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Modulation Systems
EMS 310
Practical 2: Report

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Introduction

For a frequency modulated the signal the information is contained in slight variations in the frequency of the signal. This frequency of the carrier signal is alter in proportion to the amplitude of the message signal.

Frequency modulation is a inherently non-linear modulation. It can be achieved either by frequency modulation (FM) or phase modulation (PM). These methods are similar; for PM the instantaneous angular frequency varies linearly with derivative of the message signal, whereas for FM it varies with the message signal. These methods are described by the following formulas.

$$u_{PM} = A\cos\left(\omega_c t + k_p m(t)\right)$$

$$u_{FM} = A\cos\left(\omega_c t + k_f \int_{-\infty}^{t} m(\alpha) d\alpha\right)$$

Fm is used in both the broadcast of radio and television audio. The spectrum from 88 MHz to 108 MHz is reserved for FM radio broadcast. Stations separations for FM radio broadcast stations are 200 kHz Peak frequency variation is 75 kHz. Originally FM radio broadcast was monophonic. Later stereophonic broadcast was adopted in such a manner that a receiver designed for monophonic broadcast would still function; although only output a monophonic blend of the stereophonic broadcast. A super heterodyne AM/FM receiver can be used for reception.

The audio portion o television broadcast is modulated using stereophonic FM at a centre frequency of 4.5 MHz and a bandwidth of 10 kHz.

Objectives

The objectives of this practical are to:

- Analyse and study FM modulation by means of generating a FM modulated signal using a voltage controlled oscillator.
- To demonstrate demodulation using a frequency discriminator circuit and envelope detector circuit.
- To investigate Woodward's theorem.
- To investigate β multiplication.

Theoretical preparation

Frequency modulation circuit:

A CLAPP oscillator as a circuit that is commonly used for frequency modulation. The general configuration of the CLAPP oscillator is I shown in the schematic bellow.

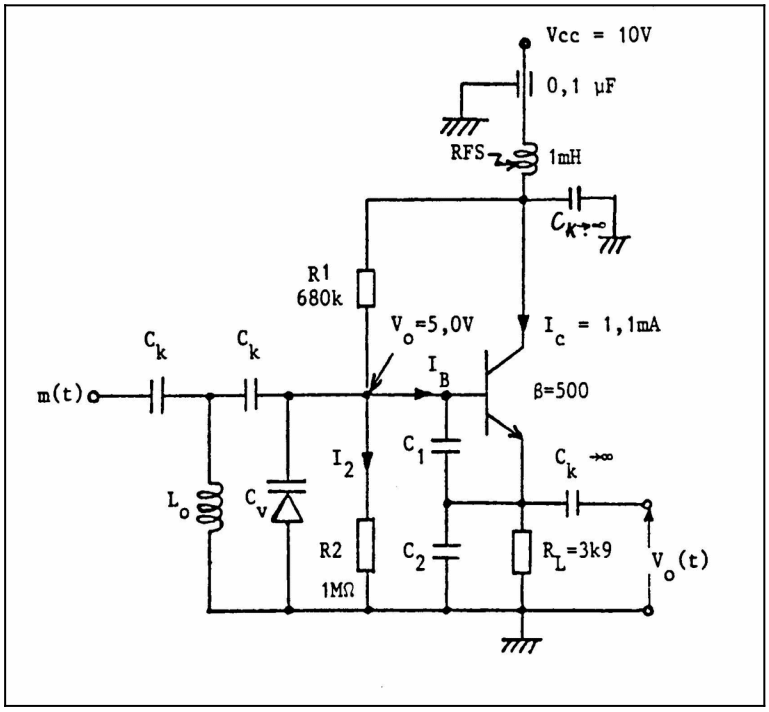


Figure 1 CLAPP oscillator

The behaviour of the clap oscillator is determined by it component values as relater in the following equation.

$$f_o = \left[\frac{1}{2\pi\sqrt{L_o(C_{vo} + C_s)}}\right]$$

When $v(t) = V_0$ $(m(t)\equiv 0)$

When a signal, m(t) is applied the reverse bias across the varicap changes. By changing the capacitance C_v the oscillation frequency of the parallel RC (tank) circuit is changed. The parallel RC circuit is the input to the amplifier. The change in oscillation frequency is seen at the output $V_o(t)$. The output is fed back into the input of the amplifier. Due to the change in oscillation frequency at the output, a FM signal is generated.

