THE TRIESTE SOLAR RADIO SYSTEM (TSRS) AS A NEAR REAL-TIME MONITOR OF CORONAL RADIO EMISSIONS

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ABSTRACT

We describe the operational mode of the Trieste Solar Radio System for the surveillance of the coronal radio activity at six frequencies in the metric and decimetric bands by stressing the role of the derived coronal radio indexes as proxies of geo-effective phenomena such as the Coronal Mass Ejection associated with the X14.4 flare occurred on 2001 April 15.

1. THE TRIESTE SOLAR RADIO SYSTEM

The Trieste Solar Radio System (TSRS) is a set of two multi-channel solar radio polarimeters with full-disk spatial resolution but very high time resolution (1 ms in synoptic mode), which perform a continuous surveillance of the decimetric and metric coronal radio emissions in unattended mode. The facility is located in the Basovizza Observing Station operated by the Trieste Astronomical Observatory of the National Institute for Astrophysics (INAF). A scheme of TSRS is reported in Figure 1 and depicts the four main subsystems, i.e., the metric (mMSRP) and the decimetric (dmMSRP) multi-channel solar radio polarimeters, the ultra-fast data acquisition system (UFDAS), the near-real-time data processor (NRTDP) and the Solar Radio Data Archive System (SOLRA). In 2000 TSRS was set up to comply with the requirements of Space Weather (SpW) monitoring and prediction applications, so that a synoptic multi-channel radio graph, which shows the time evolution of the radio flux density and circular polarization in the decimetric (2695 and 1420 MHz) and metric (610, 408, 327 and 237 MHz) channels, is generated and updated at 10-mins time intervals as well as the graphs of the time evolution of the relevant 10-mins-averaged radio indexes together with a 10-mins ahead radio index prediction. These coronal radio surveillance data are made available in near real-time on a dedicated web site (*http://radiosun.ts.astro.it*) and automatically updated for continuous display of the time evolution. Figure 2 shows the control room of TSRS, where all the subsystems are operating and communicate via a dedicated fast networking system connected to but independent of the main Intranet to prevent operational gaps due to connectivity failures to the WAN. In fact, acquired data and the relevant radio indexes are redundantly buffered and published on the remote web site upon connectivity restoration. Continuously updated information on solar activity and Space Weather conditions is displayed by the SWARM software (Solar Warning and Real Time Monitor, by Solar Terrestrial Dispatch, Canada) and information on the coronal radio activity by the TSRS web server. Post-processed radio data are permanently stored on DVDs and made available online by the SOLRA which manages a DVD juke-box with a storage capacity of 1 TB.

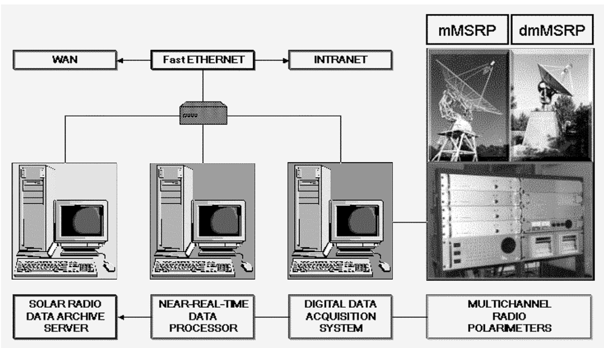

Figure 1. Operational scheme of TSRS.

2. SPW SOLAR RADIO PROXIES BY TSRS

TSRS has valuable potentialities for: (a) identifying **radio precursors** of flares and Coronal Mass Ejections (CME); (b) issuing warnings about **radio flares** in progress; (c) detecting high levels of impulsive and continuous **radio noise**; (d) providing **input radio data** to SpW forecasters.

