Development Of A Receiver Circuit For Medium Frequency Shift Keying Signals

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Abstract: The design of a receiver circuit at a frequency of 500 kHz for an input frequency shift keying (FSK) signal from a transmitter is presented. A receiver is to receive an RF signal, amplify it, filter it to remove unwanted signals, and recover the desired base band information. It consists of an amplifier, tuned circuits and mixers which filters the base-band information. A comparator circuit is incorporated, to detect the digital signal received. The output from the comparators is the digital equivalent of the coded signals sent by the transmitter circuit, and transferred to a microcontroller circuit, to act as a coded signal representing information from the transmitting end. The bode-plot response of the receiver to the incoming signals using a FET tuned circuit, shows that only frequencies above 470kHz, and below 495kHz are allowed to pass through the network with a resonant frequency of 483.553 kHz and a gain of 27.734dB, while others are totally attenuated. The reliability of the designed receiver circuit was evaluated for a 1 year continuous operating period and was found to be 74.7%, with the area of application discussed.

Key words: Band-pass network, resonant circuit, detector, comparator, FSK signals, Quality factor, FET amplifier.

INTRODUCTION

A receiver is the destination end of any communication system, having the capability of recovering the original information sent. The first three blocks of a generic receiver are the RF amplifier, mixer and oscillator (Andrew and Jim, 2004). They form what is known as the "front end" of the receiver as shown in Figure 1. The front end is very important in setting the noise figure of the receiver. In particular, the RF amplifier should be a low noise design because it amplifies all the low-level signals from the antenna – including noise – with a significant amount of gain. The better the low-noise design of the RF amplifier, and the mixer, the better the receiver sensitivity (Hudson and Luecke, 1999)**.** The RF amplifier designed to amplify the low level signal from the antenna. At the input terminal of the amplifier, a rhombic antenna was connected which receives the signals and other surrounding signals which needed to be separated. A FET amplifier was selected to amplify the received signals from the antenna end. The choice was based on its advantages over bipolar transistors which include (i) extremely high input impedance (ii) less noise and better thermal stability (Anand ,2001; Theraja, 2003).

The receiver circuit consists of an AM receiver and a comparator circuit. The basic purpose of a receiver is to receive an RF signal, amplify it, filter it to remove unwanted signals, and recover the desired base band information. Since the RF signal usually comes from an antenna, its amplitude is very small, often in the order of a few micro-volts (Beasley and Miller, 2005; Berube, 2002). The receiver is to amplify the signal from a very small level up to usable levels of several volts or more. The basic digital modulation techniques used in wireless communications include the frequency shift keying (fsk) among others (Beasley and Miller, 2005), and fsk is a form of frequency modulation in which the modulating wave shifts the output between two pre-determined frequencies, usually termed the mark and space frequencies. Because of the narrow bandwidths in fsk, it offers only slightly improved noise performance over the AM two-tone modulation scheme, however, the greater number of sidebands transmitted in fsk allow better ionospheric fading characteristics than do a two-tone AM modulator schemes. Recalling that we modulate a sine wave carrier with the baseband binary stream of necessity to shift the resultant modulated signal to an appropriate frequency for transmission, at the receiver we must undo this process or demodulate the signal to recover the original binary stream (Fagbohun,2010). This process of demodulation is often called detection. There are essentially two common methods of demodulation (Schwartz,1980). One, called synchronous or coherent detection, simply consists of multiplying the incoming signal by the carrier frequency that is locally generated at the receiver and then low-pass filtering the resultant multiplied signal. The other method is called envelope detection. The synchronous detection procedure in which FSK signals require two sine waves, one for each frequency transmitted is used for this work.

