JOURNAL OF CRITICAL REVIEWS

ISSN- 2394-5125 VOL 06, ISSUE 05, 2019

# IMAGE-GUIDED MICROWAVE THERMOTHERAPY BY LOCALLY-INDUCED HYPERTHERMIA FOR PROSTATE CANCER

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*Abstract*- **Hyperthermia is a prominent promising adjunct for traditional cancer therapy. The traditional thermotherapy antennas are designed to be totally non-invasive, which in return has many defects. Hence now the concern for various invasive antennas designing is taken into the discussions worldwide. The invasive antenna designed inturn have some defects that even non-cancerous tissues are also affected on placing the antenna on healthy tissue. So a integrated probe for microwave antenna and optic fiber is used for Image-guided thermotherapy.**
**Key terms-- Hyperthermia, Non-Invasive Antenna, Invasive antenna, Prostate cancer, Image-Guided Thermotherapy**

## I. INTRODUCTION

Cancer is one of the world biggest challenging diseases. Cancer and tumor are the uncontrolled proliferation of the cells. Due to this uncontrolled proliferation of cells normal biostatics of the body is affected. Cancer occurs in any part of the body and the only exception is the heart. The major types of cancer frequently encountered across the globe in throat, mouth, breast, prostate, bone marrow, lungs. Traditionally chemotherapy and thermotherapy are the treatments for cancer. The thermotherapy is used for noninvasive method. In this paper a method is proposed on Image-Guided invasive microwave antenna for thermotherapy. Further a discussion on the digital image processing is also given for future extension

## II. TRADITIONAL THERMOTHERAPY

Traditionally for treatment of the tumor and cancer doctors prefer either chemotherapy or thermotherapy, sometimes a combination of chemotherapy with thermotherapy is done. Chemotherapy and thermotherapy have many temporary and permanent side effects on human body. The side effects also produce adverse effects, even failure of the neighboring organs or even organ system.

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The proposed technique overcome many of the above adverse effects and reduces the cost for invasive antennas and image guiding techniques.

The topics from III to IV deals with microwave effects on body and topic V relates the human body tissue SAR and the electromagnetic waves. The topic VI cancer physiology. Topic VII to end explains the treatment process and its discussion.

## III. ELECTROMAGNETIC EFFECT ON HEALTHY BODY

It is known that electric and magnetic fields have opposite effects on the water clustering. Unstructured water with fewer H-bonding is a more reactive environment. An open more hydrogen bonded network structure slows down the reactions due to its increased viscosity, reduced diffusivity and less active participant of the reaction. Electric fields increase the reactivity due to the breakage of H-bonding or its strength, hence to say electric fields increase the reactivity in liquid water. Water clustering, even in random arrangement, has equal H-bonding in all directions. An electric or electromagnetic fields that attempt to reorient the water molecules should necessitate the break of some H-bonds. Electromagnetic waves exert its effect primarily through electrical effect rather than its magnetic effect. The increased hydration ability of the water in electromagnetic fields has shown dissociation of the enzyme dimer leading to a gel-like formation, due to the microwaves from a mobile phone.

The solubility property of the water will change in the presence of such EM fields and may result in the concentration of dissolved gases and hydrophobic molecules at surfaces followed by the reaction or phase changes. It is also possible that these processes may result in the production of low concentrations of $H_2O_2$ in a similar manner to mechanical vibrations. Such changes can clearly result in effects lasting for a considerable amount of time, giving rise to claims like memory effects. The important aspect to be taken to consideration is that the effect of electrical and electromagnetic field on the property of water last for long lifetime.

In addition to the breakage of the H-bonds, Electromagnetic fields may perturb in the gas or liquid interface and produce reactive oxygen species. Changes in H-bonding may affect $CO_2$ hydration resulting in pH changes. The role of dissolved gases in water chemistry is likely to be more important than commonly realized nanobubbles detected by light scattering experiments. Gas accumulating at hydrophobic surfaces promotes the hydrophobic effect and low density water formation. The accumulated gas molecules in such hydrophobic surfaces become supersaturated when electromagnetic effects disrupt this surface low density water.

