M2

Team WERMS
(WE Rectify Microwave Signals)

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Motivation

Why Microwave?

- Efficient method of transmitting large amounts of energy
- Small wavelength = higher energy
- Passes easily through the atmosphere

Uses

- Orbiting solar “power plant” satellites
- Aircrafts
- Transportation (“Space Elevator”)
- Basically anywhere large power sources are not feasible to store, a tether is near impossible, and a high energy demand exists

Requirements

- Provide enough power to the climber over 50 seconds to meet the following requirements from it’s capacitor array
  - 24 V
  - 400 W
  - 16.7 amps
- Properly shield the rest of the climber from the microwave source

Parameters

- Must optimize for efficiency
  - Power Out/Power In
  - Constraints
    - -Size of Beam
    - -Speed of climber
    - -Amount of capacitor energy
    - -Efficiency of Climber

$$0 \le \int_0^t (P_{out} - W_{\text{climber}} / \varepsilon_{\text{climber}})dt \le \tfrac{1}{4} m_{gross} h_{\text{climb}} g$$

$$0 \le \int_0^t (\rho_\mu r_{use/nonuse} A_{panel} \varepsilon_{rect} - \tfrac{1}{2} m_{gross} v^2 / \varepsilon_{\text{climber}})dt \le \tfrac{1}{4} m_{gross} h_{\text{climb}} g$$

Arriving At An Answer

“Rectapenna”

MILAX (Canada)

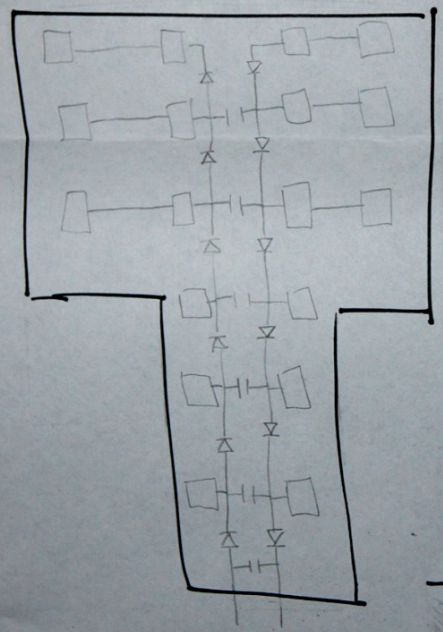
Texas A&M University Rectenna

- Research into microwave power transmission started after WWII
- NASA got involved in the 70s and 80s
- Currently mostly space-based applications are being explored

