

Energy Meter Reading through Powerline Communication Channel

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Abstract

Power utility companies have suffered revenue losses due to uncollected bills and energy tampering for many years. The use of remote monitoring system to overcome the problem using powerline communication has been identified as a solution. This needs transceiver capable of communicating data through powerline channel. In this paper we present simulated results of BPSK (DSSS) transceiver for energy metering based on powerline channel as media for communication. The choice of spread spectrum BPSK modulation scheme is based on its robustness and its ability to spread signal into wide band to protect jamming and interference. The performance of the designed transceiver and selection of suitable parameter is verified using matlab simulation.

1. Introduction

The power utility companies have several ways of collecting readings of consumed energy from its customers. These include manual meter reading, estimation, prepaid meter, computerized hand held recording devices, remote electronic meter reading, drive by or mobile radio-meter reading and full remote monitoring or automatic meter reading (AMR). Most of the mentioned systems have problems such as delay in billing, wrong estimates, meter tampering, huge cost of disconnection and re-connection for non-paying customers, difficult in accessing meters due to scattered customers and power tampering which are the sources of revenue losses. The magnitude of the revenue losses worldwide are as follows USA 4% of the sales, UK £250 million per year, Pakistan losses exceed 35% of the sales, S. Africa over 38% of the sales and India over 10% of the total sales [1] and for African power utility companies, losses are estimated to be approximately 35% of sales or USD 200 million per annum [2].

To overcome the problems, in developed countries they adopted the use of metering system like computerized hand held recording devices, remote electronic meter reading, drive by or mobile radio-meter reading and full remote monitoring or automatic meter reading. It has been

suggested that automatic meter reading provides solutions for energy theft and revenue collection by power utility companies while others considers prepayment-metering systems as the solution [3][4]. In developing countries the use of full remote monitoring systems based on powerline channel (PLC) [5] with an intelligent transceiver meter is proposed as cost effective solution to address the above problems.

Due to the nature of powerline communication media, the transceiver parameters have been chosen careful to enable communication at low cost. The spread spectrums with BPSK modulation have being chosen to effect communication through powerline. In this paper, the use of BPSK modulation scheme has being discussed. In addition, the selection of transceiver parameters like chip rate, data rate, PN code generator, signal to noise ratio, receiver sensitivity, required bandwidth of powerline channel and processing gain (PG) have been chosen based on their significance in improving BER. The BER of 10^{-8} has been used as the required performance of received signal.

Simulation results show that the energy metering can be achieved with data rate of 10kbs and chip rate of 327.67Mchips/s. The processing gain (PG) of 45dB or above and receiver signal to noise ratio (SNR) of 28dB is required. The required receiver sensitivity, and signal power transmitted is $-110dB$ and 10mW respectively with channel bandwidth of 5kHz, which is half the data rate. However transceiver matlab program written for transmitting and receiving data at distance of 400 meter did not achieve the BER obtained in simulation. This is caused by error in synchronization (PN acquisition and PN tracking).

2. Powerline Energy Meter Reading

The remote energy metering through powerline is designed as shown in figure.1 where the meter is connected to customer with BPSK transceiver, which transmit and receive meter data through powerline.

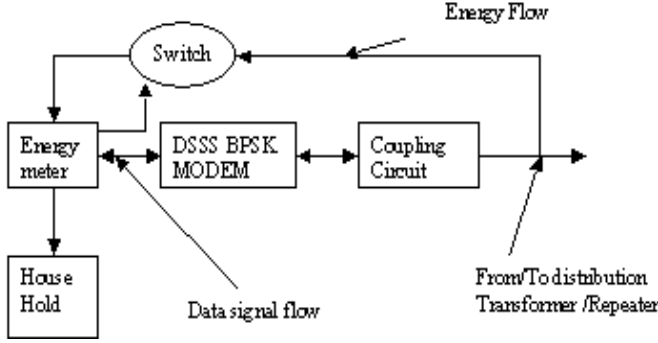


Figure 1: Layout of energy meter reading through PLC

The switch is incorporated for the purpose of tampering protection purposes and is controlled by signal from control unit. The isolation of transceiver from high voltage is achieved by coupling circuit.

