums (licensed bands) are already allocated for license users for exclusive use. Few, unlicensed bands are left open for unlicensed users. Cognitive radios (CR) offer a solution to this spectrum scarcity problem and the demand for reliable high data rate transmission had been increased significantly these days, which leads the way to modulation techniques.

The main objective of this paper is designing and analyzing of FSK Transceiver using Lab-VIEW and to measure the graphical representation of BER VsEb/No in the presence of Additive White Gaussian Noise (AWGN) of digital modulation schemes. FSK is chosen as modulation scheme for design of CR system is widely used for data transmission applications over band pass channels such as Cordless and paging systems, Telephone-line modems, Caller ID, Microcomputers, Audio cassettes, Radio control etc. FSK Transceiver is used to control the power for CR system. It is easy to implement and widely used for the wireless communication in VHF and UHF Frequency bands giving very good BER with high data rates.

Index Terms— Bit error Rate (BER), Cognitive Radio, Digital communication, Frequency Shift Keying, Lab-VIEW graphical programming, Signal-to-Noise Ratio (SNR).

I. INTRODUCTION

From many years modulation techniques have been designed and extensively used for various applications but the modern communication system requires data transmission at a higher rate, larger bandwidth in order to have multimedia transmission.

This paper discusses a Cognitive Radio (CR) is an advanced version of software-defined radio (SDR) system built using LabVIEW for FSK Transceiver. Cognitive radio (CR) provides an alternative (a new paradigm) to systems such as the third generation (3G) and the fourth generation (4G). There are two frequency bands where the cognitive radios might operate in the near future i.e. 54-862 MHz (VHF and UHF TV bands) and 3-10 GHz (Ultra-wideband (UWB) radios) [2]. Figure 1 shows the CR system architecture. The system is hybrid and contains two networks; a primary radio network and a cognitive "adaptive" radio network. The two networks are not physically connected however they meant to coexist [3]. A Cognitive radio consists of a programmable communication system by updating software, functional changes can be made. Similar to other digital communication systems, the transmitter of a CR system converts digital signals to analog waveforms. These waveforms are then transmitted to the receiver.

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The received waveforms are down converted, sampled, and demodulated using software on a reconfigurable baseband processor. Normally, high-performance digital signal processors are used to serve as the baseband processor. Basically, the programmability and flexibility of a CR system makes it possible for it to be used in ubiquitous network environments.

One of the main advantage of using digital modulation technique is that the use of digital signals reduces hardware, noise and interference problems as compared to the analogue signal where large number of waveforms will be required resulting in a larger bandwidth for the symbol to be transmitted.

In this paper, Frequency Shift Keying (FSK) is chosen to be the modulation scheme of the designed Cognitive radio system noting that this modulation is widely used for data transmission applications over band pass channels such as Cordless and paging systems, Telephone-line modems, Caller ID, Microcomputers, Audio cassettes, Radio control etc. Due to its easy implementation and widespread usage in legacy communications equipment, FSK modulation techniques to be very common technology for transmission and reception in current and future wireless communication, especially in the VHF and UHF frequency bands giving very good BER with high data rates. Transferring from analogue formats to digital formats data communications is growing importance, and along with it the various forms of modulation which are used to carry data [1].

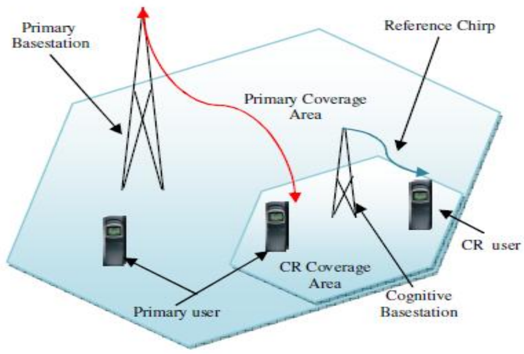

Fig. 1. CR System Architecture

In this paper, the software simulation of the FSK Transceiver system is accomplished using LabVIEW (short for Laboratory Virtual Instrumentation Engineering Workbench) [4] as a time-efficient and cost effective solution. LabVIEW is a graphical programming environment developed by National Instruments which allows high-level or system-level design via its flow-chart intuitive block-based programming as compared to the commonly used text-based programming languages [5]. A design using LabVIEW is achieved by integrating different blocks, components or subsystems, called Virtual Instruments (VIs), within a graphical framework.

