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Design of Power Line Modem for PLC Integrated with VLC

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ABSTRACT

Power line communication (PLC) make use of existing power line infrastructure to transmit data over power lines with simultaneous transmission of electrical energy, a power line modem serves the purpose by modulating data through some suitable modulation scheme and then coupling it with power line. Power lines modem make use of existing power line for high frequency, low voltage data communication faces some serious problems like signal distortion, multipath fading, reflection and return loss and noise to communication signal. We designed a power line modem for 220V 50 Hz power line, which employ ASK modulation. Digital data of 9Kbps was modulated through carrier of 1 MHz and sent through power line and subsequently transmitted through VLC.

1. INTRODUCTION

VLC (visible light communication) is a new emerging field of communication in which visible light spectrum from 380nm to 780 nm is used for illumination and short range optical wireless communication simultaneously. LEDs offer some dominant properties over conventional light sources such as incandescent and fluorescent lamps [1]. Due to advantageous properties of LED and rapid improvement in the efficiency of LEDs has brought LED to strong candidate for next generation source of illumination and wireless communication source [2]. Although Radio frequency wave (below 10GHz frequency of electromagnetic wave) are widely used for wireless communication however the bandwidth of radio wave is not capable to provide the capacity and high date rate demands for (Wi fi, Bluetooth, cellular phone network and cordless phone) in this narrow spectrum [3]. So research focused on increasing the operating frequency interval. Visible light has bandwidth around 60 GHz therefore VLC seem to be the promising solution for achieving high date rate [4]. However, shifting the working frequency towards high frequency reduces wave length but shorter waves length EM wave have short coverage range therefore VLC is intensively studies for short range communication only [2].
Noise in VLC channel is mainly Additive White Gaussian (AWGN), and channel quality in optical channel is dominated by shot noise [1]. Optical wireless channel can be modeled as follow.

$$Y(t) = \gamma X(t) \otimes h(t) + N(t)$$

Where Y(t) is the received signal current, γ is the responsivity of detector, X(t) is the transmitted optical signal, h(t) is the impulse response and N(t) represent the additive white Gaussian noise (AWGN), the symbol represent convolution. VLC receiver usually consist of an optical filter, concentrator and photodetector, preamplifier and a signal recovery circuit. The function of optical filter is to block ambient light and in effect provide a narrow band for modulated signal to be detected by photodetector, the function of concentrator is to collect light and concentrate it on photodetector. The photo detector produces current proportional to optical power incident on its surface and amplify it usually using trans-impedance amplifier [4].

An indoor VLC channel is subjected to intense ambient light from day light from sun light, sky light and from fluorescent and incandescent lamps. These ambient light sources induce in the signal and hence degrading the performance of link. sun light and incandescent lamps are unmodulated source of noise and at the receiver side the noise average power can be larger

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than the desired signal, even when optical filtering is employed. The resulting current in photodiode is the major cause of short noise [5]. On the other hand, fluorescent lamps light is modulated in a periodic manner with the lamp drive frequency, the resulting noise power spectrum consist of discrete components at harmonics of the drive frequency of lamp (usually 50 to 60 Hz) [5].

Power line communication for short (PLC) is a communication technology which make use of existing power lines for the transmission of data, although the use of power lines for data communication (PLC) has old roots from early transmission of electricity, at 1910s Major George squier of US army first demonstrated the transmission of voice signals over power cables [6].

Recent improvement in performance of coupling and decoupling circuit PLC has gained significant attention in scientific community because of its promising potential of viable source for data communication which could significantly reduce the cost of installation of new wires for communication system. PLC system can be classified into different categories based on range of frequency, type of coupling, and voltage level. Based on frequency range PLC system are classified into two broad frequencies band i.e narrow band and broad band, narrow band PLC refers to data communication in the range from zero to 500KHZ, while broad band PLC refer to frequency range from 1.7MHZ to 500 MHZ and may even higher [6].