3. BPSK Modem System

The BPSK modulation scheme is used for energy meter data transmission through powerline. This is spread spectrum techniques in which the signal occupies a bandwidth in excess of the minimum necessary to send information. We have chosen the BPSK for powerline modem design due to its desired attributes such as insensitive to narrowband disturbances, selective attenuation, works well with low signal power and has forward error coding through spreading and despreading which provides robustness to noise in the channel [5]. The transceiver for energy metering using BPSK modulation is shown in figure. 2 and 3. The transmitter has information bit of 10kbps, coding block, PN code generator of 15 chips, BPSK modulator and the channel, the receiver has synchronization block, BPSK demodulator, decoder and PN code generator which is identical to that of transmitter. Each block of transceiver was implemented through matlab program with parameter as selected below.

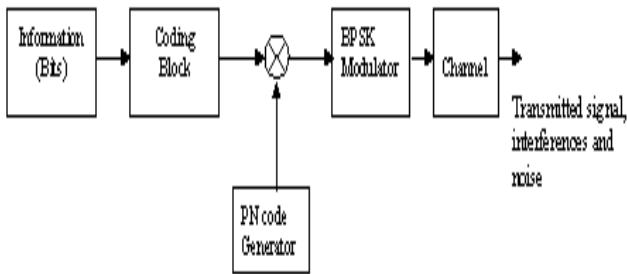


Figure 2:Block diagram of Transmitter

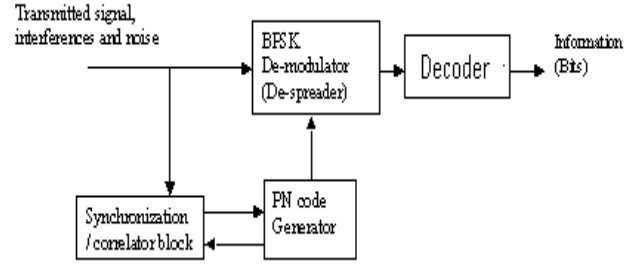


Figure 3: Block diagram of Receiver

4. Transceiver Parameter

For effectively transmission of data, the network was design, which has the receiver/repeater at a distance of 400 meters [6]. The task was to transmit and receive data at 400 meter with BER of 10^{-8} , to effect this the transceiver parameter like PN code generator, chip rate, receiver sensitivity, bandwidth, data rate, processing gain and receiver SNR was selected.

The maximum length sequence (M sequence) PN generator was chosen due to its good autocorrelation and easiness of implementation and the spreading code period is given by equation (1) where N represents a spreading factor and k is a number of bits. The value of k was found to be 15 (15-chip PN sequence), which gives spreading factor (N) of 32767.

$$N = 2^k - 1 \quad (1)$$

The data rate (r_b) of 10kbps was calculated to be enough for meter reading and tampering control purpose [6] which gives bandwidth (B_T) of transmitted signal through powerline of 5kHz as calculated by equation (2), where w is factor which relate bandwidth, channel properties with different modulation scheme. For BPSK modulation scheme it was taken to be 0.5.

$$B_T = w r_b \quad (2)$$

The system chip rate (r_c) of 327.67Mcps was proposed from equation (3).

$$r_c = N r_b \quad (3)$$

5. Processing Gain

The processing gain (PG) is defined as the quotient between the spread signal and signal bandwidths and is calculated as equation (4), which gives the PG of 45dB[7]. The simulated

results in figure 3 and table 1 agree with the use of PG of 45dB and suggest that the higher the PG the better BER.

$$PG = 10 \log\left(\frac{r_c}{r_b}\right) \quad (4)$$

The signal to noise ratio (SNR) was found to be 15dB as equation (5), with $\frac{E_b}{N_o}$ as ratio of received power signal to noise power signal of 12dB. These values were obtained at required BER.

$$SNR = \left(\frac{E_b}{N_o}\right)\left(\frac{r_b}{B_T}\right) \quad (5)$$

6. Receiver Sensitivity

To optimize SNR , the parameters optimization for receiver sensitivity and transmitter power is required [8]. The receiver sensitivity P_r of $-110dB$ was obtained as equation (6) with noise floor (N_o) of $-125dB$ at the receiver.

$$P_r = N_o + SNR \quad (6)$$

The Noise floor (N_o) was calculated as equation (7) with N_F as noise figure assumed to be 15dB, B_T is channel bandwidth (Hz), T_A is ambient temperature, k_B is boltzman's constant of 1.38×10^{-23} and N_B taken as background noise and was estimated to be $-140dB$.

$$N_o = N_B + k_B T_A B_T + N_F \quad (7)$$

The receiver sensitivity shows the required minimum received signal power at receiver for demodulation.

