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International Telecommunication Union
Radiocommunication Sector

Report ITU-R BT.2526-0

(09/2023)

BT Series: Broadcasting service (television)

Field trials of terrestrial multimedia mobile broadcasting systems

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Note*: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2023

REPORT ITU-R BT.2526-0

Field trials of terrestrial multimedia mobile broadcasting systems

(Question ITU-R 132/6)

(2023)

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Scope

This Report collects summary descriptions of trials in different countries of new technologies for terrestrial multimedia broadcasting for mobile reception in the broadcasting bands. As technology for terrestrial multimedia broadcasting for mobile reception is still evolving, new trials will be done, and this Report will be updated accordingly.

Keywords

Broadcasting bands, field trials, mobile reception, terrestrial multimedia broadcasting.

Abbreviations/Glossary

1T2R	1 Transmit 2 Receive
4T4R	4 Transmit 4 Receive
AMC	Adaptive modulation and coding
API	Application programming interface
APP	Application
ARFCN	Absolute radio frequency channel number
AWGN	Additive white gaussian noise
BBU	Baseband unit
BLER	Block error rate
BSCC	Broadcast service and control centre
C/*I*	Carrier-to-interference
C/*N*	Carrier-to-noise
CAS	Cell acquisition subframe
CBN	China Broadnet
CCTV	China Central Television
CDN	Content delivery networks
CF	Centre frequency
COFDM	Coded orthogonal frequency-division multiplexing
CP	Cyclic prefix
CPU	Central processing unit
DASH	Dynamic adaptive streaming over HTTP
DTTB	Digital terrestrial television broadcasting
eMBMS	LTE evolved multimedia broadcast multicast services
EMF	Electromagnetic field
ERP	Effective radiated power
FeMBMS	LTE further evolved multimedia broadcast multicast service
FLUTE	File delivery over unidirectional transport protocol
G-RNTI	Group radio network temporary identifier

GNSS	Global navigation satellite system
HbbTV	Hybrid broadcast broadband TV
HD	High definition
HE-AACv1	High-efficiency advanced audio coding, version 1
HEVC	High efficiency video coding
HLS	HTTP live streaming
HPHT	High-power-high-tower transmitters
ILS	Internet link service
IoT	Internet of Things
IPv4/IPv6	Internet Protocol version 4/ Internet Protocol version 6
ISD	Inter-site distance
LPLT	Low-power-low-tower
LTE	Long term evolution
MBS	Multicast and broadcast system
MCS	Modulation and coding scheme
MPEG	Moving Pictures Experts Group
NR	New radio
OTT	Over-the-top
PBCH	Physical broadcast channel
PPS	Pulse per second
PNT	Positioning, navigation, and timing
PTN	Packet transport network
PUCCH	Physical uplink control channel
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio access network
RF	Radio frequency
RRU	Remote radio unit
RSRP	Reference signal received power
RTP	Real-time transport protocol
SCS	Subcarrier spacing
SDI	Serial digital interface
SDL	Supplemental down link
SDR	Software defined radio
SFN	Single frequency network
SINR	Signal-to-interference plus noise ratio

SNR	Signal-to-noise ratio
SS_RSRP	SS reference signal received power
SSA	Seamless switching application
SSB	Single-sideband
TOD	Time of day
TOV	Threshold of visibility
TsoIP	Transport stream over IP
TU6	Typical urban scenario
UE	User equipment
USD	User service description
V2X	Vehicle-to-Anything
VDCM	Virtual digital content manager
VR	Virtual reality

1 Introduction

The objective of this Report is to collect summary descriptions of trials of new technologies for terrestrial multimedia broadcasting for mobile reception in the broadcasting bands.

The way in which media content and services are delivered to viewers and listeners is evolving and, in particular, is driven by the rise of the Internet and the popularity of personal devices (smartphones, tablets) to access audiovisual media content and services. With the fast development of mobile Internet services, users are getting used to viewing and generating video anywhere anytime. The existing terrestrial multimedia broadcasting systems, with main attribute of downlink-only and large/static transmission areas, have not been integrated widely into mobile devices. New multimedia broadcasting technologies, integrated in the same chips with mobile technologies, have been standardized in 3GPP and are still evolving.

Apart from the video applications, other services can be offered by these new terrestrial broadcasting multimedia systems. Such services include public safety, V2X (vehicle to anything) communications, IoT software upgrade and others.

To verify the system design and the performance of the new technologies for terrestrial multimedia broadcasting, Broadcast network operators and Research and Development organizations have developed prototype trial systems and in collaboration with Broadcasters, have conducted field experiments with both high-tower deployment and regular base station deployment. Some initial results for relevant experiments were achieved.

The Annexes to this Report collect the field trials information of new technologies for terrestrial multimedia broadcasting systems by different operators and in different countries. It is important to note that the trials and projects featured in this Report constitute a snapshot in time. More trials and eventually deployment of commercial networks can be expected in the times to come. This Report is updated as required to reflect the ongoing developments.

2 Status of standardization of terrestrial multimedia mobile broadcasting systems

2.1 Status of standardization of the LTE-based 5G terrestrial broadcast system

2.1.1 Standardization within ITU

The standardization of parameters for LTE-based 5G terrestrial broadcast system has been completed in ITU-R and different Recommendations and Reports have already been published, for example:

– Recommendation ITU-R BT.2016-2 – Error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands

– Recommendation ITU-R BT.1833 – Broadcasting of multimedia and data applications for mobile reception by handheld receivers

– Report ITU-R BT.2049-7 – Broadcasting of multimedia and data applications for mobile reception

– Report ITU-R BT.2295-3 – Digital terrestrial broadcasting systems.

2.1.2 Standardization within 3GPP

The LTE-based 5G Terrestrial Broadcast system is standardised in 3GPP Release 16.

Further normative work has been completed, with the addition of 6/7/8 MHz bandwidths in Release 17. This has subsequently been profiled as ETSI TS 103 720 [1].

2.2 Status of standardization of 5G new radio multicast and broadcast system

2.2.1 Standardization within ITU

The standardization of parameters for 5G new radio (NR) multicast and broadcast system (MBS) has been completed in ITU-R and different Recommendations and Reports have been published, for example:

– Recommendation ITU-R BT.2016 – Error-correction, data framing, modulation and emission methods for terrestrial multimedia broadcasting for mobile reception using handheld receivers in VHF/UHF bands.

– Recommendation ITU-R BT.1833 – Broadcasting of multimedia and data applications for mobile reception by handheld receivers.

– Report ITU-R BT.2049 – Broadcasting of multimedia and data applications for mobile reception.

– Report ITU-R BT.2295 – Digital terrestrial broadcasting systems.

2.2.2 Standardization within 3GPP

The standardization of parameters for 5G NR MBS is underway at 3GPP, for example:

– 5G NR MBS is one of the major focuses of 3GPP in Release 17, and a number of new study items and work items were approved in Release-17 targeting to make NR support of multicast and broadcast and to offer efficient support of services like public safety, mission critical communications, V2X applications, transparent IPv4/IPv6 multicast delivery, IPTV, and software delivery over wireless networks.

3 Initiatives to promote trials and implementation of multimedia broadcasting systems

5G-Media Action Group (5G-MAG)

5G-Media Action Group (5G-MAG) provides a framework to collaborate on a market-driven implementation of technologies for the connected media world. In particular, those in the domain of 5G applied to content creation, production, distribution and consumption. 5G-MAG is a cross-industry, non-profit, association that gathers content and service providers, network operators, technology solution suppliers, software developers, equipment manufacturers, R&D organizations, universities, regulators or policy makers.

5G-MAG develops open-source tools that support 5G-based media distribution (https://www.5g-mag.com/reference-tools). These tools implement specifications and so allow for testing and for use in trials and in production. 5G-MAG also promotes and reports on trials and demonstrations (https://www.5g-mag.com/trials).

4 Field trials of terrestrial multimedia mobile broadcasting systems

The Annexes show details of trials conducted for new terrestrial multimedia broadcasting systems in different countries.

As this report deals with evolving technologies, the implementation and the performance of the receiving and transmitting equipment can be improved in the future.

The following Table summarizes the trials and indexes the Annexes.

Summary of trials of terrestrial multimedia mobile broadcasting systems

Annex/Section	Country	Cities	Trial name	TMMB system	Frequency range used	Date
Annex 1/§ 1	China	Beijing, Shanghai	5G NR MBS Trial in Beijing and in Shanghai	5G NR MBS	758-768 MHz	October 2020/ November 2021
Annex 1/§ 2		Nanjing	5G NR MBS Trial in Nanjing	5G NR MBS	Within the 700 MHz range	October 2021
Annex 1/§ 3		Beijing	HPHT and LPLT 5G NR MBS cooperative networking test	5G NR MBS	Within the 700 MHz range	May 2023
Annex 1/§ 4		Laboratory tests	Laboratory testing of 5G NR systems in the 700 MHz band	5G NR MBS	Within the 700 MHz range	January 2023
Annex 1/§ 5		Shenzhen	The Test Report of the Wireless Digital Multimedia Broadcasting Network	LTE-based 5G Terrestrial Broadcast	682 MHz	August 2022
2	Switzerland France Germany Italy Austria	Geneva Paris Stuttgart Turin Vienna	LTE-based 5G broadcast of the Eurovision Song Contest 2022	LTE-based 5G Terrestrial Broadcast	600 MHz range 219.5 MHz (VHF ch. 11 used in Turin only)	April/May 2022 October 2021
Annex 3/§ 1	Germany	Stuttgart, Heilbronn	5G Media2Go	FeMBMS (Release 14) LTE-based 5G Terrestrial Broadcast LTE Unicast	622-630 MHz	October 2020/ September 2022
Annex 3/§ 2		Hamburg	LTE-based 5G broadcast in Hamburg	LTE-based 5G Terrestrial Broadcast	574-582 MHz	October 2021/ December 2023

Annex/Section	Country	Cities	Trial name	TMMB system	Frequency range used	Date
4	Austria	Vienna	Vienna field trials	FeMBMS (Release 14) LTE-based 5G Terrestrial Broadcast	734-744 MHz 662-672 MHz 638-642 MHz	2020/2021 – Phase 1 2021/2023 – Phase 2
5/§ 1	Italy	Aosta Valley	LTE-based 5G broadcast trial in Aosta Valley	LTE-based 5G terrestrial broadcast	726-734 MHz	November 2021/ June 2022
5/§ 2		Turin and Palermo	Rai Way Trial of LTE-based 5G broadcast network and services in the 700 MHz band in the cities of Turin and Palermo	LTE-based 5G terrestrial broadcast and seamless switching broadband/broadcast	743-748 MHz (SDL-B2)	July 2022/July 2023
5/§ 3		Lissone (Monza-Brianza)	EI-Towers LTE-based 5G broadcast field Trial in Lissone (Monza-Brianza)	LTE-based 5G terrestrial broadcast	738-743 MHz (SDL-B1)	March 2023
6	Denmark	Copenhagen	LTE-based 5G Terrestrial Broadcast field trials in Denmark	LTE-based 5G terrestrial broadcast	617-622 MHz	June – July 2022
7	Spain	Barcelona	LTE-based 5G Broadcast trial during MWC in 2020, 2022 and 2023	FeMBMS (Release 14), LTE-based 5G terrestrial broadcast and eMBMS (Release 12)	750-755 MHz 617-627 MHz 617-622 MHz	February 2020 February 2022 February 2023

5 References

[1] ETSI TS 103 720 V1.2.1 (2023-06), "5G Broadcast System for linear TV and radio services; LTE-based 5G terrestrial broadcast system"
https://www.etsi.org/deliver/etsi_ts/103700_103799/103720/01.02.01_60/ts_103720v010201p.pdf

Annex 1

Field trials of 5G new radio multicast and broadcast system (5G NR MBS) and of LTE-based 5G terrestrial broadcast in China

1 The 5G NR MBS trial in Beijing and in Shanghai

1.1 Background

To verify the system design and the performance of 5G NR MBS, China Broadnet (CBN) has developed a prototype trial system following the design principal of 5G NR MBS. Field experiments were conducted in Beijing, with both high-tower deployment and regular base station deployment. This paper provides some initial results for relevant experiments.

