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Abstract: [Antenna for Medical Implanted Communications System]

Purpose: [To provide an introduction to the antenna design for medical implanted communications system]

BODY IMPLANTED ANTENNA

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Outline

- Introduction
- Antenna Design Considerations
- Antenna Design
- Results
- Safety Issues
- Conclusions

Introduction

- Medical Implant Communications System: The MICS is an ultra-low power radio service for the transmission of non-voice data for the purpose of facilitating diagnose and/or therapeutic functions.
- Frequency band: 402-405 MHz, shred with weather balloons/satellite telemetry (400-406 MHz). Hence, the output power is limited.
- ETSI (European Telecommunications Standards Institute): The output power is set to a maximum of 25 uW ERP.
- FCC & ITU-R: The output power is set to a maximum of 25 uW EIRP, which is ≈ 2.2 dB lower than the ERP level.
- The 25 uW limit applies to the signal level outside of the body (total radiating system), which allows for implant power levels to be increased to compensate for body losses.

Antenna Design Considerations

Medium

An antenna can be designed to either air or the dielectric of the body;

• If the implant antenna is designed in air: the antenna's best performance will be achieved when air surrounds the implant.
• If the implant antenna is designed in the dielectric of the body: the best performance from the implant antenna will be achieved when the antenna is actually inside the body cavity.

Ideal Medium for RF Wave?

The human body is not an ideal medium for RF wave transmitting;

- It is partially conductive and consists of materials of different dielectric constants, thickness and characteristic impedance.
- Depending on the frequency of operation, the human body can lead to high losses caused by power absorption, central frequency shift and radiation pattern destruction.
- The absorption effects vary in magnitude with both frequency of applied field and the characteristics of the tissue, which is largely based on water and ionic content.

Placing a Device into a Body

- The device will be affected by the direct surrounding
- The device behaves in a different way if positioned in an arm, just under skin or in the abdomen
- Dependency on the surrounding tissue type. For example, variation in the thickness of fat layer for different patients with respect to the size over time
- Movement of the patient change the direct surrounding of the implanted device

(Antenna is an integrated part of a medical implant device)

Body Organs and Shape of the Implant Antenna

- A physically small antenna must be used in an implant application.
- The shape of the implant device will dictate the type of antenna to be used.
- The body organs or place of usage will dictate the shape of the implant device.
- A circumference antenna will be suitable for a pacemaker implant, while a helix antenna is required for a stent or urinary implant.

Effect of Covering Layer and Tissues on the Implant Antenna

- The thickness of non-conducting covering material has a major impact on the antenna performance.
- The resonant frequency of the antenna will be changed due to an increased effective permittivity in surrounding of antenna.
- If antenna was designed to a resonant frequency of 403.5 MHz in free space, the resonant frequency will be reduced by a few MHz when the antenna will placed in the tissue.

In-Body Antenna and Wave Propagation

- The wave propagation is affected by the material which an antenna is attached on it.
- The MICS frequency band, 402-405 MHz, corresponds to a $\lambda_{air} \approx 74$ cm @ 403.5 MHz and $\lambda_{body} \approx 9$ cm.
- We can not design the implant wireless device without investigating the electromagnetic properties of the body.
- The E & H-fields inside a dielectric tissue depend both on the depth and on the exact composition of the body.