7. Transmitter Power

The minimum transmitted signal power (P_{tx}) of $-20dB$ (10mW) was determined. Its calculation includes path loss /channel attenuation (PL), receiver sensitivity and fade margin (FM) as equation (8).

$$P_{tx} = P_r + PL + FM \quad (8)$$

The PL equation (9) is estimated to be 60dB, with $H(f, d, N)$ as transfer function for powerline channel with d, f, N the transmitter/receiver distance, modulation

frequency and number of interconnection in the channel respectively. The fade margin was taken as 30dB.

$$PL = 20 * \log_{10} |H(f, d, N)|^2 \text{ dB} \quad (9)$$

For data communication through powerline, the maximum permitted signal power is 500mW (CENELEC standard). This gives the optimal SNR of 32dB as equation (10).

$$SNR = P_{tx} - PL - FM - N_o \quad (10)$$

8. Derivation of SNR and BER for Powerline Channel

From the Powerline channel, with the BPSK modulation scheme the SNR can be viewed as equation (11) with W, r_b as the chip rate and data rate of transmitted signal respectively.

$$SNR = \left(\frac{E_b}{N_o}\right)\left(\frac{W}{r_b}\right) \quad (11)$$

The noise power level (N_o) can be modeled as noise power spectral density (σ_k^2) and W/r_b refers PG of the system. This gives the SNR of the system of equation (12) in terms of transmitted signal, channel properties, noise power spectral density and PG. The variation of E_T and PG has impact in SNR and hence BER. The BER is given by equation (13).

$$SNR = \frac{E_T |H(f, d, N)|^2 PG}{\sigma_k^2} \quad (12)$$

$$BER = \sqrt{SNR} \quad (13)$$

9. Simulation Results

Simulation of SNR versus BER for different PG in figure 4 shows that with PG of 14dB, 17dB, 21dB and 24dB requires SNR of 54dB, 51dB, 47dB and 44dB respectively to effect the same BER. Result from table 1 for different value of PG agree with figure 1 that the higher PG values the lower SNR to achieve the same BER. To transmit signal at a distance of 400 meter with the required BER the PG of 45dB was realized.

complexity. With the target of achieving demodulation at 400 meter with BER of 10^{-8} and maximum of SNR of

32dB, the simulation shows that the PG of 45dB (15-chip sequence) and SNR of 28dB is required.

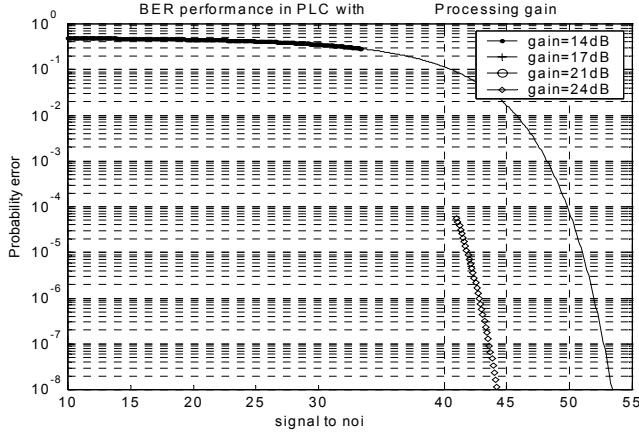


Figure 4: Simulated systems BER performance with different Processing gains

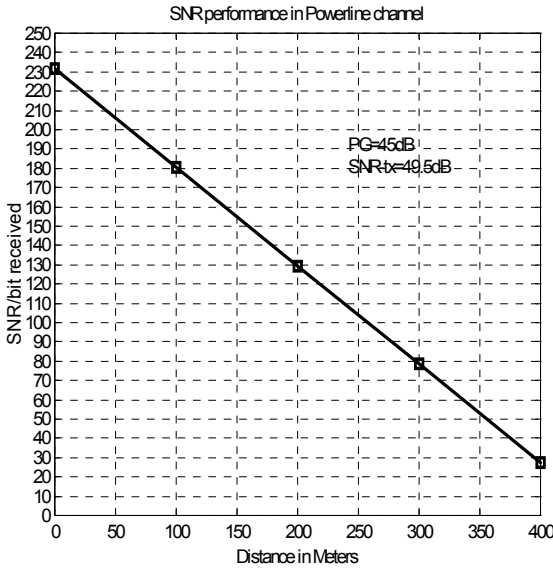


Figure 5: Variation of received SNR with distance in Powerline Channel

The variation of PG , transmitted signal power (SNR) and BER at the distance of 400 meters was observed as shown in table (1) and figure 5, 6 & 7. The results shows that the higher the transmitted signal power (SNR) the lower the BER with the given PG . This implies that the required BER is achieved by increasing either the transmitted signal power (E_T), PG or both of them. This can be verified with results from table 1. However, care must be taken to E_T as its increase associate with increases of transmitter.

