무선통신에 영향을 미치는 태양폭풍의 통계적 분석

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Statistical analysis for the solar eruption effect on wireless communication

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요 약

세계2차대전을 통해 태양폭발은 레이더시스템에 큰 영향을 주는 것으로 밝혀졌다. 1942년 2월 28일의 전파교란 현상은 태양활동의 극대기에 증가한 우주 광선(cosmic ray)에 의한 것이었다. 이러한 사실들이 밝혀지면서 태양폭발 및 태양 입자 활동에 관한 연구가 활발히 이루어졌다. 태양폭발이 우주선에 미치는 영향, 극 운행 비행기에 미치는 영향, 레이더 시스템에 미치는 영향, 무선통신시스템에 미치는 영향 등에 대한 연구가 다양하게 이루어 지고 있다. 본 논문에서는 지난 40여년 간의 태양전파 관측자료를 분석하여 태양폭발에 의해 무선통신에 미치는 영향과 태양활동주기간의 상관관계를 분석하였다.

Key Words : Solar eruption, Wireless communication systems, Sunspot number, Solar radio burst, solar activity

ABSTRACT

In World War II, the solar eruption (solar flare) was revealed to make a significant effect to radar systems. The radio disturbance in February 28, 1942 was due to increased cosmic ray during solar maximum. Since such phenomena had been disclosed, many studies were accomplished on solar flare and solar particle event. Now various researches about the effects of solar flare on the spacecrafts, the airplanes flying across the pole, the radar systems, and wireless communication systems are studied. In this paper we analyzed the relationship between the harmful effect on the wireless communication by the solar eruption and the period of solar activity from the sunspot number data and the solar radio burst data for last 40 years.

I. Introduction

In World War II, the solar eruption (solar flare) was revealed to make a significant effect to radar systems [1]. The radio disturbance in February 28, 1942 was due to increased cosmic ray during solar maximum [2]. Since such phenomena had been disclosed, many studies were accomplished on solar flare and solar particle event [3][4]. Now various researches about the effects of solar flare on the spacecrafts, the airplanes flying across the pole, the radar systems, and wireless communication systems are studied.

Bala, Nita, and Lanzerotti have investigated the effects of solar flare on wireless communication systems [5][6][7]. Since the nominal noise power level is PT=3.8x10-21 W/Hz = 38 SFU m2for a receiver of bandwidth, B = 1Hz operating at temperature, T = 2730K[8],so the receiver power PR will be

$$P_R = GB\lambda^2 F/(8\pi) \text{ W/Hz} \quad (1)$$

where, λ is the carrier wavelength received, G is

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a single polarization antenna gain, and F is an isotropic radio flux.

If the thermal noise level is equivalent to solar noise level, Equation (1) is shown as follows:

$$kTB = GB\lambda^2 F_{eq}/(8\pi) \qquad (2)$$

where, Feq is an equivalent solar flux.

Typically Feqis about 960 SFU for a wireless communication base station where the operating frequency is about 1 GHz and an antenna gain is about 10 dB, so the total input noise (PT + PR) is 3dB more than thermal noise. The equivalent solar flux Feq at a frequency of 1 GHz in some typical wireless communication is in the range from 300 SFU to 1000 SFU. Thus the harmful amount of a solar flux to wireless communication system might be more than 1000 SFU [9].

In this paper we analyzed the relationship between the harmful effect on the wireless communication by the solar eruption and the period of solar activity from the sunspot number data [10] and the solar radio burst data [11] for last 40 years.

2. Solar Flare Event Analysis

NGDC solar flare data in condition of the peak flux ≥ 103SFU and the flare event time duration ≥ 12 min are statistically analyzed for the observed frequency ranges from 30MHz to 2500MHz and from 1GHz to 20GHz.

2.1. Yearly Sunspot Numbers

A sunspot number is varied daily and monthly. Thus the data of Yearly Mean Sunspot Numbers in the NGDC's Daily Sunspot numbers in yearly tables were used for analysis. The yearly mean sunspot numbers observed from 1960 to 2007 are as shown in Figure 1.

