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Wideband and high-gain BeiDou antenna with a sequential feed network for satellite tracking

Key words: BeiDou antenna; Wideband circularly polarized radiation; Four-port sequential feed network; Global navigation satellite system (GNSS) receiver; Satellite tracking

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Motivation

1. BeiDou antenna is an important terminal equipment of the BeiDou navigation system. BeiDou-3 navigation satellite system was officially opened in 2020. While bringing high-performance services to people around the world, the navigation system requires well-designed BeiDou antennas. The current BeiDou antenna has the problems of narrow bandwidth and high axis ratio.
2. We are committed to designing a BeiDou antenna with broadband and high performance to meet the requirements of the future BeiDou navigation system.

Main idea

1. BeiDou antenna uses broadband feed network to achieve broadband working band.
2. The broadband feed network is realized by power splitter and phase shifter.
3. The small size of the feed network can realize the miniaturization of the BeiDou antenna.
4. The BeiDou receiver is used to test the actual positioning results of the BeiDou antenna.

Method

1. A broadband circular polarization feed network is designed through the combination of Wilkinson power splitter and 180° / 90° broadband phase shifter. Then the broadband circular polarization of the antenna is realized through the feed network.
2. 180° broadband power division phase shifter and 90° broadband power division phase shifter are etched on the upper and lower layers of the dielectric plate respectively, and the profile size of the feed network is greatly reduced through this structure, and the antenna is miniaturized.

Major results

1. The test results of the antenna prototype are as follows:

Table 1 Measurement results of the proposed antenna

Bandwidth (GHz)		RHCP gain	Size
$S_{11} < -10$ dB	AR < 3 dB	(dBi)	(mm×mm×mm)
1.05–1.80	1.05–1.80	4.0–7.1	120×120×20

AR: axial ratio; RHCP: right-handed circular polarization

Major results (Cont'd)

2. Results of the proposed antenna comparison with other similar literature

Table 2 Comparison of our proposed antenna with those proposed in other studies

Reference	Bandwidth (GHz)	CP BW	RHCP gain (dBi)	Size (mm×mm× mm)
Liu SH et al., 2019	1.40–1.68	14.5%	7–8*	200×200×4.8
Sun et al., 2014	1.192–1.215 1.258–1.278 1.559–1.591	5.5%	–10–1*	π ×30×12
Tamjid et al., 2020	1.16–1.61	32.5%	4.80–7.33	112×112×30
Yang et al., 2019	1.538–1.685 2.400–2.525	2.6%	3.3–4.2	70×70×4.6
Zhang HL et al., 2019	1.04–2.00	52.4%	2–4	80×80×29*
This work	1.05–1.80	52.6%	4.0–7.1	120×120×20

* The value is read from a plot and it can have $\pm 10\%$ error in reading.
CP BW: circular polarization bandwidth; RHCP: right-handed circular polarization

Conclusions

The opening of the BeiDou-3 navigation satellite system has promoted the development of BeiDou antennas, and a wideband GNSS antenna loaded with a four-port sequential feed network was proposed. By analyzing the principle of the phase shifter, we designed a high-precision phase shift power divider with a phase imbalance $<7^\circ$ and a bandwidth that covers the entire GNSS frequency band. The main structure of the antenna uses four rectangular patches to achieve high gain. Measurement results show that the highest gain is 7.1 dB, which is higher than those of most microstrip GNSS antennas. The proposed antenna can track 24 satellites (12 BeiDou satellites) when connected to a GNSS receiver, and the C/N_0 is greater than 30. In short, the developed antenna could be a good candidate for BeiDou applications or other GNSSs.



Zhuolin DENG, born in 1998, is currently a first-year PhD student at Hunan University. His main research interests are BeiDou antenna theory and design and electromagnetic compatibility.



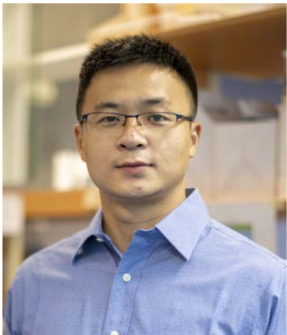
Zhongyu TIAN graduated from Hunan University in 2023 with a master's degree in engineering. The research contents include the theory and design of irregular array antenna and BeiDou antenna.



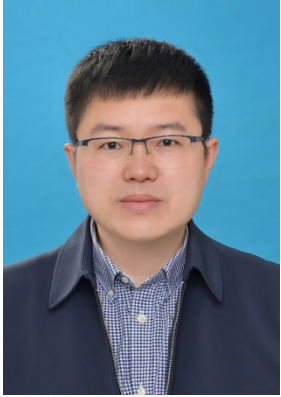
Chenhe DUAN graduated from Hunan University in 2023 with a master's degree in engineering. The research contents include radar scattering cross sections and polarized rotating surfaces.



Pei XIAO, born in 1989 in Hunan, PhD, associate researcher, graduated from the University of Electronic Science and Technology of China. He joined the School of Electrical and Information Engineering of Hunan University full-time in July 2019, and was appointed as an associate researcher of Hunan University in January 2021. He is engaged mainly in ship/submarine/carrier-borne aircraft/large electric drive platform/high voltage pulse device/integrated circuit/SiC power semiconductor device and other electromagnetic interference modeling, calculation methods and protection design research, and antenna theory and technology teaching and research work.



Zhu LIU received the PhD degree from the University of Electronic Science and Technology of China in 2018. He conducted research work with Hunan University from January to September 2019 as a postdoctor. He is currently as a research fellow in the National University of Singapore, Singapore. From 2017 to 2018, he was a visiting scholar with Dalhousie University, Halifax, NS, Canada, sponsored by China Scholarship Council (CSC). His research interests include wireless power transfer, wireless energy harvesting, antennas, and wearable electronics.



Gaosheng LI, born in 1980, Doctor, professor, doctoral supervisor. He received his bachelor's, master's, and doctor's degrees from National University of Defense Technology in 2002, 2004, and 2013, respectively, served as an assistant professor, lecturer, and associate professor of National University of Defense Technology in 2004, 2006, and 2011, a professor of Hunan University in 2018, a deputy director of the Department of Electronics in 2019, and a secretary of the Department of Electronics in 2020, and an assistant to the Dean of the School of Electrical and Information Engineering in 2021. He is also responsible professor of Electronic Information Engineering (national first-class undergraduate major) and director of Antenna and Electromagnetic Compatibility Research Center. His research interests include antenna theory and technology, electromagnetic compatibility, and protection technology.