L band solar radio burst events—a potential interference for navigation signal and pre-alarm method research

Liang Dong [1 2 3], Huipeng Qu[4], Min Wang[2 3] , Jun Lin[2], Gunnan Gao [2 3]

1. Information college of Yunnan University, KunMing 650002 , dongliang@ynao.ac.cn

2. Yunnan Astronomical Observatories, Chinese academy of sciences, KunMing 650011

3. Yunnan University- Yunnan Astronomical Observatories information technology united laboratory, KunMing 650002

4. Beijing Institute of Tracking and Telecommunications Technology.100032, quhuipeng@139.com

Abstract

Most navigation satellites transmit navigation signals within L band, such as GPS, Galileo, BeiDou and so on. Solar radio bursts frequently occurred also with strong emission in L band, which are potential interferences for the navigation service. During the most intense solar radio bursts, the obviously decreasing performances of navigation systems were found.

In this work, we get the threshold values for the three communication frequency points by theoretical arithmetic.

At the same time, we will set up the real-time solar radio flux monitor system for test and verify the real threshold value in natural space based on 10m solar radio telescope. At last, we will try to build the pre-alarm system combining optical observation data.

1. Introduction

Solar radio burst are natural phenomenon caused by solar flares, eruptive prominences, and coronal mass ejections (CMEs). When the bursts coming, the burst flux in the radio band may increase more than 30dB comparing with the flux of quiet Solar period. And the solar radio bursts transmit strong noise signals with different temporal and spectral characteristics, so it is very difficult to forecast the solar radio bursts.

So the solar may be a potential interference for the wireless communication systems especially the navigation satellites such as GPS, Galileo, BeiDou and so on.

In the latest solar active period, some researchers have observed several events. Zhiyu Chen et.al[1] analyzed the strong event in 28-Oct-2003, and found the loss lock time when the flare reached Goes-X level:

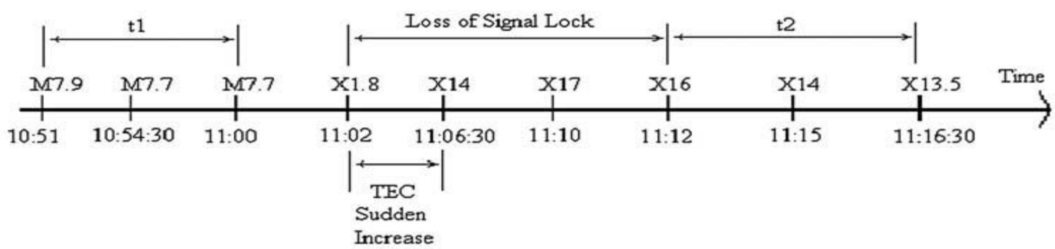

Fig1. The variation of X-ray flux and the quality of GPS signal during the event in 28-Oct-2003

During this time, they found different Rate of loss of lock of different GPS land stations in different times, in according with the different flux density and solar zenith angles :

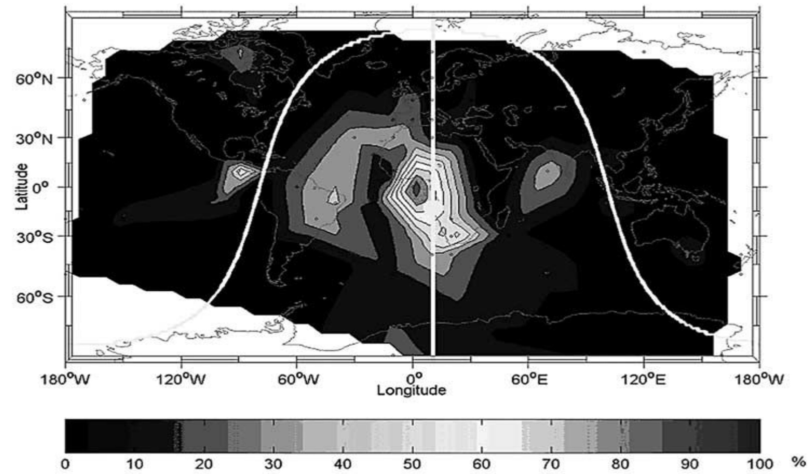

Fig2. Rate of loss of lock for IGS network during 11:02:00~11:12:00 UT, 28 October 2003

