ISSN 2229-5518

RF & MW radiation based solution for Insect control in Agriculture: A Review and Proposed System

Mr. Sandeep V.Gaikwad, Dr. A.N.Gaikwad

Abstract- Major problem in the Agriculture are the pest insects which infest the seeds, crops and end products like fruits, vegetables and grains. In the paper, different treatment method used in agriculture to control the insects and germs has discussed. The RF and Microwave radiation has already tested during the post harvesting and at seed infest control. It is very important to find out the dielectric properties of agricultural products like vegetables, fruits and grains. Based on the pervious measured permittivity data, related to fruits insects and human tissue dielectric constants and appropriate frequency spectrum need to select to control the insect infest on agriculture products. Here we are proposing system which will be effective during the development stages of the agriculture products. The proposed system required blocks during the research work and its instrumentation are discussed. This can be utilized to improve efficiency of crop production and enhance crop quality .Some successful applications of microwaves in agriculture are reviewed and future prospects are discussed.

I. INTRODUCTION

Recent years, interactive relations between various branches of science and technology have improved interdisciplinary fields of science. In fact, most of the research activities take place somewhere among these branches. Therefore, a specialist from one branch usually can propose novel methods, whenever enters a new field, based on his previous knowledge.

Taking a look at the extensive problems in the field of agriculture, an expert in the field of Electromagnetic waves can easily suggest some innovative solutions to solve them. The major suffering problems are the damages caused by the harmful pests as well as the product freezing in unexpected cold weather. The promising available biological methods of treatment have decreased the need for new treatment methods effectively. There are many treatments to control the insects in agriculture. The environment-friendly methods has introduce in this paper are to use electromagnetic waves to kill or irritate pest insects without compromising the taste or texture of the food they infest.

S.V.Gaikwad, Research student, SCOE, Vadgaon, Pune.
sandipv_pict@yahoo.co.in
Dr. A.N.Gaikwad, Principal, MMCOE, Pune.

Electromagnetic radiation can be one of the fast method as well as it will not keep any chemical residual in the agriculture products. Review focusing on the traditional methods to control the pest insects as well as the challenges to implement electromagnetic solution for the agriculture.

1. Treatment Methods

1.1 Chemical Fumigation

Chemical fumigation has two distinguish advantages for postharvest control in nuts, including ease of use and low cost. Most postharvest pest management programs, therefore, rely heavily on fumigants, and most processing systems are designed to allow for fumigant treatments. Since hydrogen Phosphide fumigation takes a relatively long time (Yokoyama et al., 1993), methyl bromide (MeBr) fumigation has become a common phytosanitation treatment because its treatment is usually under 3 hours, and it is used to control codling moths in cherries, in watermelons and in unshelled walnuts [1].

1.2 Ionizing Radiation

Irradiation treatment is a process to expose infested commodities to ionizing radiation so as to sterilize, kill, or prevent emergence of insect pests by damaging their DNA. This method includes three types of ionizing radiation used on foods: gamma rays from radioactive cobalt-60 and cesium-137, high energy electrons, and x-rays. The gamma ray method is one of most commonly used in postharvest pest control because of the gamma ray ability to deeply penetrate pallet loads of food.

Nuclear energy also can be used for development of new quality product which can give more throughputs and quality product. Major problems for irradiation begin with the substantial initial investment per site to establish irradiation facilities, including a radiation shield control system and other auxiliary equipment. Such an investment requires continuous operation of the facility to remain economically feasible, but the seasonal nature of commodity treatments prevents efficient use of facilities. Consumers also have concerns for disposal of radioactive wastes, the safety of the irradiation technology and its effect on food [1].

1.3 Conventional Heating

Conventional heating methods are increasingly being used to provide an alternative treatment of the chemical fumigation, which include forced hot air and hot water treatments. Since the heat mechanism is simple and the process can be easily controlled, many studies on different fruit types and insect species have been carried out using different thermal treatments alone or in combination with cold or controlled storage conditions To be effective, the fruit core must reach certain temperatures so that the treatment is effective even in the most insulated areas, such as inside nuts or into the center flesh, seeds and kernels. Slow heating rates by forced hot air or water result in a long treatment time [1] [4].

