THE EMC IMPACT OF SPS OPERATIONS ON LOW EARTH ORBIT SATELLITES

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Low orbiting (LEO) satellites have a significant probability of passing through an SPS main beam or principal sidelobes. This probability, and consequently the frequency of traversal, depends on the number of SPS stations in operation.

Operational effects for LEO satellites depend on orbits, equipment complement and usage modes, and vehicle physical configuration. Existing and planned LEO systems include remote sensing, navigation and position fixing, and communications functions. Sensors include electro-optical devices, active and passive microwave systems, and particle detectors.

The susceptibility of various operational and planned LEO satellites have been examined during the course of the SPS EMC evaluation program. Functional degradation for the electronic systems on LANDSAT, GPS, and the Space telescope is described in relation to the amplitude of the SPS illumination components. Analyses and tests include the modes of coupling to devices and subsystems, and performance effects in relation to satellite mission.

The SPS energy coupling into LANDSAT subsystems is indicated in Figure 1. As diagrammed, the communications, sensor, power bus, and attitude control functions can be effected. Coupling would occur through the communications antennas, attitude sensor optical apertures and the optical apertures and thermal louvers of the multispectral scanner (MSS) and thermatic mapper (TM). Energy coupling through the solar panels to the power units, which would transmit noise to the on-board computers and instrumentation, is not a problem because of circuit filtering and regulation presently designed into the systems. Exposed area and scanner locations on the satellite indicate that the optical aperture is the principal SPS energy coupling mode for these sensors.

Figure 2 shows the SPS microwave beam geometry at LANDSAT orbit altitude of 704 km. From this field intensity estimation coupling energies can be calculated. From tests and analysis it was determined that at SPS main beam energy levels an increase in video channel noise of 8 percent was present in the TM/MSS instrumentation, and a decrease in modulation transfer function of 18 to 20 percent was induced which affects the spatial imaging capability by approximately 20% These data are still being analyzed to determine the complete effects. For the direct earth-station to satellite S-band link, a bit error rate (BER) increase of 70 to 85 percent would occur during a period of about 16 seconds while the satellite was exposed to the SPS main beam and principal sidelobes. For the wide band communication channel used to transfer information via the tracking and data relay satellite system (TDRSS) the BER would increase by 20 to 40 percent during a pass through the power beam.

Mitigation techniques to be investigated include rejection filters and antenna modifications. For the TM and MSS, mitigation techniques to be confirmed include circuit filters, noise extraction in the data analysis process, and extended shielding for the detectors and colocated video amplifiers. Additional shielding for the video channel and scan control circuitry is recommended to eliminate jitter in the line scans, if the coupling is proven to be directly into these circuits and not through internal common connections.

The Global Positioning System has a satellite NAVSTAR at an orbit altitude of 10,900 miles. The SPS beam geometry at NAVSTAR orbit altitude is shown in Figure 3. The power coupling modes are diagrammed in Figure 4. Coupling to sensors and communications is similar to the LANDSAT. There can be direct coupling through the thermal control louvers that control the temperature of the principal electronic functions; clock, computer, and command/control receiver and decoder components. Induced jitter in the internal clock and message decoder logic is estimated to be in the 10 percent to 65 percent range for SPS power coupling of 10 watts to 25 watts. The S-band communication receiver and associated processor would experience an increase in BER in the range of 50 to 1,000 times with the antennas exposed to SPS power densities to 10 mw/cm^2 to 100 mw/cm^2. The mitigation techniques would be very similar to LANDSAT.

The space telescope is in circular orbit some 312 miles in altitude. Communications with earth are via TDRSS. The telescope is a Cassegrain configuration and other on-board instrumentation under study are: wide field/planetary camera, faint object spectograph, faint object camera, high resolution spectrograph, and high speed photometer/polarimeter. Figure 5 shows degradation in resolution for a 512 element array, charge coupled device (CCD) similar to one of the imaging devices on board space telescope. SPS effects and mitigation techniques for all system on board are under study.

