Physics Research Experience for Six form Student
Electricity and Magnetism

Abstract:

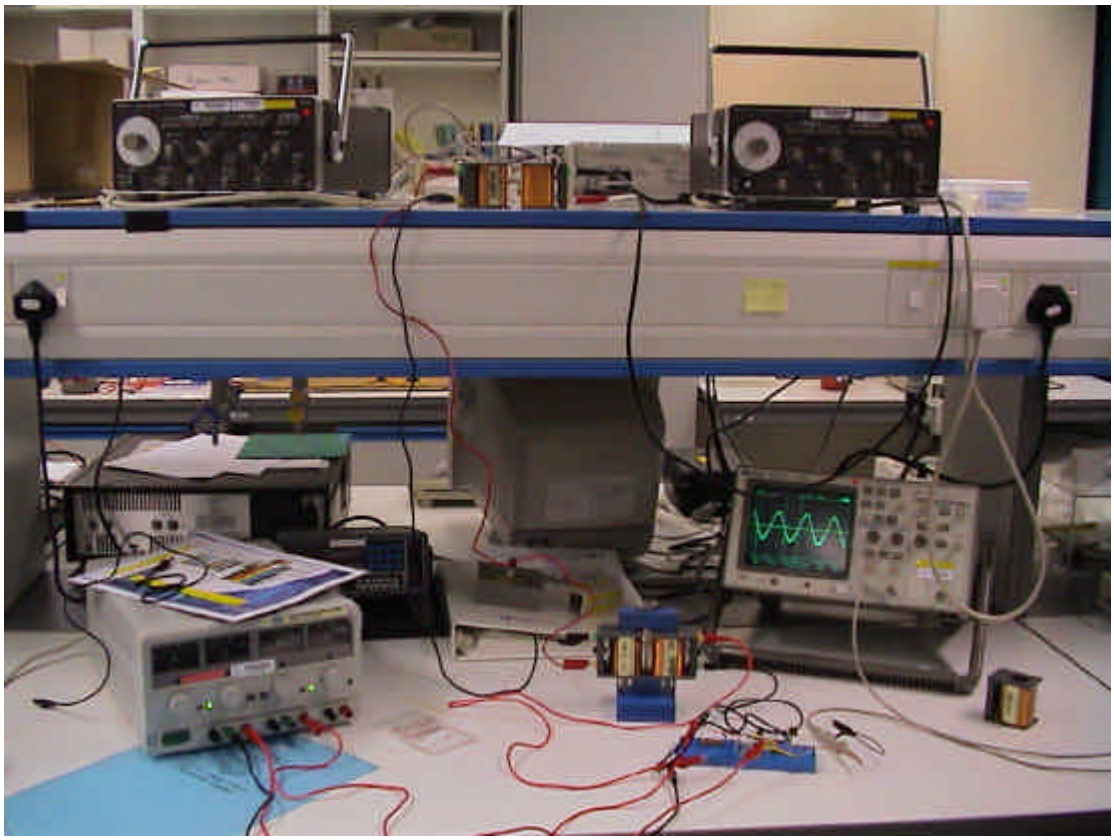
Electromagnetic wave

Through building an electromagnetic wave transmitter and receiver, we aim at demonstrating the laws of wave and the effect of wave frequency and other factors on the output signal.

Background & Aim:

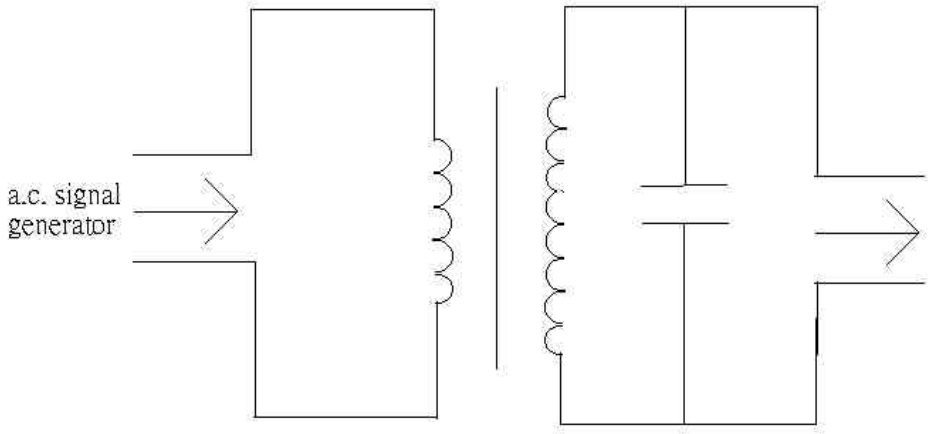
Our group consists of Vincent Ng, from Diocesan Boys' School, and Ho Ming Yan, from Wah Yan College Kowloon. After through discussion with our supervisor, Dr. T.K.Ng, we decided to build an EM wave transmitter and receiver that can transmit signals through a distance. We shall start from what we learnt form secondary school and information available from the Internet. The idea of the project is to illustrate that the knowledge we learnt from textbook can be put into reality.

The design of our transmitter is simple. It consists of a signal generator and an antenna. The receiver is more complicated. Firstly, we used a coil to receive the signal, then this signal is passed through a step-up transformer with a capacitor in parallel to it. The capacitance of the capacitor is carefully chosen, so that the circuit is in resonance with a particular frequency can then be amplified about 40 times and all other noises will be filtered away. Finally, this amplified signal will passed through an operational amplifier circuit, which further amplified it by about 10 times, the final output voltage should be large enough to switch on a buzzer or light bulb.



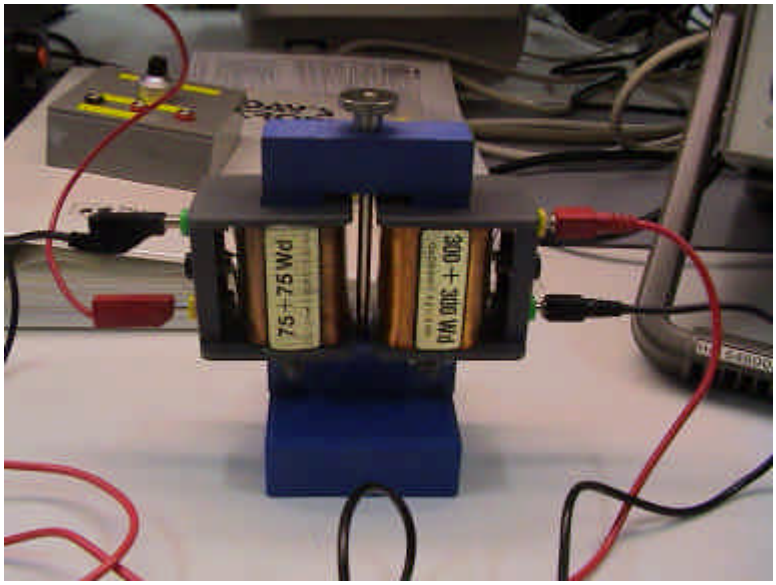
Procedure:

The filter was firstly built up as the following:

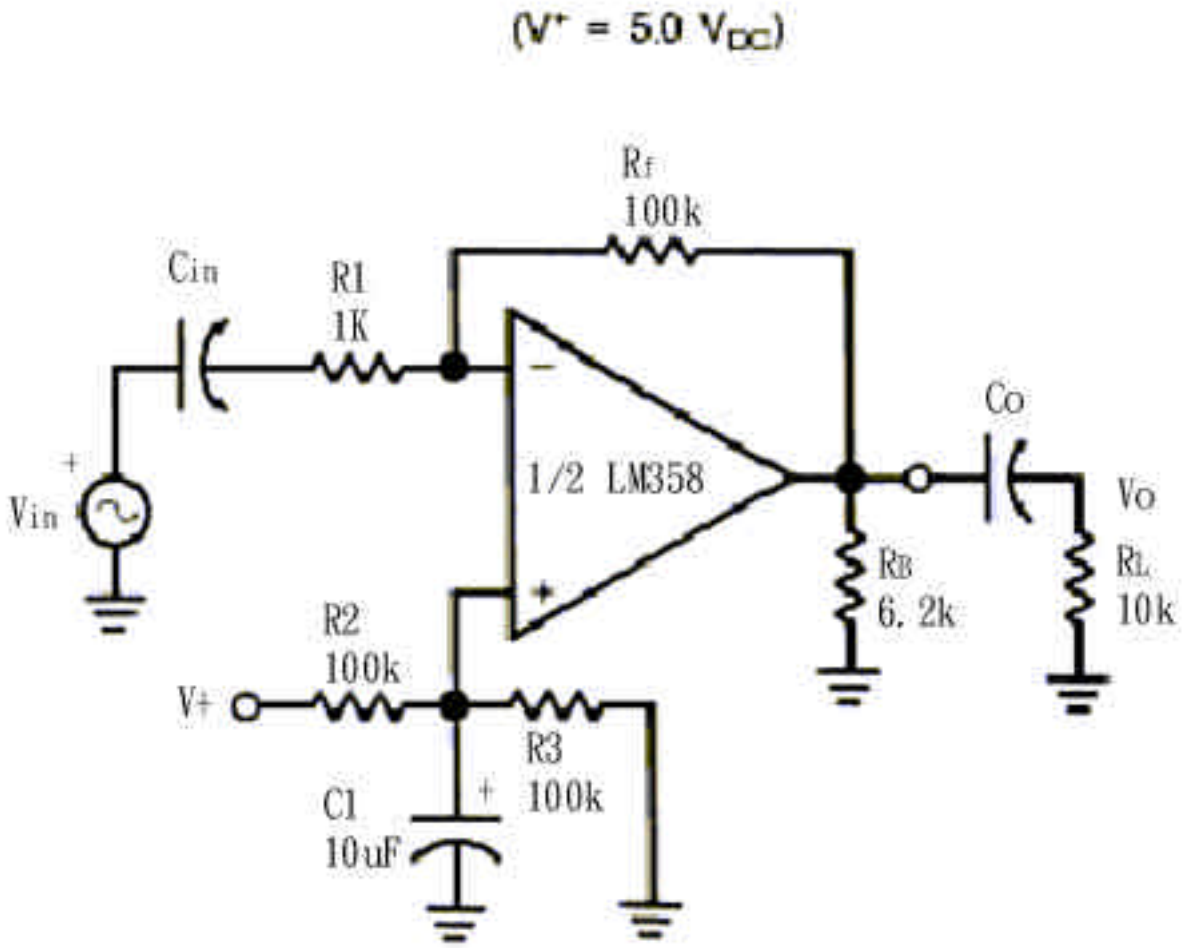


The capacitance was chosen to be $0.2\,mF$, which was formed by combining five $1\,mF$ capacitors. 150Wd(0,35mH) and 600Wd(6mH) coils were used as the primary coil and secondary coil in the transformer, respectively. The input frequency was adjusted to resonant frequency. The voltages and the frequencies of the signal at the primary coil,

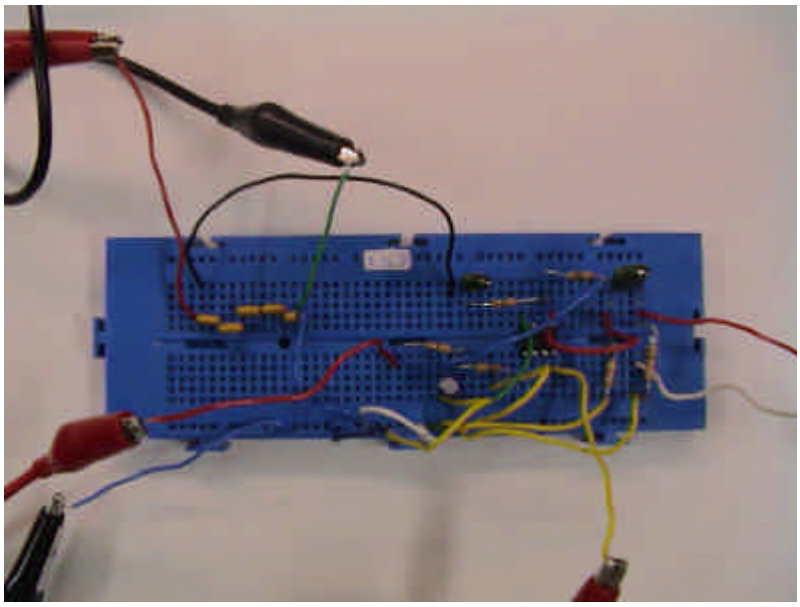
the secondary coil and that passed through over the capacitors were recorded.