1.4 Dielectric Heating

Dielectric heating is a term that covers both RF and MW systems which are high frequency electromagnetic waves generated by magnetrons and klystrons. When the material with water molecules is subjected to an electromagnetic field that rapidly changes direction, the water molecules rotate into alignment with the direction of electrical field. The water molecular friction produces the internal heat of the material. The frequency in a range of 12 MHz-2450 MHz is usually used in food engineering. Dielectric materials, such as most agricultural products, can store electric energy and convert electric energy into heat. The increase in temperature of a material by absorbed electromagnetic energy can be expressed by (Nelson, 1996):

$$\rho C \frac{\Delta T}{\Delta t} = 55.63 \times 10^{-12} f E^2 \varepsilon'' \quad (1)$$

where C is the specific heat of the material ($J.kg^{-1}.°C^{-1}$), ρ is the density of the material ($kg.m^{-3}$), E is the electric field intensity ($V.m^{-1}$), f is the frequency (Hz), ε'' is the dielectric loss factor (-) of the material, Δt is the time duration (s) and ΔT is the temperature rise in the material (°C). From Equation1, the raise in temperature depends on the power, frequency, heating time and the materials dielectric loss factor. Higher temperatures in commodities can be achieved by long heating duration and high power input. If the dielectric loss factor is relatively constant, rapid dielectric heating using higher frequencies can be achieved with much lower field intensities. However, the frequency interacts with the dielectric loss factor where the latter variable is a function of the frequency, temperature and water content of the material.

Electromagnetic energy has been studied to control insects in commodities for many years. Initial investigations using RF heating to control pests of grain and nuts were conducted. A recent study demonstrated the possibility of using 2450 MHz MW to destroy woodworms by heating the larvae to 52-53 °C for less than 3 minutes.

RF and MW treatments under different conditions and insects at different temperatures. Since the congested bands of RF and MW have already been used for communication purposes, the Federal Communications Commission’s (FCC) allocated five frequencies for industry, scientific and medical (ISM) applications: 13.56, 27.12 and 40.68 MHz for RF, 915 and 2450 MHz for MWs. Higher temperature was used for stored grain than for fruits. The product quality after RF and MW treatments was rarely examined. More recently, Wang et al. reported that MW and RF treatments might have particular advantages over conventional heating methods in treating cherries and walnuts, because the desired level of insect mortality was achieved without quality damage [9][14][19].

II. ELECTROMAGNEETIC WAVES IN AGRICULTURAL APPLICATIONS

Electromagnetic radiation as tools in the field of agriculture have been used in many applications such as remote sensing, imaging, and dielectric heating in a pre-harvest or post-harvest environment. However, the goal here is to discuss about applications which are directly related to the main electromagnetic wave effect which is warming. RF wave very effectively used as thermal heating to kill bacteria. It can be used to disinfest various foods and non food materials including soil.

2.1 Pest control and electromagnetic waves

Traditional agricultural producers usually use simple conventional chemical fumigation to control pest insects. Despite the simplicity of use, these chemical fumigants such as Methyl Bromide have many disadvantages such as reducing the thickness of Ozone layer. Additionally, the probable international ban of methyl bromide for post-harvest treatments will increase the attention to other methods. Three other methods including ionizing radiation, cold treatments and conventional heating have been reviewed. In ionizing radiation, the main problem is that it is not possible to shut of the radiation after ending the treatment. Cold treatments are not a complete method due to high price and relatively long required time. The drawback of the conventional heating methods originates from the fact that this kind of heating warms both pest and the agricultural product similarly which may destroy product's quality. To overcome these problems, some modern techniques such as genetic treatments, ultrasonic waves and electromagnetic treatments have been suggested in the literature.

The use of electromagnetic exposure, mainly electromagnetic heating has been started in 1952 by Frings and then Thomas in 1952 and Nelson from 1966. But today there are vast applications for electromagnetic waves are proposed at least to be an alternate treatment method. Formerly, the electromagnetic wave method was suggested as a post-harvest treatment, but recently, it has been suggested to be used as an in-the-field method for pest control or to prevent the agricultural product from getting freezed [2] [8] [11] [12] [20].

2.2 Electromagnetic selective heating

2.2.1 Introduction

There are various ideas about the mechanism of pest control using electromagnetic waves. Most of the researchers believe that the waves can only warm up the pests. This belief originates from the fact that these insects are mostly composed of water. Normally, the water percentage in their body is more than the other materials present in the surrounding environment. On the other hand, there are some claims expressing that not only do the Electromagnetic waves heat the pest, but also they can interfere with their bodies functionality with their none-thermal effects.

