Investigating SRBs effect on GPS derived TEC

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Outline

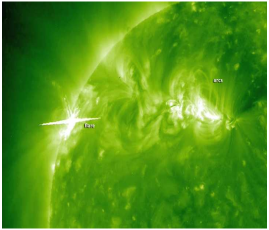
SRBs and Space Weather

Space Weather issue

Solar radio observations play an important role in the monitoring of Space Weather sources. Space Weather is the study of the conditions on the Sun and IP medium that can affect life on the the Earth's environment, particularly the increasingly technologically sophisticated devices that are part of modern life (e.g. GNSS applications)

SRB relationship with SFs and CMEs

- Low frequency SRB arise at the same levels in the solar atmosphere as..
- Geo-effective SFs, CMEs and related shocks
- Source of EM and particle radiations



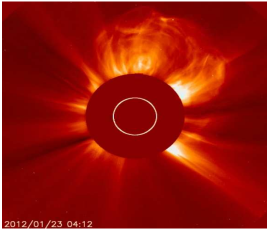


Abbildung :

Emission mechanisms

Plasma Frequency

- Both type II and type III solar radio bursts are generated by the 'plasma emission' mechanism.
- The radio emission is generated at the local electron plasma frequency $f_p = 9000\sqrt{n_e}$ Hz (since $n_e = 1/R^2$, the emission frequency goes as $\sqrt{n_e}$, and scales as $1/f$ with heliocentric distance, R).
- Its harmonic at $2f_p$
- Associated with the presence of a suprathermal electron beam.
- However, the detailed physics of the process is not yet completely understood, due largely to a lack of appropriate measurements.

Emission mechanisms

- At low frequency (below 100MHz), most emission are plasma emission
- Languimir waves at electron plasma frequency $\nu_p = 9000\sqrt{n_e}$.
- Driven to very high effective brightness temperatures by coherent interaction with a beam and then converted to propagating transverse EM waves at ν_p or its harmonic, $2\nu_p$
- Radiation at ν_p is damped by collisional opacity, so emission is seen at low frequencies
- Plasma emission bellow 100 MHz dominate most of observed SRB types

SRBs Types

- **Type I**
  - ***type I bursts*** or chains, narrowband, non-drifting bursts of short duration
    - cause is unknown, but emission appears to be plasma emission
  - ***type I storm*** -- a continuum emission with many type I bursts embedded, duration days
    - cause is unknown, but related to continuous reconnection above active region
- **Type II**
  - ***type II*** slowly drifting, often with fundamental/2nd harmonic structure, due to plasma emission
    - cause is a shock wave, propagating at 500-2000 km/s outward into the corona into interplanetary space *(also seen down to kilometric wavelengths).*
- **Type III**
  - ***type III burst***, rapidly drifting, often with fundamental/2nd harmonic structure, due to plasma emission. The fundamental is highly o-mode polarized, and the 2nd harmonic is weakly (15%) x-mode polarized.
    - cause is a stream, or beam, of electrons moving at speed ~ *c*/3, propagating from low corona into interplanetary space *(also seen down to kilometric wavelengths).*
  - ***type III storm*** -- a long lasting (up to a day or more) series of type III bursts, RS (reverse slope) bursts, reverse-drift pairs, and continuum.
- **Type IV**
  - ***stationary type IV*** -- broadband continuum emission, sometimes highly polarized, due to either plasma emission (o-mode polarized) or gyrosynchrotron emission (x-mode polarized).
    - cause is a plasmoid or high, filled loops of non-thermal particles
  - ***moving type IV*** -- a similar cause, but entrained in a CME or expanding arch.
- **Type V**
  - ***type V burst***, continuum emission following a type III burst, x-mode polarized (opposite sense to the associated type III)
    - cause is slower type III-like electrons in widely diverging magnetic fields, with both forward and counterstreaming langmuir waves, perhaps generated by previous passage of type III electrons.