Antenna Design

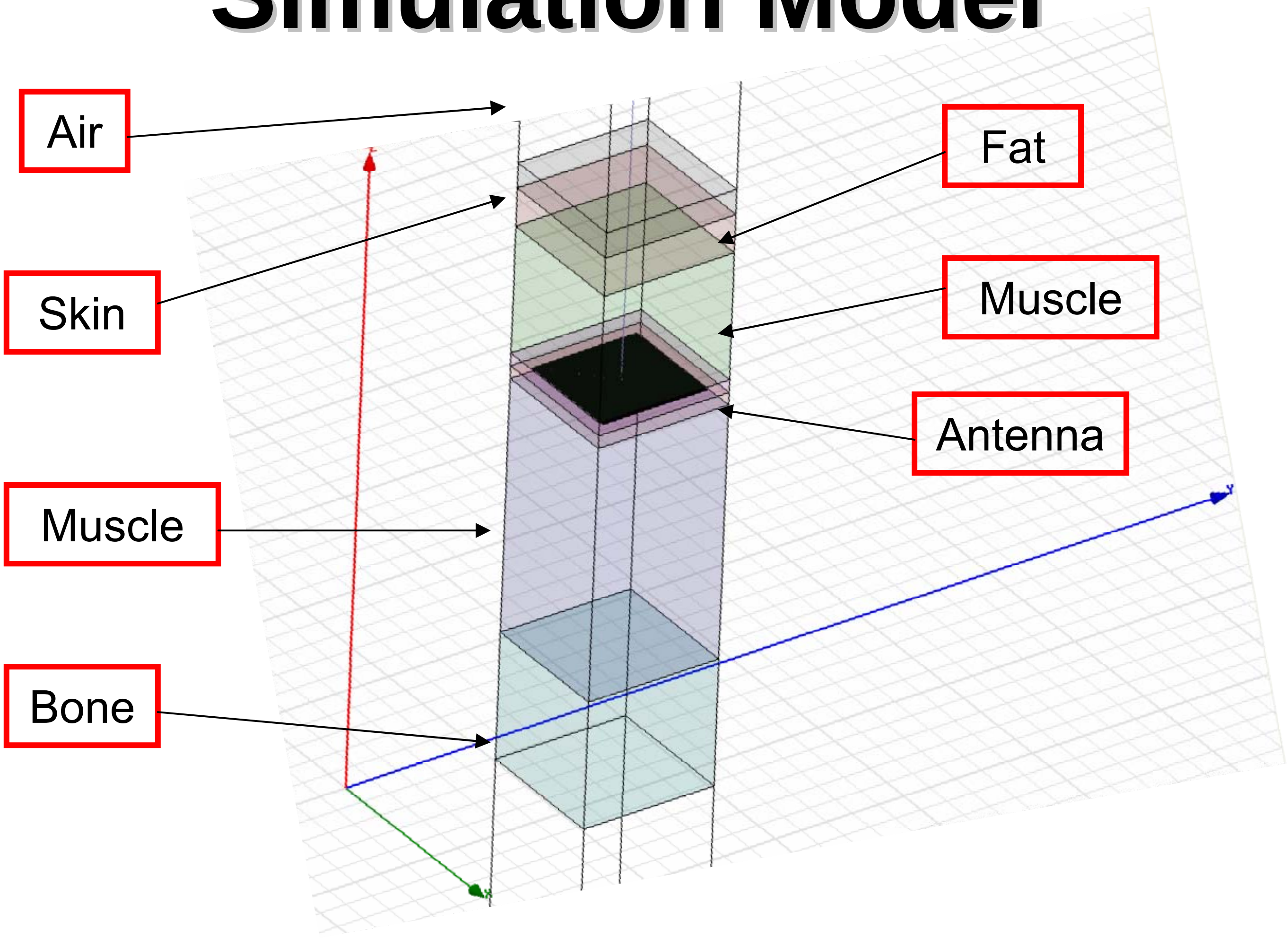
Placing an Antenna in a Simplified Biological Tissue Model

	Air	
Tissue	Skin	2mm
Tissue	Fat	3mm
Tissue	Muscle	10 mm
Substrate	RH-5	1 mm
Metal	Copper	0.036 mm
Substrate	D51(NTK)	1 mm
Tissue	Muscle	20 mm
Tissue	Bone	10 mm

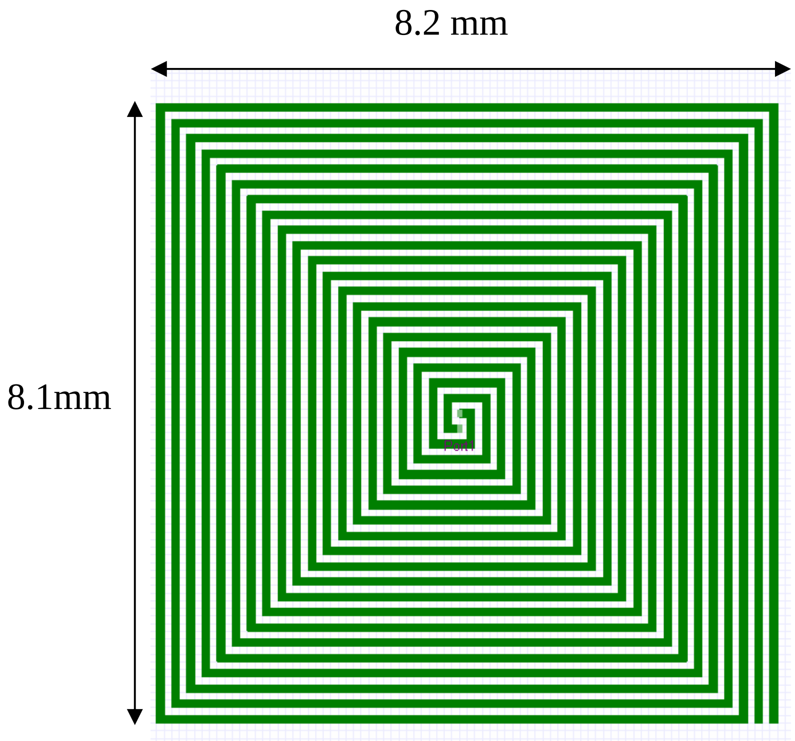
Electrical Properties of Human Body Tissues at 403.5 MHz

	ε_r	σ (S/m)	tan θ
Skin	46.7060	0.6895	0.6577
Fat	5.5783	0.0411	0.3288
Muscle	57.10	0.7972	0.6219
Bone	22.4230	0.2350	0.4670

