Implementation of a Hairpin Model Based Passive Microwave Tag Using Microstrip Structure

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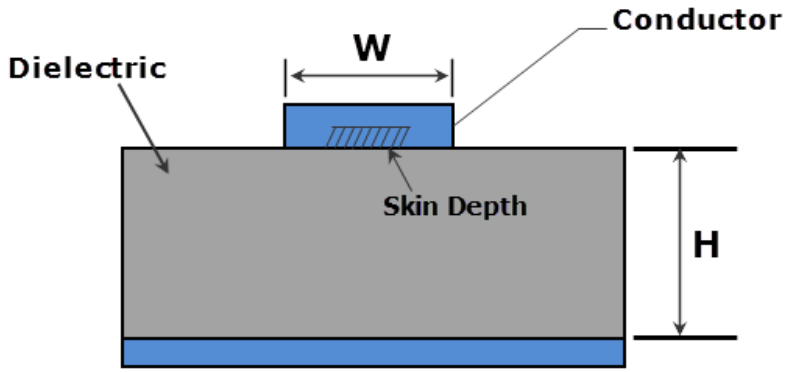
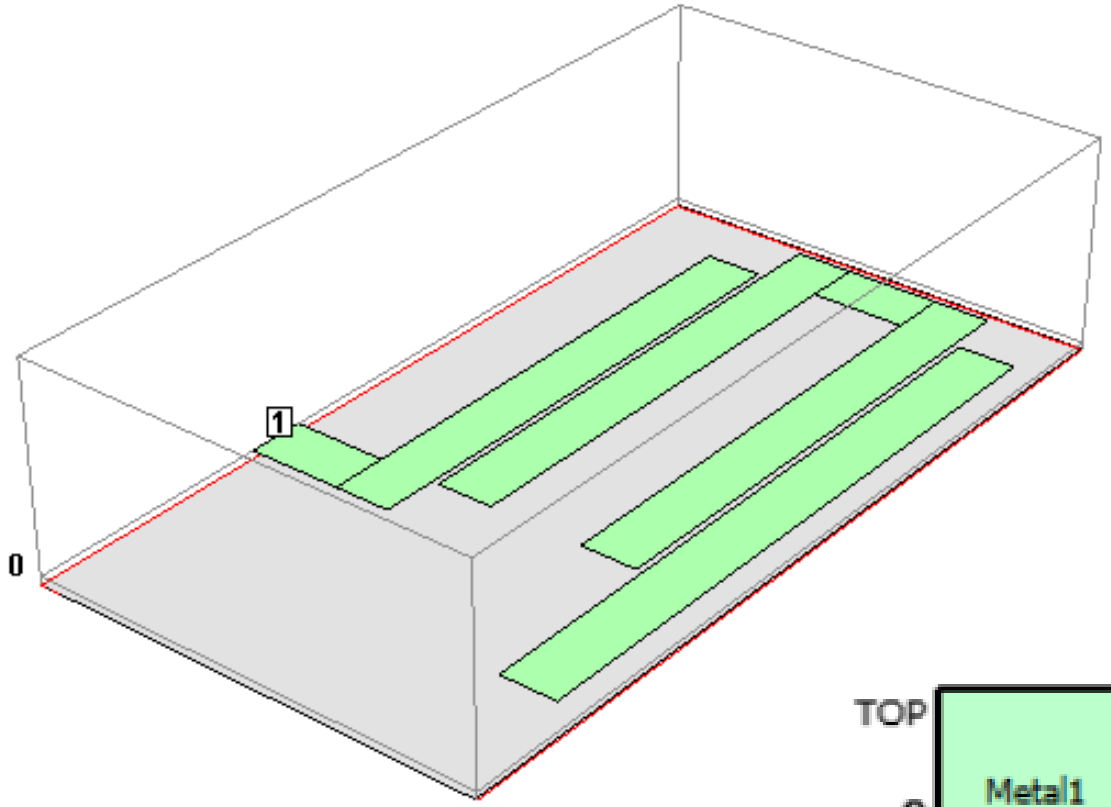
Advantages of Using Microstrip Structure

