A THEORETICAL STUDY OF MICROWAVE BEAM ABSORPTION BY A RECTENNA

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Power Beam Absorption

The Rectenna's microwave power beam absorption limit is theoretically confirmed to be 100%. Two mathematical models descriptive of the microwave absorption process were derived from Maxwell's equations. The first model is based on the current sheet equivalency of a large planar array above a reflector. The model is characterized by a mathematical expression for the fraction of an incident plane wave's power that is reflected from the sheet.

The second model, which is based on the properties of a waveguide with special imaging characteristics, quantifies the electromagnetic modes (field configurations) in the immediate vicinity of a Rectenna element in the Rectenna array. This model then gives the limits for element spacing which permit total power beam absorption by preventing unwanted modes from propagating (scattering).

Rectenna Design Improvements

Several improvements in the Rectenna design have been indicated by the mathematical modeling.

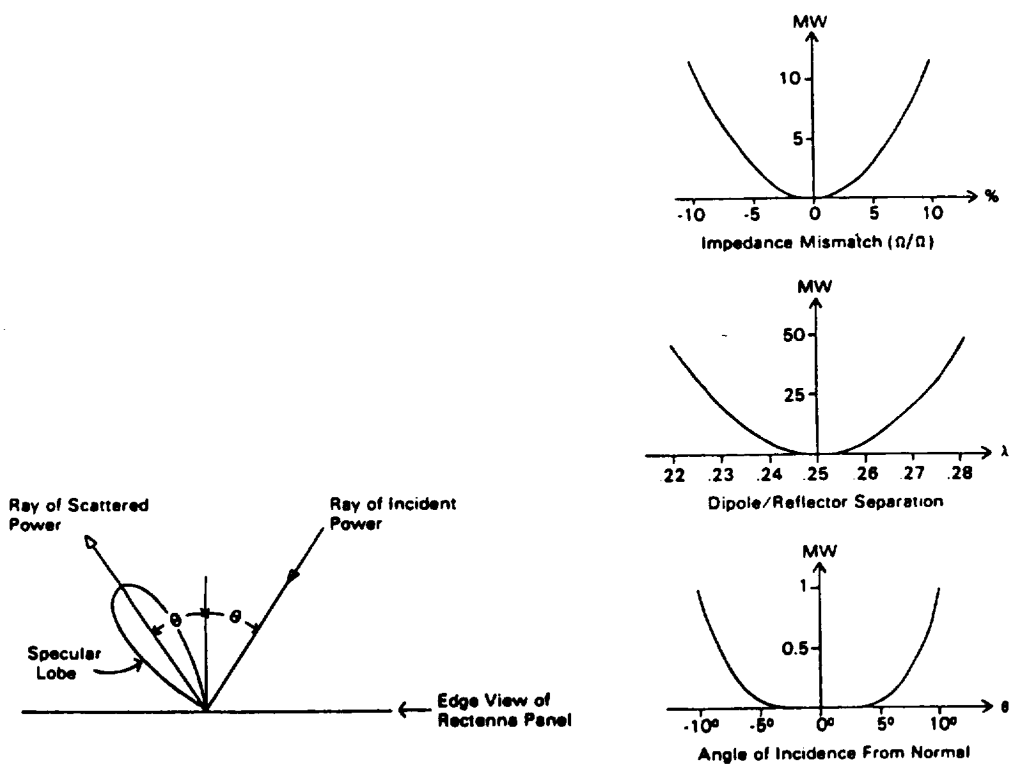
1. A significant reduction can be made in the density of the Rectenna elements needed for total beam absorption. This would not only significantly reduce the cost of the Rectenna but also indicates greater diode efficiency because of the higher power density per diode.

2. The Rectenna panels can be made to totally absorb at any angle of incidence by adjusting reflector and element spacing and load impedance as seen by the dipole elements. This suggests a flat or terrain conforming Rectenna eliminating the need for the "billboard" or "Venetian blind" design and essentially conforming to the terrain.

