Habib University

iSciM
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ENER 104L RENEWABLE ENERGY

LABORATORY REPORT 1

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6 Introduction

The process of sending, propagating and receiving an analogue or digital information signal over a physical point-to-point or point-to-multipoint transmission medium, either wired, optical fiber or wireless is called transmission. A distortion is defined as the alteration of the original shape of an object, image, sound, waveform or other form of information or representation. Distortion is usually unwanted, and often many methods are employed to minimize it in practice.

In this experiment, we are dealing with frequency response of RC circuit. Frequency response is defined as the analysis of circuit with different frequency of a sinusoidal source. With the sinusoidal source, the transfer function, $H(s)$ will be the magnitude and phase of output voltage to the magnitude and phase of input voltage of a circuit :

$$H(s) = \frac{V_o(s)}{V_i(s)}$$

The circuit in Figure **??** is a first order low pass filter circuit. First order is defined as 1 pair of resistor and capacitor connected in series in a circuit. A low pass filter attenuates high frequency signal input and only allows low frequency which below the cut-off frequency to pass through. Cut-off frequency is the frequency filter start to attenuate the passage of the input signals: $f_c = 2\pi RC$. At low frequncy, the reactance of capacitor is high and the resistance is low. This result the voltage potential across the capacitor is higher than voltage drop across the resistor. Therefore, high frequency signals are attenuated in the experiment.

The circuit in Figure **??** is acting as second order high pass filter which is oppose to the meaning of low pass filter. High pass filter passes signals above the cut-off frequency and attenuates low frequency signals. By reversing the roles of resistors and capaciors, the reactance of capacitors are low at high frequency signals. Therefore, the capacitors in the circuit act as open circuit and attenuate low frequency input signals until cut-off frequency reached.

In last part of this experiment, we are studying the multipath propagation as show in Figure **??**. Multipath occurs when a signal takes more than one path from the transmitting antenna to the receiving antenna. Regarding to lecture notes, the signals are received in a terrestrial environment, i.e. where reflections are present and signals arrive at the receiver from the transmitter via a variety of paths. The overall signal at the radio receiver is a summation of the variety of signals being received. As they all have different path lengths, the signals will add and subtract from the total dependent upon their relative phases. Sometimes these will be in phase with the main signal and will add to it, increasing its strength. At other times they will interfere with each other. This will result in the overall signal strength being reduced.

7 Objectives and Learning Outcomes

1. Distortion of signal during transmission occurs if the frequency response of the transmission channel is not of constant amplitude and linear phase. In this laboratory work, the student will:

   (a) Design and conduct an experiment to analyse the frequency, amplitude and phase responses of a RC transmission line model.

   (b) Conduct an experiment to demonstrate the frequency sensitive fading phenomenon using a simple two-path model of multi-path propagation.

2. To understand some factors that may cause signal transmission distortion, and be motivated to study further other factors such as non-linearity, load mismatching, time variant transmission medium properties and Gaussian noise.

8 Equipments

- Breadboard, two 100 Ohm resistors, two 51 Ohm resistors, and three 10 k Ohm resistors, four 1µF capacitors and three µ741 Op-Amp.
- DC power supply, Function generator, Oscilloscope and Digital multi- meter.

9 Methodology

9.1 Frequency Response Measurement

9.1.1 Part 1

1. An experiment was designed to study the amplitude and frequency response of the circuit shown in Figure ??.

2. Data collected was recorded in an appropriate format. The results were analysed and interpreted.

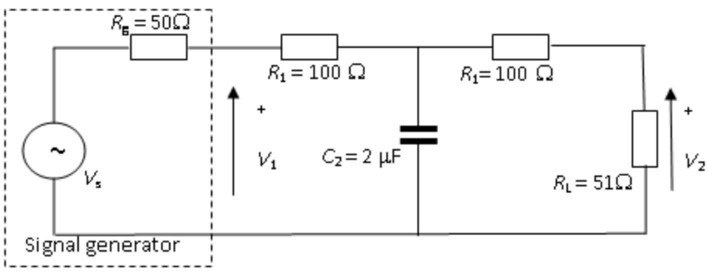


Figure 1: RC circuit(Low pass filter)

9.1.2 Part 2

1. A 100 Hz square wave was applied to the input and the effect on the output waveform V_2 was observed.
2. Repeated with 1kHz follow by 10 kHz square wave.
3. The observations were analysed and interpreted.

