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GMSK- WORLD'S MOST WIDELY USED MODULATION TECHNIQUE

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Abstract

GMSK is a spectrum-efficient modulation scheme, and it is adopted as the modulation standard of GSM systems. GMSK is used in, several mobile systems around the world. Global Speciale Mobile (GSM), Digital European Cordless Telephone(DECT), Cellular Digital Packet Data(CDPD), DCS1800 (Digital Communications Systems in the 1800 MHz band) in Europe, and GSM-based PCS1900(Personal Communications Services in the 1900 MHz band) in the U.S. uses GMSK. In this paper we have shown the generation of GMSK signal using quadrature baseband processor The phase and amplitude relations between carrier cycles over adata bit are developed, enabling rigourous modelling of ensemble fields to be carried out.In this paper we are demonstrating the use of GMSK modulation Technique in GSM by looking at a Gaussian filter with a bandwidth of Bb =1000 and a bit rate of T=1/2000, i.e. a normalised bandwidth BN=Bb.T =0.5 and at a modulation rate of 271kbauds. For a BN of 0.5 the filter response is truncated, symmetrically around zero, to two bit periods, i.e. from -T to T. However, because of its phase modulation, Gaussian filtering, and partial response signaling properties, GMSK is not a linear modulation.

1. Introduction

This paper discusses the modulation technique being used in GSM (Global System for Mobile Communication) i.e. about GMSK(Gaussian minimum shift keying).GMSK is most notably used in the Global System for Mobile Communications (GSM) in most of the world's 2nd generation cell phones. It is also used in 802.11 FHSS, Bluetooth, and many other proprietary wireless modems.

GMSK is explained through following:-

i. Modulation
ii. CPM(Continuous Phase Modulation)
iii. GMSK
iv. GSM and GMSK (With graphs and block diagram)

2. Modulation

In telecommunications, modulation is the process of varying a periodic waveform, i.e. a tone, in order to use that signal to convey a message, in a similar fashion as a musician may modulate the tone from a musical instrument by varying its volume, timing and pitch. Normally a high-frequency sinusoid waveform is used as carrier signal. The three key parameters of a sine wave are its amplitude ("volume"), its phase ("timing") and its frequency ("pitch"), all of which can be modified in accordance with a low frequency information signal to obtain the modulated signal. A device that performs modulation is known as a modulator and a device that performs the inverse operation of modulation is known as a demodulator (sometimes detector or demod).

The aim of digital modulation is to transfer a digital bit stream over an analog bandpass channel, for example over the public switched telephone network (where a filter limits the frequency range to between 300 and 3400 Hz) or a limited radio frequency band.

The aim of analog modulation is to transfer an analog lowpass signal, for example an audio signal or TV signal A device that can do both operations is a modem (short for "MOdulate-DEModulate"))., over an analog bandpass channel, for example a limited radio frequency band or a cable TV network channel. Analog and digital modulation facilitate frequency division multiplex (FDM), where several low pass information signals are transferred simultaneously over the same shared physical medium, using separate bandpass channels.

The aim of digital baseband modulation methods, also known as line coding, is to transfer a digital bit stream over a lowpass channel, typically a non-filtered copper wire such as a serial bus or a wired local area network.

The aim of pulse modulation methods is to transfer a narrowband analog signal, for example a phone call over a wideband lowpass channel or, in some of the schemes, as a bit stream over another digital transmission system.

3. CPM (Continuous Phase Modulation)

Continuous phase modulation (CPM) is a method for modulation of data commonly used in wireless modems. In contrast to other coherent digital phase modulation techniques where the carrier phase abruptly resets to zero at the start of every symbol (e.g. M-PSK), with CPM the carrier phase is modulated in a continuous manner.

For instance, with QPSK the carrier instantaneously jumps from a sine to a cosine (i.e. a 90 degree phase shift) whenever one of the two

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message bits of the current symbol differs from the two message bits of the previous symbol. This discontinuity requires a relatively large percentage of the power to occur outside of the intended band (e.g., high fractional out-of-band power), leading to poor spectral efficiency.

Furthermore, CPM is typically implemented as a constant-envelope waveform, i.e. the transmitted carrier power is constant. Therefore, CPM is attractive because the phase continuity yields high spectral efficiency, and the constant-envelope yields excellent power efficiency. The primary drawback is the high implementation complexity required for an optimal receiver.