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II. FREQUENCY SHIFT KEYING

This paper is designed to examine the Frequency Shift Keying (FSK) digital modulation scheme. Digital modulation requires changing characteristics of the carrier wave with the time and this change results in a sine wave with a different phase, amplitude, or frequency. As a result, different "states" of the sine wave are referred to as symbols which represent some digital bit pattern. To construct LabVIEWVIs that transmit and receive a digital bit stream using FSK.FSK is a method of transmitting digital signals of two binary states, logic 0 (low) is represented by a wave at a specific frequency, and logic 1 (high), is represented by a wave at a different frequency by an analog waveform. The binary data from a computer to FSK can be converted by modem for transmission over wireless media, telephone lines, optical fibre etc. The modem also converts incoming FSK signals to digital low and high states, which the computer can "understand." A typical BFSK modulated signal is shown in the figure 2 below.

A. Coherent FSK: In Coherent FSK, switch from one frequency signal to the other only occur at the same phase in the signal.

B. Non Coherent FSK:In this scheme, if there is a change from one frequency to the other, do not adhere to the current phase of the signal.

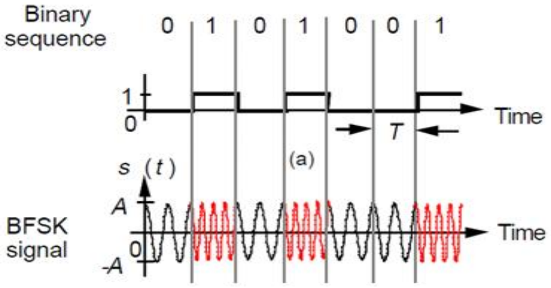


Fig. 2.BFSK modulation: (a) binary signal and (b) BFSK signal.

Detailed block diagram of Digital Communication System as shown in figure 3. The first three modules (message source, pulse shape filter, and FSK modulator) make up the transmitter part and the other modules make up the receiver part [6].

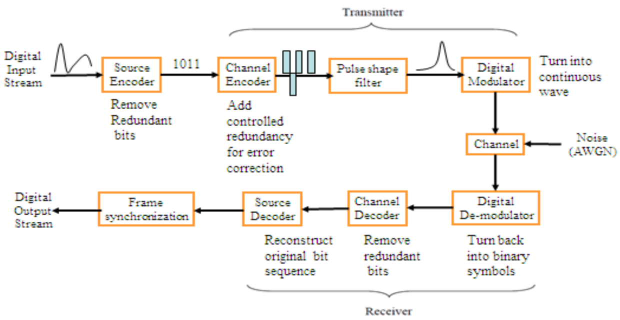


Fig. 3. Detailed block diagram of Digital Communication System based on M-ary FSK modulation scheme.

A brief description of each block as follows.

A. Digital Input Stream

This is a sequence of binary bit streams (ones and zeros) or information often termed as baseband (low-pass)signal to be modulated.

B. Information/Message source

The first component of the FSK Transceiver is the message source. The Information or message to be transmitted comes from the information source. Here, Pseudo Noise (PN) sequences are used for this purpose.

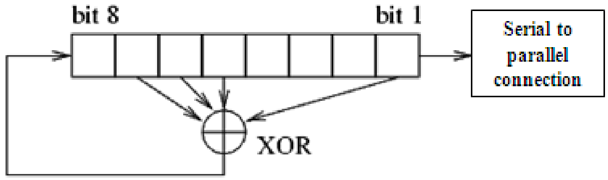


Fig. 4.PN generation with shift registerandXOR gate.

