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Test Results for 5G Indoor Pico Base Station

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Abstract. The fifth generation (5G) New Radio (NR) has attracted a large amount of interest with its improvement of user experience and capacity. But the anticipated use of the new technology brings serious challenges to existing solutions for its high spectrum and large bandwidth. Among them, indoor coverage is an important issue before commercial deployment. However, there are few evaluation targeting the pico base station. A new distributed antenna system (DAS) solution towards 5G indoor coverage is introduced. In this paper, the new indoor picocell with different RF configuration is introduced to build more flexible, efficient and evolving network. Besides, A series of trials are carried out to verify the RF performance of two types of radio frequency units (RRU).

1. Introduction

In the approaching 5G era, 70% of new business will occur in indoor scenes, and 80% of high-value customers work in indoor environments. Therefore, indoor coverage has become the key to operators' development of 5G services. However, the 5G deployment frequency band is generally high, which leads to significant increase on path loss and penetration loss. Taking 3.5GHz as an example, it is difficult to cover indoor areas with the outdoor base station. (3GPP TR 38.901 formula) Besides, the existing distributed antenna systems (DAS) can't be updated and reused, since the passive components does not support 3.5GHz frequency band. Therefore, the specific focus of 5G indoor coverage research is pico base station (BS) based on digital DAS, which is one of the most important deployment modes in the future indoor scenarios.

There are various picocell configurations for different requirements. For indoor hotspot scenes, high-capacity and high-density are required to carry out the new 5G services. The picocell with four antennas (4T4R) is more in line with the demand. On the contrary, ensuring coverage at a lower cost is the primary focus of the low-traffic scenario. To reduce the deployment costs, low specification small cells with double antennas (2T2R) will be one of the choices. In this paper, the two types of 3.5GHz picocells is studied by means of a few RF performance trial with a testbed.

In Section 2, we introduce the new DAS solution for 5G and describe its architecture. Section 3 gives an overview of the testbed used and field-trial environments. Section 4 presents the results. Finally, the conclusions are drawn in Section 5.

2. 5G Indoor Coverage

2.1. Digital DAS System

The new digital DAS is seen as the main solution in specific indoor scenarios. As shown in figure 1, The pico BS is mainly composed of a baseband unit (BBU), an extension unit (EU), and several radio frequency units (RRU). The BBU is mainly responsible for baseband signal modulation and demodulation, wireless resource management, mobility management, physical layer processing, equipment state monitoring and other functions. The EU is used for the extension of the wireless baseband signal to enhance the indoor coverage and system capacity. The RRU realizes the radio frequency processing and the radio signal transmission and reception. However, only BBU and RRU are needed to complete the tests.

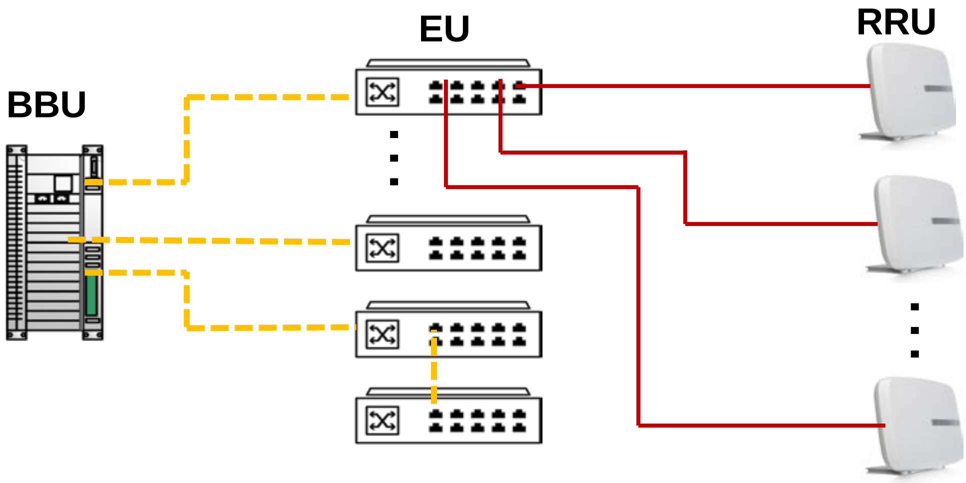

Figure 1. Pico base station system architecture.

The new system architecture has many advantages over traditional passive DAS. At the BBU side, capacity requirements of different scenarios can be dynamically met through cell merging and splitting. On the other hand, benefiting from the active digital device, new functions can be realized such as precise positioning and fault monitoring, which will certainly be of much help RRU maintenance and management. Currently, the active digital DAS has become the mainstream indoor 5G scheme for multiple vendors.