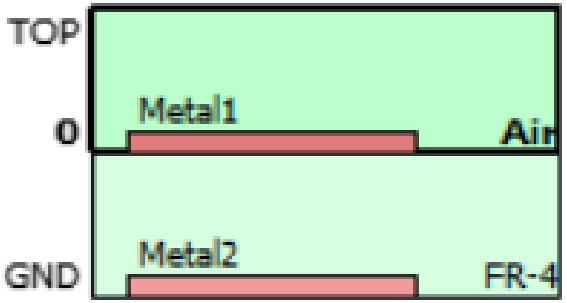
- Wide range of applications as Radio-Frequency Identification (RFID)
  - Asset Tracking
  - Theft Prevention
  - Security Identification Systems
- Cost efficiency
  - Can be produced with commonly available, low-cost materials
  - Does not require a clean room or expensive fabrication equipment
  - Does not involve use of any hazardous chemicals
- Compact design reduces power loss due to skin depth at higher frequencies

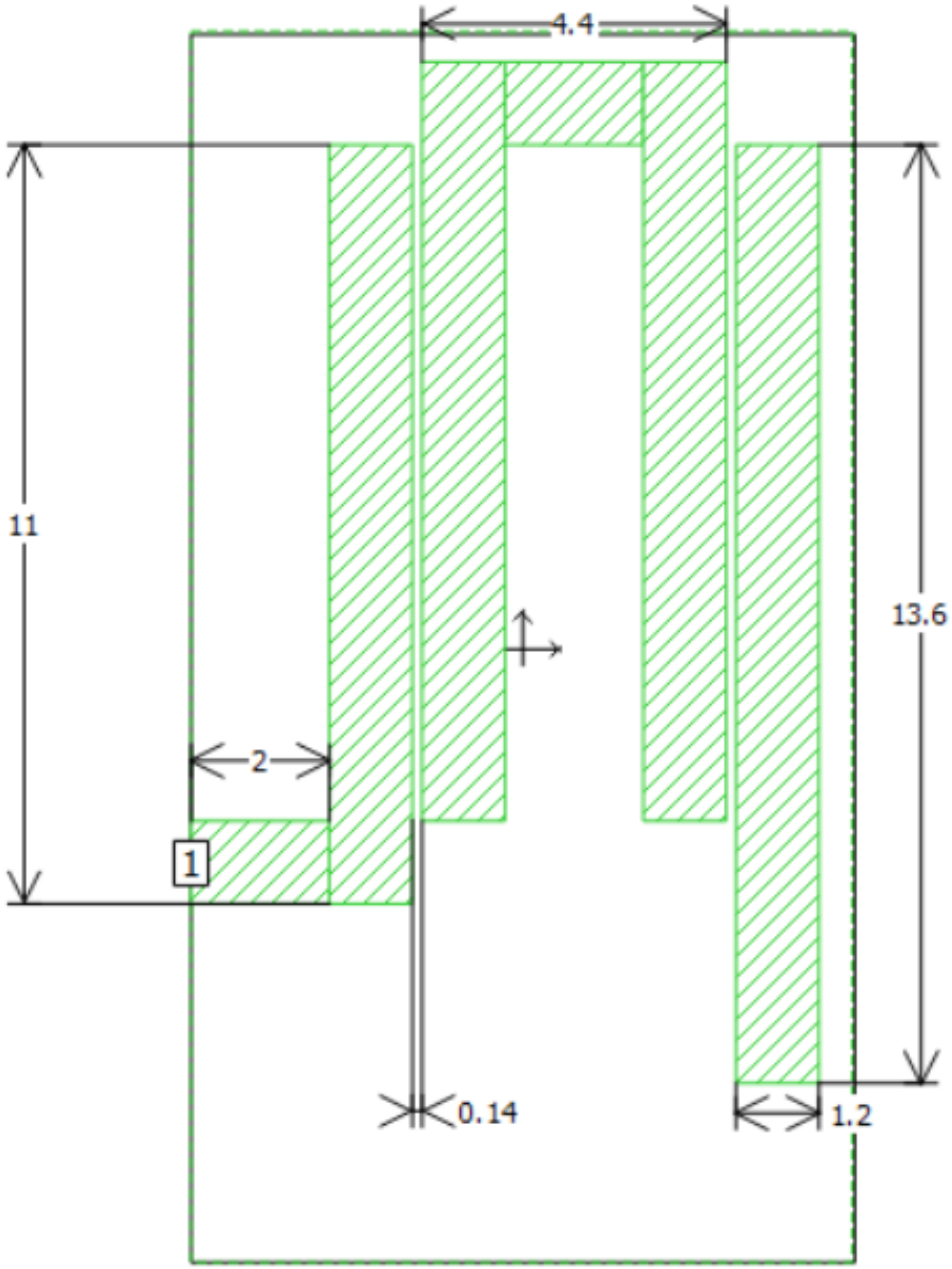
- Skin depth: $\delta = \sqrt{\frac{\rho}{\pi f_0 \mu_0 \mu_r}}$
  - Higher frequency means smaller skin depth
  - Skin depth of copper at 7.1 GHz: 0.774 μm