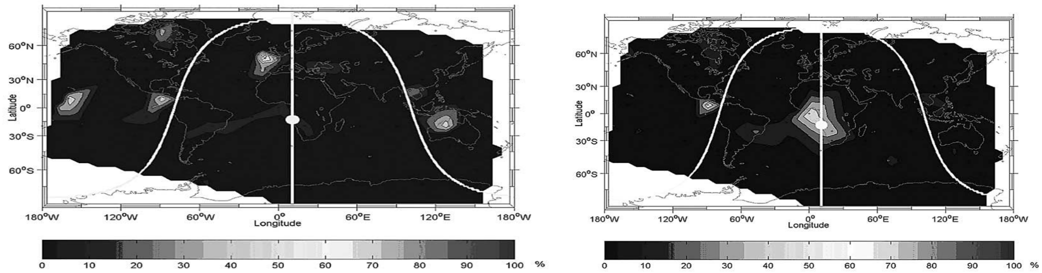

Fig3. Rate of loss of lock for IGS network before burst (L2 signal, 10:51~11:00 UT)and after burst (L2 signal, 11:12:00 ~11:16:30 UT)

And Charles S. Carrano[2] analyzed the impacts of the December 2006 solar radio bursts events on the performance of GPS, The radio burst events happened in 5, 6, 13, 14-Dec-2006

But through these events from 5-Dec-2006 to 14-Dec-2006, we found that there was no congruent relationship between flux density in L band and X-ray which is a traditional method for evaluating the levels of solar flares.

Table1. The flux density in X-ray and C/N_0 decreasing from 5-Dec-2006 to 14-Dec-2006

Data	X-ray level	Whether C/N0 decreasing?
5-Dec-2006	X9.0	No
6-Dec-2006	X6.5	Yes
13-Dec-2006	X3.4	Yes
14-Dec-2006	X1.5	Yes

From some events and analyses, we can get some conclusions: First, the threshold solar radio flux for GPS is less than 4000 S.F.U, rather than the former estimated value of 40000 S.F.U [4]. At the same time, it is meaningful to compute the theoretical threshold value.

Second, there may be some relationships between interference levels and the solar zenith angle. Because the most GPS receiver antennas are Omni directional antennas, these areas where solar elevation angle is 80~90 degree have worse influence situations.

Third, by the correlation analysis research, we can see the more close correlation with the nearer the GPS's L1 and L2 communication frequency points. It is necessary to build a real-time solar monitor system at L1 and L2, for finding the real threshold in these frequency points.

At last, it is possible to forecast the solar radio burst by combing multi-wavelength observations. It is useful to decrease the influences of the solar radio burst to the navigation systems.

2. Some analyses

The radio burst power P_R coming into the receiver system can be computed by this equation:

$$P_R = \frac{1}{2} GB \frac{\lambda^2}{4\pi} F_{eq} \qquad (1)$$

F_{eq} ($W \cdot Hz^{-1} \cdot m^{-2}$)is the flux of radio burst, B (Hz)is bandwidth of receiver system, G (dB) is the antenna gain (the maxim gain value without regard to the pattern) and the λ (m) is the wavelength of communication frequency points.

