A Continuous Phase Modulation Scheme for Telemedicine Systems

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Abstract: - We study the use a continuous phase modulation (CPM) system providing mobile data service with QPSK transmission for a telemedicine system. The results of using an I/Q modulation and CPM schemes with their BER performance are compared. The system provides direct symbol-by-symbol detection with no special decoding mechanism necessary. We have compared the performance in bit error rate (BER) with coherent detection of CPM and I/Q modulation. The scheme offers high bandwidth and power efficiency making it particularly suitable for telemedicine applications.

Key-Words: - modulation, polarization, rain, wireless networks

1 Introduction

Telemedicine systems require transmission of a large amount of data such as images showing the extent of injury suffered by a patient and medical history of a patient. Bandwidth availability becomes an important factor to provide such services and to incorporate emerging technologies for service enhancement. Since most existing network access systems such as wireless local area network (WLAN) and wireless local loop (WLL) operate in the very congested part of radio spectrum, maximizing utilization of licensed bandwidth is therefore a crucial issue for both service providers and subscribers. While the choice of modulation scheme has a significant impact on the bandwidth efficiency, parameters such as noise immunity and receiver circuit complexity is compromised when using more bandwidth efficient modulation schemes. In mobile computing applications, modulation schemes that have a constant or near constant envelope are often desirable due to power amplification requirements. Continuous phase modulation (CPM) provides a bandwidth and power efficiency transmission method that is particularly suitable for small portable network nodes such as laptop computers, personal digital assistants (PDAs), and cellular phones. Quadrature phase shift keying (QPSK or 4-QAM) is a popular choice for minimizing equipment bulkiness and power consumption with the added advantage of a relatively wide geographical coverage.

This paper presents results of CPM using QPSK scheme applied to a broadband wireless access (BWA) network for a telemedicine system developed to provide data transfer for personnel attending accident scenes. In a wideband communications system where power and spectrum efficiencies are important considerations in system implementation, the complexity of system circuitry can be reduced by the use of QPSK compared to higher order M-ary QAM making it more suitable for highly portable devices for used by paramedics attending an accident scene. Earlier research has been performed on a 120Mbps radio link for QPSK signals [1], which proposes a remote modulation architecture. Based on this result, we work on a system with CPM scheme for QPSK signal that has been implemented under I/Q modulation with quasi-constant amplitude and continuous phase properties. Also, the low power transmitter used in this scheme eliminates the need for a power amplifier since the carrier is directly modulated at the pre-determined power level by a local oscillator before transmission [2].

This paper is organized as follows. Section 2 defines the problems that lead to the study of using CPM and Section 3 discusses various modulation options and the reasons for choosing QPSK for CPM. The system is discussed in Section 4 followed by its performance analysis in Section 5. Finally, Section 6 concludes the paper.

2 Problem Formulation

Low power single-chip wireless transceivers using I/Q modulation have been widely used in mobile devices [3]. With I/Q modulation, signal mixing and matching between signal paths require high precision circuitry in order to minimize gain and phase mismatch. To reduce circuit complexity that in turn provides a transmitter circuit with lower cost and power consumption, we investigate the potential improvement on system performance using CPM for telemedicine applications to facilitate transmission of data between the hospital and personnel attending an accident scene. The constant envelope requirement can be achieved by QPSK with optimized bandwidth and power efficiencies.

3 Modulation Scheme

Spectral efficiency is an important factor in wireless multimedia services at a metropolitan scale since available channels for a given network are primarily predetermined by local authorities and operational environments. Further, wireless communication channels suffer from multipath fading particularly at radio frequencies around 10 GHz due to long path lengths. The use of multicarrier modulation such as OFDM provides numerous advantages in terms of bandwidth efficiencies and minimizing the effects of multipath [4], [5]. However, single carrier modulation schemes such as variants of QAM are more suitable for mobile applications due to the following features: efficient and low power consumption [6]. Further, high level of noise immunity with low order modulation is a good reason to choose a modulation such as QPSK.