Methodology of Research:
a). Materials Used:
An op-amp in summing mode and a FET transistor 2N4416A as the amplifier circuit with frequency tuning were used in the design with calculations made to select the circuit parameters. A diode 1N914 was used as a

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detector and an fsk mode of frequency modulation was developed using two separate band pass filters with an op-amp LF411CN. A comparator TLC 372D was used to generate the digital circuit. Multism -10 was used for the design schematics and analysis of the circuit with measurements using Oscilloscopes and Bode plotter.

b). Receiver Circuit Design For Frequency Shift Keying Signals:

The circuit design for the receiver for an fsk signal is developed from the block diagram of figure 1. The signal impinging on the rhombic antenna is represented by an input source of 18uV, 500kHz 20kHz, which is pre- amplified by FET amplifier Q1 and Q2, with its collectors connected with a parallel tuned circuit mixed with a 500kHz, 10Vpp oscillator base-band frequency. A tuned circuit amplifier offers a way to achieve gain and a particular response at high frequencies. The amplifier circuit pass-band can be controlled by the design of a resonant circuit as long as the transistor has the necessary gain. The tuned circuit for the FET amplifier was designed using equations 1 and 2, it is a narrow band filter that passes frequencies in the range of 475- 495kHz, noting that the transmitted frequency lies between 480kHz and 490kHz. To determine the parameters of the parallel resonant circuit, the quality factor (Sheda,2004);

$$Q, \text{ is } = f_R / BW \qquad\qquad 1$$

where the bandwidth ;
$B = f_{L1} - f_{L2} = 495 - 475 \text{ kHz} = 20 \text{ kHz}$
and the resonant frequency
$f_R = \sqrt{f_{L1} f_{L2}} = 485\text{kHz}$
Thus,
Q is 485/20 = 24.3 which is a narrow band pass filter design specification.
For a parallel resonant circuit,

$$Q = Rp / X_L \text{ or } R_P / X_C \qquad\qquad 2$$

where $X_L = 2\pi f_R L$ and $X_C = 1/2\pi f_R C$, and $Rp = QX_L$.
If L is taken as 10uH , then $X_L = 2\pi \times 485 \times 10^3 \times 10 \times 10^{-6} = 30.473$
Therefore Rp = 24.3 x 30.473 =741Ω or 750 Ω .
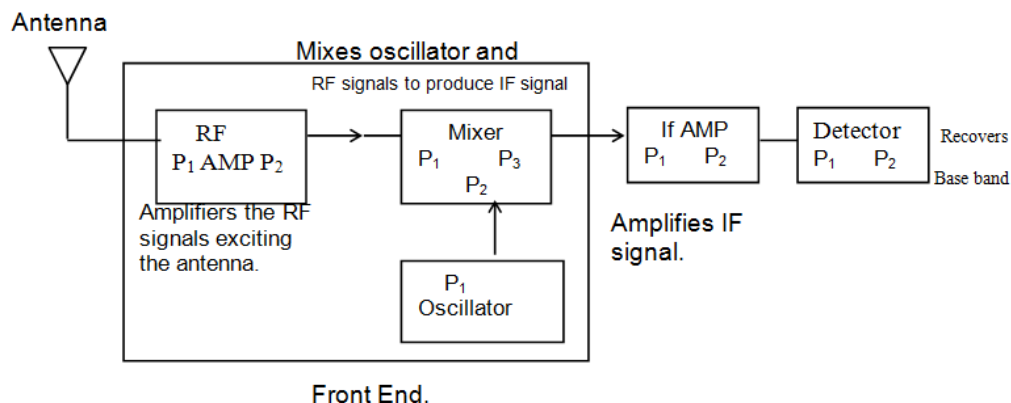At resonance, $X_L = X_c = 2\pi f_R L$; thus
$X_c = 30.473 = 1/2\pi f_R C$
$C = 1/2\pi f_R . 30.473 = 10.76\text{nF}$
For a tuned amplifier circuit, the gain,

$$A_v = - g_m . Z_L \qquad\qquad 3$$

Where Z_L is the net impedance seen by the drain circuit i.e r_L // QX_L, thus,
$Z_L = 1.5//1.5 \text{ k}\Omega = 0.75 \text{ k}\Omega$; and $A_v = - g_m . Z_L = - 3.33 \times 10^{-3} \times 0.75 \times 10^3 = - 2.50$ (the –ve sign indicates a 180^0 phase shift)

Fig. 1: Receiver circuit block diagram.

