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MULTI-ANTENNA TECHNOLOGY

Multi-antenna Future Requirements

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Abstract

This deliverable is produced by the NGMN project MATE –Multi-Antenna technology.

This document provides the guideline for future multi-antenna development and deployment. It concludes 4 main technical trends and requirements of multi-antennas and then introduces the solutions and key parameters as reference. Last, the future possible antenna types are discussed.

The intention is to provide a specific, yet generic, description of future multi-antenna requirements.

CONTENT

0 INTRODUCTION AND SCOPE

The Multi-antenna Technology (MATE) project of NGMN Alliance will share the information and experiences on antenna deployment and conclude some basic modes for reference for future 3G/LTE antenna deployment. The project will mainly focus on the multi antenna tech since it has been considered as the future trend for both TDD/FDD systems.

This document provides the guideline for future multi-antenna development and deployment. It includes 4 main technical trends and requirements of multi-antenna and then introduces the solutions and key parameters as reference. Last, the future possible antenna types are discussed.

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1 BACKGROUND & REQUIREMENTS

In D1 (compact antenna solutions) and D2 (co-site antenna solutions), we have discussed 2 different solutions in multi-antenna systems to solve the deployment challenges. In this document, we will introduce the future multi-antenna requirements according to technical development and operators' deployment experience. Globally, there are hundreds of operators using plenty of antennas with huge differences such as bandwidth, columns, systems supported. However, most of the operators are facing the similar challenges on antenna deployment, such as co-site requirement, wideband to support all possible systems, simplified design for installation and maintenance.

2 MULTI-ANTENNA FUTURE REQUIREMENTS

2.1 Multi-band

Recently, with the rapid development of FDD and TDD LTE application, more and more operators consider using multi-band antenna with wideband support instead of single/narrow band antennas in their network in order to cope with the challenges of 2G/3G/4G co-existence.

To cover lots of different bands such as 790-862 MHz, 880-960 MHz, 1710-1880 MHz, 1880-2025 MHz, 1920-2170 MHz and 2490-2690MHz, antenna vendors need to develop very wide band antennas upon to different customers' requirements. For example, to develop a 790-960/1710-2690 MHz wideband antenna, it has to cover most of 2G, 3G and FDD LTE applications. And to develop a 1880-2690 MHz wideband antenna, it has to cover most of TD-SCDMA and TDD LTE applications for multi operators requirements.

Table 2.1 The applications of multi-band

Common Bands(MHz)	790-862	880-960	1710-1880	1880-2025	1920-2170	2300-2400	2490-2690
Combination 1	√	√	√		√		√
Combination 2	√	√	√		√		
Combination 3	√				√		

Combination 4	√		√				
Combination 5		√			√		
Combination 6		√	√				
Combination 7			√				√
Combination 8					√		√
Combination 9				√			√
Combination 10						√	

2.1.1 Antenna Element

Wideband dipoles are used in the antenna which supports the wide and multi band to cover the possible 3G/4G band requirements. The dipoles have been modified to have relatively large band-width.

2.1.2 Multi-band antenna

A multi-band antenna is generally designed using wideband antenna elements. The TD FAD (F:1880~1920MHz、A:2010~2025MHz、D:2500~2690MHz) antenna is a type of wideband antenna used for both TD-SCDMA and TD-LTE networks. So the antenna can be shared by two different systems. For constructed TD-SCDMA areas, the TD-LTE BTS can also be simply constructed with new RRU and shared antenna.

The most important function of TDD multi- antenna is beam-forming. There are three different types of beam-forming for performance testing in chamber. One type is that the beam is steered towards to 0^{o}, the second type is that the beam is steered towards to 60^{o}, and the third type is that the beam is at broadcasting mode with 65^{o} beam. As for the first type, four different ports in same polarization are fed with equal amplitude and phase. For the second type, four different ports are fed with same amplitude and different phase. However, for the third type, four different ports are fed with different amplitude and different phase. So the antenna can be designed with various beam-widths such as 30^{o}, 65^{o} and 90^{o}. And generally the 65^{o} is most used.

For the TDD wideband FAD antenna, the performance of FA band is same with the TD FA narrowband antenna. Compared with a non beamforming antenna, the beam-width can be formed easily using different amplitudes and phases. So it is tremendously better than a non beamforming antenna to cover different cellular area easily.

2.2 Multi-mode

There are mainly 3 type antennas at the moment:

- 2×2: two ports in one antenna (+/-45 degrees polar). Support BF&MIMO; Support 2G/3G/4G bands(verified in 2G/3G network)

- 4×2: four ports in one antenna (+/-45 degrees polar). Support BF&MIMO; Support 2G/3G/4G bands (verified in 2G/3G/4G network)
- 8×2: eight ports in one antenna (+/-45 degrees polar). Support BF&MIMO; Support 2G/3G/4G bands (verified in 3G/4G network)

For the Co-site requirement, the antenna should support at least two modes including 2×1 MIMO. The multi-mode antenna will be the mainstream among all the base station antennas with the development of the mobile communication technology.

In the multi-mode design, we can achieve this target by four ways:

1. Sharing the antenna with diplexer. In this way, two modes should be in a close frequency band, such as among 790~960MHz or 1710~2700MHz, so that one wideband antenna can support all. The diplexer can be set in the antenna or out of the antenna as shown on figure2.2. In this solution, the antenna will have the same downtilt angle for the two modes.

An alternative option can be of inserting triplexers, therefore allowing the simultaneous use of the same antenna for 3 signals in the F, A and D bands

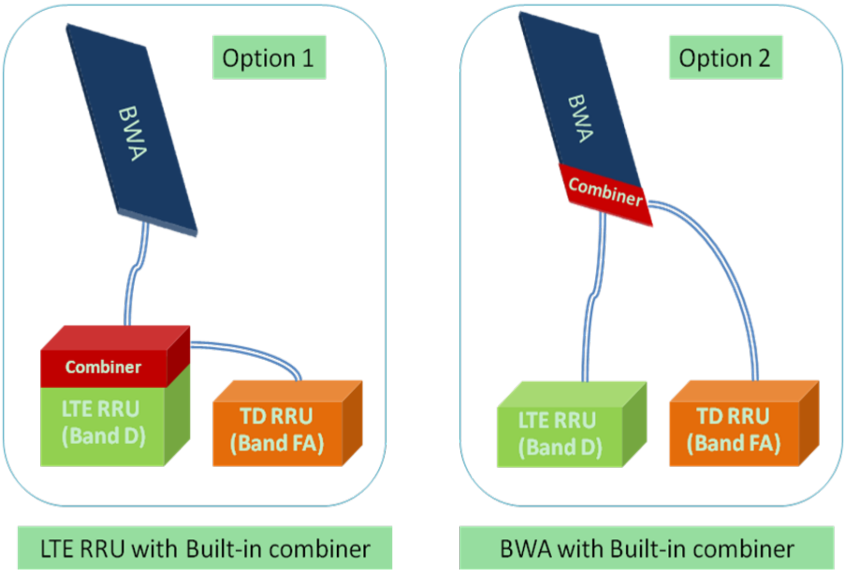


Figure 2.2 Multi-mode antenna layout

2. Sharing the dipole with diplexer. In this solution, the dipole element should work on at least two modes and the antenna will have many diplexers, just as many as dipole number. These diplexers will generate more Gain loss, but, can support two modes have an independent electrical tilt-down tuning. This solution is shown in Figure 4.3.
3. Combine different bandwidth antenna elements in a reasonable layout in one antenna. Co-axial, Side-by-side and Side-by-side with co-axial are possible choices. This will be introduced as Figure 4.2.
4. Mixed-solution: as an example we can choose the solution shown below in Figure 2.3.

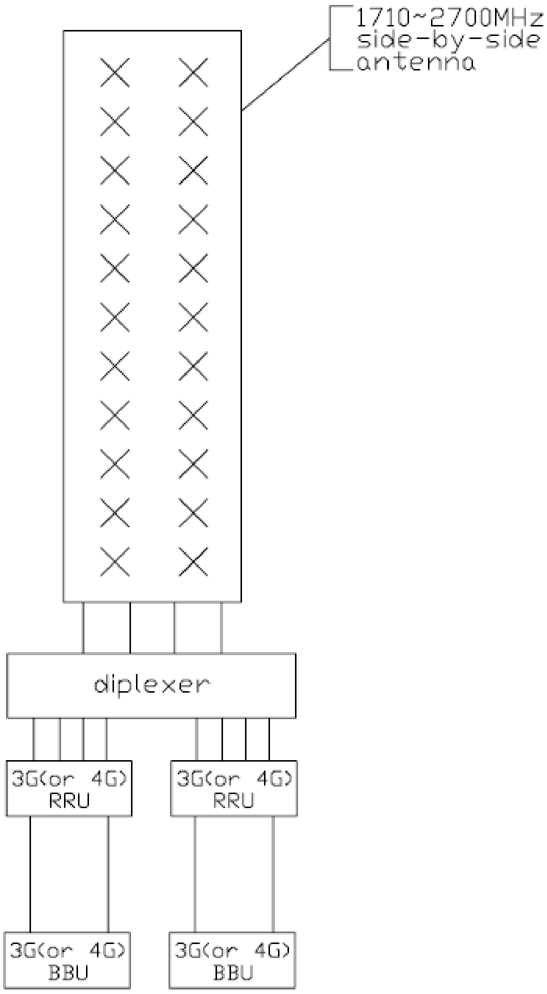


Figure 2.3 multi-mode solution for 3G&4G

2.3 Simplified

Comparing with ordinary antenna, the extra complexity of the multi-antenna technique brings new challenges which require simplified designs.

One of these challenges is the increased number of ports and RF cables. A typical 8 path TD-SCDMA antenna has 9 ports (8 RF + 1 Cal). A 3-sector site will have 27 cables connecting from the antennas to the RRUs. Not only this gives a bad visual impact which can raise the difficulty of the site deployment due to the unwillingness of the public, but also it makes the engineering of the installation and maintenance hard and time consuming. There is also the possibility that cables are being mistakenly plugged into the wrong ports because they are physically interchangeable. To address these issues, a simplified connection method named MCIC interface which can vastly ease the connection procedure has been developed.

Another challenge is how to monitor these more advanced multi-antennas and keep them in the top performance. A remote information management system combined with RET has been developed.

2.3.1 MCIC Interface

The MCIC (Multi Coaxial Interface Connector) interface provides a solution to solve the connection problems previously mentioned. By using a pair of cluster connectors and cluster cables, the electrical and mechanical connections between the antenna and the RRU can be easily achieved. The MCIC interface simplifies outside panel structure and reduces both installation time and cost.

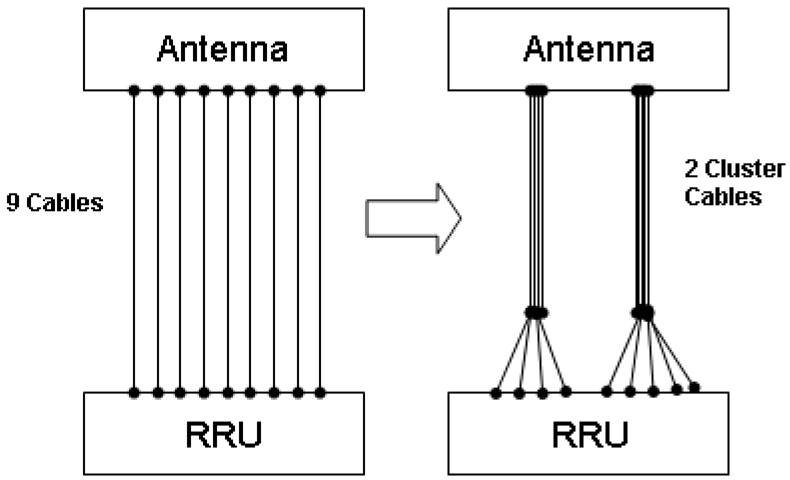


Figure 2.4. MCIC Interface simplified 9 cables to 2 cluster cables

2.3.2 Remote Information Management Combined with RET

Base station antennas had been treated as dumb devices for a long time, with no mechanism to feedback their status. With the increasing demand of higher speed and better QoS of the communication systems, it's often required to monitor the antennas in real time and adjust them on demand to keep the best performance. With the advance of the AISG RET technique, it's now possible to integrate ALDs (Antenna Line Device) into antennas for the purpose of monitoring, and adjust antennas when needed to keep the best system performance. These ALDs have the abilities to report the tilt angle, azimuth angle, geographic location, temperature, VSWR, antenna weighting factor in beamforming and other antenna parameters in real time. A remote CCU(Central Control Unit) is connected to these ALDs via RS485 cable and AISG 2.0 protocol. The CCU can be accessed and controlled remotely by computers running the network monitoring software, via either the Ethernet or the wireless. With dedicated servers, the OMC (Operation and Maintenance Center) can monitor and control thousands of CCUs distributed in a large area.

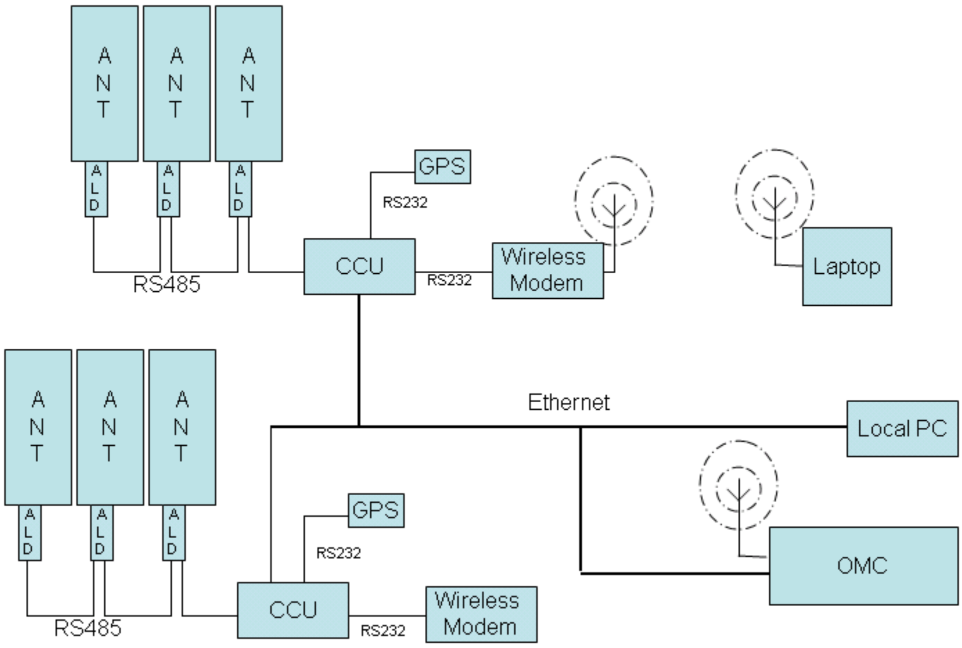


Figure 2.5 Scheme of Remote Information Management

2.4 Compact design

The compact antenna solution has improved the smart antenna deployment problems in 3G network. It will be also a good solution in 4G network for multi-antenna application which has been used in TDD LTE trials.

The network deployment will face many more challenges than 3G because of the limitation of antenna installation space, especially in dense urban areas. The compact antenna solution is intended to solve this problem.