9.1.3 Part 3

1. The changes in the results obtained in Part 2 were discussed if the circuit shown in Figure ?? is replaced with circuit shown in Figure ?? below:

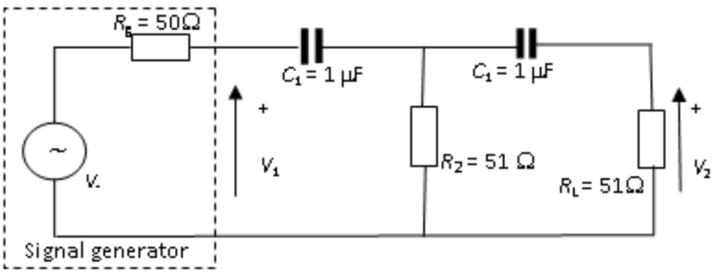


Figure 2: CR circuit(High pass filter)

9.2 Fading due to Multipath Propagation

1. V_s was set to sine wave, frequency 500 Hz and Amplitude 10 volts, the waveform V_2 was sketched and its amplitude was recorded.
2. Repeated for frequencies 1, 1.5, 3 and 5 kHz and identify the frequency that results in fading.

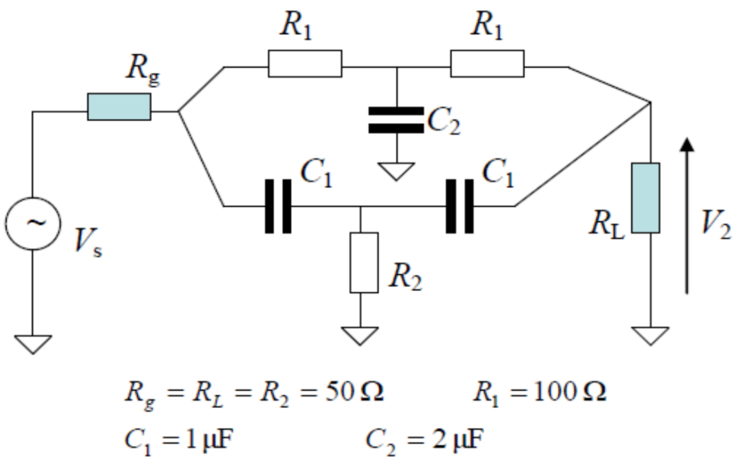


Figure 3: Multipath circuit(Band pass filter)

10 Result

10.1 Frequency Response Measurement for RC circuit(Low pass filter)

10.1.1 Experimental Result

Table 1: Experimental result for Second order low pass filter

$V_{in}(mV)$	f	$V_2(mV)$	**(I.L)dB**	**Phase (ϕ)**
5760	100 Hz	1190	-13.70	$-5°$
5730	200 Hz	1160	-13.87	$-11°$
5630	500 Hz	1070	-14.42	$-21°$
5320	1 kHz	849	-15.94	$-38°$
4930	2 kHz	560	-18.89	$-65°$
4830	5 kHz	265.1	-25.21	$-74°$
4780	10 kHz	123.86	-31.73	$-77°$
4700	20 kHz	32.55	-43.19	$-79°$
4700	50 kHz	7.7	-55.7	$-83°$
4700	100 kHz	2.29	-63.26	$-85°$

