Multiband VHF Antenna for Low-Frequency Transient Radio Telescope

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Abstract: Observation at radio wavelength has become a great scientific and applied importance in field of radio astronomy. In this paper, a design of multiband VHF novel antenna for low frequency transient radio telescope is proposed. The multiband has been achieved by combining V-shape half-wavelength dipole, traps and parasitic elements. The low return loss, multiband and maximum gain within the zenith direction is provided by V-shape half-wavelength dipole, traps and parasitic elements respectively. The study showed return loss of about -20 dB, -17 dB and -13.6 dB for three different frequencies with maximum achievable gain of about 10.28 dBi. The proposed antenna can meet well to be used in a transient radio telescope which is operated in the urban centers.

Key-Words: Transient Radio Telescope, V-shape Antenna, Trap

1 Introduction

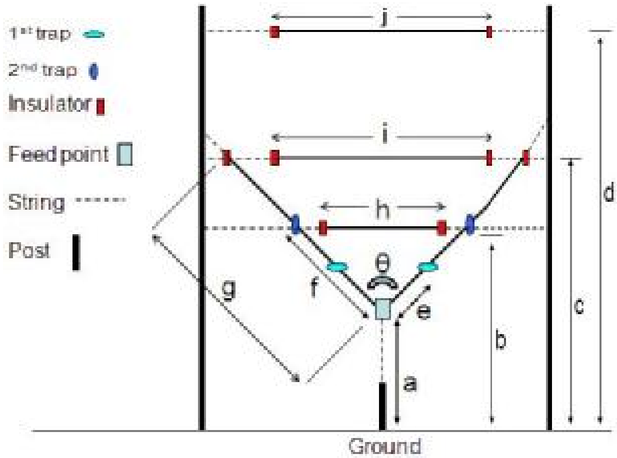
Simple wire dipole antenna has been used in many radio telescope systems. Examples of such radio telescope include the 22-MHz narrowband dipole array at Penticton, British Columbia, active during the 1960s [1] and the Radio JOVE, developed by NASA [2]. However, as it has inherently narrow impedance bandwidth, the observed frequencies are very limited. To achieve large tuning range, previous telescopes such as UTR-2 [3] and TPT [4] used antenna which have inherently large bandwidth, in the sense that the terminal impedance is nearly constant over a large frequency range. Unfortunately, such antennas (the “fat” dipoles and the conical spirals) are mechanically complex, making them expensive, difficult to construct, and prone to maintenance problems [5]. Moreover, antenna with large bandwidth introduced radio frequency interference (RFI) from man-made signals, as reported in [6] and [7].

Due to RFI in radio astronomical observation, radio astronomy observatories are usually sited at great distances from major centers of populations to minimize radio frequency interference from other radio services [8]. Several methods for RFI mitigation have been proposed. For example is spatial filtering of RFI using reference antenna [9]. As most of radio telescopes employ antenna with continuous wide bandwidth, RFI mitigation process usually started after the received signal pass through the antenna. In other words, the antenna itself cannot reject or filter the RFI. Therefore, without a sophisticated receiver system, a radio telescope will be suffered with RFI problem. However, if a radio telescope is designed to observe only within the protected frequency bands by International Telecommunication Union (ITU) for astronomical purposes, radio astronomical observation is possible to be conducted in the urban centers without additional instruments or algorithm at post-processing for FRI mitigation.

In this paper, a design of multiband VHF novel antenna for low-frequency transient radio telescope is proposed. The capability to conduct radio astronomical observation in three frequencies is provided by the proposed antenna. Nevertheless, more operating frequencies can be provided by employing more traps in the antenna. The radio telescope can be used to observe astrophysical phenomena which are suspected to produce single pulses detectable at relatively long wavelengths, as conducted by ETA [10].