An amplifier was set up as the following diagram.



0.047 mF capacitors were used as the C_{IN} and C_O.



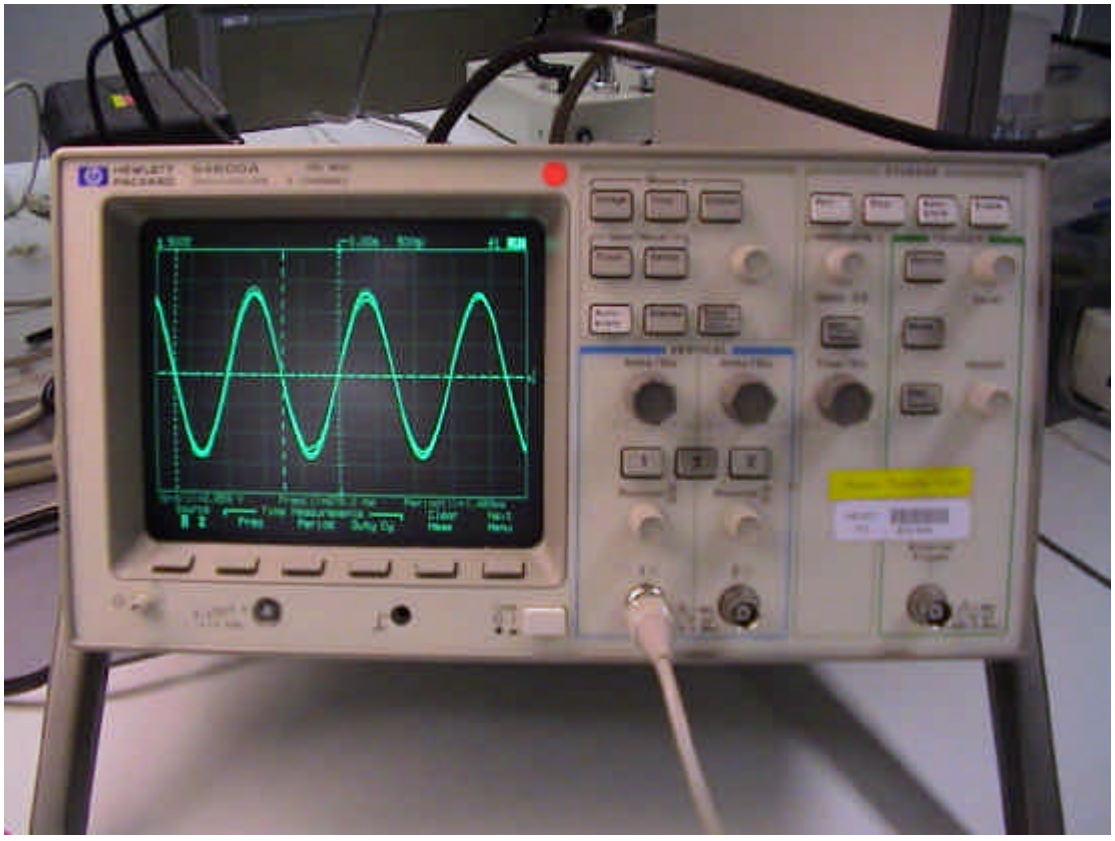
The a.c. signal passing through the filter was then sent through the amplifier and is denoted by V_{IN}.

The EM wave signal is generated by connecting a coil (which acts as the antenna) to the a.c. signal generator. Another coil placed at a distance away from the first coil acted as a receiver. The signal received from the second coil is sent through the transformer-capacitor filter.

Result:

The filter circuit in the receiver consists of transformers with primary coil of 150Wd and a secondary coil of 600Wd and 6mH. The capacitor is formed by five 1uF capacitors connecting in series, so it has a resultant capacitance of 1uF. As for the antennas, we use a coil of 12000Wd as the receiver and a coil of 2500Wd as the broadcasting antenna.

