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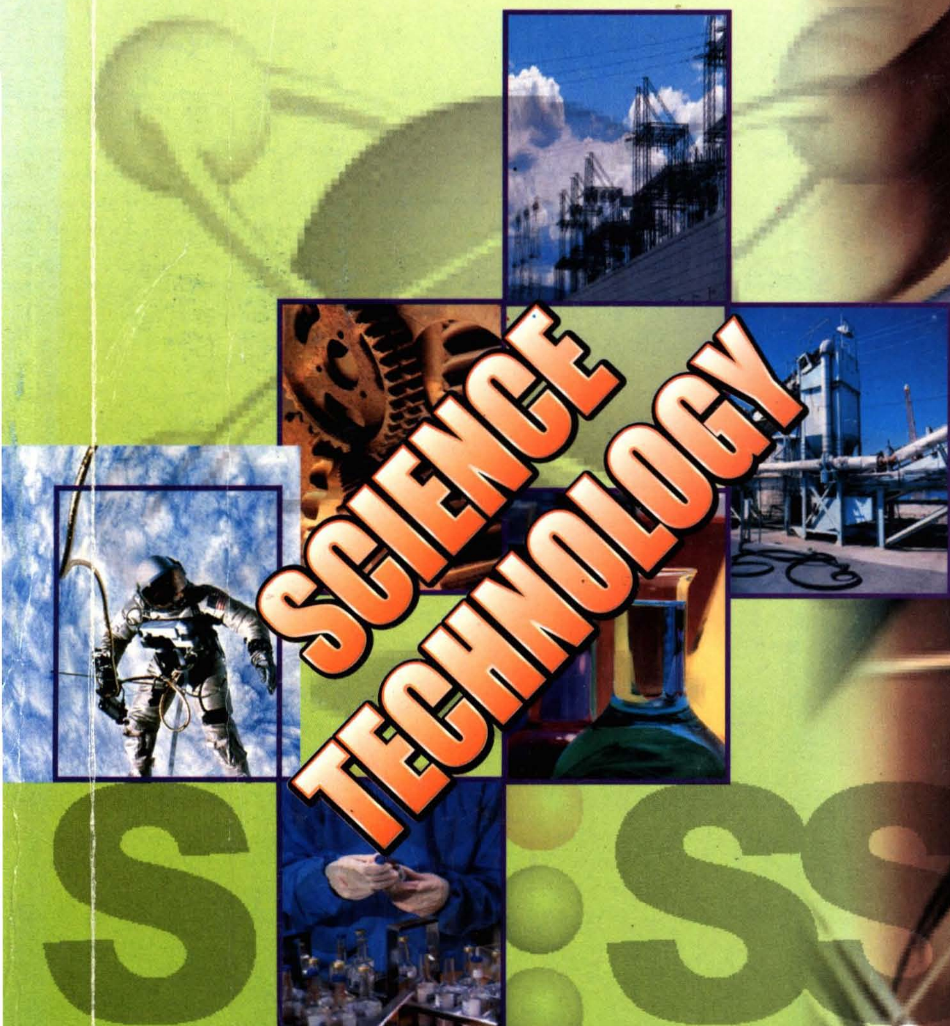

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A Base-Band I- Q GMSK Modulator Study

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ABSTRACT

This paper presents the I – Q Gaussian Minimum Shift Keying (I – Q GMSK) modulation technique. GMSK is a widely used modulation scheme because of its constant envelope property and spectral efficiency. We provide some simulation results of I-Q GMSK modulator which consists of ADC, NRZ –L, Gaussian LPF, integrator, computation of In-phase, and Quadrature-phase terms by using Matlab program. Then, this result is compare with the I-Q MSK modulator signal.

Keywords: *Gaussian Minimum Shift Keying, Inphase – Outphase GMSK, Analog to Digital Converter, Non Return to Zero Level, Gaussian Low Pass Filter, Minimum Shift Keying*

Introduction

Gaussian Minimum Shift Keying scheme is a binary digital frequency modulation technique with a modulation index of 0.5. It is widely used due to its fundamental property of constant envelope that is suitable for nonlinear amplification. Introduction of Gaussian low pass filtering increases the spectral efficiency of this modulation scheme by reducing the bandwidth of the main lobe and the spectra density of side lobes (Varma and Devesh, no date).

Ziemer and Ryan (1983) examine various methods in implementation of modulators for high data rate applications using GMSK. GMSK can be generated by modulating the frequency of a VCO directly using the base-band Gaussian pulse stream. Murota and Hirade [1981, July] explain the GMSK modulator using PLL modulator or an orthogonal modulator with digital waveform generators or a $\pi/2$–shift BPSK modulator followed by a suitable PLL phase smooter. A. Linz and A. Hendrickson (1996, January) describes an efficient method for generating equivalent base-band of an I–Q GMSK modulator, which errors are minimized. Generating of GMSK signal using a sigma delta ($\Sigma-\Delta)$ based open loop frequency modulator is demonstrated in a sigma delta based open loop frequency modulator by Daily and Carusone (2003). Varma and Devesh introduces a less complex algorithm in novel implementation of GMSK modulator.