The imaginary part of the dielectric constant can be used to heat up a material remotely using radio waves. However the main goal is not just to heat a material (*i.e.* a flower) in the indoor or outdoor environment since it can be done using a heater or 2.4 GHz microwave source. The mission, here, is to warm a material while the surrounding materials are not affected. This can be done using the difference between the imaginary parts of the dielectric constants of two different materials at a specified frequency. Taking into account that the dielectric constant of each material is frequency-dependent, there can be an appropriate frequency for which the electromagnetic energy is absorbed by the pest while the product or plant doesn't absorb the energy at this frequency. Consequently, this process will not affect the quality of the agricultural products, especially important for the products which are sensitive to the temperature increase.

2.2.2 Differential heating

The dielectric constant parameter for materials as a whole and for agricultural products specifically varies with frequency. For instance, ε″ of water has a peak in 2.4 GHz frequency. The absorption frequency of water may help us in warming the water in the insects' bodies but probably all of the other water-composed materials in the nearby environment absorb the energy as well. Thus, to be more efficient and safe, the electromagnetic wave should have a frequency which maximizes the difference between temperature increment in pest on one side and the agricultural products on the other side. This goal can be reached by using the frequency dependent character of the dielectric constants of the two materials. Using "(2)", the function in "(3)" represents a goal function which should be maximized in the volume of an electrically small object.

$$Goal(f) = \frac{(\Delta T_{pest}(f) - \Delta T_{Orchid}(f)}{\Delta t} \qquad (2)$$

$$= \frac{\alpha f E^2{}_{pest}(f)\varepsilon^{"}{}_{pest}(f)}{\rho_{pest} C_{pest}} - \frac{\alpha f E^2{}_{Orchid}(f)\varepsilon^{"}{}_{Orchid}(f)}{\rho_{Orchid} C_{Orchid}} \qquad (3)$$

Where

$\alpha = 55.63 \times 10^{-12}$

Using the assumption that specific heat capacities of the both materials are equal, goal function is reduced to "(4)".

$$Goal(f) = \frac{\alpha f}{\rho C}\left(E^2{}_{pest}(f)\varepsilon^{"}{}_{pest}(f) - E^2{}_{Orchid}(f)\varepsilon^{"}{}_{Orchid}(f)\right) \qquad (4)$$

If we simply suppose that electric field is equal in pest and agricultural product regions, the goal function is reduced to "(5)"

$$Goal(f) = \frac{\alpha f E^2}{\rho C}\left(\varepsilon^{"}{}_{pest}(f) - \varepsilon^{"}{}_{Orchid}(f)\right) \qquad (5)$$

Therefore, approximately, it can be stated that we are searching for a frequency at which the difference between ε″ (f) of the agricultural material and pest is the most possible value. In order to solve this problem, we are going to measure the effective permittivity of the agricultural products to find the optimum frequency in which the difference between ε″ of the pest and the agricultural product is the largest [1] [4].

2.2.3 Measurement of the dielectric constant

There are many methods for the measurement of the dielectric properties of materials. One of best way for arbitrarily shaped materials is the open-ended coaxial probe with the network analyzer which ended at the

ISSN 2229-5518

material under measurement with full contact. Using this method, we can measure the properties in a wide range of frequencies using reflection data. The more accurate one is the transmission line method, but it is necessary to fill a part of transmission line with the sample accurately .In order to measure very low materials cavity method can be used. In this method, the sample is inserted in a cavity and the change in the reflection coefficient and the resonance frequency shift is measured. Using accurate perturbation formulas, the dielectric constant can be calculated in one fixed frequency. Many experimental data has been released for several foods and agricultural products but yet few works has been done on pest's properties. The measurement results shows that the properties highly depends on frequency, temperature, moisture content and also state of the moisture, namely frozen, free or bound[12][19][20-23].

2.2.4 Anti-freezing

During cold days sudden freeze of product is one of the most damaging agricultural events. In many desert areas, temperature reduction in a few days may cause huge economic injuries. These detriments will be more painful when occur for costly productions. By the end of winter, at the beginning of spring, plants are about to flourish. Because of the fact that the weather is not stable, the temperature may fall all of a sudden. Therefore, the biological tissues of the budded pistachio or other products may be damaged. It has been found that if the temperature of the production is increased about two or three degrees, we can save them from being offended immensely. The previous techniques of anti-freezing have been limited to physical, biophysical and genetic treatments. For instance, in some areas, farmers put a fan and a diesel heater under each tree. These methods are more expensive and hard to exploit than the solution which is suggested here. Moreover, they have some potential hazards for consumers. Additionally, they need much time than they can be exploited on demand when the weather gets colder.