The distance between sites in dense urban is 300~500meters. For this kind of area, the coverage limitation is not the main issue. The interference control is vital for network optimization. This application scenario therefore allows compromises on gain in order to reduce overall antenna size and to optimize the side lobe and interference suppression.

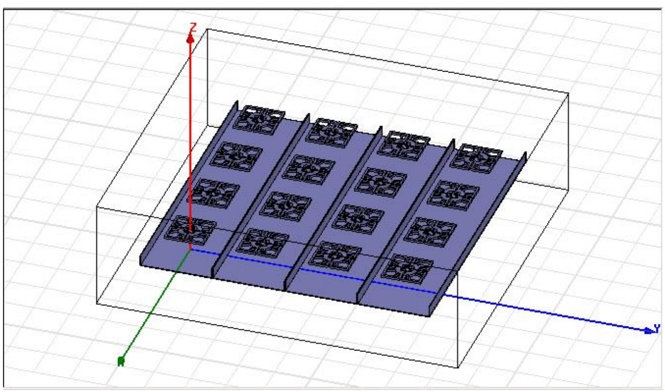


Figure 2.6 one possible antenna design mode

3 WIDEBAND ANTENNA DESIGN

3.1 Wideband multi-antenna design

3.1.1 Coupling calibration networks

The coupling calibration network is composed of power dividers and directional couplers as shown in Figure 3.2.

Using the coupling calibration network, the separation of the amplitude and phase between different antenna ports has been shown, and it's possible to compensate it and feed different antenna ports using the right amplitude and phase by the RRH.

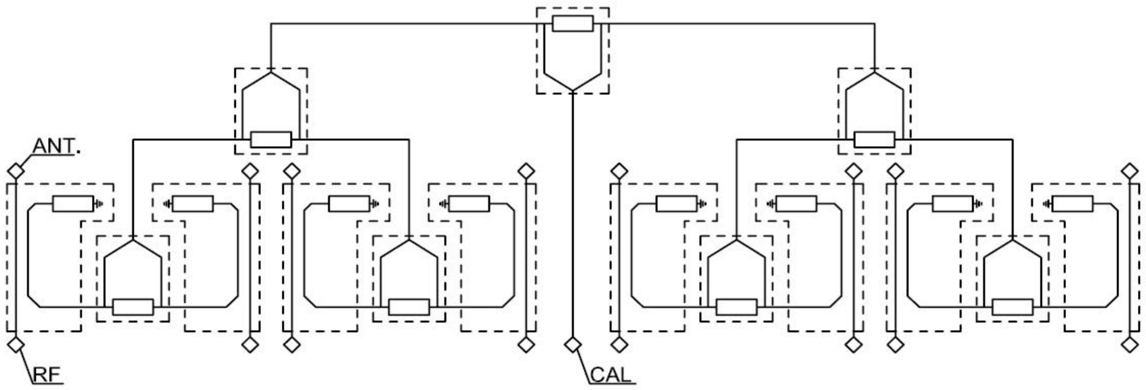


Figure3.2 Coupling calibration network

3.1.2 Feeding networks

The feeding network is one of the most important components in the antenna system. It is used to feed antenna elements with different amplitude and phase, so the vertical beam of each antenna array can be controlled to give different beam direction and side-lobe suppression.
There are various methods to design feeding networks. One of them is using the PCB (printed-circuit-board). The PCB is easy to be fabricated with correct phase and amplitude RF signal. And also its reliability is good. An example is shown in Figure3.3

Figure3.3 Feeding networks

3.2 Key parameters

Table3-1 Wideband antenna key parameters

<table>
<tr><td rowspan="4">General Parameters</td><td>Parameters(unit)</td><td></td><td>target</td><td>Target</td><td>target</td></tr>
<tr><td>Frequency Range (MHz)</td><td></td><td>1880~1920 (F)</td><td>2010~2025 (A)</td><td>2500~2690 (D)</td></tr>
<tr><td>Fixed Down-tilt (°)</td><td></td><td>0/3/6/9</td><td>0/3/6/9</td><td>0/3/6/9</td></tr>
<tr><td>Down-tilt separation (°)</td><td></td><td>±1</td><td>±1</td><td>±1</td></tr>
<tr><td rowspan="12">Calibration and electrical parameters</td><td>Loss of Antenna Element Connector to Calibration Port Connector (dB)</td><td></td><td>-26±2</td><td>-26±2</td><td>-26±2</td></tr>
<tr><td>Difference in transmission coefficient between any 2 antenna element connector to calibration connector, Magnitude (dB)</td><td></td><td>≤0.7</td><td>≤0.7</td><td>≤0.7</td></tr>
<tr><td>Difference in transmission coefficient between any 2 antenna element connector to calibration connector, Phase (°)</td><td></td><td>≤5</td><td>≤5</td><td>≤5</td></tr>
<tr><td>VSWR</td><td></td><td>≤1.5</td><td>≤1.5</td><td>≤1.5</td></tr>
<tr><td rowspan="4">Co-polarization isolation (dB)</td><td>0°</td><td colspan="3">≥20dB</td></tr>
<tr><td>3°</td><td colspan="3">≥25dB</td></tr>
<tr><td>6°</td><td colspan="3">≥28dB</td></tr>
<tr><td>9°</td><td colspan="3">≥28dB</td></tr>
<tr><td rowspan="4">Cross-polarization isolation (dB)</td><td>0°</td><td>≥25dB</td><td>≥25dB</td><td>≥25dB</td></tr>
<tr><td>3°</td><td colspan="3">≥28dB</td></tr>
<tr><td>6°</td><td colspan="3">≥30dB</td></tr>
<tr><td>9°</td><td colspan="3">≥30dB</td></tr>
<tr><td rowspan="5">Radiation parameters</td><td rowspan="5">element beam</td><td>Azimuth 3dB Beamwidth (°)</td><td>100°±15°</td><td>90°±15°</td><td>65°±15°</td></tr>
<tr><td>Single Beam Gain</td><td>≥14dBi</td><td>≥15dBi</td><td>≥16.5dBi</td></tr>
<tr><td>±60°signal dop</td><td>/</td><td>/</td><td>12±2dB</td></tr>
<tr><td>Vertical 3-dB Beam-width</td><td>/</td><td>/</td><td>≥5°</td></tr>
<tr><td>Cross-polar ratio (0°)</td><td>≥18dB</td><td>≥18dB</td><td>≥18dB</td></tr>
</table>

		Cross-polar ratio（±60°）	≥10dB	≥10dB	≥10dB
		F/B Ratio	≥23dB	≥23dB	≥25dB
		First Side-lobe Level	/	/	≤-16dB
	Broadcast beam	Azimuth 3dB Beamwidth (°)	65°±5°	65°±5°	65°±5°
		BCH Gain	≥14dBi	≥15dBi	≥16dBi
		±60°signal drop	12±2dB	12±2dB	12±2dB
		Vertical 3-dB Beam-width	≥7°	≥6.5°	≥5°
		Cross-polar ratio (0°)	≥22dB	≥22dB	≥22dB
		Cross-polar ratio（±20°）	≥20dB	/	≥22dB
		Cross-polar ratio（±60°）	≥10dB	≥10dB	≥10dB
		F/B Ratio	≥28dB	≥28dB	≥28dB
		First Side-lobe Level	≤-16dB	≤-16dB	≤-16dB
		First Null Fill	≥-18dB	≥-18dB	≥-18dB
	Service beam	0° Beam Gain	≥20dBi	≥21dBi	≥22dBi
		0° Beam Azimuth 3dB Beamwidth (°)	≤ 29°	≤26°	≤25°
		0° Beam Side-Lobe Level	≤-12dB	≤-12dB	≤-12dB
		±60° Beam Gain	≥17.5dBi	≥17.5dBi	≥19.5dBi

		±60°Beam Azimuth 3dB Beamwidth (°)	≤32°	≤32°	≤23°
		±60° Beam Side-Lobe Level	≤-5dB	≤-5dB	≤-4dB
		Cross-polar ratio (0°)	≥22dB	≥22dB	≥22dB
		0° Beam F/B Ration	≥28dB	≥28dB	≥28dB
Mechanical parameters	Mechanical Down-Tilt（°）	-5～10			
	Connector	N-Female			
	Clamp Diameter (mm)	φ50～φ115			
	Radome Material	UPVC/FRP			
	Dimension(mm)	≤1400x320x150			
	Weight(kg)	≤11			

*Note: all parameters are only for reference.

3.3 Test in chamber

The following 3 tables are the results of one wideband antenna tested in chamber:

Table 3-2 Element beam

	Frequency (MHz)	Vertical 3-dB Beam-width (°)	First side-lobe Level (dB)	Vertical down-tilt (°)	Azimuth 3dB Beamwidth (°)	F/B Ratio (dB)	Gain (dBi)	XPD (dB)	±60ºXPD (dB)
Port1	1900	7.3	-19.3	5.5	101.71	31.69	16.1	35.59	17.27
	2018	6.89	-22.89	5.5	97.63	28.95	16.75	30.39	16.08
	2600	5.31	-16.22	5.5	70.18	30.39	17.23	25.51	13.06
Port2	1900	7.18	-19.04	5.5	111.09	30.01	15.05	32.96	20.47
	2018	6.65	-20.96	6	105.58	33.19	16.06	27.92	16.78
	2600	5.02	-15.11	6	62.25	31.86	17.93	31.58	17.27
Port3	1900	7.15	-23.47	5.5	110.27	31.18	15.46	33.04	21.68
	2018	6.87	-22.61	6	104.95	32.35	16.03	34.71	16.03
	2600	5.28	-18.23	6	63.81	28.66	17.68	28.61	14.61
Port4	1900	7.27	-22.8	5.5	98.43	27.28	16	29.36	20.99
	2018	6.76	-23.88	6	96.38	27.2	16.54	26.45	13.97
	2600	5.46	-23.59	6	65.7	27.43	17.66	24.81	12.06

Port5	1900	7.37	-22.25	5	97.08	26.67	16.05	27.46	21.56
	2018	6.92	-25.89	5.5	95.43	28.27	16.58	36.18	15.83
	2600	5.04	-21.44	6	62.98	26.23	17.76	20.38	12.99
Port6	1900	7.05	-19.46	5	107.11	29.38	15.8	36.96	18.62
	2018	6.77	-22.78	6	100.64	32.13	16.32	28.51	14.2
	2600	5.13	-39.41	6	59.36	29.23	17.72	24.34	13.28
Port7	1900	7.25	-21.85	6	111.55	30.34	15.43	27.27	20.86
	2018	6.76	-25.9	5.5	105.13	30.93	16.06	27.06	19.03
	2600	5.1	-19.91	6	60.86	31.32	17.64	25.33	14.66
Port8	1900	7.24	-21.9	6	100.92	30.24	16.18	31.78	19.66
	2018	6.78	-22.17	5.5	95.31	29.04	16.62	24.22	18.09
	2600	5.31	-20.1	6	62.74	30.79	17.46	22.24	11.58

Table 3-3 Service beam

	Frequency (MHz)	Vertical 3-dB Beam-width (°)	First side-lobe Level (dB)	Vertical down-tilt (°)	Azimuth 3dB Beamwidth (°)	F/B Ratio (dB)	Gain (dBi)	XPD (dB)	Side-lobe suppression (dB)
0° (+45°)	1880	7.38	-17.76	5.5	26.45	38.86	21.9	34.87	-13.81
	1900	7.08	-19.35	5.5	26.06	39.94	22.18	33.28	-14.03
	1920	7.06	-20.13	5	25.97	40	22.15	32.96	-13.95
	2010	6.74	-22.52	6	24.79	38.98	22.27	31.44	-13.61
	2018	6.82	-27.72	6	24.86	40	22.21	29.81	-13.3
	2025	6.85	-25.91	5.5	24.69	38.79	22.27	29.29	-13.46
	2555	5.29	-21.7	5.5	19.5	37.77	23.61	26.7	-13.57
	2570	5.19	-20.77	5.5	19.27	38.56	23.72	25.54	-13.7
	2590	5.1	-19.51	6	19.3	37.18	23.33	24.96	-13.77
	2600	5.08	-21.88	6	19.13	37.65	23.26	24.94	-13.7
	2620	5.09	-20.93	6	19.23	37.13	22.66	26.13	-13.63
	2635	5.09	-19.08	6	19.02	37.9	22.49	26.61	-13.67
0° (-45°)	1880	7.13	-19.01	5.5	26.35	38.94	21.51	31.28	-13
	1900	7.04	-19.63	5.5	26.34	38.88	21.78	30.52	-13.19
	1920	7.01	-21.55	5.5	25.79	36.48	21.94	29.51	-13.06
	2010	6.91	-25.9	6	25.02	36.67	21.87	28.94	-12.73
	2018	6.88	-25.46	6	24.65	36.98	22.23	28.71	-12.88
	2025	6.97	-23.37	6	24.42	37.08	22.43	28.83	-12.99
	2555	5.35	-22.49	6	19.55	34.82	23.52	27.74	-13
	2570	5.34	-21.87	6	19.47	35.87	23.43	28.53	-12.94
	2590	5.36	-21.67	6	19.22	35.78	23.13	29.51	-13.02
	2600	5.29	-24.47	6	19.39	35.17	22.98	29.26	-12.86
	2620	5.22	-25.83	6	19.28	34.78	22.61	30.63	-12.88
	2635	5.16	-25.05	6	19.1	34.04	22.38	29.41	-12.75

60° (+45)	1880	7.47	-18.63	5.5	31.77	30.68	19.9	26.85	-8.41
	1900	7.48	-19.67	5.5	31.91	30.28	19.87	28.77	-8.17
	1920	7.56	-20.76	5.5	31.36	30.32	19.77	28.53	-8.22
	2010	6.81	-21.21	5.5	29.87	32.13	19.89	21.93	-8.11
	2018	6.89	-19.75	5.5	29.23	31.57	20.26	22.6	-8.56
	2025	6.81	-20.73	5.5	29.64	31.7	20.1	21.87	-8.37
	2555	5.3	-21.24	5.5	20.78	29.62	21.6	18.02	-7.55
	2570	5.2	-18.84	5.5	20.74	29.89	21.25	17.01	-7.29
	2590	5.2	-17.46	5.5	20.76	31.12	20.81	15.88	-6.88
	2600	5.16	-17.56	6	20.78	31.78	20.96	15.84	-6.98
	2620	4.97	-17.48	6	20.75	32.42	20.18	14.9	-6.81
	2635	4.85	-17.13	6	20.53	31.2	20.31	15.98	-6.63
60° (-45)	1880	7.52	-20.45	5.5	32.35	32.34	19.52	28.94	-9.3
	1900	7.38	-21.24	5.5	31.78	32.05	19.91	29.02	-9.3
	1920	7.33	-21.63	5.5	31.89	34.2	19.67	26.63	-8.88
	2010	6.83	-16.74	5.5	30.42	32.26	20.34	26.8	-9.54
	2018	6.72	-17.4	6	30.58	32.79	20.44	25.96	-9.43
	2025	6.65	-18.2	5.5	30.59	32.25	20.33	28.39	-9.31
	2555	5.38	-18.94	5.5	21.18	31.81	21.91	18.59	-9.35
	2570	5.19	-18.84	5.5	21.23	29.82	21.49	17.13	-9.19
	2590	5.12	-18.46	6	21.39	29.93	21.14	19.66	-9.02
	2600	5.09	-18.08	6	20.94	31.38	21.37	19.13	-9.11
	2620	5.03	-17.82	6	21.07	32.83	20.53	18.77	-8.61
	2635	4.96	-16.87	6	20.66	32.96	20.59	16.85	-8.03