The tuned circuit amplifier with calculated inductance value of 10µH and a capacitance value of 10nF, acts as an input preamplifier circuit for the incoming signal as shown in Figure 2 . This is required to pass a frequency of 480 kHz and 490 kHz freely, and reject any other frequencies surrounding it. A circuit that extracts the original baseband signal from the modulated carrier is called a demodulator or detector. The AM

demodulator is the key circuit used for the demodulation of the FSK signal used. The diode detector used is basically a half-wave rectifier circuit with a low-pass filter (Coates,1982). The diode conducts during the positive half cycle of the amplitude-modulated carrier. During the negative half cycle, the diode is reverse biased and no current flows through it or resistor R_{29}. This causes the voltage across resistor R_{29} to be a series of positive pulses whose amplitude follows the amplitude of the modulated carrier.

For the circuit, R_{12},and R_{10}, R_{28}, R_{32} provides the leakage path to the gate current, and also serves the purpose of avoiding short circuiting of the ac input voltage; while R_7,R_9,R_{29} and R_{33} develops the gate bias for the FET amplifier circuits. The capacitors C_3, C_4, C_{11}, C_{14}, C_{15}, C_{18} are used to couple the input voltages and the output voltages respectively. Capacitor C_5, C_6, C_{12}, and C_{16} keeps the input of the FET effectively at ac ground.

Capacitor C_{11} forms an R-C filter with resistor R_{29}. The operation of the R-C filter can be analyzed in the time domain or the frequency domain (Schwartz,1980). If we examine the operation of the R-C filter in the frequency domain, it can be considered to be a low-pass filter. This low-pass filter should pass the modulating signal frequencies and reject the carrier frequency and all other harmonic frequencies generated by the nonlinear diode. If the correct value of C_{11} is selected for a cutoff frequency that is above the modulating frequencies and below the carrier frequency, the waveform across capacitor C_{11} will be a close approximation to the original modulating signal. If the cutoff frequency is too close to the carrier frequency, the output ripple will be too large. If the cutoff frequency is lower than the modulating frequency, diagonal distortion will result. The purpose of coupling capacitor C_{15} in the AM diode detector is to remove the dc component from the recovered signal. The coupling capacitor will eliminate this dc component because a capacitor can pass an ac signal, but does not pass a dc voltage. The coupling capacitor (C_{15}) and load resistor (R_{33} combination acts like a high-pass filter (Milman and Halkias, 1991).

