SUMMARY OF THE ELECTROMAGNETIC COMPATIBILITY EVALUATION OF THE PROPOSED SATELLITE POWER SYSTEM

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The EMC Evaluation program concerns the effects of the proposed SPS operations on electronic equipment and systems by fundamental, harmonic, and intermodulation component emissions from the orbital station; and the fundamental, harmonic, and structural intermodulation emissions from the rectenna site. With each satellite transmitting a power of 6.85 GW, and the reference design including 60 satellite-rectenna systems, the coupling and affects interactions encompass a wide spectrum of electronic equipments.

The primary EMC tasking areas are listed.

1. Describe the ranges of beam distortion expected because of troposphere scatter and refraction anomalies. Short term transient modes are included to support beam control system stability and pointing dynamics, and short term interference events during periods of storm front passage or high density anomalies.

2. Evaluate the modes of SPS power coupling into susceptible systems, and the induced functional degradation.

3. Relate susceptible system performance effects to operational applications (e.g., air traffic control, utility/pipeline command/control military test range and operations instrumentation and command/control, GEO and LEO satellites, and network throughput priorities) to identify specific sets of safety and operational effectiveness impact areas.

4. Evaluate mitigation techniques to assure an acceptable performance for affected systems in SRS environments. Specify rectenna site-susceptible system separations for the rectenna siting project area for situations where safety risks, political sensitivities, and mitigation effectiveness uncertainties dictate.

5. Develop cost factor data; susceptible system investment and mitigation incremental costs related to applications and geographic areas in CONUS.

6. Evaluate beam transmission and spacetenna-rectenna characteristics for other SPS frequency alternatives.

The EMC evaluation methodology is illustrated by the data flow diagrammed in Figures 1 and 2. In Figure 1, the rectenna site input refers only to the testing of specific site candidates relative to EMC variables. All susceptibility testing was site independent so as to be maximally useful to siting studies and mitigation trade-off analyses.

The susceptible system categories evaluated are indicated in Figure 3. These are coupled to applications as indicated in Figure 4. Time line and decision event procedures are employed to identify operational impacts relative to affected system performance effects.

The principal types of systems tested with associated performance measures are summarized in Figure 5. Typical performance effects for SPS power densities within 100 km of the rectenna edge (~1 mw/cm^2) for microwave FDM communications, instrumentation radar, and high resolution plumbicon cameras are presented in Figure 6. These data were derived as part of an examination of the utility of a candidate rectenna site in the Mojave Desert. Performance scores for all systems evaluated included fundamental power densities over the range of 0.1-1 mw/cm^2, and 10^{-7} - 10^{-4} mw/cm for harmonics. These ranges are typical of sets of scores that provide a continuum of performance measure-SPS interference ratio responses which guide the priorities for functional mitigation.

Sensors employed for satellites include high resolution vidicons, image dissectors, charge coupled devices, and IR scanners. These are utilized for mapping, speedrometry, attitude control, and transient event detection as required for LANDSAT, NAVSTAR and surveillance operations. Performance criteria affected by passage through the SPS power beam include video noise, spatial resolution, and video dynamic range. Guidelines for future satellite developments address mitigation methods for optical sensors, communications, and special purpose RF sensors (monostatic and bistatic holographic radar, synthetic aperture radar).