Power lines network at first place is designed mainly to transmit low frequency 50/60 Hz power line from power station to end users, unlike most common communication mediums like twisted pair, coaxial and fire optic cables, the characteristics of power line network dependent on time, frequency and access impedances and high attenuation is possible at frequencies used for broadband PLC [2, 7]. the appliances connected to the power line are turn and off randomly and this makes the power line impedance variable and unpredictable. This hostile nature of power lines makes power line channel inadequate for high frequency carrier communication. The transfer function of PLC channel can be modeled as below [7, 8].

$$H(f) = \sum_{i=1}^{N} g_i . e^{-(a_o + a_1 f^k)li} . e^{-j2\pi f \tau_i}$$

Where g_i represent weighing factor for path i and represent the product of reflection and transmission factors, ao and a_1 are attenuation factor, the variable represent the delay due to multiple paths and can be calculated by dividing the path length by phase velocity which is 150 x 106 m/sec. N represent the total number of reflection paths and li is the length of path i.

Power lines at first place are designed mainly for transfer of low frequency, high voltage electrical power, thereby using existing power line for high frequency, low voltage data communication pose some serious problems regarding the efficient use power lines, besides signal distortion, multipath fading, reflection and return loss, power line add noise to communication signal, and if the noise characteristics are not understood, and a proper mechanism is not adopted to filter out noise at the receiver end, the proper reception of communication signal is very difficult. Furthermore, unlike other telecommunication channels noise in PLC channel is not Additive White Gaussian Noise (AWGN), which has uniform noise power spectral density (PSD) over whole range of spectrum [8, 9, 10]. Therefore, a lot of research and investigation results classification of noise into the following categories. Power line channel is a very harsh medium for communication because it characteristics changes greatly with frequency, location, time and load (type of equipment's connected) [9].

The main objective of this research is to design a power line modem which has the capability of injecting/coupling communication signal to and from power line, and then to send the received data at the end of power line and transmit through VLC.

2. EXPERIMENTAL AND METHOD

The schematic of transmission of digital data through both PLC and VLC are depicted in Fig 1 and PLC alone in Fig 2.