Radio precursors have been observed in different radio bands before flares as well as CMEs (see, e.g.,

Figure 2. *The TSRS control room (center panel) and the different subsystems (side panels).*

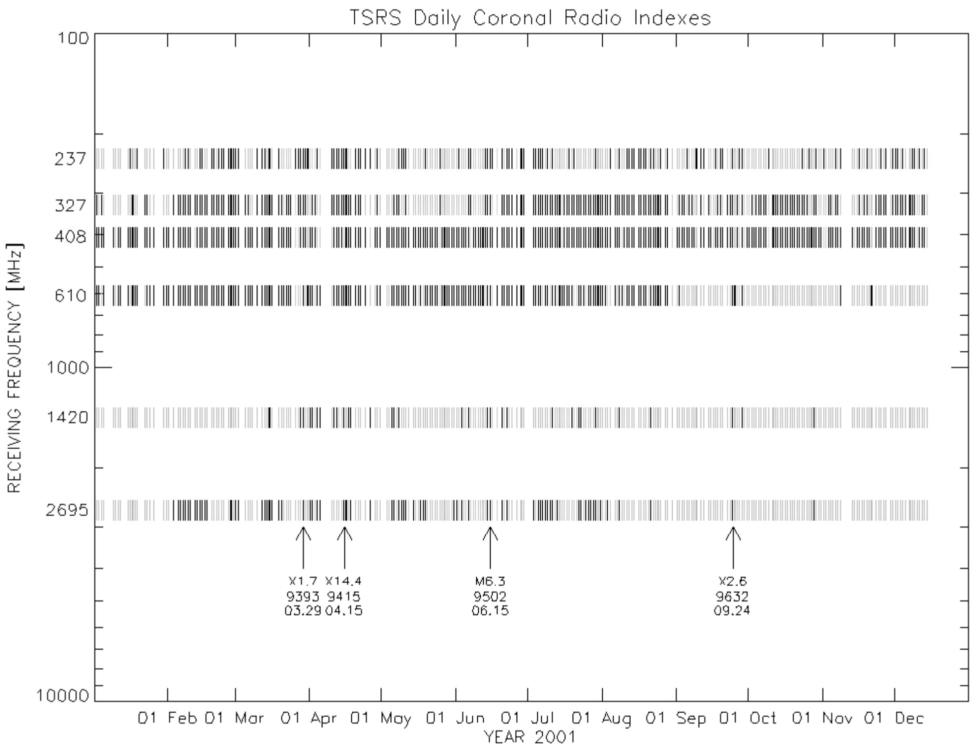

Figure 3. *Synoptic chart of the maximum daily radio index values for the year 2001.*

[1]) and are presumably indicative of pre-heating process and re-arrangements of the magnetic field topology, which result in radio emission, before or during the build-up of the conditions for the major event to be triggered. Not a large statistical analysis has been performed yet on such radio precursors, which deserve a great attention as proxies in major events prediction. **Radio flares** are observed in the decimetric and in the metric band as continuum enhancements with a variety of fine structures in association with flares. Typically the maximum radio emission occurs first in the decimetric band (Tenflare = flare at 10.7 cm wavelength) as the response of coronal plasma layers at lower altitudes and later in the metric band (Type IV burst) as the response of higher coronal layers, which can be perturbed by the complex set of flare- and post-flare-related phenomena. The onset of both Tenflares and Type IV bursts is an effective proxy of a flare in progress. **Radio noise** is a general term to indicate large- or narrow-band enhancements in the background radio flux, which can disturb ground-ground and space-ground telecommunications. Solar radio emissions can significantly contribute to this phenomenon, when strong solar noise storms or Type IV flare continua are triggered for hours or when groups of fast and extremely intense radio pulses (spikes) are generated for tens of minutes. **Input radio data** to SpW forecasters are the radio indexes, which are used in prediction models as proxies of the global activity of the Sun, the most widely used being the daily 10.7 cm (2800 MHz) one [2], fairly well associated with the sunspot number. In reality radio indexes computed at shorter timescales are effective indicators of flare occurrence and their ahead prediction is worthwhile investigating as a proxy in flare prediction. Figure 3 depicts the synoptic chart of the maximum daily radio index observed by TSRS in the year 2001. Four major flares of the M and X classes are indicated by arrows.

3. THE RADIO FLARE ON 2001 APRIL 15

To better specify the framework outlined in the previous section, it is worthwhile illustrating the TSRS observation of a major radio flare occurred on 2001 April 15. On that day, the active region AR9415, in decay phase but still with beta-gamma magnetic configuration, produced an X14.4/2B flare, which peaked at 13:50 UT (Figure 4, large panel). As reported by NOAA/SEC, this flare was associated with a CME (Figure 4, left panels), a 48000 SFU (Solar Flux Units) Tenflare, Type II and IV radio bursts, solar proton events at greater than 100 MeV and 10 MeV with an associated polar cap absorption (PCA) and a ground level event (GLE) on the same day. The passage at the Earth of the CME on April 18 disturbed the geomagnetic field to high and severe storm levels (Figure 5, bottom panel).