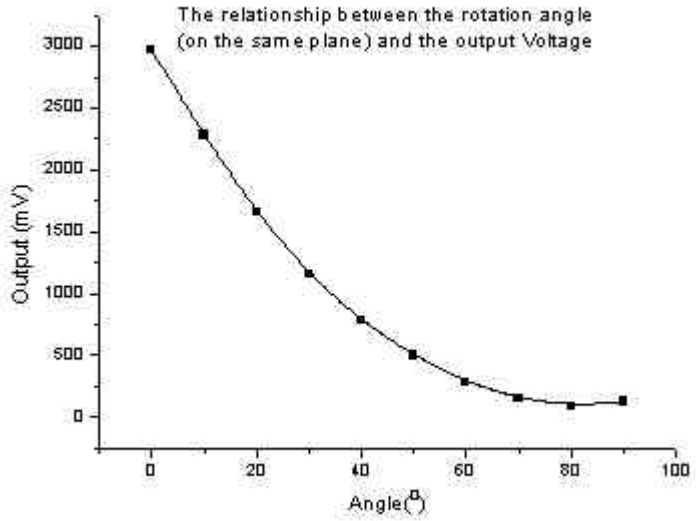
The circuit is found to give the largest signal when the input signal is 680Hz. When the generator voltage is 7.75V and the two antennas are 5cm apart from each other, the output voltage is 3.15V and the maximum current is 0.5mA. The output voltage is found to decrease rapidly as the two antennas get further away from each other as a power law with voltage ~ $1/(\text{distance})^{2.25}$. Due to the internal restrictions of the operational amplifier, if the input voltage is further increased or the antennas are put closer to each other, the output signal will be distorted by noise.



Rotation of coil (on the same plane)

Input: 925Hz, 4cm, 57mV

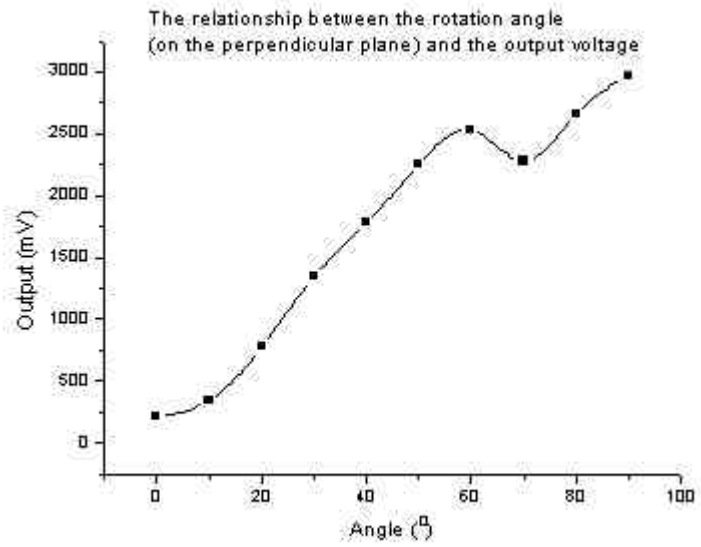
Angle(^{o})	Output (mV)
0	2969
10	2281
20	1656
30	1156
40	781.2
50	500
60	281.3
70	156.3
80	93.75
90	125



Rotation of coil (on the perpendicular plan)

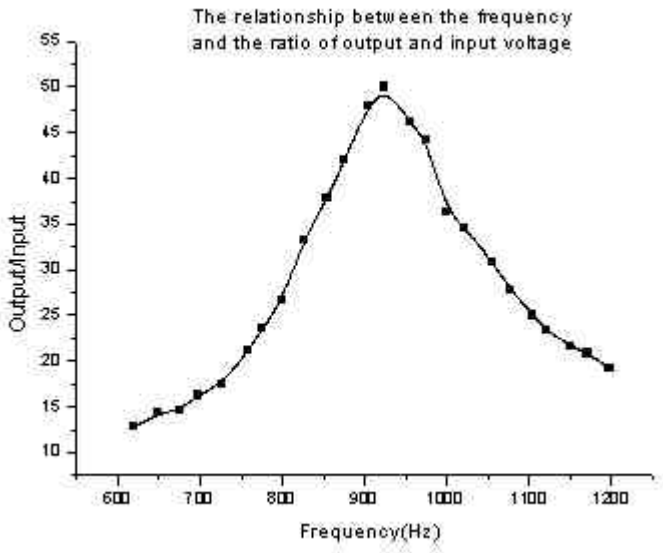
Input: 925Hz, 4cm, 57mV

Angle(^{o})	Output (mV)
0	218
10	343.8
20	781
30	1344
40	1781
50	2250
60	2531
70	2281
80	2656
90	2969