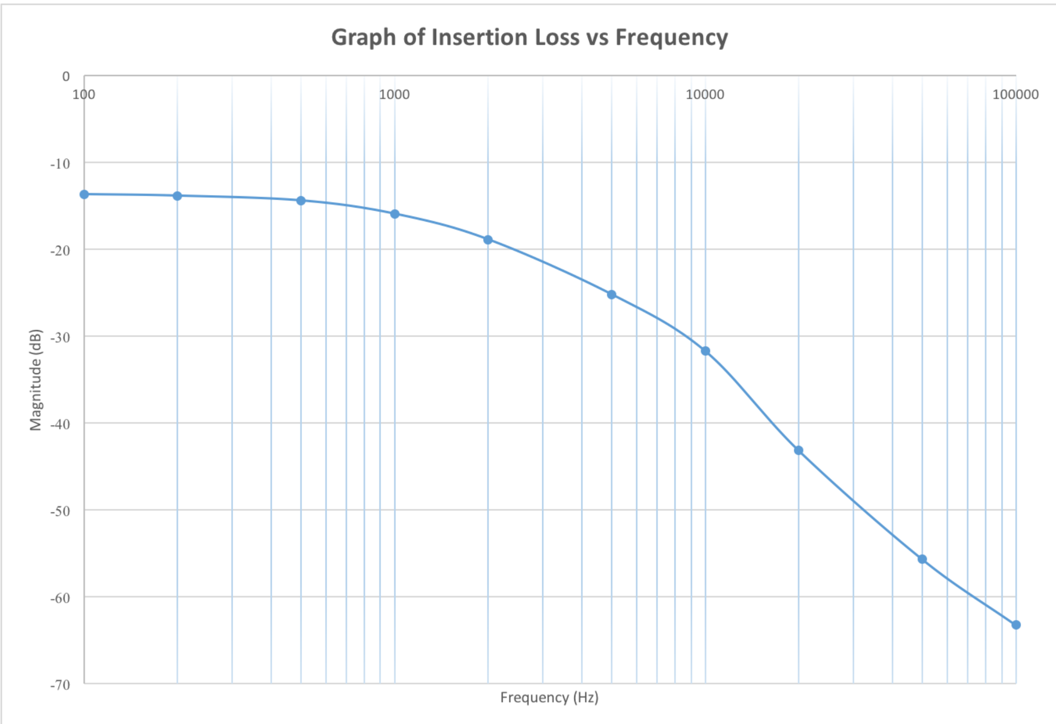


Figure 4: Graph of insertion loss versus frequencies (Low pass filter)

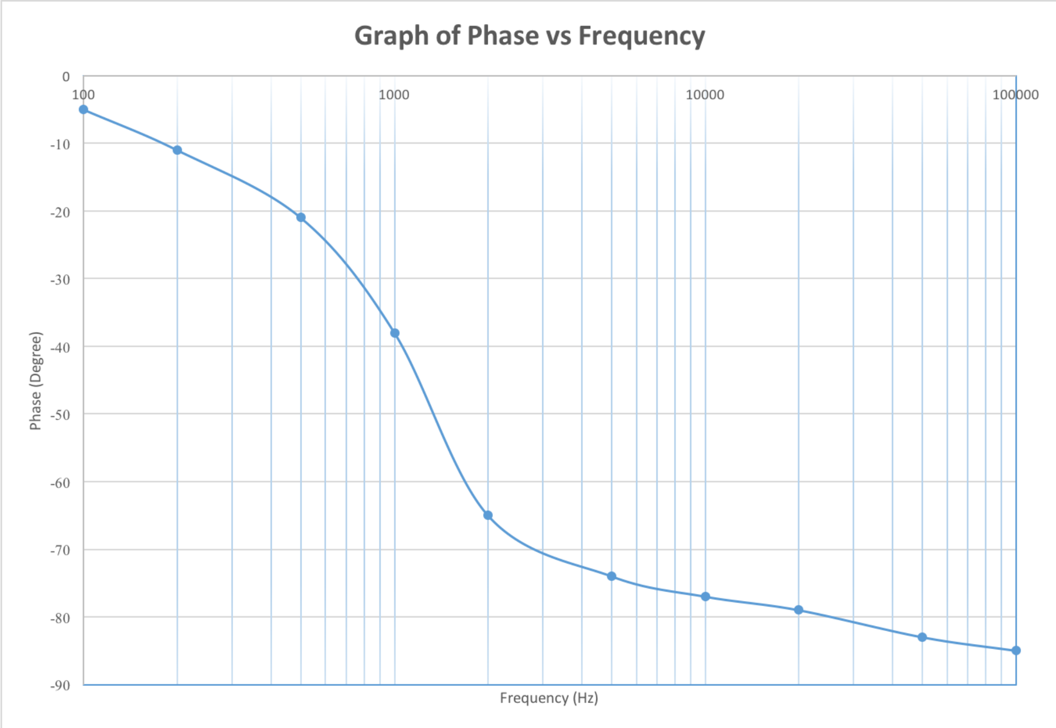
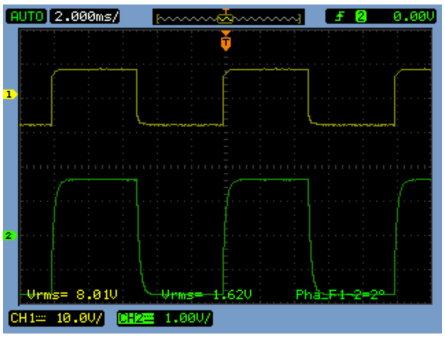
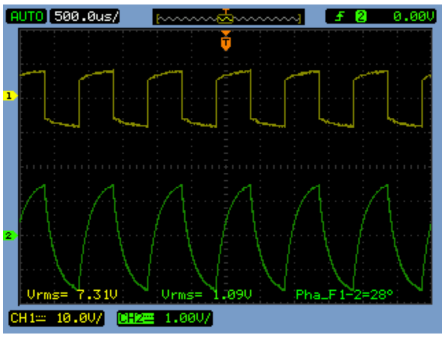