The output from the detector, which is the FSK signal generated at the transmitting end, is fed into two separate band –pass filters with Q3 and Q4; one for mark at 20kHz and the other for space at 10kHz. To extract the 10 kHz space frequency from the base-band information received after the amplification of the detected signals, a band-pass filter network was designed to pass a frequency of 10 kHz . To determine the parameters of the parallel resonant band-pass circuit and the quality factor , we use equation 1 , 2 and 3 to arrive at $Q = f_R /$ BW = 100 for a bandwidth of 100hz . If L is taken as 10uH, we get by calculation, C = 25.36uF with Rp = 63 **Ω**
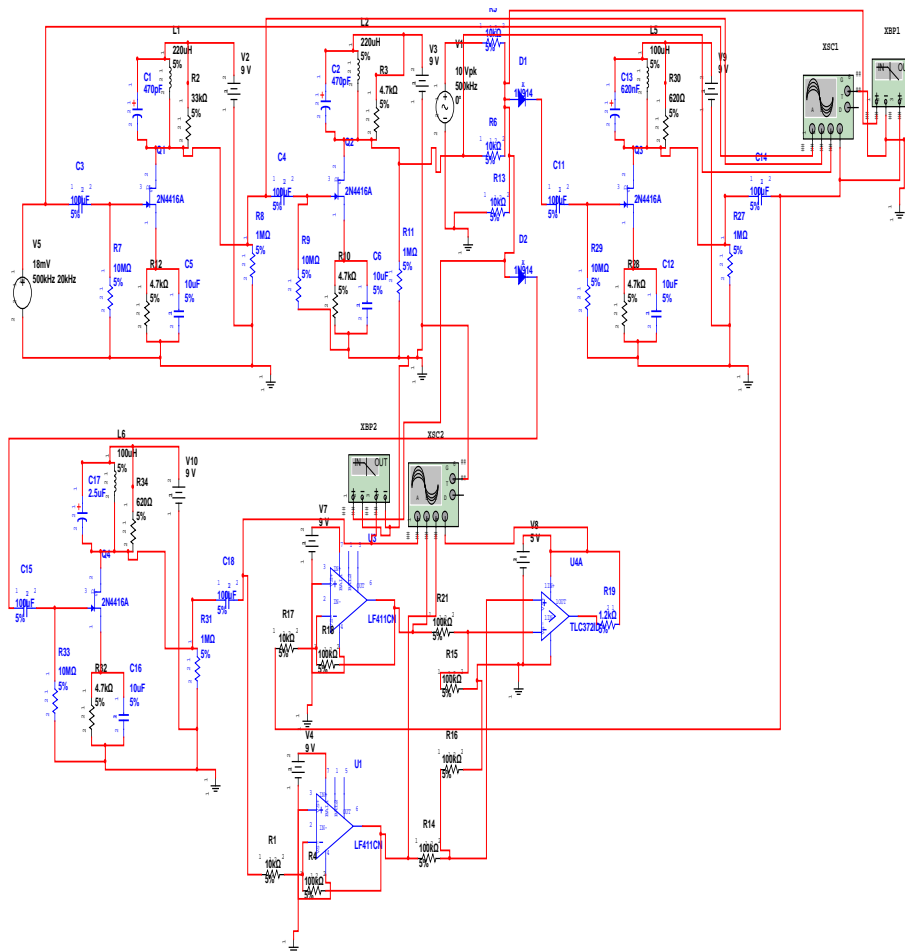

Fig. 2: Receiver circuit for the medium frequency fsk circuit.

To extract the 20kHz mark frequency, a band-pass filter network was designed with the same equations as applied to the extract of 10kHz information, but here, using a bandwidth of 200Hz, to get Q = 100, Rp =1.2k and C = 25.36uF. The output from the parallel filters are fed to a comparator circuit. A comparator is a circuit which compares an input signal Vi(t) with reference voltage Vr. When the input exceeds Vr, the comparator output voltage Vo takes on a value which is very different from the magnitude when Vi is smaller than Vr. If the input to an op-amp comparator is a sine wave, the output is a square wave. If a zero crossing detector is used, (i.e. when Vr is set to zero), a symmetrical waveform results.

The output from the comparators is the digital equivalent of the coded signals sent by the transmitter circuit, and this can be transferred to a microcontroller circuit, to act as a coded signal representing an information from the transmitting end.

For the circuit analysis, the a.c equivalent circuit of a common source amplifier obtained by short-circuiting the capacitors and the d.c supplies, with the FET replaced by its low frequency model. (Sheda, 2004), shows that, $A_v = V_o / V_{in}$; and the current through R_{27}, R_9, R_{29}, and R_{33} as the drain current (by current divider rule) is