GMSK Modulation

GMSK Signal Overview

GMSK is derived from continuous – phase FSK (CPFSK) by selecting the frequency deviation to be the minimum possible (MSK) and filtering the base-band modulating signal with Gaussian filter (GMSK). The base-band equivalent of the I-Q GMSK modulator is shown in Figure 1 Linz and Hendrickson 1996).

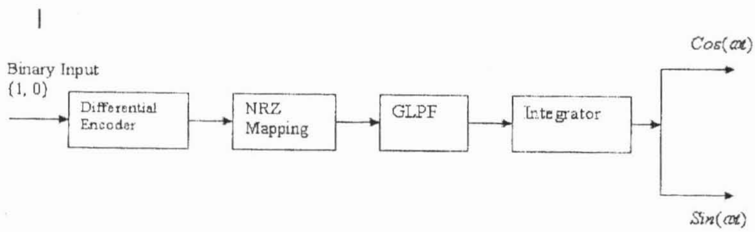

Figure 1: A Base– band I-Q GMSK Modulator

Figure 1 shows the modulation process which has two steps in GSM system. First step is regarding to the differential encoding and second step is about the GMSK modulation. Varma and Devesh (no date) and Laster (1997) show that in differential encoding, each input data bit d_i is differentially encoded using an exclusive operation, where the resulting output of the differential encoder is;

$$\hat{d} = d_i \oplus d_{i-1} \qquad (d_i \in \{0,1\}) \tag{1}$$

The differentially encoded bits are then mapped to get NRZ bits as;

$$\alpha_i = 1-2\hat{d}_i \qquad \alpha_i \in \{-1,+1\} \tag{2}$$

These NRZ bits are then subjected to GMSK modulation. The GMSK modulated signal generated by exciting a linear filter which impulse response is;

$$g(t) = h(t) * rect\left(\frac{t}{T}\right) \tag{3}$$

With data values $\{\alpha_i\}$, where * denotes convolution of notion. The function $rect(t)$ is defined as;

$$rect\left(\frac{t}{T}\right) = \begin{cases} 1/T & for\,|t| < \frac{T}{2} \\ 0, otherwise \end{cases} \tag{4}$$

In (3), $h(t)$ is given by;

$$h(t) = \frac{1}{\alpha T\sqrt{2\pi}} \exp\left(\frac{-t^2}{2\sigma^2 T^2}\right) \tag{5}$$

where $\sigma = \frac{\sqrt{\ln(2)}}{2\pi BT}$ with $BT = 0.3$ for GSM and BT=0.5 for CDPD

Here, B is the $3dB$ bandwidth of the G-LPF with impulse response $h(t)$, and T is the duration. The pulse response $g(t)$ can be written as;

$$g(t) = \frac{1}{2T}\left[Q\left(2\pi BT\,\frac{t-T/2}{T\sqrt{\ln(2)}}\right) - Q\left(2\pi BT\,\frac{t+T/2}{T\sqrt{\ln(2)}}\right)\right] \tag{6}$$

Whereas the Q – function, $Q(t)$;

$$Q(t) = \int_t^\infty \frac{1}{\sqrt{2\pi}} \exp(-\tau^2/2)\,d\tau$$

$g(t) = 0$ for $0 \le t \le LT$ with L defined as the number of intervals over which the pulse is spread.

The phase of the modulated signal is;

$$\theta(t) = \sum_i m_i \,\pi h \int_{-\infty}^{t-iT} g(u)\,du \tag{7}$$

where $m_i \in \{\pm 1\}$ is the modulating Non Return to Zero (NRZ) data. The modulation index h = 0.5 results in the maximum phase change of $\pi/2$ radians per data interval. The final GMSK signal is represented as;

$$S(t)_{GMSK}(t) = \sqrt{\frac{2Eb}{T}} \cos\left(2\pi fot + \theta(t) + zo\right) \tag{8}$$

Where Eb is the signal energy per bit and zo is a random phase constant which can be assumed to be zero $(zo = 0)$

GMSK Application

From Laster (1997), we can understand that GMSK has been used in many important wireless standards. GMSK (with BT = 0.3) is the modulation format in Group Special Mobile, or GSM (also known as Global System for Mobile Communications) and BT = 0.5 for CDPD (Cellular Digital Packet Data). Others system like a Digital European Cordless Telephony (DECT), DCS1800 (Digital Communications System in the 1800 MHz band) and PCS1900 (Personal Communications System in the 1900MHz band) also using the GMSK format.

