THE EMC OF SATELLITE POWER SYSTEMS AND DoD C-E SYSTEMS

James H. Atkinson
DoD ECAC - Annapolis, Maryland
Marvin D. Aasen
IIT Research Institute - Annapolis, Maryland

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The Department of Defense (DoD) is vitally interested in the satellite power system (SPS) concepts presently being proposed, since electromagnetic spectrum sharing would be required with many military C-E systems. The objective of this discussion is to present the DoD Electromagnetic Compatibility Analysis Center's (ECAC) technical understanding of the SPS and to assess the potential electromagnetic impact on existing DoD operations in the southwestern portion of CONUS. This geographical area is of principle concern because of the likelihood of SPS earth rectenna locations.

First, those SPS technical parameters that are needed to accurately assess the EMC between SPS systems and DoD communications-electronics (C-E) systems are identified. Next, the assessment is performed by: presenting the type of electromagnetic interactions that could degrade the performance of C-E systems; identifying the major military installations in the southwestern portions of CONUS where specially sensitive C-E systems are being used for combat training and evaluation; identifying classes of C-E systems that are generally in the vicinity of these military installations; identifying those technical parameters that govern the degree of compatibility of the SPS with these C-E systems; and identifying some technical requirements that are necessary to ensure short-term and long-term EMC.

Electromagnetic interference from the satellite microwave power transmissions will depend upon the characteristics of power in and near the carrier, harmonics, noise frequencies, and the antenna beam pattern offered by each of these. Scattering and reradiation of the satellite transmitter frequencies at the earth receiving rectenna and the effect of the rectenna directivity pattern is not covered in this evaluation. Interaction of these signals with DoD equipments potentially could degrade their performance. Table 1 presents a list of general C-E system types, their corresponding degradation criteria, and associated interference thresholds.

Southwestern CONUS is the most likely geographical area for SPS earth location(s), especially for prototype equipment. Major DoD test range, training facilities, and military bases are identified in this geographical area to illustrate proximity to potential SPS sites. Two of these DoD facilities are examined to illustrate the extent of C-E systems, types, quantity, and the potential EMC issues of concern. Areas examined are those at the Tactical Fighter Weapons Center (TFWC) at Nellis AFB, Nevada, and the National Training Center (NTC) at Fort Irwin, California. The mission of the TFWC is to develop, maintain, and operate a DoD major test and training facility for the use of all DoD components. The mission of the NTC is to train and evaluate U.S. Army arms units in a realistic tactical and electronic countermeasures environment. At each of these two geographical sites, the general type of DoD C-E system such as voice communications, telemetry, radar, etc.; the C-E system function (e.g., air traffic control, mobile communications, research radar, etc.); along with the expected range of system parameters such as receiver sensitivity, bandwidth, and antenna gain are examined.

Basic calculations of power levels of the SPS transmission at DoD C-E system receivers indicate interaction with the carrier and with the harmonics of the carrier. Calculations are based on SPS technical characteristics as given in Reference 1. Such interactions can be greatly reduced by limiting operation of C-E systems to certain frequencies and maintaining distance separations. For example, based on expected sensitivities of C-E systems at the DoD locations and their associated antenna gains, in-band (SPS carrier) EMC will be achieved when frequency separation (Δf) $\geq$50 MHz and a distance separation of more than 25 km exists between the SPS satellite transmitting antenna pattern and the DoD C-E receiving system. In the case of harmonics (the out-of-band case), assuming the harmonics being 100 dB below the carrier, a Δf >20 MHz and a distance separation of more than 25 km are necessary. A number of factors are not included in these calculations, however, that could potentially result in operational constraints that are much more restrictive. Component aging (degradation) may affect both satellite radiated carrier spectrum and antenna beam formation. The element pattern of the array at the harmonics is not known and most certainly will be different than that at the carrier frequency. Hence, the antenna pattern (including harmonic grading lobe positions) will be different than that of the fundamental frequency. Further study and measurements in these areas are required.

