# Interference Assessments between Solar Power Satellite (SPS) and Space / Terrestrial Systems

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## ABSTRACT

The Interference assessments between Solar Power Satellite/Station (SPS) system and fixed satellites service (FSS)/ terrestrial fixed service (FS) and 5.8 GHz wireless LAN are carried out. The SPS system is assumed as alternate 5.8 GHz operating frequency and satellite patch array antenna. Interference calculations are carried out for fundamental frequency (5.8 GHz ) interference to wireless LAN, 2$^{nd}$ harmonic frequency (11.6 GHz) interference to 14/11 GHz band FSS down-link, and 5$^{th}$ harmonic frequency (29.0 GHz) interference to 30/20 GHz band FSS up-link. As assumed calculation parameters, magnetron spurious radiated power levels and calculated patch array antenna higher mode gains are referred. As a result, interference constraints in fundamental frequency and 11.6 GHz frequency are relatively severe. Some strategies for relaxation of interference are discussed for co-existing between SPS and other systems.

## 1. INTRODUCTION

The SPS system is considered as one solution for future energy problems. The SPS system with 2.45 GHz transmitter, 6.72 GW power and one km square antenna on the geostationary satellite orbit (GSO) are proposed and some studies were carried out[1~2]. On the other hand, the congestion of the GSO is very severe and there are many existing satellites on the GSO. Then, interference from SPS transmitter harmonics to down-link of FSS on the GSO and FS system etc. must be assessed. Fig. 1 shows interfering fundamental and harmonics frequencies of SPS, interfered frequencies of FSS/FS and wireless LAN etc. As shown in Fig. 1, the interference circumstances are very complicated. In Ref.[2], the interference assessment of 2.45 GHz SPS has been examined by carrying out interference calculations, and desired and undesired signal power ratios (D/U) for 4.9 GHz, 12.25 GHz and 19.4 GHz can be clarified. However, interference constraints in some parts of frequency bands are very sever. Another possible alternate frequency for SPS transmitter is 5.8 GHz. However, related interference calculations have not been examined. Furthermore, comparison between 2.45 GHz and 5.8 GHz transmitter frequencies will be necessary for establishing the SPS system.

In this paper, interference assessments for alternative SPS transmitter frequency (i.e., 5.8 GHz) are examined.

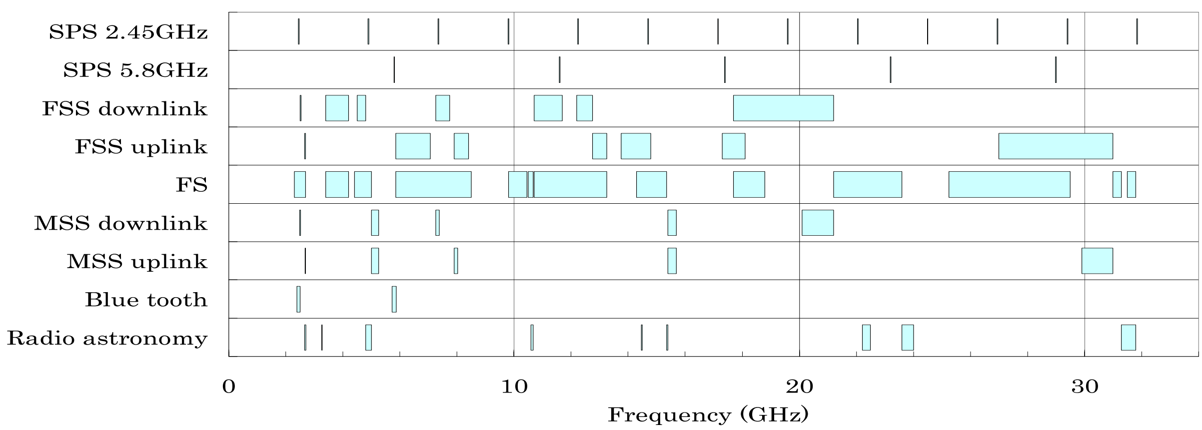


Fig. 1 Frequency diagram between SPS frequencies and interference related other services frequencies.