$$i_d = r_d (g_m . v_{gs}) / (R_d + r_d) \qquad\qquad 4$$

where g_m is the FET transconductance in mA/V or mS; and v_{gs} is the gate –to- source voltage. Thus, the output voltage can be calculated as
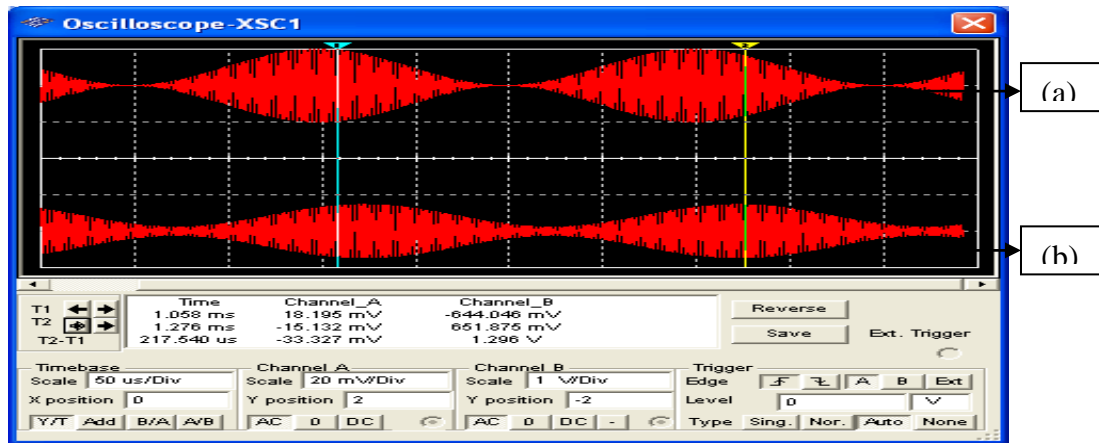
$$V_o = - i_d . R_d = - g_m . R_d \backslash\backslash r_d . v_{gs} = - g_m . r_L . v_{gs}   \text{ with } (r_L = (R_d \backslash\backslash r_d))$$

$$\text{or} \quad V_o = - g_m . r_L . v_{in} \qquad\qquad 5$$

and from Shockey's equation (Sheda, 2004), $I_D = I_{Dss} (1 – V_{gs} / V_p)^2$ \qquad\qquad 6

Results Of The Designed Receiver Circuit:

The response of the receiving RF amplifier is as shown in Figure 3 giving an output voltage of 660mV, which is further amplified using the common source FET amplifier of Figure 2, to give an output of about 4.5V, as shown in Figure 4. The bode-plot response of the receiver to the incoming signals using a FET tuned circuit is as shown in Figure 5. The peak voltage measured is 4.5V. This voltage is enough to drive the AM diode detector whose forward voltage response is 0.7V. The bode-plot response of the receiver to the incoming signals using a FET tuned circuit of in Figure 5 shows that only frequencies above 470kHz and below 495kHz are allowed to pass through the network with a resonant frequency of 483.553 kHz and a gain of 27.734dB, while others are totally attenuated.
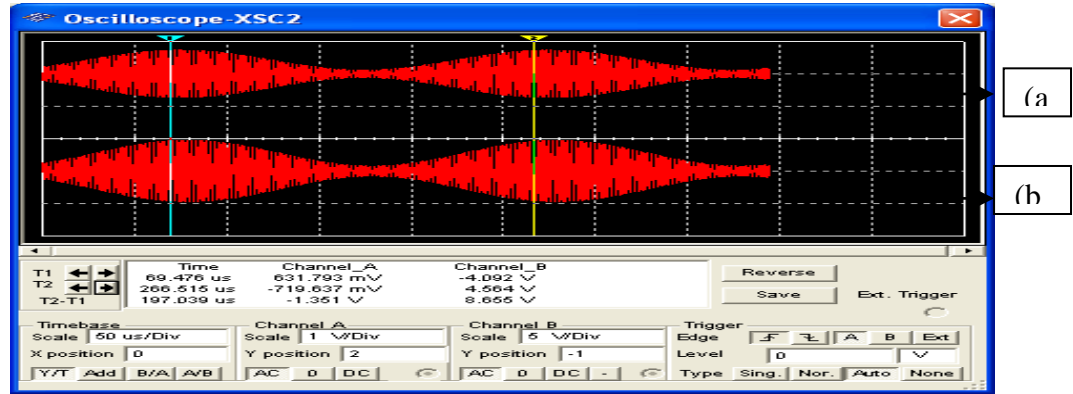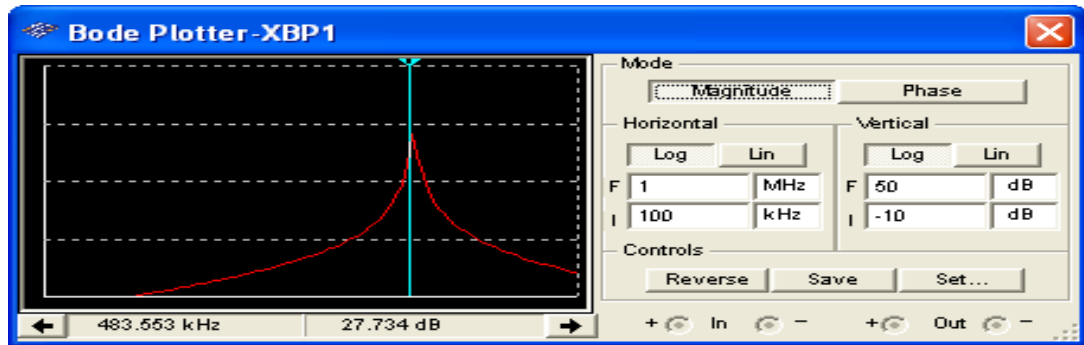

Fig. 3: Waveform of the FET receiving amplifier response

The output voltage from the diode detector 1N914 circuit is 1.32V, as measured by the oscilloscope, and this voltage is amplified using the FET rf amplifier circuit of Figure 2. The output from the detector is the frequency shift keying signal transmitted from the OTS at a voltage of 8.5V and 7.4V as shown in Figure 6. The output from the detector is the frequency shift keying signal transmitted from the OTS at a voltage of 8.5V and 7.4V as shown in Figure 6. The detector output signal is fed to two separate band – pass filters (one for 10kHz and the other for 20kHz), with their component values calculated to give a response as shown in Figure 6. This shows that the 20 kHz was separated from the 10 kHz signal.

Table 1: Measured Band pass frequencies and gain for resonant frequency of 20kHz.

Bandpass frequency in kHz	Measured gain in dB
18.29	- 42.037
19.055	- 37.494
19.449	- 33.718
19.851	- 26.789
20.261	- 23.76
21.108	- 34.519
22.445	-42.401
23.382	-45.272

Fig. 4: Amplification of RF amplifiers output voltage to 4.5V using FET amplifier.

Fig. 5: Bode plot of the receiving rf amplifier circuit response

Table 2: Measured Band pass frequencies and gain for resonant frequency of 10kHz.