Figure 5: Graph of phase versus frequencies (Low pass filter)

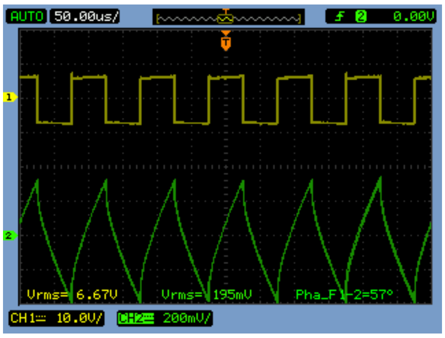
10.1.2 Transmission distortion over a RC channel



(a) frequency = 100Hz



(b) frequency = 1kHz



(c) frequency = 10kHz

Figure 6: Signal Transmission Distortion for LPF

10.2 Frequency Response Measurement for the CR circuit(High pass filter)

10.2.1 Experimental Result

Table 2: Experimental result for Second order low pass filter

$V_{in}(mV)$	f	$V_2(mV)$	**(I.L)dB**	**Phase (ϕ)**
7310	100 Hz	14.19	-54.24	173°
7040	200 Hz	40.0	-44.91	164°
6720	500 Hz	170.0	-31.94	151°
6430	1 kHz	492.85	-22.31	131°
5370	2 kHz	1050	-14.18	108°
3920	5 kHz	1840	-6.57	72°
3180	10 kHz	2040	-3.86	45°
2840	20 kHz	2170	-2.34	25°
2530	50 kHz	2200	-1.21	12°
2580	100 kHz	2230	-1.27	7°