Simulation Model



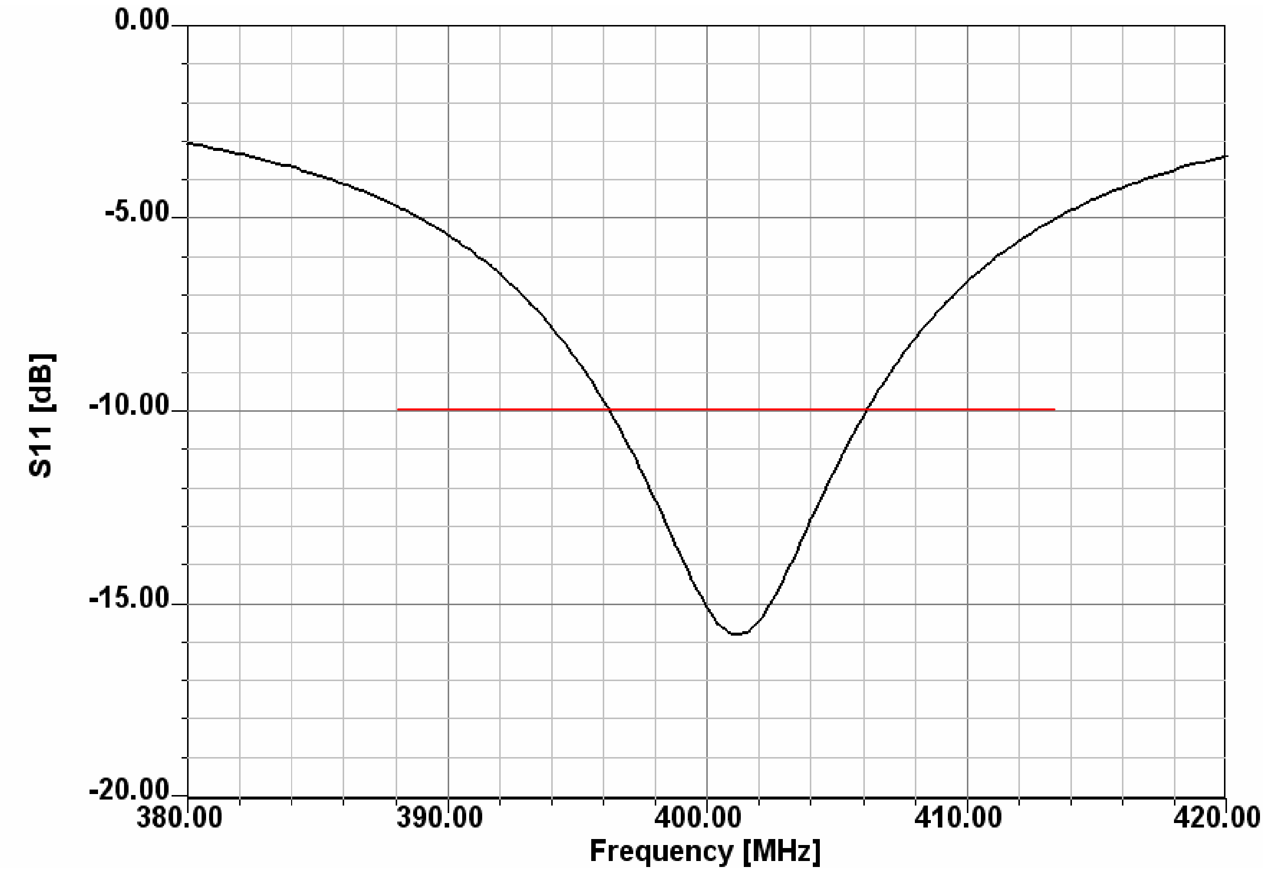
Antenna Layout



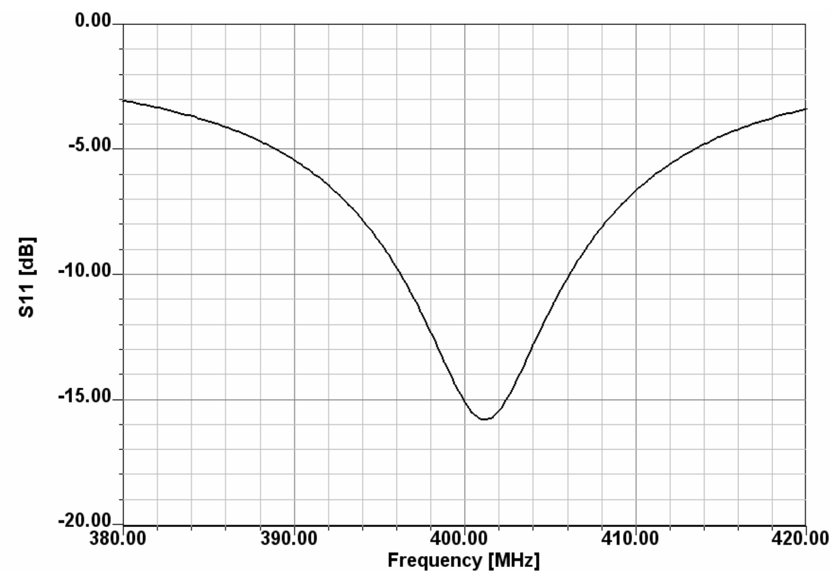
- Metallic layer: Copper, t = 0.036 mm
- Substrate: D51(NTK), ε_r = 30, tan θ = 0.000038, and t = 1 mm.
- Size: 8.2 x 8.1 x 1 mm
- The metallic layer is covered by RH-5, ε_r = 1.0006, tan θ = 0, t = 1mm.