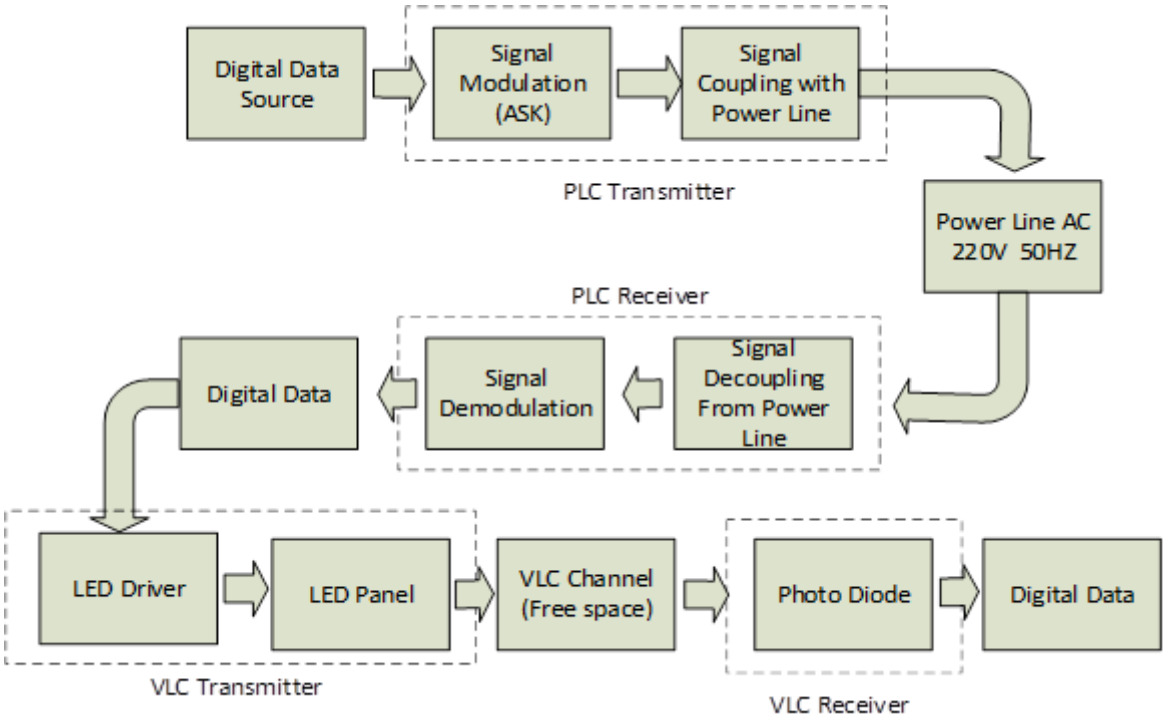

Fig 1. Schematic of data flow through PLC and VLC.

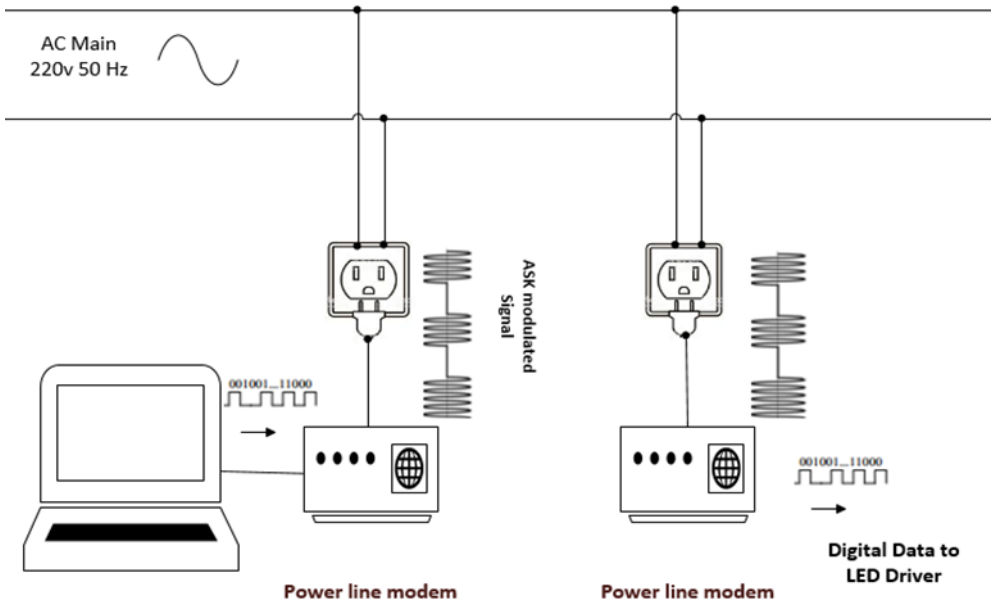

Fig 2. Digital data transmission over power line using ASK modulation.

2.1. COUPLING/DECOUPLING CIRCUIT

The main part of power line modem is coupling circuit whose sole purpose is to inject communication signal to power line at transmitter side and retrieve at receiver side. we used LC high pass filter for coupling and decoupling at transmitter and receiver side respectively, due to its efficient coupling of signal with power line as compared to RC filters. The coupling circuit is shown in Fig 3. Iron core inductors have low frequency operating range because it saturates at high carrier frequency, since carrier frequency is many orders of magnitude of AC 50/60 Hz frequency therefore a suitable ferrite core inductor was used, ferrite core inductor has high operating frequency range. The cut off frequency of LC high pass filter was so chosen to offer high impedance to main AC from power line to the communication side and provide a low resistance path for modulated signal to couple with main AC. The specification of inductors, capacitors and LC cut off frequencies are given in Table 2.1.