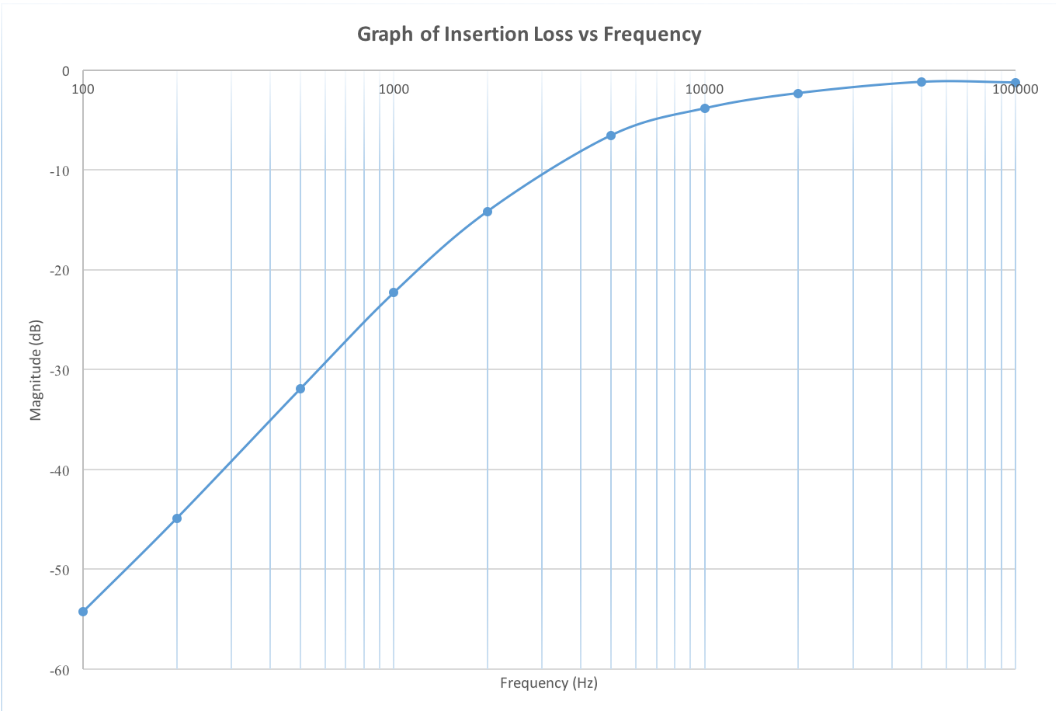


Figure 7: Graph of insertion loss versus frequencies (High