The radio manifestations of the flare were observed by TSRS as a series of great bursts at decimetric wavelenghts and strong Type IV bursts at metric ones (Figure 6). A detailed analysis of high time resolution recordings shows that at 2695 MHz as well as in the other frequency channels (Figure 7) a possible radio precursor occurred at 13:38 UT. In the decimetric bands the radio flare starts at 13:44 UT and two minutes later in the metric ones, where a Type II burst was detected a few minutes before the X-ray peak at 13:50 UT.

Radio indexes are derived as the mean of the radio flux density over 10-minutes time intervals for each circular polarization component, i.e., the Left-handed (LCP) and the Right-handed (RCP) one, and

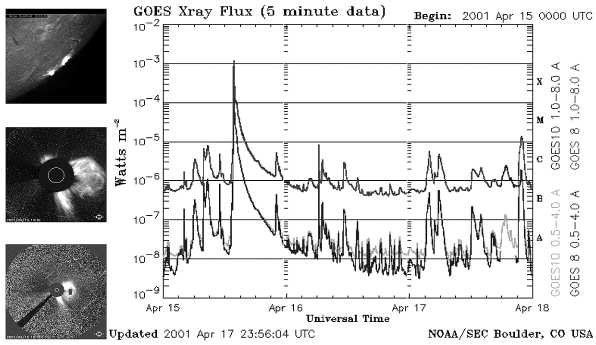

Figure 4. GOES and SOHO data relevant to the X14.4/2B major flare occurred on 2001 April 15.

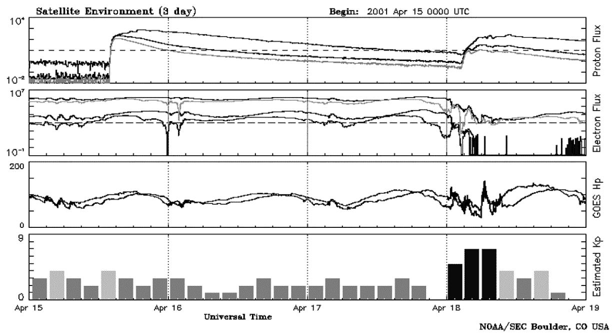

Figure 5. NOAA/SEC data for the satellite environment from 2001 April 15 to 17.

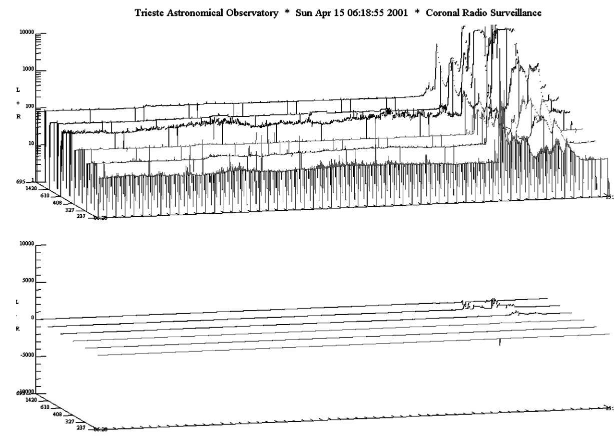

Figure 6. Multi-channel synoptic graph of the radio emission of the perturbed corona observed by TSRS.

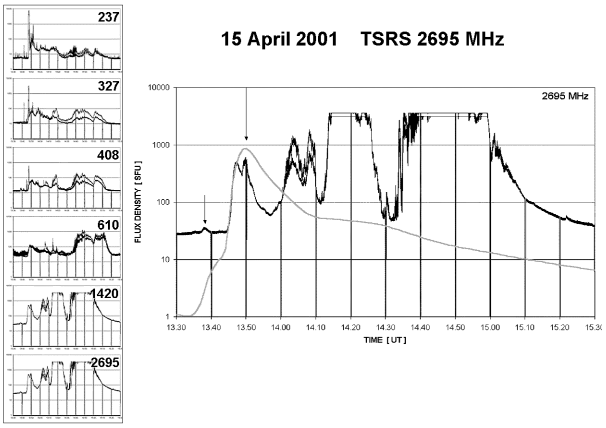

Figure 7. Time evolution of the Tenflare at 2695 MHz with respect to the X-ray flare evolution.