While high order modulation schemes such as 64-QAM or above offer high bandwidth efficiency, the requirements for highly sophisticated circuitry make equipment expensive to manufacture. In addition, severe cell-to-cell interference and reduction in range make it undesirable when a high degree of mobility is required. In spite of a lower bandwidth, QPSK offers the best compromise as it is easy to implement and more tolerant to interference and noise. Low cost consumer devices can be built with a high level of mobility due to size, weight and power consumption. Therefore QPSK is optimal for consumer applications with high mobility [7].

CPM is an efficient transmission scheme because its constant envelope provides a high level of power efficiency and the constant phase continuity provides a high level of spectral efficiency. The generated signal is given by

$$s(t) = A\cos(w_c + f(t)) \qquad (1)$$

where A is the amplitude, wc is the angular carrier frequency and *f(t)* is the phase. A CPM scheme for QPSK signal with quasi-constant amplitude and continuous phase properties is chosen with a modulation index of 0.5 being that of Tamed Frequency Modulation (TFM) which can be generated by an FM modulator [8], [9].

4 Telemedicine System

The system is developed based on that proposed in [10]. The configuration of our QPSK modulator is shown in Fig. 1. The system is proposed for transmission of 45 Mbps over a wireless link with 13 GHz carrier. The transmitted data sequence is converted to a 2-bit parallel data sequence by the serial-to-parallel (S/P) converter. The symbol duration T_s is twice the bit duration T_b (i.e. $T_s = 2\,T_b$). The baseband signal of the incoming data is given by

$$b(t) = \sum_{i=0} b_i d(t - iT_s) \qquad (2)$$

where $d(t)$ is the Dirac's delta function and b is the transmitted symbol at time $t = nT_s$

From (1), the differential encoder produces data represented by

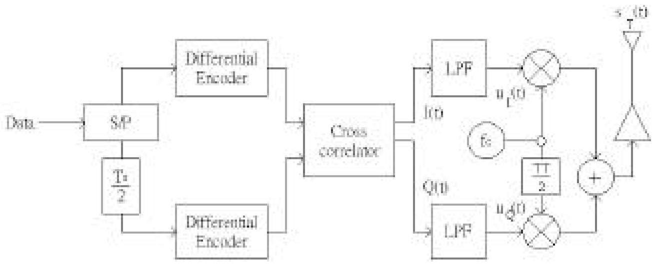

Fig 1. Block diagram of system modulator structure

$$s(t) = \frac{1}{2}(1 + \cos\frac{2pt}{T_s}) \qquad (3)$$

A cross correlator is added to compensate for a 3 dB envelope the fluctuation in modulated signal. The signal is then filtered by a Nyquist low pass filter having impulse response

$$h(t) = \frac{1}{pt}.\frac{1}{1-(Wt)^2}\sin\left[2p.(1-a)\frac{t}{T_s}\right] + \frac{1}{p}.\frac{W}{1-(Wt)^2}\cos\left[2p\,(1+a)\frac{t}{T_s}\right] \qquad (4)$$

where $W = \frac{4a}{T_s}$

In a CPM signal, the modulated signal represents information in continuously varying frequency and phase with the envelope remains unchanged. The phase alters in the I/Q phase space as described by [11]. The initial phase is π/4. At the I/Q modulator, a carrier of frequency f_c is modulated by $u(t)$ for transmission where the transmitted signal is represented by

$$s_T(t) = u_I(t)\cos(w_c t) - u_Q(t)\sin(w_c t) \qquad (5)$$

where $w_c = 2\pi f_c$

The I/Q signals are correlated to obtain a quasi-constant amplitude. The general form of a CPM signal is represented by:

$$s(t) = \sqrt{\frac{2E}{N_0}}\cos[w_0 t + f(t) + f_0] \qquad (6)$$

where E is the symbol energy, N_0 is the noise energy, f_0 is any arbitrary carrier phase and $f(t)$ is the information carrying phase function which is given by

$$f(t) = 2p\int_0^t \sum_{i=-\infty}^{\infty} h_i a g(t - iT)dt \qquad (7)$$

as a function of the frequency pulse shape g, which is the impulse response of the pre-modulation filter, h_i are the modulation indices that alter periodically based on the i^{th} term. Finally, a represents each element of the binary data sequence. A single phase change between two adjacent phase points at $t = 2n.T_b$ and the next point $t = (2n + 1).T_b$ is given by their phase difference as

