Transmission of an Information Signal over a Power Line Carrier (PLC) using DSB – SC Modulation Technique

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Abstract— During the recent years, we focused on creation and also dispersion of information. In purpose to reach the end users for the provision of information, different types of technologies currently being used include telephone wires, fiber optic, wireless and satellite technologies. But each has its limitations of cost and availability to reach the maximum number of users and also major considerable parameters in a communication system are transmitting power and bandwidth. Hence, it is very much necessary to save the power and bandwidth in a communication system. In this paper, we proposed that power line carrier is used as medium instead of traditional transmission mediums for carrying the information from sender to the receiver. Based on the proposed method, we designed a Fire Alarm System based on Power Line Carrier (PLC) using DSB-SC modulation rather than DSB – FC modulation and which is a prototype that enables to transmit signal from located sensor using existing power distribution line cable to give warning for possible fire hazards to local residents. Before transmit the signal over a PLC, modulate the signal using double side band with suppressed carrier amplitude modulation technique and transmitted.

Key words: Information, Power Line Carrier (PLC), DSB – SC Modulation, Fire Alarm System, Power, Bandwidth

I. INTRODUCTION

In earlier days, fire Alarm system is used as detection system which consists of sensor, controller and oscillator circuits. So, the oscillator circuits will generate two different signal which is modulating signal and carrier signal when the sensor sense any extreme changes in term of temperature and then these two different signals will be pass through the modulator circuit for the transmission over power distribution line. With the help of electric power line which can be used as the medium for data transmission very easily because every home and building is already equipped with the power line and it is connected to the power grid. There is an advantage of using PLC is that reducing the extra wiring cost. The power line carrier (PLC) communication systems use the existing AC electrical wiring as the network medium to provide high speed network access points almost anywhere there is an AC outlet. Using the existing AC electrical wiring is easier than trying to run wires, we are getting the more secure and more reliable than radio wireless systems and relatively inexpensive as well. Power line has been considered for the transmission of electricity in the past. Now days, we are able to deliver not only electricity but also used to full duplex high-speed data and multimedia content and now it is still being explore.

A. *DSB-SC Modulation Technique*

In *AM* with Carrier, only 33% of power is used and the remaining power is wasted by the carrier transmission along with the side bands. In order to save the power, the carrier is suppressed because it does not contain any useful information. This method is called Double Side band with Suppressed Carrier amplitude modulation (DSB-SC AM). The DSB-SC AM modulated wave form is expressed as below.

$$V(t)_{DSB-SC} = \frac{V_m V_C}{2}[\cos(\omega_c - \omega_m)t - \cos(\omega_c + \omega_m)t \quad (1)$$

We know that, the AM modulated wave form equation is as shown below.

$$V(t)_{AM} = V_c \sin\omega_c t + \frac{m_a V_c}{2}\cos(\omega_c - \omega_m)t - \frac{m_a V_c}{2}\cos(\omega_c + \omega_m)t \quad (2)$$

Comparing the above two equations, the carrier term $V_c \sin\omega_c t$ is missing and only two side bands are presents in Equation (1). The carrier term ω_c is suppressed. It contains only two side bands terms having the frequency of $(\omega_c - \omega_m)$ and $(\omega_c + \omega_m)$ as shown in the below and also graphical representation of DSB-SC AM is as shown below