1.2 Initial experimental results for 5G NR MBS with high-tower deployment

As illustrated in Fig. 1, regular 5G base station is deployed on the centre radio and TV tower, 200 metres above the ground. Directional antennas are used for the base station, with one antenna pointing the east and another antenna pointing the south. Detailed parameters for the test setup are listed in Table 1.

TABLE 1

Test setup for 5G NR MBS

Testing frequency range	758-768 MHz
Carrier bandwidth	10 MHz
Base station transmission power	240 Watts (4 × 60 Watts)
modulation mode	QPSK
MCS	4
Rank	1
Base station height	207 m
Antenna direction	90 degrees (due east), 180 degrees (due south)
Antenna dip angle	2 degrees
Device	Huawei Mate 30 pro

TABLE 1 *(end)*

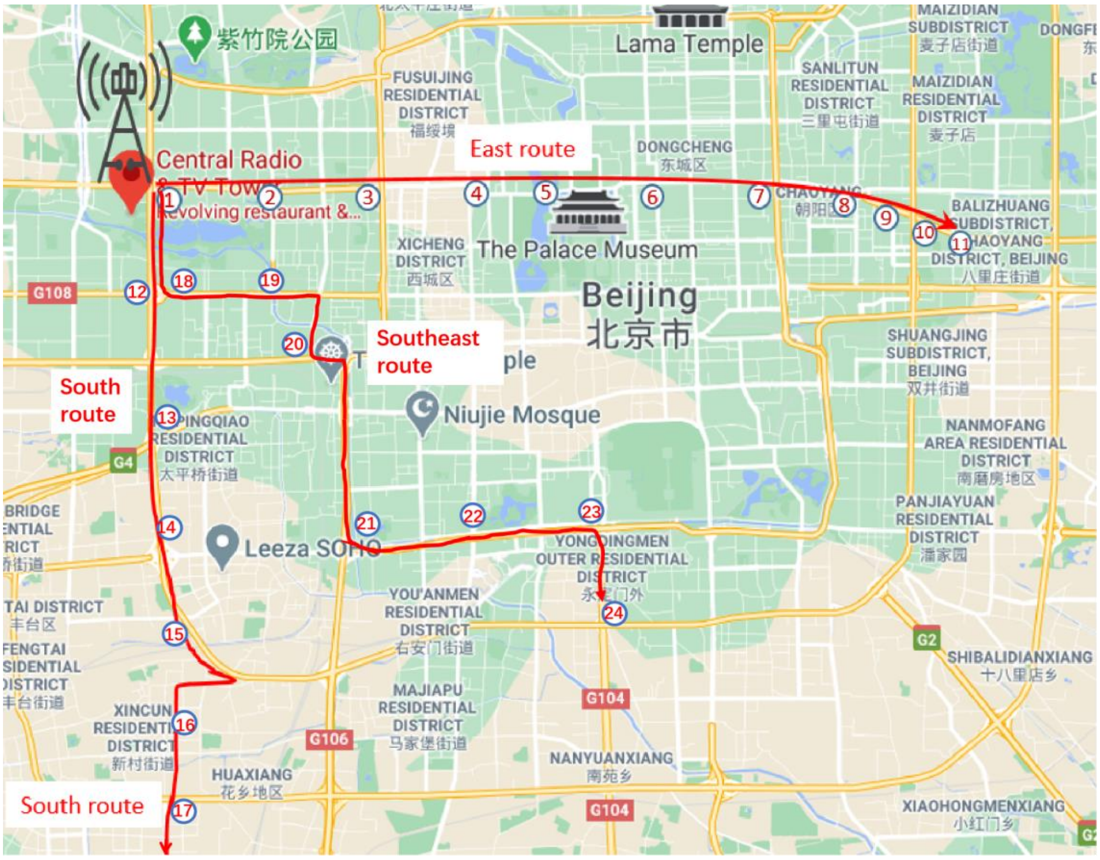
Receiving device location	In the car
Receiving device height	1 m
Receiving conditions	On-board road test in the car, hand-hold
Testing date	From October 2020 to January 2021

NOTE – This NR MBS experiment based on high-tower deployment is in Read Only Mode, data transmission on receiving devices is downlink-only.

There are three routes tested. The east route represents typical urban scenario with dense buildings and high buildings. For the south route, it includes high-speed freeway and sub-urban scenario. And for the southeast route, it includes high-speed freeway and urban scenario. Four test devices receive the same video broadcast services from the base station.

FIGURE 1

Field experiments for 5G NR MBS



Initial test results show that test devices can receive video broadcast service with good quality from more than 10 km away from the central radio and TV tower for east route and south route as well as southeast route. Due to speed limitation in the city, the highest speed tested is 80 km/h. For such relatively high-speed scenario, no performance degradation was observed. The test adopts 10 MHz channel bandwidth. Testing video format is 576 × 720, 1 Mbit/s bitrate[1], and H.264 encoding profile. Detailed test results can be found in Tables 2 to 4.

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1 The testing video uses around 1.66 MHz, MCS = 4.

TABLE 2

Test results for east route

Test point	SSB RSRP (Reference signal received power) (dBm)	Distance from base station (km)	Video experience
1	−87	0.636	smooth
2	−86	2.2	smooth
3	−91	4.2	smooth
4	−112	6.0	smooth
5	−97	7.1	smooth
6	−102	8.8	smooth
7	−103	10.8	smooth
8	−115	12.1	smooth
9	−113	12.7	stalling
10	−119	13.2	stalling
11	−117	13.7	stopped

TABLE 3

Test results for south route

Test point	SSB RSRP (Reference signal received power) (dBm)	Distance from base station (km)	Video experience
12	−85	1.3	smooth
13	−103	3.8	smooth
14	−93	5.8	smooth
15	−106	7.7	stalling
16	−107	8.4	stopped
17	−116	9.5	stopped

TABLE 4

Test results for southeast route

Test point	SSB RSRP (Reference signal received power) (dBm)	Distance from base station (km)	Video experience
18	−89	1.3	smooth
19	−100	2.8	smooth
20	−103	3.9	smooth

TABLE 4 *(end)*

Test point	**SSB RSRP (Reference signal received power) (dBm)**	**Distance from base station (km)**	**Video experience**
21	−104	4.4	smooth
22	−106	6.7	stalling
23	−107	8.7	stalling
24	−111	9.8	stopped

The 5G NR MBS video experiments (Fig. 2) based on cellular base station have proved that under R17 NR MBS architecture we can realize the dynamic switch between unicast/multicast/broadcast on a regular 5G cell phone.

FIGURE 2

Video experiments on 5G NR MBS

The experiments reveal that regular 5G base station can be deployed on radio and TV towers and efficiently provide multicast and broadcast video services. And NR MBS based on regular cellular 5G base station can provide dynamic switching between unicast/multicast/broadcast on regular 5G devices. As the experimental test is based on the hardware of commercial devices, it also proves that 5G NR MBS does not require extensive change of 5G NR devices and can hence have short time-to-market.

1.3 Construction of 5G NR MBS trial station on TV tower in Shanghai

On 6 August 2021, CBN completed the construction of 5G NR MBS trial station on the Oriental Pearl TV Tower in Shanghai (shown as Fig. 3), in accordance with the CBN 5G NR MBS promotion plan after the trial testing conducted in Beijing in Q1, 2021. This trial station is based on a commercial 5G NR cellular station which installed 5G NR MBS software working on 700 MHz spectrum, the antenna is mounted on the tower at the height of approximately 320 metres. The expected signal coverage is around 15 km within the tower. Some trials are shown as Fig. 4 and Fig. 5.

In the next stage, CBN will verify the technical feasibility of the 5G NR MBS in various scenarios based on the TV tower deployment in Shanghai. Live TV streaming services/emergency broadcasting services/ultra-high-definition live broadcast, etc. will be tested, and relevant technical preparations will be made for the large-scale commercial deployment of 5G NR MBS services in China.

FIGURE 3

Trial station on Oriental Pearl TV Tower in Shanghai

FIGURE 4

5G NR MBS demo on regular 5G cell phone

FIGURE 5

Panoramic video playback based on 5G cell phone

1.4 5G NR MBS capability verification in commercial scenario

In November 2021, based on 5G NR MBS, CBN completed the verification of new broadcasting services such as multi-angle viewing and panoramic VR video live broadcasting in the Beijing Winter Olympics test events. This is the world's first system capability verification of 5G NR MBS in commercial scenarios, which is of great significance to the subsequent acceleration of the industry chain maturity and full-scenario business innovation.

With 5G NR MBS, audiences in the stadium can freely choose to watch live content such as multi-angle and VR panoramas on 5G terminals including mobile phones and VR wearable devices (shown as Figs 6 to 8), without video jams caused by high concurrency. 5G NR MBS realizes the high-concurrency transmission of high-bitrate multimedia content on consumer mobile phones, which cannot be achieved by traditional broadcasting technologies. The 5G NR MBS deployment integrating VR/XR and other new multimedia formats will create innovative services for broadcasting industry.

In the next stage, CBN will not only innovate and upgrade traditional broadcasting service, but also expand other new multimedia communication services in To-Customer/To-Business, such as integrated high-tech media live broadcast, live broadcast of popular Internet content, Internet of Vehicles, Internet of Things through free switching between multicast and broadcast modes.

Relevant information will be presented in on-line meeting.

