CHAPTER I

INTRODUCTION

1.1 Background

The proposed communication system in this thesis is based on the need for a more reliable communication system to transmit data from weather stations to the monitoring station. In a previous research conducted by Oka Mahendra [1–4], we have made an intelligent data logger system. The data logger reads the data from the sensors which can be configured based on the type of sensor and sensor value [1]. Communication system using Short Message Service (SMS) was added in the data logger [2]. By using SMS, the data transmitted from the sensor from a remote station (data logger) to the monitoring station (master). SMS data transmission system used in these systems is reliable, but it is relatively expensive. For a cheaper solution, we developed a communication system for data logger with General packet radio service (GPRS) [2]. GPRS systems meet the constraints in the network coverage and reliability. For data communication system in weather stations, failure rate on the GPRS system is 5.7 % [3] and 5.18 % [4]. To improve the reliability, the chosen alternative solution is to modulate the data on the mobile voice channel, because the use of the mobile voice channel is considered quite reliable and has wide coverage in each region.

In this research, the data will be modulated on the mobile voice channel. Testing will be performed primarily on the Global System for Mobile Communications (GSM) voice channel. We plan to use this channel for the weather stations of P2I (Research Center for Informatics) LIPI (Indonesian Institute of Sciences). Some of them will be placed in Cimahi, Bangka, Belitung, and Jakarta.

Communication system through GSM voice channel has been proposed by Rashidi [5]. Rashidi proposed and tested a method of digital data transmission over GSM voice channel. The process used is to transform digital data into speech-like waveform with a data-mapping. The system is optimized for use on the GSM full rate codec. Rashidi stated that he could achieve data rates 1.15 kbps for bit error rate (BER) 0.2 %, and 600 bps for BER 0.02 % after error correction code applied.

The method of sending data over voice channels was studied by Chmayssani [6]. Chmayssani used Quadrature amplitude modulation (QAM) and Frequency shift keying (FSK) modulation technique. This method is specifically used to address speech coder algorithm and Voice Activity Detector (VAD). The simulation results in a throughput of up to 3 kbps and bit error rate less than $3x10^{-3}$.

The method proposed by Rashidi and Chmayssani have problems when there is a change in the channel conditions, so the method is more suitable to be applied on a channel with certain characteristics that have been previously known. To make modulation-demodulation system more flexible, the new method proposed by Dhananjay [7], which is called Hermes. Hermes was developed to transmit digital data through an unknown voice channel characteristics. Binary frequency shift keying (BFSK) modulation was used. Frame transcoding using ½ codes. Initialization parameter determines the carrier frequency used, and then the frequency difference is determined by the hill-climbing algorithm. In this research, they achieve throughout of 1.2 kbps for BER of 10^{-5}.

Hermes method uses BPSK modulation and hill-climbing algorithm. It is good enough to select the best frequency to be used in the modulation system. Hermes is not adaptive, because the determination of the parameters is done only once, when the initialization is done. A number of carrier frequencies have been determined (BFSK), with the frequency difference can be varied as needed on the fly. In the Hermes system, he select the frequency in the certain band and fixed modulation scheme

(BFSK), so the other frequency bands and modulation schemes may be more optimal if used.

In a research conducted by Ali [8] the proposed system used M-ary FSK (MFSK) modulation. Ali [8] conducted research to find most optimal MFSK configuration on the GSM voice channel. The prototype produces a bit rate of 80 to 250 bps with BER < 10^{-2}. Given the GSM voice channel vocoder is adaptive multi rate (AMR), the modulation scheme (base frequency, modulation order, and rate) that is optimal in a lower AMR rate is not optimal for use at higher AMR rate.

In a research conducted by Ladoe [9], data are encoded into the symbols, and the symbols are voice coded as they were speech, modulated into the GSM signal, sent over the air, GSM demodulated, voice decoded, and converted back to data. The symbols are synthesized by a genetic algorithm with the aim of maintaining separability after passing them through the voice codec. The use of the genetic algorithm make the implementation is hardware dependent and is not able to be implemented in many low cost and low power microcontrollers.

1.2 Problems

The major challenges in the data communication over a mobile voice channel are the operation of speech coder or vocoder (AMR) and Voice Activity Detector (VAD) which makes the voice signal quality decreases. These challenges already have been addressed by previous researchers [5]-[9] with non-adaptive modulation configuration.