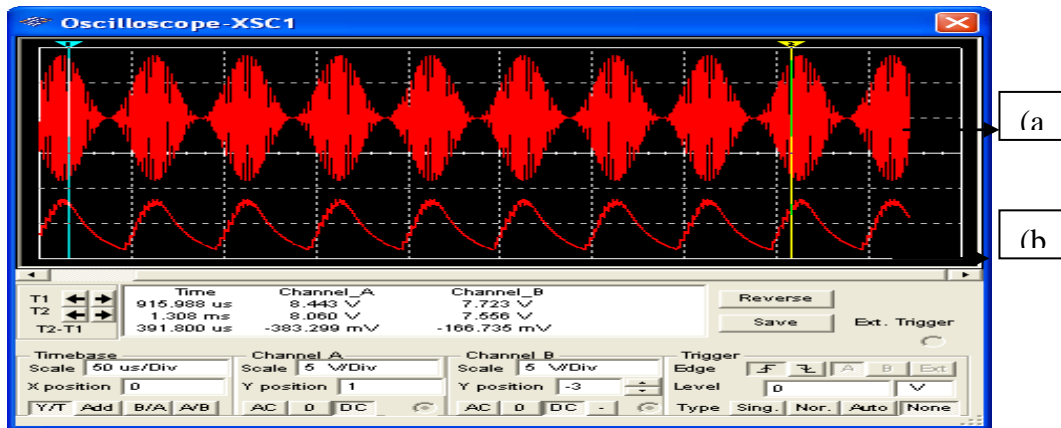| Bandpass frequency in kHz	Measured gain in dB
9.12	- 52.385
9.698	- 48.116
10.00	- 44.970
10.312	- 39.583
10.633	- 19.688
11.307	- 42.074
12.023	- 48.954
14.017	- 56.330

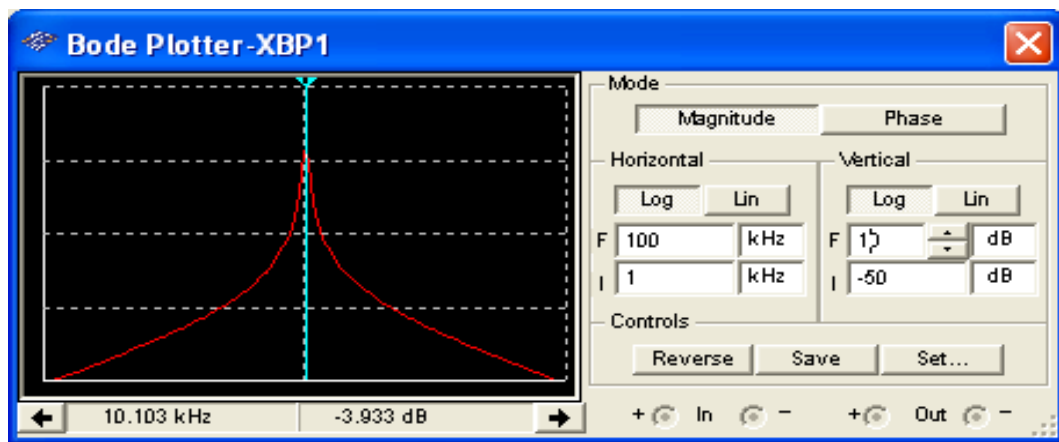**Fig. 6:** Diode detector output response a). Input b). output

Fig. 7: Band –pass network response diagram to extract the 10kHz signal.
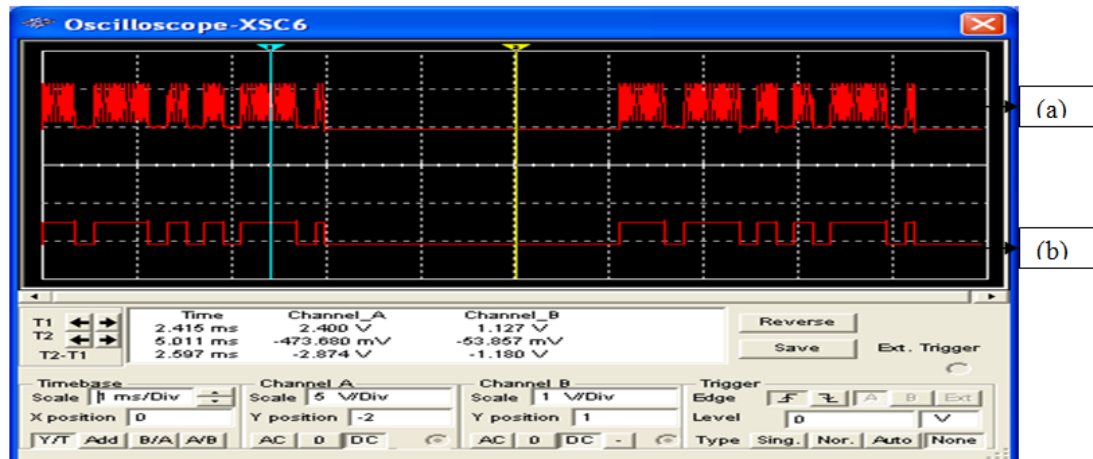

Fig. 8 a: output from the 20kHz filter, b). The comparators output giving the digital signals.