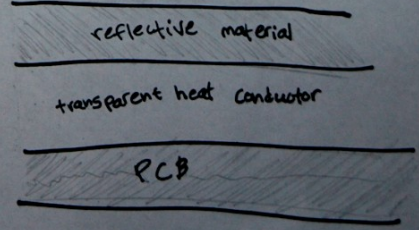
Rectenna Array

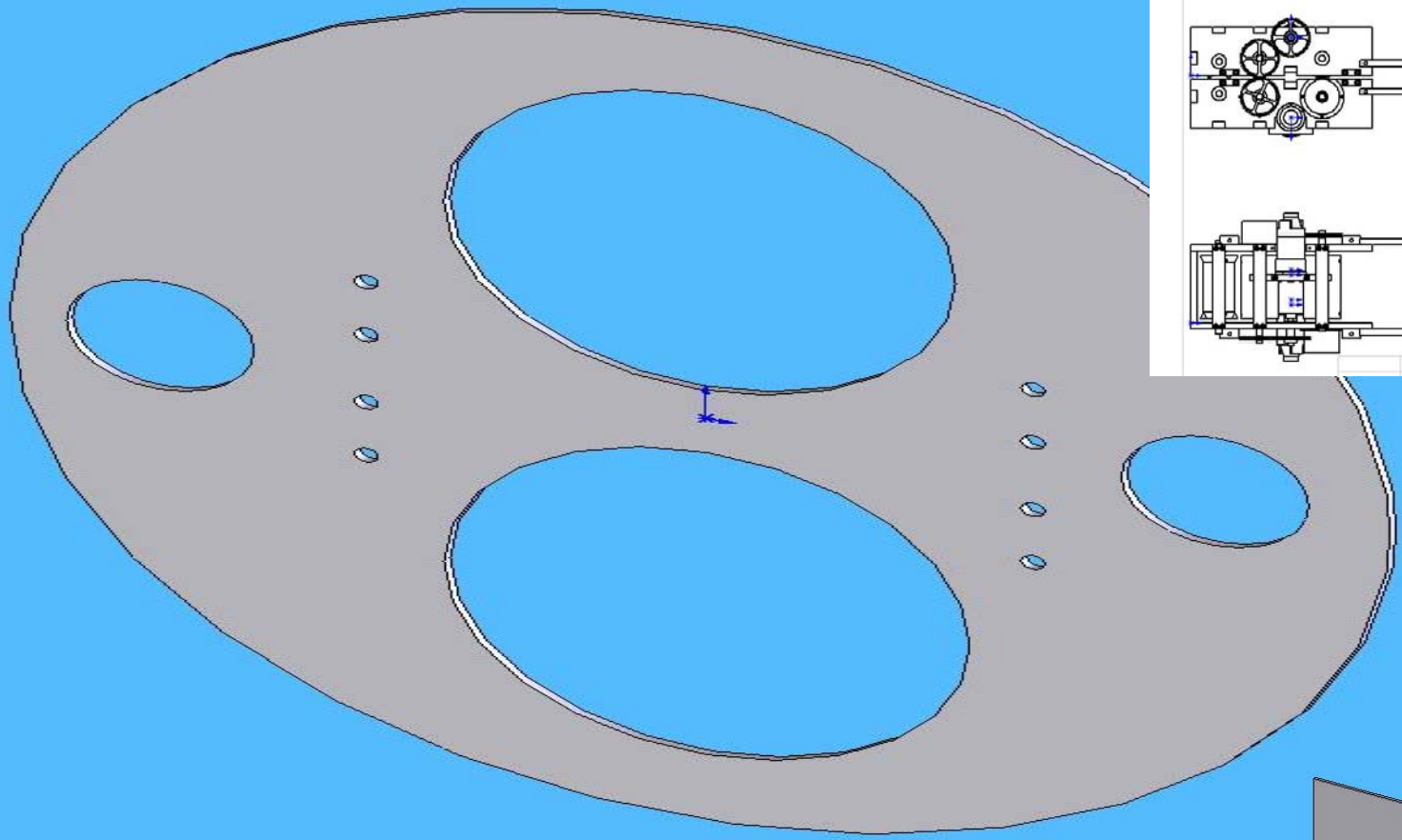
Overview

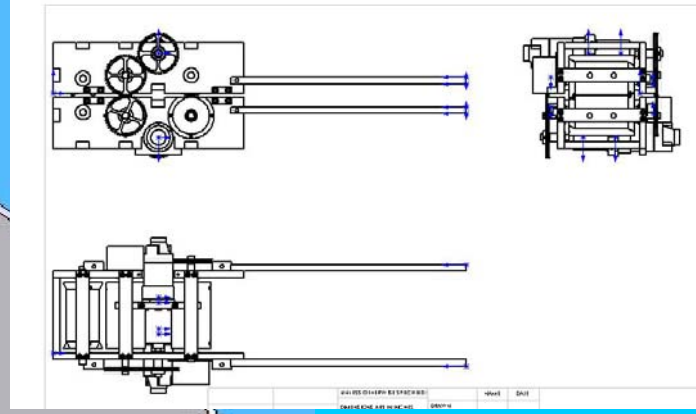
Individual Panel

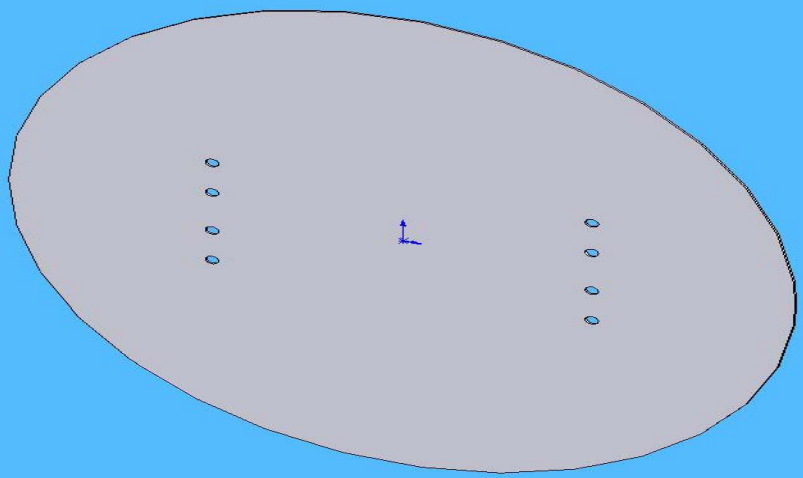


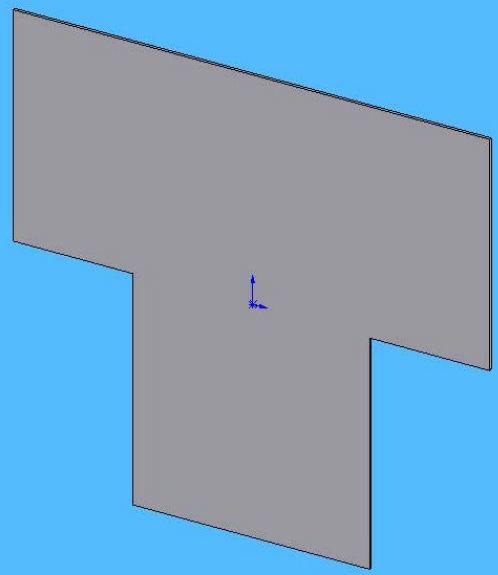
Cross section

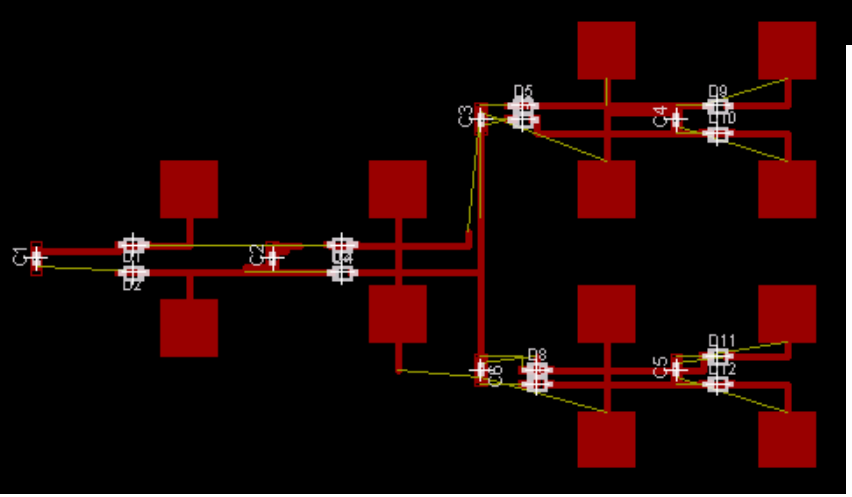











D5
D9
C3
C4
D7
D10
D8
D11
C6
C5
D6
D12
D1
D3
C1
C2
D2
D4

Performance Estimate

Key Elements of Current Design

$$0 \le \int_0^t (P_{out} - W_{\text{climber}} / \varepsilon_{\text{climber}})dt \le \tfrac{1}{4} m_{gross} h_{\text{climb}} g$$

$$0 \le \int_0^t (\rho_\mu r_{use/nonuse} A_{panel} \varepsilon_{rect} - \tfrac{1}{2} m_{gross} v^2 / \varepsilon_{\text{climber}})dt \le \tfrac{1}{4} m_{gross} h_{\text{climb}} g$$