FIGURE 6

The ice hockey test field at Beijing Wukesong Stadium

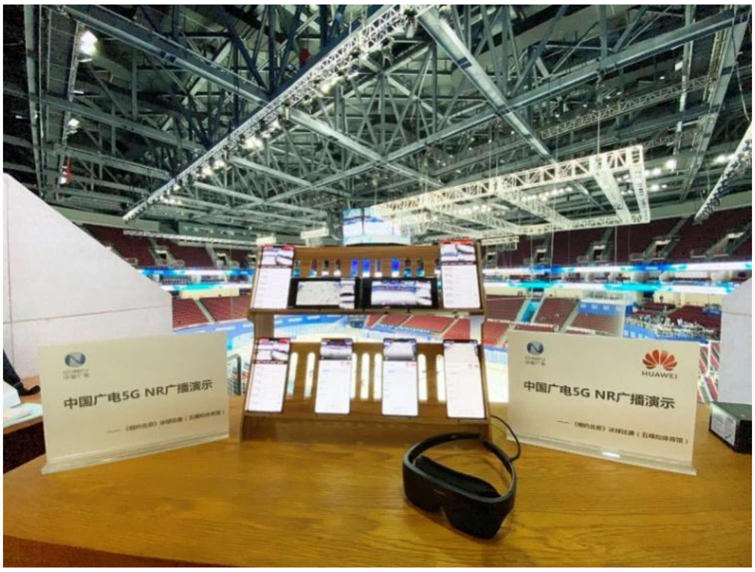


FIGURE 7

Live content such as multi-angle and VR panoramas on 5G terminals including mobile phones and VR wearable devices

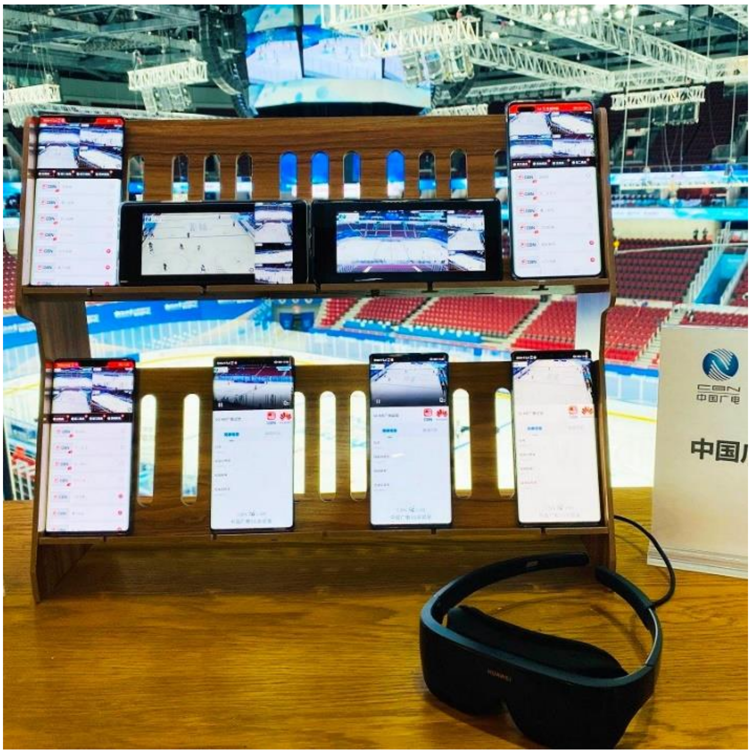
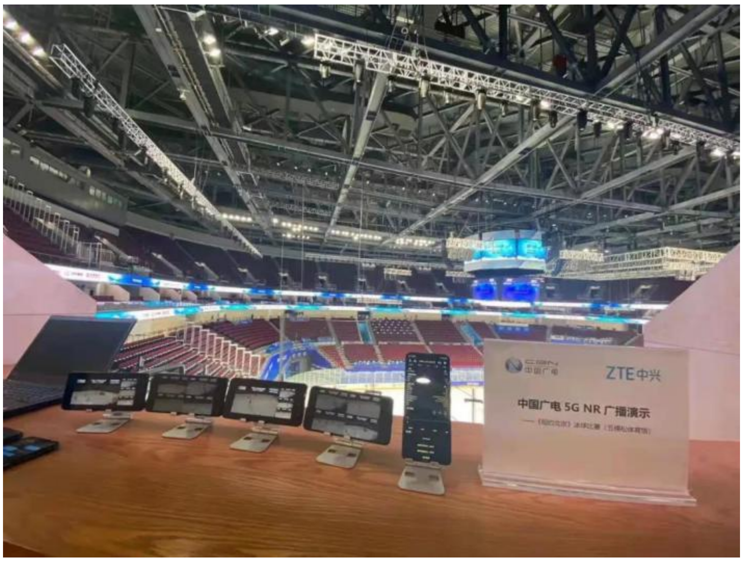


FIGURE 8

Panoramic video playback based on 5G mobile phones



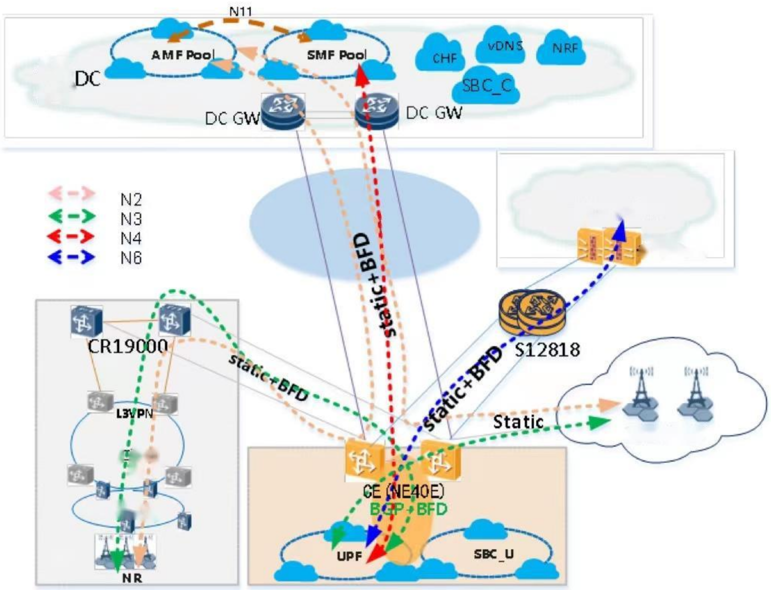
2 The 5G NR MBS trial in Nanjing

2.1 General network architecture

In order to test and verify the performance of 5G NR MBS and explore commercial application experience, CBN conducted a 5G NR MBS trial in Nanjing, Jiangsu Province of China in October 2021. The block diagram of the trial system is shown in Fig. 9.

FIGURE 9

Block diagram of Trial System



2.1.1 Base station parameters

Two base stations were used during the test, the large tower base station (Base station L) and the small tower base station (Base station S), respectively. Base station L is located at the TV tower in

Nanjing, Jiangsu Province of China, and Base station S is located at Jiangsu Cable TV industry park in Nanjing, Jiangsu Province of China. Figure 10 shows the Nanjing TV Tower.

FIGURE 10

Nanjing TV Tower

2.1.2 Base station configuration

The two base stations used in the test were built as the outdoor macro base station mode, and the Building Base band Unit (BBU) used during the test is Huawei 5900. The BBU in Base station L was placed in the Jiangsu TV tower service room. The station type was configured as three sectors, and the coverage angle of each sector was 60 degrees.

The BBU of Base station S was placed in the core computer room of the fourth building of Jiangsu Cable TV industry park. The station type was configured as three sectors, and the coverage angle of each sector was set to 120 degrees.

2.1.3 Service streams during the trial

A transcoding system was set up in the TV tower service room, and the video stream was transmitted to the big tower base station and Base station S using fibre optic link, and the information of programme stream was as follows:

1 480P programme stream: H.265 encoding, the bit rate was 1.1 Mbit/s.

2 1080P programme stream: H.265 encoding, the bit rate was 1.5 Mbit/s.

2.1.4 Terminal for the test

During the test, Huawei Mate 40 Pro cell phone (supporting NR MBS version) was used as the test terminal, frequency scanner and road tester were used to help to complete the collection of information.

2.2 Field trial

2.2.1 5G NR MBS coverage test (5 MHz bandwidth)

The purpose of this test is to examine the farthest coverage distance in outdoor open area when 700 MHz base station is configured with 5 MHz bandwidth. The base station used during the test was Base station L.

Shown as Fig. 11, during the test, the test cell phone 1 was placed inside the test vehicle at about 1.5 m above the ground, and was set to play the received broadcast video. Test cell phone 2 was placed next to cell phone 1 and ran the monitoring tool. The test vehicle started from Base station L and moved away along the radial direction until the farthest point where it can receive normally. Due to the topography of Nanjing, the test was carried out in the directions of northwest, southwest and southeast.

FIGURE 11

Test cells phone in test vehicle

(1) Northwest direction

For the 5G NR MBS, the signal started to stutter when the test vehicle travelled to 8.8 km from the base station, and the signal terminated when it reached 10.3 km from the base station.

For two-way data service, when the test vehicle travelled to 5.5 km from the base station, the test cell phone could not link to the base station.

(2) Southwest direction

For the 5G NR MBS, the signal started to stutter when the test vehicle travelled to 9.7 km from the base station, and the signal terminated when it reached 12.1 km from the base station.

For two-way data service, when the test vehicle travelled to 6.2 km from the base station, the test cell phone could not attach to the base station.

(3) Southeast direction

For the 5G NR MBS, the signal started to stutter when the test vehicle travelled to 11.1 km from the base station, and the signal terminated when it reached 12.5 km from the base station.

For two-way data service, when the test vehicle travelled to 4.5 km from the base station the cell phone could not attach to the base station.

2.2.2 5G NR MBS coverage test (10 MHz Bandwidth)

The purpose of this test is to examine the farthest coverage distance in outdoor open area when 700 MHz base station is configured with 10 MHz bandwidth. The base station used in the test was a large tower base station.

During the test, the test cell phone 1 was placed inside the test vehicle at about 1.5 m above the ground and was set to play the received broadcast video. Test cell phone 2 was placed next to cell phone 1 and ran the monitoring tool. The test vehicle started from Base station L and moved away along the radial direction until the farthest point where it could receive normally. Due to the topography of Nanjing, the test was carried out in the directions of northwest, southwest and southeast.

(1) Northwest direction

For the 5G NR MBS, the signal started to stutter when the test vehicle travelled to 7.9 km from the base station, and the signal terminated when it reached 9.4 km from the base station.

(2) Southwest direction

For the 5G NR MBS, the signal started to stutter when the test vehicle travelled to 8.2 km from the base station, and the signal terminated when it reached 10.7 km from the base station.

(3) Southeast direction

For the 5G NR MBS, the signal started to stutter when the test vehicle travelled to 8.1 km from the base station, and the signal terminated at 9.2 km from the base station.

2.2.3 5G NR MBS mobile performance test

The purpose of this test is to examine the outdoor mobile reception performance of the terminal in the open area under different speed. The base station used in the test was Base station L.

During the test, the test cell phone 1 was placed inside the test vehicle at about 1.5 m above the ground and was set to play the received broadcast video. Test cell phone 2 was placed next to cell phone 1 and ran the monitoring tool. The test vehicle started from the near point of the test cell and pulled away radially at different speeds to record the video playback. Due to the topography of Nanjing, the test was carried out in the directions of northwest, southwest and southeast.

The test results showed that the faster the vehicle travelled in the same test area, the more obvious the video jamming was.

2.2.4 5G NR MBS inter-site switching test

The purpose of this test is to test the scenario of service switching when the terminal moves between different stations. The test was conducted in an open scene with a joint test by Base station L and Base station S. The test receiver used two broadcast cell phones (one of which has a built-in CBN SIM card).

The video stream of Jiangsu City Channel was pushed at Base station L, and the video stream of CCTV was pushed at Base station S. Two steams were set at the same bit rate.

The test vehicle started from the near point of the coverage area of Base station L, moved along the test route to Base station S until the near point of the coverage area of Base station S, and observed the broadcasting service playback of the test terminal.

In the near point of the coverage area of Base station L, the test receiver could properly play the Jiangsu City Channel video. When the test vehicle travelled to the far point of Base station L, video playback started to stutter. When the test vehicle travelled to the coverage area of Base station S, the test receiver could properly play the video, the program converted to CCTV-1 video automatically. When the test vehicle travelled to the near point of Base station S, the video play smoothly.

The test results showed that the test receiver can automatically complete the base station switching and program switching.

2.3 Conclusion

Through the field trial in Nanjing, the following can be concluded:

1 Coverage range.

Under the same power and modulation and coding schemes (MCS), the coverage range is affected by the operating bandwidth.

