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The Dependence of the Out Put Power and Absorptivity of Waveguides and Nano Solar Cells on the low Frequency and Dimensions

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ABSTRACT

One of the most prominent problems facing Scientists in designing solar cells nowadays is to design highly efficient solar cells by increasing its light absorptivity. This needs a design of highly efficient solar cells having nanometer dimensions in a form of a waveguide.

Since the design of such cells is difficult in the Sudan, this paper attempted to design absorption microwave cells to know how the absorption depends on the dimensions of the rectangular waveguide,

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INTRODUCTION

Energy is the means which man uses to achieve progress and build civilizations. Coal and Petroleum discovery is the corner stone in the civilization building process. Till now, petroleum is still the main source of energy. The problem facing people today is that the main sources of energy are running out. Of course using nuclear energy for electricity generation is a risky business, and the uranium resources are limited. The energy produced through the process of nuclear fusion could satisfy all human needs for thousands of years; however, technical problems are, still, hindering the achievement of this aim (Amar, 1989; Cassedy andGrossman, 1998).

For technical difficulties, no serious attention was paid to solar energy as an alternative energy source until recent years, despite the fact; that this kind of energy is needed world wide. The reason is that it is scattered and it is not concentrated in specific place (Amar, 1989).

So many researches and efforts have been made so as to exploit solar light energy directly. This work could be achieved by using solar cells with special materials known as semiconductors (Cassedy and Grossman, 1998; Krene, 1989). In this case this energy could be used instantly or stored for future use (Amar, 1989) These cells have been designed to run for long periods of time in places where electrical generators are inexistent. The maximum efficiency level of a solar cell ranges between 28— 29%. This argument is perfectly true when the energy gap is in the range of 1.4 to 1.6 ev.There are some factors that come together to reduce, to some extent, the solar cell's efficiency. Some of them are related to light reaction with the cell's materials. Some other factors are related to the recombination process which takes place inside the material of the semiconductor (Krene, 1989).The third type of factors is associated with the auto- resistance of the cell Krene, 1989) All these factors make cells efficiency low. The fabrication of solar cells is also expensive (Khiri et a" 2002). Therefore, the present solar cell technology needs to be modified.

It seems that the major problem facing the solar cell resides in its limited absorption capability. It depends on the characteristics of the medium, which can not be fully controlled. For this reason, there is a need for an absorption mechanism that can be easily controlled This task can be accomplished by utilizing the waveguides. The absorption coefficient depends on the guide's dimensions, and it enables better control of the absorption, and designing of a highly efficient solar cell (Abdallah ei.a/.2008). The dimensions of this solar cell are in the range of nano meters (Sealy, 2004). One can call this cell a nano Solar cell.

Such solar cell needs a guide with nano dimensions. Unfortunately nano technology is not widely spread in the Sudan. An alternative way is needed to construct a model resembling a solar cell. This model can be made with the aid of a microwave waveguide.

The relation between absorptivity, frequency and the dimensions of the waveguide

Electromagnetic waves reaction with matter has considerable significance in many fields; one of these fields is the field of solar cells (Abdallah ei.a/.2008).Although, solar cells are one of the important sources of the promising clean energy, they are still facing a big problem associated with their limited efficiency which does not exceed 30%. Therefore, it became important to think of new ways to increase this efficiency. This depends on factors that could, easily, be controlled as it will be shown below. The rectangular wave guide absorption coefficient with the b length and a height IS given by the following relationship (Abdallah et al.2008):

$$\gamma = \sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 - \mu\varepsilon\omega^2} \qquad (2.1)$$

Usually Y can be written as a sum of real and imaginary part. In view of equation (2.1), one can write:

$$\gamma = \alpha + j\beta\sqrt{\left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2 - \mu\varepsilon\omega^2} \qquad (2.2)$$

Where $\propto$ is the absorption coefficient, and β is the wave number. This equation shows that the absorption coefficient α can be controlled through the dimensions of the waveguide. Thus one can enhance the absorptivity to a very high degree. It also helps in solar cell designing as a shape of a guide that could capture light energy and increase its absorptivity (Abdallah, 2008).