Table 2.1: Components of coupling circuit.

	Inductor	Capacitor	Cutoff frequency
Coupling side	7.6 H	0..33µF	100 Hz
Decoupling side	7.6 H	0..33µF	100 Hz

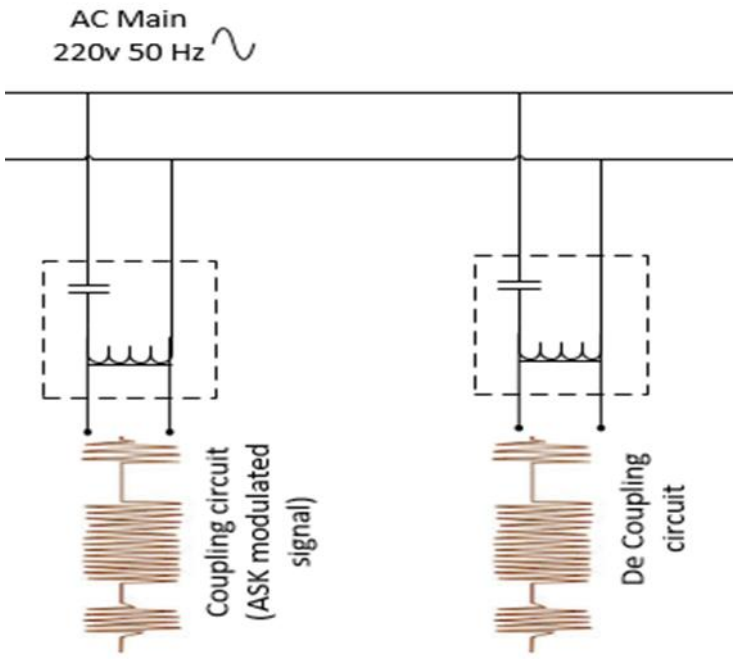

Fig 3. Coupling and de- coupling part of modem.

2.2. OSCILLATOR CIRCUIT

The data from computer serial port is digital in nature and has a speed of about 9kb/sec, for effective transmission of signal an efficient modulation schemes must be applied to the data before it is injected to power line. We used ASK modulation and the carrier of about 1MZ for the modulation was generated by Hartley oscillator. As shown in Fig 4.

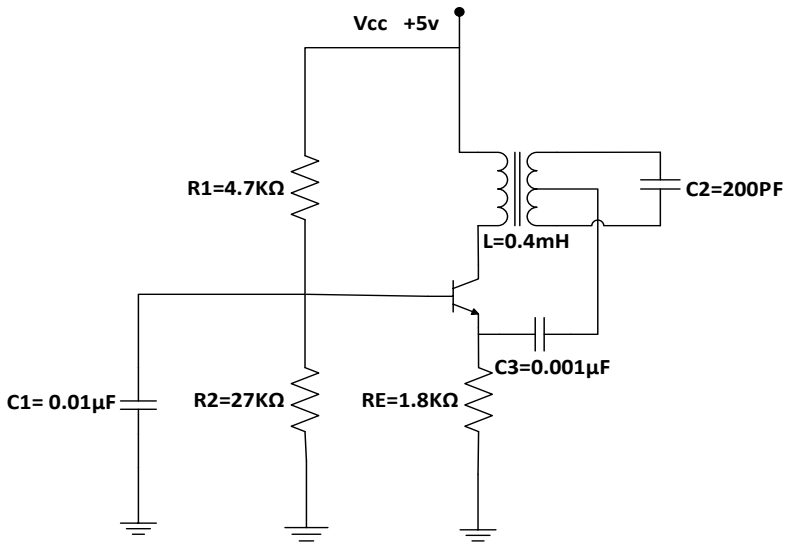

Fig 4. Hartley oscillator used for generating carrier of around 1 MHz.

the power line modulation of carrier with data is carried out by a classical C amplifier as shown in Fig 5a and designed modulator on PCB is shown in figure 5b.