## IV. MICROWAVE HEATING

The microwaves break the H-bonds and hence the energy is released in form of heat and random motion of molecules occurs. The molecular charges separated by a small distance forms a dipole. When this dipole is placed in the electric field or microwave falls over the dipole re-orient takes place. At higher frequency this heating is caused by the rotational motion within the water, here dielectric.

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Molecular rotation occur in water containing polar molecules, here polar molecules come to picture because of the break of the H-bonds, having an electrical dipole moment. The dipoles align themselves in the microwave field. When the electromagnetic field of the applied wave changes alternately, the dipole rotates. This rotation is called the dipole rotation. This dipole rotation creates push, pull and collide with other molecule distributing the energy to adjacent molecules and atoms in water. This distributed energy appears as the heat energy.

Temperature is the average kinetic energy of the atoms or molecules in water so agitating the molecules in this way increases the temperature rapidly. The electric potential energy of two charges is equal to the work done to assemble the charges or work done in bringing each charge.

## V. SPECIFIC ABSORPTION RATE

The Specific Absorption Rate, SAR in tissue is a common parameter used to characterize the heating of tissue. It is given by the formula,

$$SAR = \frac{1}{2} \frac{\sigma |E|^2}{\rho}$$

Where ρ is the tissue density, σ is effective conductivity, E is the electric field.

$$\frac{dT}{dt} = \frac{SAR}{C_s}$$

Where T is the temperature, t is the time and $C_s$ is the specific heat capacity of the tissue where it is employed.

SAR is then can be inferred as the electromagnetic radiation energy absorbed by unit mass of a biological tissue.

## VI. PHYSIOLOGY OF CANCER

Cancer is the uncontrolled growth of the cells.

The cells divide irregularly and grow uncontrollably, forming malignant tumors and invade the nearby organs of the body. The cancer also spread to the more distant organs through lymphatic system and blood stream.

It is found that the hydration in the cancerous cells is high due to the increased rate of cell proliferation and cell living activity. It is estimated that the water content of the cell cancerous cell is more than 80 per cent than any other cells. It is confirmed that the normal living cell has 20 per cent low water content in tissues. Also the fat reduction and sugar cycle in the cancerous cycle is very high hence it forms high water and carbon dioxide in the cells. As the water content is far high than the normal cells, H-bonding is also far high than the normal cells or tissue.

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## VII. MICROWAVES ON CANCER CELLS

Dipole rotation is the primary mechanism normally referred to as dielectric heating, and is most widely used for cancer treatment.

Microwave acts good in water rather more actively in fats and sugars. This is because the fats and the sugars have far less polar than water molecules, thus less affected by the forces generated by the alternating electromagnetic fields.

Dielectric heating is different from the Joules heating of conductive media, which caused by induced electric current in the media. In high frequency $\sigma \ll \omega\varepsilon$, then dielectric heating is dominant mechanism of loss of energy from the electromagnetic field into the medium.

Microwave frequency penetrates in living tissues, to a distance defined by the skin depth. The penetration essentially stops where all the penetrating microwave energy has been converted to heat in the tissue. For this reason it is a difficult task to have radiotherapy with antenna being outside and the waves may damage the cells all through the way to the tumor. This may damage the non-cancerous cells too, and causes severe burns to the cells.

## VIII. PRESENT TECHNIQUES USED IN RADIOTHERAPY

The invasive radiotherapy was made a better option. Physicists use image guided radiation therapy, IGRT. This improved the better delivery of the radiation therapy to the tumors. This is very helpful since tumors can move between the treatments due to differences in organ filling or movements while breathing. IGRT involves using the conformal radiation treatment guided by specialized imaging tests like ultrasound, CT scans or X-rays. IRGT is the 2-D or 3-D imaging during a course of therapy. The positron emission tomography is one of the good imaging techniques.

