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An Efficient FEA on an RF Structure Used to Evaluate the Effect of Microwave Radiation on Uveal Melanoma Cells

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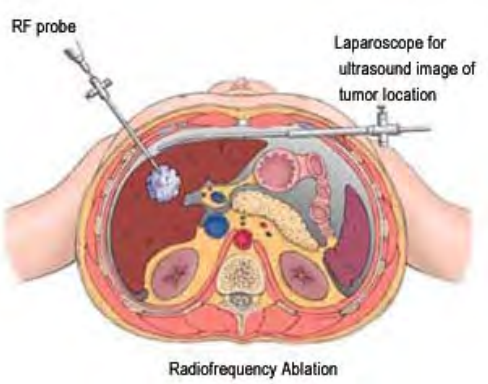
PLAN OF THE PRESENTATION

- Objective of the research
- Goals of this project
- Introduction
- RF and microwave equipments set up
- FEA design and simulation results
- Results assessment and general discussions
- Conclusions and future works

OBJECTIVE OF THE RESEARCH

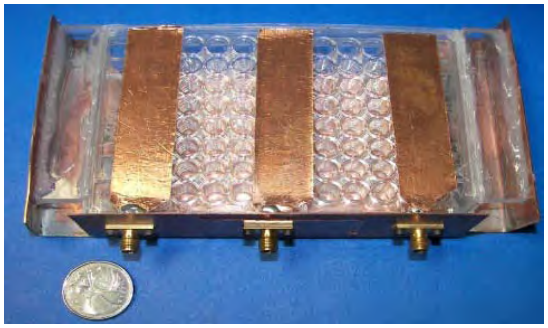
Effect of LOW POWER
RF Energy
on Normal Cells

NO EFFECT / CANCER
Contradictory Answers ?
(Time of Exposure)
(Region of Exposure)



Effect of HIGH POWER
RF Energy
on Cancer Cells

TUMOR ABLATION
Successful Results ?
(Controlled operation)



Effect of LOW POWER
RF Energy
on Cancer and Normal Cells
in Vitro

Purpose of this RESEARCH
(Frequency of Exposure)
(Power of Exposure)

Note: Low Power <1 Watt, High Power >50 Watts

GOALS OF THE PROJECT

- Evaluate the electromagnetic energy distribution over the transmission line of the RF structure using COMSOL FEA software

- Confirm the statistical validity of the proliferation test results on malignant and fibroblast cells

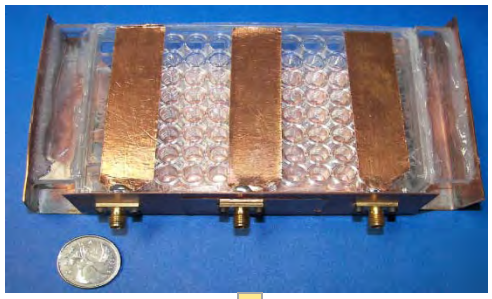
INTRODUCTION (1)

- RF, microwave and millimeter waves affect the particles or cells
- Extensive use of cell phone could lead to potential increase in human Uveal Melanoma and other cancers
- Electromagnetic radiation therapy with low power (non thermal) is not really investigated
- Radiation penetrates the cell membrane and dielectric properties affecting the content of the biological molecules
- Low power RF energy = level below the cellular phone transmission
- Big challenge to find the appropriate frequency range and power level for low power RF therapy

INTRODUCTION (2)

- RF structure is adapted and fabricated for RF energy injection on normal and malignant cells
- Analysis is required to verify analytically or by simulation the energy distribution over the cells & over the structure
- Best to DO SIMULATION
  - Actual geometry
  - Simulated environment
  - Results
  - Interpretation
  - Validation with experimental results

RF AND MICROWAVE EQUIPMENTS SET UP (1)



