MICROWAVE POWER TRANSMISSION SYSTEM WORKSHOP

SESSION ON SOLID STATE

BY WOOLSEY FINNELL/MARSHALL SPACE FLIGHT CENTER

INTRODUCTION

"Why should we study a solid state SPS" is a valid question and one that we do not have a complete system answer for at this time. The first chart is an attempt to list some of the reasons a solid state SPS should be investigated. Solid state is no magical solution to SPS designs but it does attack three very important aspects of SPS - the potential for low cost through mass manufacturing techniques that are well established, reliability, and essentially maintenance free operation. Solid state was not considered in the original Raytheon study for LRC in 1975 on the microwave system. Low efficiency and power levels of a kilowatt or larger made them unatrractive for SPS. NASA decided to investigate the possibility of a solid state design that incorporated a much lower device power requirement. A design was developed requiring 120W devices or amplifiers which appeared more reasonable but still very difficult for S-band.

The next step was to determine if solid state devices could potentially be highly efficient. An analytical approach was selected to investigate this potential. Dr. Roulston of Waterloo University performed the analysis and indicated there were no fundamental limitations on the efficiency of solid state devices. Further study by the systems contractors and NASA has produced two concepts that will be given a more detailed systems analysis. These concepts produced amplifier power requirements of 5 to 30 watts. One concept simply substituted a solid state

antenna for the reference Klystron antenna. The other concept produced an entirely new SPS conceptual design and was called a solar cell solid state sandwich design. Both of these designs will be discussed by other summaries in this section. However, it should be noted that all solid state designs have thus far been characterized by larger antennas, smaller rectennas, and less delivered power than the SPS reference concept. There is no solid state reference concept at present because of the systems analysis on solid state concepts is not complete. Much data has been generated by numerous sources on the solid state concepts. The following summaries in this section are just representative of the study effort. Thus far Rockwell, Boeing, Raytheon and RCA have been directly involved in the solid state studies. The last two charts list the preliminary conclusions and issues related to this solid state study effort. Solid state continues to be a viable alternative to the reference Klystron concept and is included in the six year planning document (Ground Based Exploratory Development - GBED) now being finalized.

MSFC SOLID STATE ACTIVITY

WHY SOLID STATE

- HIGHER RELIABILITY THAN TUBES
  (- 10^6 HOURS VS. 10^4 HOURS)
- TECHNOLOGY BASE
- POTENTIAL FOR LOW COST
- SYSTEM COSTS OPTIMIZES AT LOWER POWER OUTPUT
  AT UTILITIES (1.0-1.5 GW)
- POTENTIAL FOR REDUCING FRONT END COST
- MORE EASILY ADAPTABLE TO FLIGHT/GROUND TEST
- START-UP - SHUT-DOWN

SOLID STATE CONCLUSIONS

1. Solid state SPS concepts have not had the same depth of systems definition as the reference concept; however, preliminary results indicate the following.
   a. The system sizing parameters optimize such that lower power is delivered to the utility grid.
   b. The transmit antenna is larger primarily because of the thermal limitations.
   c. The rectenna land requirement is smaller.
   d. Weight per delivered kilowatt is projected to be more.
   e. Maintenance projections are better because of the higher reliability.
2. Type of Power Amplifier - Based on studies to date, the GaAs FET is the preferred solid state power amplifier.
3. Antenna Unit Costs - Solid state antennas will have high parts count similar to the solar array, and therefore unit costs are a critical item.
4. Mitigating Designs - Conceptual designs have to some degree mitigated the issues of thermal and low voltage power distribution.
5. Items of Concern - Techniques of phase distribution, (possibly to more points on the array), and power distribution (on the end mounted configuration more DC-to-DC converters are required) are major items of concern in the solid state concept.
6. Technology - Associated technology development is more likely for solid state due to the advancing technology base.
7. Continued Investigation - Based on current findings, continued investigation of solid state concepts and issues is warranted.

SOLID STATE ISSUES

- Efficiency
- Operating Temperature
- Low Voltage Distribution
- Harmonic Noise Suppression
- Power Combining
- Subarray Size
- Monolithic Technology
- Life Time
- Mutual Coupling
- Amplifier gain
- Input to Output Isolation
- Charge Particle and UV Radiation Effects