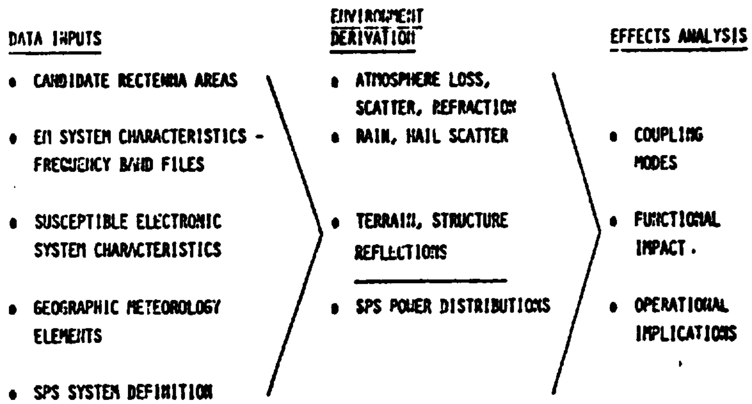
GEO satellite interference areas include communication relays (COMSTAR, INTELSAT, DSCS), future switching and processing satellites (computer controlled spotbeam operations), and satellite-satellite spotbeam modes. The latter includes the interference caused by SPS reflective multipath; identifying the necessity for a frequency offset transponder on the SPS vehicle to eliminate the effects of the SPS reflection component.

Mitigation techniques include antenna pattern control, cable and module shielding, single point grounding methods with low resistance connections, and modification of module interface circuitry and transient protector circuits. For terrestrial and aircraft communications, radars, sensors, and computer/processors, these methods restore capabilities to the 96-100% range. More specialized shielding and procedural modifications are required for LEO and GEO satellites. Mitigation techniques being investigated for radio astronomy equipment include cryogenic rejection filters, and interference cancellation in the preamplifier waveguide or coaxial cable.

Rectenna site-susceptible system separation distance categories for positive and potential exclusions have been specified where dictated by safety and sensitivity considerations; 150 km for military OT&E and radio astronomy sites, 100 km for air and missile defense sites and radar astronomy facilities, 60 km for military development test ranges and ATC sites, and 50 km for nuclear and optical astronomy facilities.

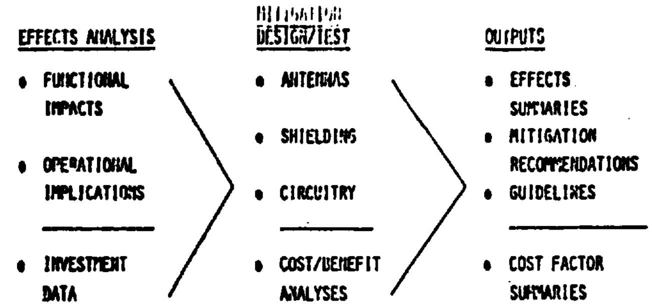
An evaluation of possible alternative frequency ranges for the SPS covers the range of 2.45-30 GHz. Parametric displays of spacetenna and rectenna area, attenuation, and refraction and scatter losses are being developed. Spacetenna far field criteria varying from a maximum distance of $2D^2/\lambda$ are played into the sizing exercises to determine a range of minimum rectenna areas.

Technical reports provide details for the performance effects and operations evaluation, satellite operational impacts, SPS power densities at fundamental and harmonic frequencies over CONUS and the western hemisphere, system investment and mitigation cost factors, and Design Guidelines to assist future system development.



SPS EMC ANALYSIS - FUNCTIONAL EFFECTS EVALUATION

Figure 1.



SPS EMC ANALYSIS - INITIAL MITIGATION TECHNIQUES EVALUATION

Figure 2.

..COMMUNICATIONS--
SATELLITE, SURFACE COMMON CARRIER NETS, DEDICATED SERVICE NETS

..RADARS--
AREA SEARCH/MONITOR, TRACK/CONTROL

..NAVIGATION--
LORAN/SHORAN, SATELLITE

..BROADCAST SERVICES--
DOMESTIC/INTERNATIONAL AM, FM/TV

..RECREATION SERVICES--
AMATEUR, CB

..COMPUTERS--
CENTRAL SERVICE SYSTEMS, DISTRIBUTED MINI/MICRO SYSTEMS

..SENSORS--
TV/IR MONITORS, EM INTRUSION ALARMS

..MEDICAL EQUIPMENT--
CLINICAL DIAGNOSTICS, BIOTELEMETRY, HEART PACERS

..RESEARCH SUPPORT--
PHOTOMETRY, RADIO ASTRONOMY

EMC EFFECTS ANALYSIS - SYSTEM CATEGORIES

Figure 3.