Change of frequency

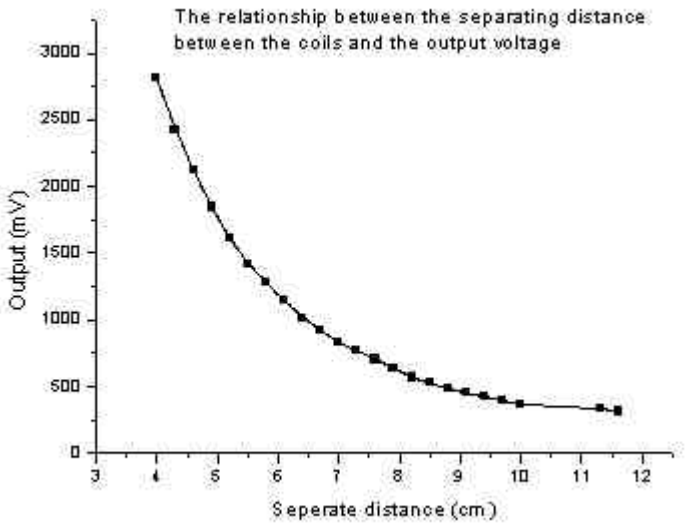
Frequency (Hz)	Output (mV)	Input (mV)	Output/Input
621	562.5	43.75	12.857
650	625	43.75	14.286
675	687.5	46.88	14.665
697	812.5	50	16.25
726	875	50	17.5
759	1125	53.13	21.174
775	1250	53.13	23.527
800	1500	56.25	26.667
826	1875	56.25	33.333
854.7	2250	59.38	37.892
876	2500	59.38	42.102
904	3000	62.5	48
925	3125	62.5	50
955	3000	65	46.15
975	2875	65	44.231
1000	2500	68.75	36.364
1022	2375	68.75	34.545
1055	2125	68.75	30.909
1077	2000	71.87	27.828
1105	1875	75	25
1120	1750	75	23.33
1151	1625	75	21.667
1171	1625	78	20.833
1198	1500	78.12	19.201



Change of distance between the two coils

Input: 680Hz, 195mV

Distance (cm)	Output (mV)
4	2813
4.3	2422
4.6	2125
4.9	1844
5.2	1609
5.5	1422
5.8	1281
6.1	1141
6.4	1016
6.7	922
7.0	828
7.3	767
7.6	703
7.9	641
8.2	568
8.5	525
8.8	487
9.1	450
9.4	425
9.7	393
10	362
11.3	338
11.6	313