Results

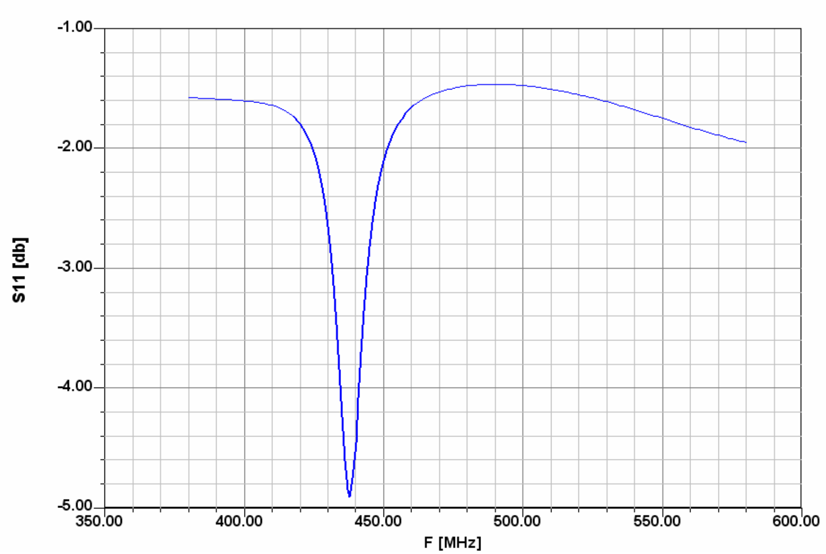
Return Loss


0.00
-5.00
-10.00
-15.00
-20.00
S11 [dB]
380.00
390.00
400.00
410.00
420.00
Frequency [MHz]

Return Loss
(In-Body & Free Space)