Under bandwidth of 5 MHz, the farthest coverage distance is 11.1 km, and the video playback stops at 12.5 km.

Under bandwidth of 10 MHz, the farthest coverage distance is 8.2 km, and the video playback stops at 10.7 km.

2 In the same test area, the faster the vehicle travels, the more obvious the video jamming is.

3 When the terminal mobile moves between different base station, the receiver can automatically switch between different base stations and programs. the receiver can continue to play properly after switching.

CBN will continue to test and build the 5G NR MBS and will keep ITU informed of the latest progress.

3 HPHT and LPLT 5G NR MBS cooperative networking test

3.1 Overview

This test studies the signal coverage and reception of 5G NR MBS under the conditions of key system parameters such as specified transmission power and modulation mode under the cooperative networking of TV tower and mobile cellular network.

3.2 Test environment

The central TV tower provides 5G NR MBS signal coverage for long-distance and wide-area scenarios. The hanging height is 207 meters, the transmitting antenna is 4T4R, the downtilt angle is 4 degrees, the transmitting power is 240 W, the operating frequency is 768-773 MHz, and the modulation method is QPSK.

The two mobile cellular base stations located in Beijing mainly provide deep coverage of 5G NR MBS signals in key areas.

One of the mobile cellular base stations (mobile cell base Station 1) is hung at a height of 50 meters, the transmitting antenna is 4T4R, the downtilt angle is 6 degrees, the transmitting power is 200 W, the frequency is 763-768 MHz, and the modulation mode is 16-QAM.

Another mobile cellular base station (mobile cell base Station 2) is hung at a height of 22 meters, the transmitting antenna is 4T4R, the downtilt angle is 2 degrees, the transmitting power is 120 W, the frequency is 758-763 MHz, and the modulation method is 16-QAM.

Other configuration parameters are shown in Table 5.

TABLE 5

Configuration parameters

Index	Parameter
NR frequency (MHz)	700
NR cell bandwidth (MHz)	5
PRACH format	Format0
PRACH cycle	10
PUCCH format	Format2
SSB sub-carrier spacing (kHz)	15
PBCH cycle (ms)	20
Antenna channels	4
Uplink power control	Enable
AMC	Enable
Terminal	SA: 1T2R (Commercial mobile phone)
RF module specifications	4T4R
Terminal transmit power	The total power of SA shall not exceed 23 dBm
Business type	5G NR TV broadcasting (Video)
Wireless and terminal transmission	IPv6

The mobile cellular base station uses Huawei BBU5900 baseband unit and radio frequency unit RRU5304W.

The terminal uses Huawei's commercial Mate40 Pro.

The program sources adopt two typical resolutions of 576 × 720 (standard definition) and 1080 × 1920 (high definition), and the frame rate is 25 fps. Under the H.265 encoding format, the program bit rates are 250-300 kbit/s and 700-800 kbit/s respectively.

3.3 Key technologies

3.3.1 Program list

User Service Description (USD) file: program list file, which configures the sending information and program names of all programs. Channel 1 is fixedly designed to send USD files. The server sends USD to the terminal APP through channel 1. Each site can deliver the same or different program list. Due to the collaborative network test in this test, the program list issued is the same program list.

The relevant parameters are shown in Table 6.

TABLE 6

Relevant parameters

	Program 1	…	Program 254
Channel number	2		255
Port number	Port Y		Port xx
Frequency point	ARFCN – ValueNR2		ARFCN – ValueNRx
Business channel name	Text 2		Text x
Site type	Site A		Site B

3.3.2 Frequency sweep/frequency hopping

The G-RNTI mapping relation is shown in Table 7.

TABLE 7

G-RNTI mapping relation

	Program 1 (Program list)	**Program 1**	**…**	**Program 254**
G-RNTI	Value X	Value Y		Value XX
Channel number	1	2		255

1 After the modem receives the frequency sweeping command, it will perform sweep frequency on the corresponding frequency band, and try to read the program list at each available frequency point and report it to the APP.

2 Turn on the split frequency reselection function.

3 Support frequency + program setting. The current version already supports program setting, adding the frequency setting function. After the modem receives the command to set the frequency from the APP, it sets the frequency as a high priority. If the set frequency point is not the current working frequency point, the transmitter will try to switch the UE to the target frequency point. Modem will read services after switching.

3.3.3 Signal source switching scheme

The program list (USD file) is sent to UE through channel 1, and the USD file contains program information and frequency point information in all frequency points.

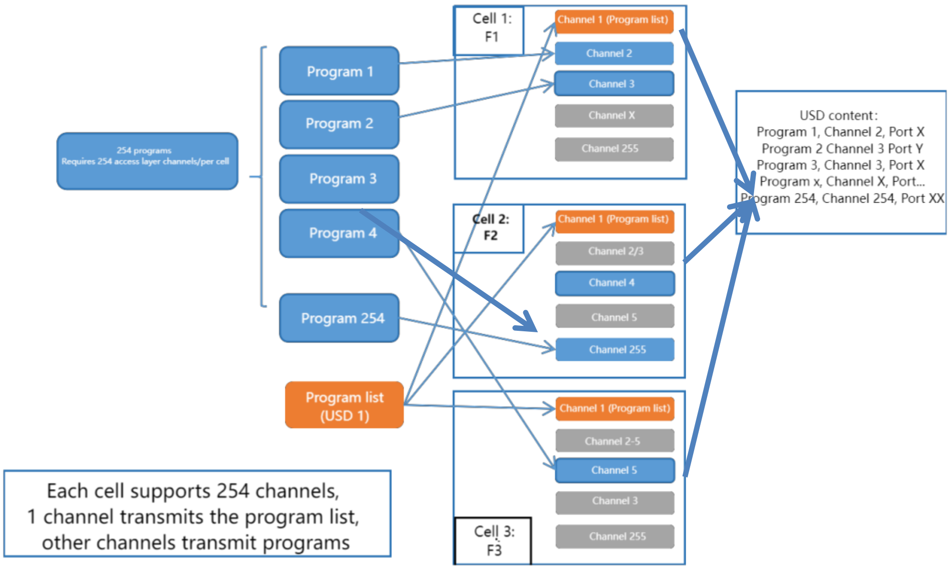
The UE obtains the cell information on the 700 MHz frequency band through frequency scanning, and obtains the program list on each cell frequency point.

The UE obtains the program according to the frequency selected by the user to switch to the corresponding cell, and the frequency corresponding to the program is set as the highest priority. After the user selects a program, the modem is controlled to stay at the corresponding frequency point to receive the program.

Each cell supports 254 channels, 1 channel transmits the program list, and the other channels transmit the program channel/G-RNTI/program for one-to-one mapping. No matter which frequency point the service is provided, the channel used remains the same. The signal source switching scheme is shown in Fig. 12.

FIGURE 12

Signal source switching scheme



3.4 Test results

3.4.1 5G NR MBS basic business

The terminal is tested at a field strength of SS_RSRP = −77 dBm and SINR = 27 dB. The UE receives the broadcast service of the server through the NR multicast broadcast APP. The video playback is clear and smooth.

The basic service status when the terminal only receives the broadcast signal in one cell is shown in Fig. 13.

FIGURE 13

5G NR MBS basic service test results

3.4.2 5G NR MBS cross-cell channel switching

UE receives the broadcast service of TV tower through the 5G NR MBS APP, and switches channel CCTV 1 (mobile cell base station 2) to channel CCTV 1 (mobile cell base Station 1) and to channel CCTV 13 (TV tower) through the APP. Broadcast service reception is normal, and video playback is clear and smooth.

When the terminal is covered by the broadcast signals of two cells at the same time, the service status when the user selects Cell-1 is shown in Fig. 14.

FIGURE 14

5G NR MBS cross-cell channel switching test results

When the terminal is covered by the broadcast signals of three cells at the same time, the service status when the user selects Cell-2 is shown in Fig. 15.

FIGURE 15

5G NR MBS Cross-cell Channel Switching Test Results

3.5 Conclusion

This test verified the signal coverage and reception of 5G NR MBS under the condition of cooperative networking of TV tower and mobile cellular network. New features such as program list, terminal frequency sweep and frequency hopping switching are fully functional and work normally. 5G NR MBS has complete functions in TV tower and mobile cellular network signal coordination, and its performance meets expectations, which further expands the practicability of 5G NR MBS.

4 Laboratory testing of 5G NR MBS in the 700 MHz band

4.1 Overview

In order to test the terminal reception capability, the test of 5G NR MBS was carried out. This test verifies the commercial terminal's support for the operation of 5G NR MBS in the 700 MHz band.

4.2 Test environment

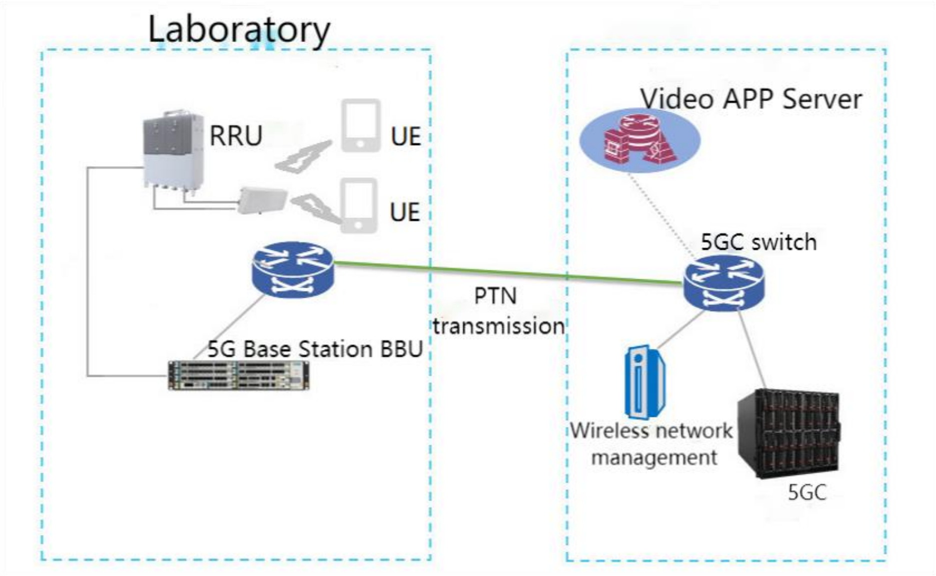
This test is mainly conducted in the laboratory, using the virtual system built in the laboratory. The system architecture is as follows:

4.2.1 System architecture

The architecture of the laboratory test environment is shown in Fig. 16.

FIGURE 16

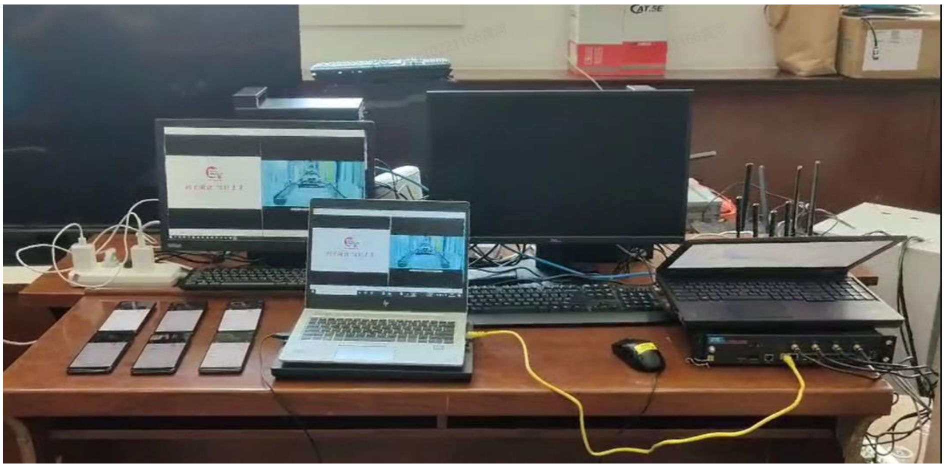
Laboratory test environment architecture



The laboratory equipment is shown in Fig. 17.