Two PN sequence generators are used in order to create the message sequences for both the in-phase and quadrature phase components. In the constellation of 4-FSK, the reference signals are located at each quadrant. A PN generator produces a sequence of bits that appears random. As shown in Figure 4, the PN generator is simply a shift-register and XOR gate. Bits 1, 5, 6, and 7 of the shift-register are XOR^{ed}together and the result is shifted into the highest bit of the register. The lowest bit, which is shifted out, is the output of the PN generator. The PN generator is a useful source of random data bits for system testing. The PN sequence will repeat with period N= 2^m-1, where m is the width in bits of the shift register. The sequence generated via Eq. has a period of 31bits (=2^5-1).

C. SourceEncoder

The source encoder is to improve efficiency by reducing redundant bits, compressing the digital sequence into a more competent symbol for transmission.

D. ChannelEncoder (Line)

The channel encoder is to improve reliability by adding redundant bits to the compressed information in order to control the errors offered by channel impairments. There are different methods of line coding which includes unipolar encoding, polar encoding, bipolar encoding, Manchester encoding.

E. Pulse shape filter

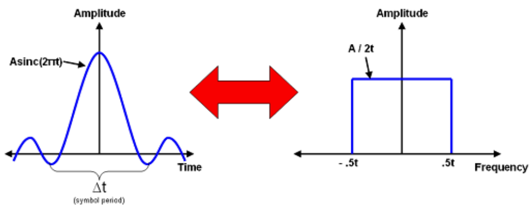


Fig. 5. Pulse shape filter

In communications systems, two important requirements of a wireless communications channel demand the use of a pulse shaping filter [8] as shown in figure 5.

These requirements are:

a)Generating band limited channels, and

b) Reducing Inter Symbol Interference (ISI) arising from multi-path signal reflections and also reduces adjacent channel interference.

By a pulse shaping filter which is applied to each symbol both requirements can be accomplished.

a. Nyquist techniques reduce the bandwidth requirement and eliminate inter symbol interference.

b. Non-Nyquist techniques reduce the bandwidth requirement but do not eliminate inter symbol interference.

F. FSK modulator

The FSK modulator converts the input bit stream into an electrical waveform suitable for transmission over the communication channel. Modulator can be effectively used to minimize the effects of channel noise, also to match the frequency spectrum of transmitted signal with channel characteristics, and to provide the capability to multiplex many signals.The output of the raised cosine filter is then used to build a complex envelope. The data are transmitted by shifting the frequency of a continuous carrier in a binary manner to one or the other of two discrete frequencies. One frequency is designated as the "mark" (1) frequency and the other as the "space" (0) frequency.

G. Channel

The Channel provides the electrical connection between the source and destination. The different channels which are used broadly are Coaxial cable, Optical fibre, pair of wires, Satellite channel, radio channel or combination of any of these.

H. Noise (Additive White Gaussian Noise (AWGN))

Noiseis random, undesirable electrical energy that can interfere with the transmitted message in a communications system. In communication systems, the most common type of noise added over the channel is the Additive White Gaussian Noise (AWGN). It is additive because the received signal is equal to the transmitted signal plus the noise. It is white because it has a constant power spectral density. It is Gaussian because its probability density function can be accurately modeled to behave like a Gaussian distribution. It is noise because it distorts the received signal. The more is the deviation of the received symbols as the variance of the noise is higher with respect to the constellation set and, thus in AWGN the probability to demodulate a wrong symbol is higher and make errors.

I. FSK demodulator

FSK demodulation is the process of recovering the original message from the information bearing waveform produced by the modulation is accomplished by the demodulator. The output of the FSK demodulator is bit stream.

J. Channel decoder (Line)

The Channel decoder recovers the information bearing bits from the coded binary stream. The channel decoder performs error detection and possible correction.

K. Source decoder

The source decoder converts the binary output of the channel decoder into a symbol sequence. The decoder for a system using fixed – length code word is very simple, but the decoder for a system using variable – length code words will be quite complex.

L. Frame Synchronization

Frame synchronization is required for properly grouping transmitted bits into an alphabet. In order to achieve this synchronization, a measure, consisting of cross correlation, is computed between the known marker bits and received samples.