GMSK Simulation Result

Signal Waveforms

The modulated signal waveforms are generated by MATLAB like shown in Figure 2. The first plot is randomly generated data to be transmitted. The second and the third plots are in-phase and quadrature components respectively. The last plot is passband signal waveform and power spectrum density. From the plots, the result can notice that GMSK signal waveforms are quite smooth, phase change gradually without any abrupt jump. Another obvious property of GMSK is that it has constant envelope.

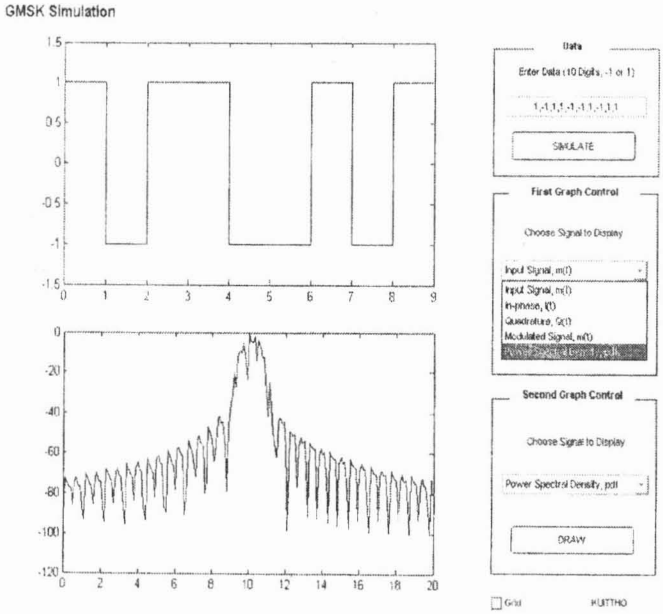

Fig. 2: GMSK Simulation will Plot Input Signal, in Phase and q Phase Signal, Modulated Signal and Power Spectrum Density

Result Comparison

The signal streams are used in this project is NRZ-L. NRZ-L is used extensively in digital logic circuits. A binary signal is represented by one voltage level and binary zero is represented by another voltage level. There is a change in level when the data changes from one to zero or from zero to a one. When the NRZ-L is performed, the zero, or space, is represented by a change in level, and the one, or mark, is represented by no change in level.

For a data stream of 8 bits, the odd and even bits are separated for I and Q modulation. The input data of sequence above e.g. [1,-1, 1, 1,-1, 1, 1].

- I and Q can be defined as:
  Even

  $\alpha_I(t)\cos(\pi t/2T)$

  $d_1(t) = d_0, d_2, d_4, ...(even\ bits)$

  Odd

  $\alpha_Q(t)\sin(\pi t/2T)$

  $d_2(t) = d_1, d_3, d_5, ...(odd\ bits)$

It can be seen how these data are separated. The original bit stream as well as the I and Q components can clearly be seen.

- I Bit Stream Times Carrier

  $$a_I(t)\cos(\frac{\pi t}{2T}) \bullet \cos 2\pi f_c t$$

- Q Bit Stream Times Carrier

  $$a_Q(t)\cos(\frac{\pi t}{2T}) \bullet \cos 2\pi f_c t$$

The combination of these two signals provides the modulated signal as seen in Figure 2 and Figure 3.

Conclusion

In this paper we present the I-Q GMSK modulator base band signal. The GMSK simulator was developed and displays the I- phase signal, Q- phase signal, GMSK signal and power spectrum density (psd). The comparison of signal characteristic between GMSK and MSK is also given. Further analysis to calculate BER value for both modulation scheme in AWGN and fading channel is recommended.

References

Daily, D. & Carusone, A.C. (2003). *A Sigma Delta Based Open Loop Frequency Modulator*. University of Toronto.

Laster, J. D. (1997). *Robust GMSK Demodulation using Demodulator Diversity and BER Estimation*. PhD Thesis. Virginia Polytechnic Institute and State University.

Linz, A. &. Hendrickson, A. (1996, January). *Efficient Implementation of an I-Q GMSK Modulator*. IEEE Trans. On Circuit and Systems, vol. 43, No 1.

Murota, K. & Hirade, K. (1981, July). *GMSK Modulation for Digital Mobile Radio Telephony*. IEEE Trans. Commun., vol. COM-29, pp.1044-1050.

Rodger E. Ziemer & Carl R. Ryan. (1983, October). *Minimum-Shift Keyed Modem Implementations for High Data Rates*. IEEE Communications Magazine, pp. 28.

Varma, N. &. Devesh, K. (no date). *A Novel Complexity GMSK Modulator for GSM/GPRS*. India: Hellosoft Pvt. Ltd.

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