We must estimate the weather condition far before necessity while, with the use of electromagnetic waves, there is no need to an exact prediction of weather condition. Regarding these advantages, it seems that this method can find a suitable place among the other methods in anti-freezing application. Electromagnetic exposure while the other materials of the environment are not warmed up. The most significant work is to find the optimum frequency in

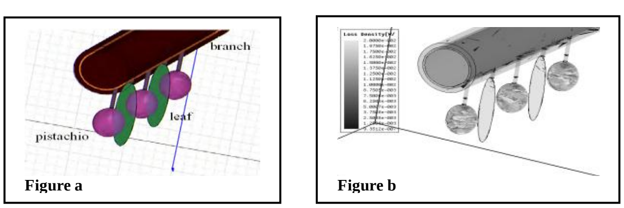

Fig.1: (a) Pistachio branch model b) Volume loss density, the hatched lines show losses [1]

which the difference in the absorption rate of energy in pistachio and sensitive objects is the most. This frequency also depends on the electromagnetic characteristics of the objects and can be measured practically. They have done some primary simulations using approximate parameters. Fig. shows an HFSS model of a pistachio branch and the volume loss density caused by an incident electromagnetic wave respectively. The simulation in 2.4 GHz in Fig. shows that volume loss density in the pistachio is higher than leafs, branch lines, and stems due to difference in dielectric constant in the used frequency [1].

III. CHALLENGING PROBLEMS

There are few challenging problems against the vast implementation of electromagnetic waves use in agricultural applications like, high electromagnetic power needed, probable human health effects, and probable biological effects on the surrounding environment, finalized price, frequency allocation and system design complexity.

Power problem can be easily solved if the employed frequency is not more than the low gigahertz range. Based on the fact that high power sources are now available in VHF and UHF frequencies the power problem can be solved.

The problem of frequency allocation in some countries is crucial. However, shifting the frequency to the closest ISM bands can solve the frequency allocation problem. Another problem is to design such a proper controllable system to warm up pests uniformly. Moreover, the frequency of treatment must be selected in such a manner that the absorption of energy by pest be more than other materials available.

Today, electromagnetic wave is known as a potential hazard of health and biological effects such as cancer. It is tried to shield and protect the radiation space from the outside environment. On the other hand, in the outdoor problems, we reduce the hazard lowering the exposure time and the radiated power. Moreover, treatment environments are usually empty of human population. In spite of the health effect, biological effects of electromagnetic exposure should be evaluated to ensure that it does not have a harmful effect on the ecosystem [6].

IV. PROPOSED SYSYTEM

Insect control during agricultural product grow is very important. Due to frequent chemical fumigation chemical residues becomes more dangerous to human body. To avoid the chemical residues ,with view of all above references we are proposing RF & MW radiation for controlling the temperature, insect and germs control on Grapes and Mango fruits during their development stages .

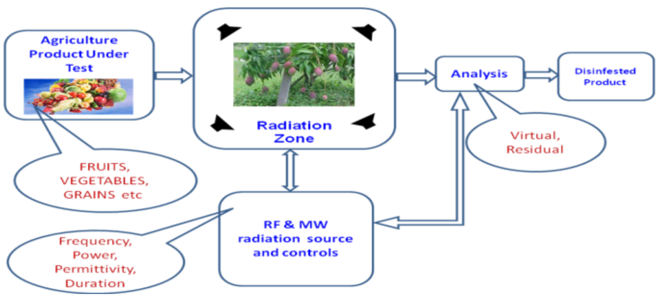

Fig.2: Block Diagram of proposed system

Proposed system steps for Implementation:

1. Find relative permittivity of fruit during different development stages using the open-ended coaxial probe and Network analyzer and use as data base.
2. Find out the harmful insect related to selected fruit, which we need to control e.g. Amritodas at KinsoniL or Jassids ,Bactrocera (Mango hopper), mango stone weevil etc.
3. Measure the permittivity of that insect. Using differential heating calculation determine the frequency, power and duration for which object can be exposed under electromagnetic radiation.
4. Based on the observation and available data Insects will be exposed to the decided frequency and power to determine the actual values of the variable parameters, so that insect's mortality and irritation can be observed in anechoic chamber.
5. Design of system will be based on the parameters have observed so that it will be effectively used as out-door system.
6. Adjust the radiation system in such a way that it will not hamper other communication media and not hazardous to human.

