M2

Team WERMS
(WE Rectify Microwave Signals)

Zack Anderson
Darrell Cain
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 its 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

\[
0 \leq \int_{0}^{t} \left( P_{\text{out}} - W_{\text{climber}} / \varepsilon_{\text{climber}} \right) dt \leq \frac{1}{4} m_{\text{gross}} h_{\text{climb}} g
\]

\[
0 \leq \int_{0}^{t} \left( \rho_{\mu} r_{\text{use}/\text{nonuse}} A_{\text{panel}} \varepsilon_{\text{rect}} - \frac{1}{2} m_{\text{gross}} v^2 / \varepsilon_{\text{climber}} \right) dt \leq \frac{1}{4} m_{\text{gross}} h_{\text{climb}} g
\]
Arriving At An Answer
- Research into microwave power transmission started after WWII
- NASA got involved in the 70s and 80s
- Currently mostly space-based applications are being explored

"Rectapenna"

MILAX (Canada)

Texas A&M University Rectenna
Performance Estimate
Key Elements of Current Design

\[ 0 \leq \int_{0}^{t} (P_{\text{out}} - W_{\text{climber}} / \varepsilon_{\text{climber}}) dt \leq \frac{1}{4} m_{\text{gross}} h_{\text{climb}} g \]

\[ 0 \leq \int_{0}^{t} (\rho \mu r_{use/nonuse} A_{\text{panel}} \varepsilon_{\text{rect}} - \frac{1}{2} m_{\text{gross}} v^2 / \varepsilon_{\text{climber}}) dt \leq \frac{1}{4} m_{\text{gross}} h_{\text{climb}} g \]

\[ \frac{1}{4} m_{\text{gross}} h_{\text{climb}} g = 6125 J \]

\[ \rho \mu = 254.7 \text{ W/m}^2 \]

\[ A_{\text{panel}} = 3.14 \text{ m}^2 \]

\[ v = 2 m / s \]

\[ r_{use/nonuse} = .2628 \]

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