The radiation therapy techniques employ the process of Intensity Modulation Radiotherapy (IMRT). This process of radiation treatment uses computer and linear accelerators to sculpt a 3D radiation dose map specific to the target's location, shape and motion characteristics. Detailed data about the tumor location is recorded. This enhanced the reduction of more normal cells and also to assure for destroy of more cancerous cells. Even the invasive radiology method shows good results in destroying the cancerous cells and in tumor, it brings many side effects and other related problems for life.

Proposed method**:** Hence now research is going on parallel to design new methods for non-invasive thermotherapy. Many desired results are found. Now scientists propose some instrumentation methods for microwave thermotherapy using microwave array antenna.

The focused microwave radiation is the treatment which avoids heating the skin.

Here needle like antennas are used to radiate the microwaves on the cancer cells. The antennas are made up of conductor like metals. Here th proposed model conductor used is the stainless steel. This is a partially invasive type of treatment for cancer. Here no catheter probe is used in all cases. In case of deep tissue exposure a probe is used. Using a probe increases the efficiency

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by reducing exposure area to the radiation. Here needles with thickness of a few millimeters are used. A third needle is used to increase the efficiency by varying the electric field. Each part of body has different Specific Absorption Rate, SAR, depending on the amount of its fat content. Different intensity of radiation is applied and radiation intensity differs from one part to another depending on this SAR of the tissue. This reduces the time of exposure and number of sitting for thermotherapy is also reduced.

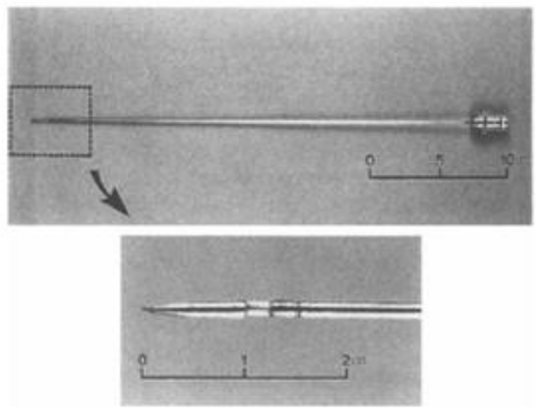


Fig.2. The custom-made microwave antanna

The varying electric fields induce dipoles and also create rotational motion. This rotational motion is increased by passing some electromagnetic waves, here the focused microwave. The change in electric field in 3D helps to break the H-bonds and also reduces the Vander Waal’s attraction between the water molecules.

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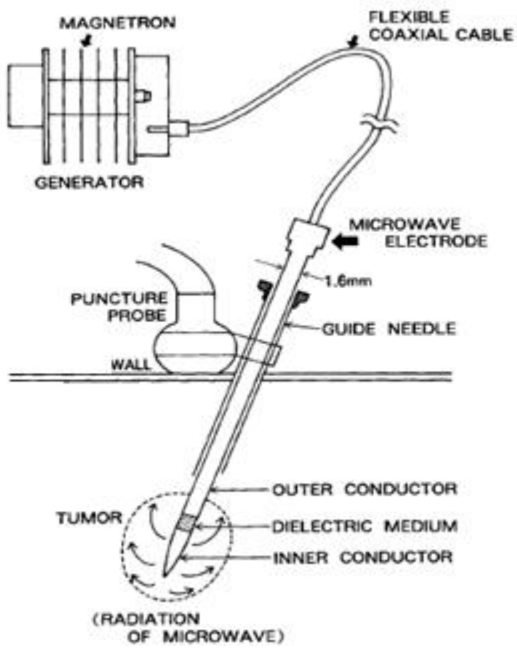


Fig.3. A Typical Microwave Electrode Applied In Cancer.