## 2. ASSUMPTION OF FUNDAMENTAL CALCURATION PARAMETERS

### 2.1 Harmonics levels of the SPS transmitters

The SPS transmitter harmonics power levels are different characteristics depend on devices, e.g., TWT, magnetron or SSPA. To carry out the assessment calculation, measured data of 2.45 GHz magnetron, which is used for microwave oven, are referred for calculation assumption.

### 2.2 Antenna spurious frequency characteristics estimation

A microstrip patch antenna array is assumed to compose the SPS antenna, as shown in Fig. 2.. Radiated electric fields of a circular patch antenna, excited by $TM_{mno}$ mode, are expressed by following equations.

$$E_\theta = j^m K \frac{e^{-jk_oR}}{R} \cos m\phi \left\{ J_{m+1}(k_o a \sin\theta) - J_{m-1}(k_o a \sin\theta) \right\} \qquad (1)$$

$$E_\phi = j^m K \frac{e^{-jk_oR}}{R} \cos\phi \sin m\phi \left\{ J_{m+1}(k_o a \sin\theta) + J_{m-1}(k_o a \sin\theta) \right\} \qquad (2)$$

where, $E_\theta$ and $E_\phi$ are $\theta$ and $\phi$ components of the electric field, ($R$, $\theta$, $\phi$) is an observation point on a spherical coordinate, $k_o$ is the wave number in the free space, a is a radius of the patch, $J_m(x)$ is the Bessel function of m-th order. Fig. 3 shows an example of sidelobe characteristics of patch array for 5.8 GHz and 11.6 GHz, TM110.

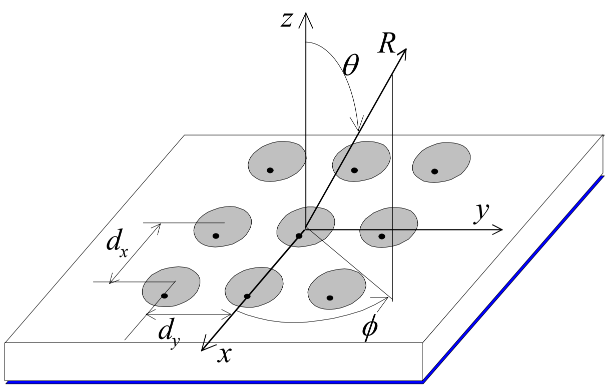


*Fig.2 Geometry of an array of circular patches*

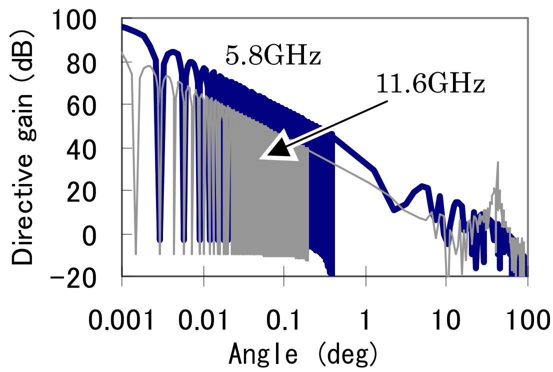


*Fig.3 Side robe characteristics of harmonics of patch array, for 5.8 GHz and 11.6 GHz, TM110.*

### 2.3 Interference Calculation of D/U between SPS harmonics and FSS/FS

In the interference calculation, the FSS/FS are suffered by the SPS power from the GSO. Calculation model for possible interferences is shown in Fig.4. As shown in this Figure, FSS/FS are suffered by the SPS power transmitted by sidelobe of SPS antenna from the GSO. Desired (*D*) and undesired (*U*) signal power ratio (D/U) value is used for interference assessment between SPS and FSS/FS systems. In this model, the SPS signal is non-modulated carrier.