$$\Delta f_{2n} = f[(2n+1).t_b] - f(2n.T_b) \qquad (8)$$

From (7),

$$\Delta f = 2p\sum a h_i((n-i+1).T_b - q((n-i).T_b)) \qquad (9)$$

$$q(t) = \int_{-\infty}^{t} g(t)dt$$

with q being a phase pulse shape function of g. A continuous phase change is given by the alteration between $2n.T_b$ and $(2n + 1).T_b$ with quasi-constant amplitude in the CPM signal.

5 System Performance

Computer simulations have been performed to evaluate the performance of QPSK with CPM under various conditions as described below.

5.1 BER Performance under AWGN

The system performance under the presence of additive white Gaussian noise (AWGN) is shown in Fig. 2, which shows a 0.3 dB loss at BER = 10^{-4} relative to the performance of I/Q modulation under the influence AWGN based on coherent detection. The curve below represents the results for I/Q modulation while the curve above represents a CPM QPSK. It shows that CPM offers a very slight improvement in BER performance over I/Q modulation. The link availability is compared in Fig. 3 and it shows that CPM offers marginally larger coverage, a range of 5 km for an availability of 99.99%. Finally, the spectrum utilization efficiency require to achieve a bit error probability of 10^{-6} is shown in Fig. 4. Again, similar E_b/N_o performance is

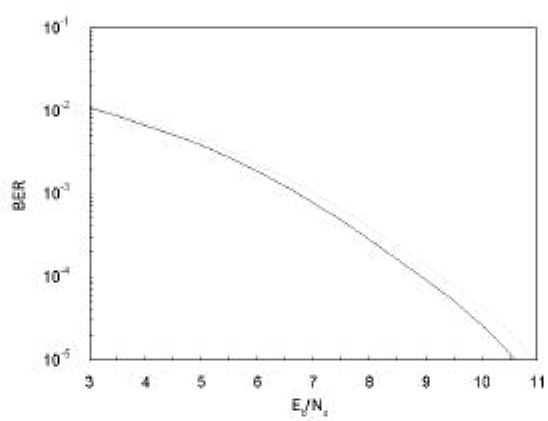

Fig 2. Performance of QPSK with I/Q and CPM

observed between CPM and I/Q modulation under the presence of low level AWGN simulation parameters are based on [12] by assuming the number of paths *L* is 5. Results show that increase in *m* achieves a slight but noticeable improvement.

5.2 Effects of rain attenuation

The presence of rain has a significant impact on outdoor wireless channels. Rainfall causes depolarization, and signal loss due to rain is more severe with horizontal polarization [13]. The availability of vertically polarized signals under the influence of rainfall is presented in Fig. 5. Simulation results show that a sharp decrease in coverage is observed up to approximately 70 mm/hr and the signal loss decreases almost linearly at a much slower rate above 70 mm/hr. Finally, a comparison of necessary fade margin for vertically polarized signals transmitting I/Q and CPM QPSK with 99.99% availability is shown in Fig. 6. Result shows that their required fade margin is almost identical with a bandwidth of 50 MHz.