SIMULATION:

Using HFSS (Ansoft) simulator floquet port, it has observed S11(Reflection coefficient) and S21(Transmission coefficient) for Mango and Codling moth at 27.12, 40.68, 915, 1800MHz in it.

RESULTS: HFSS design: FLOQUET port and object as mango and codling moth dielectrics at the center, to measure the S11and S21.

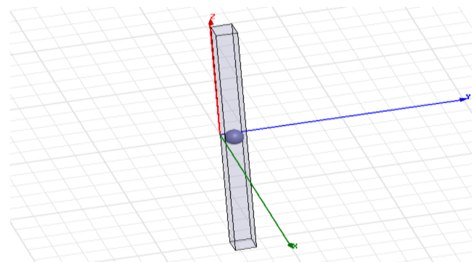

Fig. 3 Floquet port and object as Mango and codling moth

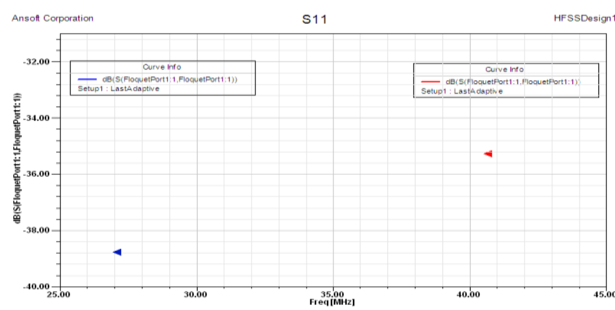

Fig.4 Mango: S11 in dB @ 27.12 & 40.68MHz.

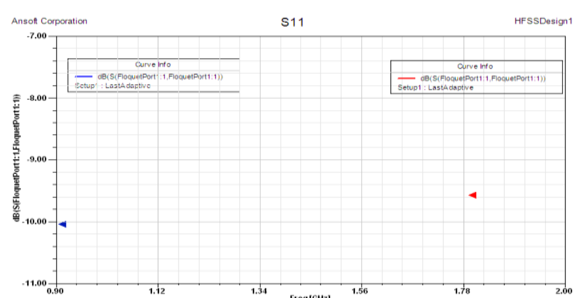

Fig.5 Mango: S11 in dB @ 915 & 1800MHz.

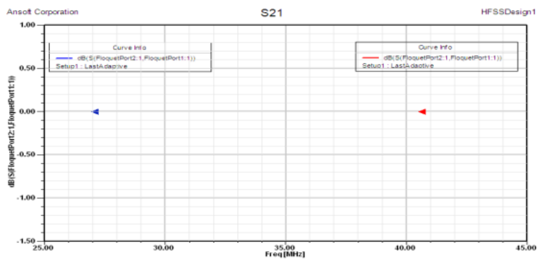

Fig.6 Mango: S21 in dB @ 27.12 & 40.68MHz.

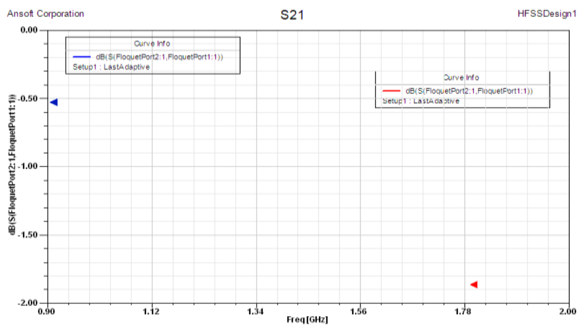

Fig.7 Mango: S21 in dB @ 915 & 1800MHz.