3.1 Phase Memory

Each symbol is modulated by gradually changing the phase of the carrier from the starting value to the final value, over the symbol duration. The modulation and demodulation of CPM is complicated by the fact that the initial phase of each symbol is determined by the cumulative total phase of all previous transmitted symbols, which is known as the phase memory. Therefore, the optimal receiver cannot make decisions on any isolated symbol without taking the entire sequence of transmitted symbols into account. This requires a Maximum Likelihood Sequence Estimator (MLSE), which is efficiently implemented using the Viterbi algorithm.

3.2 Phase Trajectory

Minimum-shift keying (MSK) is another name for CPM with an excess bandwidth of ½ and a linear phase trajectory. Although this linear phase trajectory is continuous, it is not smooth since the derivative of the phase is not continuous. The spectral efficiency of CPM can be further improved by using a smooth phase trajectory. This is typically accomplished by filtering the phase trajectory prior to modulation, commonly using a Raised Cosine or a Gaussian filter. The raised cosine filter has a strictly finite duration, and can yield a full-response CPM waveform that prevents Intersymbol Interference (ISI).

3.3 Partial Response CPM

Partial-response signaling, such as duo-binary signaling, is a form of intentional ISI where a certain number of adjacent symbols interfere with each symbol in a controlled manner. A MLSE must be used to optimally demodulate any signal in the presence of ISI. Whenever the amount of ISI is known, such as with any partial-response signaling scheme, MLSE can be used to determine the exact symbol sequence (in the absence of noise). Since the optimal demodulation of full-response CPM already requires MLSE detection, using partial-response signaling requires little additional complexity, but can afford a comparatively smoother phase trajectory, and thus, even greater spectral efficiency. One extremely popular form of partial-response CPM is GMSK, which is used by GSM in most of the world's 2^{nd} generation cell phones. It is also used in 802.11 FHSS, Bluetooth, and many other proprietary wireless modems.

4 GMSK (Gaussian Minimum Shift Keying)

In digital communication, Gaussian minimum shift keying or GMSK is a continuous-phase frequency-shift keying modulation scheme. It is similar to standard minimum-shift keying (MSK); however the digital data stream is first shaped with a Gaussian filter before being applied to a frequency modulator. This has the advantage of reducing sideband power, which in turn reduces out-of-band interference between signal carriers in adjacent frequency channels. However, the Gaussian filter increases the modulation memory in the system and causes intersymbol interference, making it more difficult to discriminate between different transmitted data values and requiring more complex channel equalization algorithms such as an adaptive equalizer at the receiver.GMSK is most notably used in the Global System for Mobile Communications (GSM).

4.1 Spectral Efficiency

GMSK has high spectral efficiency, but it needs higher power level than for instance Quadrature phase-shift keying (QPSK) to reliably communicate the same amount of data.After acceptance of Gaussian-filtered minimum shift keying (GMSK) modulation for the Global System for Mobile Communications (GSM) in Europe, this digital modulation technique had been adopted for other new mobile telephone systems and digital wireless data services all over the world. GMSK is the world's most widely used modulation technique for mobile digital telephony and digital wireless applications. GMSK has two types of modulator structures, the voltage controlled oscillator (VCO) and the quadrature modulator structure. The tremendous advantages of the quadrature modulator structure for practical GMSK modulator implementations are emphasized.