2 Design of the Antenna

In VHF region, the assigned frequency bands for astronomical purposes are 37.5 MHz–38.25 MHz, 73.0 MHz–74.6 MHz and 150.05 MHz–153.0 MHz [11]. Therefore, the radio telescope is designed to be operated within these frequency bands. Configuration of the proposed antenna for the radio telescope is shown in Fig. 1. The proposed antenna is a combination of V-shape



half-wavelength dipole, trap and parasitic elements, comprising a driven element in V-shape and three parasitic elements as director. The antenna is designed to operate in three frequency bands where the resonant frequencies are determined by employing two pairs of trap in the driven element. Each trap made by using commercial-off-the shelf components, comprising two inductors and one capacitor in order to keep the trap as light as possible, as heavy weight trap may lead the antenna to be bended downward and hence ruin its V-shape. The inductors are arranged in series form and parallel to capacitor, to perform a band-stop filter.

The overall length of the driven element is about 3.364 meters. The feed point in the center of the driven element is about 1.6 meter above ground, while the other ends of the driven element are hanged on the main post about 2.59 meters above ground, resulting a V-shape antenna with angle between the arms of about 108°.

Yagi-Uda antenna concept [12] is adopted in the proposed antenna director configuration. The first parasitic element is placed at 2.258 meters above the ground with length of 0.888 meters. This length is equal to 90% of half-wavelength of about 152 MHz. The second and third parasitic elements are placed at 2.962 and 4.324 meters respectively above the ground with equal length of 1.839 meters. This length is equal to 90% of half-wavelength of about 73.4 MHz. The distances of these parasitic elements from feed point are about λ/3 of its estimated frequencies. Table one showed the parameters of the proposed antenna.

The traps have been simulated using RFSim99. The first pair of trap comprising 61.5 nH and 49 nH inductors, and a 10 pF capacitor to perform a band-stop filter at 151.403 MHz. The trap is placed at each arm of the driven element at distance of 0.471 meters from feed point. At 150.05 MHz–153.0 MHz, the normalized |S11| parameter of this trap is 1, showing that it can work properly to isolate the signal in the driven element between the trap within this frequency band.

Table 1
Summary of antenna parameters.

Parameters	Values
Feed point (a)	1.6 m
1st parasitic element (b)	2.258 m
2nd parasitic element (c)	2.962 m
3rd parasitic element (d)	4.324 m
1st trap (e)	0.471 m
2nd trap (f)	0.942 m
Driven element (g)	1.682 m
1st parasitic element length (h)	0.888 m
2nd parasitic element length (i)	1.839 m
3rd parasitic element length (j)	1.839 m
Angle (θ)	108°

The second pair of trap comprising 220 nH and 246 nH inductors, and a 10 pF capacitor to operate at 73.727 MHz. It is placed at each arm of the driven element at distance of 0.942 meters from feed point. At 73.0 MHz–74.6 MHz, the normalized |S11| parameter of this trap is 1.

3 Result and 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. Through a series of simulations of varying the design parameters, the optimized results are obtained for the required return loss and radiation pattern.

Simulated return loss and gain of the proposed antenna are shown in Fig. 2 and Fig. 3 respectively. The return loss ≤ -10 dB are obtained at 37.5 MHz – 38.5 MHz, 73.3 MHz – 73.9 MHz and 150.9 MHz – 152 MHz. The study showed that value of inductors within

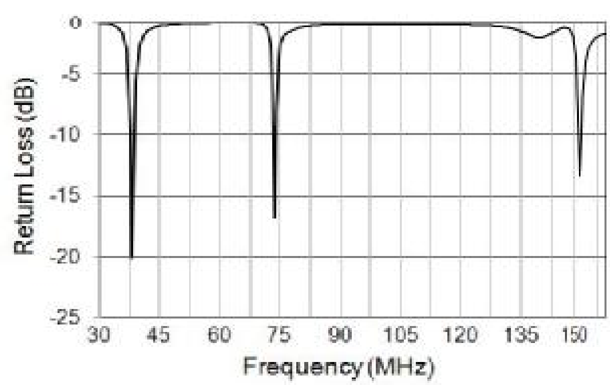


Fig. 2. Simulated return loss of the proposed antenna.