Desired (*D*) and undesired (*U*) signal power can be calculated by following equations[3]、

$$D=(P_{st}-P_{sb}-L_{stf}+G_{st})-L_{se}+(G_{er}-L_{fer}) \qquad (3)$$

$$U=(P_{spst}-P_{spsh}-L_{spstf}+G_{spst})-L_{se}+(G_{er}-G_{\theta e}-L_{fer}) \qquad (4)$$

where, $P_{st}$, $P_{spst}$ : FSS and SPS transmitting power [dBW], $P_{sb}$ : FSS transmitter back off [dB], $P_{spsh}$ : SPS transmitting harmonics power level [dB], $L_{stf}$, $L_{spstf}$ : FSS and SPS transmitter feeder loss [dB], $G_{st}$, $G_{spst}$ : FSS and SPS transmitting antenna gain [dB], $G_{\theta e}$ : Earth station receiving antenna side lobe gain for angle $\theta$e, $L_{se}$ : Free space loss [dB], $G_{er}$ : Earth station receiving antenna gain [dB], $L_{fe}$ : Earth station feeder loss [dB].

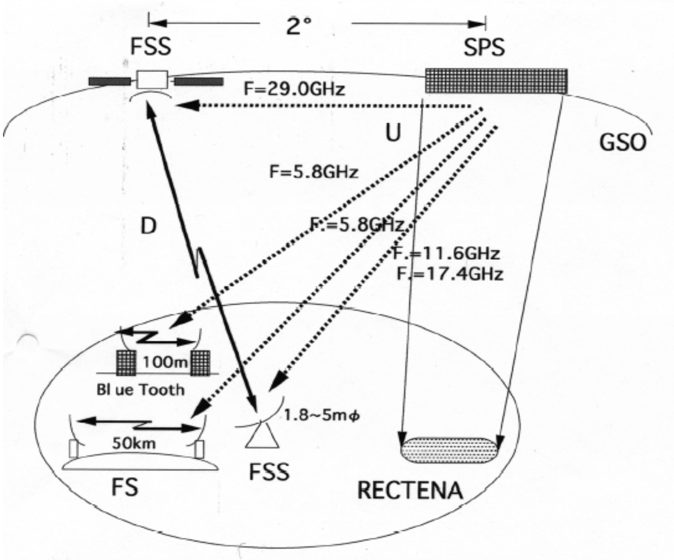


*Fig.4 Concept of interference between SPS and other systems*

## 3. CALCULATED INTERFERENCE ASSESMENT RESULTS

### 3.1 *Interference assessment parameters*

Main assumptions for calculation are as follows;

(1)The SPS transmitting harmonics power levels are around -70 dBc,

(2) Service areas separation between FSS and other systems are considered as 10 km and this means that the off-axis angle is about 0.016 degrees,

(3) Orbital separation angle between FSS and SPS is assumed as 2 degrees,

(4) Required D/U value for FSS/FS is 30 dB.

### 3.2 Fundamental frequency (5.8 GHz) interference to wireless LAN

The 5.8 GHz band is used in the Bluetooth system and many mini-PCI cards have been used for Note-PCs now and future. Interference budget (D/U) calculation is shown in Table 1. In this case, as shown in calcurated result, interference from SPS to Bluetooth system is very severe. Dedicated frequency allotment for SPS would be necessary for SPS system achievement.

### 3.3 2nd harmonics frequency (11.6 GHz) interference to FSS down-link

The 11.6 GHz band is used in the 14/11 GHz band FSS down-link (10.7~11.7 GHz), e.g., INTELSAT system. Interference budget (D/U) calculation example is shown in Table 2. In this case, interference is relatively severe. Then, interference coordination between two systems will be necessary. In this case, interference circumstances are relatively relaxed than fundamental frequency case.

### 3.4 5th harmonics frequency (29.0 GHz) interference to FSS up-link

The 29.0 GHz band is used in the 30/20 GHz band FSS up-link (27.5~31.0 GHz). In this frequency band, several satellites have been operated in Japan, USA etc. In this frequency case, interference is not so severe.

## 4. Improvement of D/U value strategies for 11.6 GHz frequency

Possible D/U improvement strategies for mainly 2nd harmonics interference are as follows;

(1) <u>Large service areas separation</u> between FSS and SPS systems can relax interference circumstances between FSS and SPS. If 10 km separation distance between FSS earth-station and SPS rectena is increased to 20 km, about 7 dB interference improvement can be achieved.