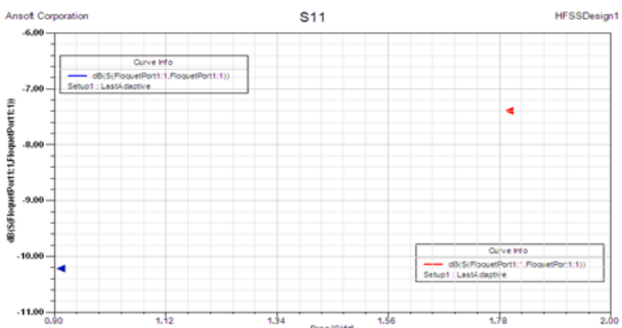

Fig.8 codling moth: S11 in dB@ 27.12 &40.68MHz.

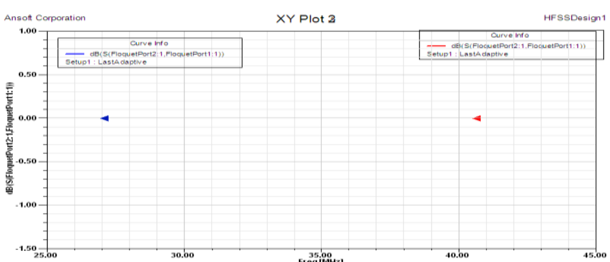

Fig.9 Codling moth: S11 in dB @ 915 & 1800MHz.

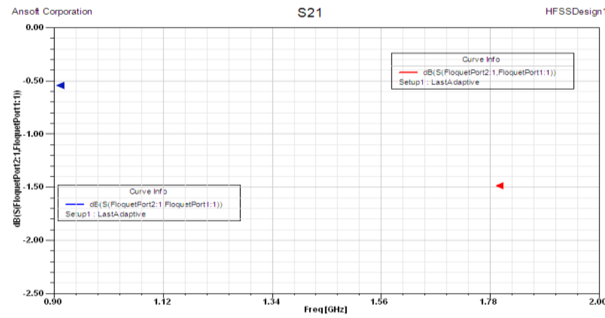

Fig.10 Codling moth: S21 in dB @ 27.12 & 40.68MHz.

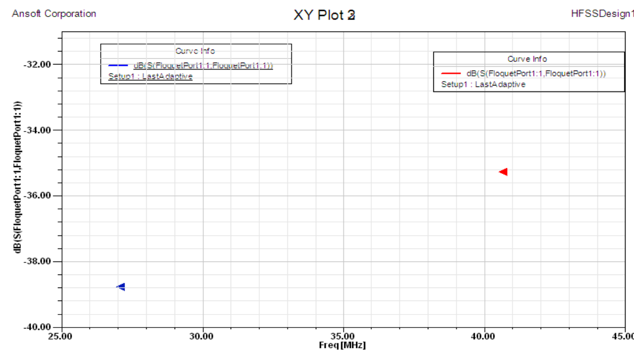

Fig.11 Codling moth: S21 in dB @ 915 & 1800MHz.

RESULT SUMMARY:

1. For lower side of frequency depth of penetration is more and at higher side of frequency depth of penetration is low.
2. Based on the material dielectric property reflection and transmission coefficient can be determine.
3. Here in the simulated results Mango and codling moth (Insect) response to the different ISM band frequency has observed.

CONCLUSION

Literature survey reveals that the RF and MW energy radiation method is an alternative to control insects and the germs on the agriculture products. With the proposed method we can get result during short time period without damaging product. Heating effect of the waves, especially if used as differential heating, is an efficient way to keep the pests away from the valuable products. The treatment base on EM wave can be employed to indoor or outdoor environments. This method can be an attractive quarantine treatment because it is quick, safe and operation costs are comparable to chemical fumigation.

RF and MW energies leave no chemical residues on products. These processes are safe to operators and have little impact on the environment. Electromagnetic waves have been suggested for use in a vast range of applications in agriculture and food processing society. The treatment base on EM wave can be employed in indoor or outdoor environments.

By finding the dielectric properties of both agriculture product like fruit and insects, germs which can be harmful to the fruit can be disinfested by using RF and MW energy radiation using selective heating technique.

REFERENCES

[1] Hadi Aliakbarian, Amin Enayati, Hossein Ameri, Maryam Ashayer Soltani, "Agricultural Applications for Electromagnetic Exposure," *Proceedings of Asia-Pacific Microwave Conference 2007 IEEE*.

[2] S. Wang and J. Tang, "Radio Frequency And Microwave Alternative Treatments For Insect Control In Nuts: A Review," *Agriculture Engineering Journal 2001*, 10 (3&4): 105-120.

