



Development of V-Shape Dipole Antenna for 20 MHz Astronomical Observation

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Abstract

The utilization of dipole antenna has includes various applications, including communication and astronomy. It has been developed in various manners, from the simple half-wavelength wire antenna to the printed micro strip antenna. This paper presents a V-shape dipole antenna for 20 MHz radio astronomical observation. The V-shape concept is adopted to provide low impedance at terminal point for 50 ohms transmission line. It is also provide a wider beamwidth compared to the conventional half-wavelength dipole antenna, make it suitable to be used in a transient radio telescope system. Simulation result shows that the designed antenna inherits a low SWR (Standing Wave Ratio), of about 1.024, relatively wide beamwidth, up to 114°, and a good achievable maximum gain of 7.85 dBi at zenith direction. The prototype of the designed antenna has been constructed and installed in the antenna farm for radio astronomy research at the National Space Center of Malaysia, Banting, Selangor. Some preliminary observational data are also presented in this paper.

Keywords: Antenna, Dipole, V-Shape, Astronomical observation

1. Introduction

Dipole antenna has been developed in various manners and employed in many applications, including for radar (Song et al., 2015), satellite communication (Parameswari et al., 2015), indoor

base station (Bakar et al., 2015), Near Vertical Incidence Skywave (NVIS) communication (Witvliet et al., 2015), WLAN (Pawar & Shandilya, 2016; Maricar et al., 2016) and RFID (Yu et al., 2015; Zuffanelli et al., 2016). It is also has been utilized as a wearable antenna in the Wireless Body Area Network (WBAN) application (Acti et al., 2016; Wang et al., 2016).

In radio astronomy, dipole antenna has been utilized in many low-frequency radio telescope systems, including the Long Wavelength Array (LWA) (Ellingson et al., 2013), Low Frequency Array (LOFAR) (van Haarlem et al., 2013) and Radio JOVE project (NASA). Most of these systems are employing either the conventional half-wavelength dipole or the inverted-V dipole antenna. In this paper, a new 20 MHz V-shape dipole antenna has been designed and used in a low-frequency radio telescope system. The V-shape concept provides a lower standing wave ratio at its resonant frequency compared to the inverted-V, and inherits a more compact geometry compared to the conventional half-wavelength dipole antenna. Moreover, the impedance at the terminal point is 50 ohms, which is suitable for most of receiver or spectrum analyzer nowadays.

2. Antenna Architecture

20 MHz is not among the protected frequency for radio astronomy application by the International Telecommunication Union (ITU). However, it is utilized by NASA in Radio JOVE project for solar and Jupiter observations. The applicability on using this frequency for radio astronomy observation will vary based on location. The designed antenna is meant to provide an alternative design for similar observation, with 50 ohms impedance at the terminal point and hence it can be combined with various receiver modules.

The entire geometry of the designed antenna is shown in Fig. 1, while the summary of the antenna geometry is listed in Table 1. The antenna is placed of about 1/6 lambda above the ground, which is 2.5 meters high. The length of total dipole arms is 7.3 meters, with angle between the dipole arms of about 110°.

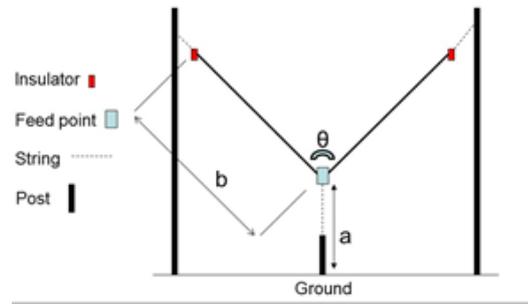


Fig.1: Geometry of the designed antenna

Table 1: Summary of the antenna geometry

| Parameters | Values |
|--|----------------------------|
| Height of feed point from ground (a) | 2.5 meters ($\lambda/6$) |
| Length of dipole arm (b) | 3.65 meters |
| Angle between the dipole arms (θ) | 110° |

3. Results and Discussion

Design of the antenna has been simulated with numerical electromagnetics code software. Table 2 shows the summary of the antenna characteristic. It can be seen that the achieved SWR is very low, of about 1.024, with gain of about 7.85 dBi and beamwidth of about 114°.