Effects through the sun sensors for satellites in general are insignificant; approximately 2 percent increase in noise, primarily because of SPS harmonics would be present. This noise would cause less than 2° to 5° orientation change of the solar panels over a period of 1 to 1.3 seconds of maximum SPS beam exposure, and be corrected within 2 to 5 seconds after the satellite departs the SPS beam.

Figure 6 shows attitude error versus time for a star tracker sensor system used for satellite attitude stabilization. The lower curve shows the normal response as the system settles in with no outside influence. The upper curve shows the attitude error in arc-seconds where a satellite is in a stable position and the star tracker illuminated with a 15 mw/cm^2, 2.6 GHz microwave signal. Since the satellite will be in the beam only short time, there may be between 3 to 8 arc-seconds of error introduced during a passage through the SPS beam, but as the lower curve shows this will settle out in 5 to 8 seconds after leaving the beam.

The analysis of data from the above satellites will be extrapolated into guidelines for future satellites indicating the character of degradation expected for proposed electronic elements. This will include specifications regarding the physical configuration and testing procedures pointing toward satisfactory performance of future satellites operating in an SPS environment.

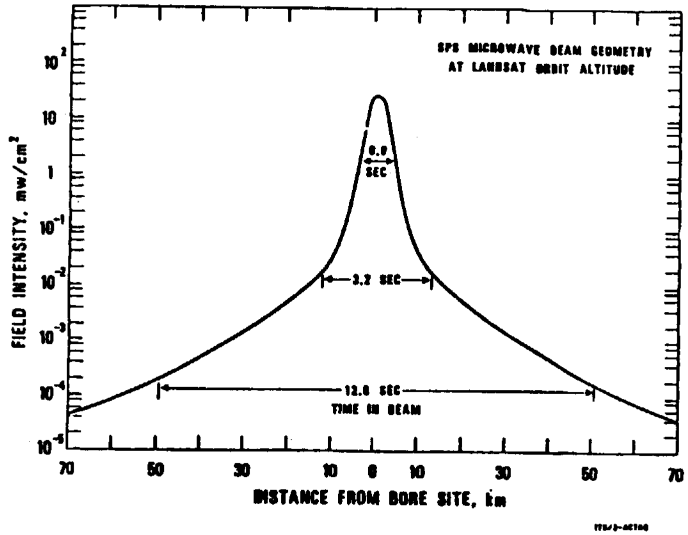


Figure 1

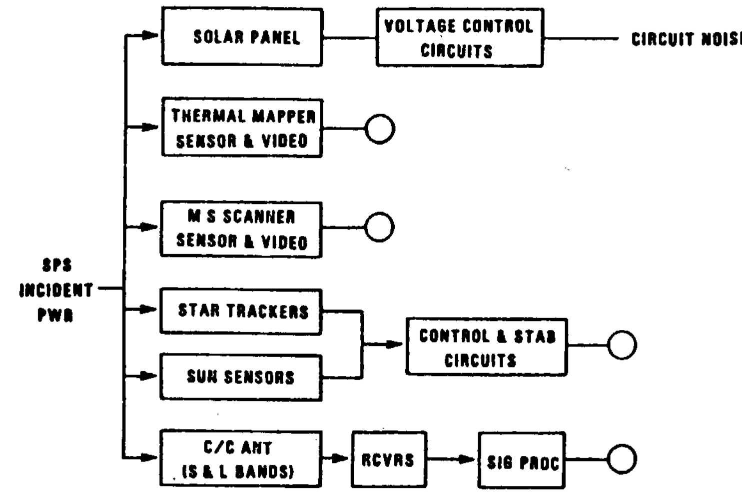


Figure 2

LANDSAT FUNCTIONAL IMPACT MODES

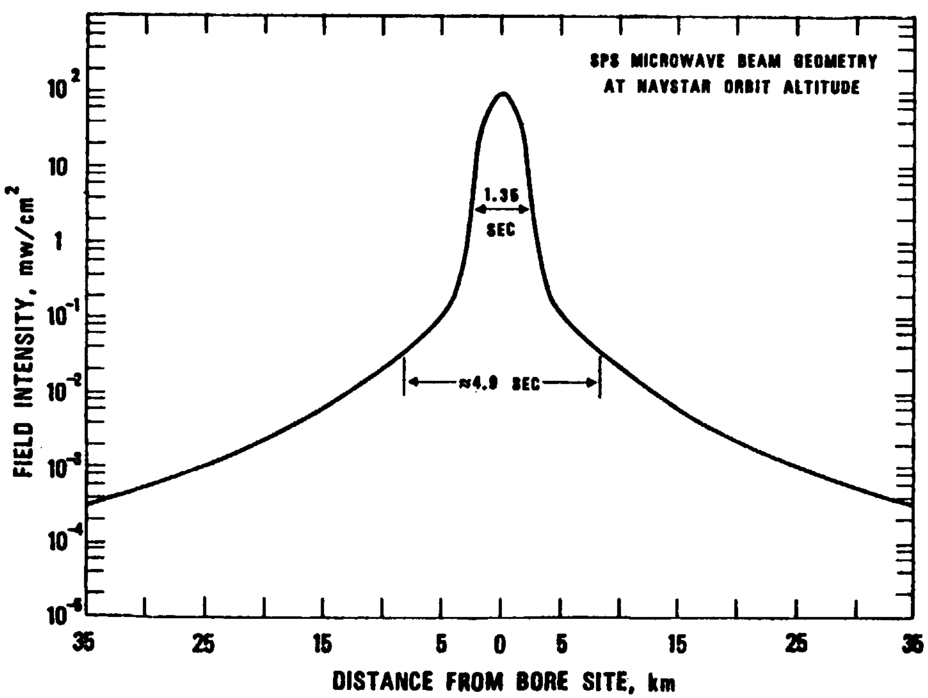
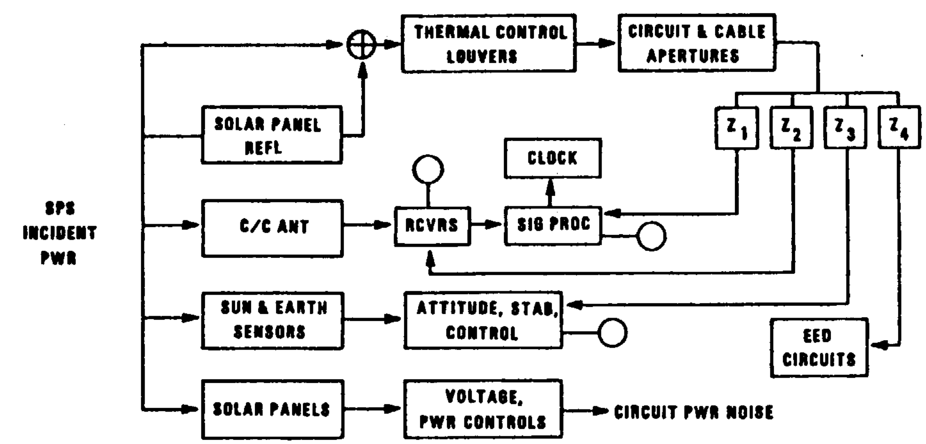
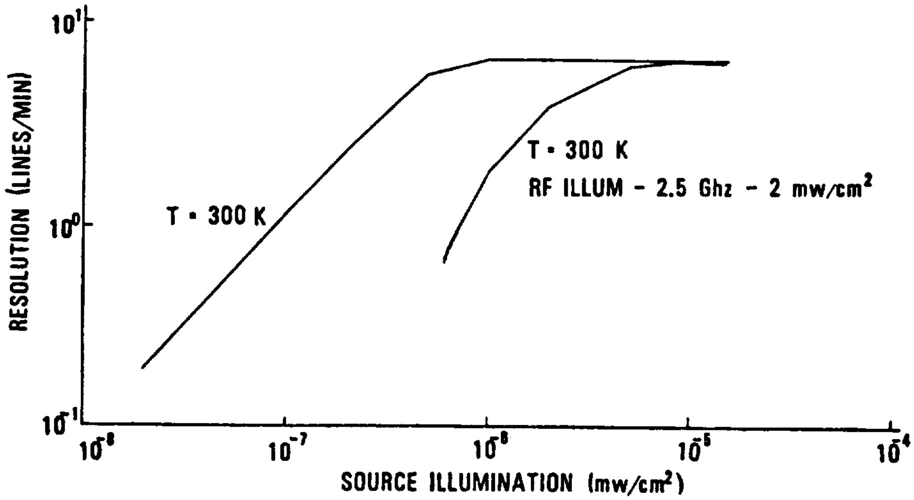