[3] Andrzej W. Kraszewski and Stuart 0. Nelson, "Application Of Microwave Techniques In Agricultural Research," *SBMO/IEEE MIT-S IMOC'95Proceedings*, 1995, pp.117-126.

[4] Stuart 0. Nelson, "RF and Microwave Energy for Potential agriculture Applications," *J. Microwave Power*, 1985, pp 65-70.

[5] Stuart O. Nelson, Laverne E. Stetson, "Possibilities for Controlling Insects with Microwaves and Lower Frequency RF Energy, " *IEEE Transaction On Microwave Theory and Techniques*,Dec.1974,pp 1303-1305.

[6] J. M. Osepchuk, "Health and safety issues for microwave power transmission," *Sol. Energy*, 1996,vol. 56, No. 1, pp. 53–60.

[7] M. Craig Dobson and Fawaz T. Ulaby, " Active Microwave Soil Moisture Research", *IEEE Trans. on Geo science and Remote Sensing*,Vol.GE-24 No.1,January 1986,pp 23-27.

[8] S. O. Nelson, "RF And Microwave Permittivities Of Insects And Some Applications", *URSI EMTS2004*, pp1224-1226.

[9] S.O. Nelson, "Dielectric properties of agricultural products and some Applications", *RES.AGR.ENG.*,54,2008 (2):104-112.

[10]V.M Rashkovan, N. Khizhnyak, L.Bazyma," Interaction of Electromagnetic Waves with Granular Agriculture Products and Insects ", *IMPI,J.Microwave Power & Electromagnetic Energy*, Vol. 38,No.4,2003, pp. 225-235.

[11] H. Frings', "Factors determining the effects of radio-frequency Electromagnetic fields on insects and materials they infest", *J Econ. Entomol*, 1952, vol.45 (3), pp. 396.

[12] S. Wang, J Tang, J. A. Johnson, E Mitcham, J. D. Hansen, G. Hallman,S. R. Drake, Y. Wang, "Dielectric Properties of Fruits and Insect Pests as related to Radio Frequency and Microwave Treatments", *Bio-systems Engineering Journal*, April, 2003, pp.:201-212.

[13] Nelson, S.O.,"Electromagnetic and Sonic energy for Insect control," *Transactions ASAE*, 1966, 9(3), pp. 398-40.

[14]Nelson, S.O., "Dielectric properties of agricultural products: Measurements and applications."*IEEE Transactions on Electrical Insulation*, 1991, 26(5): 845-869.

[15]Andreuccetti, D., M. Bini, A. Ignesti, A. Gambetta and R. Olmi, "Microwave Destruction of woodworms, " *Journal of Microwave Power and Electromagnetic Energy* 1994,29(3): 153-160.

[16] Carl H. Durney, Habib Massoudi, Magdy F. lskander, "Radio frequency Radiation Dosimetry Handbook", Prepared for:Armstrong Laboratory(AFMC) Occupational and Environment Directorate Radiofrequency Radiation Division.

[17] Zoya Popovic and Edward F. Kuester," Principles of RF and Microwave Measurements: Book," Electromagnetic Laboratory Department of Electrical and Computer Engineering.

[18] Elhadi Yahia, "Effect of insect Quarantine treatment on quality of Horticulture Crops," *An International Journal for review in Postharvest Biology and Technology*,2006.

[19] S.O. Nelson," Fundamental of dielectric properties measurement and agriculture applications", *Journal of Microwave power and electromagnetic energy*,2010,pp.98-112.

[20] S. Wang, J.Tang," Dielectric properties of fruit and insect pests as related to Radio frequency and microwave treatments ", *Bio systems Engineering* (2003), pp.201-211.

[21] J.Ondrack , V. Brunnhofer, "Dielectric properties of Insect tissues", *Gen. Physiol. Biophys.* (1984), vol-3, pp-251-257.

[22]Francis X. Hart ,et al, "Electrical Properties of Tissues", Wiley Encyclopedia of Biomedical Engineering, 2006 John Wiley & Sons, Inc.

[23]Agilent Basics of Measuring the Dielectric Properties of Materials: Application Note.

[24] Shyam N. Jha, K.Narsaiah,et al ,"Measuement Techniques and application of electrical properties for nondestructive quality evaluation of food-a review", *J food Sci Technol (2011) ,Springer*, 48(4), pp-387-411.