## IX. IMAGE-GUIDED SURGERY

Image-guided surgery (IGS) is the term used for any surgical procedure where the radiologists employs tracked surgical instruments in connection with preoperative or intra-operative images in order to guide the surgery. Image-guided surgery is part of the wider field of computer-assisted surgery. Most image-guided surgical procedures are minimally invasive. A field of medicine that pioneered and specializes in minimally invasive IGS is interventional radiology. IGS was originally developed for treatment of tumors using stereotactic surgery and radio-surgery that are guided by magnetic resonance imaging (MRI) and computed tomography (CT) using a technology known as the N-localizer. However, Image-guided surgery has found widest application when applied to surgery of the sinuses, where it helps to avoid damage to brain and nervous system. A hand-held surgical probe is an essential component of any image-guided surgery system. During the surgical procedure, the IGS tracks the probe position and displays the anatomy beneath it as, for example, three orthogonal image slices on a workstation-based 3D imaging system. Existing IGS systems use different tracking techniques including mechanical, optical, ultrasonic, and electromagnetic.

When fluorescence modality is adapted to such devices, the technique is also called fluorescence image-guided surgery.

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## X. IMAGE ACQUISITION PROCESS

Echo-planar imaging, EPI, is a very fast magnetic resonance (MR) imaging technique capable of acquiring an entire MR image in only a fraction of a second. In single-shot echo-planar imaging, all the spatial-encoding data of an image can be obtained after a single radio-frequency excitation. Multishot echo-planar imaging results in high-quality images comparable to conventional MR images. However, echo-planar imaging offers major advantages over conventional MR imaging, including reduced imaging time, decreased motion artifact, and the ability to image rapid physiologic processes of the human body. The use of echo-planar imaging has already resulted in significant advances in clinical diagnosis and scientific investigation, such as in evaluation of stroke and functional imaging of the human brain, respectively. The clinical indications for echo-planar imaging are expanding rapidly, and it can now be applied to many parts of the body, including the brain, abdomen, and heart. Today, with the availability of echo-planar imaging–capable MR imagers at many sites, the general radiologist can benefit from echo-planar imaging and its clinical applications. The time required to gather a complete set of image data. The total time for performing a scan must take into consideration the additional image reconstruction time when determining how quickly the image may be viewed.

## XI. ADAPTIVE MEDIAN FILTERING

The adapted median filtering is known as a reference method in the visual inspection. In reference methods it is necessary to take still images at selected programmed inspection positions. The image of the subject under test ($x$)is compared with a healthy tissue image ($y$), called the reference image. If a significant difference is identified ($e$), then the test piece is classified as defective. In these approaches, the reference image is estimated from the test image using a filter consisting of several masks. The key idea of reference methods is that the masks of the filter are configured off-line from a training set of real defect-free images, and the line inspections ensured.

The reference methods based on Modified Median (MODAN) filter have become most widely established in industrial applications in this field [6]. With the MODAN Filter it is possible to differentiate regular structures of the piece from defects. The MODAN Filter is a median Filter with adapted Filter masks. If the back-ground captured by the median Filter is constant, it is possible that structures in the foreground will be suppressed if the number of values belonging to the structure is less than one half of the input value to the Filter. This Characteristic is utilized to suppress the defect structures and to preserve the design features of the test piece in the image.

The goal of the adapted median Filtering is to create a defect-free image from the test image. Thus, the MODAN Filter is used in order to suppress only the defect structures in the test image. Locally variable masks are used during MODAN Filtering by adapting the form and size of the median filter masks to the design structure of the test piece. This way, the design structure is maintained in the estimated reference image (and the defects are suppressed). Additionally, the numbers of elements in the operator are reduced in order to optimize the computing time by not assigning all positions in the mask. This technique is known as a sparsely populated median Filter. Typically, only three inputs are used in the MODAN Filter. In this case, the reference image is computed as:

$y[i; j] = = \text{median}(x1, x2, x3)$ *(1)*

With

$x1 = x[i; j]$
$x2 = x[i + dij\ ; j + eij\ ]$
$x3 = x[i$ ¡ $dij\ ; j$ ¡ $eij\ ];$

where $x[i; j]$ and $y[i; j]$ are the grey values at pixel $(i; j)$ in the test and reference images respectively. The filter direction of the masks is determined by the distances *dij* and *eij* . Defects are detected when

$|y[i; j]$ ¡ $x[i; j]| > \Theta ij$ *(2)*

where *Θijis* the threshold of pixel $(i; j)$.
The parameters *dij*, *eij*and *Θij*are found in an off-line configuration process. For this task, a bank of 75 different filter masks with three inputs is used.