(2) <u>Energy dispersal</u> for SPS spectrum can decrease the SPS interference potentiality.

(3)Utilizing higher <u>harmonics microwave filters</u> will be effective.

(4) <u>Larger orbital angles</u> between FSS and SPS satellites on the GSO would be effective. If the orbital angle (θ) increase from 2° to 5° in earth station side lobe characteristics: G=29-25logθ, interference value can be decreased about 10 dB.

(5) <u>Reduction of the required D/U values</u> for FSS system will be effective for coexistence between FSS and SPS systems, e.g., D/U=20 dB, which is smaller than 10 dB from assumed calculation parameter.

(6) Selection of <u>smaller harmonics SPS power amplifiers</u>, e.g., TWT, and optimum designed SSPA etc..

By those strategies, about 50 dB interference reduction would be achieved, then, the co-existence between FSS and SPS systems could be achieved. However, precise SPS antenna pointing and station keeping accuracies etc. will be necessary for the practical SPS system.

## 5. CONCLUTIONS

The Interference assessments between 5.8 GHz SPS system and other services (FSS and other terrestrial services) are carried out. Interference from SPS to Bluetooth system is very severe. Dedicated frequency allotment for SPS would be necessary for SPS system achievement. The 2$^{nd}$ harmonics frequency (11.6 GHz) interference to FSS down-link is relatively severe. However, co-existence would be possible by proper improvement strategies discussed above. Further studies will be necessary for more detail interference calculations and devices reliabilities etc. This research is supported by the Grant-in-Aid for Scientific Research No.13650422 from the Ministry of Education, Science and Culture of Japan.


**[References]**

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*TABLE 1 INTERFERENCE BUDGET (D/U) CALCULATION BETWEEN SPS (U) AND BULUETOOTH (D), for f=5.8 [G Hz].*

| ITEMS | UNITS | SPS (U) | FSS(D) |
|---|---|---|---|
| Frequency | [GHz] | 5.8 | 5.8 |
| Transmitter power | [dBW] | 98.3 | -17.0 (20mW) |
| Branching loss | [dB] | 10.0 | 1.0 |
| Back off | [dB] | | 0 |
| Transmitting antenna gain | [dB] | 75.0 | 3.0 |
| Transmitting EIRP | [dBW] | 163.3 | -15.0 |
| Free space loss | [dB] | 205.0 | 205.0 |
| Rain attenuation loss | [dB] | 0.0 | 0 |
| (FSS) Receiving antenna gain | [dB] | 3.0 | 3.0 |
| Branching loss | [dB] | 1.0 | 1.0 |
| Receiver input level | [dBW] | -133.6 (U) | -100.7 (D) |
| D/U | [dB] | -67.0 | |
| Required D/U | [dB] | 30.0 | |
| Required improvement value | [dB] | 97.0 | |

*TABLE 2 INTERFERENCE BUDGET (D/U) CALCULATION BETWEEN SPS (U) AND FSS SERVICE (D), for f=4.9 [G Hz].*

| ITEMS | UNITS | SPS (U) | FSS(D) |
|---|---|---|---|
| Frequency | [GHz] | 11.6 | 11.6 |
| Transmitter power | [dBW] | 98.3-70.0[1]=28.3 | 15.0 |
| Branching loss | [dB] | 10.0 | 1.0 |
| Back off | [dB] | | -22.0 |
| Transmitting antenna gain | [dB] | 72.0 | 46.5 |
| Transmitting EIRP | [dBW] | 90.3 | 38.5 |
| Free space loss | [dB] | 205.0 | 205.3 |
| Rain attenuation loss | [dB] | 0.0 | - 10.0 |
| (FSS) Receiving antenna gain | [dB] | 21.5 | 49.7 |
| Branching loss | [dB] | 1.0 | 1.0 |
| (FSS) Receiver input level | [dBW] | -94.2 (U) | -114.5 (D) |
| D/U | [dB] | 20.6 | |
| Required D/U | [dB] | 30.0 | |
| Required improvement value | [dB] | 50.6 | |