M. Digital Output Stream

Recovers the message from the electric signal.

III. FSK PARAMETERS

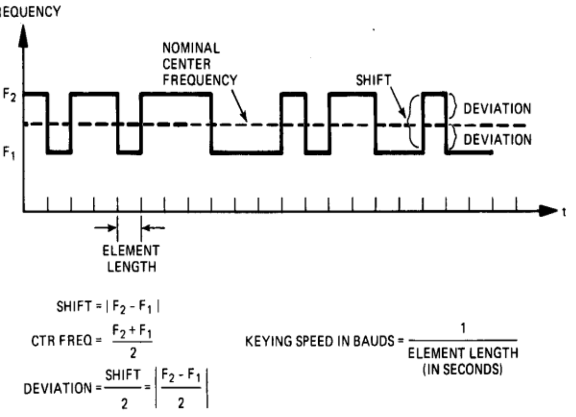


Fig.6. FSK Parameters

A. System Filter:

System filter parameter specifies either alpha (rolloff for raised cosine and square root raised cosine filters), or BT (the product of the -3 dB bandwidth and the symbol period for a Gaussian filter). This parameter is ignored when the pulse shaping filter parameter is set to none.

a. Alpha (roll-off factor):

Alpha defines the filter parameter for Raised Cosine and Root Raised Cosine. Which ranges from 0 to 1.

b. Filter length:

Filter length specifies the length of the transmit pulse shaping filter in symbol.

For example,when the Filter length equals 6 symbols, and the samples per symbol equals 4, then the overall filter length will be 4*6+1=25 samples.

B. Transmitter filters:

Transmitter filter defines the type of band-limiting filter employed at transmitter for pulse shaping the symbols output by the modulator.There are many different varieties of filtering as shown in figure 7. The most common are

- Raised cosine (Nyquist)
- Square-root raised cosine
- Gaussian filters

Raised cosine filter*:*The raised cosine filter is one of the most common pulse-shaping filters in communications systems. In addition, it is used to minimize inter symbol interference (ISI).

Root Raised Cosine Filter:The root raised cosine filter at low frequency produces a frequency response with unity gain and complete at higher frequencies.

Gaussian filter: The Gaussian pulse-shaping filter reduces the levels of side-lobes of the FSK & GMSK spectrum.

C. FSK System Parameters (M):

a. Symbol map: specifies an ordered array that maps each Boolean symbol to its desired deviation frequency. The number of FSK levels in the array must be 2^N, where N is the number of bits per symbol.

*b. Symbol phase continuity:*specifies whether the phase transitions between symbols are continuous.

Continuous (0): Specifies continuous phase transitions between symbols. This value is the default.

Discontinuous (1): Specifies discontinuous phase transitions between symbols, that is, discontinuous phase FSK (DPFSK).

c. *FSK deviation:* specifies the maximum FSK frequency deviation. At base band frequencies, deviations for individual symbols are evenly spaced in the interval [[$-f_d$, f_d], where f_d represents the frequency deviation. The default value is 15,000.

d. *M-FSK:* specifies the *M*-ary number, which is the number of distinct frequency deviations to use as symbols. This value must be a positive power of 2.As the number of levels increase the amount of information transmitted increases – but the probability of receiving an error also increases.

e. *Sample per symbol:*Samples per symbol are the ratio of the sampling rate employed by system to the transmitter symbol rate.

f. *Symbol rate or Baud rate (R_s), Hz:*The signal bandwidth for the communications channel depends on the symbol rate or also known as band rate. Symbol rate the number of transmitted symbols per second. R_s=1/T,T = time of one signaling element or Symbol period,The Symbol rate (R_s) is measured in symbol/second.