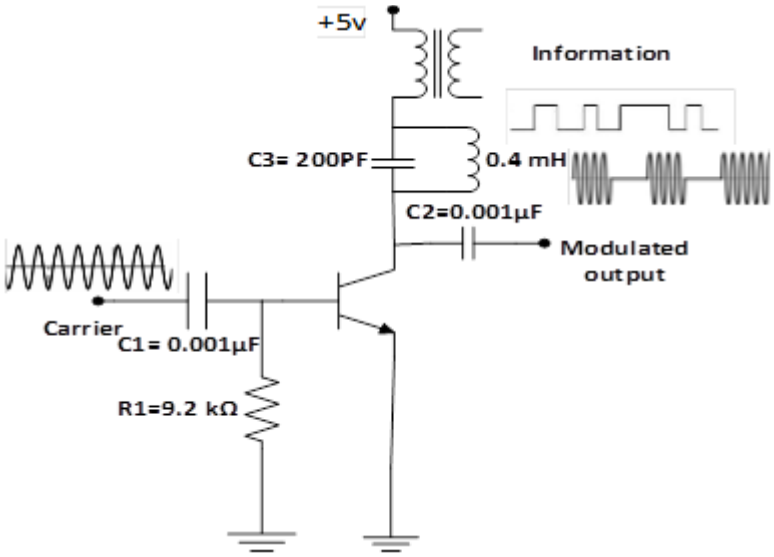

Fig 5a Circuit diagram of modulator circuit **5b.** Designed Modulator using a Class C amplifier.

The complete designed modem in a single unit consisting of 5v power supply, oscillator, modulator and coupling circuit is depicted in Fig 6.

Fig 6. Modem at transmission side consisting of power supply, Oscillator, modulator and coupling circuit.

The main parts of VLC system are shown in Fig 7.

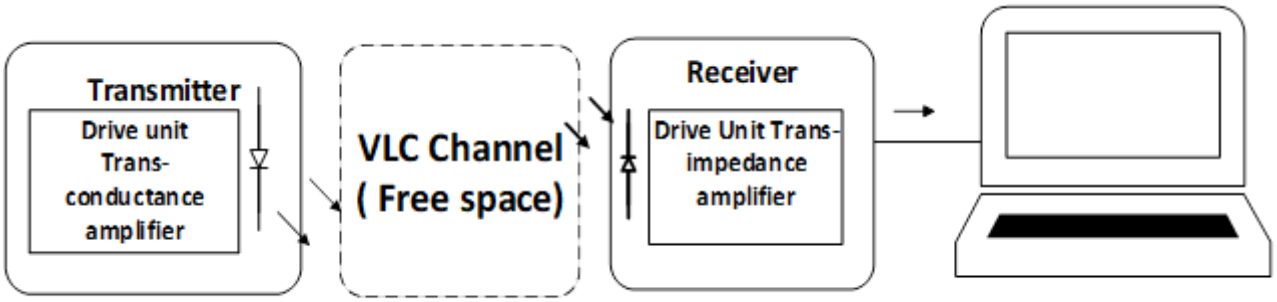

Fig 7. Schematic of VLC system.

2.3. LED DRIVE UNIT

Since LED is a current driven device (its produce light proportional to input current) therefore the drive unit for LED panel consist of a transconductance amplifier which serves as current modulator, the input of which is a voltage and its output a current. BJT used in Trans conductance amplifier forward current gain usually have high variation. To overcome high variation in gain [11] discussed and analyzed the current series feedback topology. Which yield a trans conductance amplifier that can be used for current modulation of LED and is in fact insensitive to the current gain variation, the LED driver is shown in Fig 8.