Table 2: Summary of the antenna characteristics

| Parameters | Values |
|------------|----------|
| SWR | 1.024 |
| Gain | 7.85 dBi |
| Beamwidth | 114° |

As a transient antenna facing the zenith direction, the designed antenna is highly affected by the incident signal reflected by the ground. It can be observed from Fig. 2 that the antenna SWR is changing as the antenna heights are varied. However, ground is not the only component that affects the antenna SWR. The angle between the dipole arms is clearly put some effect on the antenna SWR. When the angle between the arms is small, the arms are facing each other and hence the capacitive component of the antenna is also relatively small. As the angle between the arms is increases, the capacitive component is also increases, resulting some changes at the reactive component, and thus the impedance, of the antenna.

Ground is not only affecting the SWR, but also the gain of the antenna. As the antenna is placed at shorter distance to the ground, gain of the antenna is increases, as shown in Fig. 3. Since the antenna gain is inversely proportional with its beamwidth, the beamwidth is decreasing as the gain is increasing (Fig. 4).

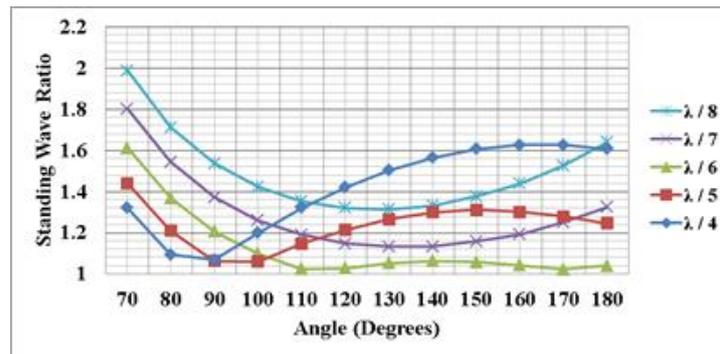


Fig.2: SWR variation of the designed antenna

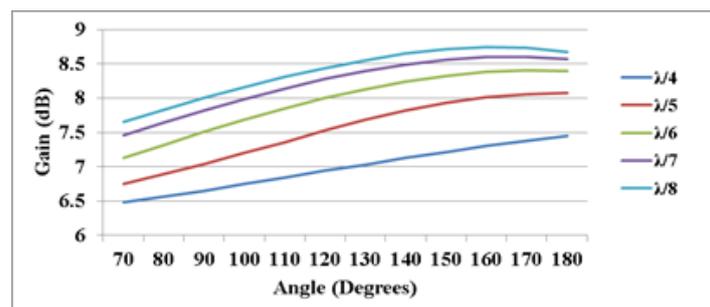


Fig.3: Gain variation of the designed antenna

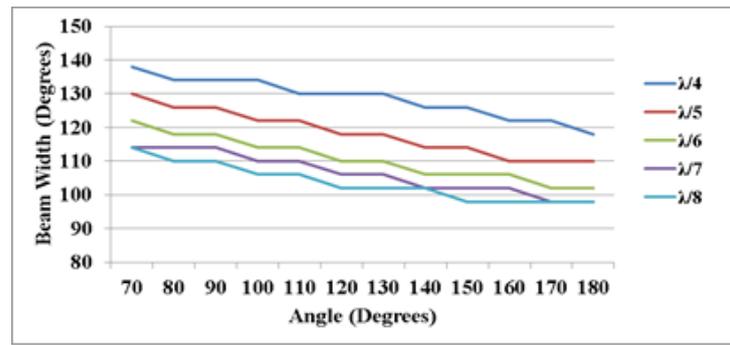


Fig.4: Beamwidth variation of the designed antenna

Since the antenna geometry is relatively large, measurement in an anechoic chamber was unable to be conducted. The proposed geometry was directly constructed and used for observation. The designed antenna has been installed in an antenna farm at the National Space Center of Malaysia, Banting, Selangor (2.783N, 101.507E), as shown in Fig. 5. The antenna is made by utilizing 6 millimeters aluminium rod. Due to the extreme weather in Malaysia, posts from stainless steel have been utilized as the support of the antenna, instead of PVC or acrylic. These posts may slightly change the antenna characteristic, but not to the extreme numbers.



