The simulated results of folded log-periodic antenna used for observing the sun

Sha Li[(1)], Yihua Yan [(1)], Zhijun Chen[(1)] and Wei Wang[(1)]
(1) Key Laboratory of Solar Activity, National Astronomical Observatories, Chinese Academy of Sciences

Abstract

Log periodic antenna is a well-known frequency independent antenna, it radiates structures capable of maintaining consistent impedance characteristics over wide bandwidth. This log periodic antenna is used in many broadband applications due to the ability of achieving constant gain. Hence, a folded log periodic antenna array was simulated in 30-400 MHz frequency band for Meridian project. In order to improve its return loss, this antenna is optimized with the width of each pole and the height of the substrate. This optimized process has been implemented in simulated software HFSS. The original results are shown in this paper.

1. Introduction

Mingantu Spectral Radio heliograph (MUSER) is an aperture synthesis solar radio heliograph located in Inner Mongolia. It consists of 100 reflector antennas, which are grouped into two antenna arrays (MUSER-I and MUSER-II) for low and high frequency bands respectively. The frequency band of MUSER-I is 0.4-2GHz and for MUSER-II, the frequency band is 2-15GHz. Now, another new frequency band of 30-400MHz telescope is investigated for observing the Sun in lower frequency band.

In solar radio observations, the Sun exhibits a variety of large dynamic phenomena in different frequencies. At the same time, it transmits constant energy to the Earth. These phenomena reveal the links between solar astronomy and other branches of physics. The gyro-synchrotron emission has been tried as an explanation for most of the broad band types of burst, which are observed due to plasma emission processes. because the study of meterwave solar radio bursts leads naturally to a study of the theory of waves in a plasma.

Considering solar flares at various heights in the atmosphere ranging below the chromosphere through the corona and into interplanetary space, it is not easy to relate the manifestations in one wavelength because flares often include a wide range of phenomena. At each height range observations in specific wavelength bands have provided different information. The magnetic field strength in the corona within active regions is rather uncertain because there are yet no reliable techniques for making direct measurements. The best values to date come indirectly form radio observations. Over the whole electromagnetic spectrum of the Sun the meter wavelength band is unique, the photosphere and chromosphere and longer wavelength come mainly from interplanetary space, meter waves alone are generated in the tenuous plasma known as the solar corona, and they reveal a spectacular range of phenomena undreamed.

Bursts of hard X-rays and centimeter radio waves attributed to electrons with E>10keV gyrates on filed lines of magnetic tubes. The initiation of a shock wave, manifested a few minutes later by a burst at meter and longer wavelengths. Hence, it is necessary to establish telescope with wide frequency band. Since we have already built telescopes with decimeter and centimeter, the next plan is to establish telescope with 30-400MHz telescope, which is different from the former ones, this meter wavelength telescope will be designed as folded log-periodic antenna, also all the antennas are located in three spiral beams.

2. Traditional Log periodic antennas

A series of printed log-periodic antennas were proposed and all of them are evolved from the traditional LPDA, Cross feeding structure was adopted, which feeds on one side of short dipole. This kind of feeding method is disadvantageous for being integrated. However, Log-periodic dipole antenna (LPDA) is widely used due to its simple structure, good performance and wide bandwidth. The basic concept is the gradually expanding periodic dipoles radiating most effectively when the array are near resonant so that the change of an antenna characteristics in a cycle is a little, therefore LPDA belongs to the non-frequency-dependent antenna and it is the representative of the popular wideband antennas. LPDA is a classic non-repeat form of frequency varying antenna, its impedance and radiation characteristics are repeated by the logarithm of the frequency. The transmission of electromagnetic energy is from the feed point along the antenna structure to push forward. The resonance occurs at the teeth of a quarter-wavelength and then the radiation occurs. The remaining part of energy will move forward, and then reflect back at the end of the antenna, where the energy is weak. When the frequency is changed, the resonant point will move too. But the geometric form of the antenna will not be effected by the move of the resonant point. The feed way of LPDA is cross power feeding. The feeder is a cross-connect between two adjacent poles, and the purpose is to ensure the poles in the radiation area can obtain appropriate phase relationship. So that the phase of long poles is before the short ones, thereby the result is the end fire pointing to the vertex direction. Fig.1 gives the schematic of log periodic antenna array.