Table 3-4 Broadcast beam

	Frequency (MHz)	Vertical 3-dB Beam-width (°)	First side-lobe Level (dB)	Vertical down-tilt (°)	Azimuth 3dB Beamwidth (°)	F/B Ratio (dB)	Gain (dBi)	±60ºXPD (dB)	XPD (dB)
65° (+45°)	1880	7.32	-19.11	5.5	60.79	34.55	17.04	22.08	26.59
	1900	7.21	-20.5	5.5	61.16	35.98	17.13	21.86	27.41
	1920	7.11	-23.02	5	61.65	35.44	17.05	21.32	29.01
	2010	6.87	-23.88	6	63.71	36.91	16.6	20.47	30.08
	2018	6.88	-23.88	5.5	63.46	33.65	16.71	19.59	30.08
	2025	6.94	-21.92	5.5	62.56	34.67	16.68	19.42	28.23
	2555	5.15	-22.3	6	70.19	29.21	16.47	10.35	30.9
	2570	5.05	-19.07	6	68.76	29.8	16.33	11.29	27.96
	2590	5.02	-17.71	6	68.04	30.36	16.53	12.87	26.53
	2600	5.05	-20.28	6	67.29	32.33	16.33	13.51	26.87
	2620	5.04	-20.43	6	66.65	30.39	16.23	13.06	28.19
	2635	5.01	-17.79	6	66.28	29.98	16.05	12.54	30.93
65°	1880	7.41	-18.79	5.5	63.25	33.59	16.12	20.78	37.4

(-45°)	1900	7.23	-20.25	5.5	62.49	33.46	16.42	20.84	37.46
	1920	7.17	-20.17	5.5	64.1	33.74	16.36	20.43	35.87
	2010	6.77	-20.44	6	65.47	32.95	16.03	12.76	31.09
	2018	6.77	-20.42	6	65.53	31.13	16.16	13.34	31.52
	2025	6.74	-19.9	6	65	31.9	16.05	13.43	31.38
	2555	5.41	-20.24	5.5	66.26	27.63	16.56	13.4	24.85
	2570	5.4	-20.43	6	67.09	28.73	16.19	13.9	26.05
	2590	5.44	-20.08	6	66.99	27.57	16.38	11.53	26.17
	2600	5.42	-19.64	6	66.14	27.83	16.23	11.97	25.77
	2620	5.4	-19.06	6	65.62	27	16.19	11.19	25.21
	2635	5.26	-18.24	6	64.66	26.47	16.14	11.87	24.73

From the above measurement results, the element horizontal beam-width of the side column is larger than the middle column. The front to back ratio of the side column is better than the middle column. And the element gain of the middle column is larger than the side column.

When the beam is steered to 0° or 60°, it can be found that the side-lobe suppression of the 0° beam in vertical pattern is better than the 60° beam. That is because for the 0° beam, the interference between different columns is smaller than that of the 60° beam.

4 MULTI-MODE SUPPORT

4.1 Multi-mode antenna

Multi-mode antenna can support GSM1800MHz&3G&4G with a super-wide band 1710~2700MHz.It supports BF&MIMO with at least 2 RX and 2 TX.

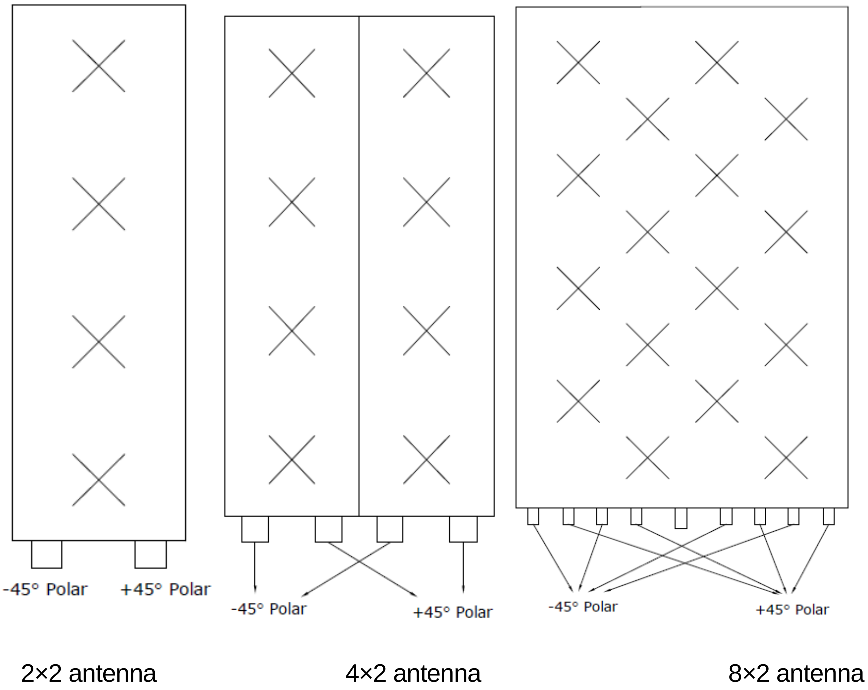


Figure 4.1 Multi-mode antenna (BF&MIMO) Array layout

4.2 Co-site antenna design

To achieve desired system performance, array layout of antenna for co-site solution should be treated carefully. Co-axial, Side-by-side and Side-by-side with co-axial are steady choices. These Co-site antennas are designed in one radome to be fixed co-site, it can save a lot of base station resources. Also there is another idea for co-site than using the duplexer or even triplexes to get multi-mode from the same dipole, this way can save more size for antenna.

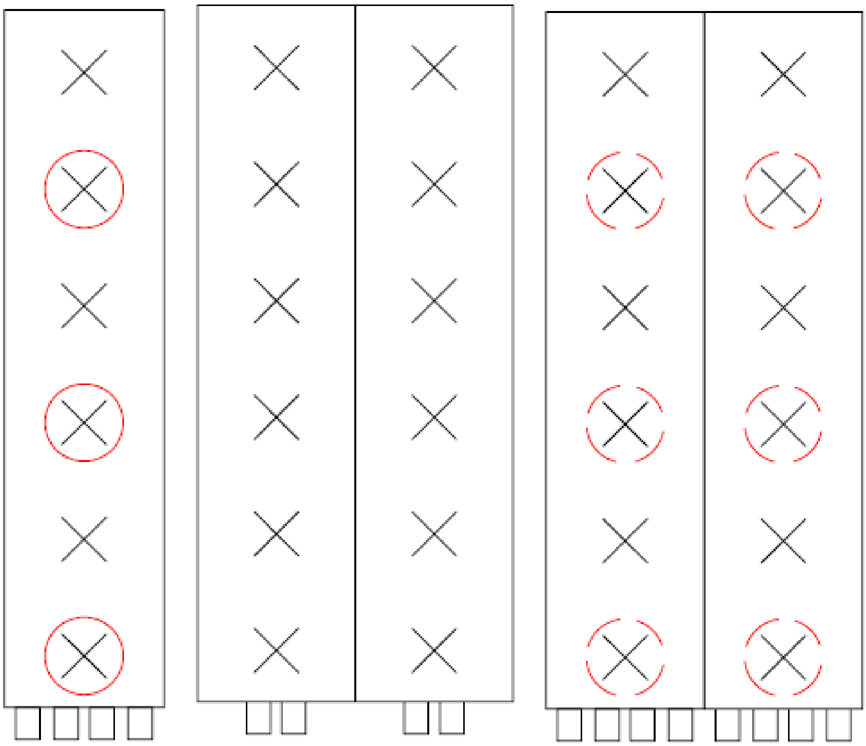


Figure 4.2 Co-site antenna Array layout

Co-axial layout is more suitable for the application where frequencies are far away from each other in spectrum and the frequencies have a constrain relationship. It can get good H-radiation pattern and compact size, but impact between low and high frequency units especially in the V-pattern which want have good electrical specifications are difficult to achieve. Side-by-side layout can reduce the impact between units in V-pattern, but the H-pattern will have a bad symmetry curve and the antenna is wider. In the side by side layout, the phase centre of each antenna should be taken care, and when tested, the antenna should be fixed aiming at the phase centre.

Radiator element level sharing (RELS) is new solution based on combiner（cavity designing or PCB）with feeding network. The antenna size for this layout keeps the same, performances of different bands are similar, and down tilt can be tuned independently. However, the reliability of this antenna is more difficult when a large number of combiners are arranged and the high gain will be difficult to achieve.

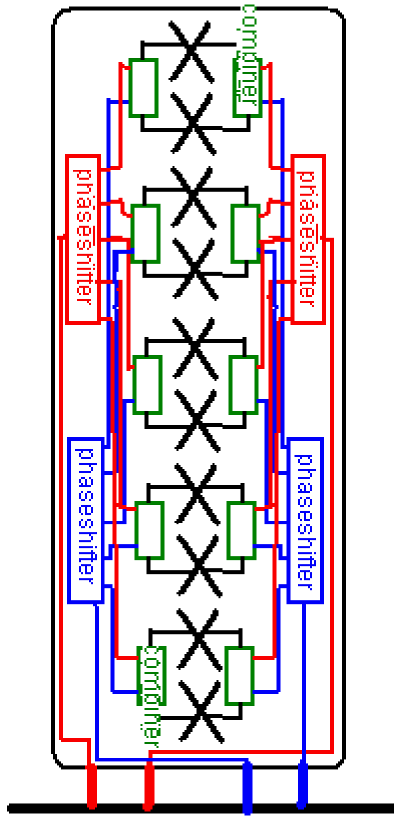


Figure 4.3 Sharing element layouts—ERLS

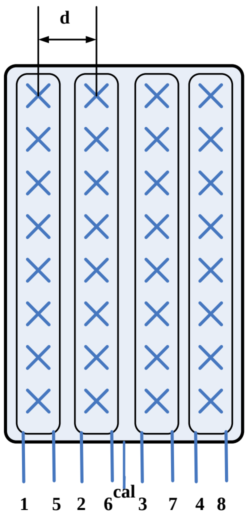


Figure 4.4 4 columns 8 smart antenna

There is another kind of multi-mode antenna: 8x2 smart antenna. The 4 columns 8 antenna elements dual polarized smart antenna is referred to 8 path smart antenna or dual polarized smart antenna. Dual polarized smart antenna technology, also termed as beamforming, exploits knowledge of channel information at the transmitter. It utilizes the channel information to build the beamforming matrices as pre-filters at transmitter to achieve link gain and capacity gain.

When evolving to TD-LTE, dual polarized smart antenna can be used to substantially improve the TD-LTE system performance by leveraging the “spatial” characteristics of the wireless channel. Dual polarized smart antenna with the single-antenna port (port 5) can improve the power efficiency, and Dual polarized smart antenna with dual layer transmission (port 7 & port 8) can increase the effective date rate. So the dual polarized smart antenna is the best choice for TD-SCDMA and TD-LTE.

At the same time, when evolving to TD-LTE, many operators find it difficult to obtain new sites for TD-LTE base stations. Likewise, due to restrictions from authorities, zoning regulations, or concerns regarding RF exposure, it is often difficult to add antennas to existing sites. However, co-site solutions enable operators to reuse existing equipment. The co-site solution is used to simplify the sharing of equipment between different systems at a given site, for example, the antenna, system, power and battery backup system, transmission, cooling, and shelters.

TD-LTE system is being rolled out in some global operators’ network. Furthermore, TD-LTE has raised a great interest to more and more operators in the world. TD-LTE networks have been or will be rolled out by operators who own GSM network or LTE FDD network simultaneously. It means that operators need co-site solutions in network deployment. In the text that follows, we take an investigation in co-site solutions of antenna system for

- TD-LTE and TD-LTE with different frequency spectrum
- TD-LTE and TD-SCDMA
- TD-LTE and GSM
- TD-LTE and FDD-LTE
- TD-LTE and TDD-LTE-A

Depending on the requirements, there is a way of co-site antenna systems solution for TD-LTE and TD-SCDMA. The simplest method is to share an antenna for TD-LTE and TD-SCDMA, replacing existing TD-SCDMA 1880~1920/2010~2025 MHz dual-polarized smart antennas with1880~1920/2010~2025/2500~2690MHz dual-polarized smart antennas.

Three co-site solutions of antenna system for TD-LTE/TD-SCDMA or TD-LTE/TD-LTE are:

1. Smart antenna sharing solution: smart antenna, filter combiner
2. Smart antenna sharing solution smart antenna Integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC)
3. Smart antenna sharing solution: independent Electrical Tilt smart antenna Integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC)

The solution 1 shares smart antenna by filter combiner. Figure 4.5 shows smart antenna sharing solution 1. In this solution, after replacing existing TD-SCDMA dual-polarized smart antenna with smart antenna, we should add filter combiner and TD-LTE RRU to existing sites. We can find it is difficult to add filter combiner and TD-LTE RRU to existing sites.

In this case, in order to solve difficulty in the installation of filter combiner, we develop smart antenna integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC). Existing TD-SCDMA dual-polarized smart antenna is replaced with smart antenna Integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC), this solution is called smart antenna sharing solution 2, and is shown as Figure 4.6.

Since the antenna down-tilt angle and antenna direction are the same for TD-LTE and TD-SCDMA system in smart antenna solution 1 and solution 2, the antenna down-tilt angle does not need to be adjusted independently which would affect the cell planning. So the smart antenna sharing solution 3 is designed, and FA/D independent Electrical Tilt smart antenna Integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC) is used in smart antenna sharing solution 3, and is shown in Figure4.7. The down-tilt angle of TD-LTE and the down-tilt angle of TD-SCDMA can be adjusted independently from 2 degree to 12 degree.

This three smart antenna sharing solutions are also being used in co-site solutions of antenna system for TD-LTE and TD-LTE with different frequency spectrum. For example, the frequency range of first TD-LTE system is 1880~1920/2010~2025, and the frequency range of another TD-LTE system is 2500~2690 MHz.

The three type smart antenna will be introduced in the following section.

