9-GHz-Band Active Antenna System for Cellular Base Stations

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Abstract –In this paper, a 9-GHz-band AAS for cellular base stations is investigated as the basis for a massive MIMO. The proposed AAS has orthogonal dual polarization patch antennas. The designed orthogonal dual patch antenna has a return loss characteristic relative bandwidth of 24%. Low sidelobes, beam scanning, and null stealing radiation patterns have been realized by setting the feeding phase and amplitude of each one of the 64 antenna elements.

Index Terms — massive MIMO, AAS, 5G, cellular base station.

1. Introduction

The application of the active antenna system (AAS) as a cellular base station antenna in 5G has been studied [1]. The AAS consists of antennas and radio units in a radome and has an advanced beam forming technology. The introduction of the AAS will be necessary for realizing massive MIMO or for advanced beam forming as the main technologies in 5G.

Moreover, allocation of a high frequency band is considered in addition to the present frequency band in 5G. At high frequencies, high-speed communication by broadband is possible compared to lower frequencies, whereas, the losses in the power supply and propagation increase. Generally, in the AAS, the RF front ends are connected directly to the antenna elements for reducing the feeding loss. Therefore, it can be seen that the introduction of the AAS is desirable from the point of view of loss reduction. We have conducted a basic study on the AAS [2],[3],[4], and have designed an AAS in the 2 GHz band (Band 1) and the 800 MHz band (Band 19). On the field, we have studied the effect of the reduction in the interference by beam forming and area expansion by noise figure improvement, using the AAS.

In this paper, a 9-GHz-band AAS for cellular base stations is investigated as the basis for a massive MIMO. Initially, the specifications and configuration of the 9-GHz-band AAS for cellular base stations is discussed. This paper also displays the results of the simulations of the patch antenna element design for the proposed AAS, the array configuration, and the beam forming technology.

2. 9-GHz-band active antenna system specifications and configuration

TABLE 1 shows the specifications of the 9-GHz-band AAS. The design frequency is 9.5 GHz. The AAS has a 64 element square array configuration. It has an orthogonal dual polarization for the MIMO. We have designed the maximum antenna gain to be more than 25 dBi for a uniform excitation. The half power beam widths in the horizontal plane and vertical plane are variable in the range, 10–80 deg. The maximum EIRP is +40 dBm. The range of the phase shift is from 0–360 deg. and the range of the amplitude is from -20–0 dB. The size of the AAS (including the RF front end, RF divider, and the control/power supply) is W: 180 mm × H: 180 mm × D: 200 mm.

TABLE I
9-GHz-band active antenna system specifications

No.	Topics	Values
1	Frequency band	9.5 GHz±500 MHz
2	Number of antenna elements	64 elements
3	Polarization	Orthogonal dual polarization
4	Antenna gain	Max. 25 dBi
5	Half power beam width in the horizontal plane directivity	range of 10–80 deg.
6	Half power beam width in the vertical plane directivity	range of 10–80 deg.
7	EIRP	+40 dBm
8	Range of the phase shift	0–360 deg.
9	Range of the amplitude	−20–0 dB
10	Size of the AAS	W:180 mm × H:180 mm × D: 200 mm

Fig. 1 shows the Tx configuration of the AAS. The Tx signal is divided equally to be fed to the RF front end by the divider. First, in the RF front end, the signal is shifted to the desired phase by the phase shifter. Next, the signal is attenuated to the desired relative amplitude at the antenna feed point by the variable attenuator for beam forming. Finally, the signal is amplified by the power amplifier and input to each antenna element. The antenna element can be connected or detached at the antenna connector.

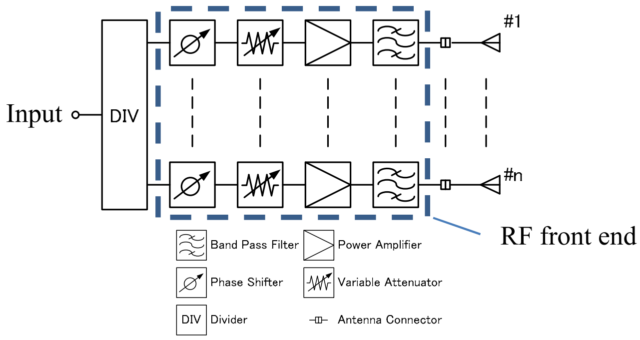


Fig. 1 9-GHz-band active antenna system configuration

3. Antenna element configuration

Fig. 2 shows the configuration of an antenna element. The antenna element is a patch antenna with an electromagnetic slot feed. The antenna element has a broadband characteristic because of the parasitic element above it. In the center of the slot feed, the bridge circuit in a multilayered board is configured for realization of the orthogonal dual polarization. A tri-plate feeding line through the via holes is configured for reduction of unnecessary radiation.

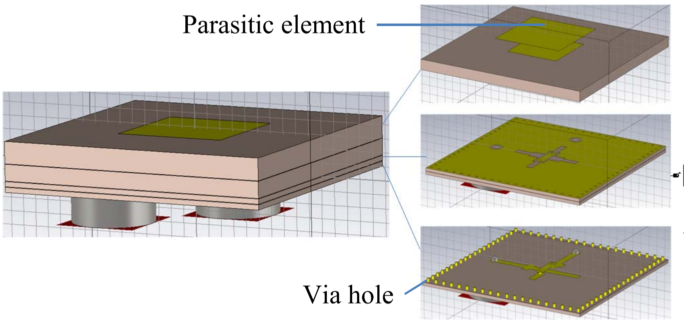


Fig. 2 Antenna element configuration

Fig. 3 shows the frequency response of the s-parameters of the proposed patch antenna element. The return losses of both the vertical (V) pol. and the horizontal (H) pol. are below -10 dB around the design frequency of 9.5 GHz (relative bandwidth: 24%). The coupling characteristic is below -24 dB around the design frequency of 9.5 GHz.