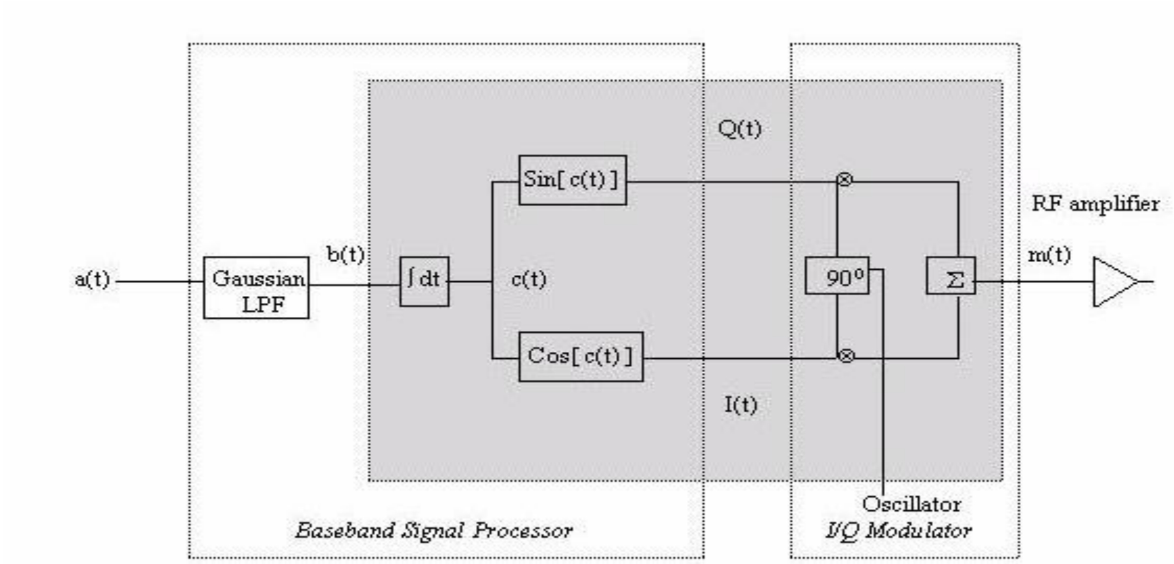

Fig 1. GMSK implemented by quadrature baseband method

Since quadrature modulator structures are used in nearly all practical GMSK chipsets, the properties of this structure are of wide interest. In this paper we highlight the crosscorrelation properties of the GMSK in-phase and quadrature-phase baseband signals, which are part of the quadrature modulator structure.

While uncorrelated in-phase and quadrature-phase baseband signals are used in traditional QPSK and OQPSK modulated systems, there is strong crosscorrelation between the in-phase and quadrature-phase baseband signals. The crosscorrelation is stronger if the observation interval is shorter. Crosscorrelated quadrature modulated systems include FQPSK-KF and GMSK.

5. GSM and GMSK

GSM is a cellular network, which means that mobile phones connect to it by searching for cells in the immediate vicinity. GSM networks operate in four different frequency ranges. Most GSM networks operate in the 900 MHz or 1800 MHz bands.

The modulation used in GSM is Gaussian minimum-shift keying (GMSK), a kind of continuous-phase frequency shift keying. In GMSK, the signal to be modulated onto the carrier is first smoothed with a Gaussian low-pass filter prior to being fed to a frequency modulator, which greatly reduces the interference to neighboring channels (adjacent channel interference).

To demonstrate this, we are looking at a filter with a bandwidth of Bb =1000 and a bit
rate of T=1/2000, i.e. a normalised bandwidth BN=Bb.T =0.5.

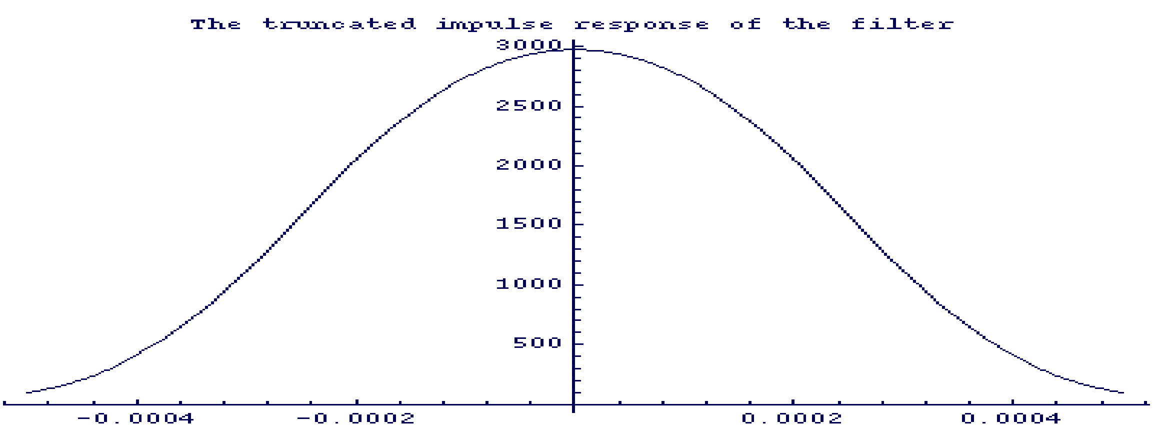

Fig 2. The Turnonated Impulse response of the filter

The impulse response of the Gaussian low-pass filter has to be truncated and scaled, according to the BN value, to ensure that the effect of a single 1 passing through the filter, is a phases change of p/2.