It is well known that solar cells are very expensive due to the high cost of silicon crystals manufacturing. It is also known that its efficiency is low and limited, that is why one needs to increase light absorption to increase efficiency (Abdallah el. al 2008). The manner by which absorption coefficient a is increased is explained in equation (2.2). From this equation it is clear that a is not equal to zero and its value could be great when (Abdallah et. al.2008):

$$\left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2 > \mu\varepsilon\omega^2 \qquad (2.3)$$

If the waveguide's dimensions are equal; then a — b. And when the first mode is chosen n = I and m =l, then the absorptivity condition will be:

$$2\left(\frac{\pi}{a}\right)^2 > \mu\varepsilon\omega^2 \qquad (2.4)$$

Since:

$$\mu\varepsilon = \frac{1}{v^2} \qquad (2.5)$$

Then:

$$\mu\varepsilon\omega^2 = \frac{\omega^2}{v^2} = \left(\frac{2\pi f}{\lambda f}\right)^2 = K^2 \qquad (2.6)$$

Substituting (2.6) in (2.4) one gets:

$$\frac{1}{a} > \frac{\sqrt{2}}{\lambda} \qquad (2.7)$$

If it is assumed that the light wave length lies within the range of $\lambda = 500$ nm , then the value of the corresponding a will be within the range of $a < \frac{500nm}{\sqrt{2}}$

When a is very small, such as $\frac{1}{a} >> \frac{\sqrt{2}}{\lambda}$, then the absorption coefficient will be [see (2.2)]:

$$\propto = 2\left(\frac{\pi}{a}\right)^2 \quad = \sqrt{2}\ \frac{\pi}{a}$$

i.e. it will become totally dependant on the dimensions of the wave guide.

By setting $\gamma_0^2 = \left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2$ in equation (2 .1) then the equation will be as follows:

$$\gamma = \sqrt{\gamma_0^2 - \mu_0\varepsilon_0\omega^2}$$

$$\gamma^2 = \gamma_0^2 - \mu_0\varepsilon_0\omega^2$$

In the case when.

$$\gamma \approx \gamma_0$$

One gets:

$$\gamma_0^2 - \gamma^2 = \mu_0\varepsilon_0\omega^2$$

$$(\gamma_0 - \gamma)(\gamma_0 + \gamma) = \mu_0\varepsilon_0\omega^2$$

$$\Delta\gamma(2\gamma_0) = \mu_0\varepsilon_0\omega^2$$

$$\Delta\gamma = \gamma_0 - \gamma = \frac{\mu_0\varepsilon_0}{2\gamma_0}\omega^2 \qquad (2.8)$$

Then, from equation (2.8) one can calculate the absorbitivity of the waveguide together with the frequency variation. From equation (2.8) one can write the current in the form:

$$I = I_0\, e^{-\gamma z}\, e^{j\omega t}$$

$$= I_0\, e^{-\gamma_0 z}\, e^{\frac{+\mu_0 \varepsilon_0}{2\gamma_0}\omega^2 z}\, e^{j\omega t} \qquad (2.9)$$

When $\mu_0\ \varepsilon_0 \omega^2 \approx 0$, i.e. it is very small, then [see (2.2)]:

$$\gamma = \sqrt{x - d}$$

Where d represents $\mu_0 \varepsilon_0 \omega^2$ and x represents $\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2$

Hence:

$$\gamma = x^{\frac{1}{2}} = \sqrt{\left(\frac{\pi}{a}\right)^2 + \left(\frac{\pi}{b}\right)^2} \qquad (2.10)$$

Then the radiation power can be written as follows:

$$p = p_0\, e^{-z\sqrt{x}} \qquad (2.11)$$

and one can write the potential as follows:

$$V = V_0\ e^{-\gamma z}\ e^{j\omega t}$$

$$= V_0\ e^{-\gamma_0 z}\ e^{\frac{\mu_0 \varepsilon_0}{2\gamma_0}\omega^2 z}\ e^{j\omega t}$$

Hence:

$$V = V_0 e^{-z\sqrt{x}}\ e^{j\omega t} \qquad (2.12)$$

Experimental set up for the microwave experiment

In this experiment, 6 waveguides, made of iron, have been used. The dimensions of these waveguides were (7.5cm x3.5cm), (6.0cm x 3cm). (5.0cm x 2.5cm), (4.0cm x2.0cm), (2.5cm x 2.5cm) and (l .5cm x 1.5c:-z respectively. The main purpose is to determine the waveguides frequency response.

In this experiment microwave communication system is used .These waves have been transmitted within the 6 waveguides and radiation power emitted from them, after being received by a receive: measured by a signal strength meter, and then the potential of these is also measured by using an oscilloscope. In this experiment. following devices have been used (Anon. 1996):

I. Base of microwave system with the electric power source:
PG 600 Multimeter out put power supply, serial No: 007482. Input: 90-260V, AC: 60 - 50Hz.