Narrowband FM signals can be generated granted that m(t) is small. This restriction is imposed by the non-linear nature of the BJT transistor and is necessary to maintain linearity. A small beta value of approximately 0.1 is required. A wideband signal can be achieved by passing the narrowband signal through a nonlinear device and a band pass filter.

Frequency demodulation circuits:

The demodulation of a FM signal can be achieved by using a frequency discriminator which will result in an amplitude modulated signal. This signal is then passed through an envelope detector circuit and finally a low pass filter to eliminate ripple effects. An alternative is to use a phase lock loop for demodulation.

Frequency discriminator

A frequency discriminator is a circuit that changes amplitude relative to the frequency of the input signal with a linear relation. The section of a high pass filter's frequency response just below the cut-off frequency acts a linear frequency sensitive attenuator.

Using a standard op-amp first order high pass filter the following equation can be used to determine the values shown in the accompanying schematic.

$$\frac{\mathbf{1}}{R_1 C_1} = 2\pi(f_c + \Delta f_{max})$$

$$f_{max} = k_f \times M$$

For the practical using the above equations:
$R_1 C_1 = 1.137 \times 10^{-5}$

Choosing C_1=2.2 nf, R_1=5.16 kΩ(Use 4.7kOhm)



Figure 2 High pass filter - discriminator

The circuit above represents the minimum cut-off for the discriminator. A safer and more practical alternative method is to intuitively design a discriminator by choosing a cut-off frequency approximately one decade larger than the centre frequency of the modulated signal. In this case:

f_{cut} = 100 Hz
t = RC 1.55 x 10^{-6}
C = 2.2nf
R = 700 Ω ≈ 560 Ω

Envelope detector:

The value of R2 and C2 can be calculated using the following inequality:

$$\frac{1}{f_c} \ll R_2C_2 \ll \frac{1}{f_m}$$

$$10^{-4} \ll R_2C_2 \ll 10^{-3}$$

$$R_2C_2 = 10^{-3.5}$$

Choose C_2=33 nF, R_2=9.58kOhm (Use 10kOhm)



Figure 3 Envelope detector

Low pass filter:

The low pass filter was designed to pass the entire baseband signal thus having a cut-off of 1 kHz. Using the Sallen-key configuration the design values where:
R1 = R2 = 11Ω
C2 = 20nf
C1 = 10nf

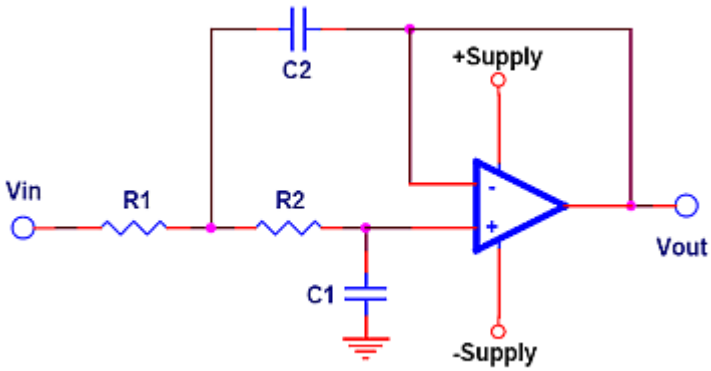


Figure 4 Low pass filter

Buffering might be necessary between phases to reduce loading.

Experimentation and results

Frequency vs. voltage of the carrier.

For the lab experiment a signal generator with a external modulation input was used to generate the carrier signal while a second signal generator was used to produce the message signal m(t).

The voltage-to-frequency transfer function of the carrier frequency generator corresponding to the lab work bench used is shown below. The measurements were taken twice and averaged to get the values in the table.