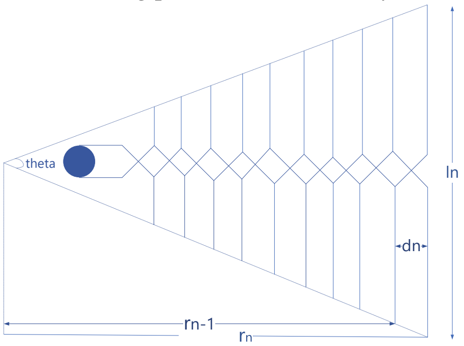

Figure1. The schematic of the LPDA

The features of pattern, gain and impedance depend on the scaling factor τ

$$\frac{l_n}{l_{n-1}} = \frac{r_n}{r_{n-1}} = \frac{d_n}{d_{n-1}} = \tau \qquad (1)$$

$$d_n = (1-\tau)\cdot r_n \qquad (2)$$

$$theta = \tan^{(-1)}\left(\frac{l_n}{r_n}\right) \qquad (3)$$

In these three equations, l represents the half wavelength of the pole, r is the distance between the vertex and each pole, d is the distance between two adjacent dipoles. Theta represents the angle. At the end of the feed lines, it can be connected with a resistance equal to its characteristic impedance, as well as up to the back of the unit within $\lambda_{\max}/8$ distance. The characteristic impedance of the feeder can affect the input impedance of the antenna. Its relationship is expressed as

$$Z_c = \frac{Z_0}{\sqrt{1+\frac{Z_0\sqrt{\tau}}{4\sigma Z_a}}} \qquad (4)$$

The length of all the pairs of pole is half wavelength. The frequency band is 30-400MHz, hence the longest length of a pair of dipole is 5m. The traditional LPDA shown in fig.2 is simulated, the size of this antenna will be very large, it is not suitable for the requirement of project. So a folded LPDA is designed and simulated. Figure 3 gives 3-dimension radiation pattern at 200MHz. The biggest gain value is about 11.7dBi.

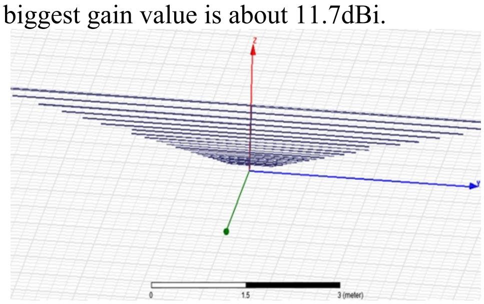

Figure 2. Log periodic antenna

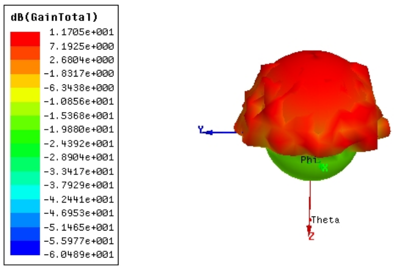

Figure 3. 3D radiation pattern at 200MHz

3. The design process of folded LPDA

According to the big size of traditional LPDA, this folded antenna model is also set up in the software HFSS. Modeling process is illustrated as follows, major parameters are confirmed, some other parameters are optimized in an appropriate range in the software and then choose the best parameter. When the distance between feeder lines is too small, the current amplitude will also be inverted, so that in the far-field region, it will affect each other.

The shape of the folded LPDA is much like the normal LPDA. The frequency band width is 30-400MHz, the designed return loss is less than -10dB, the Gain is larger than 6dBi. The folded LPDA is comprised of substrate, feed lines and poles. The geometry and configuration of the folded LPDA is shown in fig3. A 3mm-thick FR4 antenna substrate with a permitivity of 4.4 and loss tangent of 0.02 is used, the length, width and the height of the substrate dimension are set as 2*1*(0.003) m^3. Finally, the main PCB of the dimension is the system plane.

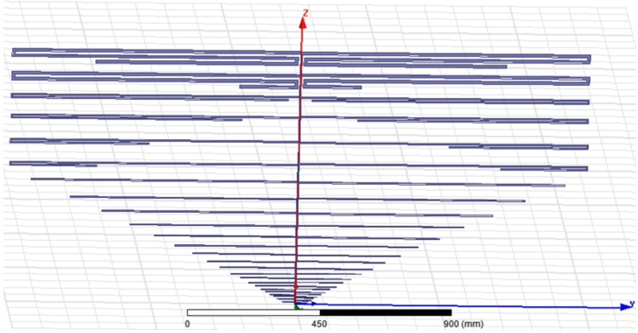

Figure 4. The folded LPDA

Fig4 shows the folded dipoles arranged in simulated software. The maximum length of dipole is 2m and the height of the LPDA is 1m. The number of the dipoles is 27, the shortest and the longest poles are designed as l_0 and l_{26}, the distance between the pole and the original point is represented as d, the width of each pole is w. The values of each pole are given in Table.1:

Table1. Parameters of the proposed antenna

dipole	Length(mm)	distance(mm)	width(mm)
l_0	40	3.6	1.0
l_1	46.8	7.7	1.1
l_2	55	12.5	1.2

l_3	64	18	1.3
l_4	75	24.3	1.4
l_5	87.6	31.5	1.5
l_6	103	39.8	1.6
l_7	120	49.4	1.7
l_8	140	60.4	1.9
l_9	164	73.1	2
l_{10}	192	87.7	2.2
l_{11}	226	104	2.3
l_{12}	264	124	2.5
l_{13}	308	146	2.7
l_{14}	360	171	2.9
l_{15}	422	201	3.2
l_{16}	494	234	3.4
l_{17}	578	273	3.6
l_{18}	676	318	4
l_{19}	788	369	4.3
l_{20}	924	428	4.7
l_{21}	1300	495	5
l_{22}	1480	573	5
l_{23}	1800	663	5
l_{24}	1960	733	5
l_{25}	2200	813	5
l_{26}	2700	893	5

At the beginning of simulation, the widths of the dipoles use the value listed in the table, and then the thickness of the optimized value is from 2 to 20mm.

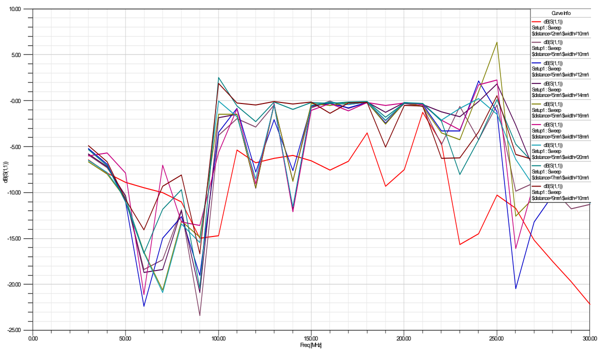

Figure 5. The return loss of the antenna at three different parameters

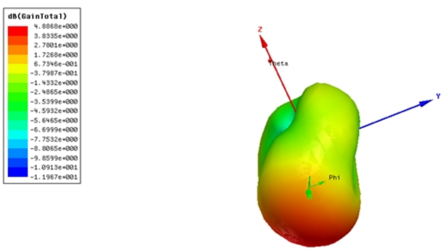

Figure 6. The radiation pattern at f=0.1GHz

The simulated return loss is shown in figure 5, different parameters show different simulated results. According to this calculation, we could pick up an optimized parameters for this log-periodic antenna. The next step is to find a more optimized parameter, the aim of the return loss is less than -10dB. Up to now, this is just an original optimized parameters we have calculated. Much work will be done later.

4. Conclusion

In this paper, the author presents a novel type of folded LPDA, which is operated over the width from 30 MHz to 400 MHz, the Gain fluctuation could be improved by optimizing the width and length of the dipoles. Compared with the conventional unfolded LPDA, the folded LPDA has compact size and similar radiation characteristics. Hence, the next work will be done to make physical antenna model and measurement.

5. Acknowledgements

This work is supported by the National Natural Science Foundations of China (Grant Nos. 61572461, 11790301, 11790305, 11573043, 11433006).

6. References

1. Chen Z N, Chia Y W M. Broadband monopole antenna with parasitic planar element[J]. Microwave and Optical Technology Letters, 2000, 27(3): 209-210.
2. Chuang K. Wideband CPW fed monopole antenna with parasitic element and slot[J]. Electronics Letters, 2004, 40(17): 1038-1040.
3.Sha Li, Yan Yihua, Chen Zhijun, Wei Wang, A New Impedance Matching Method for anUltra-Wide Band and Dual Circularly Polarised Feed, PASA, 2016, 33(e061): 2~8.
4. Sha LI, Yihua YAN, Zhijun CHEN, Wei WANG, Fushun ZHANG. Design of dual circularly polarized 2-15GHz feed and the polarization degree measurement for CSRH-II antenna system", PASA, 2015(32): pp.1-7 doi:10.1017/pasa.2015.14.
5. Ju Wang, Kang An, Yan Liu Department of Electronic and Information Engineering, Beihang University Beijing, 100191, China. Analysis of electrical characteristics of LPDA and HFSS simulation design[A]. IEEE Beijing Section、Beijing Jiaotong University. Proceedings of 2011 4th IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications[C]. IEEE Beijing SectionBeijing Jiaotong University:,2011:4.
6. A size-reduced log periodic dipole antenna[J], Journal of Electronics,2006,(06):913-914.
7. Sha Li, Yi-Hua Yan, Zhi-Jun Chen, Wei Wang, Dong-Hao Liu. Antenna system characteristics and solar radio burst observations[J].Research in Astronomy and Astrophysics,2015,15(11):1917-1930.
8. Sergey V.Lesovoi, Alexander T. Altyntsev, Eugene F.Ivanov, Alexey V.Gubin. A 96-antenna radioheliograph[J]. Research in Astronomy and Astrophysics, 2014,14(07):864-868.