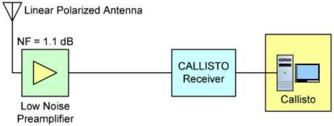
The CALLISTO solar spectrometer

- One of current techniques for SRBs radio observations
- Record the intensity of EM radiation at radio frequencies.
- Designed and built by electronic engineer Christian Monstein of the ..
- Institute for Astronomy of the Swiss Federal Institute of Technology of Zurich (ETH-Zurich)

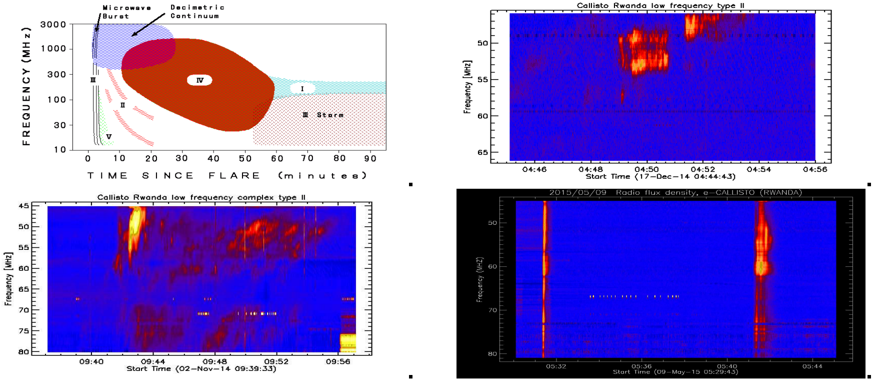
Method

"Compound Astronomical Low-cost Low frequency Instrument for Spectroscopy in Transportable Observatory. "

The Callisto Solar Spectrometer



Some dynamic spectra by Callisto: RWANDA station



SRBs effect on GNSS applications

- SRBs are often associated Solar flares; phenomena
- Characterised by sudden enhancement of solar radiation in the X-ray and EUV band
- Can lead to ionospheric disturbances and irregularities (e.g changes in ionospheric TEC)
- This can cause significant amplitude and phase distortion of GPS signals (Groves 2004, Beniguel et al. 2004 etc...)
- Observed effect of SRBs on various GPS receivers (P. M. Kintner et al., 2009)

SRBs effect on GNSS applications

Cerruti et al.2006

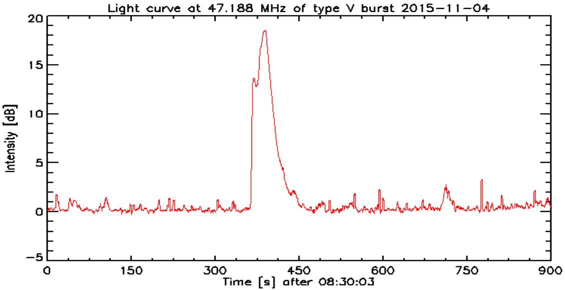
$$P_{SRB} = \frac{P_n}{A_{eff}}[10^{0.1\times\triangle(C/N_0)} - 1]W/m^2Hz$$

- P_n- system noise power; A_{eff}-effective area of the antenna
- $\triangle\ (C/N_0)$ - change in the carrier to noise ratio caused by the SRB

Intensity of SRBs

- Power level of the solar burst is often measured in terms of Y-factor expressed in dB.
- The Y-factor is the ratioof the emission's peak noise power to the mean value of the background noise power.

Power level of SRBs



Objectives of the study

- Investigate the SRBs effect on GPS-TEC
- A small part of a large research project on the characterization, trends analysis and
- ..geospace impact of SRBs phenomena
- Mostly using CALLISTO data from Rwanda stations
- TEC data are from some selected IGS stations located at almost same time Zone (UT)
- Investigate TEC variability at variaous lastitudes