2. Horn antenna microwave transmitter:
PP714A, L.J Technical System Norwich 01603 748001, England.

3. Horn antenna Microwave receiver:
PR714A, L.J Technical System Norwich 01603 748001, England.

4. - TECH 1sR 622 20 MHz Oscilloscope:
Sensitivity: 1 mv, 5v/div, frequency band width (-31b), DC— 20MHz.

The antenna microwave transmitter and the antenna microwave receiver have been put on a platform of microwave communication system. The distance between them was 21 cm, and they have been connected power outlet, whereas the horn waveguide has been put between them, as shown in Fig . 1.

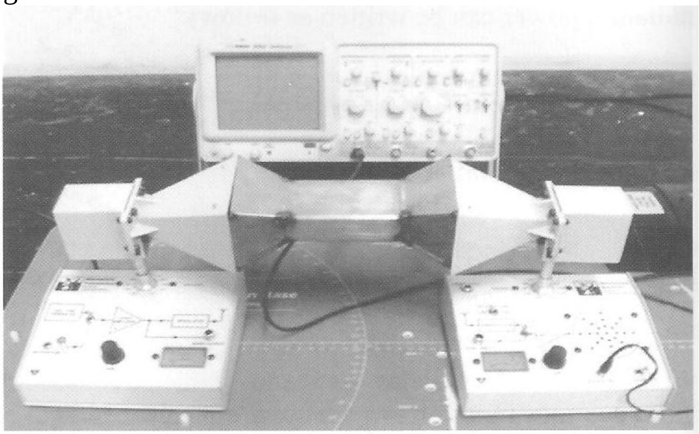


Fig. I *Microwave communication system (L.J. Technical System, England).

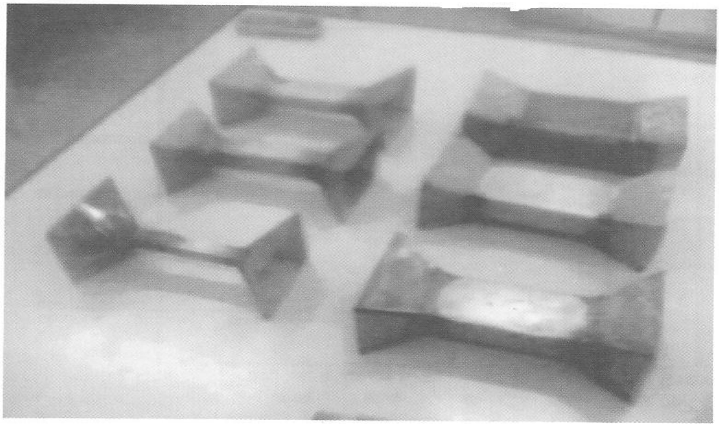


Fig.2. Depicts the 6 horn waveguides (Designed Personally).

RESULTS

The following tables show the effect of waveguides dimensions and the frequency F or the absorbitivity $\Delta\gamma$, the potential and the power emitted from six - different waveguides.

Table l. Waveguide No. l. With dimensions a= 3.5cm, b = 7.5cm.

No.	$\Delta\gamma_1$	F(Hz)
1	55.58	0.001
2	5555.80	0.01
3	555780.0	0.1
4	55578000	1.00
5	5.56E+08	10.00
6	5.56E+09	100.00
7	5.56E+10	1000.00

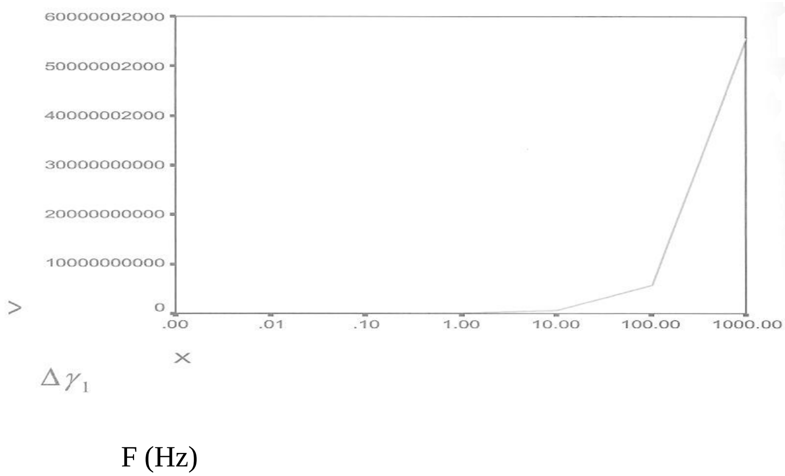


Fig. 3. The relationship between ($\Delta\gamma$& F) of the waveguide No .1.