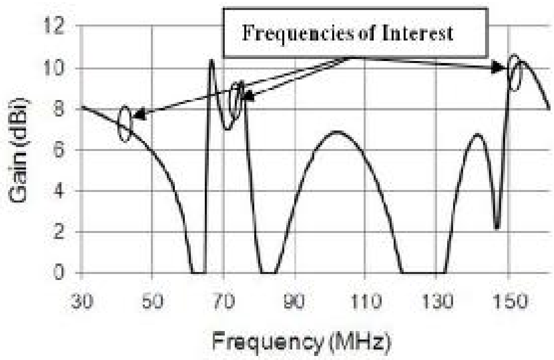


Fig. 3. Simulated gain of the proposed antenna.

the trap can be used to control the proposed antenna's resonant frequency at these frequency bands maintaining the return loss less than -10 dB. At 37.5 MHz – 38.5 MHz, return loss peak of about -20 dB is obtained at 38 MHz, with gain variation ranging from 7.56 to 7.47 dBi along the frequency band. Along 73.3 MHz – 73.9 MHz, gain are varies from 8.21 to 8.81 dBi with peak of return loss of about -17 dB at 72.6 MHz. At 150.9 MHz – 152 MHz, peak of the return loss is about -13.6 dB at 151.4 MHz, with gain variation ranging from 9.97 to 10.28 dBi.

These results are within the protected frequency bands for radio astronomical purposes, except for the first frequency band. A narrow band-pass filter will be used for further limitation of the operating frequencies to ensure that RFI can be avoided. The inductors within the traps also act as coil-loads, resulted the driven element to behave as shortened dipole [13]. Therefore, the length of the driven element is shorter than half-wavelength of the operated frequencies.

In a transient radio telescope, the maximum gain should be achieved at zenith direction. Due to the fix position of the feed point relative to ground measured in unit of wavelength, the direction of the maximum gain of the proposed antenna for the driven element alone will be different for the three operated frequencies. At the middle and highest operated frequencies, maximum gains are not achieved at zenith direction. The parasitic elements as a director are adopted in the proposed design to overcome this shortcoming. These directors provided maximum gain of the antenna within the operated frequencies are in the zenith direction.

Radiation pattern of the proposed antenna has been simulated in the E and H-plane at 38 MHz, 73.6 MHz and 151.4 MHz. At 38 MHz, the maximum gain is about 7.52 dBi with beam-width of 118° at E-plane and 74° at H-plane, as shown in Fig. 4 and Fig. 5 respectively. At 73.6 MHz, the maximum gain is about 8.51 dBi, as shown in Fig. 6 and Fig. 7 respectively. Beam-width at this frequency is 82° at E-plane and 70° at H-plane. At 151.4 MHz the maximum gain is about 10.21 dBi with beam-width of 66° at E-plane and 50° at H-plane. The radiation patterns are shown in Fig. 8 and Fig. 9 respectively. It can be seen that the antenna has almost symmetrical radiation pattern at each simulated frequency. All side-lobes occur in the radiation patterns are below -3dB.

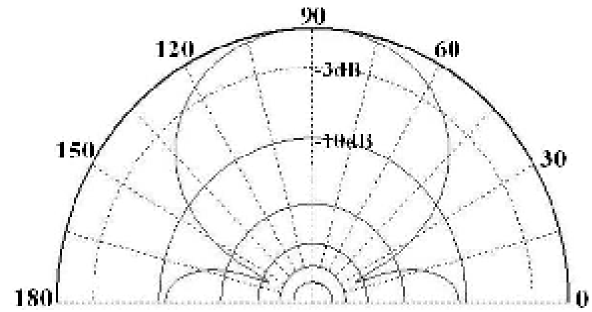


Fig. 4. Far-field E-plane pattern at 38 MHz.