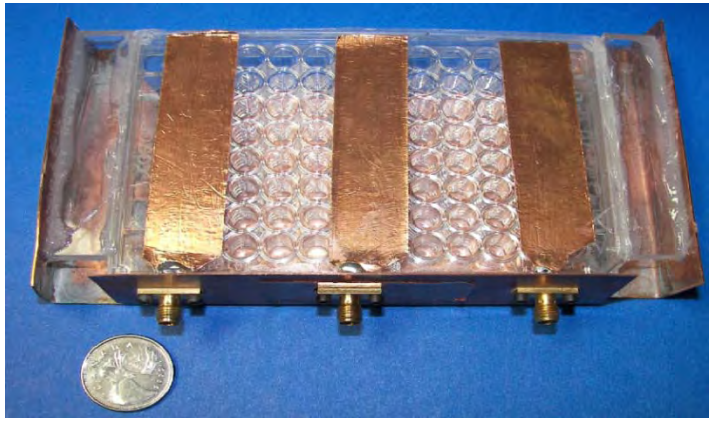
- RF electrodes made of 3 copper adhesive stripes (taper shaped on one end) connected to 3 RF SMA connectors
- The RF ground plane is insured through a single block of copper metal
- RF electrodes and RF ground plane are separated by the 96 well plate and held by a Plexiglas corner blocks

- RF/Microwave generator
- RF/Microwave spectrum analyzer
- Frequency Ranges (step 0.1 GHz)
  - Range 1 (1 GHz to 1.6 GHz)
  - Range 2 (1.7 GHz to 2.3 GHz)
  - Range 3 (2.4 GHz to 3 GHz)
- Generator Power Level:
  - About 20 dBm (100 milliwatts)

Cellular phone frequencies from 0.9 to 1.9 GHz
Microwave oven frequency 2.45 GHz

RF AND MICROWAVE EQUIPMENTS SET UP (2)

WELLS PLATES PREPARATION



IRRADIATED 96 WELL PLATE SETUP (Plate 1)

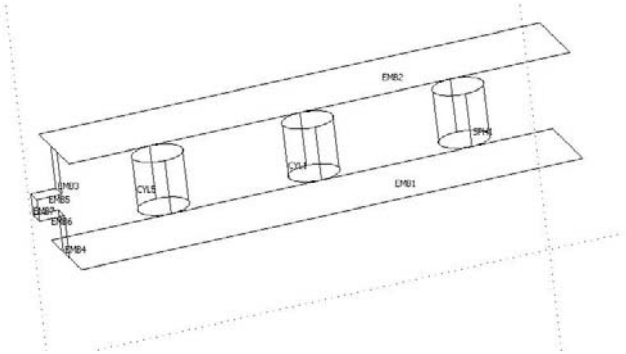
- Under each copper stripe one column contained 92.1 cells in six rows and another column contained fibroblast cells also in six rows
  - Plate 1 exposed to RF radiation
  - Exposure duration of 35 minutes per range

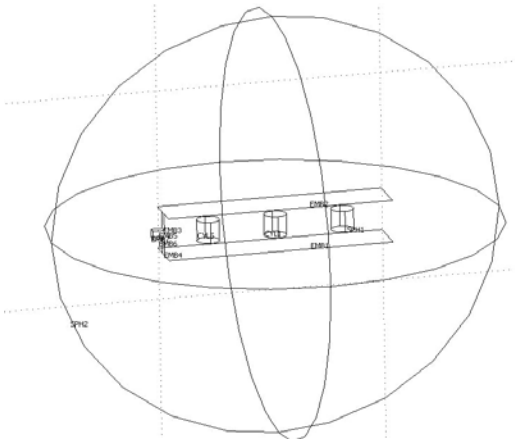
REFERENCE 96 WELL PLATE WITHOUT RF STRUCTURE (Plate 2)