Symbol rate =bit rate/the number of bits transmitted with each symbol

IV. BIT ERROR RATE (BER) & SIGNAL-TO-NOISE RATIO (SNR)

A. Bit Error Rate (BER):

In communication system the bit error rate is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. In digital transmission or digital communication system, the number of bit errors is the number of received bits of a data stream over communication channels that have been altered due to noise, distortion, interference or bit synchronization errors in the system. The bit error rate or bit error ratio (BER) is the number of bit errors divided by the total number of transferred bits during a considered time interval. While the basic concept of BER measurement is simple send a data stream through the system and compare the output to the input its execution is not trivial. BER is a unit less performance measure, often expressed as a percentage (%). Over an infinitely long period of time, can assume that a data transmission is a random process. A pseudorandom data sequence is used for this test. The "Pseudo" random cannot create a truly random signal using deterministic (mathematical) methods. The BER parameter represents the current operating BER of a specific modulation type. This value depends on several channel characteristics, including the noise level and transmits power. Better accuracy of the transmitted digital signal is measured by BER (see figure 7). Simply put, BER is:

$$BER = \frac{The\ no.of\ error\ bits}{The\ total\ no.of\ bits}$$

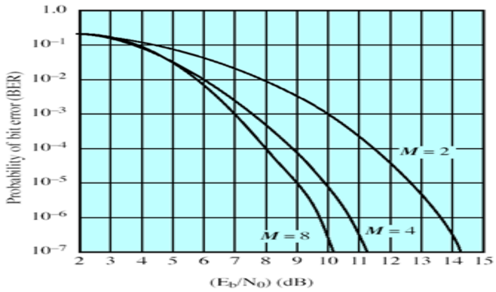


Fig.7. Theoretical BER vs. E_b / N_o for Multilevel FSK

B. Signal-to-Noise Ratio (SNR):

It is used to measure the quality of a system.The ratio of the modulated energy per information bit to the one-sided noise spectral density; namely,

$$SNR = \frac{Modulated\ energy\ per\ bit}{Noise\ spectral\ density} = \frac{E_b}{N_0} dB$$

To find the theoretical bit rate limit, SNR is defined as the ratio of a signal power to noise power and it is normally expressed in decibel (dB). The mathematical expression of SNR is

$$SNR = 10log_{10}\frac{Average\ signal\ power}{Noise\ signal\ power} dB$$

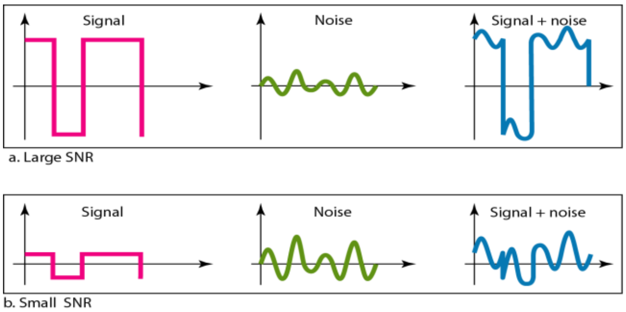


Fig. 8.Two cases of SNR: a high SNR and a low SNR

Consider the average signal power and the average noise power because these may change with time. Figure 8 shows the two cases of SNR. SNR is actually the ratio of what is wanted (signal) to what is not wanted (noise). A high SNR means the signal is less corrupted by noise; a low SNR means the signal is more corrupted by noise.

V. LABVIEW SIMULATION OF FSK TRANSRECEIVER

This section presents the Lab-VIEW software simulation of the FSK Transceiver system. Lab-VIEW is a graphical programming environment which allows one to design complex DSP systems in a relatively time-efficient manner as compared to textual programming. A Lab-VIEW program consists of two major components: Front Panel (FP) and Block Diagram (BD). A Front Panel provides a graphical user interface while a Block Diagram contains building blocks of a system resembling a flowchart.