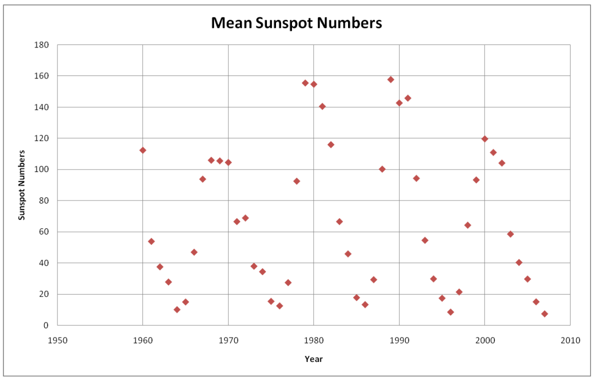

Figure 1: Yearly Mean Sunspot Numbers

In Figure 1, the yearly distribution of the observed sunspot number shows the period of sunspot number's increase and decrease according to the solar cycle, about 11 years.

2.2. Frequency Range between 30MHz and 2500MHz

Radio Research Agency (RRA) in Korea is able to measure solar flares in the frequency range of 30MHz~2500MHz, so the relationship between the sunspot number (solar cycle) and the solar flare event number in this range was analyzed.

2.2.1. Solar Flare Event Observed in the frequency range between 30MHz and 2500MHz

For the solar flare event number, the Solar Radio Burst Listing by year data provided by NGDC was used and the number of the observed solar flares is shown in Figure 2.

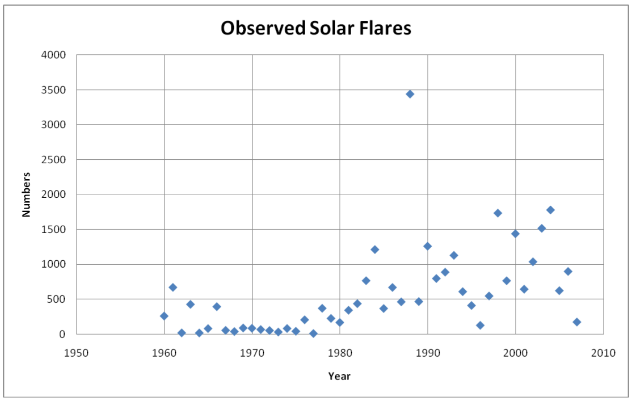

Figure 2: Observed Solar Flares (in the range of 30~2500MHz)

As shown in Figure 2, the observed solar flare events in between 1960 and 1977 are less than during other period. According to the NGDC's observation data, only 11 years including the year of 1961 have the case that the solar flare events were observed for 10 months per one year. It is difficult to decide whether the period of no data means the time of no solar flare event or other reasons like some faults in any observation equipment made no data observed.

Figure 3 shows the relationship between the yearly sunspot numbers and the solar flare events. The observed solar flare events trends to increase since 1970's. It might be caused by the development of observation equipments. The NGDC's data for solar flare events in the observed frequency range between 30MHz and 2500MHz since 1980's shows to have a trend of a relationship with a solar cycle, but this trend cannot make a conclusion for the relationship.

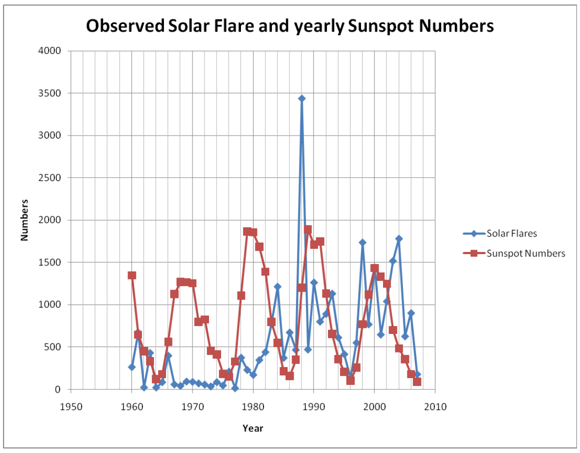

Figure 3: Observed solar flare events and the yearly sunspot numbers (30 MHz ~2500MHz)

2.2.2. Weighting Factor Calculation

Considering to any missing of solar flare events due to any reasons like equipment faults, we introduce a weighting factor for solar flare events from the number of solar flare observation days in order to estimate more practical yearly solar flare events.

The weighting factors were calculated with the number of yearly observation days based on NGDC's data of the solar flare events in the whole frequency range. The weighting factor is shown in Table 1.

Table 1 : Weighting Factors30

Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Weighting Factor	0.50	0.09	0.14	0.13	0.17	0.13	0.14	0.25	0.67	0.77
Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Weighting Factor	0.43	0.67	0.77	0.67	0.20	0.13	0.08	0.20	0.30	0.63
Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Weighting Factor	0.83	0.43	0.56	0.18	0.50	0.14	0.09	0.10	0.09	1.00
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Weighting Factor	0.50	0.50	0.50	0.17	0.11	0.08	0.09	0.08	0.11	0.20
Year	2000	2001	2002	2003	2004	2005	2006	2007		
Weighting Factor	0.20	0.25	0.20	0.14	0.10	0.20	0.08	0.08		

The estimated numbers of yearly solar flare event in the frequency range between 30 MHz and 2500MHz using the calculated weighting factors are described in Table 2 and Figure 4.