Table 2. Waveguide No. 2. With dimensions a = 6.0cm, b = 3.0cm.

No.	$\Delta\gamma_2$	F(Hz)
1	50.53	0.001
2	5052.55	0.01
3	505254.5	0.1
4	50525455	1.00
5	5.05E+08	10.00
6	5.05E+09	100.00
7	5.05E+10	1000.00

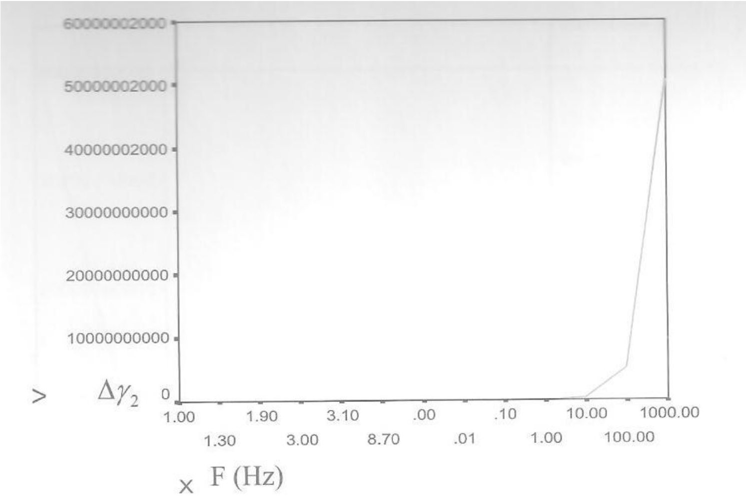


Fig. 4. The relationship between ($\Delta\gamma$& F) of the waveguide No .2.

Table 3. Waveguide No. 3. With dimensions a = 5.0cm, b = 2.0cm.

No.	$\Delta\gamma_3$	F(Hz)
1	27.78900	0.001
2	2778.90	0.01
3	277890.0	0.1
4	27789000	1.00
5	2.78E+08	10.00
6	2.78E+09	100.00
7	2.78E+10	1000.00

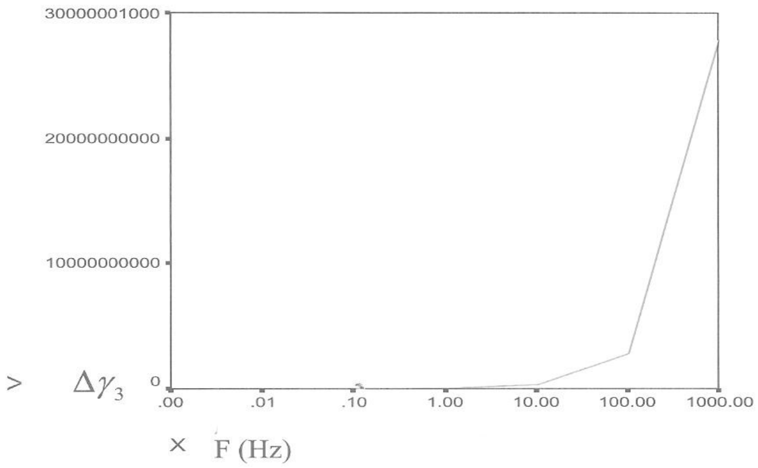


Fig. 5. The relationship between ($\Delta\gamma$& F) of the waveguide No .3.

Table 4. Waveguide No. 4. With dimensions a = 4.0cm, b = 2.0cm.

No.	$\Delta\gamma_4$	F(Hz)
1	32.69	0.001
2	3269.29	0.01
3	326929.4	0.1
4	32692941	1.00
5	3.27E+08	10.00
6	3.27E+09	100.00
7	3.27E+10	1000.00