Figure 3



GPS FUNCTIONAL IMPACT MODES

Figure 4



CCD ARRAY IMAGING CHARACTERISTIC

Figure 5

STAR TRACKER - STABILIZED PLATFORM ATTITUDE RESPONSES

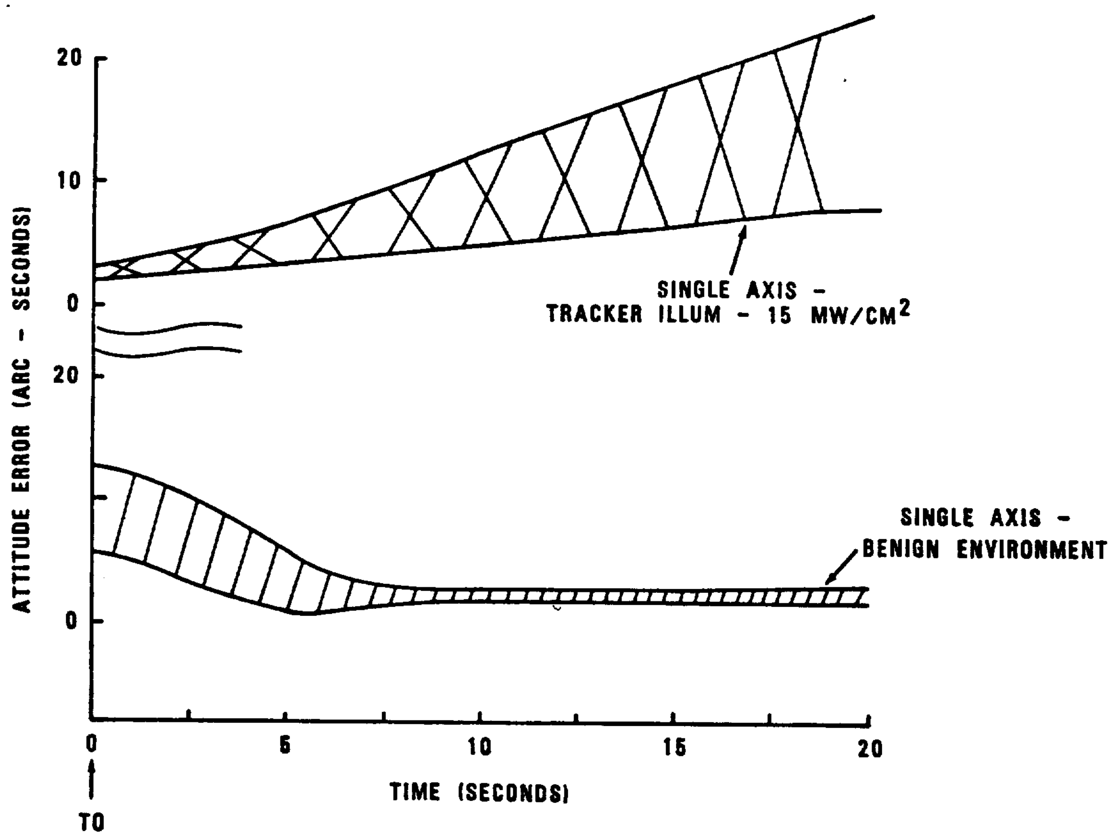


Figure 6