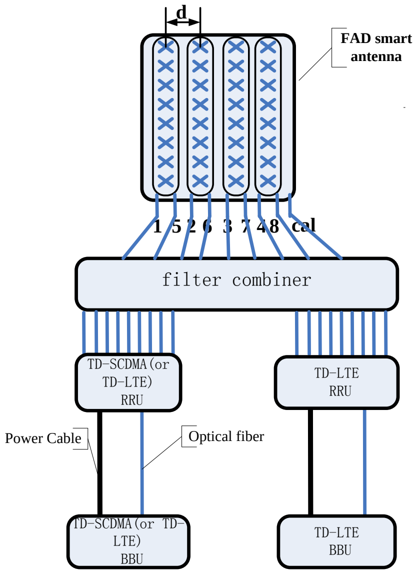


Figure 4.5 smart antenna sharing solution 1

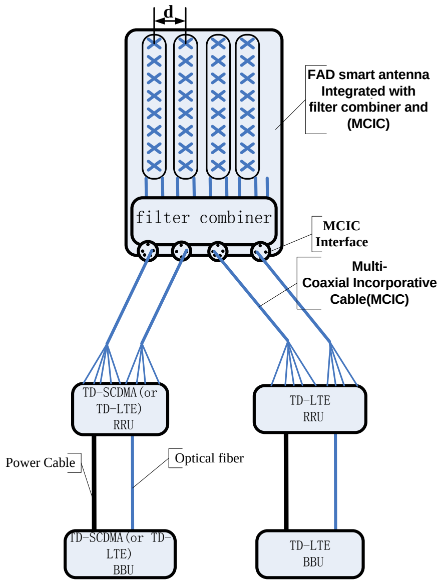


Figure 4.6 smart antenna sharing solution 2

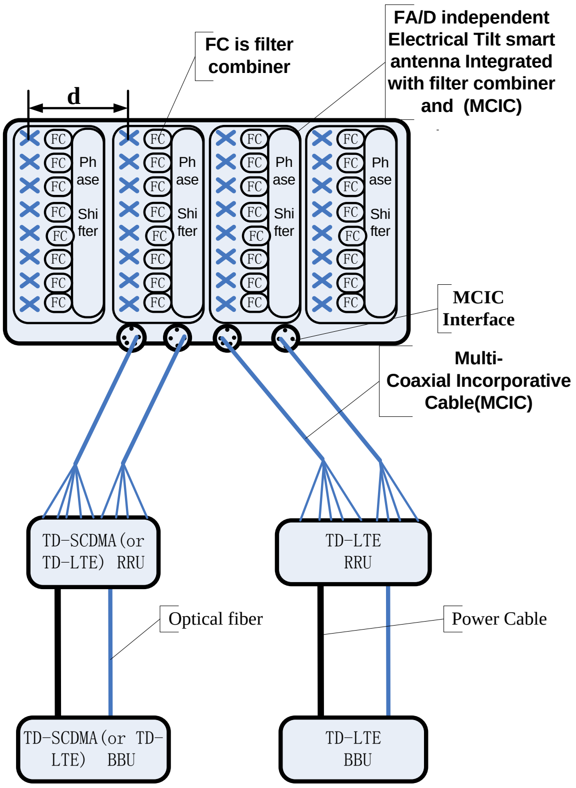


Figure 4.7 smart antenna sharing solution 3

So an independent Electrical Tilt smart antenna integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC) solution is an attractive choice for TD-LTE and TD-SCDMA co-site.

4.3 Field trials

As co-antenna technology is implemented in 3G\4G co-site scenarios, we have carried out trials to demonstrate that co-antenna (test case is in solution2) is a good choice with little performance loss. Furthermore, this technology brings many advantages such as less cost, easier installation, etc.

Take the test project located in Tianhe District, Guangzhou in CMCC's trial network as example. The test environment was characterized by dense population in CBDs with heavy traffic. The following figure shows the test route map.

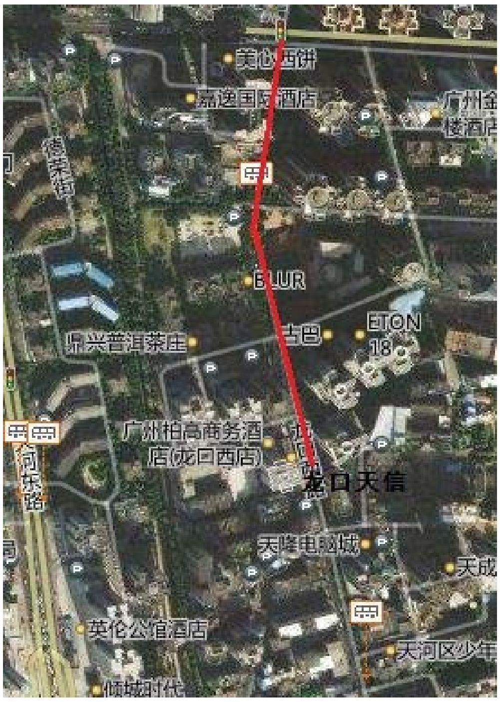


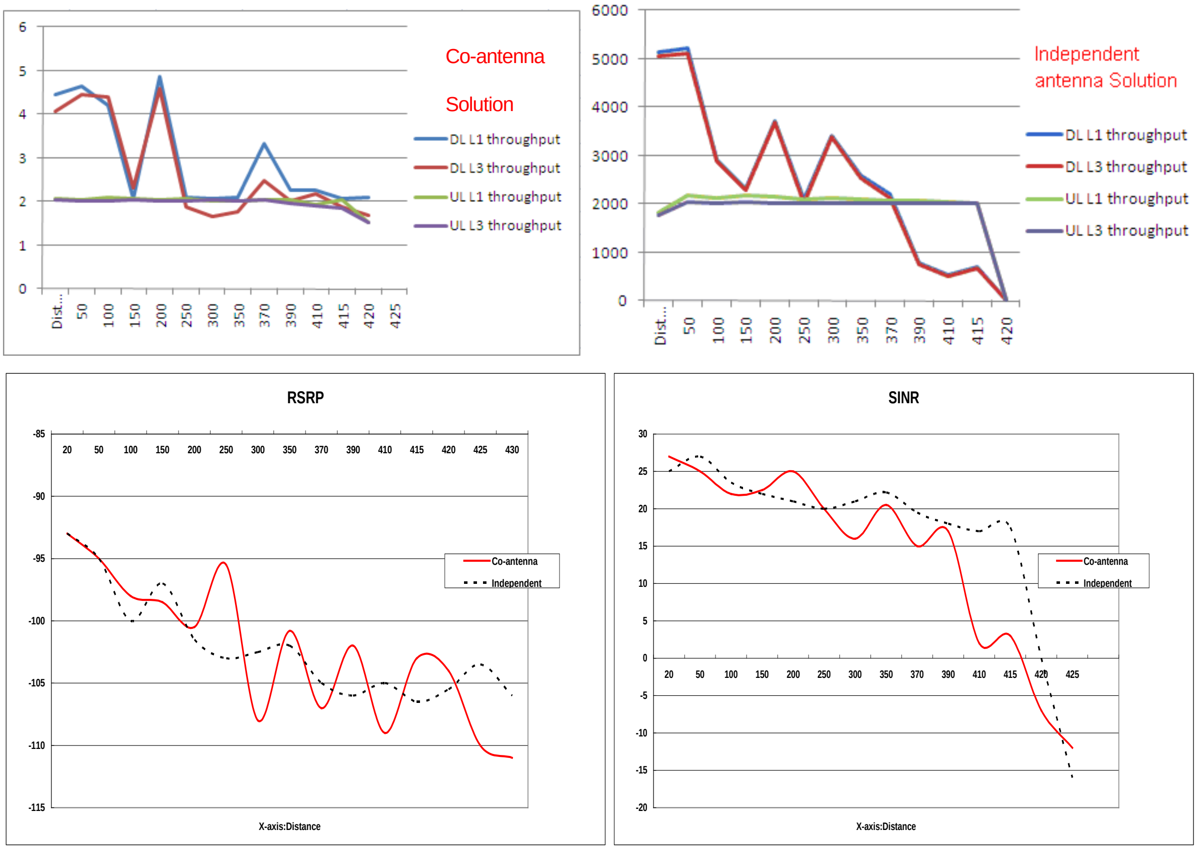
Figure 4.8 Test Route Map

We took a contrast test between the co-antenna solutions and broadband independent-antenna solutions. Both base stations and antennas were installed under the same conditions to ensure our contrast test to be more meaningful. The test included antennas on 60m high towers, down tilt angle of 6 degrees, UL\DL ratio of 2:2.

Under these conditions, we got the TD-LTE and TD-SCDMA performance results for these two solutions.

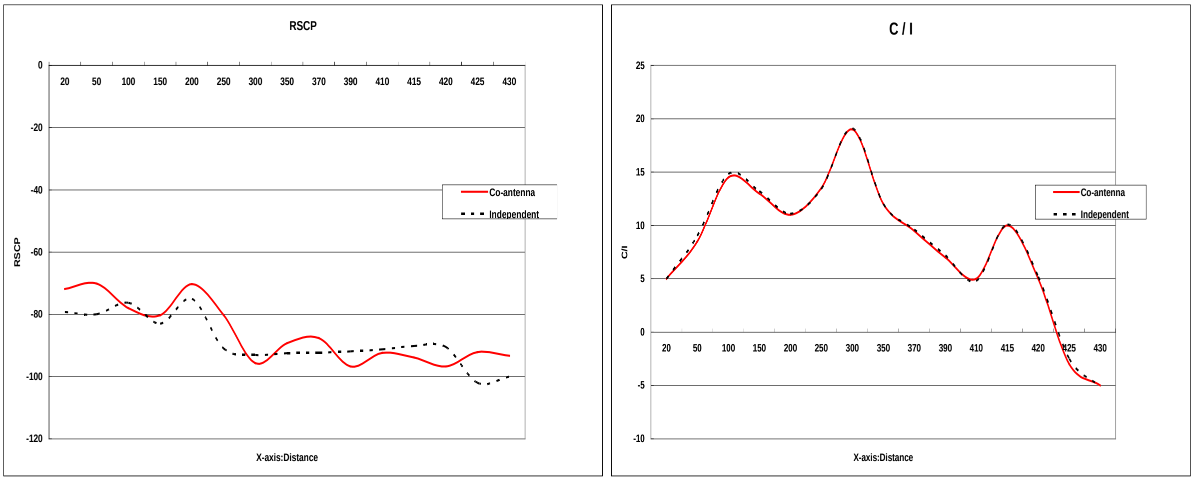
As shown in Figure 4.9 and 4.10, it is clear that the TD-LTE performance with the co-antenna solution is quite similar to that with the independent antenna solution. These performance parameters such as TD-LTE throughput, RSRP, SINR are taken into account. The results fully prove that there is little difference in performance whether the co-antenna solution or the non-co-antenna solution is adopted. This co-antenna technology is highly recommended.

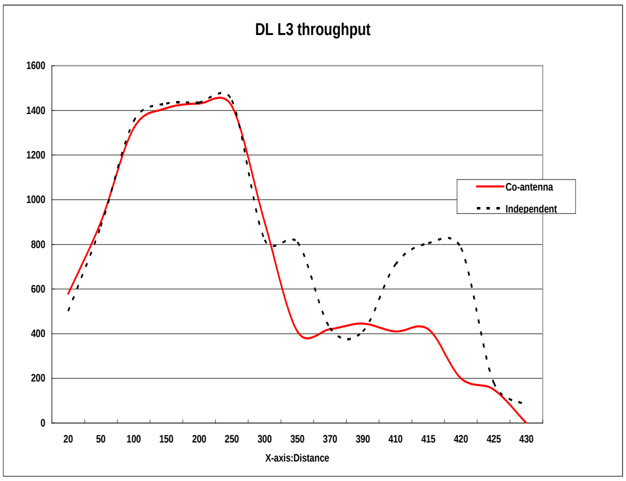
Figure 4.9 TD-LTE Test Result Comparison between Co-antenna and Independent Antenna Solution

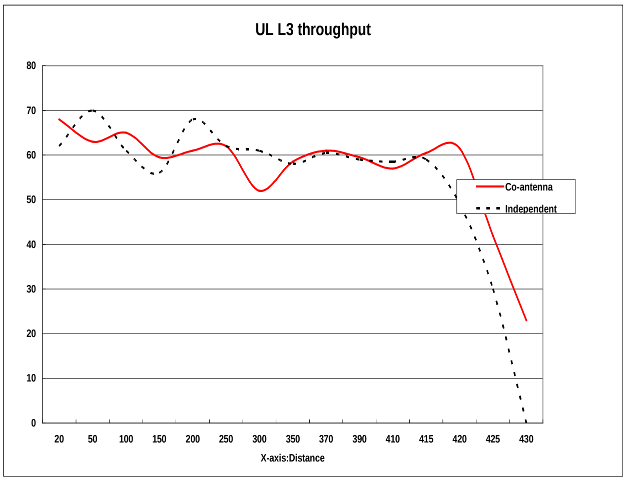


Another field test result shows that with co-antenna solution, the existing TD-SCDMA wireless performance is not affected. These parameters including TD-SCDMA throughput, BLER, RSRP, SINR are quite the same.

Figure 4.10 TD-SCDMA Test Result Comparison between Co-antenna and Independent Antenna Solution







In conclusion, the trials test results show that TD-LTE and TD-SCDMA performance with the co-antenna solution is quite similar to that with the independent antenna solution.

5 SIMPLIFIED DESIGN

5.1 MCIC interface

5.1.1 Scheme and Main Characteristics of MCIC Interface

The MCIC (Multi Coaxial Interface Connector) interface includes cluster connectors (jacks and plugs) and cluster cables, which enable bundled cable connection, making plug-in or plug-out operation more efficient. It also eliminates the possibility of misconnection by adopting the anti-misinsertion mechanism.

The cluster connectors include the 4-core jack/5-core jack (mainly for cluster cables), and the 4-core plug/5-core plug (mainly for devices).

The conductor of each connector inside the plug has the elastic contact end with elastic range of 0.3mm in the axial direction to ensure both reliable conducting and required isolation among connectors. The asymmetric design of keyway and key's positions inside plug or jack provide the anti-misinsertion mechanism which ensures correct connection of each component cable, and guarantees no inadvertent plugging either a 4-core plug into a 5-core jack or a 5-core plug into 4-core jack.

Sealing on both head face and rear port of cluster joint ensures the waterproofing after plug-in.

The supreme reliability of the cluster joint benefits from similarity to DIN type connector in connection design and adoption of SMA type connector size.

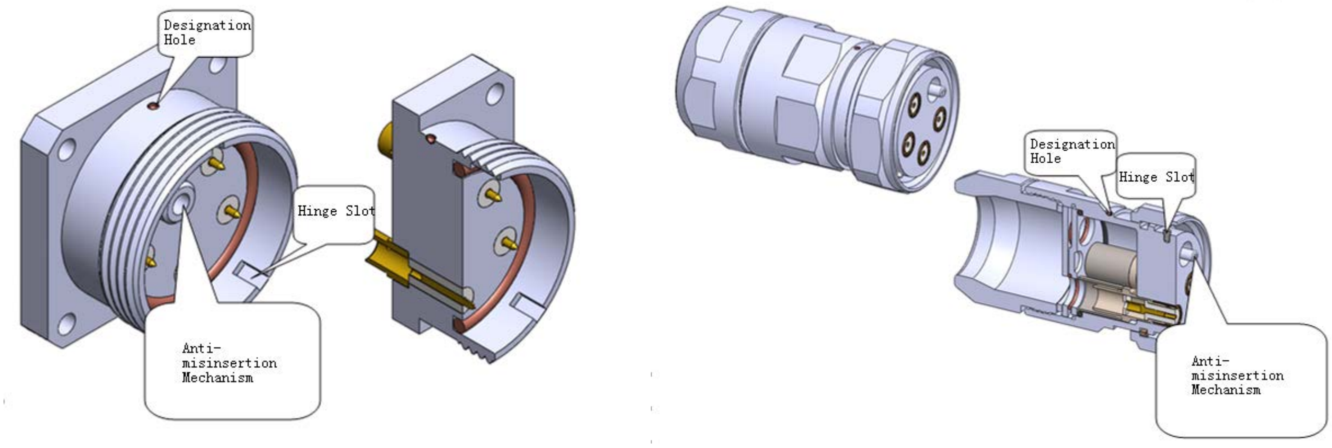


Figure 5.1 4-core jack and 4-core plug

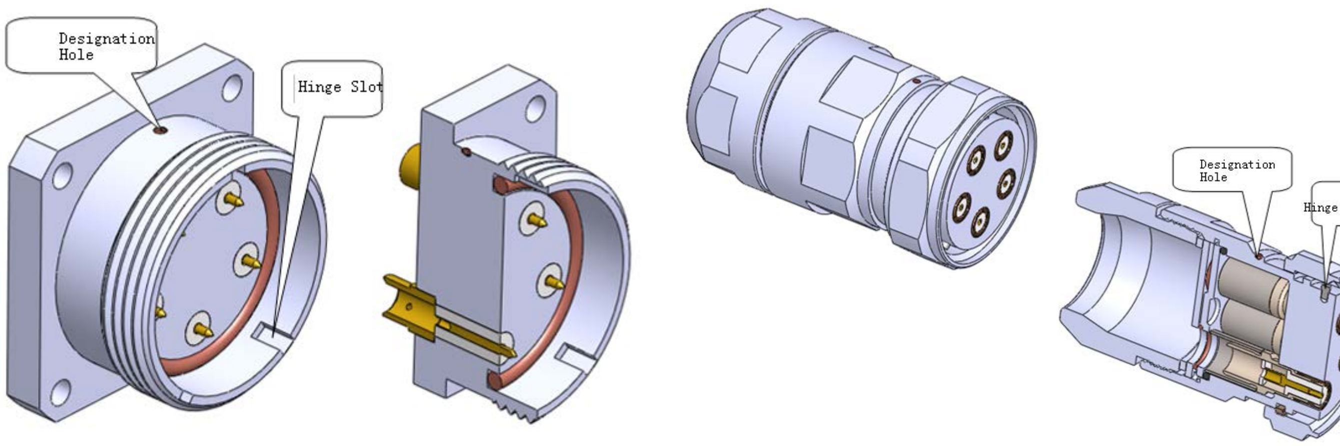


Figure 5.2 5-core jack and 5-core plug

Currently, there are 4 possible cluster cables available for different configurations of antennas and RRUs.