Noise frequencies radiated from the SPS satellite transmitter and the scattering and reradiation of frequencies at the earth rectenna could present a potential EMC problem to DoD C-E systems if not controlled. For example, in the SPS antenna array, each of the 103,000 klystrons will generate noise. The noise from each klystron will be noncoherent with the others. Reference 1 cites the use of phase control between klystrons to suppress near-in noise and multiple-cavity klystrons to suppress other noise. The adequacy of these controls for all noise emissions may require further development. Concern for the level of noncoherent noise suppression of the total array noise is of vital importance because the total array pattern will not be realized for this noncoherent noise. The beam pattern will be much broader, on the order of one degree, as found by the elements fed by one klystron in a power module. The power density of the noise in this broad, de-focused, array pattern will be reduced by the level of the noise in a klystron to that of the carrier. This broad radiation pattern would cover a radius about the rectenna of approximately 500 km. This characteristic of large phased arrays has been noted in military systems. Figure 1 illustrates a measured antenna pattern of a large phased array fed by 32 cross-field amplifiers. The broad antenna pattern formed by the array for the noncoherent noise is clearly illustrated.

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[1]Concept Development and Evaluation Program: Satellite Power System, DOE/ER-0023, January 1979.

Measurement data on noise emissions from early SPS prototype development is required to ensure control of noncoherent noise.

The EMC between SPS and military C-E equipments points to the establishment of proper specifications and standards to ensure control/quality of future compatible systems. EMC issues are expected to arise that will require technical and managerial attention. EMC issues are design dependent; however, some operational constraints will be required in military C-E equipment usage even with optimal design of the SPS. It is recommended that the SPS program initiate an EMC characteristics life test verification program. Life testing of active transmitting components should be started early in the program.

TABLE 1

C-E SYSTEM TYPES AND DEGRADATION

C-E System Type	Degradation Criteria	Interference Thresholds
Analog Voice Communications	Articulation Score and/ or Index	Interference power that reduces AI below 0.7
Telemetry	Bit Error Rate (BER) or Signal-to-Interference Ratios (S/I)	Increased BER or reduce S/I below ≃ 14 dB*
TACAN	Valid Reply Rate	Average interference power (∿ -27 dBm)
IFF	Valid Reply Rate	Average interference power (∿ -0 dBm)
Search Radar	Desensitization and False Alarms	Radar receiver (∿ 6 dB below noise level) or S/I = 12 dB
Track Radar	RMS tracking error	Average power dependent (∿ 6 dB below noise)
ILS	Change in angular direction	Change in direction of ± 5%
Microwave Relay	Bit Error Rate (BER) or S/I	Increased BER; reduce S/I below ≃ 16 dB*
Monitoring Instrumentation	(one-of-a-kind equipment, occasionally very sensitive)	

*Required S/I dependent on particular telemetry or microwave relay and radar involved.

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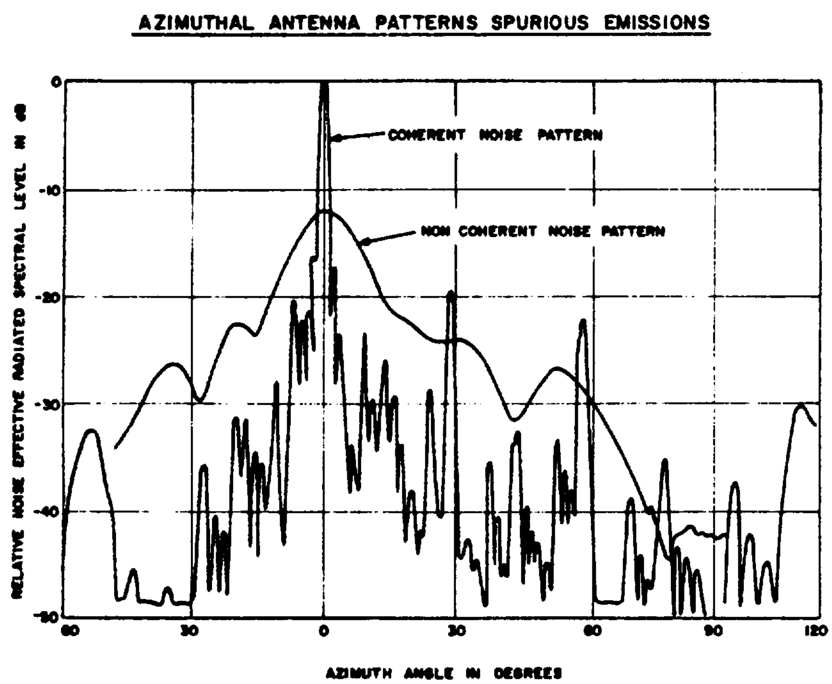

Figure 1.