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Decoupling methods of MIMO antenna arrays for 5G applications: a review

Key words: MIMO array; 5G smartphone; Decoupling methods

Corresponding author: Ying LIU
E-mail: liuying@mail.xidian.edu.cn
ORCID: https://orcid.org/0000-0002-5500-1946

Introduction

- 5G features ultra-high speed, low latency, excellent reliability, and sub-6 GHz and mm-Wave frequency bands.
- The multiple-input multiple-output (MIMO) array is used to increase the channel capacity.
- The number of antennas in smartphone increases but the space is limited.
- It is a challenge to realize the desirable isolation and ECC.

Decoupling methods of the MIMO array

1. Distance optimization and selection of different elements

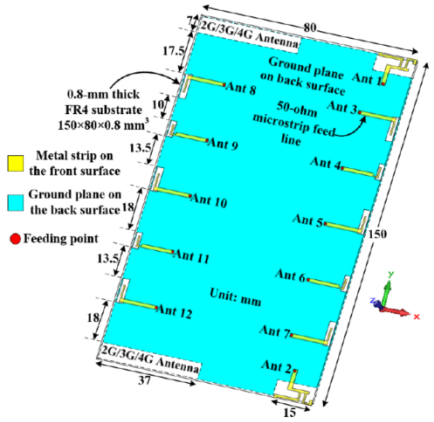

Fig. 1 Geometry of the 12-port MIMO array
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- Selecting a proper distance between elements is a traditional method.
- Different elements are selected due to the limited space.
- Different elements are alternately arranged along the four edges of the main board of the system (Fig.1).
- Isolation>12 dB (Table 1).

Table 1 Comparison between the referenced antennas selecting proper distances and choosing different elements

Reference	Center frequency (GHz)	Isolation (dB)	ECC	MIMO order
Lu et al. (2015)	3.6	>10	<0.1	8
Wong et al. (2018a)	0.79/2.2/3.75	>8.5/>20/>10	<0.4/<0.1/<0.1	2
Huang et al. (2018)	1.6/3.45/4.9	>10	<0.23	8
Chen et al. (2019)	3.5	>10	<0.2	8
Zhang et al. (2019)	4.5	>11	<0.1	8
Deng et al. (2018)	3.45	>10	<0.15	10
Li YX et al. (2018a)	3.6/5.5	>12	<0.15/<0.1	12

ECC: envelope correlation coefficient

2. External decoupling structures

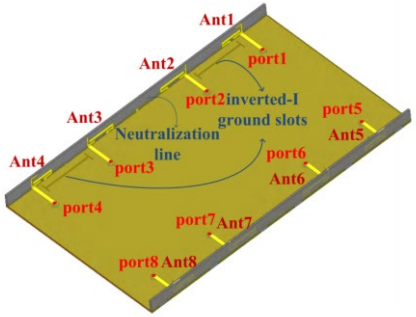

Fig. 3 Structure of the MIMO array with multi-decoupling elements
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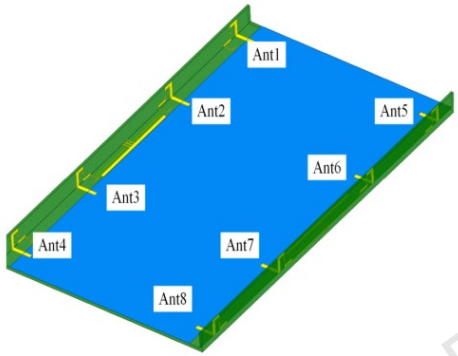

Fig. 4 Geometry of the eight-element MIMO system
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- NL: introduces opposite coupling (Fig. 3)
- DGS: etches periodic or non-periodic structures on the ground plane (analyzed by the CMT, Fig. 3)
- Grounding branches: inserted between the two elements (Fig. 4)
- Isolation>20 dB (Table 2)
- The complexity of the MIMO system is increased and an additional space is occupied

Table 2 Comparison between the referenced antennas employing additional decoupling structures