Circuit Design with Dimensions







Units in mm

Methods

- Design: Sonnet EM Simulation Software
- Material:
  - FR-4 (PCB material)
  - Copper Tape
  - Precision knife
- Analysis:
  - Used Sonnet to analyze designed RFID
  - Used VNA to analyze constructed RFID

Effective Dielectric Constant:

$$^{1}\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left(1+\frac{10h}{w}\right)^{-1/2} + 0.468\frac{\varepsilon_r+0.5}{1.5}\sqrt{\frac{t}{w}}$$

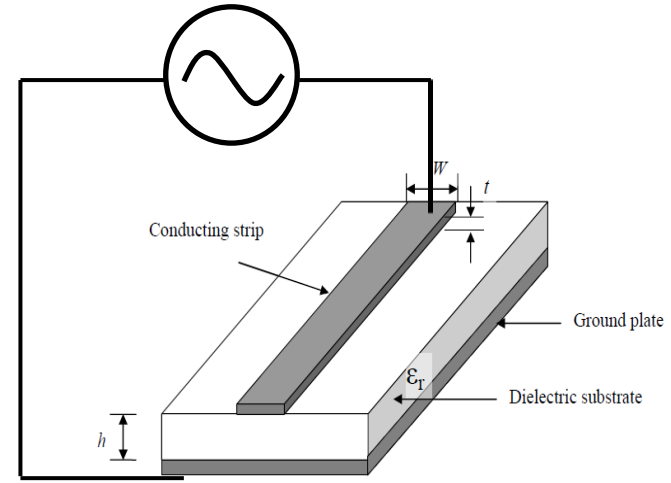
w= 1.2mm

t=0.03mm

h=1.6mm

$\varepsilon_r \approx 4.4$

$\varepsilon_{eff} \approx 3.4$



Effective Wavelength:

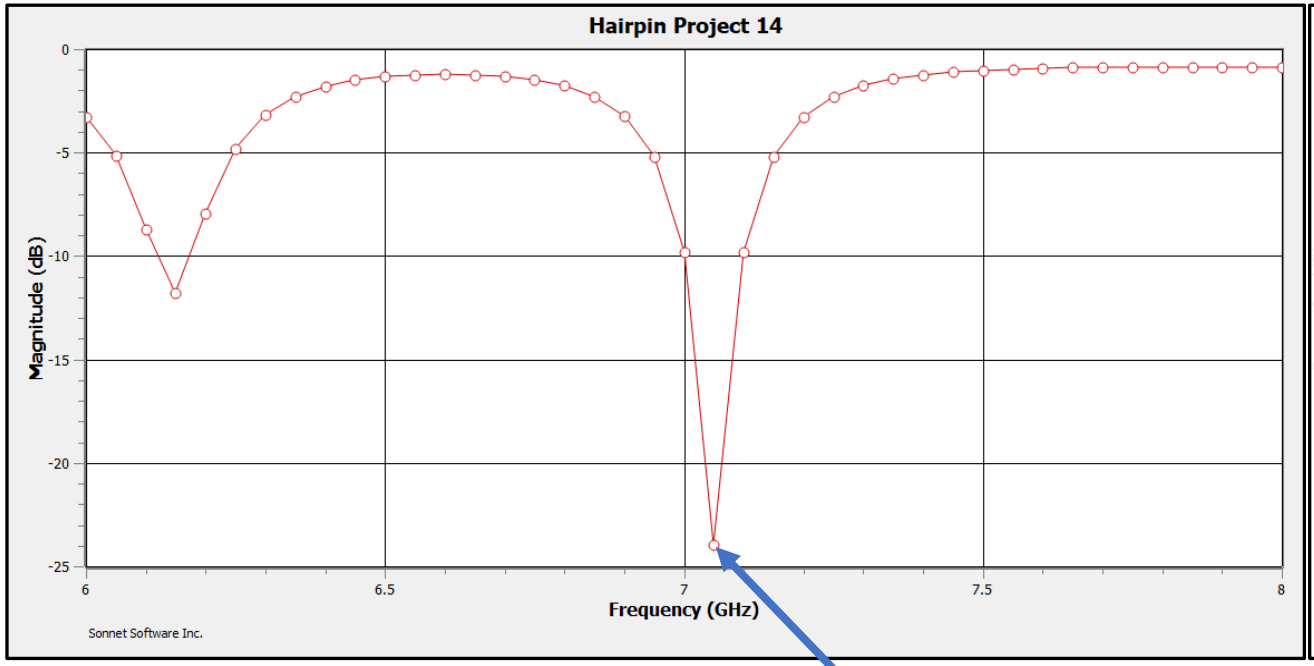
Then: $\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}}$