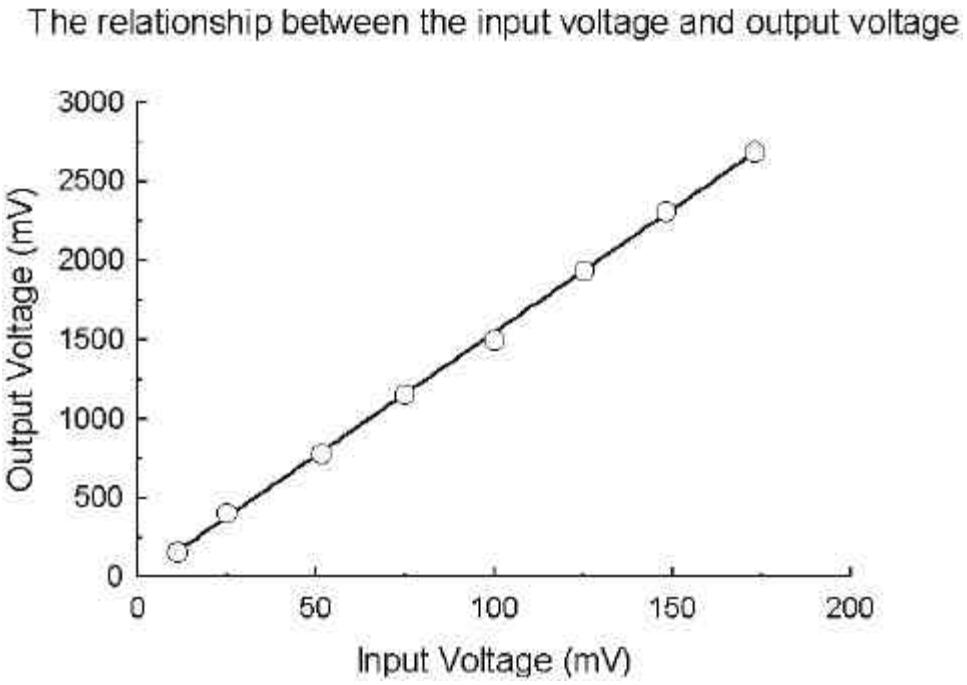


Change of input voltage

Separating Distance: 4cm

Frequency: 680Hz

Input Voltage (mV)	Output Voltage (mV)
173	2688
148	2313
125	1937
100	1500
75	1156
51.56	781.2
25	406.3
10.94	156



Discussion

During our experiment, we found that there is some signal in the surroundings and this distorted our result. This noise was a high frequency signal with frequency at around 20kHz.

Regarding our output signal, although the output voltage is very encouraging, the output current is too small. When the generator voltage is 7.75V and the two antennas are 5cm apart from each other, the maximum current is only 0.3mA. We found that the maximum output current increases when the two antennas are moved away from each other. However, the current cannot exist 1.1mA. We then tried to increase the input current feeding into the operation circuit by using a step down transformer. However, the output current remains nearly the same when the output voltage is 3.15V. The maximum output power may be governed by the intrinsic value of the operation amplifier used and regardless of the input power. So the current increases as voltage decreases and the output power always remains changed.

We then add a step-down transformer after the operation amplifier to raise the current in expense of the voltage. However, the frequency was too low and that the efficiency of the transformer was low due to the power lost, there was a drop in voltage without a significant increase in current. We also replaced one of the capacitors($1\,m$ F) to ($0.0001\,m$ F) to get a higher resonance frequency hence hoping to reduce the power lost due to the transformer. We could get a higher voltage output, but the current was still too small.

This power is too little even to work a reed relay, an another current amplifier circuit using a transistor or an opt amp is needed. However, due to lack of time, this part is not included in our experiment.

We emphasize that the result of our experiment is very limited. We had only performed the experiment with one frequency and tuning is not possible in our design due to limitation in resources. Moreover, the resonance frequency we chose is 925Hz, which is a lot smaller than the 10^8Hz used commercially. Despite all these limitations to our research, we believe we have fulfilled our aim and demonstrated the theories behind the wireless transmission we used everyday.

Lastly, we faced a lot of problems and difficulties during our research work. The most important one is that the circuit we initially designed did not work perfectly. In our original design, we used the LM 741 opt amp amplification circuit to amplify the circuit. It is the circuit taught in textbooks and we are surprised to find out that it doesn't amplify the power perfectly. Even our advisor and the laboratory technician cannot point out this problem in the early stage. We then searched through the Internet and came across this LM385 circuit. It worked perfectly and it is the circuit we are using

now.

We also compare our design with commercial radio receiver design.

Radio Receiver Design	Our Design
Output volume is controlled by potentiometer.	Output power cannot be controlled.
It consist of radio receiver IC and LM1875 audio amplifier IC.	It only consist LM358 amplifier IC.
Consist of variable capacitor and tuning is possible.	Tuning is impossible.
The output power is high enough to drive a 4-8 ohm speaker.	The output power is low.

Acknowledgements:

We thank the staffs in the HKUST physics teaching laboratories for their generous help, and Dr. T. K. Ng for his supervising.

References:

(1) Advanced Physics for Hong Kong
by Tom Duncan John Murray (Publishers) Ltd

(2) www.national.com (to get the Op. atm. Information)