Reference	Center frequency (GHz)	Isolation (dB)	ECC	MIMO order
Wong et al. (2015)	3.5	>10	<0.3	16
Wong et al. (2016)*	3.5	>10	<0.25	8
Lu et al. (2016)	3.5	>12	<0.1	8
Ban et al. (2016)	3.5	>10	<0.2	8
Guo et al. (2018)	3.5/5	>11.5	<0.08/<0.05	8
Jiang et al. (2019a)	3.5	>15	<0.15	8
Jiang et al. (2019b)	2.55/3.45	>12.5	<0.25	8
Xu et al. (2017)	3.5	>20	–	8

*Only the performance of array *A* in Wong et al. (2016) is given due to the better performance. ECC: envelope correlation coefficient

3. Orthogonal modes

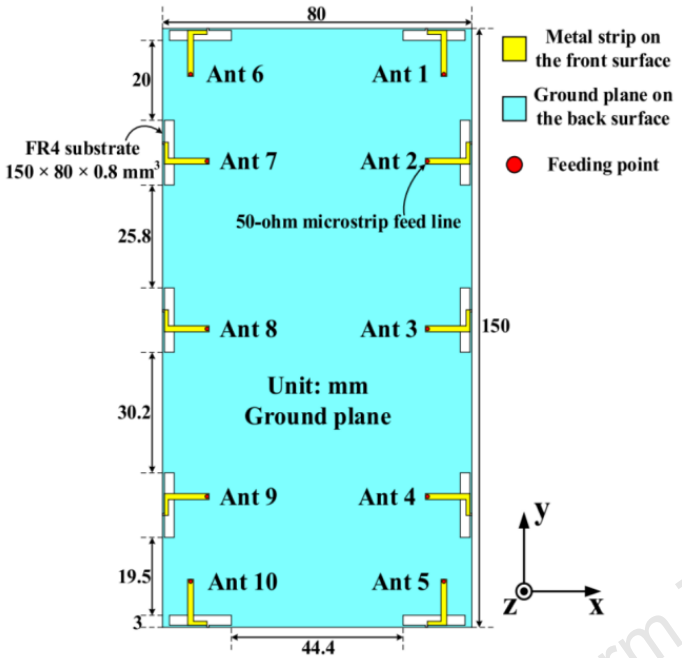

Fig. 5 Geometry of the ten-element MIMO array
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- 10-element MIMO array
- T-shaped coupled-fed slot antennas
- Four elements along the short edges
- Six elements along the long edges
- Orthogonal polarization
- Space occupied is large

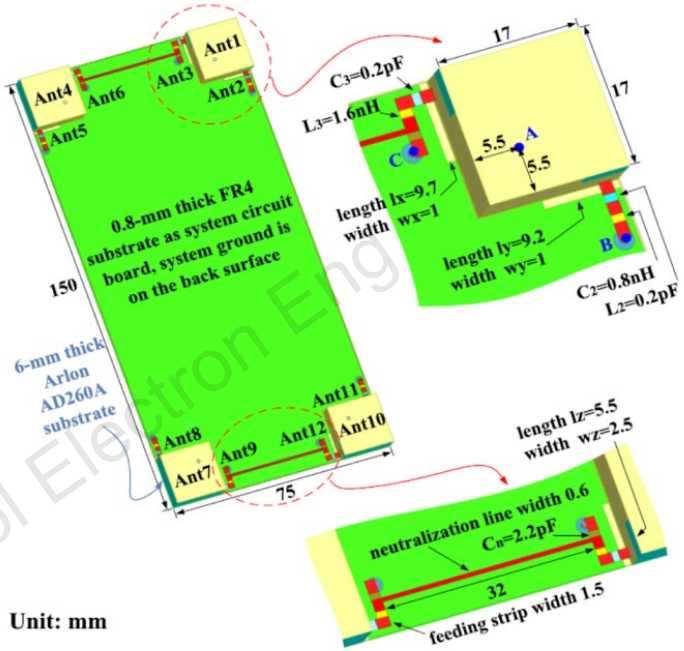

Fig. 6 Geometry of the 12-element MIMO array
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- 12-element MIMO array
- Tri-polarized building block
- Two open-end slots (*x*-, *y*-polarized waves)
- Substrate integrated wave guide antenna (*z*-polarized wave)
- Isolation>12.5 dB with NL