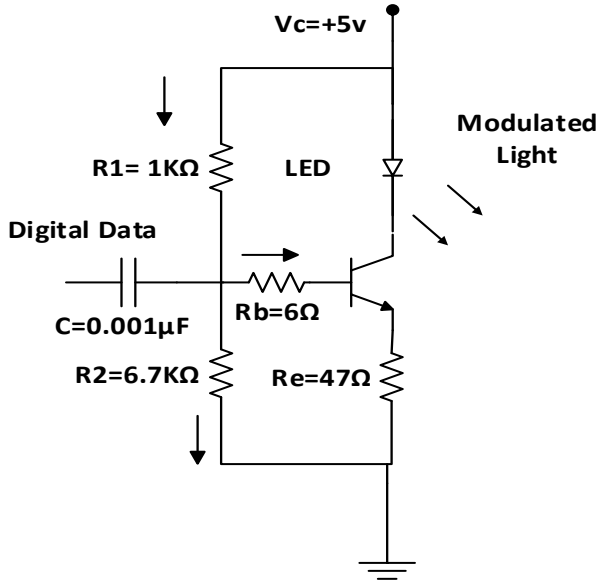

Fig 8. LED Drive Unit.

The transmitter LED Panel consist of 70 LEDs, arranged in 14 rows (five LEDS in each row). The maximum current through each LED is 5mA therefore a total of about 2 A supply is required for the illumination of LEDs panel. Since the primary function of LEDs must not be altered during data communication therefore 2.5mA was adopted for normal illumination. and a total of 14 rows.

The maximum current through a single led is 5 mA therefore a total of amperes current is required. LED panel is shown in Fig 9.

Fig 9. LED panel consisting of 72 LEDS, (14 x 5).

The complete designed modem at the receiving side of power line is depicted in Fig 10, consisting of power supply, de-coupling circuit, low pass filter, and trans-conductance amplifier.

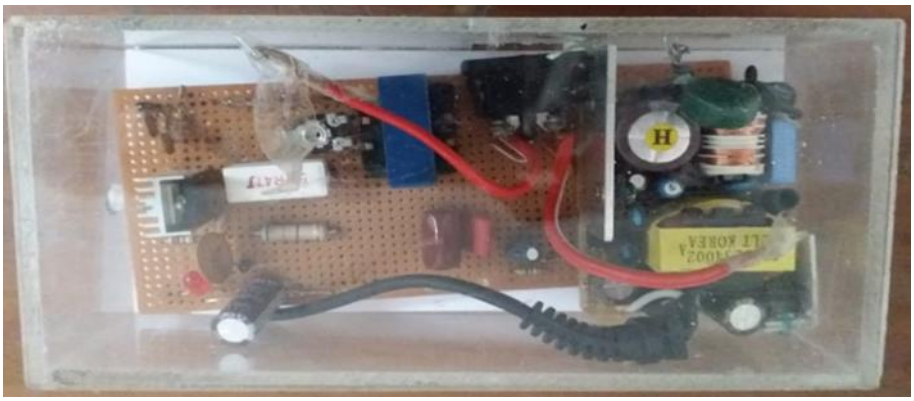

Fig 10. Modem at receiving side of power line consisting of a power supply, de-coupling circuit, Low pass filter, and tans-conductance amplifier.

2.4. PHOTO DIODE CIRCUITRY

The main component of VLC receiver is photodiode; whose primary function is to convert the modulated light striking its surface into current which is proportional to the intensity of light. since at transmitter side the signal was in terms of voltage over desired signal is voltage not current therefore trans impedance amplifier is used to amplify the current signal in terms of voltage. LM6364 op amp IC was used for amplification as it has a high switching bandwidth. The circuit diagram of transconductance amplifier is shown in Fig 11.