1) One end with 4-core jack, and the other end with 4*N-type jacks;
2) One end with 5-core jack, and the other end with 5*N-type jacks;
3) Both ends with 4-core jacks;
4) Both ends with 5-core jacks.

5.1.2 Reliability of Cluster Joint and Cluster Cable

Electrical Characteristics and engineering reliability are two factors of the cluster connector and cluster cable in reliability.

Table 5.1 Electrical requirement

	Experiment	Experimental evidence	
Part Ⅰ	Electrical Indexes	**GJB1215A-2005 4.5.8 and 4.5.9**	**EIA-364-106**
Part Ⅱ	Water Test	**GB/T 2423.38**	**IEC 60068-2-18:2000**
	Salt Spray Test	**GB/T 2423.17**	**IEC 60068-2-11:1981**
	Cable Retentivity	**GJB1215A-2005 4.5.7**	**IEC 60966-1-1999 9.1**
Part Ⅲ	Bend Test	**GJB1215A-2005 4.5.6**	**IEC 60966-1-1999 9.2**
	Endurance	**GJB681A-2002 4.5.13**	**IEC 61196-1 9.5**
Part Ⅳ	Temperature Variation	**GB/T 2423.22**	**IEC 60068-2-14:1984**
	Moisture Resistance	**GJB360A-96 method 106**	**MIL-STD-202G METHOD 106G**
	Vibration	**GB/T 2423.10**	**IEC 60068-2-6:1995**

Electrical Characteristics:

Impedance: 50Ω

Frequency range: DC-3.00GHz

Power Voltage: 500v (max)

Dielectric Withstand Voltage <750V

VSWR <1.2

Centre Contact Resistance<3.00mΩ

Outer Contact Resistance < 2.0mΩ

Reliability:

Volume deployment of TD-SCDMA systems in recent years has enabled cluster connection technique to undergo continuous improvement and optimization, making such technique to meet very high engineering standard.

5.1.3 Applications

1) Application of MCIC interface technique in TD-SCDMA

MCIC interface technique has been applied in TD-SCDMA networks in large volume. The following product forms have been verified in real networks:

a) RRU with Cluster connector + Dual polarized antenna with N connectors.

b) RRU with N connector + Antenna with cluster connector.

c) RRU with Cluster connector + Antenna with cluster connector.

2

2) Application of MCIC interface technique in TD-LTE

For the similar reason as in TD-SCDMA networks, the MCIC interface technique will play the same important role in TD-LTE network deployment in multi-antenna products. In particular, the technique is highly desirable in sites where TD-LTE and TD-SCDMA system co-exist.

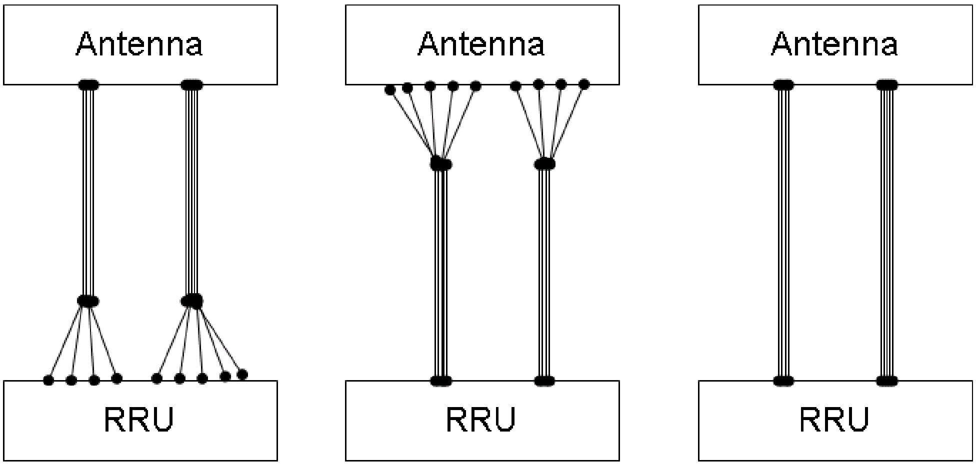


Figure 5.3 Three applications of MCIC interface

5.2 RET antenna with information management

5.2.1 Requirement for RET Antenna

There are three types of base station antennas in the real network based on downtilt:

1. Fixed electrical tilt (FET) antenna. The operator can adjust the kit of an FET antenna to achieve downtilt. In a large mechanical downtilt, the horizontal radiation pattern experiences a distortion, the vertical radiation pattern becomes wider with the back lobe tilting upwards, and the front-to-rear ratio becomes unfavorable, which causes radio frequency (RF) interference and should be controlled in urban area of networks
2. Manual electrical tilt (MET) antenna. The operator can manually adjust the level gauge and move the phase shifter inside an MET antenna to achieve downtilt, or connect an MET antenna to an external remote control unit (RCU) to achieve downtilt.
3. Remote electrical tilt (RET) antenna. RET antennas include antennas with external RCUs METs and antennas with built-in RCUs. The downtilt of RET antennas is controlled remotely by a electrical tilt management system, which enables continuous dynamic adjustment of beam downtilt, avoids shutdown of base stations in case of realtime dynamic network optimization, and balances coverage, capacity, and RF interference. Typically RET antennas are installed vertically without reserving space for downtilt. The installation components are reliable and easy for antenna camouflage. The monitoring database stores the adjustment data and historical data of antenna beams for all base stations, which facilitates analyzing and optimizing network coverage by combining remote monitoring data.

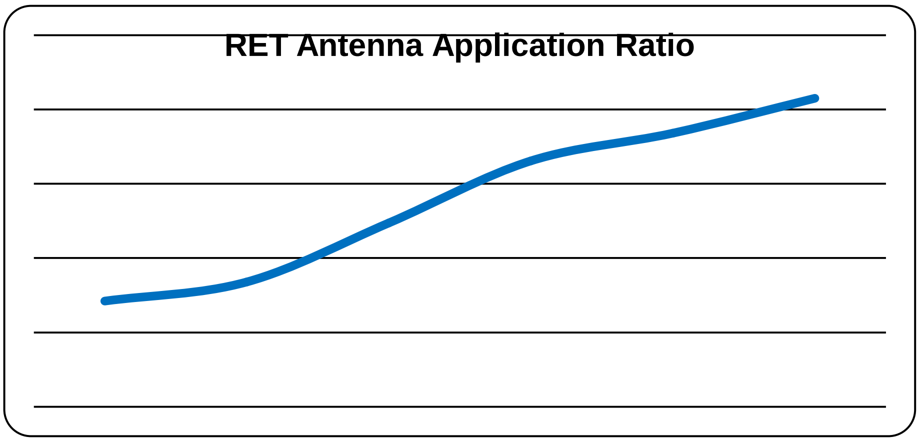


Figure 5.4 RET antenna application ratio

Operators face challenges from non-RET antenna:

1. Antenna maintenance costs much more because of the man power cost is keeping increacing.
2. The downtilt angle cannot be adjusted under heavy weather conditions.
3. The antenna types are excessive and antennas are hard to set up.
4. It is hard to enter the site and the optimization work is time-consuming.
5. The entire network cannot be optimized during a short time.

More and more operators use internal and external RET antennas. RET antennas help to decrease the times of entering sites, reduce the network parameter modification period, improve the network optimization efficiency, and lower the operating expense (OPEX).

5.2.2 Requirement for antenna information management

One key difference between smart antenna and ordinary antenna is the weighting factors, which is shown in figure 5.5, each RF port is given a weighting factor (table 5.2) including amplitude and phase to form a specific broadcast pattern (figure 5.6).

Note: the weighting factors are provided by antenna vendor, and used in base range processing in NodeB.

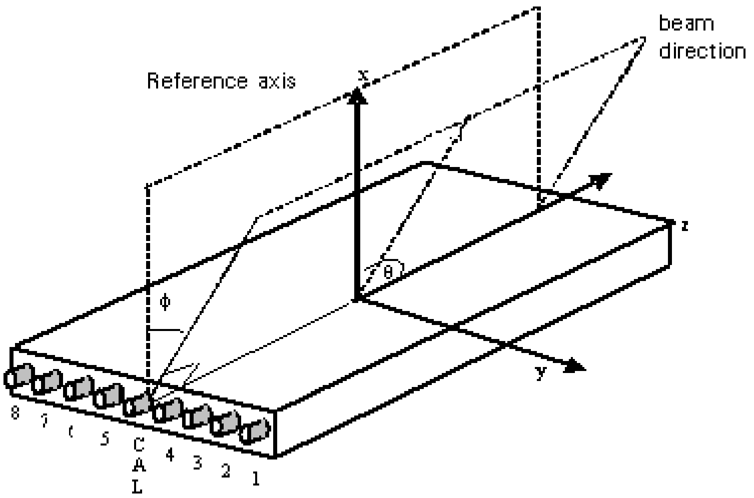


Figure 5.5 TDD multi-antenna with 8 RF port and 1 calibration port

Table 5.2 A weighting factors of TDD multi-antenna@65°Broadcast Beam width (Vendor: Huawei)

Vendor name	Huawei								
Electrical tilt	0°								
Broadcast Beam width: 65°									
Frequency Range/port		Port 1	Port 2	Port 3	Port 4	Port 5	Port 6	Port 7	Port 8
1880M~1920M	Amplitude |Ii|	0	0.45	1.00	1.00	0	0.45	1.00	1.00
	Phase	0	0	0	179	0	0	0	179

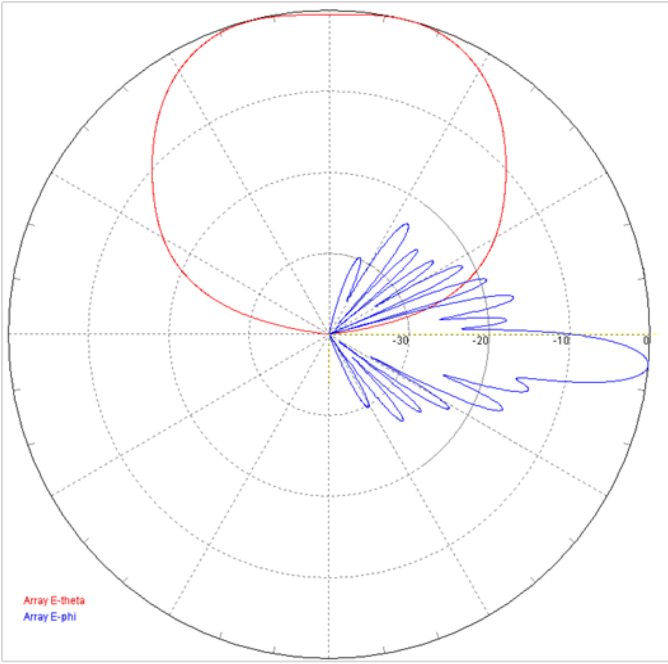
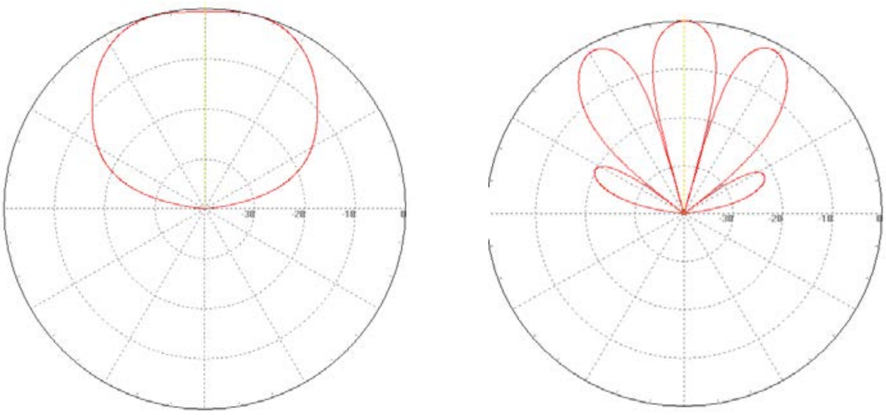


Figure 5.6 The broadcast beam of smart antenna (blue: H; red: E)

Different antennas from different vendors have different weighting factors. The bad influence is that when a wrong weighting factor is applied in the system, the wrong beam will be formed with many coverage holes which is shown in figure5.7. There are 28 models of antennas in use in the Network and it would get 756 wrong combinations.It would affect the network worsely.With the increasing of multi-antenna application, the possiblity with wrong parameters will increase and can't easily be checked out since antennas are passive.



Right broadcast beam pattern Wrong broadcast beam pattern

Figure 5.7 Broadcast beam pattern comparison

Reasons of wrongly configured weighting factors:

1. Wrong installation of antennas:

There may be2~5 antenna vendors in one area, and a very large number of antennas need to be installed in a short time; Under the complex situation, some of the information of the antenna installation gets lost (the situation will get worse when they have to change antennas with different vendors in one area).

2. The actual situation:

In many cases - unless you climb on the top of the tower to verify the antenna information- there is no better way to get the exact antenna information, while it is badly needed.

There is no alarm when the wrong parameter is set because antenna is in passive and can't perform self-check.

3. Confusing on versions of weighting factors :

Weighting factor can be changed or updated according to the antenna product update or optimization from system side . With no version management, operators may get confused by what the correct antenna's weighting factor is.

5.2.3 Information management module (RAE)

The requirements provided by antenna shall include RET andRAE features. The RET device is used for remote electrical tilting. The RAE(Remote e-Antenna information management element) device is used for information management, specially for the weighting factors information store of multi-port TDD-antenna.