$$\tfrac{1}{4} m_{gross} h_{\text{climb}} g = 6125 J$$

$$\rho_\mu = 254.7 \text{ W/m}^2$$

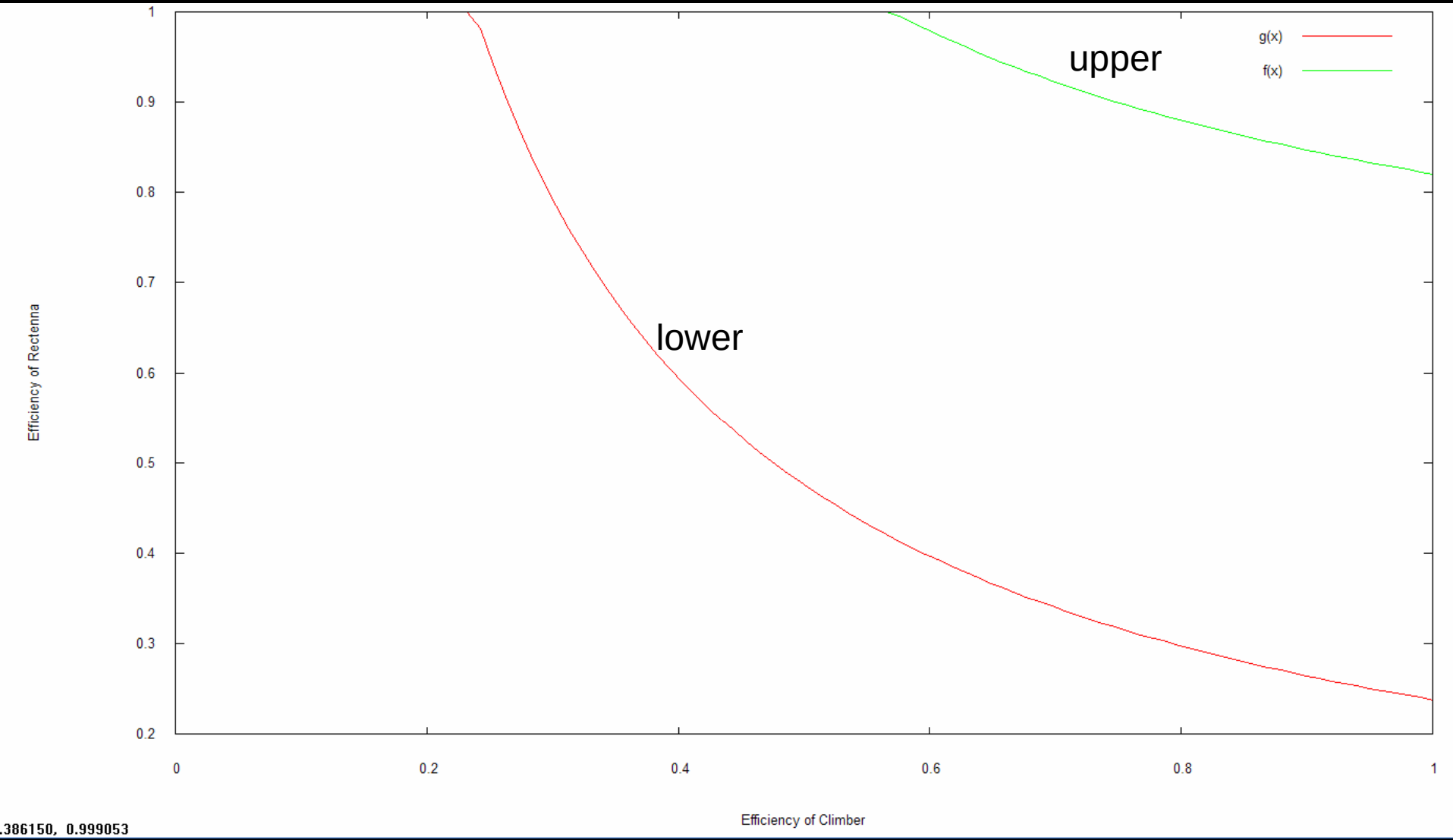
$$A_{panel} = 3.14 \text{ m}^2$$

$$v = 2 m/s$$

$$r_{use/nonuse} = .2628$$