Table 1 f vs. Vin

Vin (V)	f(kHz)
-2	12.2139
-1.8	11.993
-1.6	11.7631
-1.4	11.57
-1.2	11.3584
-1	11.16
-0.8	10.9338
-0.6	10.7094
-0.4	10.4926
-0.2	10.29285
0	10.0795
0.2	9.8327
0.4	9.63405
0.6	9.4405
0.8	9.20365
1	8.9738
1.2	8.7793
1.4	8.5823
1.6	8.38205
1.8	8.15725
2	7.9481

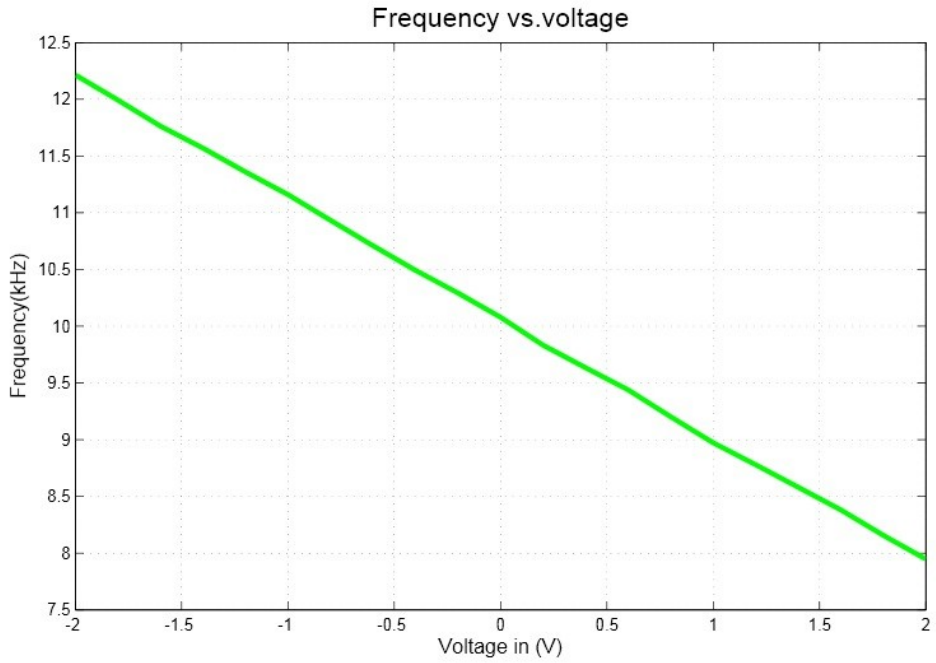


Figure 5 Frequency vs. voltage curve of carrier signal

The VCO constant, k_f (Hz/V), which is measured from the above graph is -1066 Hz/V. It was calculated as the gradient of the line as shown below.

$k_f = y_2 – y_1 / x_2 – x_1 = [7.9481 – 12.2139] / [2 – (-2)] = -1066$ Hz/V

With a carrier frequency of f_c = 10 kHz, carrier signal c(t) = Acos(2*pi*10^3), modulating signal m(t) = 2cos(2000*pi*t) the following FM-modulation parameters determined are determined.

$\beta_f = |k_f|max|m(t)| / f_m = |-1066| \times 2 / 10^3 = 2.13$
$B_c = 2(\beta_f + 1) f_m = 2(2.13 + 1)10^3 = 6.26$ kHz

β_f and B_c being the modulation index / deviation ratio and Carson's bandwidth respectively.

