Purpose

The purpose of this experiment is to demonstrate the feasibility of a microwave beaming power system for a space elevator. Specifically, the demonstration is for a NASA-sponsored contest organized by the Spaceward Foundation. The contest will take place the weekend of October 20 in Las Cruces, New Mexico. A backup location is confirmed for the same date at NASA Ames Research centre in Mountain View, CA. Punkworks Design, a team competing in the challenge, requires a license to perform testing on microwave beaming power systems in preparation for the contest.

Equipment

Two microwave generators will be used in a dual-polarization transmission. One is a Cober 6 kW generator borrowed from Communications Research Canada, while the other is a Richardson Electronics 6 kW generator (pictured in Figure 1) to be rented for the contest. Together, the generator output will be fed to a parabolic transmitter dish via two rectangular waveguides polarized in the x- and y-axis. An example of such a rectenna is pictured in Figure 2.

Figure 1: 6 kW Microwave Generator from Richardson Electronics

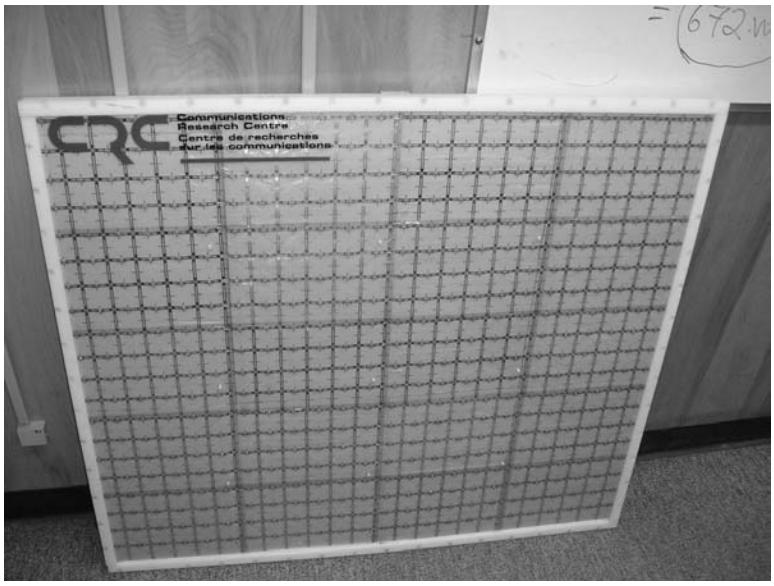

Figure 2: Rectenna (courtesy of CRC)

Requirements

The microwave power must drive a climber and its payload up a tether 200 ft above the ground. The tether is pretensioned with 5000 N force and so allows climbing. The climber uses friction-loaded rollers to roll its way up the tether, supplied with energy from the ground via a rectenna (rectifying antenna). The transmitter is a high-gain parabolic reflector fed by waveguide from a magnetron microwave generator. The transmitter will be using the 2450 MHz broadcast frequency, a public broadcast band.

Where D is the maximum diameter of the parabolic antenna, and λ is the wavelength. At frequency 2.45 GHz, λ = 0.124 m, and D = 2 m

$$G = 6\left(\frac{D}{\lambda}\right)^2 = 1560.9 = 63.9dB, B = 70\lambda/d = 4.34° \quad [1]$$

Where G is the antenna gain and B is the beamwidth.

The effective radiative power (ERP) is

$$ERP = G \cdot P_t = 1560.9 \cdot 12000 = 18.73MW(145.45dBW)$$

[1] Veley, V.F. "Modern Microwave Technology" Prentice-Hall 1987

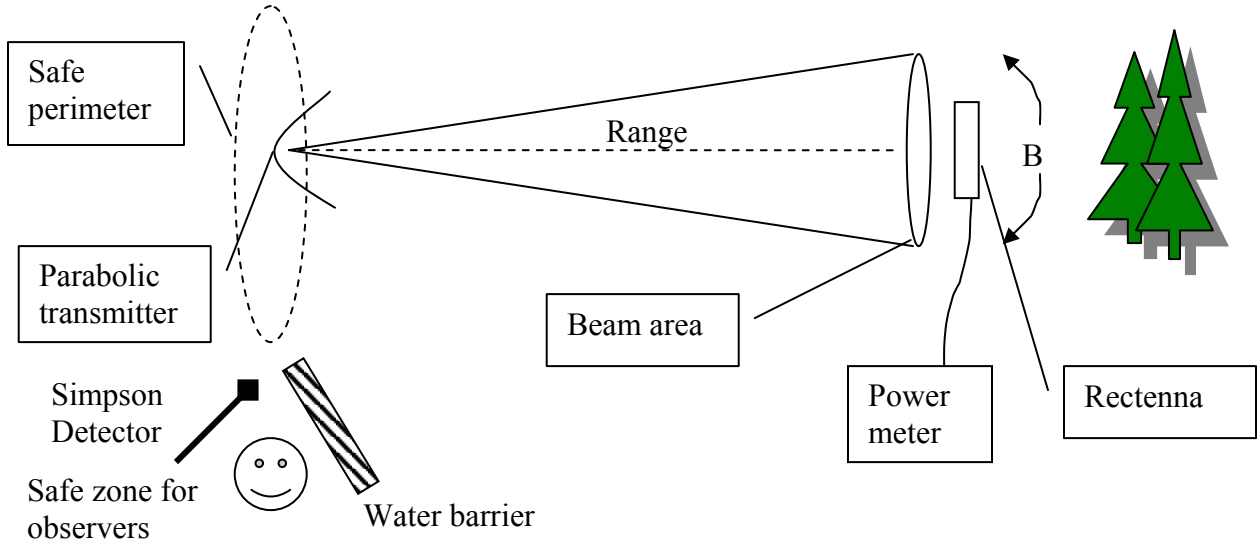

Figure 3: Horizontal beam testing schematic (top view)