IGS stations

	Station code	Country	Latitude (in degrees)	Longitude (in degrees)
High Latitude	Joen	Finland	62.39 N	30.10 E
Mid Latitude	bucu	Romania	44.46 N	26.12 E
Low Latitude	Harb hrao	South Africa South Africa	25.88 S 25.89 S	28.13 E 27.69 E
Equatorial Latitude	mbar nurk	Uganda Rwanda	00.60 S 01.94 S	30.74 E 30.09 E

SRBs events

Burst date	Time of burst (UT)	Frequency (MHZ)	Type and quality	SFs	Time of flare	Magnetic activity (Dst min)
14 Dec 2014	08:26-08:27	-	III/-	-	-	-15 nT
04 Nov2015	05:42-05:43 08:36-08:37	31-120 25-180	III/2 V/2	C	04:50-04:59	-61 nT
22 Aug 2015	06:50-07:14	45-180	II/2	M	06:39-06:59	-21 nT
25 Aug 2015	10:26-10:29	25-180	V/2	C	10:23-10:41	-19 nT
27 Oct 2015	08:36-08:39 10:14-11:56 11:51-11:56	25-180 25-180 25-180	III/2 VI/3 V/2	C	05:05-05:20	-4 nT
28 Oct 2015	05:50-05:50 06:22-06:26 06:22-06:25 09:32-09:36	18-57 18-300 25-180 25-180	III/3 III/3 III/2 V/2	C C	05:53-06:23 09:31-09:42	-1 nT

Methods

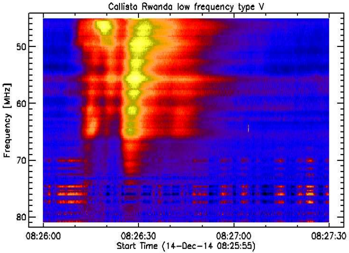
- Having the CALLISTO dynamic spectra corresponding to events investigated for a particular day
- TEC data processed from RINEX files using the software program by Seemala and Valarades, 2011
- TEC variability on the burst event day is compared to that for 10most quiet days in the Month
- Evaluate the difference in TEC of the 10 quiet-day-mean from the burst day TEC variation.

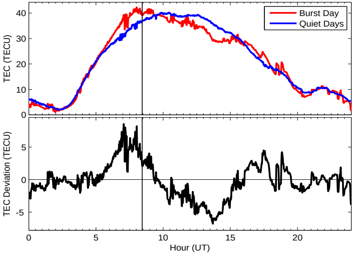
Preliminary observations

14 December 2014 SRB event

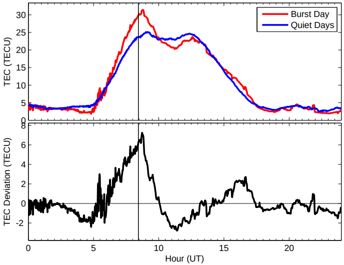
- Low frequency type V burst

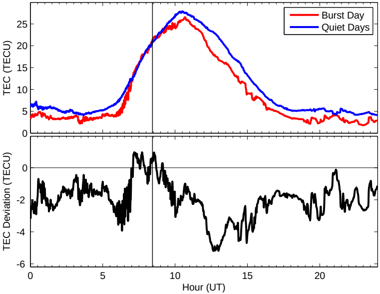
- Low latitude (hro) response



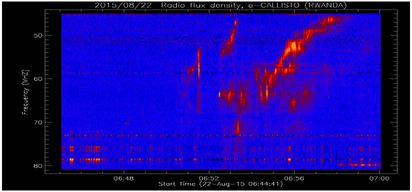


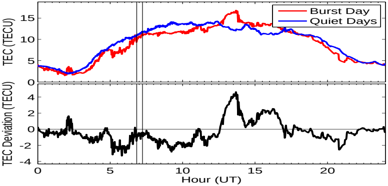
Mid (Romania) and high (Finlande) latitudes

