Ryerson University

Compact Metamaterial (MTM) Antenna Array for Wirelessly Powering Implanted Biomedical Devices

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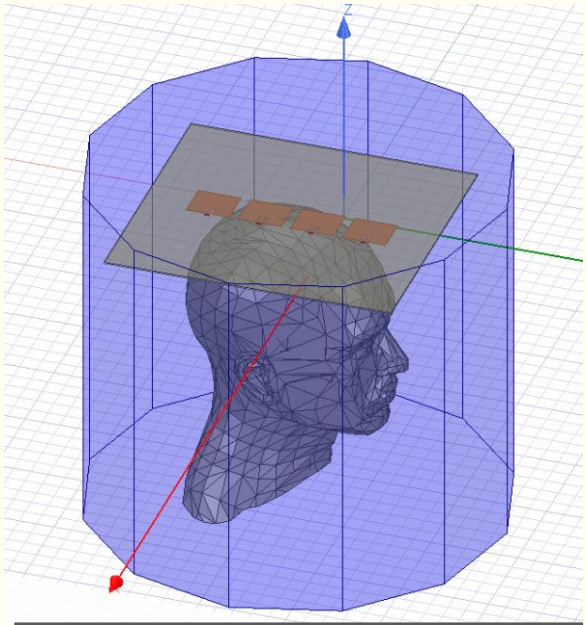
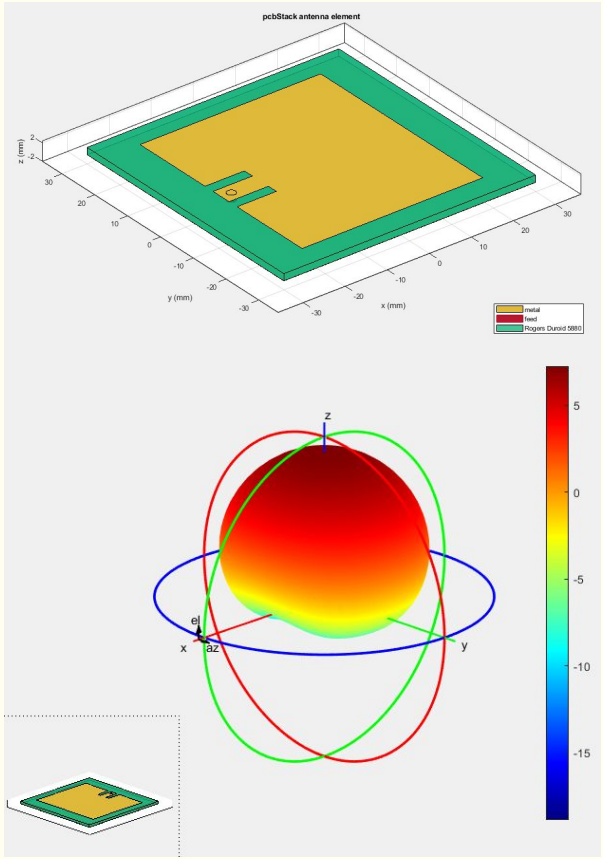


HFSS Simulation of the human head with the patch antenna array on top.

Objective / Goal

Create a helmet that can stir a beam through the human skull to reach the full depth of the brain.



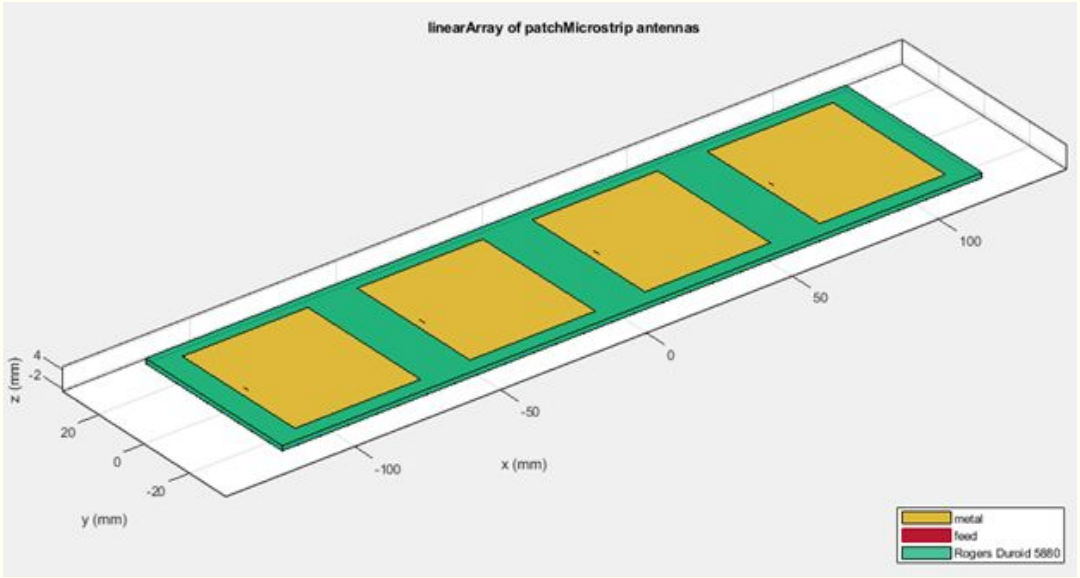
MATLAB simulation of a patch antenna along with its 3D radiation pattern.

