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Research paper

Development of 408MHz V-shape Dipole-based Antenna for Solar Observation

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Abstract

Solar is one of the most observed object in a radio astronomy, as it is highly affects the space weather. In this paper, a new 408 MHz dipole-based antenna for solar radio telescope system is presented. High gain up to 11.30 dBi with beamwidth size of about 58° has been achieved by optimizing the structure of parasitic elements on the antenna. Measurement result shows a good agreement with simulation, with error rate on frequency peak down to 0.98%. The proposed antenna has been utilized in several solar observation and the results are also presented in this paper.

Keywords: *V-Shape, Dipole-based Antenna, Solar Observation.*

1. Introduction

Observations of the solar activity have been started in about 1610 with the invention of the telescope (Steinhilber et al., 2008). Ever since, numbers of information has been collected which enhance the understanding about the Sun. One aspect that deeply investigated in observing the Sun is the effect of solar activity to the Earth.

These research includes the relation between solar activity and seismicity (Gousheva et al., 2003), the influence of solar activity on modes of tropospheric circulation variability (Dorotovic & Trigo, 2010), the effect of solar wind to the Earth geomagnetic activity (Jankovicova et al., 2008), the relationship between surface ozone and smoothed sunspot numbers (Selvaraj et al., 2010) and even to research in field of biology which presents a solution to the problem of how solar activity influences biological objects on the Earth (Evstafyev, 2009).

Nowadays, the observation of the Sun is no longer limited within the optical wavelength, but already expanding from the highest energy gamma ray to the longest wavelength at radio frequency. By observing the Sun in several wavelengths simultaneously, a better understanding about phenomena occurring in the Sun can be achieved. For example is the study the three-dimensional structure of evolving coronal loops and related signatures of impulsive and long-lasting energy release above active regions by combining data obtained from the Very Large Array (VLA), Solar and Heliospheric Observatory (SOHO) and Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) (Willson, 2004). These facilities provide the solar data in radio wavelength, UV and X-ray respectively.

As most of electromagnetic signal from outer space unable to reach the earth surface, many facilities to observe the Sun are located outside the earth atmosphere. SOHO and RHESSI are the examples of these facilities. For this reason, optical wavelength and radio frequency are still considered as the easiest way to observe the Sun as well to conduct the other astronomical research, as the observation can be conducted from the earth surface.

In radio frequency, many features of the Sun can be observed, including the bursts. The solar flare radio emission recorded by the e-CALLISTO spectrometer unit in Siberia, Russian Federation is one sample of this type observation (Monstein, 2010). However, by employing only single element, the data received by this instrument can be altered by the noises from the sky background, due to the large size of the antenna beam. In this paper, a new dipole-based antenna for solar radio telescope system is presented. The radio telescope is operated at 408 MHz, which is a protected frequency by ITU for radio astronomical observation (CRAF, 2005). Parasitic elements has been utilized and optimized to enhance the beamwidth of the antenna and hence the terrestrial communication interferences and sky background noises can be minimized.

2. Antenna Architecture

The 408 MHz V-shape dipole-based antenna without and with one parasitic element has been analyzed in (Anwar et al., 2014). However, the beamwidth is still too large for solar observation and hence another parasitic element has been added and optimized to reduce the sky coverage. Fig. 1 shows the geometry of the proposed antenna, while summary of the antenna parameters are listed in Table 1. The total length of the driven element is 0.165 meters (44.9% λ), while the length of both parasitic elements are 0.294 meters (0.4 λ). The angle between the driven element arms is 130°. Distance of the feed point from the ground is 0.122 meters (λ/6). The first parasitic element is placed 0.245 meters (λ/3) from feed point, while the second parasitic element is separated 0.092 m (λ/8) from the first parasitic element.

It is a common practice to use a dual-polarization dipole-based antenna in a radio telescope system, for example in (Ellingson et al., 2007). The proposed 408 MHz antenna is also developed in same manner, by mounting two units of the proposed antenna orthogonally one to another. Each polarization has their own feed point. Signals from these feed points are combined by utilizing a power combiner, as shown in Fig. 2.