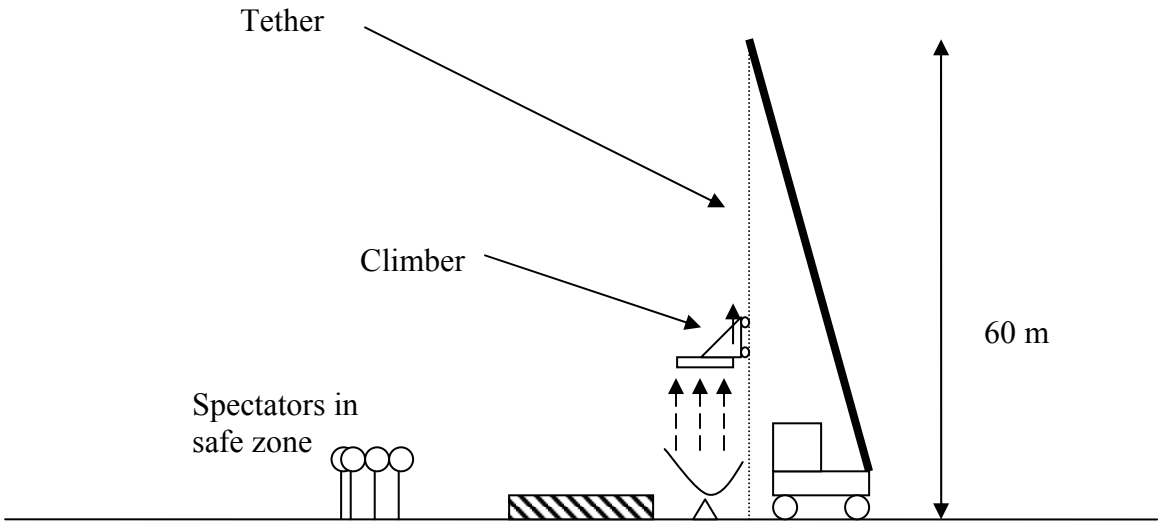

Figure 4: Vertical beam demonstration

Experimental Plan

Two types of microwave tests are planned. The first test is a horizontal tests to confirm beam transmitting capability for the entire 60 m distance. The horizontal testing schematic is shown in Figure 3. The second is a vertical test, where the full climber with rectenna attached will climb up a pretensioned tether for a short distance. A schematic of the vertical tests are shown in Figure 4. Spectactors from the general public will observe the trials, but they will not be permitted within a predefined radius around the test platform. The radius will be defined by the radiation level received in that area. The vertical tests will be evaluated based on their performance by the contest organizers. More information on the contest is available at www.elevator2010.com

Vertical beam tests shoot beams upward, and will not disrupt other communication signals broadcasting throughout the area e.g. wireless 802.11 transmitters. Vertical trials will not last longer than 60 seconds per trial with 2-3 trials in the competition. A safety officer will be appointed to ensure nobody is allowed within the beam testing area during testing. Shrouding cages will be placed around the test apparatus to ensure no leakage of microwaves to the vicinity.

Horizontal distance tests will be conducted in an open rural area nearby Las Cruces to minimize risk of injury and communications disruption to the public. The tests will be located such that trees will back the rectenna, absorbing any stray radiation from the beam path. These tests will take about 30-60 seconds per trial, with about 20-30 trials occurring over a 3-4 day period. A full summary of all testing is described in Table 1 below. Duration and cycle mentioned are upper limits on testing frequency.

Table 1: Breakdown of tests

Trial name	**Power (W)**	**Distance (m)**	**Orientation**	**Safety Measures**	**Duration / Cycles**
Distance testing	12000	50-70	Horizontal	-rural area -trees behind rectenna -safe zone behind source -MW detector readings	30-60 seconds per trial 20-30 trials
Contest testing	12000	50-70	Vertical	-outdoor area -shrouding -MW detector readings	60 seconds per trial 3 trials

Safety measures

Microwaves are dangerous if not controlled effectively. Risks of exposure exist due to the proximity of spectators. An analysis of microwave exposure power in the test area will be performed to ensure that the maximum exposure received remains within the 1.6 mW / cm^2 at 2450 MHz outlined in ANSI/IEEE-C95.1-1991[2].

A microwave detector will be carried throughout the testing area while the microwave is running. Our team is using a Simpson 380M detector capable of measuring in the range specified as shown in Figure 5. A safe perimeter will be established around the transmitter such that the radiative power within that area exceeds the maximum allowable exposure level.

Figure 5: Simpson 380m microwave detector

Jugs of water will protect investigators that need to observe rectenna performance and rectenna-reflected power. Microwave-absorbing material such as PVC can also be used[3].

A further measure of safety will be employed if reflected radiation is above acceptable safety levels. A shroud mesh will be placed around the outside of the rectenna such that it permits the incoming beam to enter, but prevents reflections away from the beampath. The shroud also eliminates side lobes around the transmitting antenna.

References

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[2] "IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz" published by ANSI
[3] "Theory of microwave technology" Anton-Paar PDF publication. http://www.anton-paar.com/ap/apinternet/file/cmse-698d4d.en.0/theory_microwave_technology.pdf

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