Patch Antenna

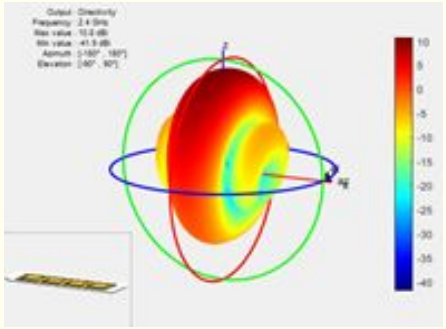
A metal surface that sit on top of a thin dielectric that separates it from its ground plane beneath.

Patch Antenna Array

Individual antenna elements can be placed together to make an array.



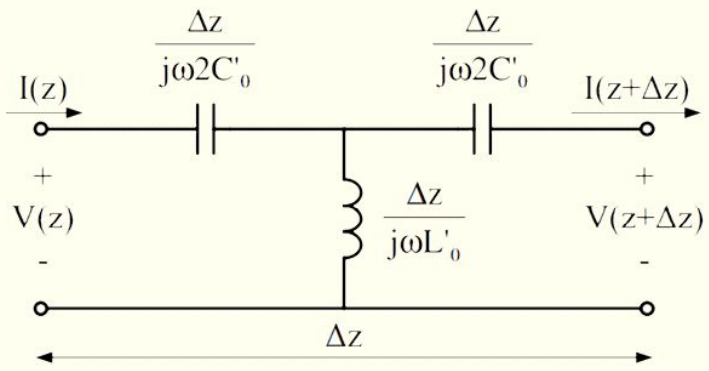
MATLAB Simulation of the Patch Antenna Array



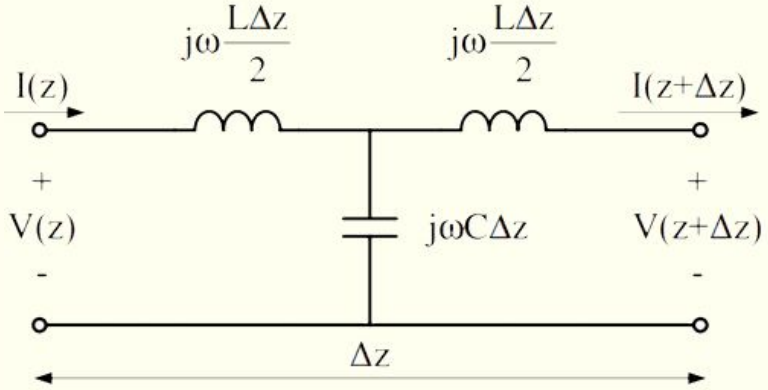
3D Radiation Pattern of the Array

Phase Shifters

Negative Refractive Index (NRI) Transmission Line



Negative Refractive Index Media
(Artificial - Dynamic Elements - Varactor)



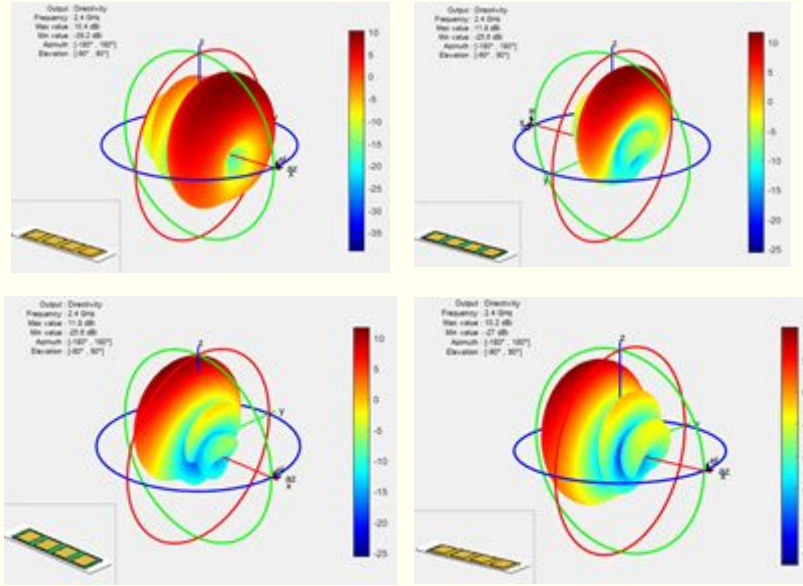
Positive Refractive Index Media
(Natural)