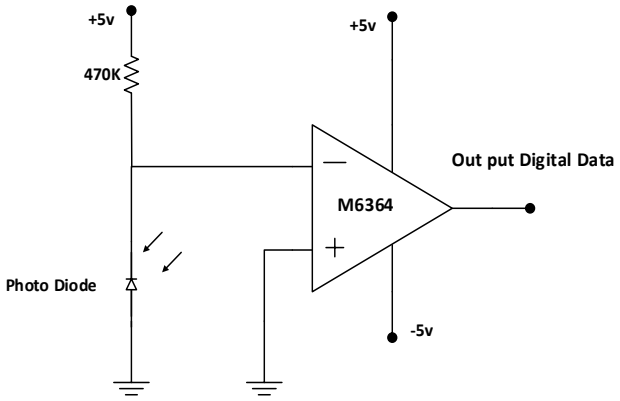

Fig 11. Photo diode, transconductance amplifier.

3. RESULT AND DISCUSSION

The primary object/focus of our research was to design a modem which has the capability of coupling communication signal with power line and out of power line. to check the performance of designed power line modem we used digital data of around 9kbs from computer, to a receiver computer at the other end, in between two channels were encounter first PLC and second VLC. Ask modulation scheme was used for data transmission over power line and a carrier of around 1MH of around 4 volts was generated for this purpose using Hartley oscillator. The wave form of carrier is shown in Fig 12.

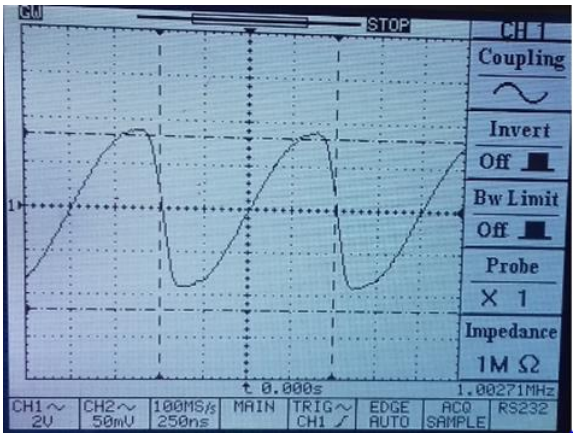

Fig 12. Carrier wave form of around 1MHZ 4 volt using Hartley oscillator.

The digital data was modulated using a class C amplifier (power amplifier) a coupling capacitor of 100μF Was used as coupling element between oscillator and the modulator. The output wave form of the class C amplifier is shown in Fig 13.

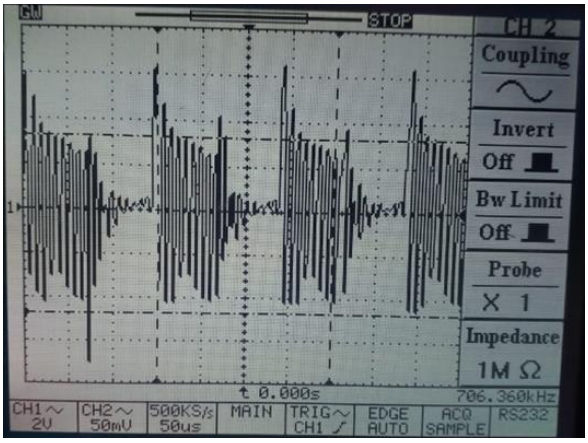

Fig 13. Modulated digital data of 9Kbs.

The modulated signal was then coupled to power line 220V 50 Hz using a high pass RL filter (RL filter serves as coupler). The modulated signal was retrieved using a high pass RL filter (RL filter at this end serves as de-coupler) and the following wave form was obtained.

The modulated signal was then fed through LED drive unit. The signal first encountered a Low pass RC filter. The RC low pass filter filtered out the low frequency (9kbs data) digital data. The wave form of signal at the end of RC low pass filter is shown in Fig 14.