3. The screen reflector should be able to be replaced by parasitic reflector dipole elements.

Scattering

Specular scattering of the power beam at the power beam fundamental frequency is expected to result from most deviations in the Rectenna parameters. The properties of this scattering, including the modeling-determined scattering losses due to variations in several parameters from design center values required for total absorption at normal incidence, are shown in Figure 1.



SPECULAR REFLECTION

• SPECULAR IS THE PREDOMINANT FORM OF SCATTERING AT THE FUNDAMENTAL FREQUENCY

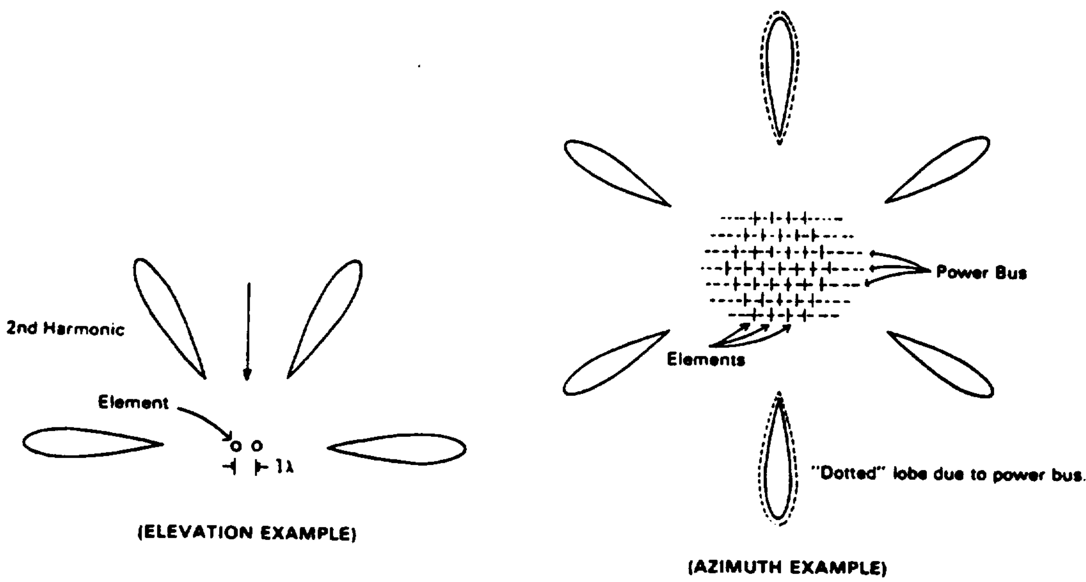
REFLECTED POWER AS A FUNCTION OF VARIOUS PARAMETERS (@ 5 GW Normal Incidence)

— MATHEMATICAL MODELING PREDICTION

FIGURE 1

PROPERTIES OF SCATTERING FROM RECTENNA AT FUNDAMENTAL FREQUENCY OF POWER BEAM

The Rectenna dipole-filter-diode assembly and power bus are expected to be the significant sources of harmonic radiation. The harmonic energy will be concentrated in calculable grating lobes, as shown in Figure 2.



• DIRECTIONAL CHARACTERISTICS OF HARMONIC SCATTERING FROM A RECTENNA CAN BE DETERMINED BY GRATING LOBE ANALYSIS, WITH THE RECTENNA RECEIVING ELEMENTS, POWER BUS, AND OTHER RECTENNA COMPONENTS AS RADIATORS.

FIGURE 2

EXAMPLES OF DIRECTIONAL CHARACTERISTICS OF SCATTERING FROM RECTENNA AT HARMONICS OF POWER BEAM FREQUENCY

A large object flying through the power beam over the Rectenna causes diffraction patterns to be generated at the Rectenna, as depicted in Figure 3. Therefore, Rectenna diodes should have tolerance to the resulting overvoltage and thermal transients.