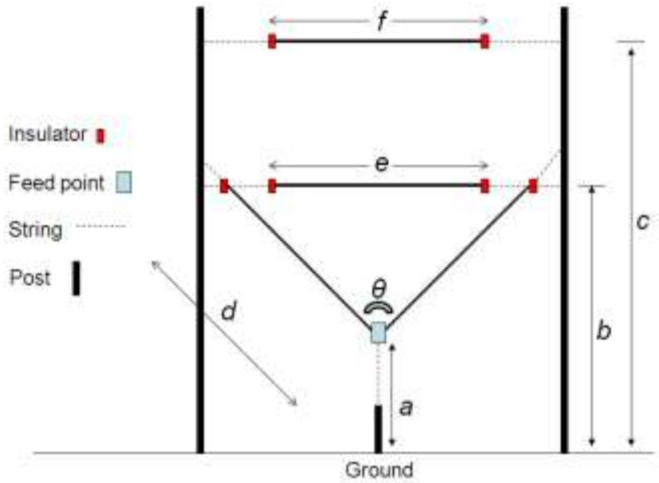

Fig. 1: Geometry of the proposed 408 MHz antenna

Table 1: Summary of the proposed 408 MHz antenna parameters

Parameters	Values
Height of feed point (a)	0.122 m (λ/6)
1st parasitic element (b)	0.245 m (λ/3 from feed point)
2nd parasitic element (c)	0.092 m (λ/8 from 1st PE)
Length of dipole arm (d)	0.165 m (22.45% λ)
Length of 1st PE (e)	0.294 m (0.4 λ)
Length of 2nd PE (f)	0.294 m (0.4 λ)
V-shape angle (θ)	130°

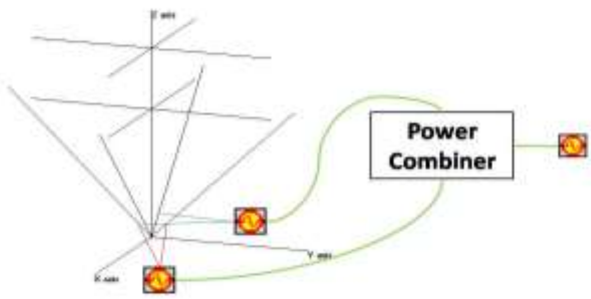

Fig. 2: Basic diagram of the dual-polarization V-shape dipole-based antenna

3. Results & Discussion

The parametric studies of the proposed antenna have been analyzed and optimized using numerical electromagnetic code based software (NEC4WIN95). The simulations are conducted with perfect ground parameters and 50 ohms impedance at the terminal point. Conductive wires with six millimeter of diameter are utilized to construct the design in the simulations. Through a series of simulations of varying the design parameters, the optimized results are obtained for the required return loss and radiation pattern.

Fig. 3, 4 and 5 shows the variation of Standing Wave Ratio (SWR), beamwidth and gain of the proposed antenna with two parasitic elements respectively. In general, at longer length of the second parasitic element, the parameter values are disperse widely, probably due to complex interaction between the driven element, first and second parasitic elements as well as the reflection from the ground. However, as the length is reduced, the values are changing convergent to the values as if the proposed antenna only utilizing one parasitic element, which is similar to the effect of the first parasitic element toward the proposed antenna without parasitic element.

Length of 0.4λ and separation of λ/8 from first parasitic element has been chosen as the second parasitic element geometry, as it provides good trade-off between the investigated parameters. The SWR is 1.615 with beamwidth of 62° and gain of 11.3 dBi. The peak of the SWR actually falls on lower frequency at 402 MHz with SWR value of about 1.463. To obtain the peak of operating frequency at 408 MHz, the total length of the driven element has been trimmed down, from 0.336 meters to 0.330 meters. The peak is then obtained at 408 MHz with SWR level is of about 1.382. Beamwidth and gain are remaining the same, of about 62° and 11.30 dBi respectively. When the proposed antenna was simulated as a dual-polarization antenna, the SWR and gain are remaining the same, while the beamwidth is reduced to 58°.