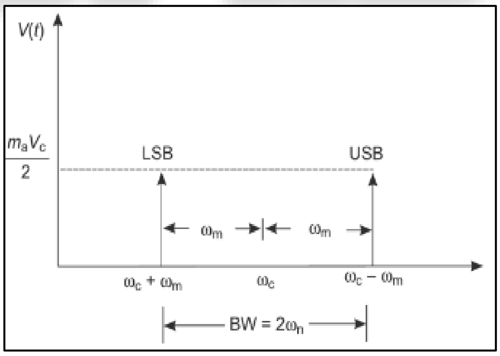


Fig. 1: Frequency Spectrum of DSB-SC AM

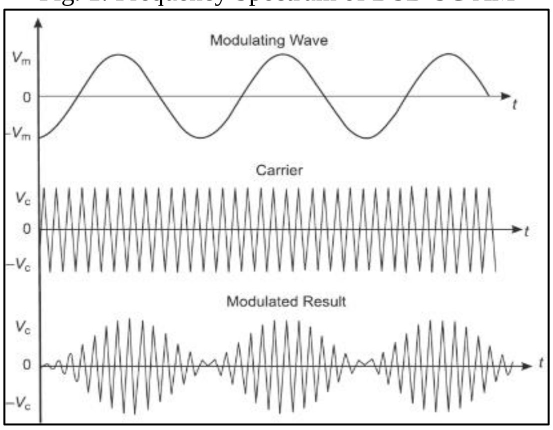


Fig. 2: Graphical representation of DSB-SC AM

Below figure the graphical representation of DSB-SC AM. It exhibits the phase reversal at zero crossing,

$$\% \text{ Efficiency } (\eta) = \frac{TotalPower \quad Sidebands}{TotalPower} X\,100 \qquad (3)$$

In AM,

$$\% \eta = \frac{m^2{}_a}{2 + m_a^2} X\,100 \qquad (4)$$

Where m_a is modulation index. If $m_a = 1$, then % η = 33.3%. From this, only 33.3% of energy is used and the remaining power wasted by the carrier transmission along with the side bands. In DSB – SC AM, %η is 100% because the total power is utilized by the two side bands completely. In DSB – SC AM, the percentage of power saving is

$$\% \text{ Power Saving} = \frac{2}{2 + m_a^2} X\,100 \qquad (5)$$

If $m_a = 1$, then 66.7% of power is saved in DSB – SC AM.

B. Power Line Coupling Network

A coupling circuit is used to connect the communication system to the power line. Two problems are solved by using the coupling network.

- Firstly, it prevents the damaging 50 Hz signal, used for power distribution, to enter the equipment.
- It certifies that the major part of the received and transmitted signal is within the frequency band used for communication. This increases the dynamic range of the receiver and makes sure the transmitter introduces no interfering signals on the channel. Thus the ultimate coupler network design becomes a compromise between the different characteristics for receive and transmit direction, plus impedance.

There are different ways for couple a communication device in to an electrical power line. Two types are described below.

- Differential mode coupling: In this case the line or active wire is used as one terminal, and the neutral wire as the second terminal. In cases where a neutral line is not present (high voltage networks), the ground line acts as the second terminal.
- Common mode coupling: In this case the line (active) wire and neutral wires are used together forming one terminal and the ground wire serves as the second terminal.

In practice, the inductance between points of coupling and the short-circuit point is large enough to allow signal transmission. However, problems exist in using common mode coupling in the presence of earth leakage protection devices, and certain countries do not allow common mode coupling because of the perceived dangers to customers. Considering the physical implementation of the coupling two methods can be identified.

- Capacitive coupling: A capacitor is used to couple the communication signal on to the power line.
- Inductive coupling: An inductor is used to couple the communication signal onto the power network. Inductive coupling provides a physical separation between power network and communications network, making it safer to install.

C. Power Line Carrier Channel

The power line carrier (PLC) channel is defined as the signal path from the transmitting electronic equipment at one terminal, through its tuning equipment, over the power line, through the tuning equipment at the receiving end, and into the electronic equipment at the receiving terminal. The power line carrier (PLC) channel is defined as the signal path from the transmitting electronic equipment at one terminal, through its tuning equipment, over the power line, through the tuning equipment at the receiving end, and into the electronic equipment at the receiving terminal.