$C=\lambda_0 f$ ⇒ $\lambda_0 = C/f$

$\lambda_g = 23\ mm$

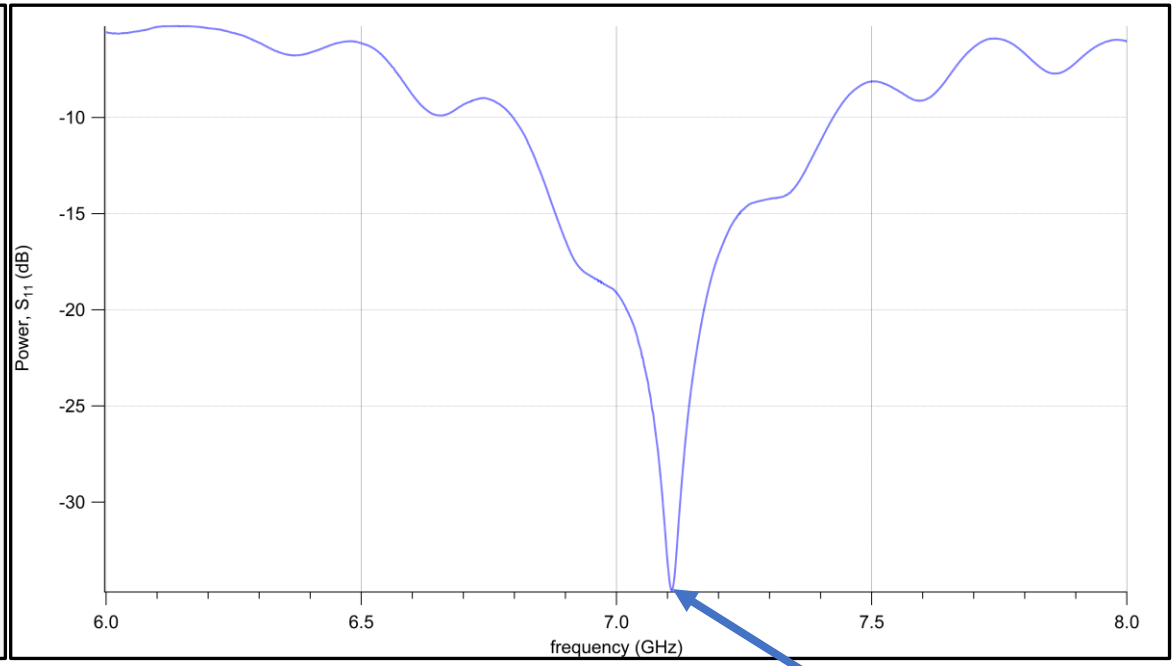
Data

Simulation Results



24 dB loss at 7.05 GHz

Experimental Results

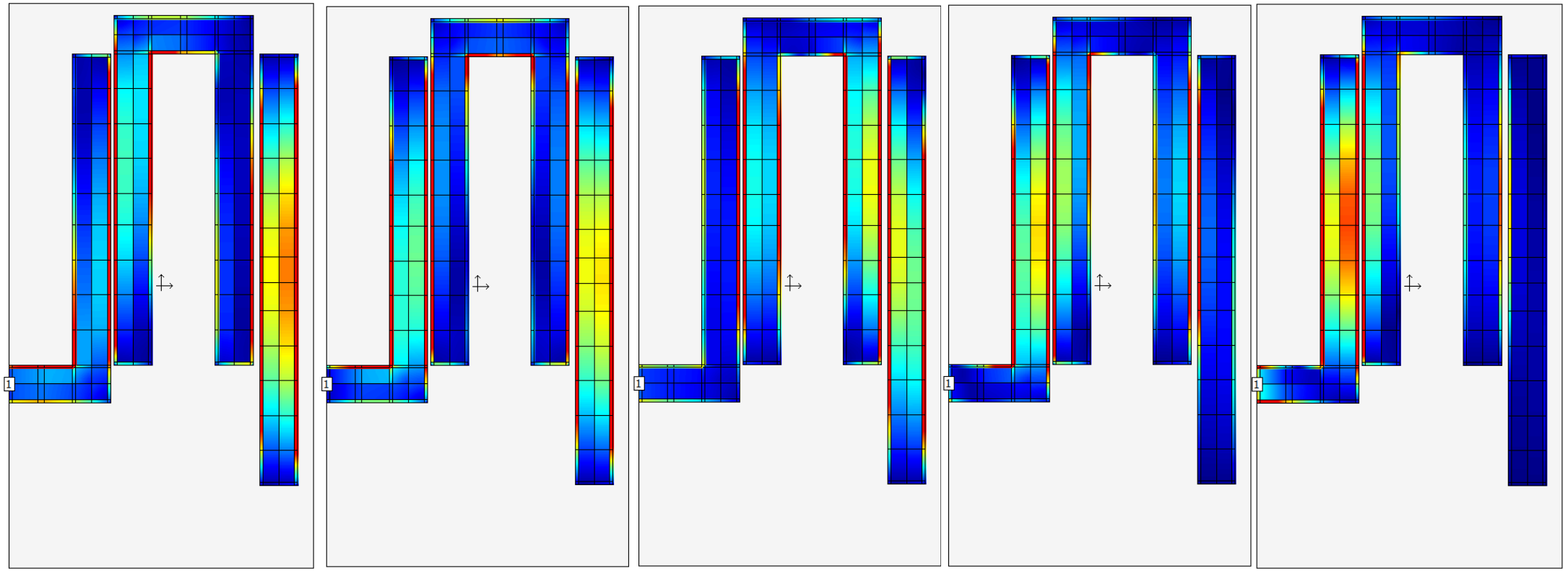


34.599 dB loss at 7.11 GHz

Power found using:

- $P(dB) = 20\log(\sqrt{(Re(E))^2 + (Im(E))^2})$
- Re(E) is Real part Electric Field Vector
- Im(E) is Imaginary part of Electric Field Vector