VI. SIMULATION RESULT

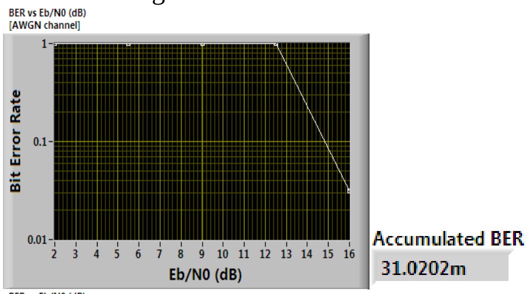
This section provides the design and simulation of the FSK Transceiver system for noisy channel. From the simulation results it can be seen that wireless system designed using FSK technique which has the major advantage in terms of Bit Error Rateproviding high data rate and SNR using Frequency Shift Keying Modulation technique which concludes that data errors can be minimized using coding techniques, hence improving Signal to noise ratio (SNR).Thus, the signal can be recovered with very less probability of error at the destination. The performance of 2, 4 and 8-level FSK systems in additive white Gaussian noise channel is evaluated and compared on the basis of the simulations in Lab-VIEW as shown in figures. In this simulation, the BERs are obtained by varying the values of Eb/No in the range of 2 to 16 The table 1 shows simulation Parameters.

Table 1: Simulation Parameters

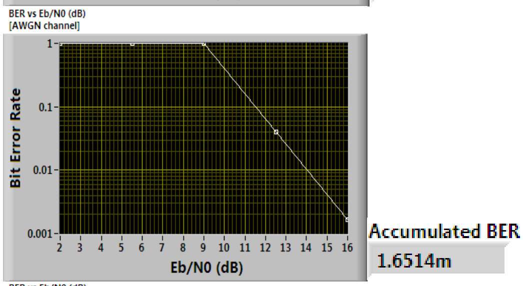
Sl. No.	Parameters	Values
1	PN sequence order	9
2	Eb/No	80 dB
3	Message symbol	1000
4	Transmission B.W (BT)	0.5
5	Symbol Phase Continuity	Continous
6	FSK fequency deviation (Hz)	25KHz
7	Filter used	Gaussian
8	Symbol Rate	100.00 KHz
9	Eb/No Sample	5
10	Sample per symbol	16
11	Modulation Index	0.5
12	BER vs Eb / No (without filter)	None
13	Current Eb/No	16 dB

BER vs SNR of FSK modulation scheme for different values of M is shown in Figure 9.

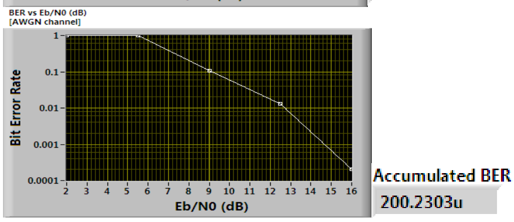
M=2



M=4



M=8



M	2	4	8
$\eta_B = \frac{2 \log_2 M}{M}$ bits/Hz (Band width efficiency)	1	1	0.75
BER	31.0202m	1,6514m	200.2303µ

(MFSK: by increasing *M* decreases BER and decreases bandwidth Efficiency)

Bandwidth efficiency defined as R_b/B bits per second per Hertz or [(2log2M/M)], where R_b is the data rate in bits per second, and B is the channel bandwidth.

Case1: When η_B<<1,

Bandwidth of the channel is large (relative to R_b), and the main concern is limitation on power. This case is usually referred to as power-limited case. Signaling schemes, with high dimensionality, such as simplex, orthogonal, and bi-orthogonal, are frequently used in these cases.

Case2: when η_B>>1,

Bandwidth of the channel is small (relative to R_b), and therefore is referred to as the bandwidth – limited case. In these case low dimensional signaling schemes with crowed constellations, for example, 256-QAM (Quadrature amplitude modulation), are implemented [7].

VII. CONCLUSION

In this paper, it is shown how Lab-VIEW can be used to build a FSK Transceiver for cognitive radio system. In particular, an FSK Transceiver system consisting of a message source, a pulse shape filter, a modulator, demodulator, a frame synchronizer, a phase continuity and frequency deviation was built in the graphical programming environment of Lab-VIEW. The use of Lab-VIEW allowed this interactive cognitive radio system to be built in a shorter time as compared to text-based programming languages.
The simulation results shows in terms of BER and SNR using Frequency Shift Keying Modulation technique which concludes that data errors can be minimized using coding techniques, hence improving Signal to noise ratio the signal can be recovered with very less probability of error with the increase in the M (number of levels) at the destination.

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