5.2.3.1 RET Feature

The RET module can be independent or integrated in the antenna. The RET module shall provide the RET functions according to AISG/3GPP standards.

While setting downtilt, the RET shall set the same electrical tilt value synchronously to all phase shifters of all antenna ports.

The RET shall provide software upgrade and infomation inquiry.

5.2.3.2 RAE Feature

The RAE moduel is integrated in the antenna. The weighting factors of the antenna shall be stored in RAE module in factory.

The RAE shall provide the RAE functions,at least including the following procedures.

RAE Get Weighting Factor

RAE Reset Factory Pattern

The RAE optionally provide the storage of test record information, such as PIM, S-parameters. The BBU device can read it back.

The RAE optionally provide the measure of installation-relative fields of device data. TheBBU device can read it back, using for the antenna management and network optimization.

The stored information includes:

-Antenna bearing

-Installed mechanical tilt

-the altitude

-the geographic location (latitude, logitude, height)

The RAE shall provide software upgrade and infomation inquiry.

5.2.4 Remote information management Solution

5.2.4.1 Block Diagram

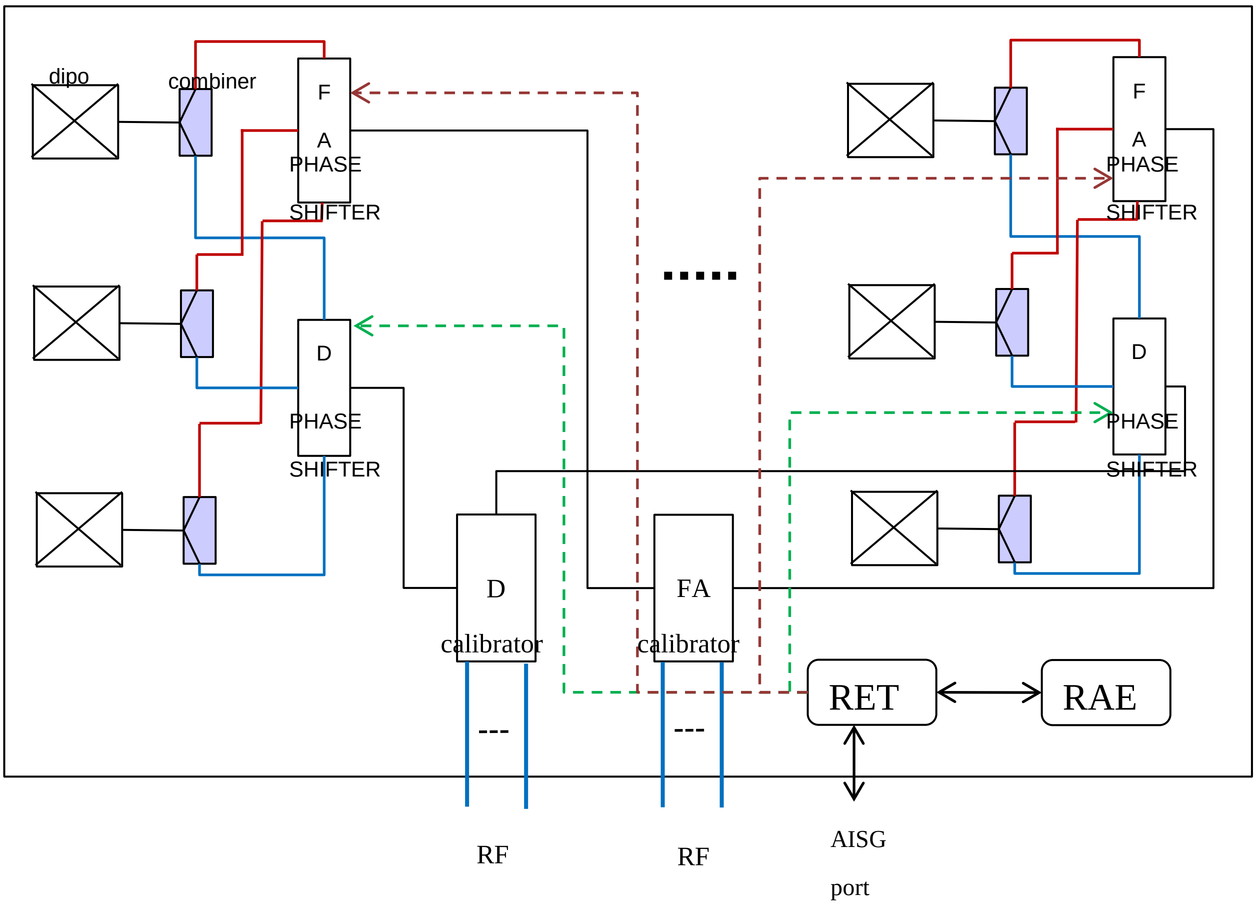


Figure 5.8 Antenna remote information management modual

(The calibrators are only used for 4 and 8 port antennas and no calibartors in 2 port antenna)

1. The antenna integrates RET unit and RAE unit inside. The RET is mandatory and the RAE is optional.
2. The RET controls one or more phase shifters to adjust downtilt angles.
3. The RAE module stores antenna key parameters(bandwidth,gain,installation date,weighting factors, antenna pattern,etc.), and they can be read by base stations by AISG interface.
4. The RAE module manage all the key antenna parameters, downloading,uploading,etc.
5. The RAE module receives DC supply and communicates with the RRU over coaxial cable.
6. RET specifications:

Input voltage range (V): DC 10 - 30

Power consumption (W): < 15 (motor activated) < 1 (stand by)

Adjustment time (full range) (min): < 0.5 (2 port typically, depending on antenna type)

Calibration time (min): < 3 (2 port typically, depending on antenna type)

Operating temperature range (°C): -40 .... +65

Environment standards: EN0950-1 (Safety) N 55022 (Emission) EN 55024 Immunity)

7. RAE specifications

Input voltage range (V): DC 10 - 30

Power consumption (W): < 1

Measure time (seconds): < 30 (Antenna bearing, the altitude over sea and the geographic location)

Operating temperature range (°C): -40 .... +65

Environment standards: EN0950-1 (Safety) N 55022 (Emission) EN 55024 Immunity)

5.2.4.2 Standards Compliance

The RET antenna with the information management function is logically presented as two antenna line devices (ALDs): RET module and RAE module.

Remote electrical tilt (RET) adjusts the tilts of all ports while managing RET information, and communicates with communications equipment over OOK signals and AISG.

Currently, the RET module supports AISG2.0 and references the following standards:

AISG v2.0, 13th Jun 2006 (or later)

3GPP TS 25.460 R10

3GPP TS 25.461 R10

3GPP TS 25.462 R10

3GPP TS 25.463 R10

The RAE module communicates with the communications equipment over OOK signals and AISG to manage antenna parameter information. This function allows the network management system (NMS) or base station to obtain antenna weights and parameters for ease of installation, test, and maintenance.

The RAE module supports AISG protocols of later versions and references ES-RAE v1.0 1 Draft1.05, Jun 2012 (or later).

5.2.5 Advantages with Remote information management module

5.2.5.1 Visualized information management

The sensors provide multiple antenna engineering parameters such as the real-time longitude and altitude, direction angle, and downtilt angle to help network optimization.
Electrical ID functions make the asset management and troubleshooting work more efficient.

5.2.5.2 Automatic data configuration

The internal RET module strictly matches the antenna, and configuration data has been loaded and corrected before delivery. Thus the BBU can read antenna information directly from antenna side by RAE modual. The BBU can apply the correct weighting factors in the systema automatically without any manual setting.
The RAE module provides complete TD weight information to avoid data configuration errors. This ensures the signal coverage and facilitates network maintenance and optimization.

5.2.5.3 Easy optimization

With RET function, operators can adjust downtilts from remote easily. Furthermore, multi-antenna can support beam adjustment by changing the weighting factors. With RAE function, BBU can get more antenna information by pattern data to optimize the broadcast beam and improve the network coverage.

6 COMPACT DESIGN

6.1 Compact antenna

As the network deployment in future will face bigger challenges because of the limitation of antenna installation space. The compact antenna solution is designed to solve the problem. The compact antenna can be used in dense urban area where the need of gain is not too high but the demand of coverage is uniformity. It supports frequency band for F (1880 ~ 1920 MHZ) A (2010 ~ 2025 MHZ) and D (2500 ~ 2690 MHZ).

The compact solution has 3 main features:
-- High efficient antenna element design with antenna height reducing by half but the gain loss 1.5dB
-- inheriting basic mode design (dual polar, wideband, etc.)
--with MCIC interface, thus only 2 connectors

Due to the above 3 main features, the compact antenna could meet the operators' need with half size and good performance.

6.2 Design requirement and product

The product of compact solution has passed the lab test and the field trial in operators' TD LTE trial network.

The figure 6.1 shows the antenna product (without MCIC interface):

Figure 6.1 Compact antenna product (two compact antenna compared with 1 basic solution antenna)

Main design requirements:

- ✓ Dual-polar 8 path
- ✓ Super wideband(3G/4G)
- ✓ Enhanced high efficient antenna element design
- ✓ Support BF&MIMO
- ✓ 2 Cables(MCIC interface)
- ✓ Half height with gain-1.5dB
- ✓ Solution for urban/dense urban

6.3 Test results

The test results just as below:

Simulation of antenna element:

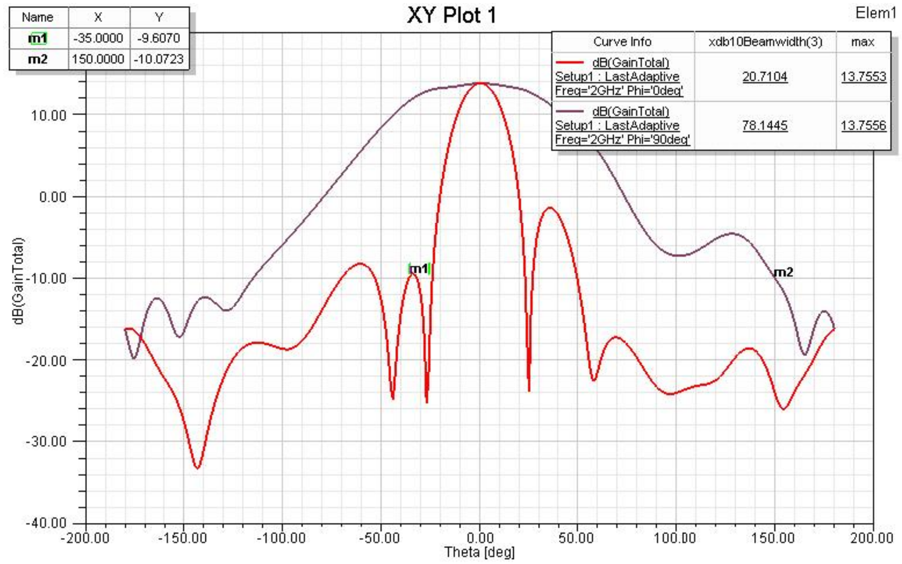


Figure 6.2 element simulation

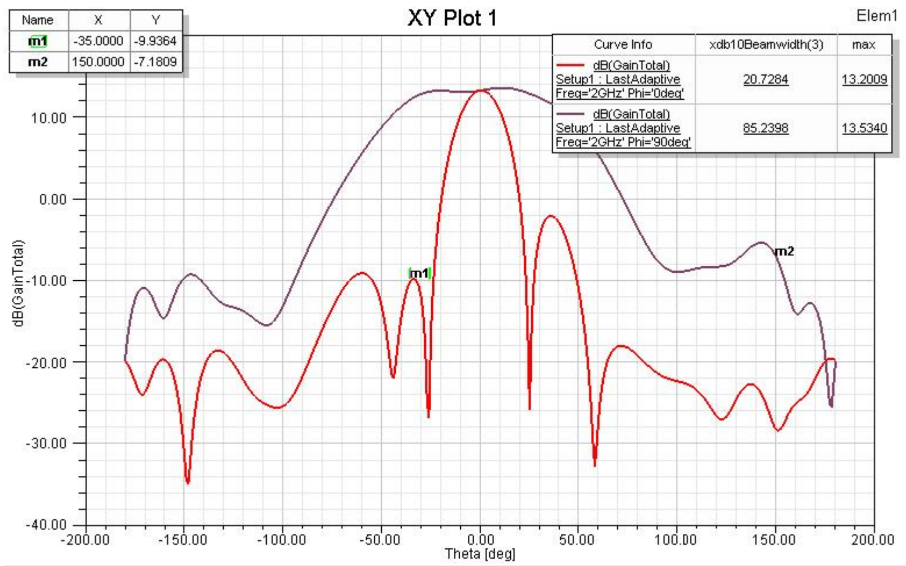


Figure 6.3 element simulation

From the simulation, the gain of it can reach 13.1 dBi (min) with only 4 antenna elements. The gain will reach 15dBi (min) with 8 antenna element for one array.

Simulation for service beam:

Figure 6.4 service beam simulation

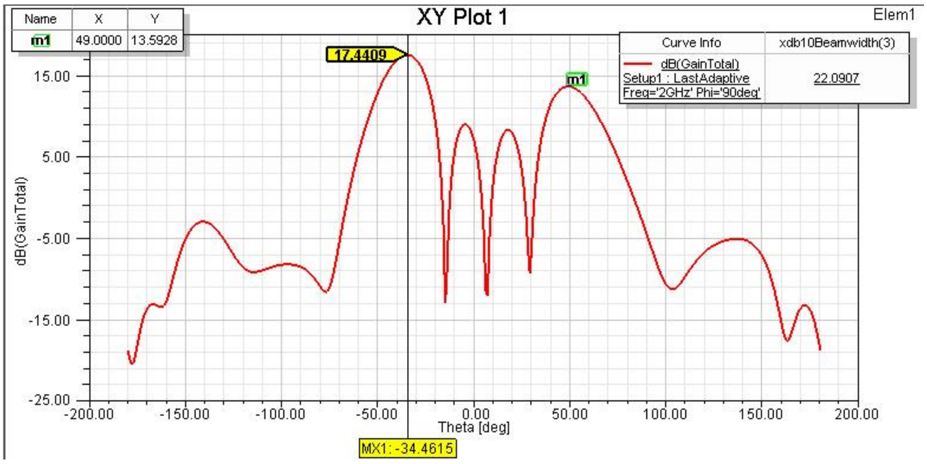


Figure 6.5 service beam simulation

Simulation for broadcast beam：

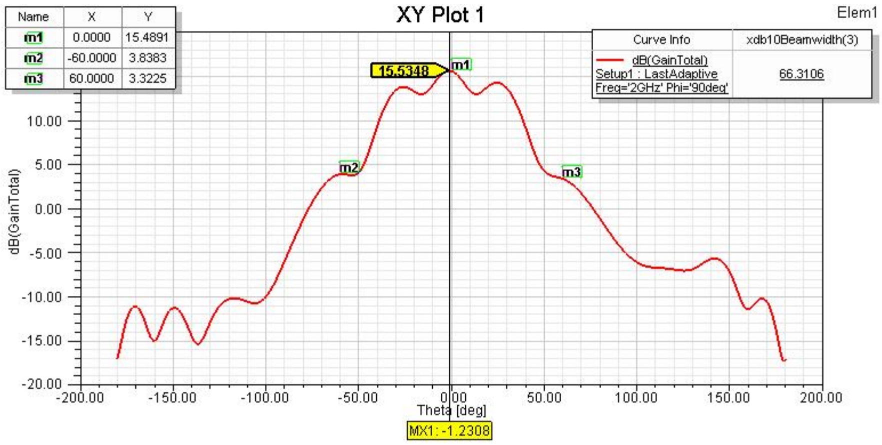


Figure 6.6 broadcast beam simulation

6.4 Trials

6.4.1 Single point throughput test

Single point throughput test was finished in KPN's TD-LTE network in Dusseldorf.