This leaves only two variables, efficiency of climber and efficiency of rectenna

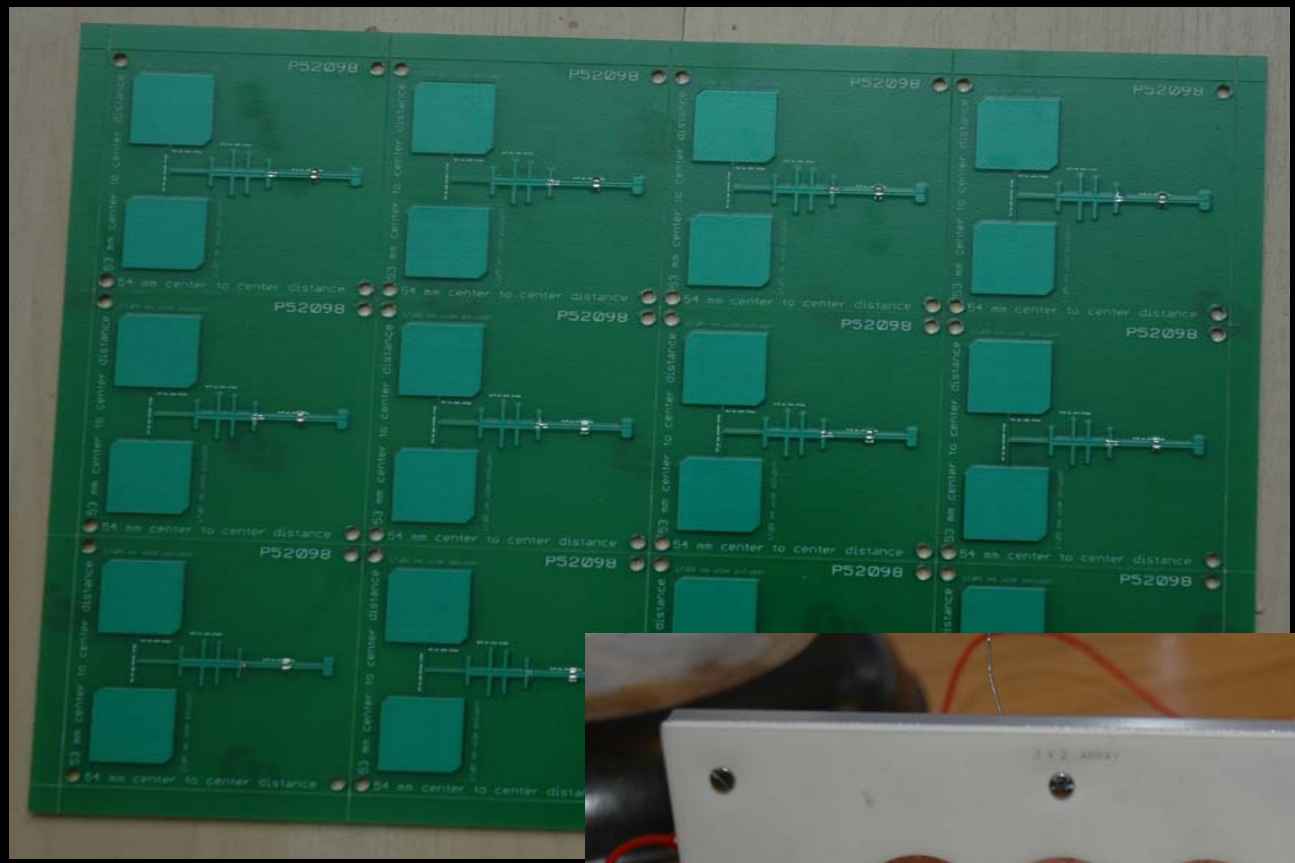
- Possible to now generate a bounding constraint on the efficiencies