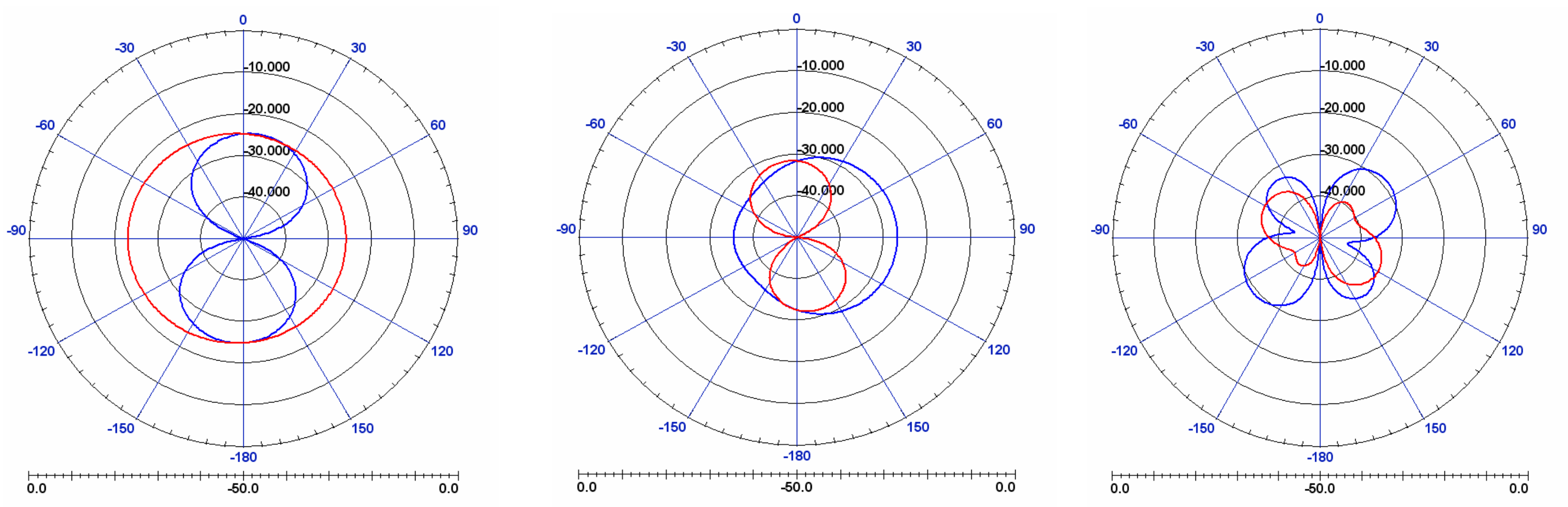


In-Body



Free Space

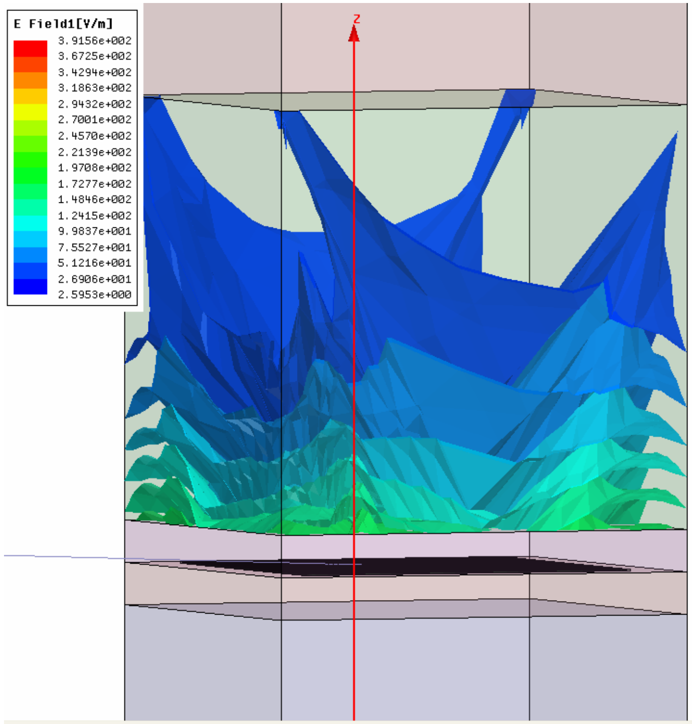
Pattern



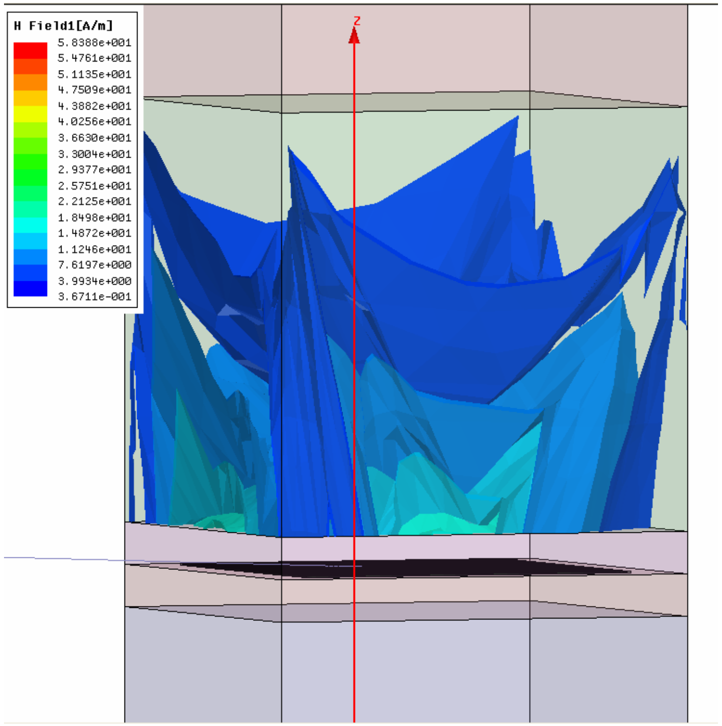
a) b) c)

Radiation Patterns of the proposed antenna in a) y-z , b) x-z, and c) x-y plane at 403 MHz for ϕ =0^{o} and ϕ =90^{o}.