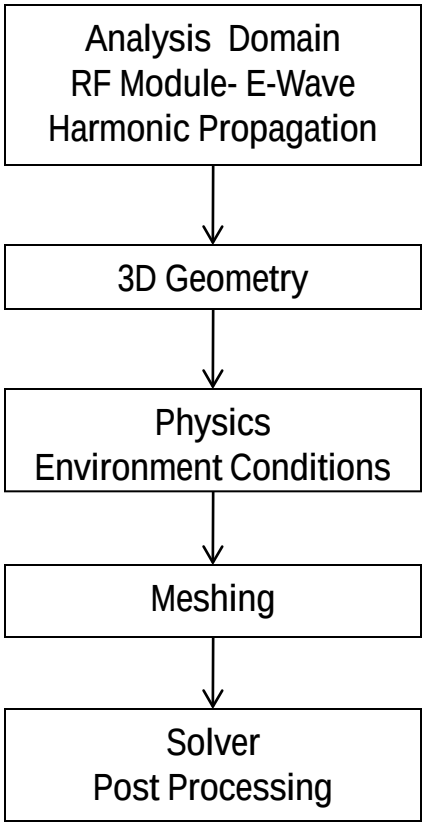
- Same experimental setup (containing 92.1 and fibroblast cells) used as a reference or control
- Plate 2 removed from the incubator, placed at ambient environment but not exposed to RF radiation

RF STRUCTURE 3D GEOMETRY (FEA)

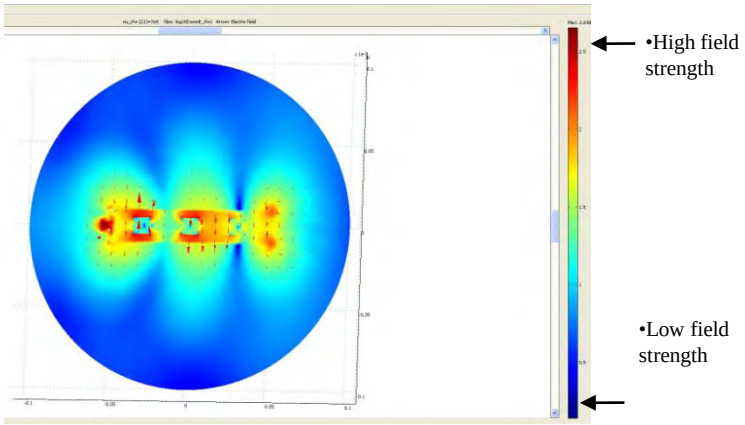
- Simplified structure
- Plates modeled as embedded areas (interior PEC) with no thickness for less mesh elements
- Cylinders of liquid with cells
- Use of little stripes for connection between the generator and the plates
- Sphere shape enclosure with a scattering boundary condition