pass filter)

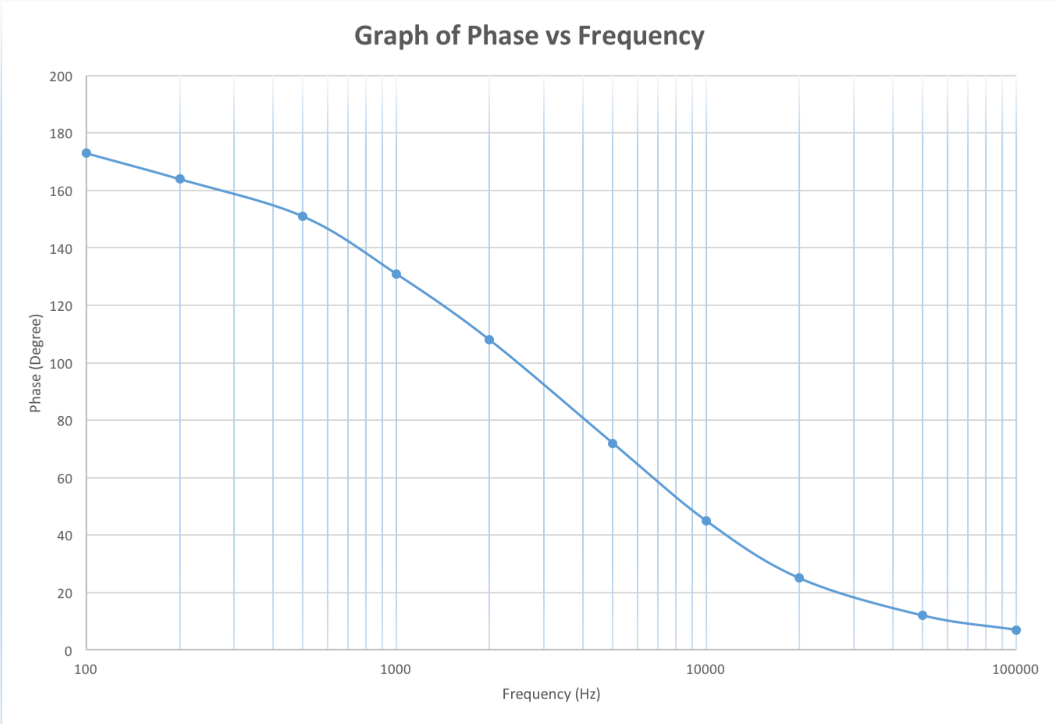
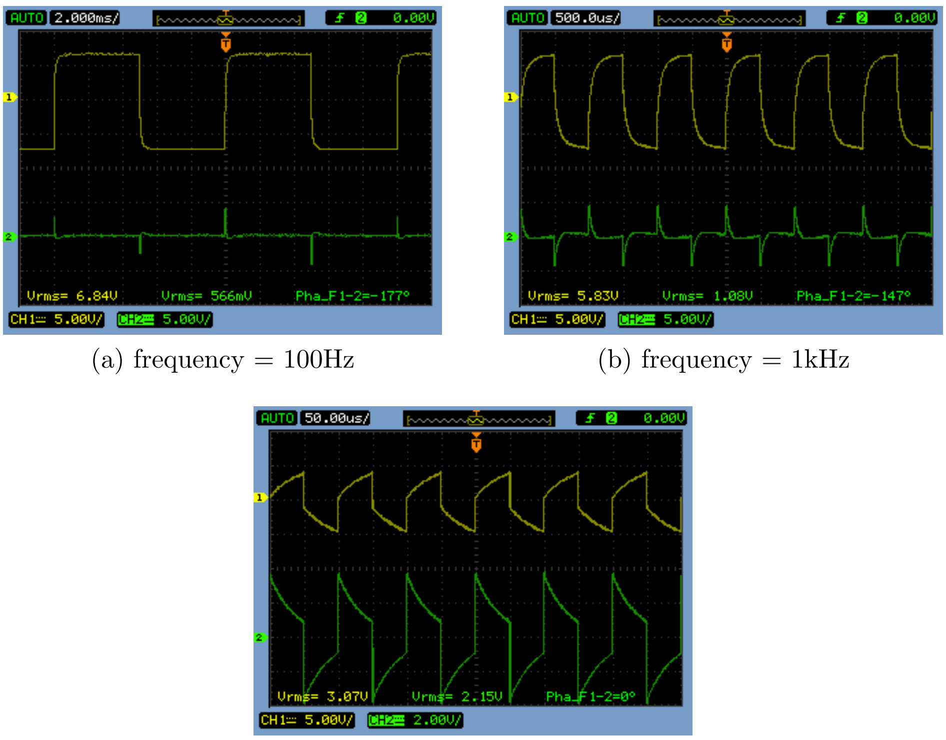