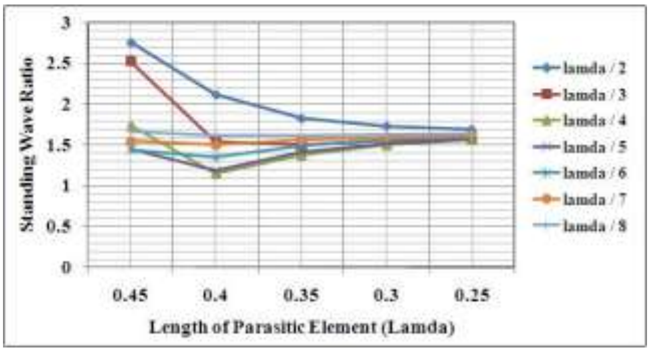

Fig. 3: Variation on SWR on the proposed 408 MHz antenna with two parasitic elements

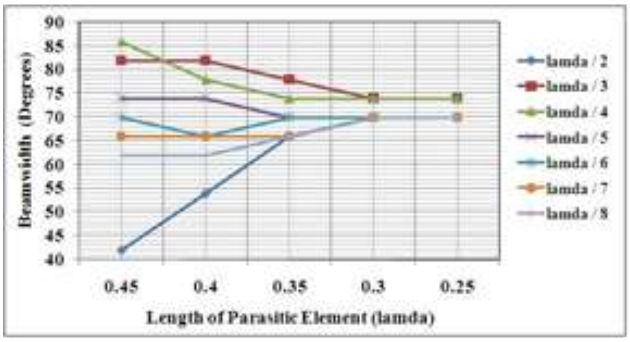

Fig. 4: Variation on beamwidth on the proposed 408 MHz antenna with two parasitic elements

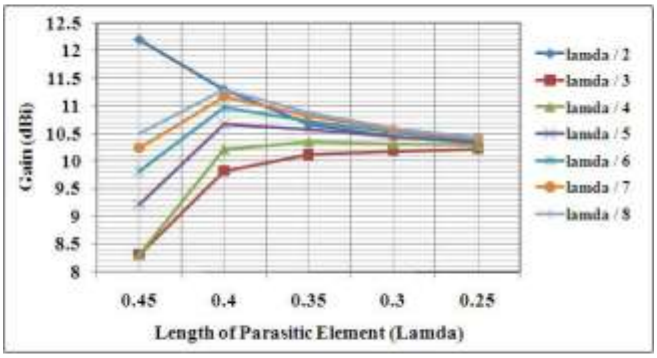

Fig. 5: Variation on gain on the proposed 408 MHz antenna with two parasitic elements

Prototype of the 408 MHz antenna is shown in Fig. 6. Six millimeters aluminium rod is utilized as material for the driven and parasitic elements. It is constructed above a circular plate made of aluminium plate to resemble perfect ground, with some wooden structure to maintain the shape of the plate. To hold the antenna elements, perspex is utilized as the posts. The driven elements for each polarization are fed independently, connected with RG58 coaxial cable. A power combiner is used to combine them into single dual-polarization driven element.

This prototype has been measured, as also shown in Fig. 6. SWR less than two is obtained in two bands. The first band is from 400 MHz to 414 MHz, with peak of SWR occurred at 404 MHz (error rate is 0.98%). The SWR value at this peak is 1.58. The second band is smaller, ranging from 420 MHz to 424 MHz. The peak of SWR is 1.71, occurred at 422 MHz. At 408 MHz, the SWR is 1.72. It is a rare occasion for a dipole-based antenna to have two operating frequencies without the help of trap circuits on it. This shortcoming was happened maybe due to the un-ideal environment where the measurements were conducted. Fig. 7 depicts the comparison of simulated and measured SWR.