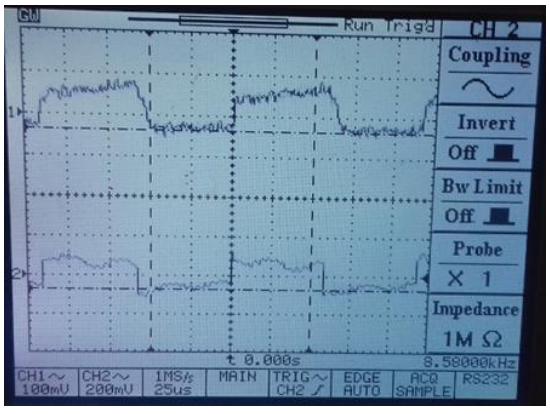

Fig 14. Transmitted digital data (bottom), received signal at the end of power line.

Since LED is a current device (its produce light proportional to input current) therefore the drive unit for LED panel consist of a trans conductance amplifier which serves as current modulator, the input of which is a voltage and its output a current. The modulated light using intensity modulation was transmitted to free space (VLC channel) using LED panel.

The main component of VLC receiver is photodiode; whose primary function is to convert the modulated light striking its surface into current which is proportional to the intensity of light. since at transmitter side the signal was in terms of voltage over desired signal is voltage not current therefore transimpedance amplifier is used to amplify the current signal in terms of voltage.

4. CONCLUSIONS

Both power line and visible light communication channels has a huge potential for economical, efficient, secure data communication specially for broadband indoor environments. With the recent ratification of broadband PLC and VLC standards, the integration of these two techniques for indoor wireless networks has begun to attract the attention of the research community. In this paper the author provided a detailed description of both VLC and PLC, and discussed various aspects of designing an effective power line modem. A typical power line modem designed has presented and its components analysis are presented.

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REFERENCES

[1]. Pavlidou, N., Vinck, A. H., Yazdani, J., & Honary, B. (2003). Power line communications: state of the art and future trends. IEEE Communications magazine, 41(4), 34-40.
[2]. Ma, H., Lampe, L., & Hranilovic, S. (2013, March). Integration of indoor visible light and power line communication systems. In 2013 IEEE 17th International Symposium on Power Line Communications and Its Applications (pp. 291-296). IEEE.
[3]. Amirshahi, P., & Kavehrad, M. (2006, January). Broadband access over medium and low voltage power-lines and use of white light emitting diodes for indoor communications. In IEEE Consumer Communications & Networking Conference.
[4]. Ding, W., Yang, F., Yang, H., Wang, J., Wang, X., Zhang, X., & Song, J. (2015). A hybrid power line and visible light communication system for indoor hospital applications. Computers in Industry, 68, 170-178.
[5]. Kahn, J. M., & Barry, J. R. (1997). Wireless infrared communications. Proceedings of the IEEE, 85(2), 265-298.
[6]. Da Silva Costa, L. G., de Queiroz, A. C. M., Adebisi, B., da Costa, V. L. R., & Ribeiro, M. V. (2017). Coupling for power line communications: A survey. Journal of Communication and Information Systems, 32(1).
[7]. Zimmermann, M., & Dostert, K. (1999, March). A multi-path signal propagation model for the power line channel in the high frequency range. In Proc. IEEE Int. Symp. Power Line Commun. Appl (pp. 45-51).
[8]. Alavi, S. E., Supa'at, A. S. M., & Idrus, S. M. (2009, December). Integrated system of visible free space optic with PLC. In 2009 IEEE 9th Malaysia International Conference on Communications (MICC) (pp. 271-275). IEEE.
[9]. Souissi, S., Benrhouma, O., & Rebai, C. (2014). Design of coupling interface for narrowband Power Line Communication channel characterization. IMEKO TC4, 483-488.
[10]. Gotz, M., Rapp, M., & Dostert, K. (2004). Power line channel characteristics and their effect on communication system design. IEEE Communications Magazine, 42(4), 78-86.
[11]. Sohail, M., Sterckx, K. L., & Saengudomlert, P. (2016, June). Linear current modulation with feedback on Light Emitting Diodes in Optical Wireless Communication. In 2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON) (pp. 1-5). IEEE.