Figure 8: Graph of phase versus frequencies (High pass filter)

10.2.2 Transmission distortion over a CR channel



(a) frequency = 100Hz

(b) frequency = 1kHz

(c) frequency = 10kHz

Figure 9: Signal Transmission Distortion for HPF

10.3 Frequency Response Measurement for Fading due to Multipath Propagation (Band pass filter)

10.3.1 Experimental Result

Table 3: Experimental result for Multipath Propagation (Band pass filter)

f	$V_2(mV)$	**(I.L)dB**
500 Hz	1520	-13.27
1000 Hz	1320	-14.49
1200 Hz	1260	-14.89
1400 Hz	1120	-15.92
1600 Hz	1280	-14.76
1800 Hz	1310	-14.56
2000 Hz	1450	-13.67
2500 Hz	1490	-13.44
3000 Hz	1510	-13.32
5000 Hz	1650	-12.55

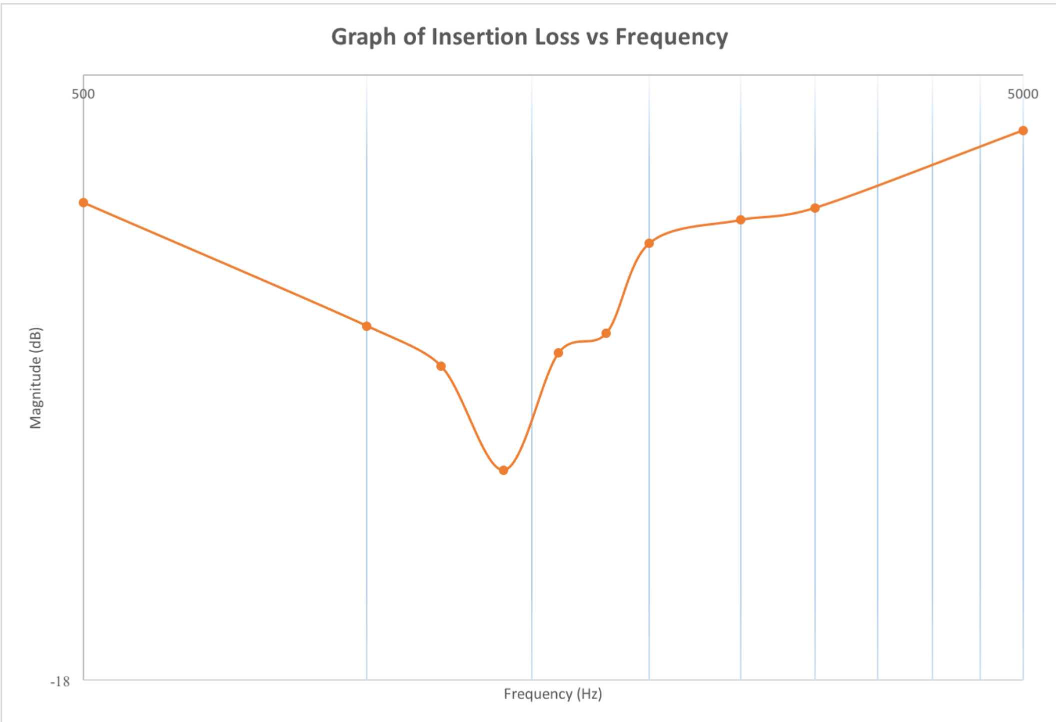


Figure 10: Graph of insertion loss versus frequencies (Band pass filter)

11 Discussion

A signal transmission system is the electrical channel between an information source and destination. Signal transmission distortion can be divided into amplitude distortion and frequency distortion. Linear distortion includes any amplitude or delay distortion associated with a linear transmission system. Amplitude distortion is easily described in the frequency domain; it means simply that the output frequency components are not in correct proportion. Since this is caused by $H(f)$ not being constant with frequency, amplitude distortion is sometimes called frequency distortion. The most common forms of amplitude distortion are excess attenuation or enhancement of extreme high or low frequencies in the signal spectrum. While the frequency-domain description is easy, the effects in the tie domain are far less obvious, except for very simple signals. The loss of the high-frequency term reduces the "sharpness" of the waveform. The "flat" frequency response means that the frequency range over which $|H(f)|$ must be constant to within a certain tolerance so that the amplitude distortion is sufficiently small.

11.1 Part1

For the part 1 of the experiment, we are dealing with the frequency response for a RC circuit which is also a first order low pass filter. The low pass filter only allows low frequency signals from 0Hz to its cut-off frequency, f_c point to pass while blocking those any higher. The circuit shown in Figure **??** uses two passive first-order low pass filters connected or "cascaded" together to form a second-order or two-pole filter network. Hence, we can see that a first-order low pass filter can be converted into a second-order type by simply adding an additional RC network to it and the more RC stages we add the higher becomes the order of the filter. As the order of the filter is increased, the roll-off slope becomes steeper and the actual stop band response of the filter approaches its ideal stop band characteristics [**?**].

Based on the Table **??**, we obtained that the range of insertion loss from -13.70dB to -63.26dB which is decreasing as the frequency increasing. The frequency response and phase response of the low pass circuit were show in Figure **??** and Figure **??** respectively. The result from the Frequency Response graph shows that the insertion loss decreases gradually as the frequency is increasing. Regarding to the Phase Response graph plotted, the degree of phase decreases as the frequency increases. The Frequency Response of the filter to be nearly flat for low frequencies until it reaches its Cut-off Frequency point (f_c). This is because the reactance of the capacitor is high at low frequencies and blocks any current flow through the capacitor. We obtained the cutoff frequency at -16.7dB (-13.7dB-3dB) which are 1100Hz experimental result. The phase shift for experimental result is $-43°$.