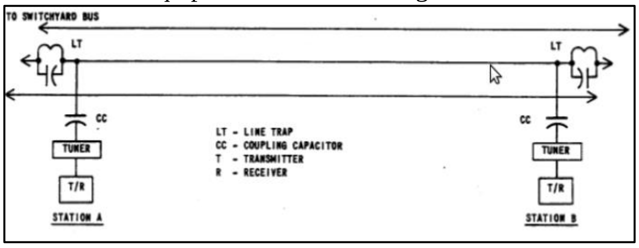


Fig. 3: PLC diagram

D. Proposed Method

To feed the signal from sensor into power distribution line, a suitable modulation technique will be used. The modulator function to convert signal from the sensor in the form of suitable signal before transmitted through power distribution line. At the receiving system the transmitted signal will be demodulated and connected to the buzzer or siren unit to warn residents. In this paper, the focus will be on ways to sending or transmitting signal over AC power line. To make this transmission possible, some equipments or circuit need to be defined such as transmitter and receiver circuit. Modulation is also important thing that need to be known to make this transmission reliable. Suitable modulation technique needs to be chosen as well as the modulator circuit. In figure 4 shows that system will be divided into two main parts which are the transmitter circuit and receiver circuit. In the transmitter circuit it consists of modulator circuit, audio amplifier circuit and coupling circuit. And in the transmitter circuit it consists of coupling circuit, filter circuit and audio amplifier circuit. Figure below shows the block diagram of PLC system design that would be use for this fire alarm system.

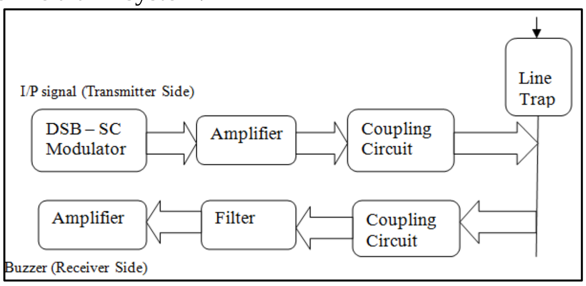


Fig. 4: Block diagram of PLC System design

II. SYSTEM DESIGN

A. DSB-SC Modulator

The generation of a DSB-SC modulated wave consists simply of the product of the message signal m(t) and the carrier wave $A_c \cos(\omega_c t)$. A device for achieving this requirement is called a product modulator, which is another term for a straightforward multiplier as shown in Figure5.

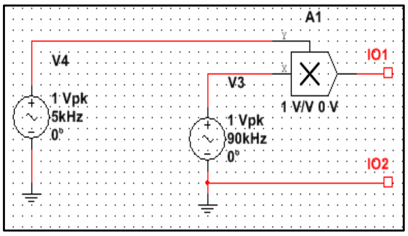


Fig. 5: DSB – SC Modulator circuit

B. Amplifier Circuit

In this communication, the amplifier circuit is needed because the transmitted signal is in low level voltage in purpose to avoid this signal affected power line signal. Due to this reason, the amplifier circuit is needed to amplify the low level signal especially at receiving system into certain higher level to ensure the signal can be used to activate the warning system. For this amplifier circuit design, IC LM741 operational amplifier (Op-Amp) was used in non-inverting configuration because; it is easy to design and also low in term of cost and easily gets it in the market. In the below figure 6 shows, R1 and R3 are input resistors to the op-amp, R2 is feedback resistor. We can simply increase the gain of this amplifier system by increasing the value of feedback resistor R2. Below is the formula to calculate the overall gain for this amplifier circuit.

$$A = 1 + \frac{R_2}{R_3} \qquad (6)$$

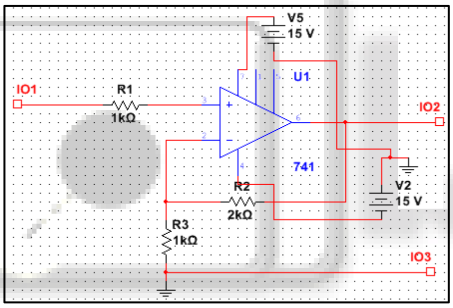
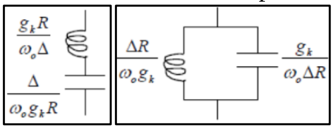