2.2. 4T4R and 2T2R

Considering the differences in coverage and capacity for different scenarios, there are two types of RRU with four or two antennas. From the perspective of coverage, 4T4R of 3.5 GHz can reach the same coverage as LTE of 1.8 GHz. As for system capacity, 4T4R can maximize the system capacity. In addition, 5G terminals support 2T4R, the picocell of 4T4R also matches the mobile phones' capabilities.

However, deployment costs are a huge challenge, and it is easy to waste resources in sparsely populated areas. To meet different scenarios, the 2T2R RRU is more suitable for the lower capacity requirements. The coverage will be lower than 4T4R if the output power is still 24 dBm for each antenna. To compensate for the gain of antenna number loss, the output power is increased to 27 dBm. Table 1 shows the link budget of two configurations. When the transmission power is increased by 3 dB, the downlink coverage are improved as much as uplink coverage. Moreover, the RRU cost is reduced by saving components and lowing the hardware configurations.

Table 1. 3.5 GHz link budget.

Item	Parameter		
Channel	PUSCH	PDSCH	PDSCH
Carrier freqence (GHz)	3.5	3.5	3.5
Sub carrier spacing (kHz)	30	30	30
RB number	100	272	272
Transmit antenna	2	2	2
Output power (dBm)	23	24	27
Receive antenna	2	4	4
Cover range (m)	32.42	26.95	33.48

3. Test Environment

3.1. Testbed Environment

The RF conduction test of the system was carried out in the electromagnetic shielding room. Figure 2 and figure 3 show the working testbed. NR signals generated by BBU are emitted through RRU. RRU can be powered by PoE network cable from BBU or direct current transformer. For transmitter test, the RRU output is connected to the signal analyzer through a feeder. A protective device is used between the RRU output and the analyser. A N9030B signal analyzer is used for high-performance research and development. The instrumentation can analyze various signals with a wide frequency range of 2 Hz to 50 GHz, and the analysis bandwidth is up to 510 MHz, which completely meet our equipment requirements. For receiver test, A N5121B RF analog signal generator is used to produce standard NR signal.

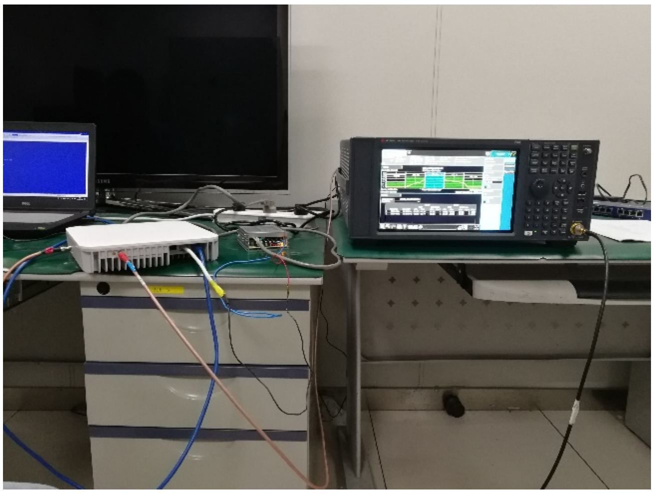

Figure 2. Testbed environments with 2T2R RRU.

Figure 3. Testbed environments with 4T4R RRU.

3.2. System Configuration

The 5G testbed radio interface has the same main structure according to 3GPP NR standard. As shown in table 1, the duplex mode is time division duplex (TDD). The testbed supports up to 256 QAM modulation in the downlink (DL) and up to 64 QAM in the uplink (UL). The bandwidth is 100 MHz, centered at 3.45 GHz. The total output power is 30 dBm, that means 24 dBm/port for 4T4R RRU and 27 dBm/port for 2T2R RRU.

Table 2. Main system parameters.

Parameter	Value
Carrier frequency	3.45 GHz
Bandwidth	100 MHz (3.40 – 3.50 GHz)
Subcarrier spacing	30 kHz
Duplex	TDD
Frame structure	2.5 ms double cycle
Duplex scheme	DDDSU DDSUU
Maximum modulation	256 QAM in DL, 64 QAM in UL
Antenna	2, 4
Total output power	30 dBm

4. Results

According to related standards and laboratory conditions, a total of 9 transmitter characteristics has been tested including output power, transmitter off power, transmitter transient period, error vector magnitude (EVM), occupied bandwidth (OBW), adjacent channel leakage power ratio (ACLR), operating band unwanted emissions (OBUE), and transmitter spurious emissions. The receiver indicator was only tested for reference sensitivity level. The detailed RF test results are listed in the table 2. Partial test screenshots are given in figure 4 and figure 5.