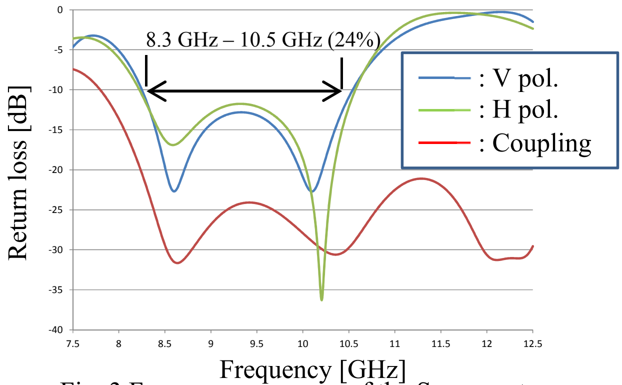
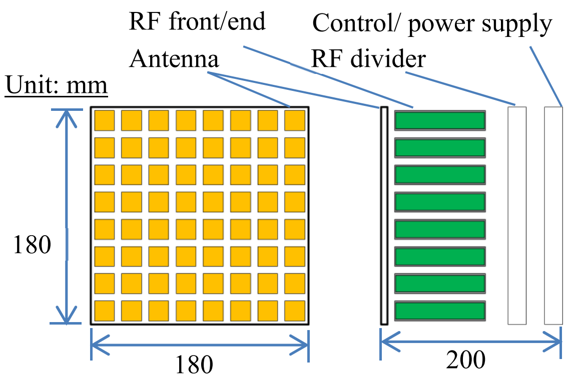


Fig. 3 Frequency response of the S-parameters

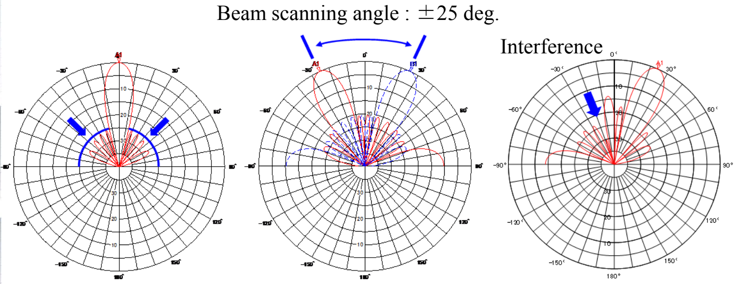


(a) Top view (b) Side view

Fig. 4 9-GHz active antenna system configuration

Fig. 4 shows the configuration of the 9-GHz AAS. The AAS has a 64 element patch square array antenna configuration. It includes an RF front end, RF divider, and a control/power supply at the back of the antenna. The AAS is designed to be considerably compact, below W: 180 mm × H: 180 mm × D: 200 mm. The distance between the antenna elements is 0.63 wavelength at 9.5 GHz.

Fig. 5 shows the simulation results of different radiation patterns using the proposed AAS. The low sidelobes, beam scanning, and null stealing radiation patterns are realized by setting the feeding phase and amplitude of each one of the 64 antenna elements.



(a) Low sidelobes (b) Beam scan (c) Null stealing

Fig. 5 Different radiation patterns of the AAS (@ 9.5 GHz).

Fig. 6 shows the prototype configuration of the 9-GHz AAS. For simplicity, we fabricated a prototype AAS that has a linear array configuration.

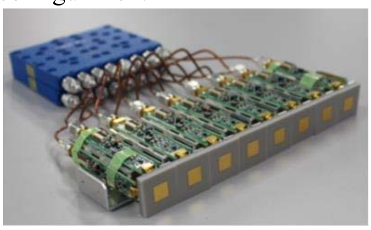


Fig. 6 Prototype of the 9-GHz-band AAS

4. Conclusion

In this study, we have investigated the 9-GHz-band AAS for next generation cellular base station antennas.

The designed orthogonal dual polarized patch antenna element has a return loss characteristic relative bandwidth of 24%. The low sidelobes, beam scanning, and null stealing radiation patterns are realized by setting the feeding phase and amplitude of each one of the 64 antenna elements.

For simplicity, we used a prototype AAS that has a linear array configuration for experimentation.

References

[1] T. Nakamura, A. Benjebbour, Y. Kishiyama, S. Suyama, T. Imai, "5G Radio Access: Requirements, Concept and Experimental Trial," *IEICE Trans. Commun.*, vol. E98-B, no. 8, pp. 1397-1406, Aug. 2015.

[2] K. Sato, I. Oshima, T. Kitayabu, M. Nakano, "Dual Frequency and Polarized Self-Diplexing Antenna," *IEICE Tech. Report*, A･P2013-141, pp. 43-48, Jan. 2013.

[3] K. Sato, S. Natori, I. Oshima, T Kitayabum, M. Nakano, K. Miyata, H. Hayashi, K. Gosui, "Active Array Antenna System for Cellular Base Station," *IEICE Tech. Report*, A･P2015-65, pp. 25-30, Aug. 2015.

[4] M. Nakano, T. Kitayabu, S. Natori, K. Sato, I. Oshima, K. Miyata, H. Hayashi, K. Gosui, "Field Evaluation of Cell Quality by Beam Control with Active Array Antenna System," *IEICE Tech. Report*, A･P2015-90, pp. 59-64, Sept. 2015.