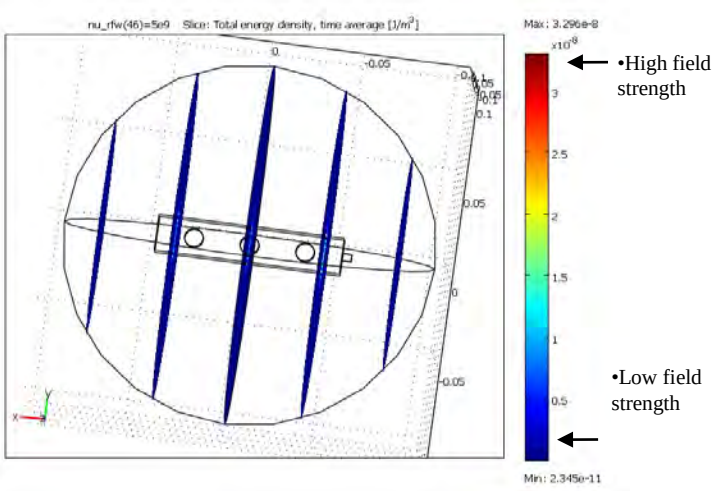




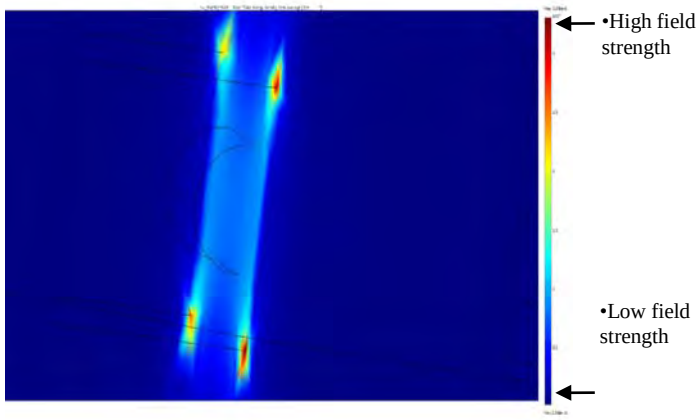
SIMULATION RESULTS



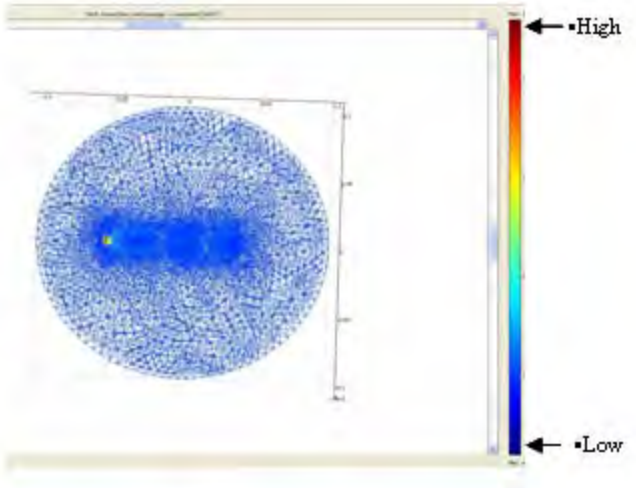
Electric field along the Ox axis



Slices of the transversal electric field

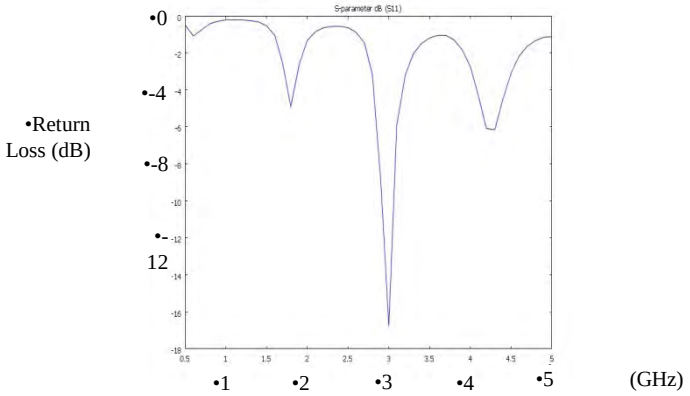


Electric field along the Oy axis



Power distribution along Ox axis

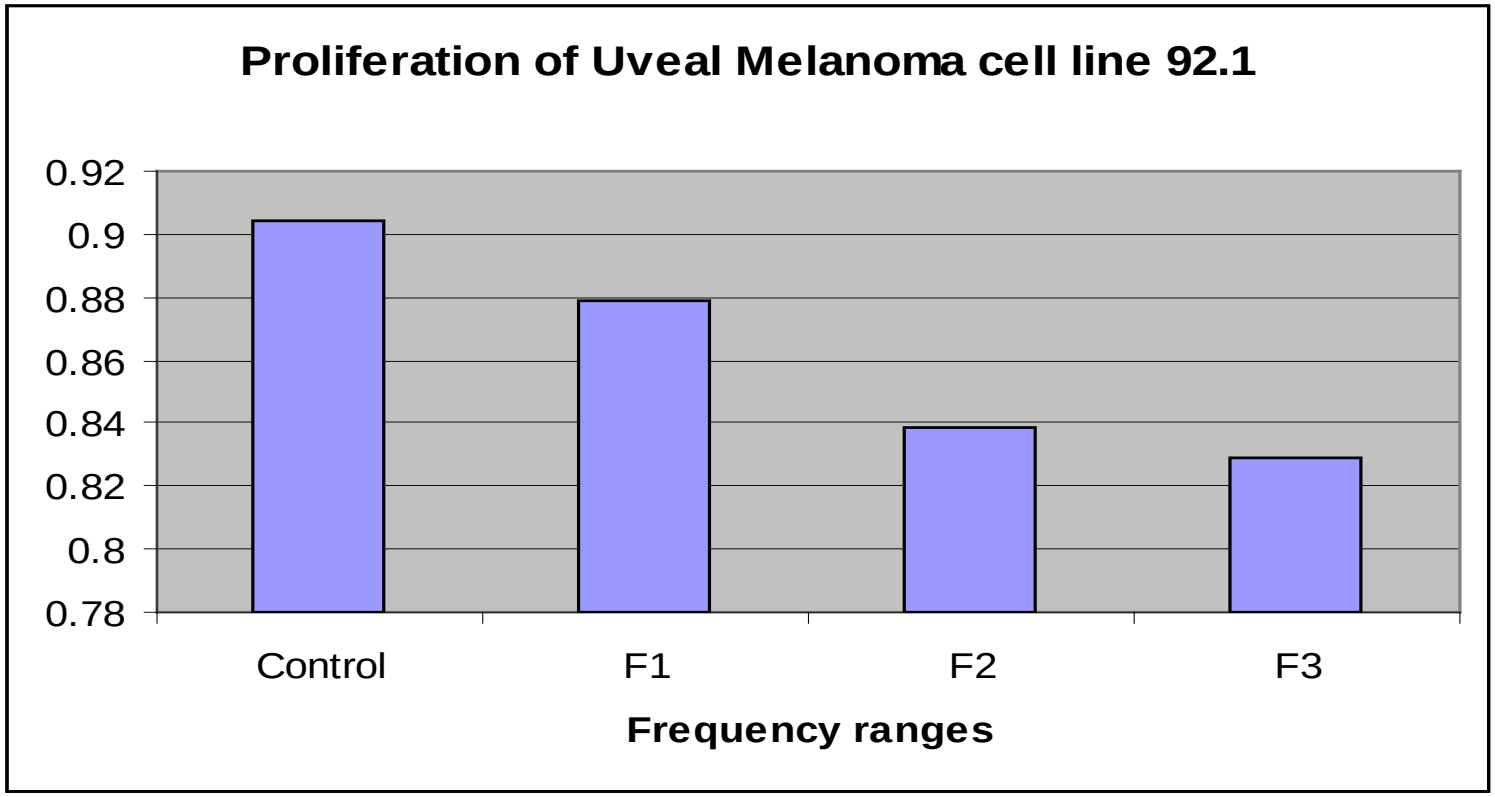
SIMULATION RESULTS



Simulation of S11 - a very useful diagram

- About -2dB Return loss (S11) for 1 to 3 GHz frequency range, so more than half of the injected power is returned to the source
- 2 spikes at 1.8 and 3 GHz with -5dB and -16dB respectively, attributed to undesired resonance
- Experimentally similar return loss (S11) response observed:
  - on a network analyzer (1 dB better return losses)
  - adjustment of the testing generator
- Return loss results imply some power variations with frequency