3. Orthogonal modes

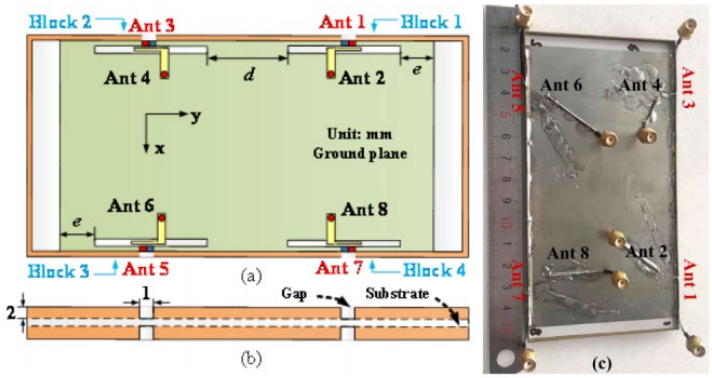

Fig. 8 Geometry of the eight-element MIMO array: (a) top view; (b) side view; (c) fabricated antenna

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Fig. 9 Manufactured eight-port MIMO array

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8-element MIMO array / compact building block with orthogonal mode technique / isolation>16 dB

8-element MIMO array / CMT / isolation>15 dB

Table 3 Comparison between the referenced antennas exploiting orthogonal modes

Reference	Center frequency (GHz)	Isolation (dB)	ECC	MIMO order
Li MY et al. (2016)	2.6	>12	<0.15	8
Li YX et al. (2018a)	3.5/5.5	>11	<0.15/<0.05	10
Li MY et al. (2017)	2.6	>13	<0.2	8
Li MY et al. (2018)	3.5	>12.5	<0.2	12
Parchin et al. (2019)	3.6	>15	<0.01	8
Sun et al. (2018a)	3.5	>17	<0.07	8
Sun et al. (2018b)	3.5	>10	<0.11	4
Ren et al. (2019)	3.5	>16	<0.05	8
Liu Y et al. (2019)	3.5	>15	<0.16	8

ECC: envelope correlation coefficient

4. Other decoupling methods

- Asymmetrically arrange the two mirrored loop antennas (Wong et al., 2017; Tsai et al., 2018)
- Adjust the shorted strips of two IFA antennas (Wong et al., 2018b)
- Self-isolated antennas (Wong et al., 2019a, 2019b; Zhao and Ren, 2019a, 2019b)
- Reduce ground effect (Liu DQ et al., 2018; Li YX et al., 2019)
- Stable null points of an electric field (Zhao et al., 2018)
- Load an inductor at the position with the minimum current or a capacitor at the position with the maximum current (Deng et al., 2019)
- Isolation is around 20 dB

Table 4 Comparison between the referenced antennas using other decoupling methods

Reference	Center frequency (GHz)	Isolation (dB)	ECC	MIMO order
Wong et al. (2017)	3.5	>10	<0.1	8
Tsai et al. (2018)	3.5	>10	<0.1	20
Wong et al. (2018b)	4.65	>10	<0.1	4
Zhang et al. (2019)	3.5	>20	<0.003	8
Zhao and Ren (2019)	3.5	>19.1	<0.0125	8
Wong et al. (2019a)	3.75	>12	<0.1	2
Liu DQ et al. (2018)	2.6/5	>10/>20	<0.2/0.1	8
Li YX et al. (2019)	3.5	>17.5	<0.05	8
Zhao et al. (2018)	3.5	>25	<0.000 12	2
Deng et al. (2019)	3.5	>11.6	–	8

ECC: envelope correlation coefficient

Conclusions

1. There are some methods that achieve great enhancement of isolation for sub-6 GHz MIMO arrays.

2. Designing multi-antenna MIMO array systems for the unbroken metal-rimmed smartphone is a trend and requires further research.

3. Miniaturization of the MIMO size is necessary. We hope that more methods of reducing mutual coupling for a miniaturized and broadband MIMO array will be developed.