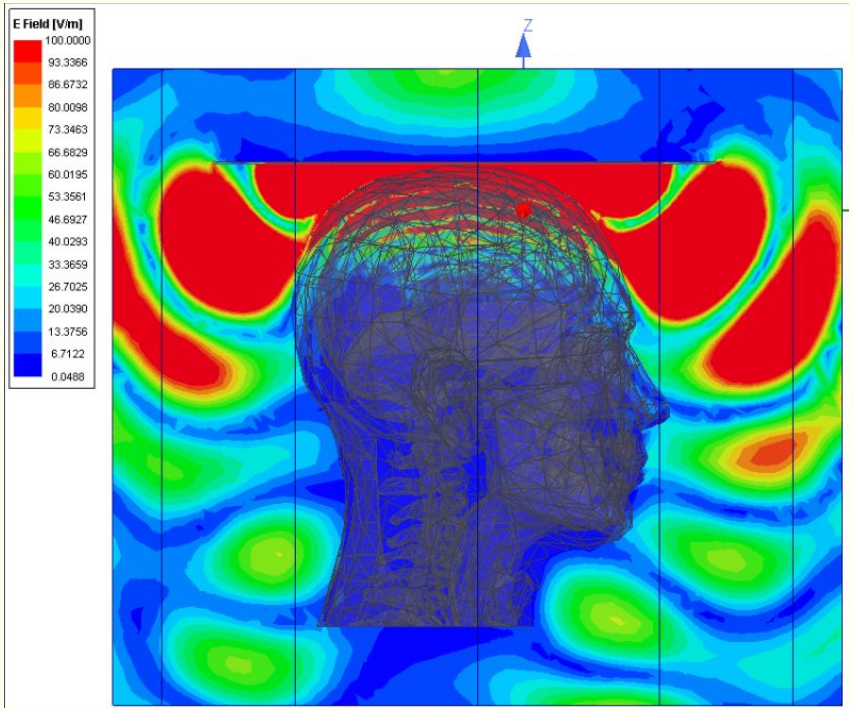
Figure 1. Circuit diagrams of negative and positive refractive index media. Adapted from “Microwave Devices and Antennas Based on Negative-Refractive-Index Transmission-Line Metamaterials”, by Antoniades, 2009, retrieved from https://tspace.library.utoronto.ca/bitstream/1807/17727/1/Antoniades_Marc_A_200906_PhD_thesis.pdf

Phase Shifters

Negative Refractive Index (NRI) Transmission Line

Parameters of the antenna array	$\phi_{MTM} = -90$	$\phi_{MTM} = -45$	$\phi_{MTM} = 0$	$\phi_{MTM} = 45$	$\phi_{MTM} = 90$
Frequency	2.40 GHz	2.40 GHz	2.40 GHz	2.40 GHz	2.40 GHz
Number of elements	4	4	4	4	4
Relative Effective Permittivity	2.11	2.11	2.11	2.11	2.11
Lambda	125.00 mm	125.00 mm	125.00 mm	125.00 mm	125.00 mm
Lambda effective	86.06 mm	86.06 mm	86.06 mm	86.06 mm	86.06 mm
Number of stages	1	1	1	1	1
Characteristic Impedance	50	50	50	50	50
Inductance of the Transmission Line	228.25 nH	228.25 nH	228.25 nH	228.25 nH	228.25 nH
Capacitance of the Transmission Line	91.30 pF	91.30 pF	91.30 pF	91.30 pF	91.30 pF
Inductance of the Backward-wave Line	1.30 nH	991.29 pH	802.79 nH	674.52 pH	581.60 pH
Capacitance of the Backward-wave Line	518.19 fF	396.52 fF	321.12 fF	269.81 fF	326.65 fF
Phase of the Transmission Line	-236.65 deg	-236.65 deg	-236.65 deg	-236.65 deg	-236.65 deg
Phase of the Backward-wave Line	146.65 deg	191.65 deg	236.65 deg	281.65 deg	326.65 deg
Total Phase of the NRI-TL Metamaterial Line	-90.00 deg	-45.00 deg	0.00 deg	45.00 deg	90.00 deg
Maximum radiation angle	58.61 deg	74.91 deg	90.00 deg	105.09 deg	121.39 deg





HFSS Simulation of the EM field on the head.

Conclusion

Acknowledgement

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References

[1] M. A. Antoniades, "Microwave Devices and Antennas Based on Negative-Refractive-Index Transmission-Line Metamaterials." Order No. NR59043, University of Toronto (Canada), Ann Arbor, 2009.

[2] Balanis, Constantine A. *Antenna Theory: Analysis and Design*. John Wiley & Sons, Inc, 2005.

[3] Ulaby, Fawwaz and Umberto Ravioli. *Fundamentals of Applied Electromagnetics*. 8th ed. Pearson Education Inc, 2020.