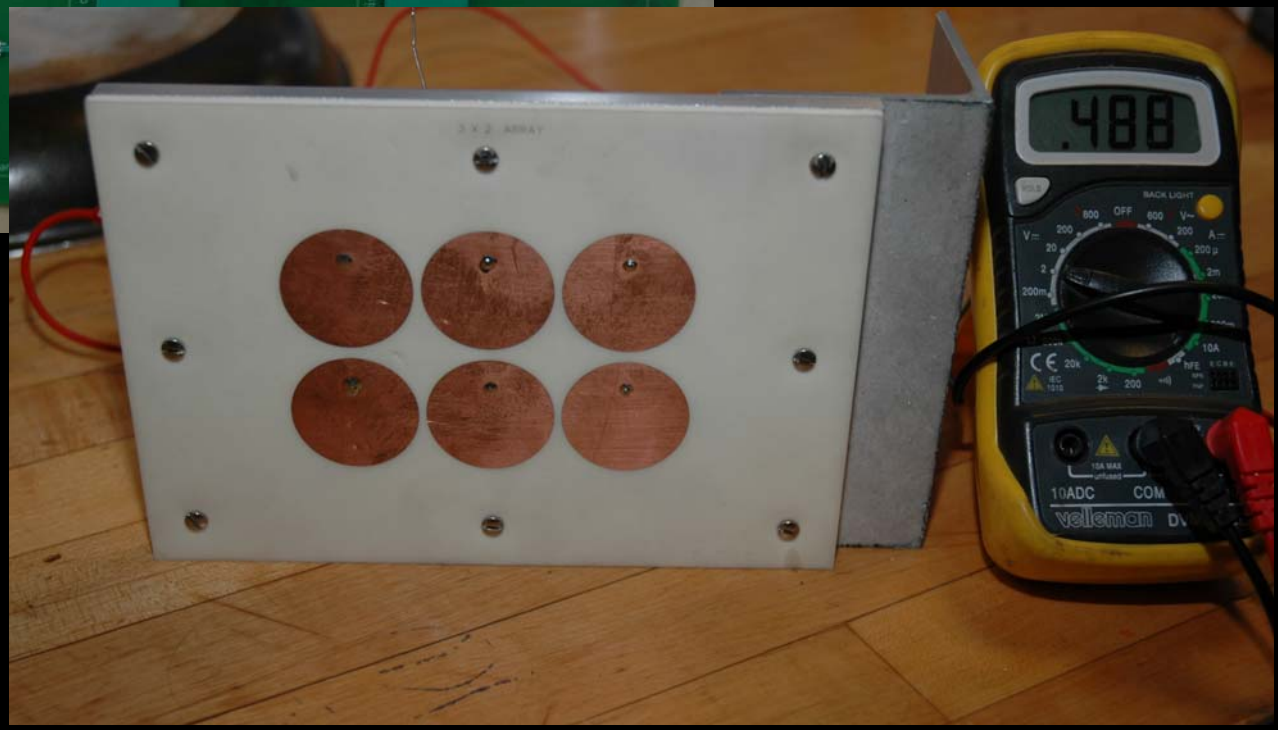


Analysis

- Beam density estimation is both low and idealized
- Ratio is extremely low

Manufacturing


P52098
53 mm center to center distance
54 mm center to center distance


.488
velleman

Cost Estimate

Cost Estimate

DESCRIPTION	RATE	QYT	TOTAL COST
Design and Engineering			
Labor Rate for each Designer	$60/hr	12	$720
Labor Rate for CAD/CAM/Altium workstation	$40/hr	5	$200
Materials Costs			
Steel Sheet (36"x48"x0.1")	$36.12	1	$36.12
Carbon Fiber Sheet (39"x47"x0.25")	$215	1	$215
PCB Manufacturing			
Advanced Circuits Quote	$2.88	156	$449.28
Waterjet Machining			
Labor Rate	$30/hr	1.5hr	$45
Machine Use	125/hr	~.1hr	$12.5
Assembly			
Labor Rate	$10/hr	2	$20
Testing			
Labor and Test Facility Operating Cost (to be determined)	TBD	-	-
		HOURS	COST
TOTAL		20.5	$1697.90

Future Work to be done

- Create a simulation of the equations mentioned above so as to accurately reflect the efficiencies envelope with various changes
- Change the rectenna design so it captures more area of the beam per square foot of the rectenna panel
- Do an actual build and test of the equipment, then tweak the tradeoff between efficiency and area of antenna till it’s optimal

Lessons Learned

- Variable optimization can be subtle
- Sometimes the fine tuned answer is not necessarily the best answer
- The best way to get results, is to perform tests
- Have very well defined goals that serve the long term