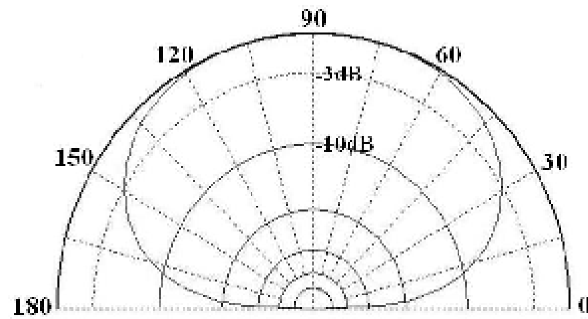


Fig. 5. Far-field H-plane pattern at 38 MHz.

4 Conclusion

A design of multiband VHF antenna for transient radio telescope has been proposed in this paper. The proposed antenna can be operated in three frequencies by using traps, with return loss value down to -20 dB. Simulation results showed that the proposed antenna has suitable radiation patterns to be used in a transient radio telescope. The radio telescope can be operated in urban centers without additional instrument or algorithm for RFI mitigation.

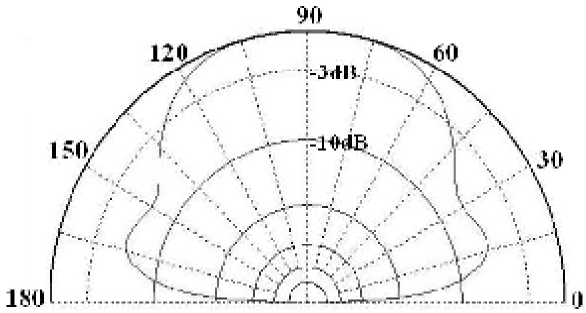


Fig. 6. Far-field E-plane pattern at 73.6 MHz.

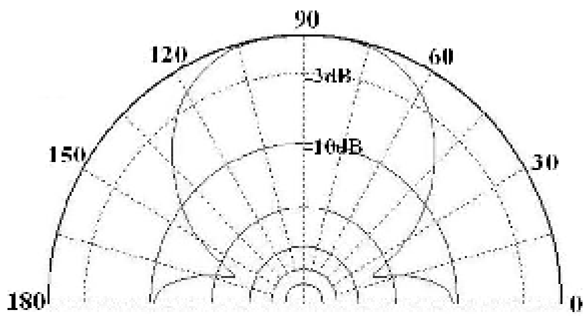


Fig. 7. Far-field H-plane pattern at 73.6 MHz.

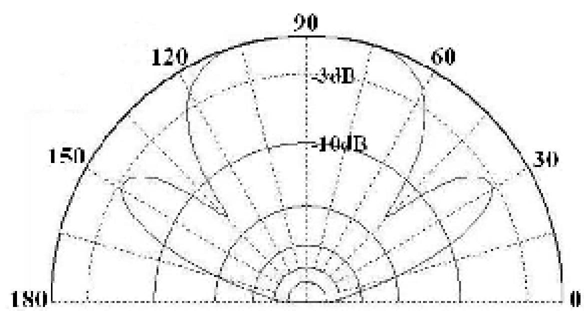


Fig. 8. Far-field E-plane pattern at 151.4 MHz.

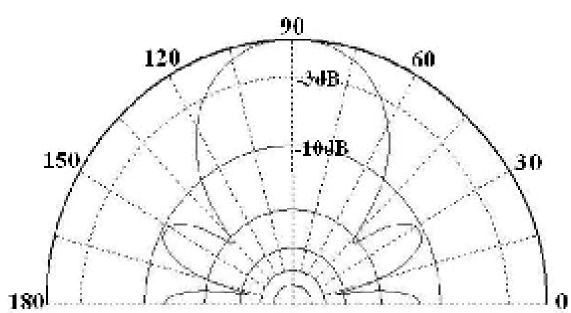


Fig. 9. Far-field H-plane pattern at 151.4 MHz.

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