Site configuration:

Figure 6.7 Testing enviornment and testing point

There was only one site for TM2&TM7 comparison test and TM3 test. Frequency Band was 2.6 GHz. Bandwidth was 10 MHz and the name of the site was E-plus office building.

In the point2, with compact antenna, we compared the throughput in TM7 which supports beamforming feature and TM2.

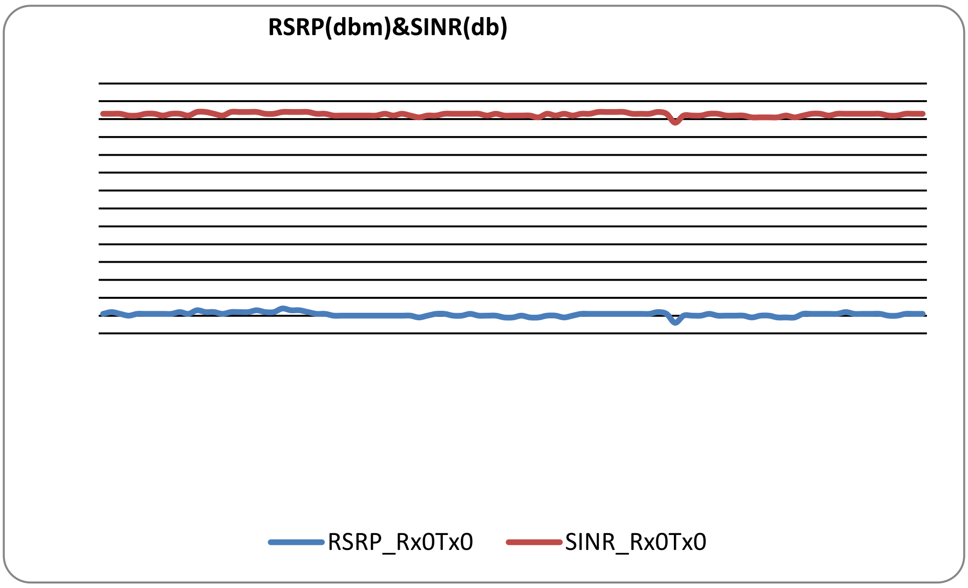


Figure 6.8 DL RSRP (dbm) & SINR (db)

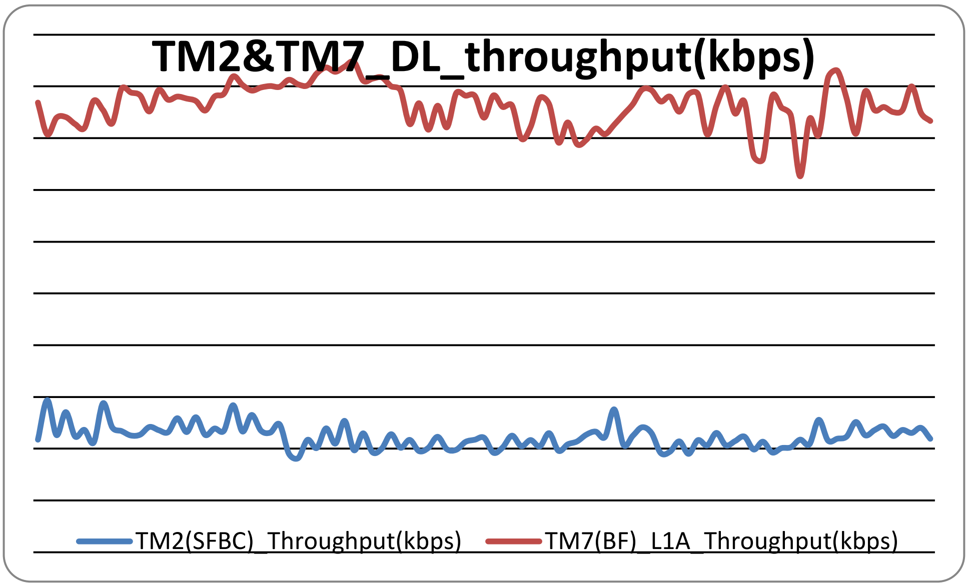


Figure 6.9 DL throughput (Kbps) of TM2 & TM7 from Network Side

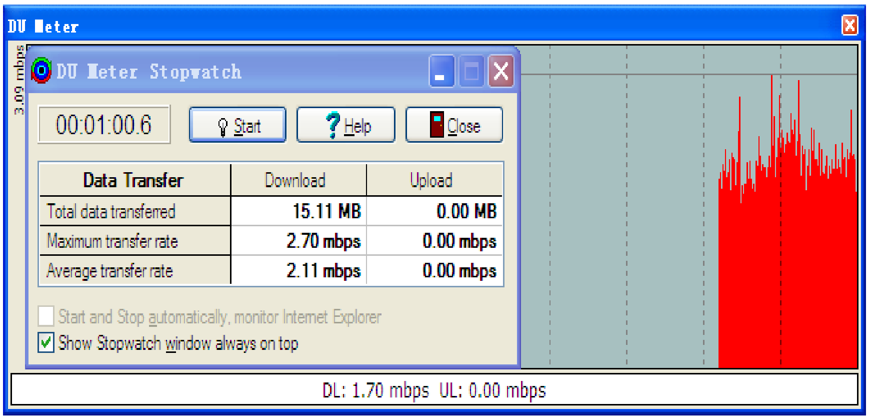


Figure 6.10 DL throughput (kbps) of TM2 from UE Side

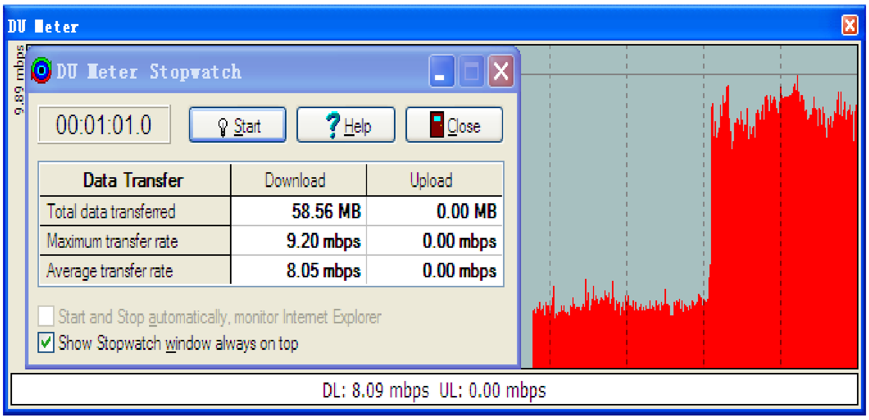


Figure 6.11 DL throughput (kbps) of TM7 from UE side

From the figures above we can see that in the test point 2, TM7 has remarkable performance improvement compared to TM2.

6.4.2 Single site draw-away coverage test

CMCC finished the compact antenna coverage test in the following test environment:

1. Band: 2570~2590 MHz (20M)
2. Mode: TM2/3/7 adaptive
3. Site distance: >500m, urban area
4. Single site with no loading
5. Type: vehicle draw-away coverage test from near point to far point until drop call
6. Height: 30m

After the compact antenna test case, vendors re-installed basic antenna, and repeated the test.

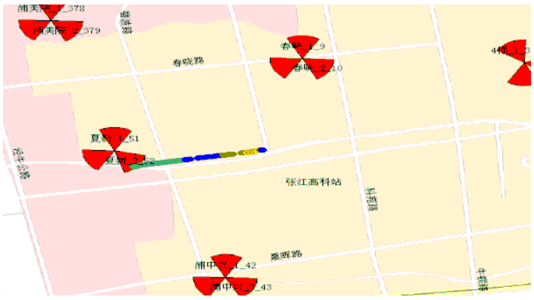


Figure 6.12 compact antennas Coverage test

Figure 6.13 Basic antenna Coverage test

The line with colours was the GPS points. Figure6.12 and 6.13 showed the coverage difference of two types of antenna based on the drop link point.

Vendors also recorded the throughput of two types of antennas, and found that within the 400m distance, the throughputs were very similar.

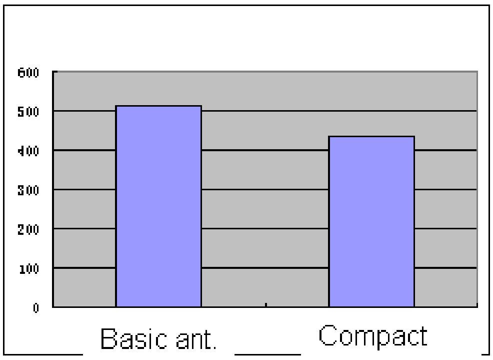
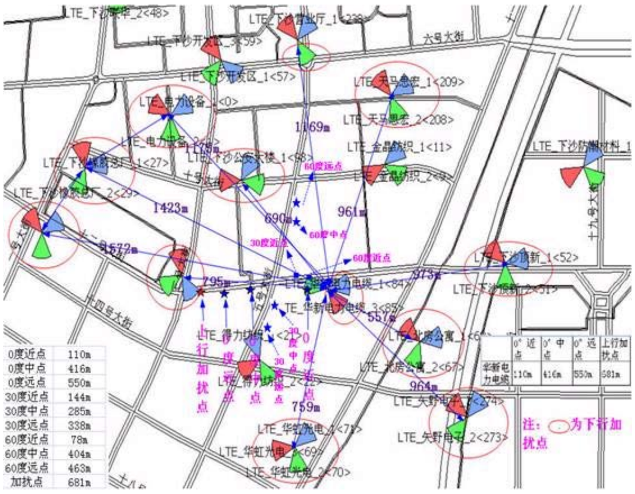


Figure 6.14 Coverage differences of two antennas

For the drop call point, vendors found that compact antenna was around 10~15% less than basic antenna. However, considering the coverage information of other test area for compact antenna, vendors found that also in some scenarios, the coverage abilities of two antennas were much more similar. Vendors believed that in urban and dense urban area with no coverage limitation but interference limitation, the basic performance of system throughput should be similar.

6.4.3 Multi-site throughput test

CMCC also compared the throughput with different system loading in another testing area in different city.
Testing area was not the typical dense urban area but similar to urban area limited to the site choice difficulty. The site distance was between 600~900m.



Throughput: Mbps in near test point

	Uplink-Basic	Uplink-Compact	Downlink-Basic	Downlink-Compact
0% loading	14.24	15.51	27.42	33.87
50%loading	14.80	15.23	20.42	24.05
70%loading	11.54	12.96	12.42	15.09

From the table in the near point, compact antenna’s performance was better than that of basic antenna.

Throughput: Mbps in far test point

	Uplink-Basic	Uplink-Compact	Downlink-Basic	Downlink-Compact
0% loading	11.94	15.42	8.41	13.64
50%loading	6.75	10.9	8.76	13.75
70%loading	3.88	8.66	8.49	6.27

From the table in the far point, compact antenna’s performance is similar or better than that of basic antenna.

7 FUTURE ANTENNA

In this chapter we will look at some future trends for antenna design driven by the need for compact, high performance solutions for deployment of TD-LTE in dense urban scenarios.

7.1 Spatial processing and antenna layout

In this document (and in the industry in general) we have focused on antennas which allows spatial processing at base band of signals on groups of antenna elements with different polarizations and/or belonging to a different vertical column. This approach allows to combine both electrical tilting and spatial processing at baseband and thus to obtain a high performance solution.

However as also discussed above the size of the antenna tends to increase when both baseband spatial processing and electrical tilting, for 8 pipe spatial processing and high gain vertical pattern with electrical tilting the number of antenna elements needed inside one antenna gets close to 100 (8 elements in horizontal and 10 in vertical domain).

While the split in horizontal and vertical domain between baseband processing and electrical tilting is working well in rural and suburban areas with good correlation of radio channel between adjacent co-polar antenna elements, it is worth to investigate whether other solutions could be also suitable for the urban and dense urban scenarios.

Basically what could be an interesting solution is to reduce to number of elements reserved for electrical tilting and use instead baseband processing to have a faster and more flexible phasing of the individual antenna elements. This is needed when correlation among adjacent co-polar elements is decreased due to significant scattering in the immediate surroundings of the antenna.

As a specific example one could take the well-known single column cross polar uniform linear array (10 elements) which have been used in many LTE deployments and divide the 20 elements into 8 groups which can then be driven from baseband reusing as much as possible the existing 8 pipe technology. A comparison between the traditional 8 pipe antenna and the proposed example of vertical pipes can be seen in Figure.

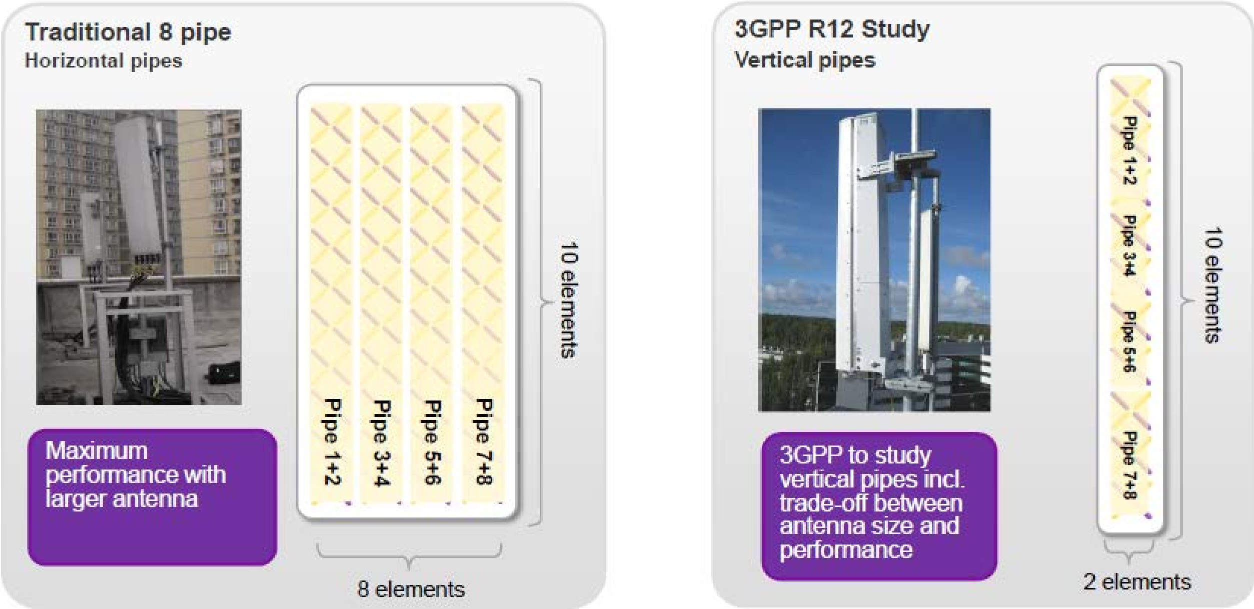


Figure 7.1 Illustration of antennas designed for horizontal and vertical pipes.