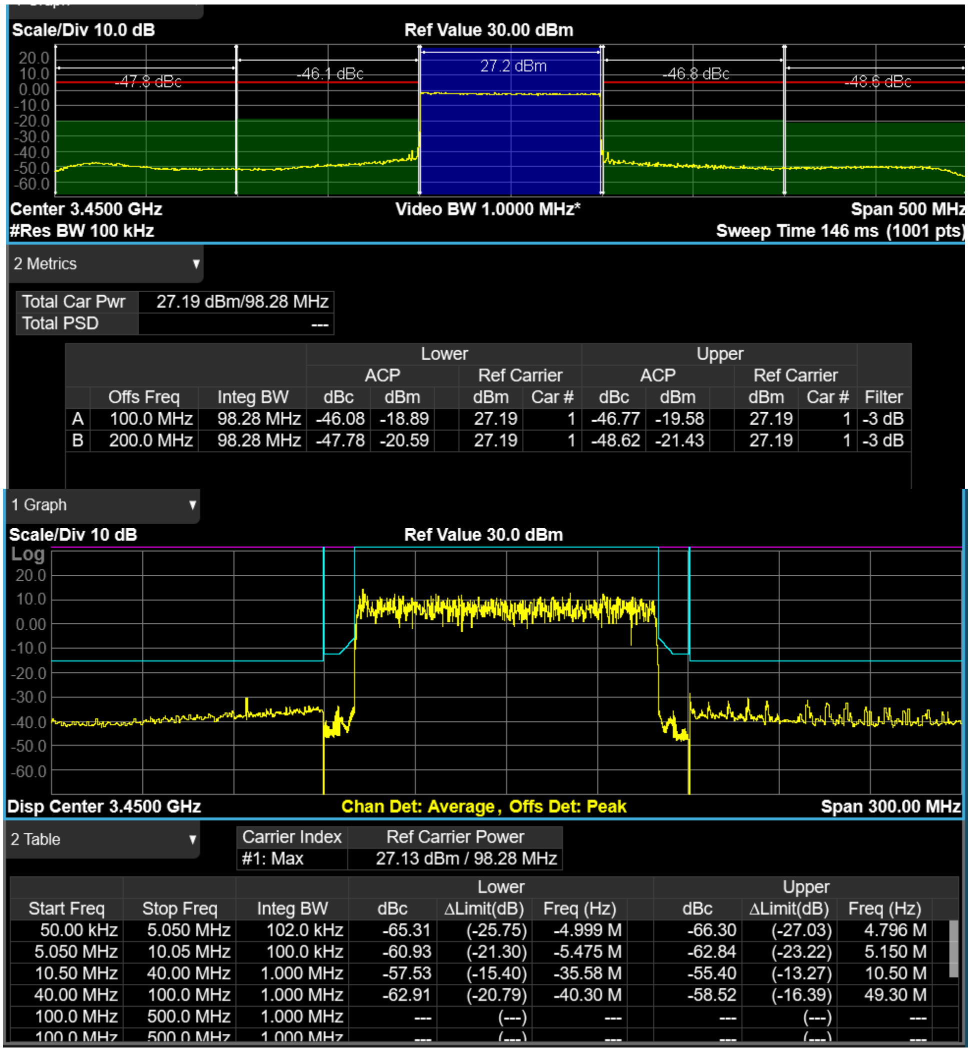

Figure 4. 2T2R RRU test results.