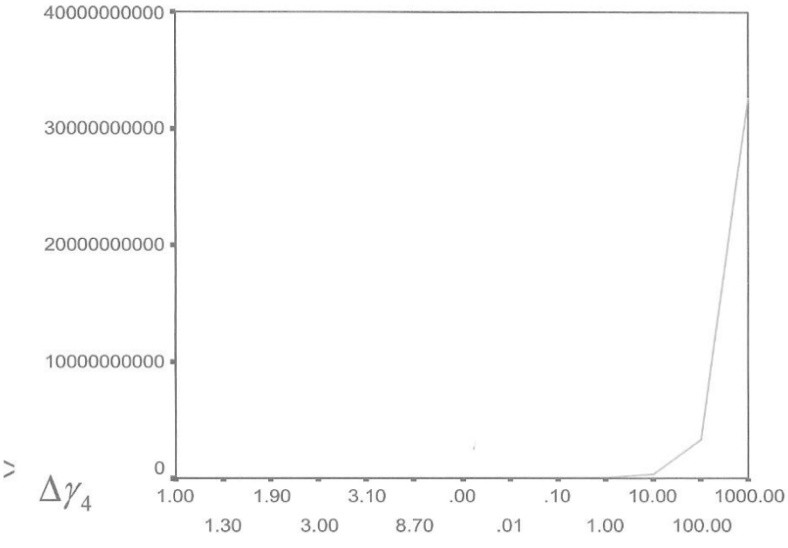


Fig. 6. The relationship between ($\Delta\gamma$ & F) of the waveguide No.4.

Table.5. Waveguide No. 5. With dimensions a= 2.5cm, b = 2.5cm.

No.	$\Delta\gamma_5$	F(Hz)
1	30.88	0.001
2	308766.7	0.01
3	3.09E+08	0.1
4	3.09E+10	1.00
5	30.88	10.00
6	308766.7	100.00
7	3.09E+08	1000.00

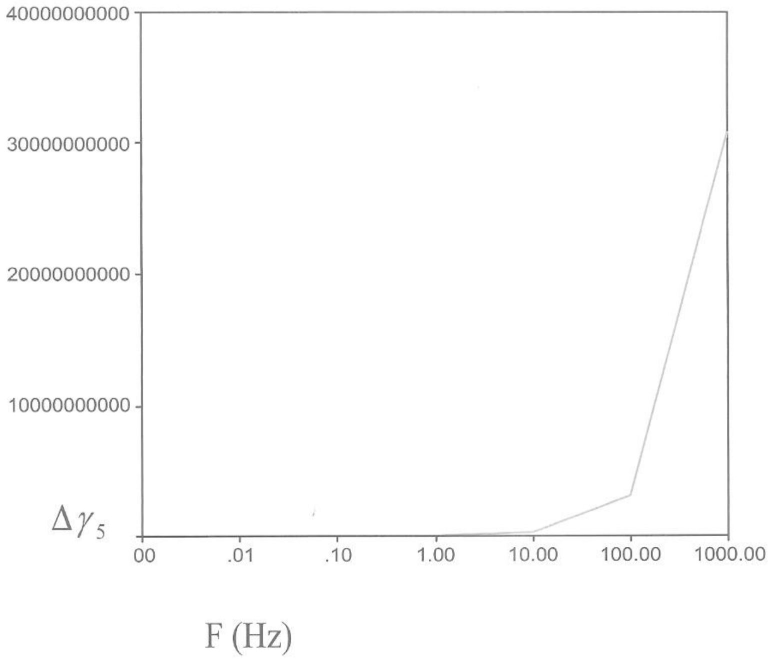
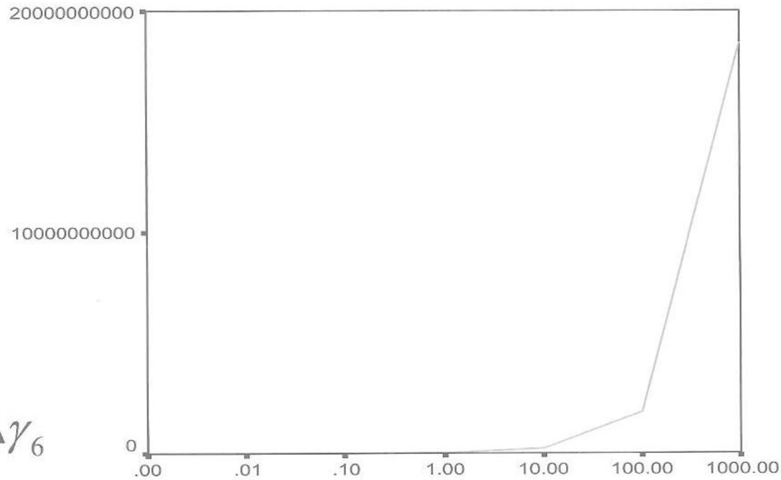


Fig.7. The relationship between ($\Delta\gamma$ & F) of the waveguide No. 5.