Fields and Type of Antenna

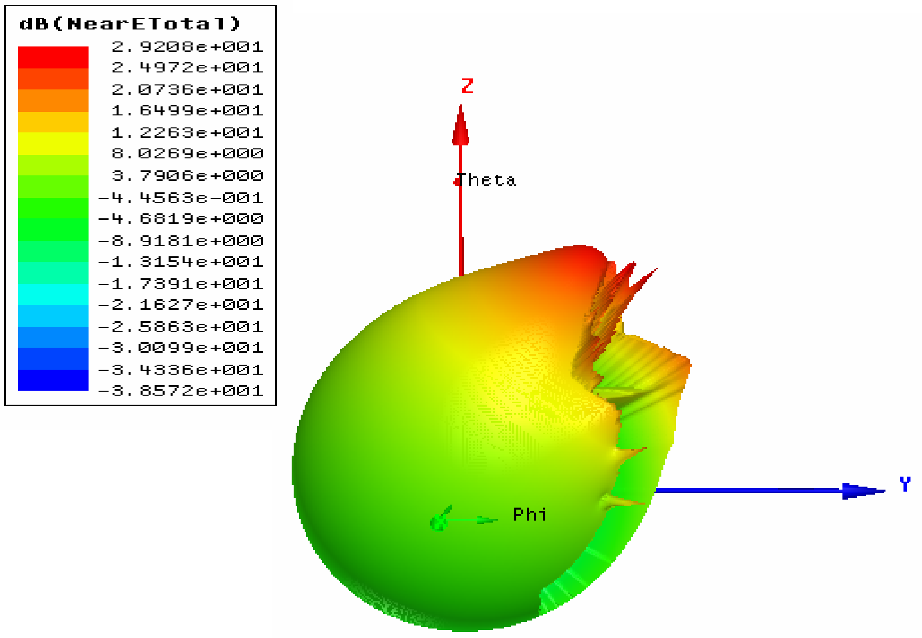


E-Field

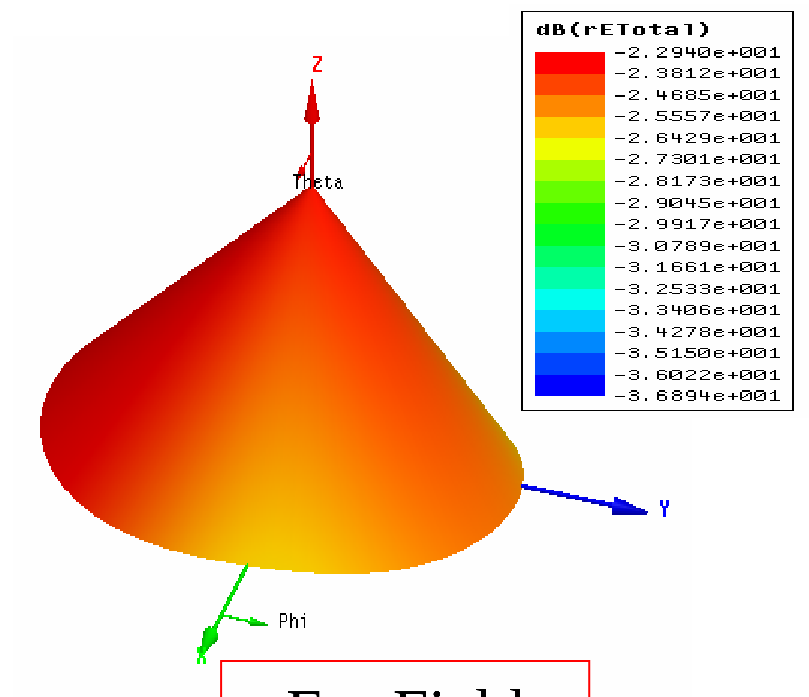


H-Field

Near and Far-Fields 3D Patterns

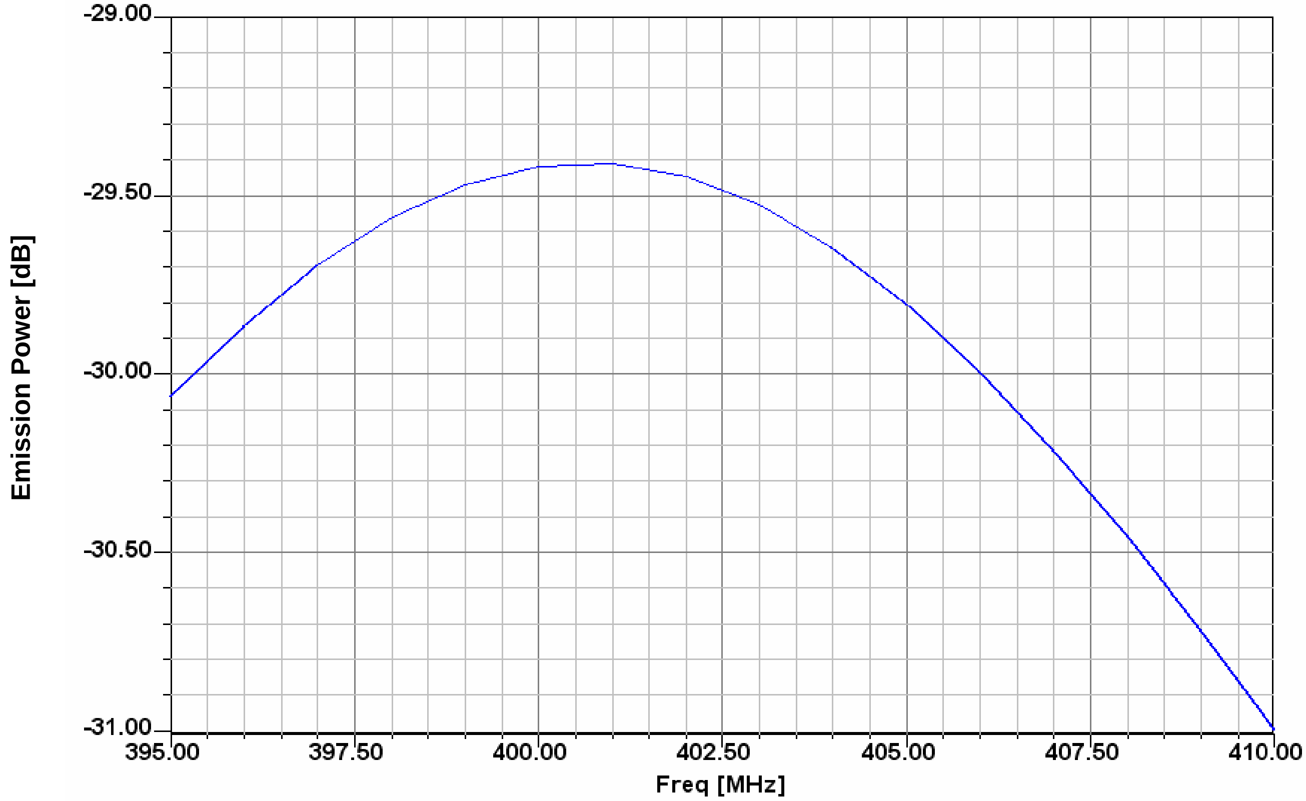


Near-Field

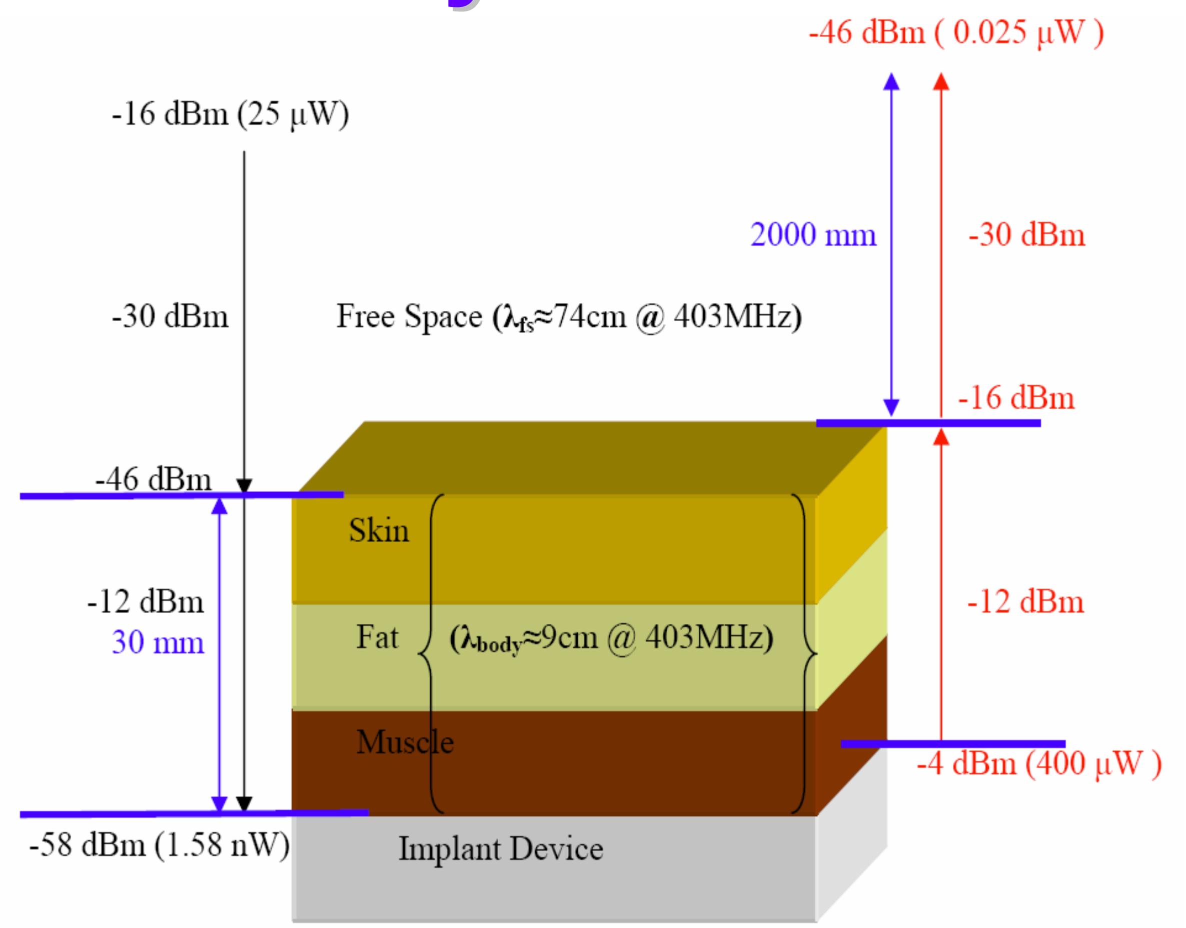


Far-Field

Emission Power at 3 m



In/On Body Power Level



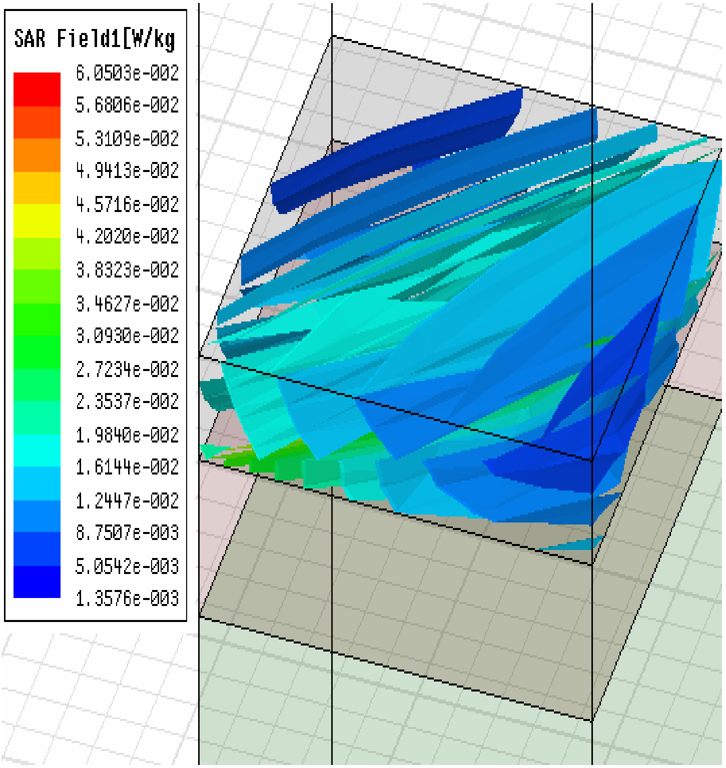
From Free Space to Implant

From Implant to Free Space