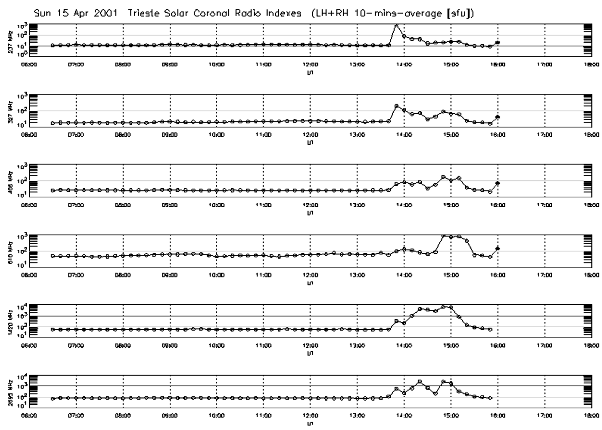

Figure 8. Time evolution of the TSRS 10-mins averaged (LCP+RCP) radio indexes for 2001 April 15.

for the total (LCP+RCP) radio flux density. Figure 8 depicts the time evolution of the total radio indexes for each TSRS frequency (2695, bottom panel, to 237 MHz, top panel), which clearly indicates the onset of the coronal perturbation associated with the X14.4/2B flare. The superimposition of such time evolutions with that of the X-ray flare (Figure 9) point out the timing of the radio peaks with respect to the X-ray one and the different radio levels reached at the different frequencies as proxies of the different perturbation levels in plasma layers at increasing altitudes (for decreasing receiving frequencies).

The NRTDP of TSRS uses a time-series projection algorithm to compute values of the radio indexes 10 minutes ahead with respect to the observed ones. Figure 10 shows the time evolution of the observed (solid line) and predicted (dashed line) total radio index at 2695 MHz on 2001 April 15. The prediction was acceptably successful in the time profile evolution but less accurate in the radio flux level of the peaks.

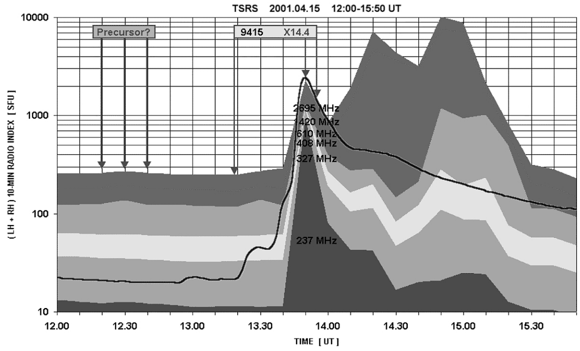

Figure 9. Timing of the radio flare described by the 10-mins radio indexes with respect to the X-ray flare.

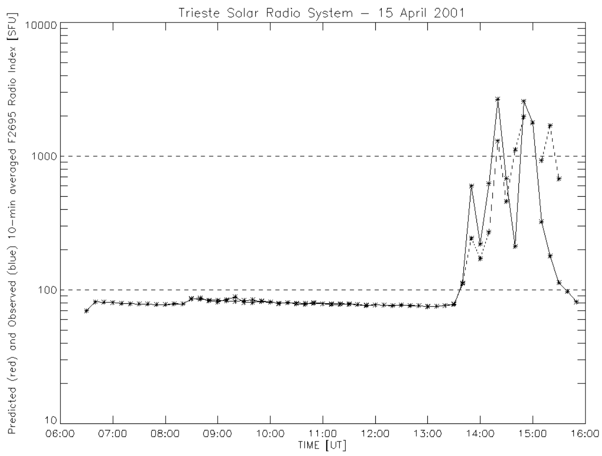

Figure 10. Predicted (dashed) and observed (solid) time evolution of the radio index at 2695 MHz.

4. CONCLUSIONS

TSRS is a flexible tool for surveying the coronal radio activity level and was set up to provide solar radio indexes relevant to SpW modeling. A new operational mode will allow the derivation of such indexes on an 1-minute timescale to better sample fast phenomena and improve their prediction reliability.

ACKNOWLEDGMENTS

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2. NOAA, *Users Guide to The Preliminary Report and Forecast of Solar Geophysical Data*, 2001.