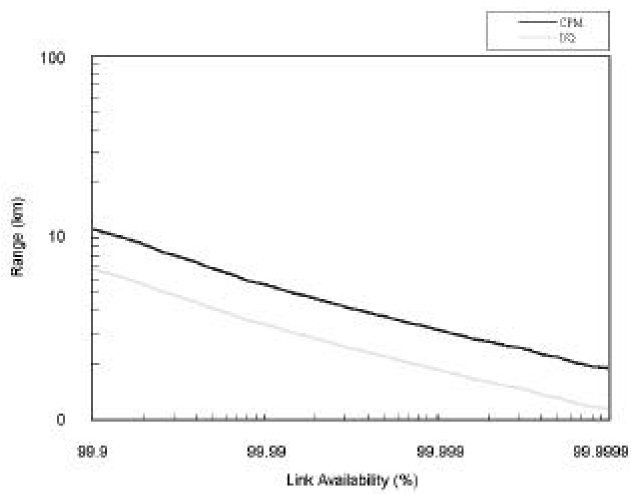

Fig. 3 Link availability analysis

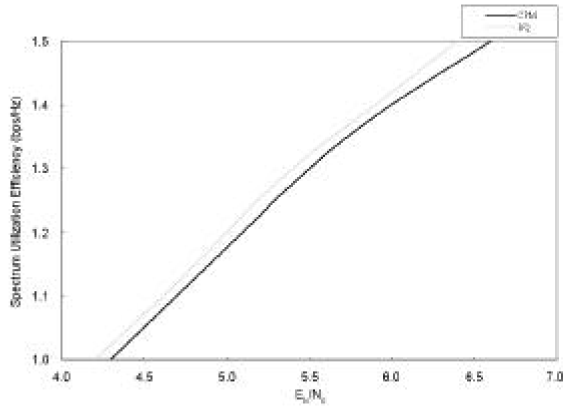

Fig. 4 Spectrum Utilization Efficiency

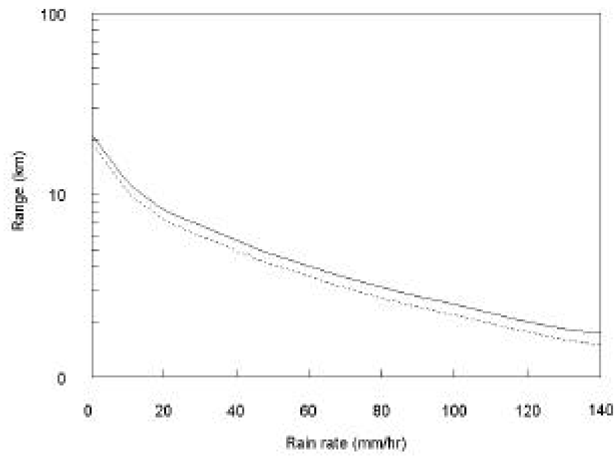

Fig. 5 Link coverage decreases under heavy rainfall

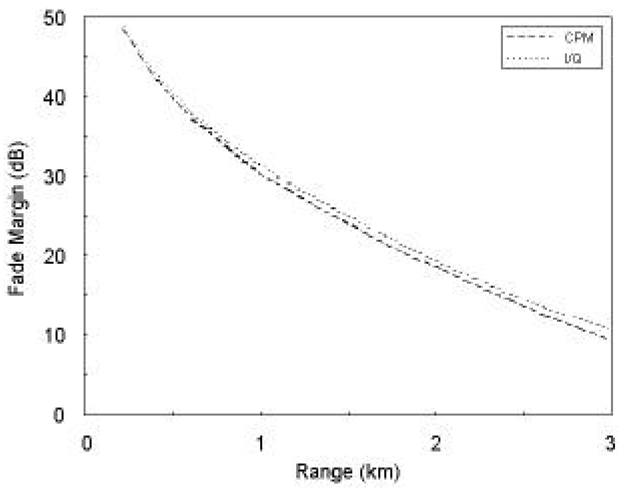

Fig. 6 Fade margin comparison for 99.99% availability

6 Conclusions

We have proposed a continuous phase modulation method for QPSK to provide a wireless link for data transmission at a bit rate of 45 Mbps. The performance of I/Q modulated QPSK signal is compared with a CPM system providing direct symbol-by-symbol detection Their performances are almost identical at BER = 10^{-2}. Overall, both schemes provide acceptable performance. QPSK offers numerous advantages in terms of low power consumption and high level of noise immunity making it particularly suitable for mobile devices. This paper shows a CPM scheme for QPSK signals derived from a quasi-constant envelope for transmission of multimedia data over wireless channels. It is shown that continuous phase modulated QPSK signal offers very similar performance as I/Q modulated QPSK signal and it is particularly suitable for small single-chip wireless transceivers in mobile device deployment offering lower power consumption, reduction in transceiver structure complexity leading to a reduction in size, weight and manufacturing cost making it particularly suitable for use by wearable devices when paramedics attending accident scenes

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