Table 2 : Estimated Yearly Solar Flare Event (30 MHz ~2500MHz)

Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Event numbers	131.00	61.09	3.00	53.63	3.33	10.38	56.57	14.25	26.67	70.00
Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Event numbers	37.83	46.00	42.31	22.00	16.80	5.50	17.33	2.40	113.03	142.50
Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Event numbers	141.67	150.00	243.89	139.64	606.50	52.86	61.00	46.50	312.55	469.00
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Event numbers	630.50	399.50	445.00	188.33	65.70	34.42	11.73	45.75	192.78	153.40
Year	2000	2001	2002	2003	2004	2005	2006	2007		
Event numbers	288.00	161.50	207.60	216.71	178.00	125.00	75.00	14.67		

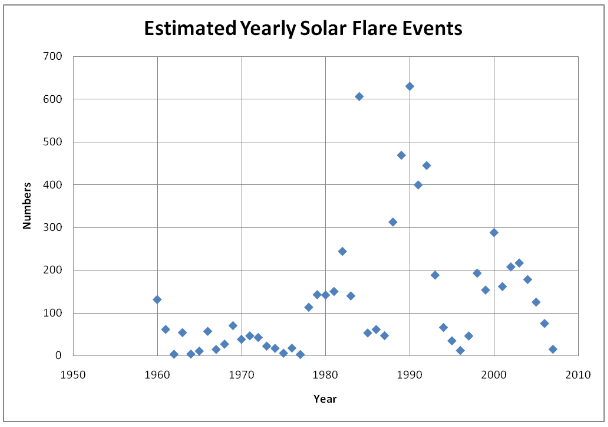

Figure 4: Estimated Yearly Solar Flare Event (30 MHz ~2500MHz)

2.2.3. Relationship between the Estimated Solar Flare Event and the Sunspot Number

The trend of the solar flare event estimated using the above method is compared with the trend of the monthly mean sunspot number in Figure 5.

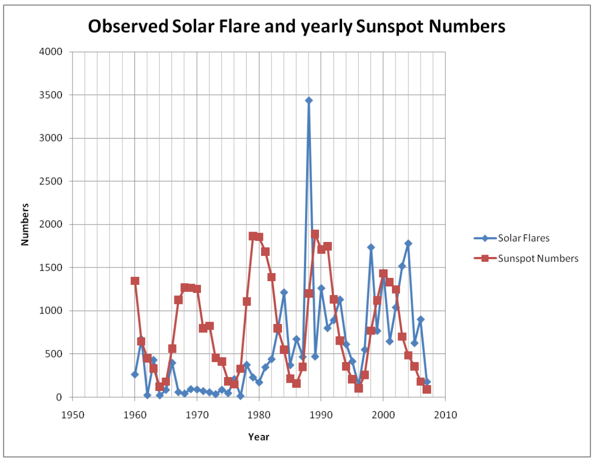

Figure 5: Relationships between Solar Flare Event and Sunspot Number (30 MHz ~2500MHz)

As shown in Figure 5, the estimated number of solar flare event in the frequency range between 30 MHz and 2500MHz must be related closely with the solar activity according to sunspot number.

3. Frequency Range between 1GHz and 20GHz

For the frequency range between 1GHz and 20GHz which is the weakest band for the wireless communication when the solar flares are occurred, the relationship between the solar flare event and sunspot number is analyzed. The sunspot number is shown in Figure 1. The weighting factor for the frequency range between 1GHz and 20GHz can be found using the same method as above. Thus the estimated numbers of yearly solar flare event in the frequency range between 1GHz and 20GHz with the weighting factors are described in Table 3 and Figure 6.