Fig. 6: Amplifier Circuit Diagram

C. Band Pass Filter

In power line carrier communication, filter is needed. The function of the filter is to provide enough attenuation on its stop band in its frequency response to produce filtering function. In this system, filter is use to filter out 50 Hz power line signal and others unwanted signal except the transmitted AM signal. In this filter design, 0.5 dB chebyshev band-pass filter using L-C components has been used. Specific calculations are used to design or calculate each filter elements. The designing procedures for this band-pass filter begin with choosing the bandwidth (BW) for the system and number of element (N). Theoretically the larger number of element (N) will provide higher attenuation at stop band but it also will increase the complexity of the circuit. After the bandwidth is chosen, then calculate Δ =f2−f1 / f0 and obtain element values (g) from the standard procedure [4] and finally calculate the value of each components using specific formula. Below is the calculation on filter design for this power line carrier system:

1) Choose BW = 12 kHz from 84 kHz until 96 kHz and N = 5. Therefore, Δ = (96k – 84k) / 90k = 0.1333
2) From standard table g1 = g5 =1.7058, g2 = g4= 1.2296 and g3 = 2.5408
3) Calculate value for each filter components



$$\begin{aligned}
L1 = L5 &= \frac{1.7058\,(50)}{2\pi(90k)(0.1333)} = 1mH \\
L2 = L4 &= \frac{0.1333\,(50)}{2\pi(90k)(1.226)} = 10mH \\
L3 &= \frac{2.5408\,(50)}{2\pi(90k)(0.1333)(50)} = 1.5mH \\
C1 = C5 &= \frac{0.1333}{2\pi(90k)(1.7058)(50)} = 2.2nF \\
C2 = C4 &= \frac{1.2296}{2\pi(90k)(0.1333)(50)} = 30nF \\
C3 &= \frac{0.1333}{2\pi(90k)(2.5408)(50)} = 2nF
\end{aligned} \qquad (7)$$

In this filter design, calculation is done on various values of bandwidth (BW) and element number in purpose to obtain the components value that match with the standard value that available in the market. And finally, filter design with bandwidth equal to 12 kHz and element number equal to 5 was chosen as the final design because all calculation on components value that obtained using both this two parameters are available in the market. Figure 7 shows the circuit diagram for this filter design.

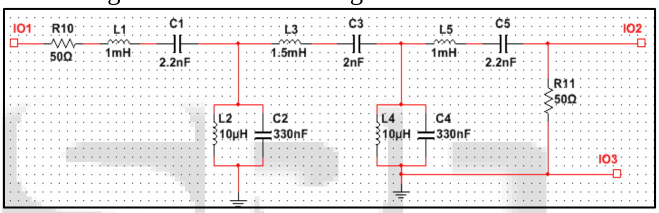


Fig. 7: Band – Pass Filter Circuit

D. Coupling Circuit

Modulated signal resulting from varying carrier amplitude based on amplitude of information signal need to be injected into power line for transmission. This responsibility is taken by the coupler circuit. The coupler circuit makes information signal transmission through power line reliable. The coupler circuit is needed both at transmitting part and receiving part. There are several components needed in coupler circuit which commonly combination of L-C components that provide impedance matching for the system. Below is the figure 8 of coupler circuit for this system.

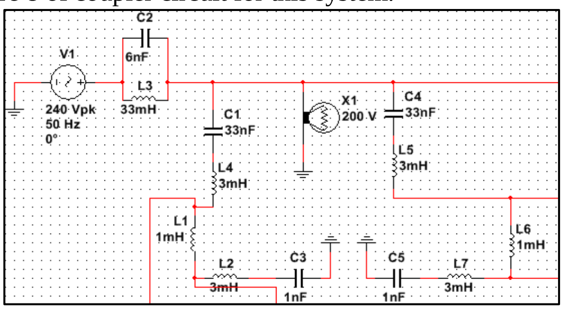


Fig. 8: Coupling Circuit

From figure 8 above, it can be seen that coupler circuit for transmitting and receiving part is same only few different at the components value. The coupler circuit consists of coupling capacitor, line tuner and line trap. C7 and C5 are the coupling capacitor for transmitting and receiving part. While parallel L-C component L4 and C4 is line trap circuit and the remaining components is the line tuner. The coupling capacitor functions as low pass filter to block high voltage power line signal from entering and damaging transmitter or receiver circuit. Line tuner components must be tuned to the carrier signal to ensure the signal can be transmit through power line. And Line Trap circuit function to direct carrier energy toward remote line terminal and to isolate the signal from bus impedance variation which can avoid carrier signal from to be attenuated by power line signal. The combination of these three circuits will provide necessary equipment in purpose for injecting AM signal into power line.