Safety Issues

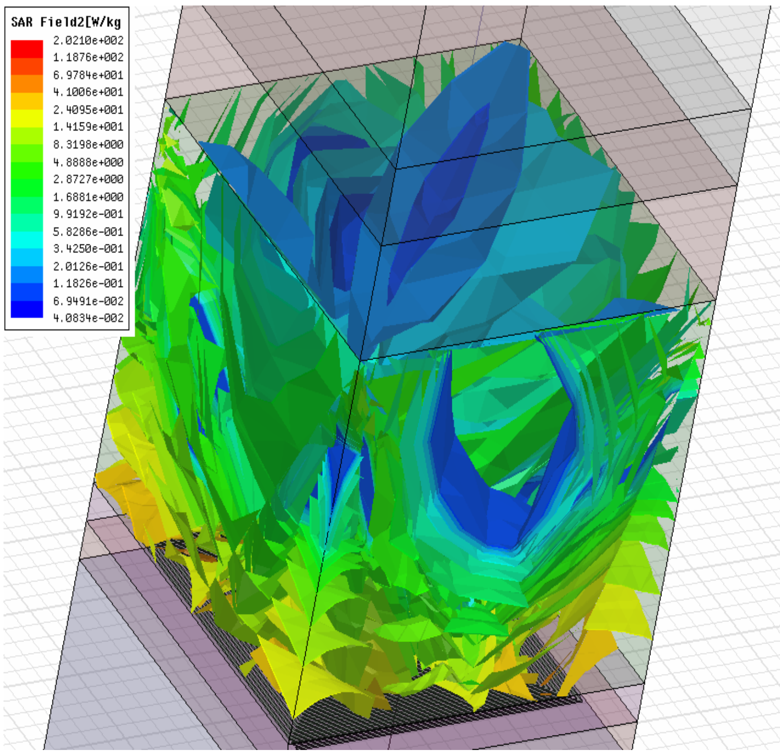
SAR

1-g SAR distribution (IEEE C95.1) when the antenna input power at feed point is 1 mW.

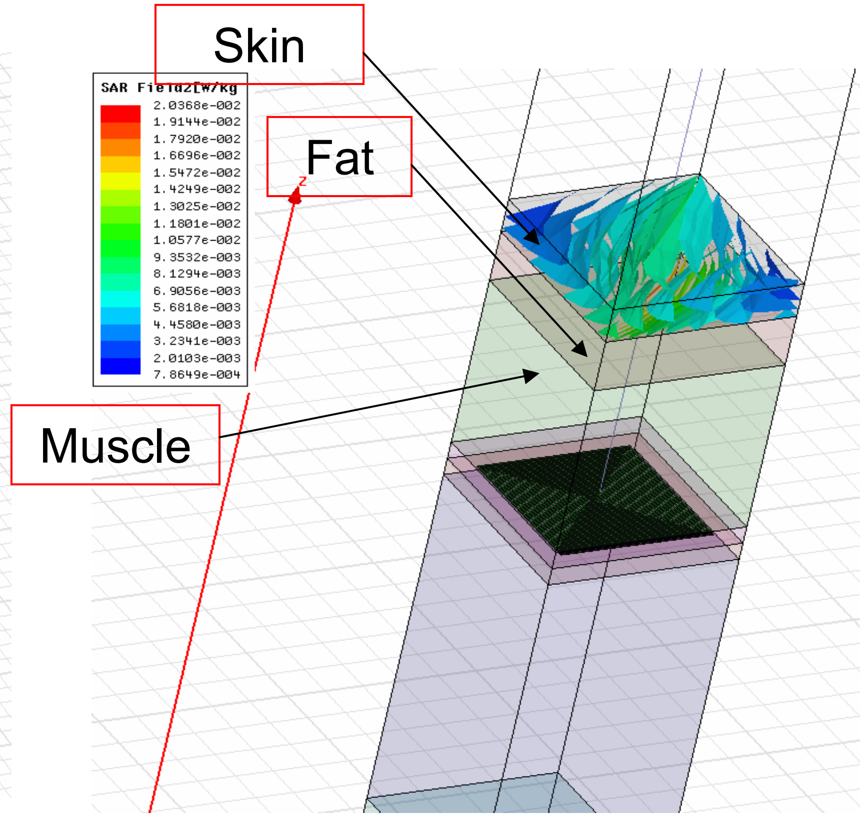


The simulation result shows that the SAR value for the designed implanted antenna is well under limitation of 1.6 W/Kg.

Near & Far-Field SAR



SAR in the Muscle (top)



SAR in the Skin

Conclusion

- The most significant complication with the MICS is that the antenna is placed inside the human body. Hence, the design of implanted antenna is different from the free space one.
- The type of an antenna for the MICS is one of the most important factor to get best performance from MICS device.
- The exact field that an implant antenna operates will depend on the thickness of tissues, which varies between individuals and with time.