Table 3: Estimated Yearly Solar Flare Event (1 GHz ~20GHz)

Year	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Event numbers	11.00	16.75	0.08	6.75	0	0	12.25	30.60	72.31	50.00
Year	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
Event numbers	30.50	16.96	15.33	11.50	7.60	1.00	5.83	1.40	33.03	65.00
Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Event numbers	70.00	47.39	157.78	54.36	57.50	19.23	18.67	5.00	53.73	230.00
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Event numbers	75.00	144.50	132.50	47.83	8.82	3.25	1.82	10.42	42.56	30.20
Year	2000	2001	2002	2003	2004	2005	2006	2007		
Event numbers	101.20	71.00	57.40	60.57	77.50	49.20	18.25	4.75		

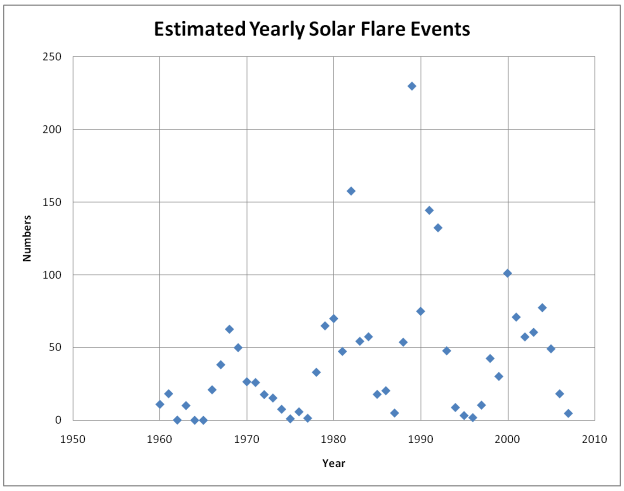

Figure 6: Estimated Yearly Solar Flare Event (1 GHz ~20GHz)

The relationship between the estimated solar flare event and the monthly mean sunspot number is plotted in Figure 7.

Figure 7 shows that the estimated number of solar flare event in the frequency range between 1GHz and 20GHz also must be related closely with the solar activity according to sunspot number.

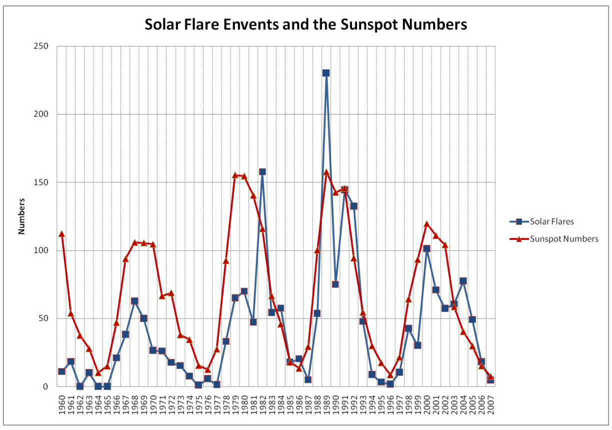

Figure 7: Relationship between Solar Flare Event and Sunspot Number (1GHz ~ 20GHz)

3. Conclusions

The estimated number of solar flare event in the frequency ranges between 30 MHz and 2500MHz and between 1GHz and 20GHz has quite close relationship with the solar activity according to sunspot number. Comparing two figures, Figure 5 and Figure 7, the solar flare event in the frequency range between 1GHz and 20GHz seems to be related with the sunspot number closer than between 30 MHz and 2500MHz.

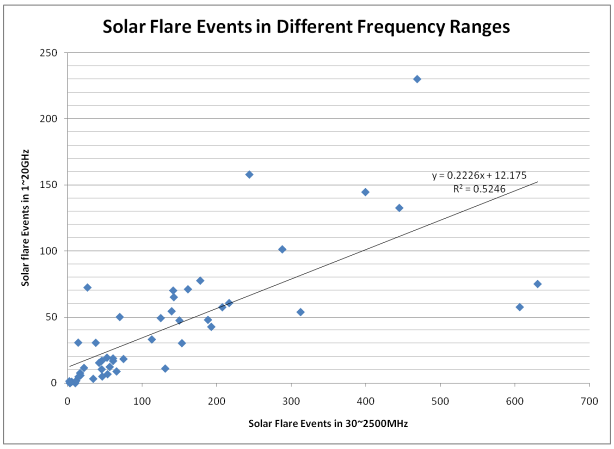

Figure 8: Relationship between the Solar Flare Events in Different Frequency Ranges

Figure 8 plots the relationship between the solar flare events in different frequency ranges. It shows the numbers of solar flare events in different frequency ranges are in proportion. So in solar maximum the number of solar flare events in from 1 GHz to 20 GHz might be estimated from the observed solar flare data in from 30 MHz to 2500MHz by RRA. The probability that the solar flare events in from 1 GHz to 20 GHz follows the solar flare events in from 30 MHz to 2500MHz might be different according to circumstances, but the solar flare events in each frequency band would be trending to increasing or decreasing in solar maximum or solar minimum, respectively.

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