FIGURE 17

Laboratory equipment



4.2.2 Base station equipment

ZTE baseband unit BBU (V9200) and RF unit RRU (R9214H) were used for the test.

4.2.2.1 Baseband unit

The ZXRAN V9200 is a baseband unit, which mainly realizes the following functions:

– provide the LTE/NR base station baseband processing functions;

– support 48 dc-power input or by an external ac/dc conversion equipment support 110/220V ac-power input;

– support built-in GNSS receiver, IEEE1588, 1 PPS + TOD and SyncE clock synchronization a variety of ways.

The appearance of ZXRAN V9200 is shown in Fig. 18.

FIGURE 18

BBU for the test

The ZXRAN V9200 contains the following functions, as shown in Table 8.

TABLE 8

Description of boards

Classification	Name	Function
Switching plate	VSWd1	It realizes baseband unit control management, Ethernet switching, transmission interface processing, system clock recovery and distribution, and air interface high level protocol processing

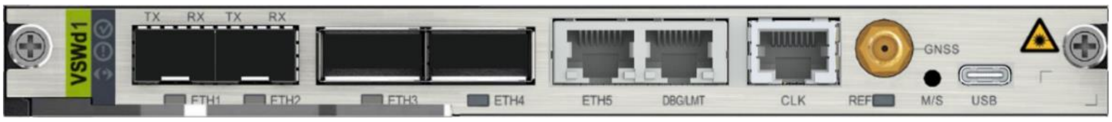
TABLE 8 *(end)*

Classification	Name	Function
Baseband processing board	VBPd0d	Protocols that deal with the physical layer and frame protocols defined by 3GPP
Environmental monitoring board	VEM	Provide site alarm contact and environmental monitoring interface
Power distribution board	VPDc1	Realize protection, filtering, anti-reverse connection of −48V DC input power supply, rated current 50A; support −48V main/standby function, undervoltage alarm, temperature monitoring, voltage and current monitoring
Fan module board	VFC1	System temperature detection control and fan status monitoring, control and reporting

VSWd1 is a switch board that implements baseband unit control and management, Ethernet switching, transmission interface processing, system clock recovery and distribution, and interface high-level protocol processing. The VSWd1 panel is shown in Fig. 19.

FIGURE 19

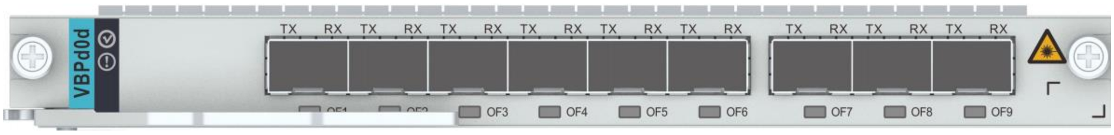
VSWd1 panel



VBPd0d is a baseband processing board used to handle the protocols of the physical layer and the frame protocols defined by 3GPP. The VBPd0d panel is shown in Fig. 20.

FIGURE 20

VSWd1 panel



4.2.2.2 RF unit

ZXRAN R9214H S7200(W) is ZTE's latest 4T4R high power distributed remote radio unit (RRU), based on the latest RAN unified platform design. Figure 21 shows the appearance of R9214H.

FIGURE 21

RRU appearance

The RRU specifications are shown in Table 9.

TABLE 9

RRU specifications

Index	Parameter
Operating frequency band	700 MHz
Capacity configuration	1 × 30 MHz NR Cell 1 × 30 MHz NR Cell + 1 × 10 MHz NR Cell 1 × 30 MHz NR Cell + 1 × 15 MHz NR Cell
Antenna port power	4 × 80 W
Static receiving sensitivity	NR: Single antenna reception-100.2 dBm (20 MHz)

4.2.3 Test Terminal

ZTE S30 5G was used as the test terminal, as shown in Fig. 22.

FIGURE 22

Test terminal

The specifications are shown in Table 10.

TABLE 10

Test terminal specifications

Index	Parameter
Mobile phone model	ZTE S30 5G
Size	Wide: 76.4 mm; Long: 164.8 mm; Thick: 7.9 mm
Weight	210 g
CPU	MTK Dimensity 720
Memory card	Support MicroSD (TF)
Memory	128 GB
Screen size	6.67 inch
Screen resolution	2 400 × 1 080
Screen material	AMOLED
Operating system	Android 11
5G Network	Support 5G (SA/NSA)
4G Network	Support 4G FDD-LTE, 4G TD-LTE
Dual card type	Dual SIM and Dual Standby
SIM card type	Nano SIM
Rear camera main pixel	64 million pixel
Charging interface	Type-C
Data interface	Bluetooth
Headphone jack	3.5 mm

4.3 Lab tests

4.3.1 Test cell configuration

Key configuration parameters of the test cell are shown in Table 11.

TABLE 11

Cell configuration parameters

Index	Parameter
Carrier bandwidth (MHz)	10
subCarrierSpacingCommon	scs15or60
RE reference power (dBm)	17.8

1 The uplink carrier configuration is shown in Fig. 23.

FIGURE 23

Uplink carrier configuration

LDN	Object ID	Carrier bandwidth (MHz)	Band List
NRRadioInfra...	1	10[10]	28

2 The downlink carrier configuration is shown in Fig. 24.

FIGURE 24

Downlink carrier configuration

LDN	Object ID	Carrier bandwidth (MHz)	Band List
NRRadioInfra...	1	10[10]	28

3 SSB frequency configuration is shown in Fig. 25.

FIGURE 25

SSB frequency configuration

subCarrierSpacingCommon	The subcarrier offset of the synchronization signal and the physical broadcast signal block	TypeA DMRS prefix symbol position
scs15or60[scs15or60]	0	pos3[pos3]

4 RE reference power is shown in Fig. 26.

FIGURE 26

RE reference power

LDN	Object ID	User ID	Cell ID	CP service status	Management status	PMI的C...	SSB索引列表	Carrier Description Object Identifier	RE reference power
NRRadioInfra...	1	CPList-1	0	在服[InService]	Unlocked			NRRadioInfrastructure...	178

5 Cell status is shown in Fig. 27.

FIGURE 27

Cell status

NR Carrier Group Identifier	license type	Reserved for operators target	Cell status	Cell service status	Cell energy saving status	Cell commissioning status
1	正式许可[for...	不预留[notReserved]	已激活[ACTI...	在服[InService]		Normal status

4.3.2 Test results

4.3.2.1 5G NR MBS basic services

The terminal is tested at a field strength of SS_RSRP = −65 dBm and SINR = 28 dB. The UE receives the broadcast service of the server through the NR multicast broadcast APP, and the video service is played clearly and smoothly. The test results are shown in Fig. 28.

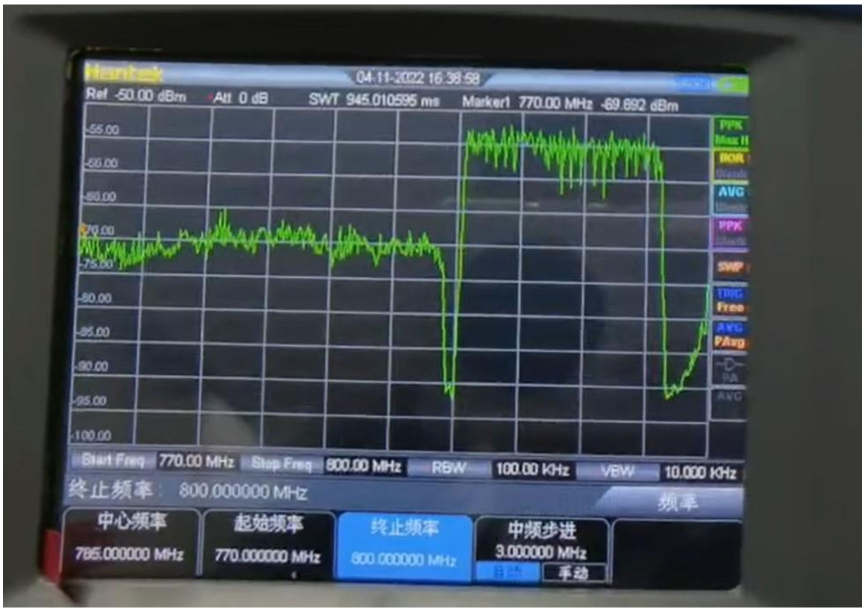
FIGURE 28

Broadcasting service test results

Spectrum scanning, the spectrum range of the strongest signal part is about 10 MHz, which is consistent with the cell configuration, and the spectrum scanning results are shown in Fig. 29.

FIGURE 29

10 MHz cell spectrum scanning result



4.3.2.2 5G NR MBS service channel switching

The UE receives the broadcast service of the server through the 5G NR MBS APP, and switches from channel 1 (CCTV 13) to channel 2 (CCTV 1) through the APP. The broadcast service is received normally, and the video playback is clear and smooth.

1 The test results of Channel 1 are shown in Fig. 30.

FIGURE 30

Channel 1 broadcasting service test results

2 The test results of Channel 2 are shown in Fig. 31.

FIGURE 31

Channel 2 broadcasting service test results

4.3.2.3 Support for different MCS

Broadcast service support is based on the 3GPP 38.214 MCS table. 3GPP defines 38.214 as different MCS used to support different business requirements. To test the terminal's support for different MCS, 7 modes were selected for testing, namely, MCS8, MSC9, MCS11, MCS13, MCS15, MCS17, and MCS18. The MCS index is shown in Table 12.

TABLE 12

MCS index

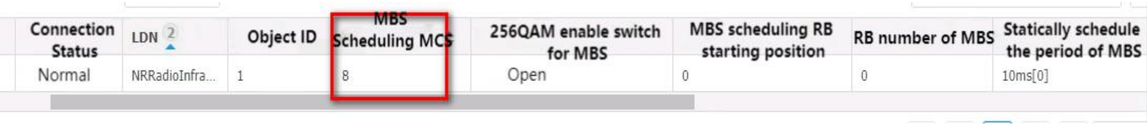
MCS index IMCS	Modulation order Qm	Target code rate R × [1024]	Spectral efficiency (bit/Hz)
MCS8	2	602	1.1758
MCS9	2	679	1.3262
MCS11	4	378	1.4766
MCS13	4	490	1.9141
MCS15	4	616	2.4063
MCS17	6	438	2.5664
MCS18	6	466	2.7305

The configuration of seven modes is shown in Figs 32 to 38.

1 5G NR MBS scheduling MCS configuration is 8, as shown in Fig. 32.

FIGURE 32

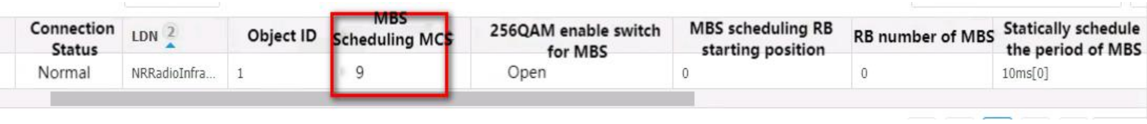
5G NR MBS scheduling MCS configuration 8



2 5G NR MBS scheduling MCS configuration is 9, as shown in Fig. 33.