Signals

The FM signal and its FFT is shown below

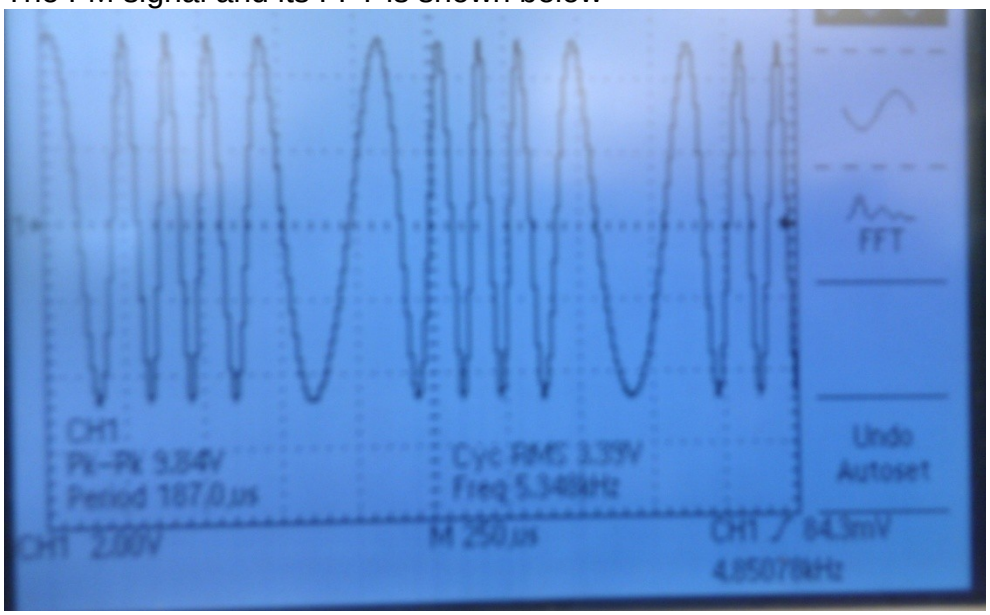


Figure 6 FM signal

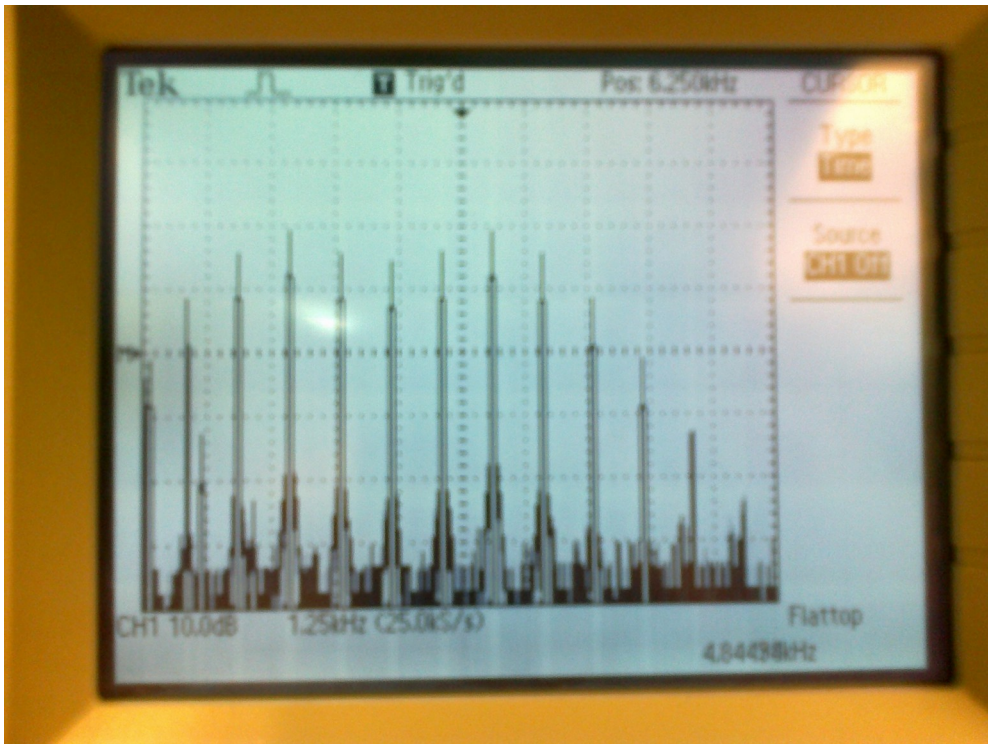


Figure 7 FFT of FM signal

FFT if the frequency of the message signal m(t) is increased

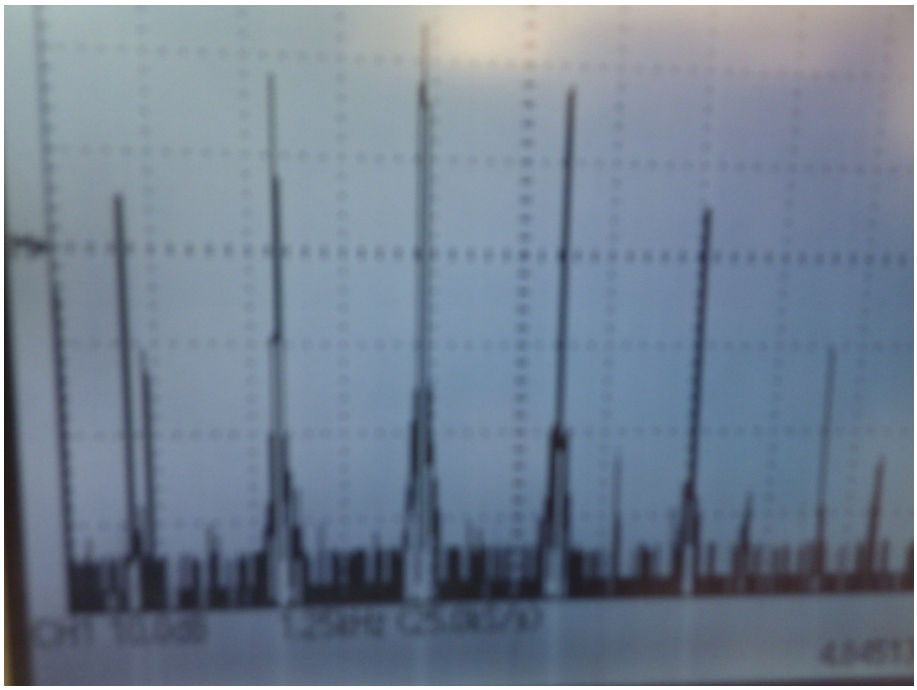


Figure 8 FFT of FM signal – increase frequency