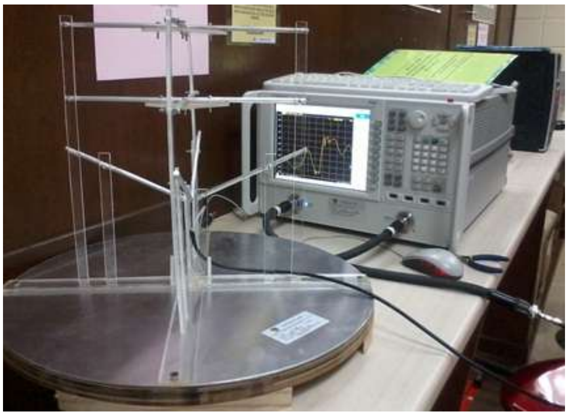

Fig. 6: Prototype of the 408 MHz antenna under measurement

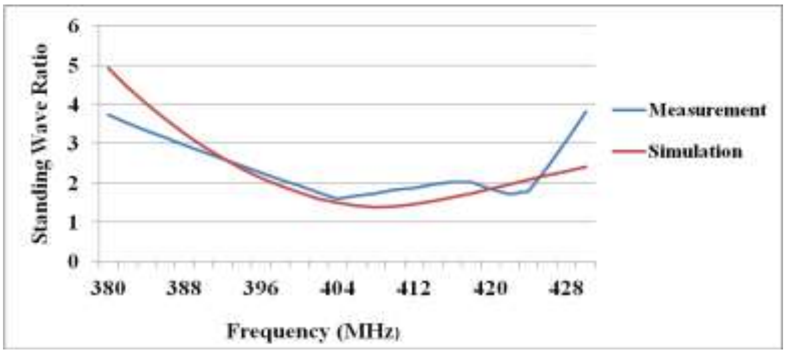

Fig. 7: Comparison on simulated and measured SWR of the 408 MHz antenna

The proposed antenna has been utilized as the front-end module in a radio telescope system in single element mode as well as two elements array system. In array system, the elements were separated of about 50 centimeters long from feed to feed, to resemble a phased array system. Both of the antennas were facing zenith direction, arranged parallel to East-West line. Outdoor LNA was not employed in the system to minimize the system noise figure. Comparison on spectral views obtained by utilizing single antenna, array antenna and 50 ohm calibration is depicted in Fig. 8. It can be seen that despite many Radio Frequency Interferences (RFI) signals were detected by the system in the whole spectral band, 408 MHz is relatively clear and can be used for observation. It should be noted that when a wideband log-periodic antenna is employed as the front-end module, the whole spectrum was saturated with RFI, as has been presented by Zavvari et al. (2014), showing that a narrowband antenna is actually can be helpful in suppressing the RFI compared to a wideband antenna.

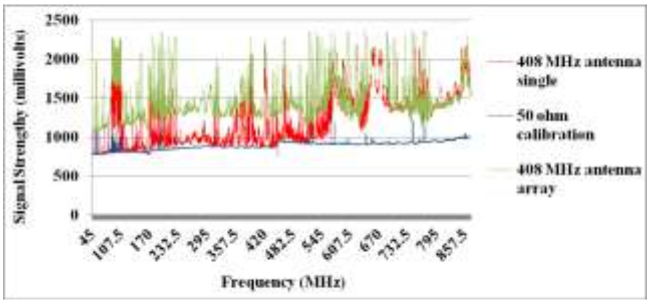

Fig. 8: Comparison on spectral views obtained by utilizing single antenna, array antenna and 50 ohm calibration

Fig. 9 shows the signal strength variability detected by the array system at 28 October 2014. The observation was conducted from 03:30:00 to 06:40:00 UT (11:30:00 to 14:40:00 local time). It can be seen that the received signal was much fluctuated, which might be related with solar activity which was observed by LPI RAS X-ray telescope, occurred within that exact date and time (LPI RAS, 2014).

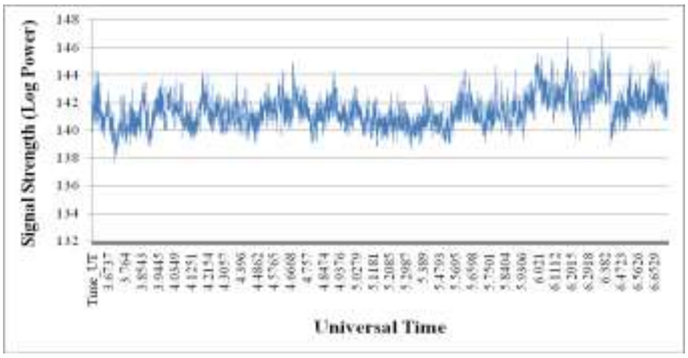

Fig. 9: Signal strength variability observed on 28 October 2014

4. Conclusion

A new 408 MHz V-shape dipole-based antenna for a solar radio telescope system is presented in this paper. It has been shown that by utilizing a parasitic element, beamwidth of the antenna can be adjusted to the required size which is suitable for observation. The antenna geometry has been fully analyzed, while the prototype has been measured and tested. Measurement and observational results shows a good agreement between the design and the prototype. The antenna has been utilized in a radio telescope system in single and array mode for solar observation and some solar activities has been detected by the system.

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