If considering the relation angle θ between solar zenith angle and the antenna pointing direction. This equation should be modified to:

$$P_R = \frac{1}{2} G(\theta) B \frac{\lambda^2}{4\pi} F_{eq} \qquad (2)$$

And then convert F_{eq} into the unit flux F_{sfu} of solar radio S.F.U (1 S.F.U=10^{-22}W • Hz^{-1} • m^{-2}):

$$F_{eq} = F_{sfu} \times 10^{-22} \qquad (3)$$

So if the F_{sfu} is more than the threshold value, the ratio of signal to noise (SNR) will decrease:

$$F_{sfu} > 8\pi * kT \big/ (G(\theta)\lambda^2) * 10^{22} \qquad (4)$$

Hypothesis G=10dB, we can get some threshold values with some communication frequencies

Table1. Some **threshold value flux with some communication frequency points**

Frequency point	**threshold value flux S.F.U.**
900MHz(GSM)	950
1227MHz(GPS ,L1)	1080
1557MHz(GPS,L2)	2560
1200MHz(B2)	1100
1270MHz(B3)	1300
1570MHz(B1)	2600

3. Solar radio flux monitor system

Nowadays, there a 10-meter solar radio telescope working in L band located at Yunnan Astronomical Observatories in the east suburb of Kunming city (102◦.79 N, 25◦.02 E， see Figure)

Fig4. 10m solar radio telescope working for the L band solar radio observation

This radio telescope equips the high performance spectrometer with high time (20ms) and spectral (200 kHz/channel) resolution for recording the short life and fine structures type II and III solar radio bursts.

For the initial monitoring the flux density of B2 and B3, we equipped a spectrometer LPT3000 behind the analog receiver by a power divider to record the power in real time. We set a GPS antenna at the focal point, and other parts of this system placed in shielding room. Take advantage of the 10m radio telescope, the GPS antenna always points and trace the solar, so the parameter in equation (2) to (7) G(θ) can be regard as constant G, you can see this initial system below:

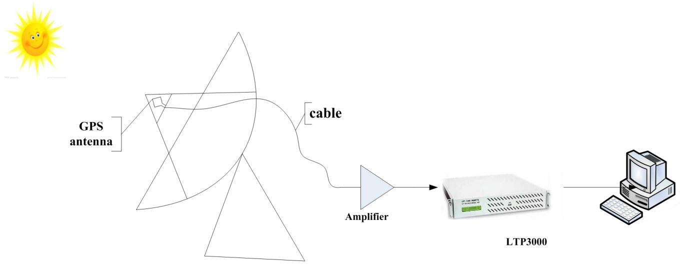

Fig5. The initial monitor system

At the same time, we get the optical data from solar-monitor network (http://www.solarmonitor.org) every day. Taking advantage of these data, we usually send pre-alarm information when there were some active with large sunspot area more than 500 units.

In another hand, Beijing Institute of Tracking and Telecommunications Technology (BITTT) will turn on the satellite receivers to record the C/N_0, if they get the alarm information from YNAO.

4. Future work

So it is necessary to build a real-time L band solar radio power monitor system with calibration function.

This system will use an analog filter bank for selecting eight “clean” 5MHz bands because that some RFIs (Radio Frequency Interferences) may affect the power result, and then compute the in band powers by a power detector after amplifying:

Each analog channel can get channel power P_n in real-time. We can get the pre-alarm information by weighted sum with this equation:

$$A = \sum_{n=1}^{8} a_n P_n$$

The weighted coefficients a_n are determined by the absolute value of frequency in channel n subtracting the communication frequency such as L1, B2 and so on.

And in future, we plan to combine the optical data as early alarm information. General speaking, there may be some large area active areas in the surface of solar before the radio burst events, so we will send early alarm information to customs as soon as we find these active areas.

5. References

1. Chen, Z., Y. Gao, and Z. Liu, Evaluation of solar radio bursts’ effect on GPS receiver signal tracking within International GPS Service network, RADIO SCIENCE, VOL. 40, 2005 RS3012, doi: 10.1029 /2004RS003066.
2. Charles S. Carrano,et.al, Impacts of the December 2006 solar radio bursts on the performance of GPS. RADIO SCIENCE, VOL. 44 RS0A25