This clearly shows the effect of Woodworths as the base bans signal gets closer to the modulation frequency the harmonics of the signal spread out and vice versa.

Below is shown the AM signal produced after the discriminator.

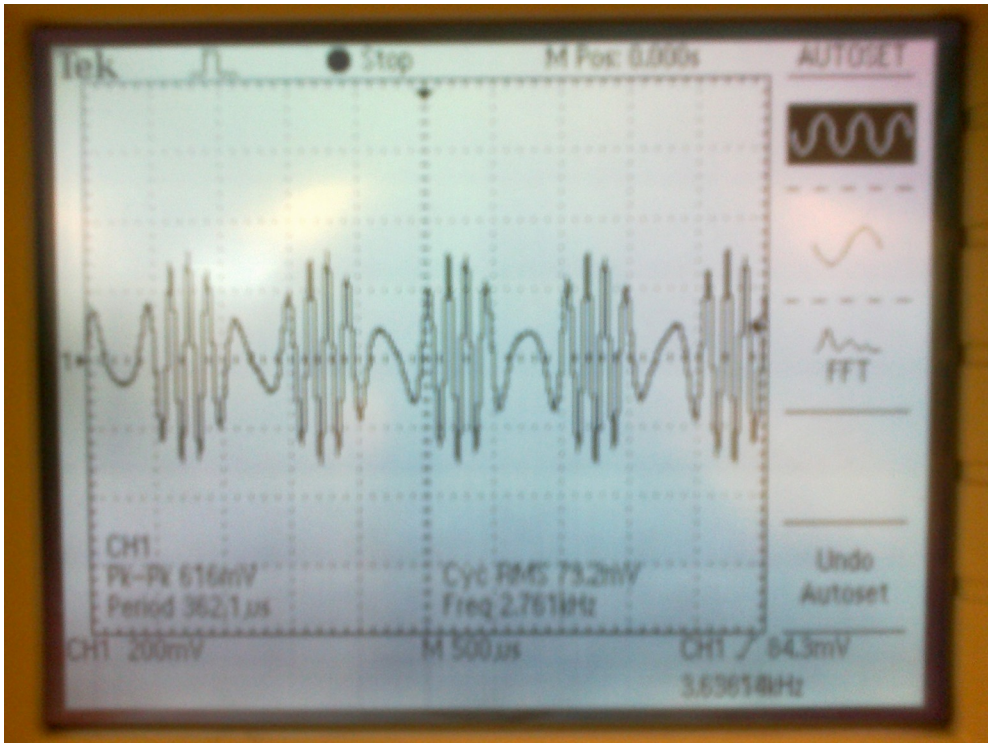


Figure 9 AM signal after discriminator

Below is the signal produced after the envelope detector.