• COMMUNICATIONS	MILITARY COMMAND/CONTROL COMMERCIAL DATA/VOICE SERVICE DEDICATED DATA/VOICE SERVICE PUBLIC SERVICE NETS TRANSPORTATION DATA SERVICES TELEMETRY	SCFM, FDM, TDMA MODES
• RADARS	AIR SPACE SURVEILLANCE MILITARY SURVEILLANCE, WEAPONS CONTROL TEST RANGE INSTRUMENTATION SPACE RESEARCH WEATHER MONITOR	AZ-EL SCAN CONICAL SCAN ON-AXIS MODES MONO PULSE COMPUTER CONTROLLED ARRAY PULSE DOPPLER
• SENSORS	AREA/FACILITY SECURITY RESOURCE MONITOR AREA SURVEILLANCE WEAPONS CONTROL ASTRONOMY - TERRESTRIAL AND SPACE	ELECTRONIC/MECHANICAL SCANNING STARING SENSORS
• COMPUTERS	INSTRUMENTATION CONTROL UTILITY/PIPELINE CONTROL DISTRIBUTED PROCESSING PROCESS CONTROL	MINI-MICRO PROCESSOR-MSI/LSI CONFIGURATIONS VIRTUAL ALLOCATION CONFIGURATIONS

Figure 4.

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COMMUNICATIONS PERFORMANCE CRITERIA

- SIGNAL ACQUISITION DELAY
- BER - SYNC, ADDRESS, DATA EFFECTS
- MUX NOISE

RADAR PERFORMANCE CRITERIA

- TARGET DETECTION RANGE
- TARGET ID DELAYS
- TRACK ACQUISITION DELAYS
- TRACK ERROR
- BEAM CONTROL INSTABILITY

COMPUTER PERFORMANCE CRITERIA

- I/O CHANNEL NOISE
- CONTROL NOISE - PULSE JITTER
- MULTIPOINT ROUTINE ERRORS

SENSOR PERFORMANCE CRITERIA

- VIDEO CHANNEL NOISE
- SCAN JITTER
- DYNAMIC RANGE REDUCTION
- RESOLUTION REDUCTION
- DISCRIMINATION FEATURE UNCERTAINTIES

Figure 5.

FUNCTION	CHARACTERISTIC EFFECT
COMMAND/CONTROL AND TELEMETRY COMMUNICATIONS (MILITARY TEST RANGES)	a. SIGNAL ACQUISITION THRESHOLD: +5 TO 20%
	b. DATA ERROR: +5 TO 28%
	c. SYNC LOSS PROBABILITY: +3 TO 25%
UTILITY AND PIPELINE COMMAND/CONTROL/TELEMETRY COMMUNICATIONS	a. SIGNAL ACQUISITION THRESHOLD: -5 TO 15%
	b. DATA ERROR: +10 TO 30%
	c. LINK NOISE: +5 TO 20%

MOJAVE RECTENNA SITE ANALYSIS - SYSTEM IMPACT DATA

FUNCTION	CHARACTERISTIC EFFECT
INSTRUMENTATION RADAR (MILITARY TEST RANGES)	A. COOPERATIVE TARGET ACQUISITION RANGE: -8 TO 20%
	B. SKIN TARGET ACQUISITION RANGE: -13 TO 28%
	C. COOPERATIVE TARGET TRACK ERROR: +15 TO 40%
	D. SKIN TARGET TRACK ERROR: +22 TO 65%
	E. LOSS OF TRACK LOOP LOCK (SKIN MODE) PROBABILITY INCREASE: +10 TO 40%

MOJAVE RECTENNA SITE ANALYSIS - SYSTEM IMPACT DATA

Figure 6.