III. Overall System Design

Figure 9 shows the complete system design, in which the designed circuits are modulator, amplifier, filter and coupler circuit combined together. By using all these circuits, successfully we transmitted the signal through the power line. In the complete system design, DSB – SC AM signal will be generated from the DSB – SC AM modulator. Before the coupler circuit injects the DSB – SC AM signal into power line, amplifier will provide some amplification on DSB – SC AM signal. From the receiving part, the coupler circuit will separate power line signal and DSB – SC AM signal and only allow DSB – SC AM signal pass through receiving part. Then received DSB – SC AM signal voltage is extremely low. So, increase the voltage level of DSB – SC AM signal by amplifying it that means using another amplifier to amplify. After amplifying, the received signal will pass through filter circuit to filter out any unwanted signal except the DSB – SC AM signal. Finally, filtered DSB – SC AM signal will feed into one more amplifier system to amplify the signal at appropriate signal before it can be used to turning alarm system ON or buzzer.

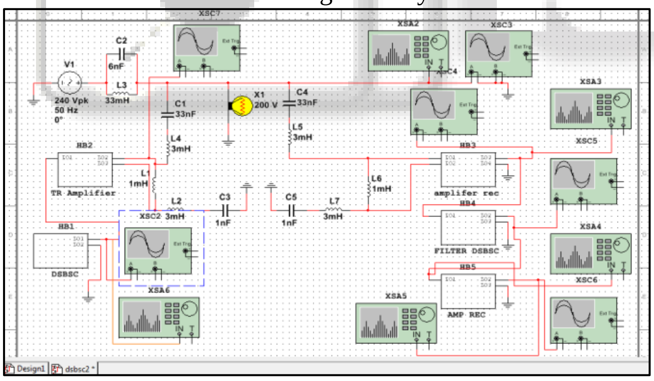


Fig. 9: Overall System Design

IV. Results

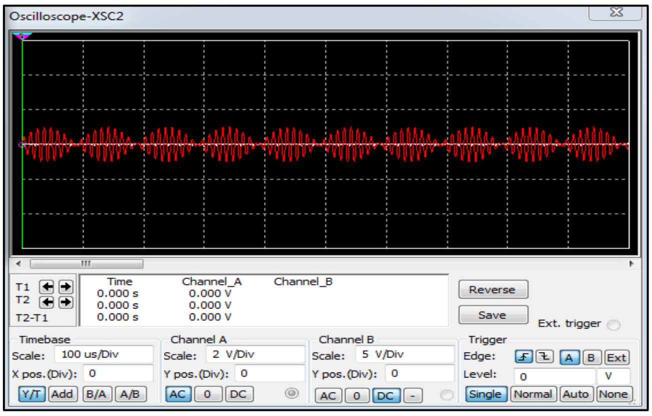


Fig. 10: DSB – SC Modulator Output

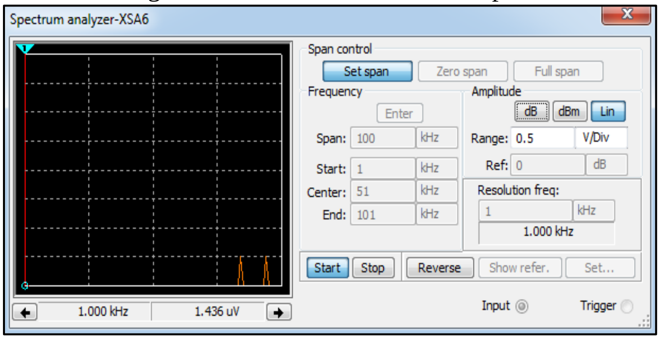


Fig. 11: Frequency Spectrum of DSB – SC modulated wave form

Figure 10 and 11 shows DSB – SC AM output from modulator as well as from the amplifier circuit. From the observation and comparison with the output of DSB – SC AM modulator circuit, it shows that this amplifier successfully provide sufficient gain to amplify the low amplitude of AM signal at its input to be higher amplitude at its output. Fig 15 shows the spectrum after coupling at transmitter. From the figure 15, it shows that power line signal and DSB—SC AM signal exists in frequency spectrum which the signal is at 85 and 95 kHz.