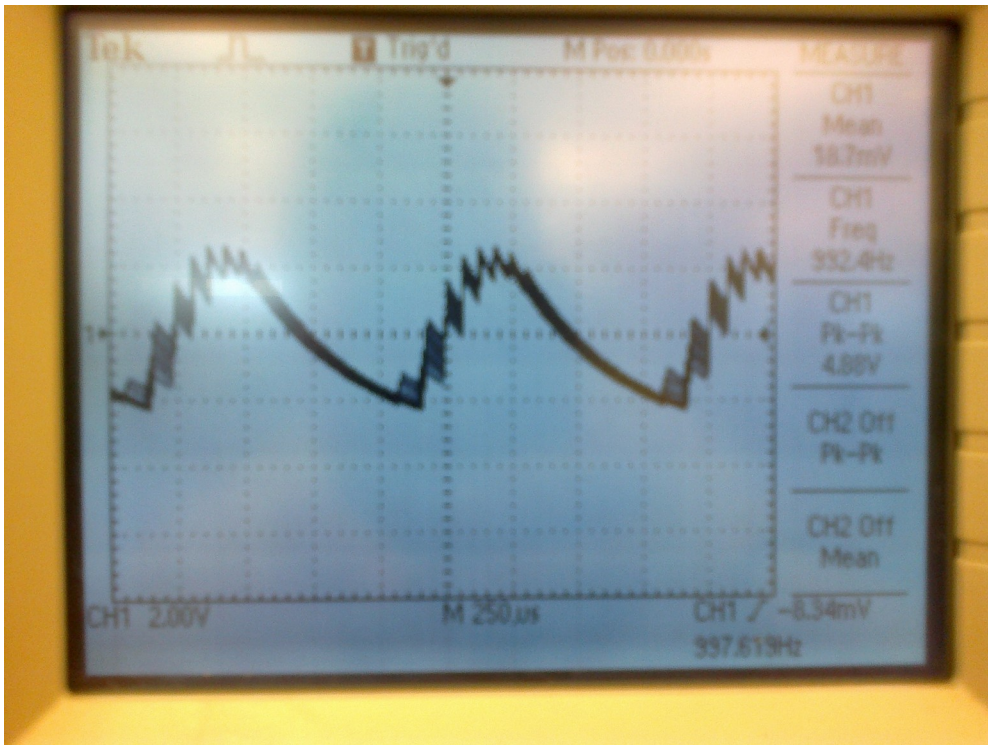


Figure 10 Signal after envelope detector

Below is the signal recovered and its FFT

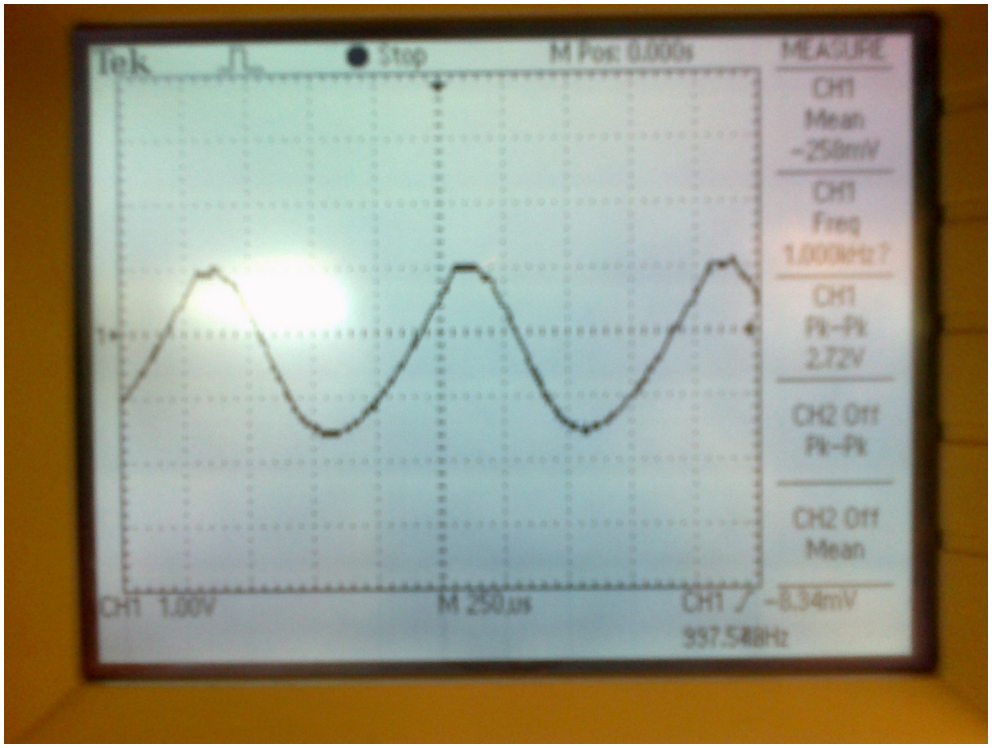


Figure 11 Output signal

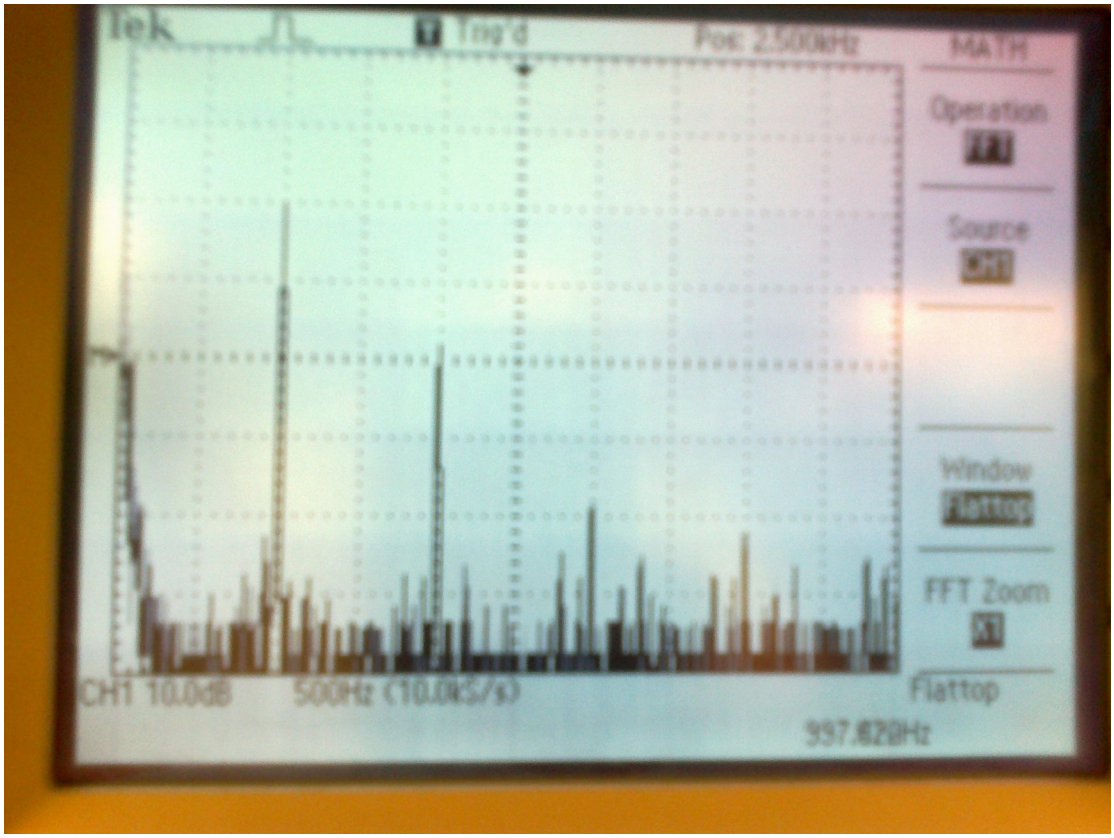


Figure 12 FFT of output signal

Discussion of results

The k_f constant of the carrier source was calculated to be 1066 Hz/V, and verified by the zero Bessel test to be 1145 Hz/V. Woodworths theorem was illustrated showing that the closer a baseband signal is to the carrier frequency the more the frequency harmonics of this signal spread out.

This practical demonstrated the viability of using simple inexpensive circuits to recover a FM modulated signal.

Conclusion

This practical demonstrates the overall simplicity with which FM modulation can be achieved and the factors that need to be considered to make the modulation and demodulation coherent. It clearly shows the effectiveness of this scheme.

References

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L.P. Linde, *MODULATION SYSTEMS EMS310: Study guide ,* Department of Electrical, Electronic and Computer Engineering, UP,2012