Design of an Active Scalable Phased Array Antenna System

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***Abstract*—This paper describes a scalable polarization reconfigurable phased array antenna system. The system was realized by using a beamformer and designing a more efficient and flexible power supply and control system, which could be exceedingly helpful to achieve a more flexible ground station design and satellite communication test. As a result, more flexible beam scanning and higher gain could be achieved. The design was simulated by CST Microwave Studio. The complexity of the system was significantly reduced by using the modular design of the active phase control structure.**

***Keywords*—polarization reconfigurable, reconfigurable antennas, phased array antenna, modular design, active phase control.**

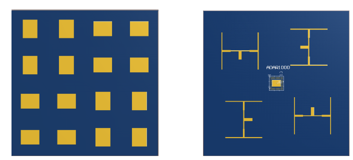
I. Introduction

With the continuous development of commercialization of aerospace projects [1], more and more small satellites are widely used in amateur satellite communications [2], education, meteorological observation, deep space exploration, and other fields. In order to achieve a more flexible ground station design and satellite communication test after launch, many solutions have been proposed to achieve a more flexible and scalable antenna system [3]. However, these solutions do not provide both practical and flexible control systems as well as portability [4]–[6]. Which is necessary for engineers who routinely conduct post-launch satellite communications testing while providing a more flexible and modular maintenance protocol that could quickly adapt to specific test needs. More efficient transceiver array construction can be achieved by replacing and arranging antennas in the transceiver module.

In this paper, a scalable polarization reconfigurable antenna array was proposed. An efficient layout of the power and control signal transmission network is achieved through the use of a modular design. The only signal source could be supplied to the entire array as the phase reference. So the clock synchronization method of multiple signal sources in a large-scale antenna array is not required to be considered. The only signal source could be supplied to the entire array as the phase reference. Only a valid calibration of the phase of the entire system is required to achieve an efficient transceiver system setup.

II. Antenna System Design And Analysis

The proper design of the sub-arrays in the entire scalable phased array antenna system is necessary, but in practical applications, these sub-arrays can be replaced at any time according to specific requirements such as the operating frequency. In order to analyze and evaluate the scalable structure proposed in this paper, a pin-fed patch antenna array is designed to form the subarray.



(a) (b)

Fig. 1: The front and back side of the single chip module formed by 2 by 2 rotated patch antenna subarray : (a) Front side; (b) Back side

Fig. 1(a) shows the schematic layout of the single chip module. The rectangular patch antenna was printed on the top layer of a ROGERS 4350B which relative permittivity is 3.3. Fig. 1(b) shows the fed network on the backside of the chip. Each four co-polarized patches are fed from a single feed point. Each two by 2 rotated subarray element make up a larger single chip element.

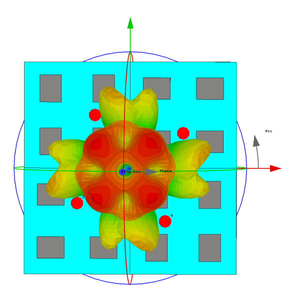
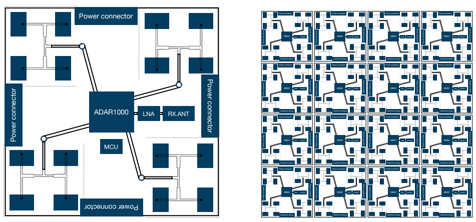


Fig. 2: 3D radiation pattern of the single chip antenna array module.

As shown in Figure. 1, the four feed ports of the sub-array antennas are independent of each other, so circular polarization could be achieved by controlling the phase of the feed signal. Switching between left-handed circular polarization and right-handed circular polarization can be achieved by changing the direction of the 90-degree increment of the four feed ports. Figure. 2 shows the 3D radiation pattern of the single chip antenna array module which is simulated by CST Microwave Studio. The gain of the single chip antenna array module is more than 13 dB.And the axial ratio within the scope of the main lobe width is less than 3 dB.

III. Scalable Structure and Its Operational Mechanism

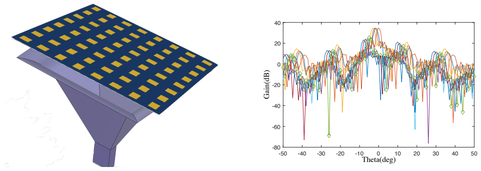
It was evident that a more flexible beam scanning and higher gain can be achieved if a plurality of single chip antenna array element is combined. Therefore, this paper proposes a more flexible antenna array extension structure. More efficient interconnections can be achieved through integrated power and phase control system. Fig. 3(a) shows the basic schematic of the single chip antenna array element.



(a) (b)

Fig. 3: (a) The basic schematic of the single chip antenna array module; (b) An array consisting of 16 single chip antenna array modules.

As shown in Fig. 3(a), the four subarrays of the single chip antenna array are connected to the beamformer which model is ADAR1000 manufactured by Analog Devices. An array consisting of 16 single chip antenna array modules is shown in Fig. 3(b). The ADAR1000 is connected to the subarray antenna by a circulator to achieve more flexible signal transmission and reception. The onboard MCU can adjust the amplitude and phase of the four elements of the subarray by communicating with the ADAR1000 through the SPI. Meanwhile, the parameters of the beam scanning could be pre-set in the ADAR1000, which could be directly used when beam scanning is required. The signal input port of the ADAR1000 is connected to a low noise amplifier, which is used to amplify the signal of the receiving antenna inserted in the back of the module.



(a) (b)

Fig. 4: (a)The overall structure of the waveguide horn antenna used to feed the array; (b) Far field patterns at various scan angles at 13GHz.

The four sides of the single chip antenna array module are designed with control data and power transmission interfaces so that the structure could be simplified in the case of multi-module large-scale expansion. Effective control of the entire array can be achieved by using NodeMcu which supports wireless communication. Large-scale array setup could be achieved by proper allocation of SPI addresses for multiple modules. The receive antennas behind each module single chip antenna array module form an active array, by which could realize the transmission and reception of signals for the entire array. Therefore, the array could be fed using a waveguide horn antenna which shown in Fig. 4(a) to simplify the overall structure. Only a valid calibration of the phase of the entire system is required to achieve an efficient transceiver system setup. As shown in Fig .4(b), the 4 by 4 phased array antenna system was simulated and verified by CST Microwave Studio.The phased array achieves efficient beam scanning and remains circularly polarized within the main beam range.

IV. Conclusion and Future Work

In this paper, a new structure of scalable phased array antenna system with circular polarization switching capability has been proposed, which is realized by using a beamformer and designing a more efficient and flexible power supply and control system. The working state could be quickly switched by flexibly replacing the antenna array modules. At the same time, by using a waveguide horn antenna to feed the entire array reduces the complexity of the feed network. The future work will focus on further optimizing the entire system to address the impact of potential problems on the system performance.

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