Fig.5: The installed antenna

Fig. 6 depicts the first light of a radio telescope system with the designed antenna utilized as the system’s front end. Around 07:07:25 UT, the antenna was connected with the receiver, shown by the increment of the background static. It is mostly contributed by the Sun with some additional signal from galactic background noise. After the antenna perfectly connected with receiver, the observation frequency was swept throughout the receiver coverage (19.950 MHz - 20.250 MHz). Some communication signals were detected, shown by the strong narrow peaks occurred at around 07:07:30 UT and 07:08:25 UT. Unfortunately, the frequencies of these stations were not recorded.

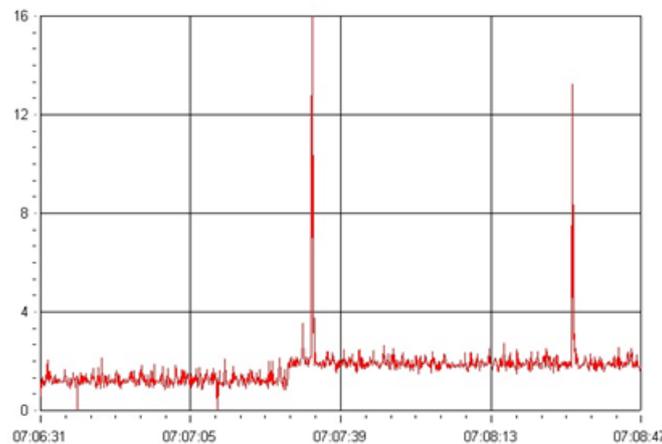


Fig.6: First light of the radio telescope system

Fig. 7 shows another signal captured by the radio telescope system. As the observed frequency was swept, the system detected a communication signal from a station and some lightning from distant place, within the beam coverage of the antenna. These lightning are shown by a smaller peaks occurred at random time.

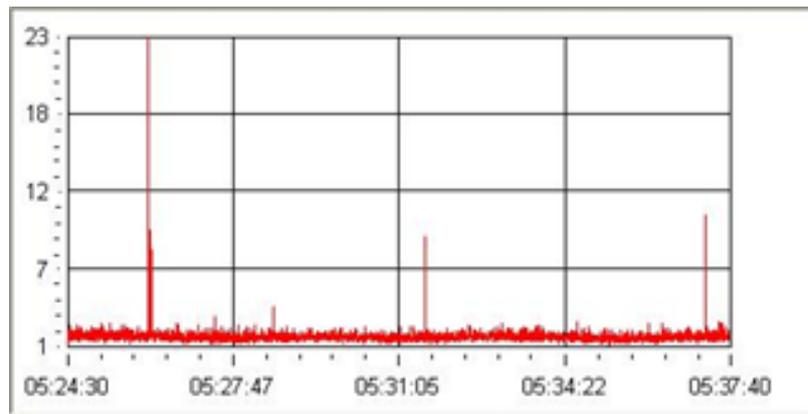


Fig. 7: Some distant lightning detected by the radio telescope system

4. Conclusion

Design of a 20 MHz V-shape dipole antenna has been proposed in this paper. The designed antenna has been constructed and utilized for astronomical observation. Since the geometry of the antenna is large, it is difficult to verify the parameters in an anechoic chamber and hence it was tested directly through field measurement. It has been showed that the antenna can operate properly in detecting sky noises which mostly were contributed by the Sun. The antenna prototype has been installed and operated at the National Space Center of Malaysia for solar monitoring.

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