Among the factors causing scattering are microwave beam depolarization and amplitude fluctuations caused by disturbances in the atmosphere. Depolarization is not expected to be a significant source of scatter. Amplitude fluctuations cause scattering by disrupting the uniformity of the Rectenna illumination. In addition, this disruption of the RF power level from design values for the diodes causes impedance mismatches resulting in further scattering.

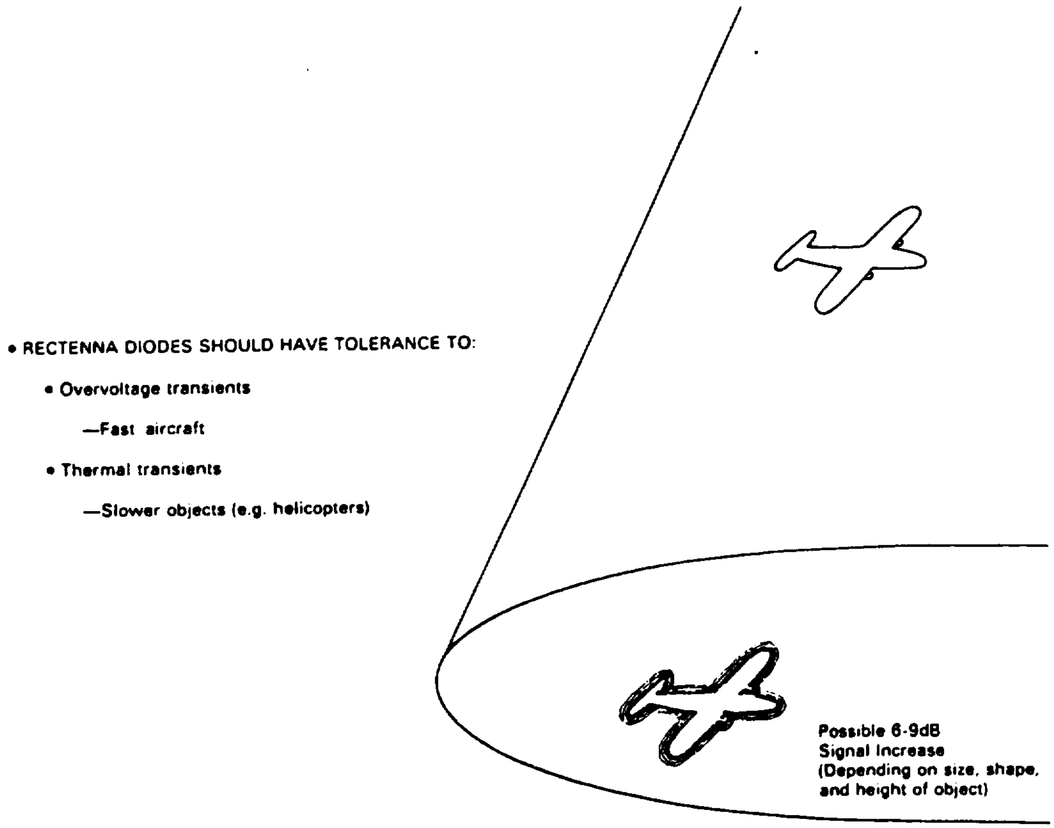


FIGURE 3

DIFFRACTED SIGNAL ENHANCEMENT AT THE RECTENNA CAN BE CAUSED BY AN OBJECT FLYING THROUGH THE POWER BEAM.

Although existing earth-space propagation measurements to date have indicated that amplitude fluctuations would cause insignificant scattering at a Rectenna, there are two factors which impair the application of this data to a Satellite Power System (SPS). In all studies found, there is significant aperture averaging due to the large aperture receiving antennas used. This is in contrast to the very small aperture area of each "independent" receiving element in the Rectenna. The second factor is that the signals measured in those studies were wide-band. Most deep fades are frequency selective. Therefore, observed amplitude fluctuations would be expected to be less than those of the monochromatic SPS power beam. Thus, further space-earth transmissions studies are proposed.