For a BN of 0.5 the filter response is truncated, symmetrically around zero, to two bit periods, i.e. from -T to T.To demonstrate the modulation, we are using the following randomly chosen binarydata stream. (This data stream repeats after 12 bits.)

{1,1,-1,1,1,-1,-1,1,-1,1,-1,-1, 1,1,-1,1,1,-1,-1,1,-1,1,-1,-1,............}.

The beginning of this data stream can be represented graphically by the following

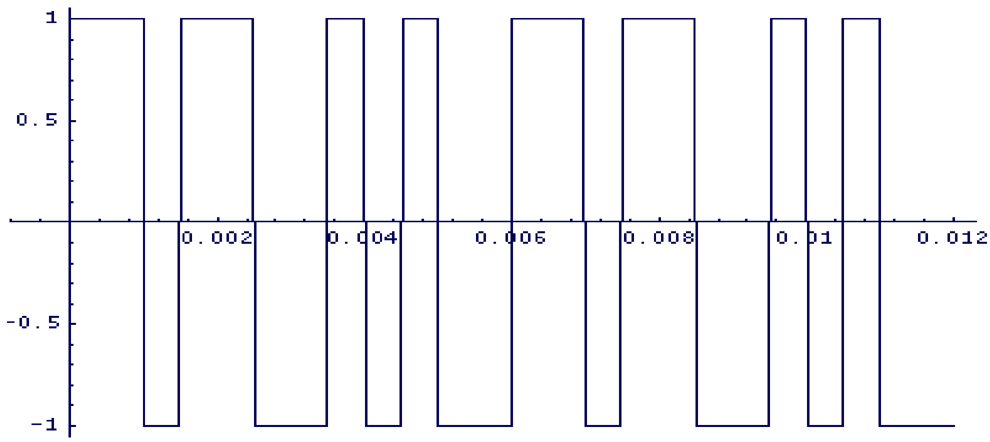

Fig 3. Representation of Data Stream

The first few Gaussian shaped pulses are represented graphically in the following figure.