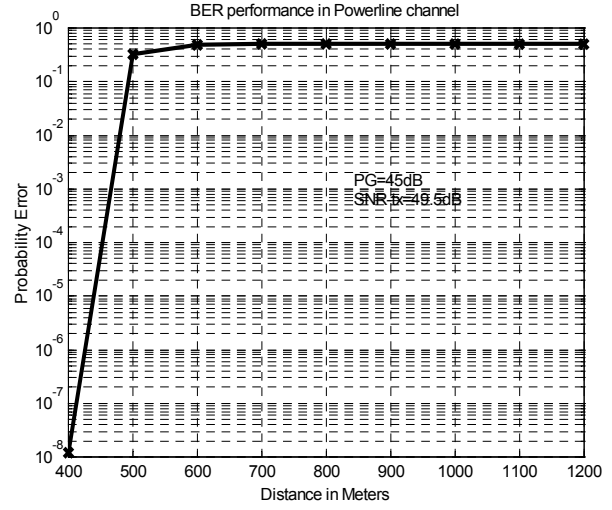


Figure 6: Variation of received BER with distance in powerline channel

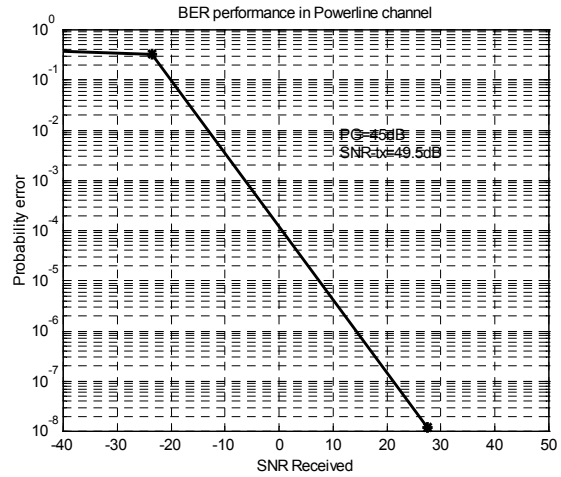


Figure 7: Variation of received SNR with BER in powerline channel

10. Conclusion

From the simulation results it is shown that with a noisy Powerline channel with a receiver at a distance of 400 meter the data transmission is achieved at data rate of 10kbps with BER of 10^{-8} using BPSK modulation scheme. The chip rate of 327.67Mcps with processing gain of 45dB and SNR at receiver of 28dB and receiver sensitivity of -110 dB with minimum transmitting power of -20 dB was realized. However utilizing the same parameter on transceiver implementation using matlab program did not achieve the required BER. This was due to error in synchronization of

receiver PN code with received data for despreading and demodulation purpose, hence care must be taken on synchronization part.

Table 1 Shows Variation of BER with the change in PG and transmitted signal power

$SNR_{tx}(dB)$	SNR_{rx} in dB	T_x-R_x Distance	PG in dB	BER
60	5	400m	20	10-8
60	5	400m	20.7	10-10
55	-5	400m	20.7	10-4
55	-5	400m	21	10-4
55	-3.5	400m	21.7	10-5
55	0	400m	23	10-6
55	3	400m	24.7	10-8
55	6	400m	26	10-11
45	-17	400m	26	10-2
45	-14	400m	27	10-2
45	-7	400m	30	10-3
45	0	400m	33	10-6
45	4	400m	34.7	10-8
45	6.5	400m	36	10-10
35	-16.5	400m	36	10-1
35	-15	400m	36.9	10-2
35	-12.5	400m	37.8	10-2
35	-11	400m	38.5	10-2
35	-10	400m	39	10-3
35	-5	400m	40.8	10-4
35	-3	400m	42	10-5
35	0	400m	43	10-6
35	0	400m	43.4	10-6
35	2	400m	43.8	10-7
35	2	400m	44.1	10-7
35	4	400m	44.8	10-8

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