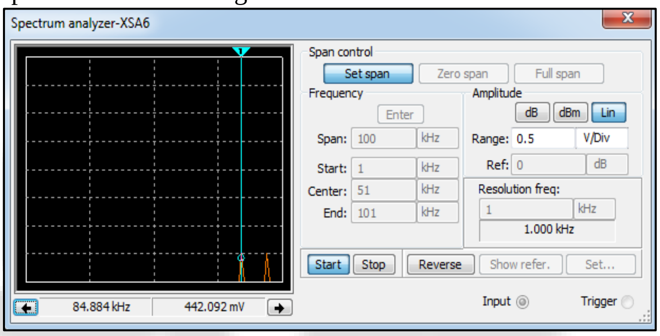


Fig. 12: Shows frequency component of DSB – SC signal at 85 KHz

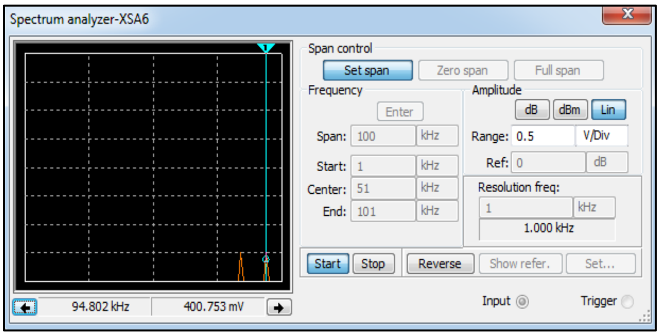


Fig. 13: Shows frequency component of DSB – SC signal at 85 KHz

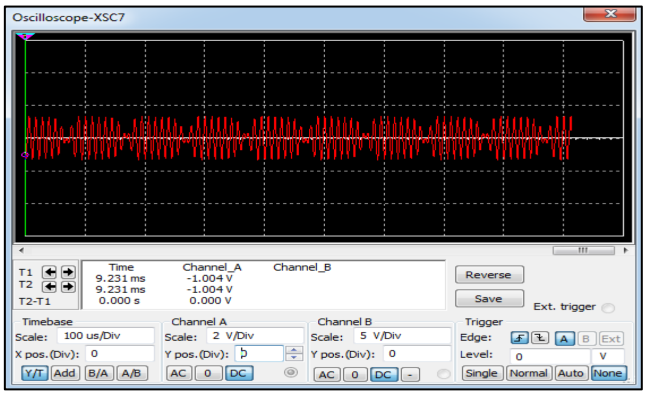


Fig. 14: Amplifier Circuit output at transmitter Side

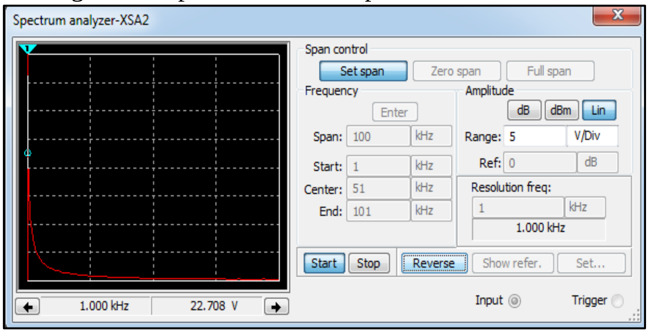
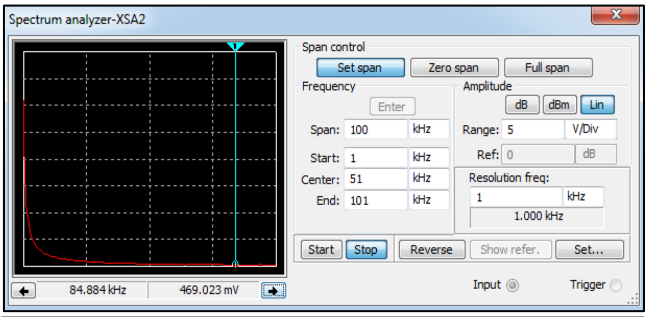


