POTENTIAL IMPACT OF A SOLAR POWER SATELLITE SYSTEM ON RADIO ASTRONOMY

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ABSTRACT

The potential impact of a solar power satellite system on radio astronomy is very severe. Receivers for radio astronomy are extremely sensitive. An engineering or operational failure placing an extremely small fraction of the radiated power inside a radio astronomy band can essentially destroy the use of that band. A.R. Thompson summarized extensive analysis of the effects of a solar power satellite system on ground-based radio and radar astronomy in a seminal paper in 1981 [1]. The results of that work are included in [2], a report prepared by the National Research Council Committee on Satellite Power Systems chaired by Dale R. Corson. Here we review the information in these and other studies [3] carried out under a program initiated by the U.S. Dept. of Energy and the NASA between 1976 and 1980, and update the results based on radio astronomy observing experience over the past twenty years.

INTRODUCTION

Solar power satellites studies received extensive funding in the US in 1976-1980. The results of those studies are available in [1], [2] and [3] and the references they cite. Both the US Department of Energy and the National Aeronautics and Space Administration participated in this work, and established a 'Reference System' for the studies. The next section describes that reference system. Part of the study effort addressed potential impact of the Reference System on other fields, including radio astronomy. The results of these studies are summarized in the final section.

REFERENCE SYSTEM

The DOE/NASA reference system consists of 60 solar power satellites spaced 1 degree apart in geosynchronous orbit above the US. Each satellite generates 6.7 GW of power at 2.45 GHz, 5 GW of which is collected at the ground and delivered to the utility power network. Each satellite consists of a 10.4 km by 5.2 km array of solar cells and a circular transmitting array of diameter 1 km. The microwave power is generated by 50 to 70 kW klystrons; crossed field tubes, such as magnetrons, and solid state devices were also considered. The array is phase locked to pilot tones transmitted from the reception area on the ground. The power collection systems consist of rectennas typically 10 km by 13 km, consisting of arrays of dipoles, each with a rectifying and filtering circuit. The power flux is 230 W m^{-2} at the center of the array, falling to 10 W m^{-2} at the edge of the array. Additional sources of radiation include harmonics of the power signal, thermal radiation from the solar cells, transmitter-generated noise, and radiation from the rectennas. Intermodulation may occur in high field regions near the rectennas. The mean spacing between rectenna sites within the US is about 350 km.

EFFECTS ON RADIO ASTRONOMY

Receivers for radio astronomy are extremely sensitive. A failure that places less than a thousandth of the radiation of one of the 6 million klystrons in orbit inside a radio astronomy band would be more than a thousand times above the detrimental limit, essentially destroying the use of that band for radio astronomy. The engineering requirements on reliability and limiting unwanted emissions are therefore truly formidable. The reference system of solar power satellites permanently blocks a strip of sky, corresponding to the geostationary arc. This severely limits future radar or other observations of solar system objects, as this strip includes much of the ecliptic plane. Several of the reference system radiation mechanisms include broad band components at levels above the detrimental interference levels given in ITU-R RA.769 in bands allocated to radio astronomy. In addition, the power signal overloads sensitive radio astronomy receivers, requiring development and installation of cryogenic, preferably superconducting, stopband filters. This reduces system sensitivity and becomes particularly problematic for modern array designs with very large numbers of antennas and receivers. It is estimated that about 2%, or 100 MW, of the power incident on the rectennas at 2.45 GHz is reflected and reradiated. This plus radiation of noise and harmonics from the rectennas will place restrictions on choice of sites for the receiving antennas relative to existing observatories, and on possible new observatory sites.

Radio astronomers' experience in the two decades since these original studies were carried out has confirmed that apparently small amounts of unwanted emission from a satellite system falling inside a radio astronomy band can have devastating effects. For example, the 10.6 – 10.7 GHz radio astronomy allocation is now virtually useless in Europe because of unwanted emission from a satellite system in a neighboring band. The intended power being transmitted is very much less than that of a solar power satellite system.

[1] A. R. Thompson, 1981, "Effects of a Satellite Power System on Ground-Based Radio and Radar Astronomy", Radio Science, vol. 16, pp 35-45.

[2] "Electric Power from Orbit: A Critique of a Solar Power Satellite System", 1981, National Academy Press, Washington, D.C.

[3] "Solar Power Satellites", 1981, Report of the Office of Technology Assessment, US Govt. Printing Office, Library of Congress Catalog Card Number 81-600129.