Table 6. Waveguide No. 6. With dimensions a = 1.5cm, b = 1.5cm.

No.	$\Delta\gamma_6$	F(Hz)
1	18.53	0.001
2	1852.60	0.01
3	185260.0	0.1
4	18526000	1.00
5	1.85E+08	10.00
6	1.85E+09	100.00
7	1.85E+10	1000.00



$\Delta\gamma_6$

F (Hz)

Fig.8. The relationship between ($\Delta\gamma$ & F) of the waveguide No.

Table 7. The relationship between the radiation powers given by x [see (2.10)] and the dimensions of the 6 waveguides.

No.	P(± 0.1 dB)	X(cm^{-2})
1	4.50	1.00
2	4.00	1.30
3	3.50	1.90
4	2.50	3.00
5	0.50	3.10
6	0.00	8.70

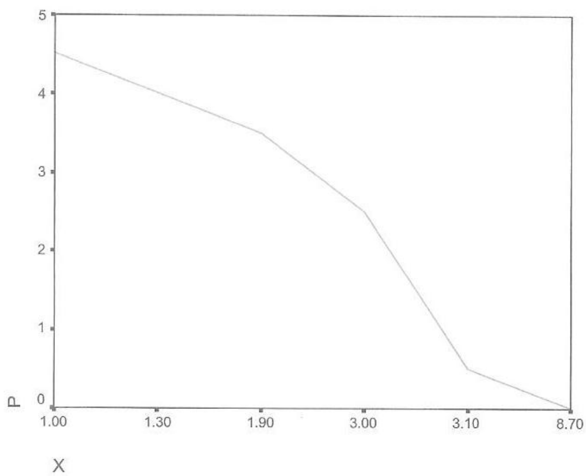


Fig. 9. The relationship between (P & X) of the 6 waveguides.

Table 8. The relationship between the potential and the dimensions of the 6 waveguides.

No.	V(volts)	X(cm^{-2})
1	0.50	1.00
2	0.40	1.30
3	0.30	1.90
4	0.20	3.00
5	0.10	3.10
6	0.05	8.70

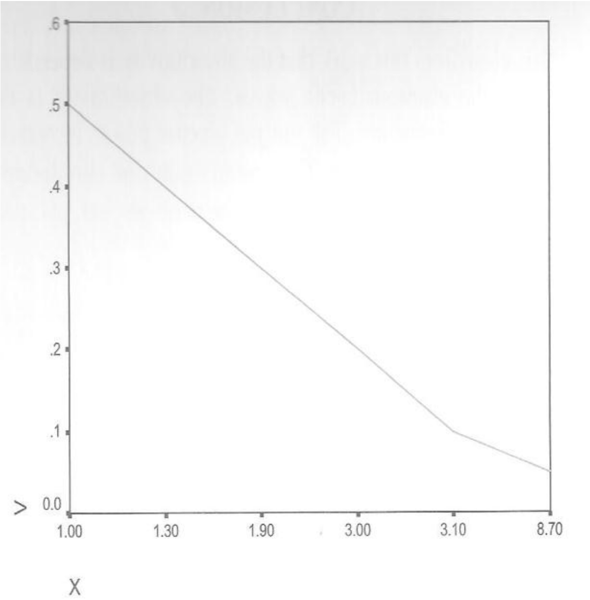


Fig. 10. The relationship between (V & X) of the 6 waveguides

DISCUSSION

Figures (5.1) up to (5.6) show that the absorbitivity increases with the increase of the frequency. This result is in agreement with equation (2.8) which shows, the absorbitivity increases with the frequency. It is clear that this absorbitivity increases gradually up to the frequency around 100Hz and then it increases abruptly in the frequency range more than I00Hz.

Figure (5.7) shows that the radiation power given by equation (2.11) increases when x decreases as the dimensions of the waveguide increase. Power with x is highly non linear and shows a gentle slope after x exceeds 3.1.

Figure (5.8) shows that the out put voltage of the 6 waveguides, decreases with the increase of x. This fact can also be explained by equation (2.12). The decrease of voltage with x is non linear in general and the decrease shows a gentle slopes after x exceeds 3.1.

CONCLUSION

It is clear from this work that the absorbitivity is dependent on the frequency of the electromagnetic waves. The absorbitivity is found to increase with the frequency. The out put electric power increases as the waveguide dimensions increase. This means that one can design a solar cell having nano meter dimensions to increase its out put power by increasing its dimensions.

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