The output of the two separated parallel filters of Figure 7, was fed into a comparator circuit TIL372ID which gives a response shown in Figure 8. When the 20KHz representing the mark frequency (or the High State of the transmitted information) passes through the circuit, a voltage of 5V is achieved and when the frequency is changed to 10kHz, the voltage is in its reference voltage level of OV. This digital signal forms an input signal to the microcontroller circuit which is in serial form. The serial digital information from the receiver, being fed into the microcontroller is processed and transferred to the on –line microcomputer for interpretation. The reliability assessment of the designed receiver circuit was carried out with the number of component parts, and the basic failure rate for each part being multiplied by the weighing factors (environmental, operating stresses

and temperature) to determine the product failure rate, and this was used to calculate the reliability for a 1 year continuous operating period (Oroge, 2006), and was found to be 74.7%.

Conclusion:

The receiver circuit designed receives an fsk signal at 500kHz, the receiving amplifier filters the incoming signal and amplifies the input voltage to a useable level at 4.5V. The output from the filters through the comparators gives the digital equivalent of the coded signals sent by the transmitter circuit, and this can be transferred to a microcontroller circuit, to act as a coded signal representing an information from the transmitting end. The reliability of the designed receiver circuit was calculated for a 1 year continuous operating period, and was found to be 74.7%.This digital signal can be used for many security information purpose including electronic coding of housing units in a decentralized community for electronic policing of an environment under surveillance, to solve the problems of household breaking –in and stealing, robberies and other crime preventive measures.

REFERENCES

Anand, M.L., 1999. Electronic principles – Devices and Circuits, 6th edition, S.Chand and Company.

Andrew, J.V. and K.O. Jim, 2004. Principles of digital communication and coding ; Third edition, Prentice Hall international, inc.

Beasley, J.S. and G.M. Miller, 2005. Modern Electronic Communication, 8th edition, Pearson Education inc.

Berube, H.R., 2002. Learning Electronics communications through experimentation using electronic workbench multisim; Prentice Hall inc.

Brad, R.J. and E.S. Carlos, 2004. Frequency shift keying (FSK) modulator using MEM's switch, www.goggle .fsk. Visited on 12th February 2006

Coates, R.F.W., 1982. Modern Communication Systems, 2nd edition, Prentice Hall, New Jersey

Fagbohun, O.O., 2010. "Development of a low cost frequency shift keying (fsk) modulator with transistor switching ; International Journal of Engineering, 4(2): 249-255. West Bengal, India.

Hudson, W.J. and J. Luecke, 1999. Basic Communications Electronics; Radio-Shark R 62-1336 , Master Publishing Inc, Lincolnwood, Illinois

Oroge, C.O., 2006. Fundamentals of reliability and testing methods; 2nd edition, Sooji press limited, ISBN 978-30901-1-9.

Schwartz, M., 1980. "Information Transmission, modulation, and Noise. 3rd edition, McGraw-Hill Series in Electrical Engineering.

Milman, J. and C.C. Halkias, 1991. Integrated Electronics, 30th edition,McGraw-Hill book Company.

Sheda, R.S., 2004. A textbook of Digital Electronics, 1st edition, S.Chand and company ltd.

Theraja, A.K. and B.L. Theraja, 2003. A textbook of Electrical Technology, 23rd ed. S.Chand & Company.