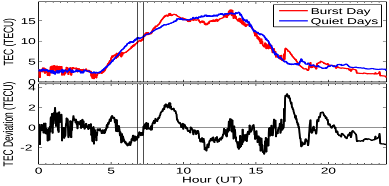


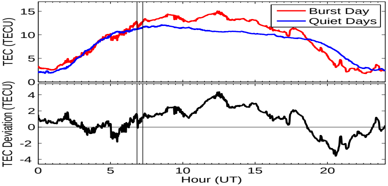


TEC variability on the 22/08/2015 type II event







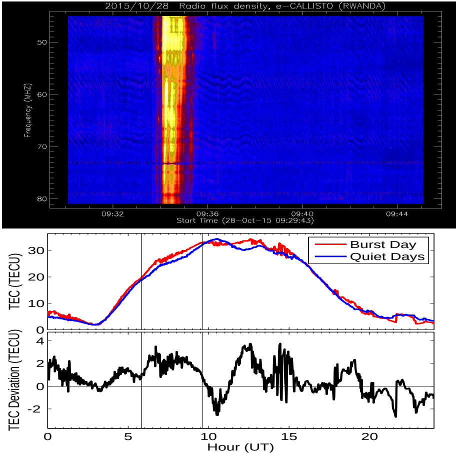


28 October 2015 events

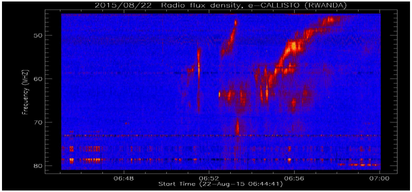
SRBs event son 28/10/2015

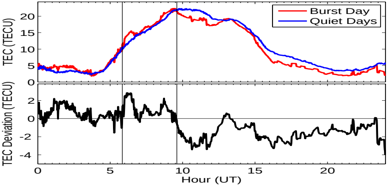
- Multiple intense type III

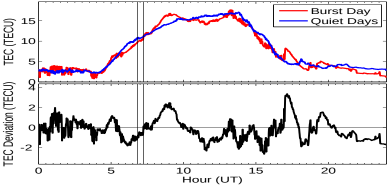
- Also a low frequency type V burst

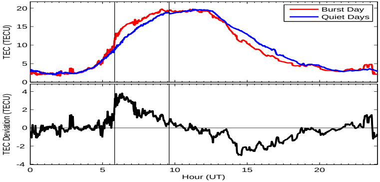


TEC variability at various latitudes IGS stations

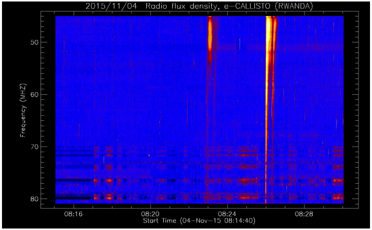


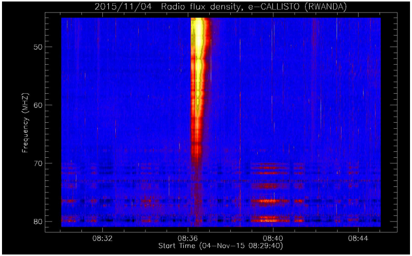




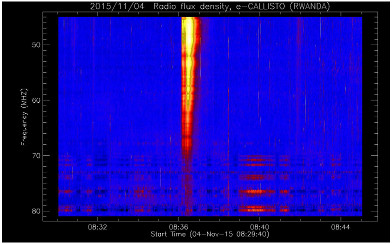


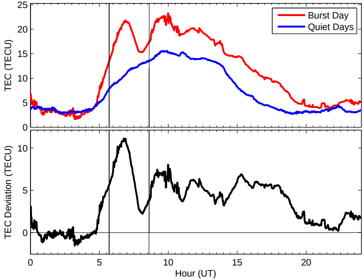
Bursts events on 04/11/2015





TEC response at mid latitude





Conclusions

No conclusion; investigation still in progess....

- In some cases, observed sudden changes in TEC at the time of SRB occurrence
- Investigation continue, trying new methods of analysis and data
- e.g: Consider short time only corresponding to the burst events
- Investigate possible associated amplitude / phase scintillations
- Emphasis on extreme cases associated with large X-class flares