Following, we have observed the transmission distortion for the RC circuit for different values of frequencies. The integrator is basically a low pass filter circuit operating in the time domain that converts a square wave "step" response input signal into a triangular shaped waveform output as the capacitor charges and discharges. A triangular waveform consists of alternate but equal, positive and negative ramps. From observation on the output waveform as show as Figure **??**, the output become more triangle in shape as the frequency of the input signal increase. This is because of the exponential charging and discharging processes of the capacitor cause the triangular waveform at output. As our input waveform is square wave, it consists of summation of odd harmonic of sinusoid. Since LPF attenuates high frequency components, the summation of low frequency of odd harmonic sinusoid give rise to the triangle shape of output waveform.

11.2 Part2

In part 2 of the experiment, we are dealing with the frequency response for a CR circuit which is also a second order high pass filter. The high pass filter only allows high frequency signals from its cut-off frequency, f_c point and higher to infinity to pass through while blocking those any lower. The circuit shown in Figure **??** uses two first-order high pass filters connected or cascaded together to form a second-order or two-pole high pass network.

Based on the Table **??**, we obtained that the range of insertion loss from -54.24dB to -1.27dB which is increasing as the frequency increasing. The frequency response and phase response of the high pass circuit were show in Figure **??** and Figure **??** respectively. The result Frequency Response graph shows a positive relationship between the insertion loss and the frequency. The insertion loss increases as the frequency increases. Whereas for the Phase Response graph, the degree of phase decreases as the frequency increases. Frequency Response for high pass filter is the exact opposite to that of a low pass filter. It has a response curve that extends down from infinity to the cut-off frequency. We obtained the cutoff frequency at -4.27dB (-1.27dB-3dB) which are 10000Hz experimental result. Also we can see that the phase angle (ϕ) of the output signal LEADS that of the input and is equal to $+46°$ for experimental result at frequency f_c.

Thereafter, we have observed the transmission distortion for the CR circuit for different values of frequencies. If we change the input signal to that of a "square wave" shaped signal that has an almost vertical step input, the response of the circuit changes dramatically and produces a circuit known commonly as a Differentiator. However, if we feed the High Pass Filter with a Square Wave signal operating in the time domain giving an impulse or step response input, the output waveform will consist of short duration pulse or spikes as shown in Figure **??**. Each cycle of the square wave input waveform produces two spikes at the output, one positive and one negative and whose amplitude is equal to that of the input. The rate of decay of the spikes depends upon the time constant, (RC) value of both components, (t = R x C) and the value of the input frequency. The output pulses resemble more and more the shape of the input signal as the frequency increases.

11.3 Part3

In part 3 of the experiment, we have dealing with the fading due to the multipath propagation. The circuit is actually a combination of first order low pass filter and second order high pass filter to form a simple two-path model of multipath propagation. As the input signal transmitted through the low pass filter and high pass filter, each of the signal will be attenuated and cause the phase shift by different amount. Hence, when the signals reach the load resistance, the summation of each signal will cause interference and phase shift of output signal which is known as multipath fading. 'Fading' means rapid fluctuations of the amplitudes, phases or multipath delays of a radio signal over a short period or short travel distance. This might be so severe that large scale radio propagation loss effects might be ignored. The frequency response is shown in Figure **??**. From the Table **??**, the fading frequency is 1.4kHz because it has the lowest amplitude among the 10 frequencies. The results proved that the frequency 1.4kHz has the narrowest bandwidth and allow minimum signal to pass through.

Last but not least, there are some precautions that we should realize throughout the experiment. The lesser number of wire are encouraged to avoid any confusion when having circuit checking if any error occurs. Moreover, the electrical devices and breadboard should be checked if its well-functioning before using it to avoid any delay. Lastly, the polarity of the capacitor must place correctly to avoid any accident happen.

12 Conclusion

There are many factors may cause distortion in signal transmission. After completion of the experiment, we understand some factors from experiment, which are channel with insufficient bandwidth, multipath propagation channel and fading channel. In the last part of this experiment, the frequency that caused fading due to multipath propagation is 1.4kHz.

13 References

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[4] Frequency response of RC and LR circuits http://www.ece.sunysb.edu/~oe/Leon/ESE211/Lab05