7.2 Standardization issues

In order to get the most out of 8 pipes mapped to element groups stacked in vertical and polarization domain it may be needed to adjust the 3GPP standard for LTE. As a starting point if uplink sounding is the main source of information for creating the beamforming weights to be applied on the different pipes, the existing Release 9 solution should be sufficient.

In the case the beamforming weights are generated based on precoding matrix indicator (PMI) reported from the UE things should also work fine as long as the number of antenna ports needed is not larger than 8 which is the maximum size supported by 3GPP Release 10 standard. Potentially there could be additional gain from optimizing the code book for particular scenarios but here further investigations are needed. With Release 11 some additional flexibility is already available as a UE can report multiple PMIs. This could potentially be useful to handle cases with more than 8 pipes.

For Release 12, 3GPP is planning a thorough study of elevation beamforming and more generally 3D beamforming and Massive MIMO techniques. The discussion of study plan is ongoing in this moment but one important issue to be discussed is how to model MIMO channels in vertical domain. Some existing studies are already available but further discussion is needed among partners to reach a commonly agreed model that can be used for 3GPP approved performance simulations.

7.3 Performance analysis

In order to decide which option is optimal for a certain scenario, performance simulations are important. In the following we present some initial results to give an estimate of the benefit from increasing the number of pipes without changing the antenna layout. The simulation results given in Table 1 are based on 3GPP agreed simulation methodology (for further details on parameters see
Table 2). All simulated cases are based on LTE R8/R10 technology, no changes to specification are assumed.

From the results we observe that using 4 pipes can give a significant gain without increasing antenna size. With vertical sectorization also 4 pipes are needed (2 per cell), and this configuration actually offers the best performance with more than 40% gain in average throughput.

Note that these are preliminary results, and further studies are needed to come to a solid conclusion on the benefits of using baseband processing pipes in vertical antenna domain. There could potentially be more benefits in case of more realistic burst traffic model, and also further solution optimization is possible. All this will be discussed further in the agreed 3GPP R12 study item.

Table 1 Simulation results(from NSN), illustrating the benefits of driving a typical single column cross-polar antenna with 4 pipes or adding dual beam vertical sectorization.

DL MIMO Configuration	Capacity (Mbps) Cell Edge (Kbps)	Gain over Baseline (%)
Baseline **2X2 SU-MIMO**	20.2 550	0 0
4X2 SU-MIMO (TM4)	20.7 620	+2.5 +12.7
4x2 MU-MIMO (TM9)	24.9 620	+23.3 +12.7
Vertical Sectorization **2X2 SU-MIMO**	29.0 590	+43.6 +7.3

Table 2 Simulation parameters

Parameter	Setting
Network Layout	3GPP Case1 (500m Inter-Site Distance)
Cell layout	19 macro-sites, wrap-around
UE placement	Uniform distribution
Traffic model	Full buffer
Transmit power	Macro-eNB: 46 dBm; pico-eNB: 30 dBm
Sub-frame duration	1 ms (11 data plus 3 control symbols)

Modulation and coding schemes	QPSK (1/5 to 3/4), 16-QAM (2/5 to 5/6), 64-QAM (3/5 to 9/10)
1st transmission block error rate target	10%
HARQ modelling	Ideal chase combining with maximum 4 transmissions
Bandwidth	10 MHz at 2000 MHz frequency
Transmission mode	SU-MIMO: TM4, 2 or 4 CRS port, MU-MIMO: TM9
UE feedback	According to 3GPP specification Narrow band CQI (6PRB) and wideband PMI 10 ms reporting period and 6 ms delay
UE Receiver	UE: MMSE-IRC receiver
Antenna gain	Macro: 14 dBi; pico: 5 dBi; UE: 0 dBi
Antenna pattern	Macro: 3D [6]; UE: Omni
eNB packet scheduling	Proportional Fair (PF)

7.4 Summary

In this chapter we have discussed the possibility of future active antennas, especially the idea that antenna elements in vertical domain can split to multiple groups and driven by separate baseband processing pipes. This provides improved performance without further increase of antenna size. Such solution is attractive in urban and dense urban scenarios where antenna sizes are constrained and heavy scattering reduces the effective antenna gain from traditional wideband co-phasing of elements.

8 SUMMARY

This document provides the guideline for future multi-antenna development and deployment. It includes 4 main technical trends and requirements of multi-antenna and then introduces the solutions and key parameters as reference.

Multi-band:

With the rapid development of FDD and TDD LTE application, more and more operators consider using multi band antenna with wideband tech support instead of narrow/single band antennas in their network in order to cope with the challenges of 2G/3G/4G co-existence.

The wideband antenna should be able to support the 3G and 4G bands. The TD FAD (F: 1880~1920MHz、A:2010~2025MHz、D:2500~2690MHz) antenna is a typical wideband antenna used for both TD-SCDMA and TD-LTE networks. The antenna can be shared by two different systems.

Besides wideband dipoles, the wideband antenna design also needs the support of coupling calibration network and feeding network.

Multi-mode:

Multi-mode antenna can support multi-systems, including GSM1800MHz&3G&4G with a super-wide band 1710~2700MHz. It can also support different transmit mode, including BF&MIMO with at least 2 RX and 2 TX.

The multi-mode antenna is also called co-site antenna when used for the on-going LTE deployment.

There are three co-site solutions of antenna system for TD-LTE/TD-SCDMA or TD-LTE/TD-LTE :

1. smart antenna sharing solution: smart antenna, filter combiner
2. smart antenna sharing solution smart antenna Integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC)
3. smart antenna sharing solution : independent Electrical Tilt smart antenna Integrated with filter combiner and Multi-Coaxial Incorporative Cable Interface (MCIC)

The second and third solutions have been verified in TD-LTE networks with good performance.

Simplified design:

Comparing with ordinary antenna, the extra complexity of the multi-antenna technique brings new challenges which require simplified designs.

The first challenge is from large amount of connectors of 8 path antenna. The MCIC(Multi Coaxial Interface Connector) interface includes cluster connectors(jacks and plugs) and cluster cables, which enable bundled cable connection, making plug-in or plug-out operation more efficient. It also eliminates the possibility of misconnection by adopting the anti-misinsertion mechanism. With MCIC interface, the number of connectors reduces 80% from 9 to 2, which have been initially used in TD-LTE antenna deployment.

The second challenge is from the management of antenna information, especially antenna weighting factors, and the optimization of two different systems with one co-site antenna. RET antenna with information management will be a very important requirement for future multi-antenna.

Compact design:

In urban and dense urban areas, compact design will be more important for the operators' deployment than the antenna gain. With compact design, the height of antenna can reduce 50% and make the deployment easier. With high efficient antenna element design, the basic performance of new antenna should be similar to ordinary one in urban area.

With these four technical improvements, the multi-antenna with high performance advantages can solve most of the deployment problems and other potential challenges.

In the future, spatial processing of multi-antenna with both vertical and horizontal can be an important trend to enhance the performance.

9 REFERENCES

[1] MIMO and Smart Antennas for 3G and 4G Wireless Systems; Practical Aspects and Deployment Considerations; 3G Americas May 2010

[2] ITU-R, M.2134, Requirements related to technical performance for IMT-Advanced radio interface(s)

[3] ITU-R, M.2135, Guidelines for evaluation of radio interface technologies for IMT advanced.

[4] 3GPP TS 36.213, v10.0.0, Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures.

APPENDIX A- WIDEBAND 8 PATH ANTENNA KEY PARAMETERS

Table A Wideband antenna key parameters

<table>
<tr><td rowspan="4">General Parameters</td><td>Parameters(unit)</td><td>target</td><td colspan="2">target</td><td colspan="2">target</td></tr>
<tr><td>Frequency Range (MHz)</td><td>1880~1920 (F)</td><td colspan="2">2010~2025 (A)</td><td colspan="2">2500~2690 (D)</td></tr>
<tr><td>Fixed Down-tilt (°)</td><td>0/3/6/9</td><td colspan="2">0/3/6/9</td><td colspan="2">0/3/6/9</td></tr>
<tr><td>Down-tilt separation (°)</td><td>±1</td><td colspan="2">±1</td><td colspan="2">±1</td></tr>
<tr><td rowspan="12">Calibration and electrical parameters</td><td>Loss of Antenna Element Connector to Calibration Port Connector (dB)</td><td>-26±2</td><td colspan="2">-26±2</td><td colspan="2">-26±2</td></tr>
<tr><td>Difference in transmission coefficient between any 2 antenna element connector to calibration connector, Magnitude (dB)</td><td>≤0.7</td><td colspan="2">≤0.7</td><td colspan="2">≤0.7</td></tr>
<tr><td>Difference in transmission coefficient between any 2 antenna element connector to calibration connector, Phase (°)</td><td>≤5</td><td colspan="2">≤5</td><td colspan="2">≤5</td></tr>
<tr><td>VSWR</td><td>≤1.5</td><td colspan="2">≤1.5</td><td colspan="2">≤1.5</td></tr>
<tr><td rowspan="4">Co-polarization isolation (dB)</td><td>0°</td><td colspan="4">≥20dB</td></tr>
<tr><td>3°</td><td colspan="4">≥25dB</td></tr>
<tr><td>6°</td><td colspan="4">≥28dB</td></tr>
<tr><td>9°</td><td colspan="4">≥28dB</td></tr>
<tr><td rowspan="4">Cross-polarization isolation (dB)</td><td>0°</td><td>≥25dB</td><td colspan="2">≥25dB</td><td>≥25dB</td></tr>
<tr><td>3°</td><td colspan="4">≥28dB</td></tr>
<tr><td>6°</td><td colspan="4">≥30dB</td></tr>
<tr><td>9°</td><td colspan="4">≥30dB</td></tr>
<tr><td rowspan="7">Radiation parameters</td><td rowspan="7">Single beam</td><td>Azimuth 3dB Beamwidth (°)</td><td>100°±15°</td><td colspan="2">90°±15°</td><td>65°±15°</td></tr>
<tr><td>Single Beam Gain</td><td>≥14dBi</td><td colspan="2">≥15dBi</td><td>≥16.5dBi</td></tr>
<tr><td>±60°signal dop</td><td>/</td><td colspan="2">/</td><td>12±2dB</td></tr>
<tr><td>Vertical 3-dB Beam-width</td><td>/</td><td colspan="2">/</td><td>≥5°</td></tr>
<tr><td>Cross-polar ratio (0°)</td><td>≥18dB</td><td colspan="2">≥18dB</td><td>≥18dB</td></tr>
<tr><td>Cross-polar ratio（±60°）</td><td>≥10dB</td><td colspan="2">≥10dB</td><td>≥10dB</td></tr>
<tr><td>F/B Ratio</td><td>≥23dB</td><td colspan="2">≥23dB</td><td>≥25dB</td></tr>
</table>

		First Side-lobe Level	/	/	≤-16dB
	BCH beam	Azimuth 3dB Beamwidth (°)	65°±5°	65°±5°	65°±5°
		BCH Gain	≥14dBi	≥15dBi	≥16dBi
		±60°signal dop	12±2dB	12±2dB	12±2dB
		Vertical 3-dB Beam-width	≥7°	≥6.5°	≥5°
		Cross-polar ratio (0°)	≥22dB	≥22dB	≥22dB
		Cross-polar ratio（±20°）	≥20dB	/	≥22dB
		Cross-polar ratio（±60°）	≥10dB	≥10dB	≥10dB
		F/B Ratio	≥28dB	≥28dB	≥28dB
		First Side-lobe Level	≤-16dB	≤-16dB	≤-16dB
		First Null Fill	≥-18dB	≥-18dB	≥-18dB
	Beam is steered towards to 0° and 60°	0° Beam Gain	≥20dBi	≥21dBi	≥22dBi
		0° Beam Azimuth 3dB Beamwidth (°)	≤ 29°	≤26°	≤25°
		0° Beam Side-Lobe Level	≤-12dB	≤-12dB	≤-12dB
		±60° Beam Gain	≥17.5dBi	≥17.5dBi	≥19.5dBi
		±60°Beam Azimuth 3dB Beamwidth (°)	≤32°	≤32°	≤23°
		±60° Beam Side-Lobe Level	≤-5dB	≤-5dB	≤-4dB
		Cross-polar ratio (0°)	≥22dB	≥22dB	≥22dB
		0° Beam F/B Ration	≥28dB	≥28dB	≥28dB
Mechanical parameters	Mechanical Down-Tilt（°）	-5～10			
	Connector	N-Female			
	Clamp Diameter (mm)	φ50～φ115			

	Radome Material	UPVC
	Dimension(mm)	≤1400x320x150
	Weight(kg)	≤11

APPENDIX B- COMPACT ANTENNA KEY PARAMETERS

Table B Compact antenna key parameters

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<tr><td>Single Beam Gain</td><td>≥12dBi</td><td>≥13dBi</td><td>≥14.5dBi</td></tr>
<tr><td>±60°signal dop</td><td>/</td><td>/</td><td>12±2dB</td></tr>
<tr><td>Vertical 3-dB Beam-width</td><td>/</td><td>/</td><td>≥9°</td></tr>
</table>

		Cross-polar ratio (0°)	≥18dB	≥18dB	≥18dB
		Cross-polar ratio（±60°）	≥10dB	≥10dB	≥10dB
		F/B Ratio	≥23dB	≥23dB	≥25dB
		First Side-lobe Level	/	/	≤-16dB
	BCH beam	Azimuth 3dB Beamwidth (°)	65°±5°	65°±5°	65°±5°
		BCH Gain	≥12dBi	≥13dBi	≥14dBi
		±60°signal dop	12±2dB	12±2dB	12±2dB
		Vertical 3-dB Beam-width	≥12°	≥11°	≥9°
		Cross-polar ratio (0°)	≥22dB	≥22dB	≥22dB
		Cross-polar ratio（±20°）	≥20dB	/	≥22dB
		Cross-polar ratio（±60°）	≥10dB	≥10dB	≥10dB
		F/B Ratio	≥28dB	≥28dB	≥28dB
		First Side-lobe Level	≤-15dB	≤-15dB	≤-15dB
		First Null Fill	≥-18dB	≥-18dB	≥-18dB
	Beam is steered towards to 0° and 60°	0° Beam Gain	≥18dBi	≥19dBi	≥20dBi
		0° Beam Azimuth 3dB Beamwidth (°)	≤ 29°	≤26°	≤25°
		0° Beam Side-Lobe Level	≤-12dB	≤-12dB	≤-12dB
		±60° Beam Gain	≥15.5dBi	≥16.5dBi	≥17.5dBi
		±60°Beam Azimuth 3dB Beamwidth (°)	≤32°	≤32°	≤23°
		±60° Beam Side-Lobe Level	≤-5dB	≤-5dB	≤-4dB

		Cross-polar ratio (0°)	≥22dB	≥22dB	≥22dB
		0° Beam F/B Ration	≥28dB	≥28dB	≥28dB
Mechanical parameters	Mechanical Down-Tilt（°）	-5～10			
	Connector	N-Female			
	Clamp Diameter (mm)	φ50～φ115			
	Radome Material	UPVC			
	Dimension(mm)	≤400x160x80			
	Weight(kg)	≤8			