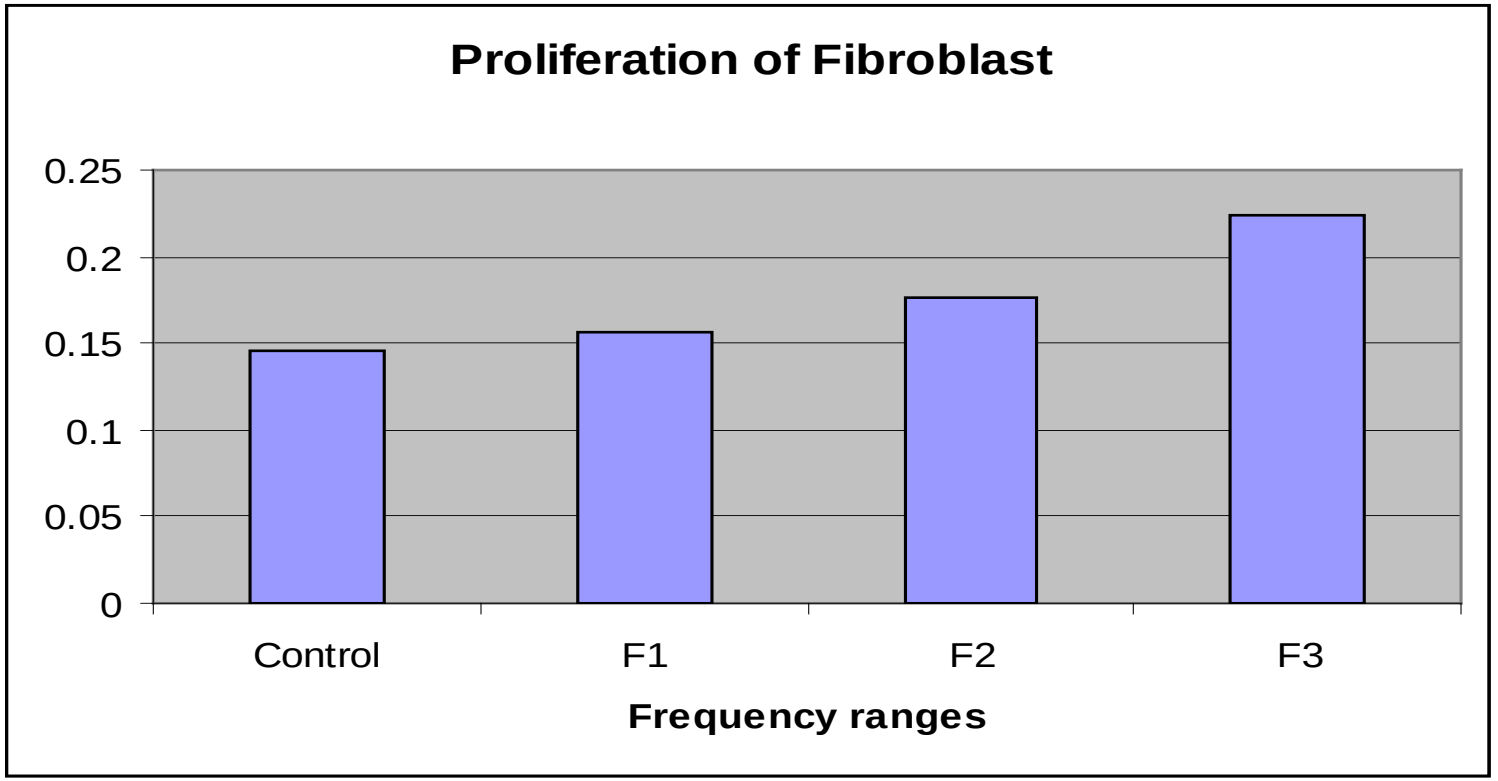
EXPERIMENTAL RESULTS OF 92.1 CELLS



RF radiation proliferation results on 92.1 Uveal Melanoma cells in a media

F1 = 1 to 1.6 GHz; F2 = 1.7 to 2.3 GHz; and F3 = 2.4 to 3 GHz

EXPERIMENTAL RESULTS OF FIBROBLAST



Fibroblast results in a media

F1 = 1 to 1.6 GHz; F2 = 1.7 to 2.3 GHz; F3 = 2.4 to 3 GHz

GENERAL DISCUSSION

- Experimental results showed a reduction more pronounced for Uveal cells at frequency ranges 2 and 3 than range 1
- Power variation with frequency due to input return loss points to a probable cause for the proliferation variation results
- For every frequency range, the proliferation results from all wells were averaged. As per simulation results, there is a uniform power distribution over the wells. Therefore, the simulation validates the averaging process

CONCLUSIONS AND FUTURE WORKS

- With COMSOL Simulation
  - Evaluate the radiation energy on Uveal and fibroblast cells and energy distribution along the transmission lines
  - Reduced the analysis time
- Identifying common trends between simulation and experimental results
- Allows research work on the effects of power distribution on proliferation
- As future works, optimizing the RF structure for longer radiation exposure time (days) , wider frequency ranges, and more uniform power distribution radiation exposure
- Design optimization could be completed with COMSOL FEA simulator

Many thanks for your attention!

Special thanks to Dr. Miguel N. Burnier Jr. and his team from Henry C. Witelson Ocular Pathology laboratory at McGill University, for the preparation of Uveal melanoma cells and the completion of proliferation tests