FIGURE 33

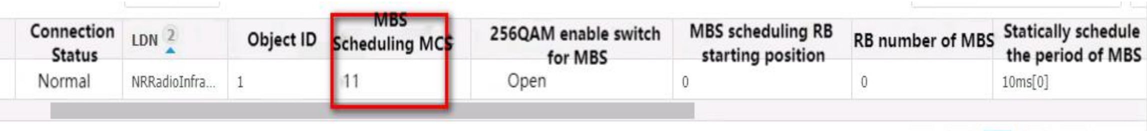
5G NR MBS scheduling MCS configuration 9



3 5G NR MBS scheduling MCS configuration is 11, as shown in Fig. 34.

FIGURE 34

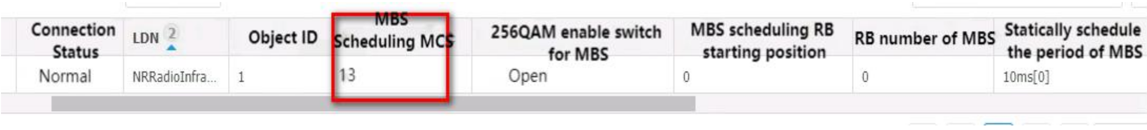
5G NR MBS scheduling MCS configuration 11



4 5G NR MBS scheduling MCS configuration is 13, as shown in Fig. 35.

FIGURE 35

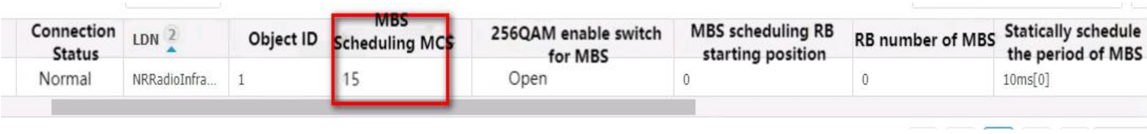
5G NR MBS scheduling MCS configuration 13



5 5G NR MBS scheduling MCS configuration is 15, as shown in Fig. 36.

FIGURE 36

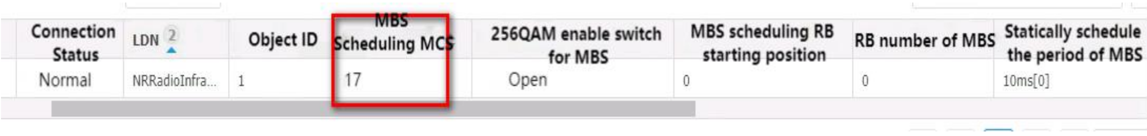
5G NR MBS scheduling MCS configuration 15



6 5G NR MBS scheduling MCS configuration is 17, as shown in Fig. 37.

FIGURE 37

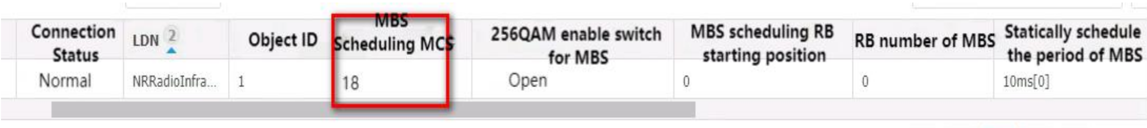
5G NR MBS scheduling MCS configuration 17



7 5G NR MBS scheduling MCS configuration is 18, as shown in Fig. 38.

FIGURE 38

5G NR MBS scheduling MCS configuration 18



According to the test, the UE can receive broadcast services at a fixed MCS level. Table 13 shows the test results.

TABLE 13

Test results of different cell configuration parameters

MCS configuration values	Verification conclusion
8	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.
9	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.

TABLE 13 *(end)*

MCS configuration values	**Verification conclusion**
11	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.
13	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.
15	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.
17	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.
18	The UE can normally receive the broadcast service delivered by the broadcast server, and the service is clear and smooth.

4.4 Conclusion

According to laboratory tests, the reception of 5G NR system can be realized in 700 MHz band. Next, CBN will prepare to conduct field trail tests to further verify the reception capacity of 5G NR MBS system.

Attachment

5G NR MBS basic service test video

Video-NR MBS Basic Services.mp4

5 The Test Report of the Wireless Digital Multimedia Broadcasting Network

5.1 Objective

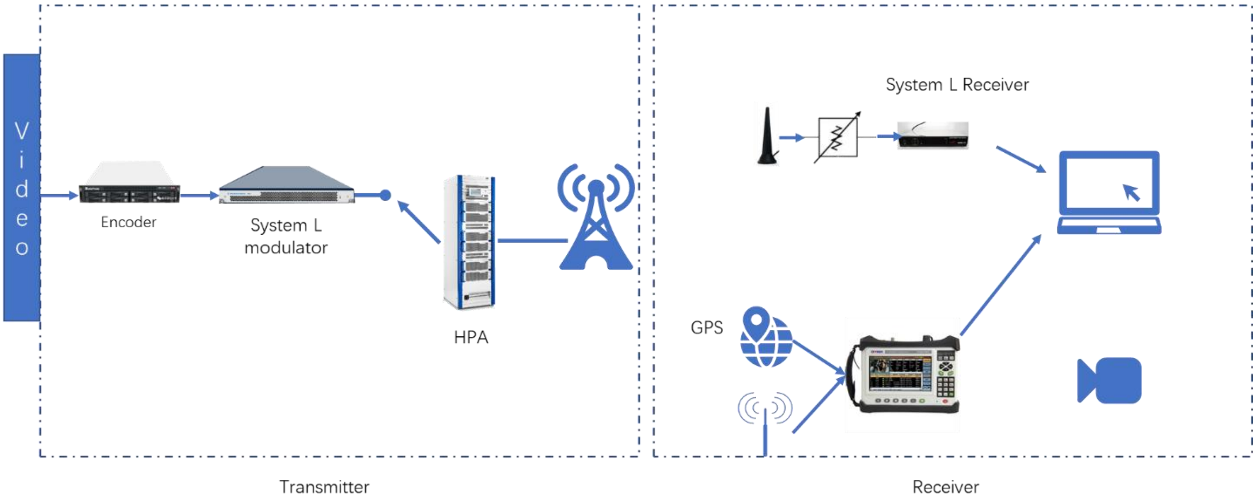
In order to evaluate the coverage performance of LTE-based 5G broadcasting system (Multimedia System L) in high-power and high-tower downlink broadcasting scenarios, Pengcheng Laboratory together with Tsinghua University, Shanghai Jiao Tong University (SJTU) and other teams carried out the field trials of System L in Shenzhen from 18 August 2022. The tests mainly focus on the coverage performance and reception capacity of in-vehicle mobile reception for high-definition TV programmes.

5.2 The test system

The test system is composed of transmitting and receiving systems, the transmitting system is located in Shenzhen TV Tower on Wutong Mountain, and the receiving system is located in the test vehicle. The functional block diagram of the test system is shown in Fig. 39.

FIGURE 39

The block diagram of the test system



5.2.1 Transmitting system

During the test, the transmission frequency of 682 MHz is used for System L with the RF bandwidths of 5 MHz. The test program streams are provided by Shenzhen TV Urban Channel. Table 14 lists the parameters of the test streams for System L.

TABLE 14

The parameters and the interfaces of the test streams

Video coding	H.264
Code rate	9 Mbit/s
Interface	IP

A self-developed System L exciter is provided by SJTU as shown in Fig. 40.

FIGURE 40

System L exciter

The power amplifier is PMU901 produced by Rohde & Schwarz company (as shown in Fig. 41) with the maximum output power of 3 000 W. The antennas are mounted on the top of the transmission tower.

FIGURE 41

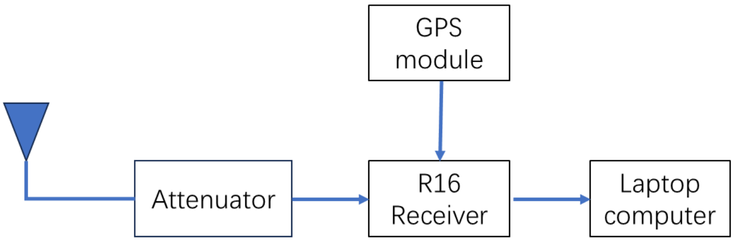
The power amplifier

5.2.2 Receiving system

The block diagram of the System L receiving system developed by SJTU is shown in Fig. 42. The gain of receiving antenna is −2 dB, the noise figure of receiver is 5 dB.

FIGURE 42

The block diagram of SYSTEM L (called R16 in the figure) receiving system

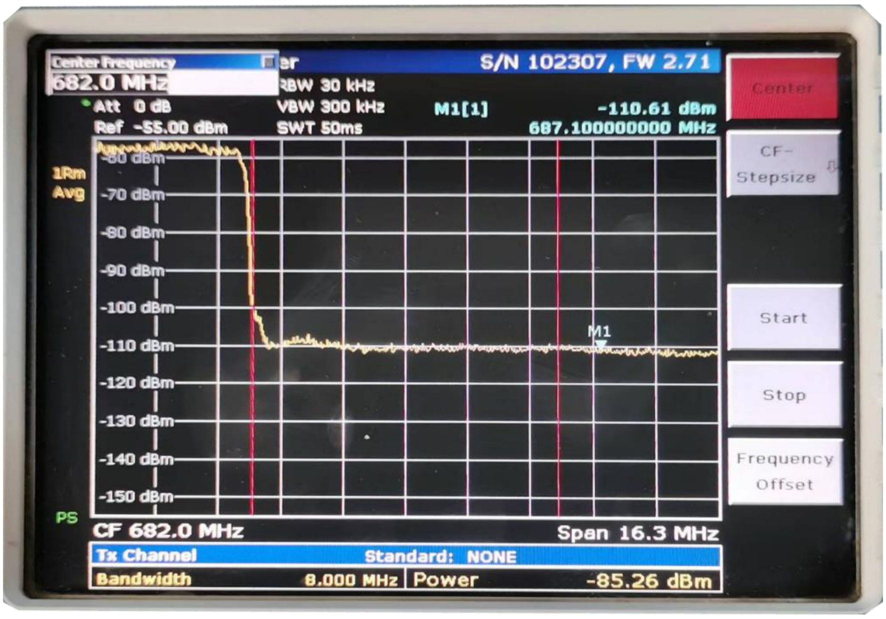


5.3 Test preparation

Considering that the noise floor has certain influence on the test results during the field trial, the noise floor test was carried out in the corresponding frequency band before the field trial. During the noise floor test, the antenna is placed on the roof of the car, and the spectrum is observed in real time by the spectrum analyser, and the test results are shown in Fig. 43. The noise floor is relatively clean in the 682 MHz band, and there are DTMB transmitting signals in the 666-674 MHz bands at the adjacent frequency, which are the signals transmitted from the Wutong mountain transmission tower, and the transmitting power is 2.5 kW.