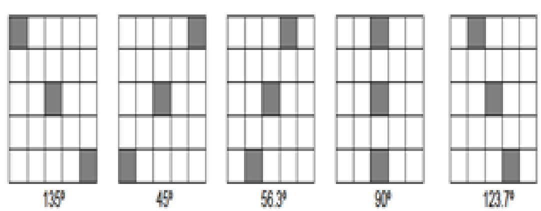


Fig.5.Some 5X5 masks used in a MODAN filter

In the bank, there are masks of $3X3$, $5X5$, ..., $11X11$ pixels. Some of them are shown in Fig. 5. Additionally, $N$ training images of different pieces without defects are taken in the same position. A mask is selected for pixel $(i; j)$ when the objective
Function

$J\text{ij} = \sum_{n=1}^{N}[Qij(dij\ ;\ eij\ )]n$ (3)

is minimized. In the objective function,
$[Qij(dij\ ; eij)]n$ is computed from the $n$-th

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image of the training set for $n = 1, \ldots, N$ as:

$$[Qij(dij, eij)]n = [Qij1((dij, eij) + Q_{IJ}^{2}(dij, eij) + Qij^{3}(dij\,;\,eij)]_{n} \quad (4)$$

where functions $Q1$, $Q2$ and $Q3$ denote the detection error, flagged false alarms, and the matrix size.Threshold $\Theta ij$ is computed from the training images a

$$\Theta ij = \max(|yn[i,j] - xn[i,j]|) + \alpha \qquad (5)$$

With $\alpha = 0$ we ensure that no false alarm is flagged in all training images.However, it is convenient to set $\alpha > 0$ to give a larger confidence region. The selection of this parameter will be studied in next section. Thus, once the mask is selected, the error-free reference image is estimated on-line using (1) when condition (2) is satisfied.

## XII. RESULTS

In order to assess the performance of the inspection, the Receiver Operation Characteristic (ROC) curve is analyzed. The ROC curve is defined as a plot of the `sensitivity' ($Sn$) against the `1-specificity' ($1 - Sp$):

$$Sn = \frac{TP}{TP+FN'} \quad 1 - Sp = \frac{FP}{TN + FP'}$$

Where,

*TP* is the number of true positives (flaws correctly classified);

*TN* is the number of true negatives (regular structures correctly classified);

*FP* is the number of false positives (false alarms, i.e., regular structures classified as defects); and

*FN* is the number of false negatives (flaws classified as regular structures).

Ideally, $Sn = 1$ and $1\text{-}Sp = 0$, i.e., all flaws are detected without flagging false contour. The ROC curve permits the assessment of the detection performance at various operating points (e.g., thresholds in the classification). The area under the ROC curve ($Az$) is normally used as a measure of performance because it indicates how reliable the detection can be performed. A value of $Az = 1$ gives a perfect classification, whereas $Az = 0{:}5$ corresponds to random guessing. αA ROC curve was computed for the inspection of the 36 test images for $\alpha$= 0,5,10,1,20. The obtained area was $Az$= 0:8932 and the best operating point was $Sn$ = 0:85 and 1-$Sp$ = 0:04, i.e., 85% of the existing contour detected The detection in two of the test images is illustrated in Fig. 5. In addition; the detection performance was evaluated in real images with simulated flaws. The simulated flaws were obtained using the technique of mask superimposition, where certain original grey values of an image without flaws are modified by multiplying the original grey value with a factor $p$.

## XIII. CONCLUSION

The prostate cancer treatment using microwaves is discussed in detail. The reason for choosing the microwave for prostate cancer thermotherapy is discussed and electromagnetic waves are also discussed in detail. The two invasive antennas with a single needle like probe and each separated with insulating ceramic material is used in place of three antennas. The image acquisition process through EPI and filtering process is discussed for MODAN filter. The various aspects on theory and in practice are discussed and put forward for further discussions in medical view points for further advancements in various parts of the body.

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