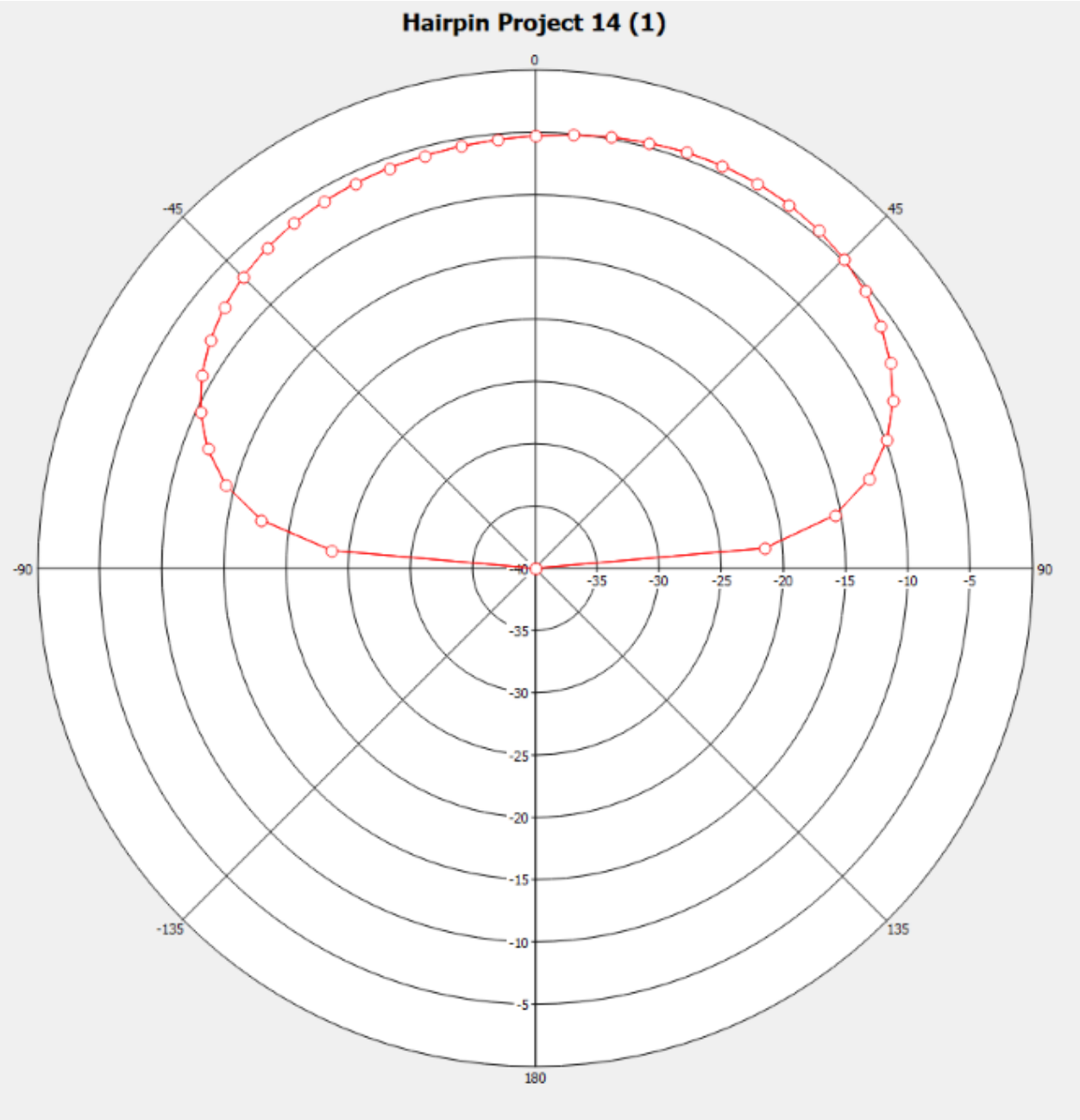
Current Density View



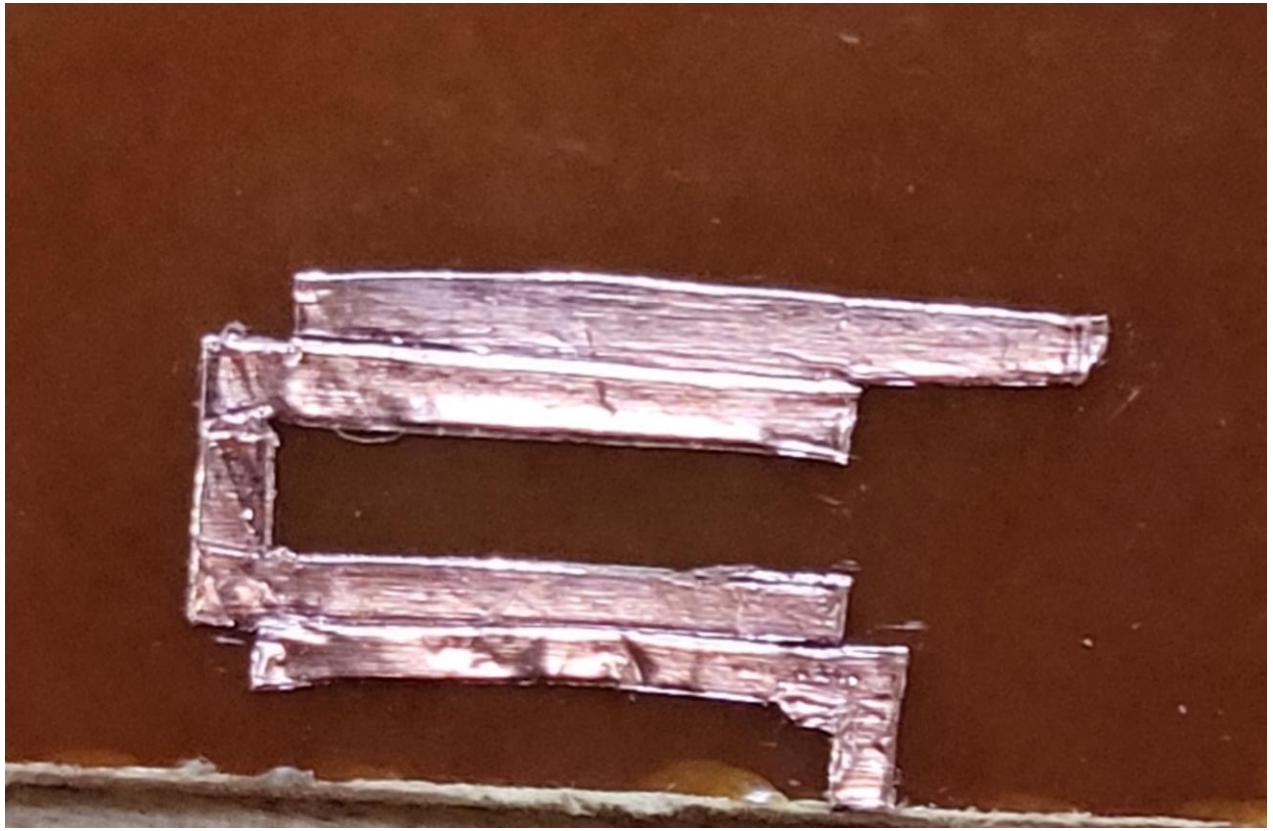
6.0 GHz | 6.5 GHz | 7.0 GHz | 7.5 GHz | 8.0 GHz

Far Field Radiation View

- Far field approximation: $R > \frac{2D^2}{\lambda}$
  - Where D is maximum linear dimension of circuit
  - Where λ is wavelength
- Far Field starts at roughly 16 mm



Final Product



Citation

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3. https://www.pasternack.com/t-calculator-skin-depth.aspx
4. Papatheologou, T., Smolders, A. B., & Johannsen, U. (2011). A hairpin antenna-in-package concept for RFID tag applications. In Radio and Wireless Symposium (RWS), Phoenix, AZ, USA, 16-19 Jan. 2011 (pp. 54-57). Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/RWS.2011.5725445