FIGURE 43

Noise floor (678-686 MHz)

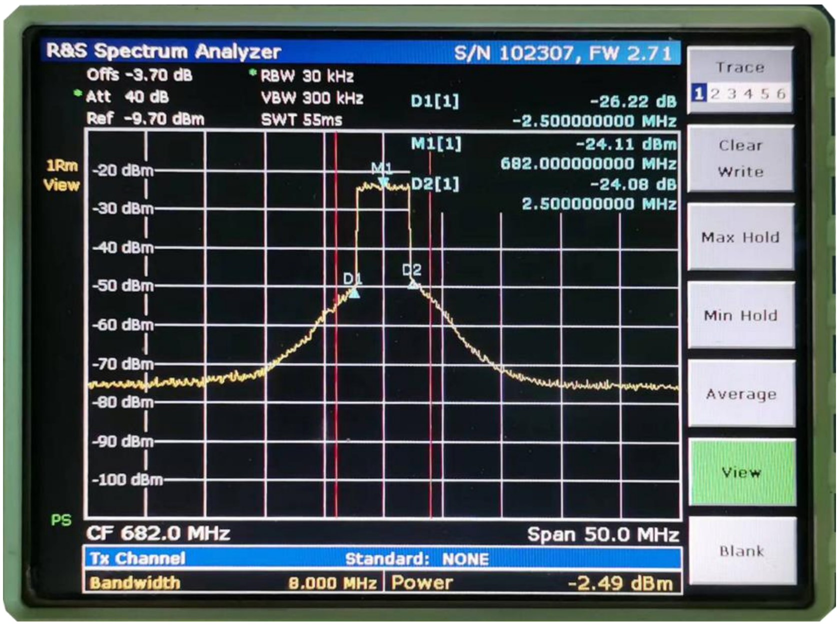


5.4 Test results

During the test, the operating modes of MCS20, MCS14 and MCS9 were selected, and the specific parameters are shown in Tables 2 to 4. The transmit power is set to 260 W and the spectrum out of the power amplifier from coupling port is shown in Fig. 44.

FIGURE 44

The spectrum of the power amplifier for System L



During the tests, the SNR output from the equalizer of System L receiver, the block error rate (BLER) as well as the subjective assessment of the video quality are collected and recorded for the result analysis.

5.4.1 MCS20 mode

Different parameter sets can be supported by System L according to different requirements of the transmission data rate and spectral efficiency. To compare with the digital terrestrial television broadcasting system, the operating mode of MCS20 with 64-QAM constellation is first selected. The spectral efficiency under 5 MHz bandwidth is 2.14 bits/s/Hz as shown in Table 15.

TABLE 15

The parameters of MCS20

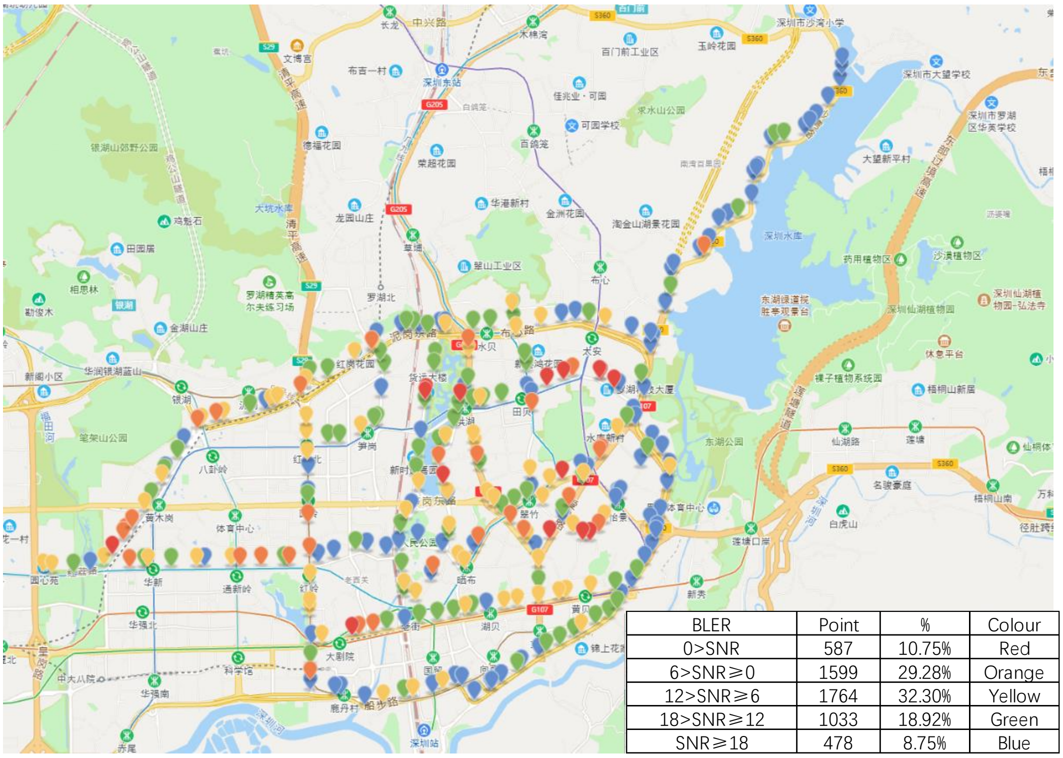
Item	Value
Bandwidth	4.5 MHz
Modulation and coding scheme	MCS20
Cyclic-prefix	200 µs
FFT length	6K
Subcarrier spacing	1.25 kHz/2.5 kHz
Constellation	64-QAM
FEC code rate	0.551
Payload data rate	9.66 Mbit/s
Spectral efficiency	2.14 bits/s/Hz

1) The performance of the subcarrier spacing of 1.25 kHz

With this parameter combination, the SNR values are below 12 dB over 80% of the test section (the SNR threshold of error free for MCS20 is about 14 dB under AWGN), as shown in Fig. 45. Here, EQ_SNR means the SNR after equalization.

FIGURE 45

EQ_SNR results for MCS20 with subcarrier spacing of 1.25 kHz

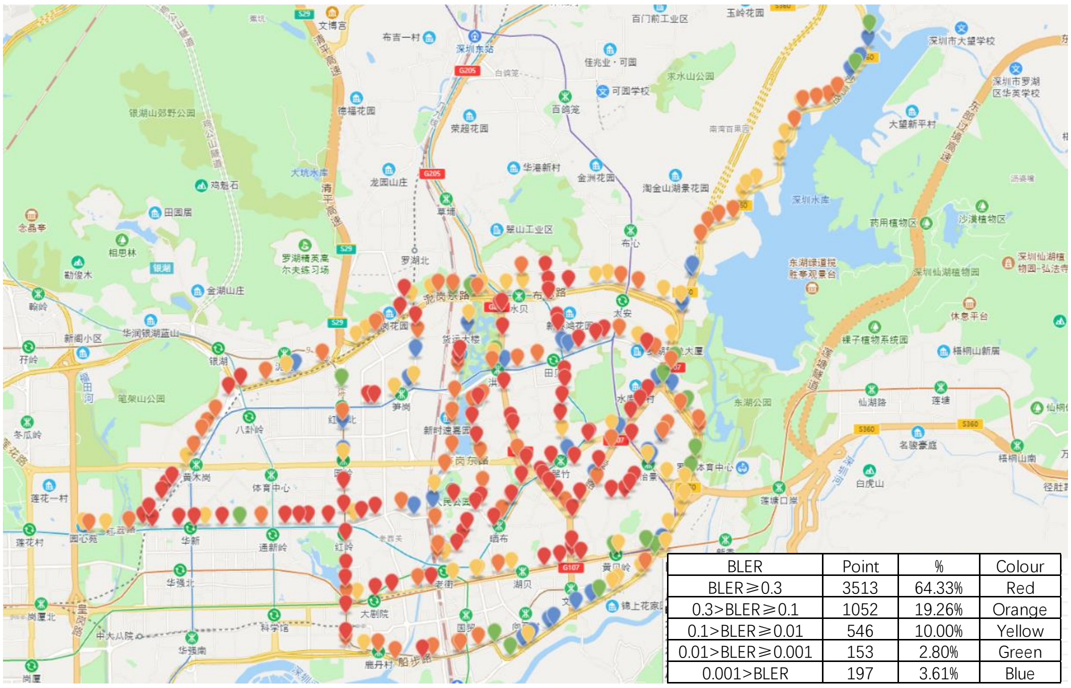


BLER	Point	%	Colour
0>SNR	587	10.75%	Red
6>SNR⩾0	1599	29.28%	Orange
12>SNR⩾6	1764	32.30%	Yellow
18>SNR⩾12	1033	18.92%	Green
SNR⩾18	478	8.75%	Blue

As shown in Fig. 46, in more than 95% of mobile reception scenarios, the performance of BLER is greater than 1% for MCS20 mode. In a small number (5%) of mobile reception scenarios and some fixed reception scenarios, BLER is less than 1% or no bit errors, which can achieve slight lag or smooth video playback. It coincides with the EQ_SNR results.

FIGURE 46

BLER results for MCS20 with subcarrier spacing of 1.25 kHz



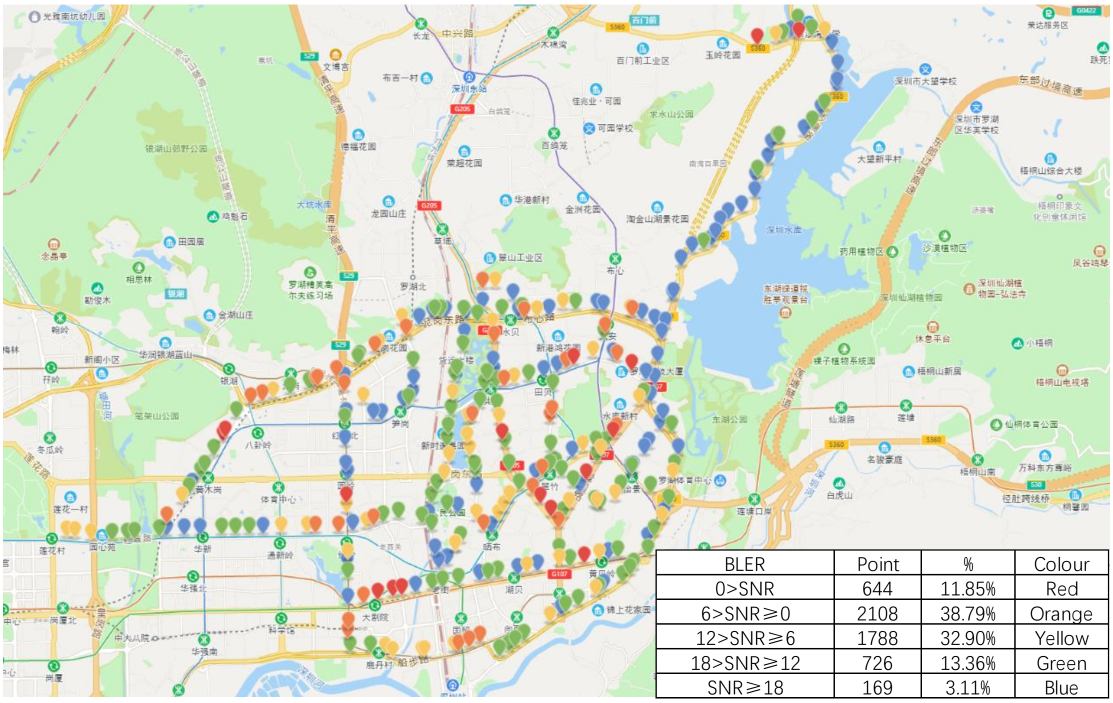
BLER	Point	%	Colour
BLER⩾0.3	3513	64.33%	Red
0.3>BLER⩾0.1	1052	19.26%	Orange
0.1>BLER⩾0.01	546	10.00%	Yellow
0.01>BLER⩾0.001	153	2.80%	Green
0.001>BLER	197	3.61%	Blue

2) The performance of the subcarrier spacing of 2.5 kHz

According to the field trial results, the difference in EQ_SNR between the subcarrier spacing of 1.25 kHz and 2.5 kHz is very small, and the difference cannot be distinguished from the statistical results which are shown in Figs 47 and 48.