The other problem in sending data over mobile voice channel is how to get optimal effective data rate according the AMR rate. The optimal modulation configuration must be adaptively adjusted according the rate of AMR. If it is not adaptively adjusted, the modulation configuration will be chosen from the one that works at the lowest rate of AMR, whereas the other modulation configuration may obtain higher data rate at higher AMR rate. With the fixed modulation configuration, the effective data rate is not optimum.

1.2.1 Problem Limitations

1. Experiments were done in the laboratory, not in the real weather station location.
2. End user product was not built, but this research evaluates the possibility of using the method in its implementation.
3. Signal strength is provided by operator and uncontrollable.

1.2.2 Problems

Problems appointed in this research are:

1. How to convert digital data to voice like waveforms.
2. How to modulate the voice like waveform to be sent through GSM voice channel.
3. How to demodulate the modulated signal from GSM voice channel
4. How to make modulation and demodulation system work effective in lower bit error rate required by the application

1.2.3 Assumptions

This research uses the assumptions:

1. The operational of the modulator and demodulator is in a fix location.
2. The audio channel on mobile networks was observed and analyzed in this project is voice channels with narrow-band AMR vocoder.

1.3 Objectives

The research objective can be mentioned as follows:

1. Designing of an adaptive m-ary frequency shift keying (MFSK) for data communication between a remote weather station and master station.

2. Implementation of the modulator and demodulator of the adaptive MFSK.
3. Analysis of the experiment and the possibility of using the adaptive MSFK modulator and demodulator for the data communication

1.4 Hypothesis

The hypothesis of this research is the adaptive non-orthogonal MFSK method can increase the effective data rate according to the channel condition (AMR rate) with limited acceptable bit error rate (BER) in a fixed bandwidth allocation. Data rate will increase due to the method of maximizing the use of frequency or tones on the voice channel, so more data can be transmitted at the same time. The effective data rate will increase because at every vocoder rate, we adjust the modulation data rate optimally, not use the lowest modulation data rate for all vocoder rates.

If the data rate without an adaptive method is equal to V, then the data rate will be used in all the vocoder rates, where V is the data rate that can work with acceptable BER at the lowest rate of the vocoder. With the adaptive method, for higher AMR rates, the system can use higher data rates than V. With this method, the effective data rate is higher than the data rate for a non-adaptive modulation.

Based on the frequency shift, FSK modulation is divided into two types: orthogonal and non-orthogonal. In the orthogonal MFSK schemes, the minimum distance between the carrier frequencies is 1/2T for coherent detection and 1/T for non-coherent detection, where T is the symbol period. The bandwidth efficiency of MFSK decreases with increasing M [10], so increasing M in the fixed bandwidth orthogonal MFSK modulation does not increase the bit rate. Increasing M can decrease required SNR for constant bit rate because the higher M gives the longer period of the symbols. The longer period of the symbols, the easier the demodulator detect the symbols. A comparison of bandwidth efficiencies for the various MFSK modulation schemes is given in Table 1-1.

Table 1-1 Comparison of bandwidth efficiency in various orthogonal MFSK schemes [10].

M	Coherent MFSK	Non coherent MFSK
2	0.400	0.250
4	0.571	0.250
8	0.545	0.188

In the non-orthogonal MFSK design, it is expected that bit rate can be increased with increasing M. In this design, there is no minimum distance requirement for carrier frequencies. In the zero crossing demodulation, symbol error rate is proportionally related to the distance between two adjacent carrier frequencies. It is expected that we can assign as many as carrier frequency as long as symbol or bit error rate is acceptable.

Although the non-orthogonal MFSK is expected to increase the bit rate, this non-orthogonal scheme will inflict higher bit error rate than the orthogonal MFSK. Increasing M in the constant bandwidth will result the distance between two adjacent carrier frequencies become closer than the distance with lower M. The closer distance between two adjacent carrier frequencies, the more likely detector will give error in detection.

1.5 Research Method

Research methods used in this research are:

1. Literature study that is related to send the data through voice channel, modulation and demodulation technique, and GSM voice channel characteristics.

2. Designing a modulation and demodulation system using digital to analog converter and zero crossing detector.

3. Collecting the data of the modulator and demodulation performance.

4. Analyzing the data from the experiment of sending the data through GSM voice channel and find the optimum way to make an adaptive MFSK modulation.

5. Writing the report and publications.