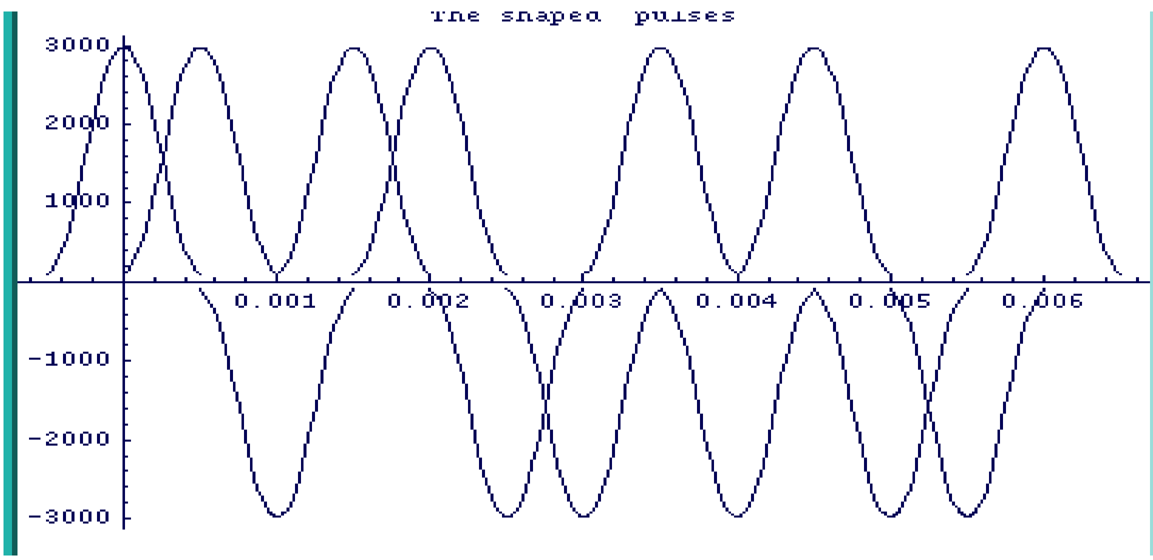

Fig 4. The first few Gaussian shaped pulses

The GMSK signal m(t) is represented

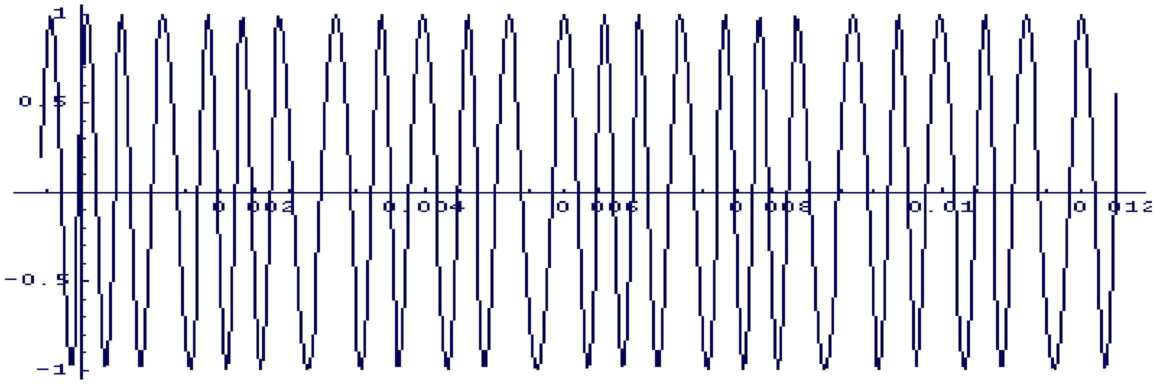

Fig 5. GMSK signal m(t)

5.1 Conclusion

GSM uses the Gaussian Minimum Shift Keying (GMSK) with modulation index $h = 0.5$, BT (filter bandwidth times bit period) equal to 0.3 and a modulation rate of 271 (270 5/6) kbauds. The GMSK modulation has been chosen as a compromise between a fairly high spectrum efficiency (of the order of 1 bit/Hz) and a reasonable demodulation complexity. GMSK differs from Minimum Shift Keying (MSK) in that a pre-modulation Gaussian filter is used. The time-domain impulse response of the filter is described in Equation 1, where

$k_1 = \frac{\pi}{\sqrt{2 \ln 2}}$ and B is the half-power bandwidth.

$$h(t) = \frac{k_1 B}{\sqrt{\pi}} e^{-k_1^2 B^2 t^2}$$

A block diagram of a GMSK modulator is as shown below:-

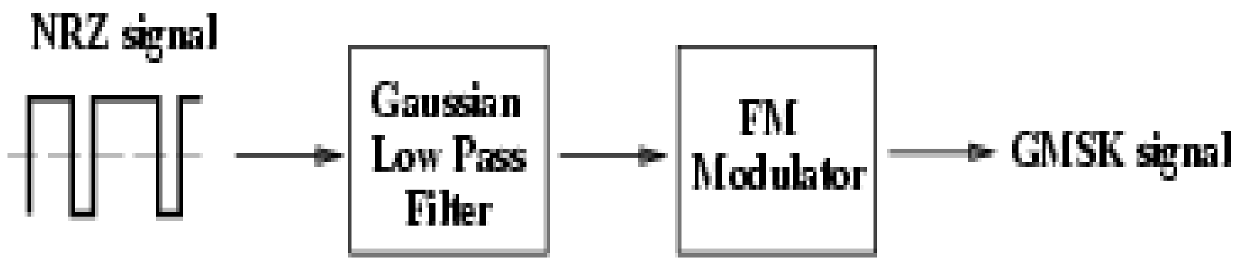

Fig 6 Block diagram of a GMSK modulator

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