Fig. 15. Frequency Spectrum of Coupling signal in power line



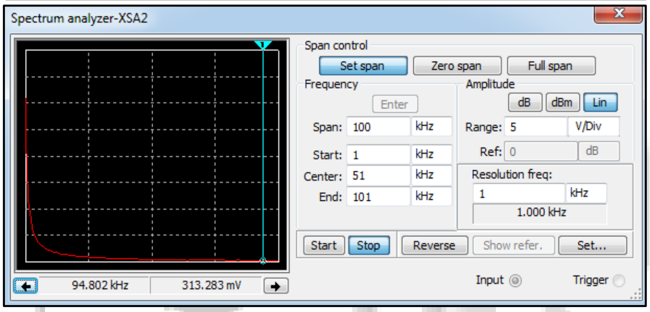


Fig. 16. Frequency component of DSB – SC signal at 85 KHz and at 95 KHz from Power Line

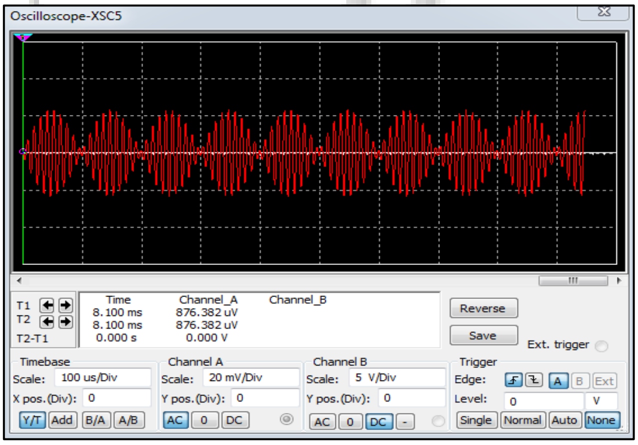


Fig. 17: DSB – SC signal at the receiver side

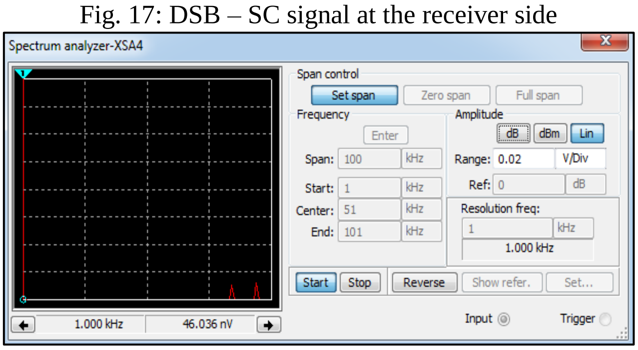


Fig. 18. Frequency Spectrum of Received DSB—SC signal

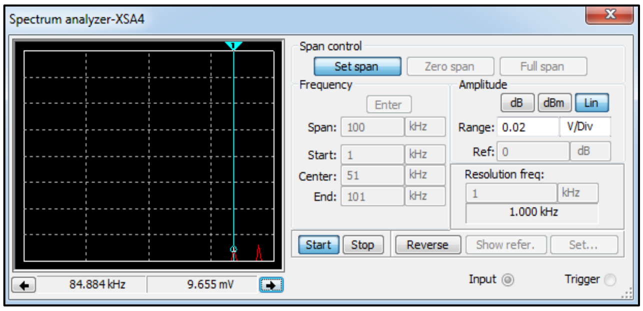


Fig. 19. Frequency component of DSB – SC signal at 85 KHz

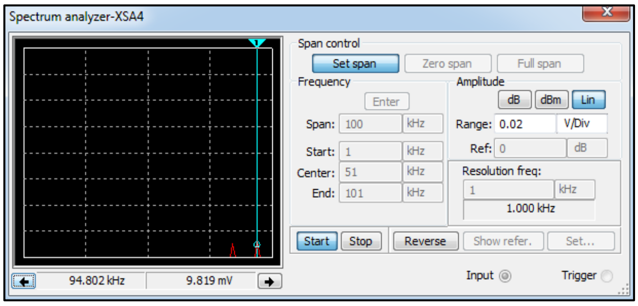


Fig. 20. Frequency component of DSB – SC signal at 95 KHz

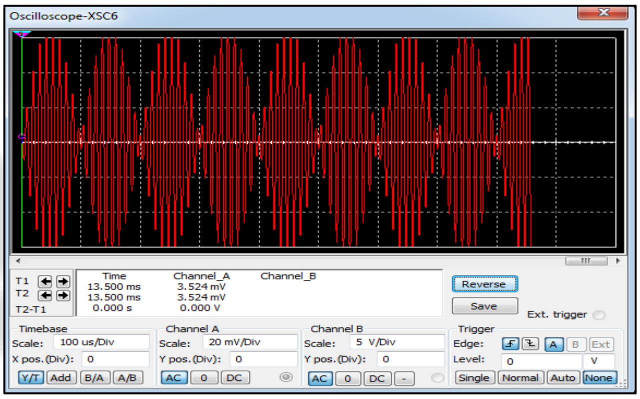


Fig. 21: Amplified version of DSB – SC signal at the receiver side

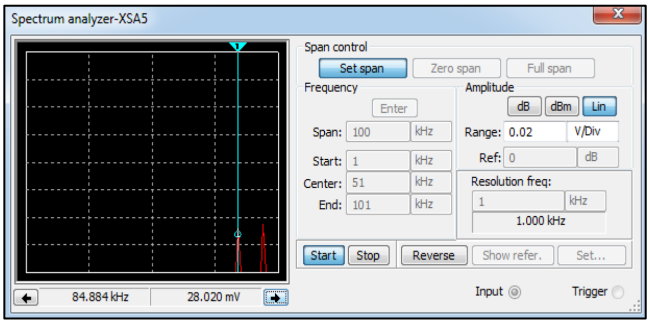


Fig. 22: Frequency component of DSB – SC signal at 85 KHz

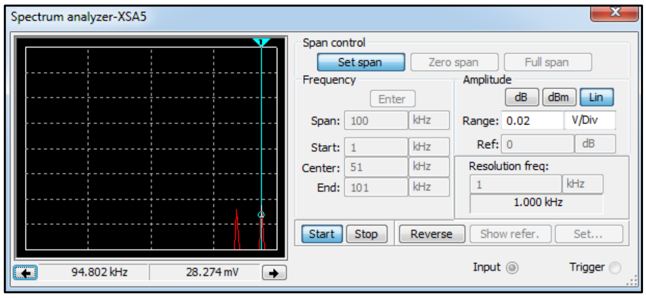


Fig. 23: Frequency component of DSB – SC signal at 95 KHz at the receiver side

V. CONCLUSIONS

Using a DSB-SC modulation technique, we designed completely a fire alarm system over a PLC by simulation. But in this paper, we mostly focusing on how to transmit an audio signal over a PLC and this method lead to get some advantages over traditional methods. For example, wiring cost becomes less. Comes to the future work, in this system design, we only use single sensor and single buzzer or warning unit. But in practically, fire alarm system requires several sensors to detect heat at several locations and also several warning unit are required to be installed in user's house. In this current design, only one signal is to be transmitted by using a proper modulation technique for realized this system. So, we have to apply some modifications especially at coupling method where the coupler must be able to working in various frequencies. It is because to implement this system design, each sensor in different location must use different carrier frequency to separate the source signal from the sensor so the activated sensor can be determined. Another future work is the use of modulation technique where the uses of higher level modulation technique such as Single Side Band (SSB) possibly improve the transmission efficiency.

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