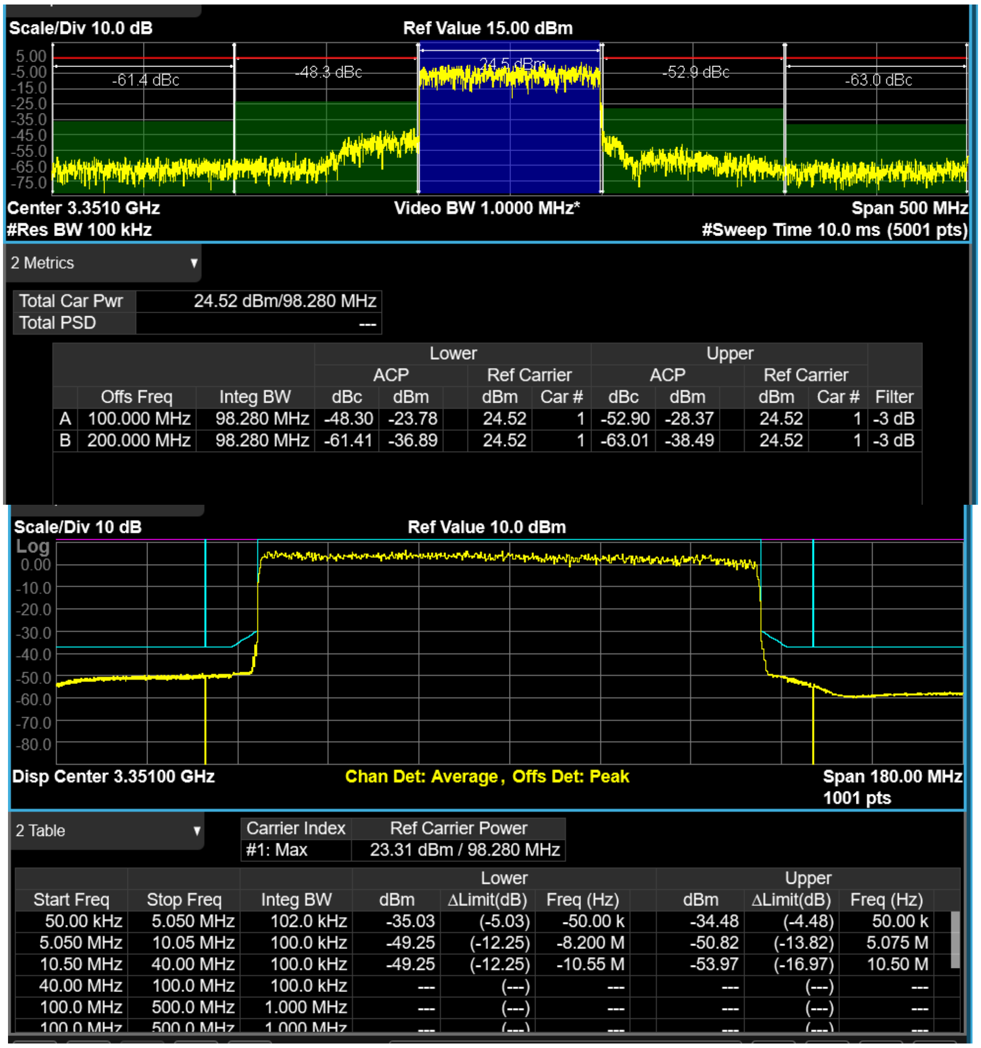

Figure 5. 4T4R RRU test results.

Table 3. RF test results.

Item		2T2R RRU	4R4R RRU	3GPP
Output power		27.19 dBm	24.52 dBm	24 dBm
Transmitter off power		-99.84 dBm/MHz	-98.88 dBm/MHz	-89 dBm/MHz
Transmitter transient period		< 0.5 us	< 2.7 us	10 us
EVM	QPSK	1.94%	1.4%	17.5%
	16QAM	1.74%	1.56%	12.5%
	64QAM	1.6%	1.67%	8%
	256QAM	1.73%	1.8%	3.5%
OBW		97.3 MHz	97.2 MHz	100 MHz
ACLR		-46.1 dBc	-48.3 dBc	-45 dBc
Reference sensitivity level		-94.5 dBm	-93 dBm	-87.6 dBm

As can be seen from table 3, the two kinds of RRU pass all the RF tests, and most of results are better than 3GPP standard requirements. Although 27 dBm exceeds the norm by 3 dB for 2T2R RRU, the total output power is still 30 dBm as same as that of 4T4R RRU. The OBUE cases in figure 4 and 5 show good NR waveforms generated by the tested device. The basic limit of transmitter spurious emissions -36 dBm under 1 GHz and -30 dBm above 1 GHz, and the test results are in line with the requirements. For 2T2R RRU, it must also be mentioned that the digital pre-distortion (DPD) algorithm is used to enhance the efficiency of power amplifier, which is one of the crucial factors of qualified RF performance.

5. Conclusion

In 5G era, the picocell based on the active digital DAS is expected to provide high quality service in specific indoor scenarios while reducing deployment costs. The 2T2R RRU with output power of 27 dBm presents a wide range of possibilities for the further development of indoor solution. A NR testbed is established and a series of RF tests are carried out in this paper. At this stage, the testbed has only examined the RF conducted characteristics, and all tested items of the two types of RRU meet the requirements of 3GPP. In the future, we will continue to verify the performance of pico base stations for indoor coverage, especially of the inexpensive solutions.

6. References

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