FIGURE 47

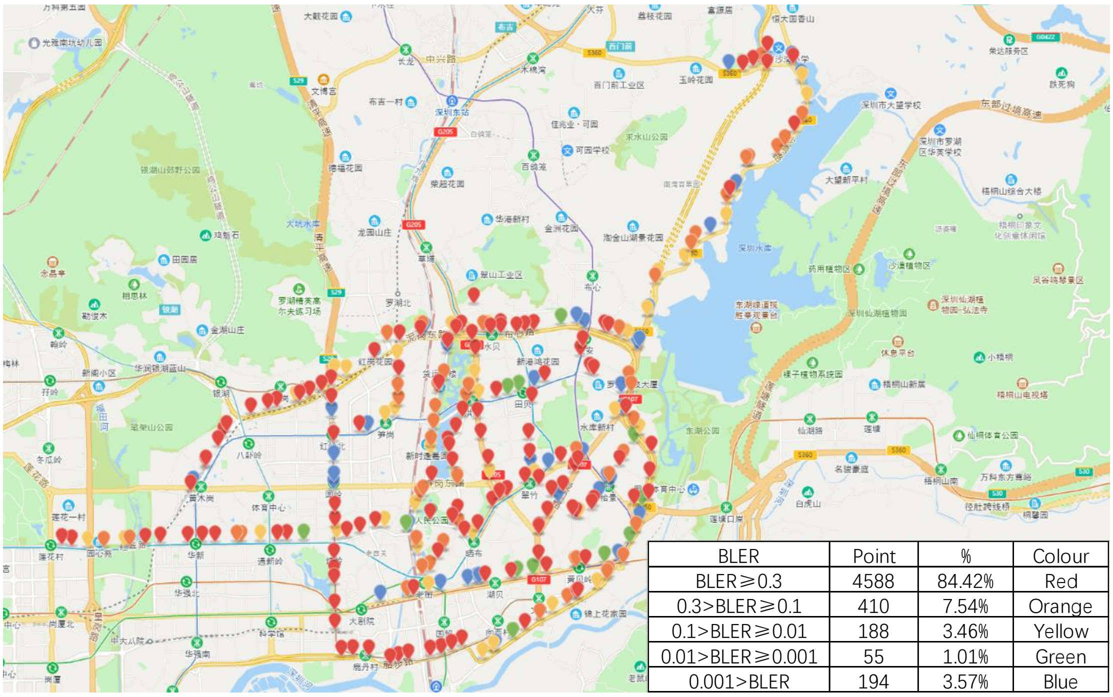
EQ_SNR results for MCS20 with subcarrier spacing of 2.5 kHz



BLER	Point	%	Colour
0>SNR	644	11.85%	Red
6>SNR≥0	2108	38.79%	Orange
12>SNR≥6	1788	32.90%	Yellow
18>SNR≥12	726	13.36%	Green
SNR≥18	169	3.11%	Blue

FIGURE 48

BLER results for MCS20 with subcarrier spacing of 2.5 kHz



BLER	Point	%	Colour
BLER≥0.3	4588	84.42%	Red
0.3>BLER≥0.1	410	7.54%	Orange
0.1>BLER≥0.01	188	3.46%	Yellow
0.01>BLER≥0.001	55	1.01%	Green
0.001>BLER	194	3.57%	Blue

According to the measurement results, the system performance even partially regresses when the subcarrier spacing is adjusted from 1.25 kHz to 2.5 kHz. The proportion of BLER greater than 30% increased from 64% to 84%, while the proportion of BLER less than 0.1% decreased from 3.61% to 3.57%.

5.4.2 MCS14 mode

The parameters of MCS14 mode are shown in Table 16.

TABLE 16

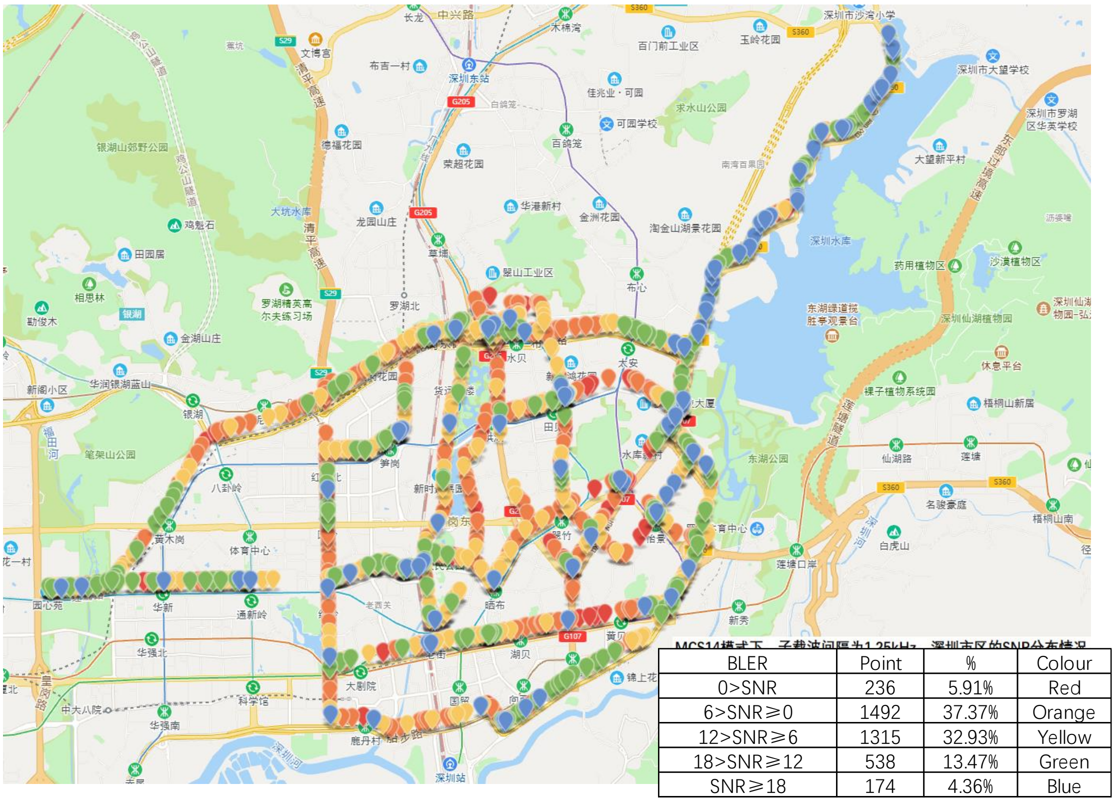
The parameters of MCS14

Item	Value
Bandwidth (MHz)	4.5
Modulation and coding scheme	MCS14
Cyclic-prefix (μs)	100
FFT length	3 072
Subcarrier spacing (kHz)	1.25
Constellation	16-QAM
FEC code rate	0.60
Payload data rate (Mbit/s)	6.295
Spectral efficiency (bits/s/Hz)	1.40

In many tests in Shenzhen, the EQ_SNR values measured by the System L receiver remained stable. Throughout the entire urban test section, SNR values below 12 dB are about 80% of the test sections (the SNR threshold of error free for MCS14 is about 10.5 dB under white Gaussian noise), as shown in Figs 49 and 50.

FIGURE 49

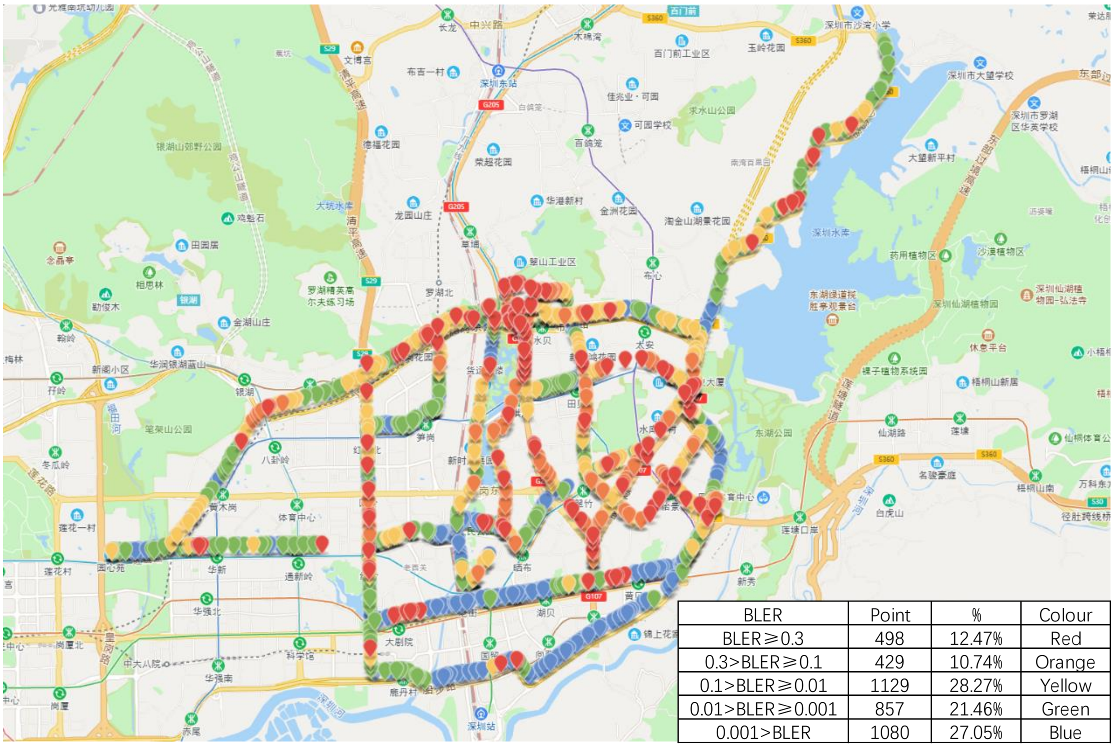
EQ_SNR results for MCS14 with subcarrier spacing of 1.25 kHz



BLER	Point	%	Colour
0>SNR	236	5.91%	Red
6>SNR≥0	1492	37.37%	Orange
12>SNR≥6	1315	32.93%	Yellow
18>SNR≥12	538	13.47%	Green
SNR≥18	174	4.36%	Blue

FIGURE 50

BLER results for MCS14 with subcarrier spacing of 1.25 kHz



BLER	Point	%	Colour
BLER≥0.3	498	12.47%	Red
0.3>BLER≥0.1	429	10.74%	Orange
0.1>BLER≥0.01	1129	28.27%	Yellow
0.01>BLER≥0.001	857	21.46%	Green
0.001>BLER	1080	27.05%	Blue

According to the field trial results, the BLER lower than 1% is 48% of test sections which is indicated as blue or green dot on the map, and the video may be played slightly stuttered or smoothly at these dots.

5.4.3 MCS9 mode

The parameters of MCS9 are shown in Table 17.

TABLE 17

The parameters of MCS9

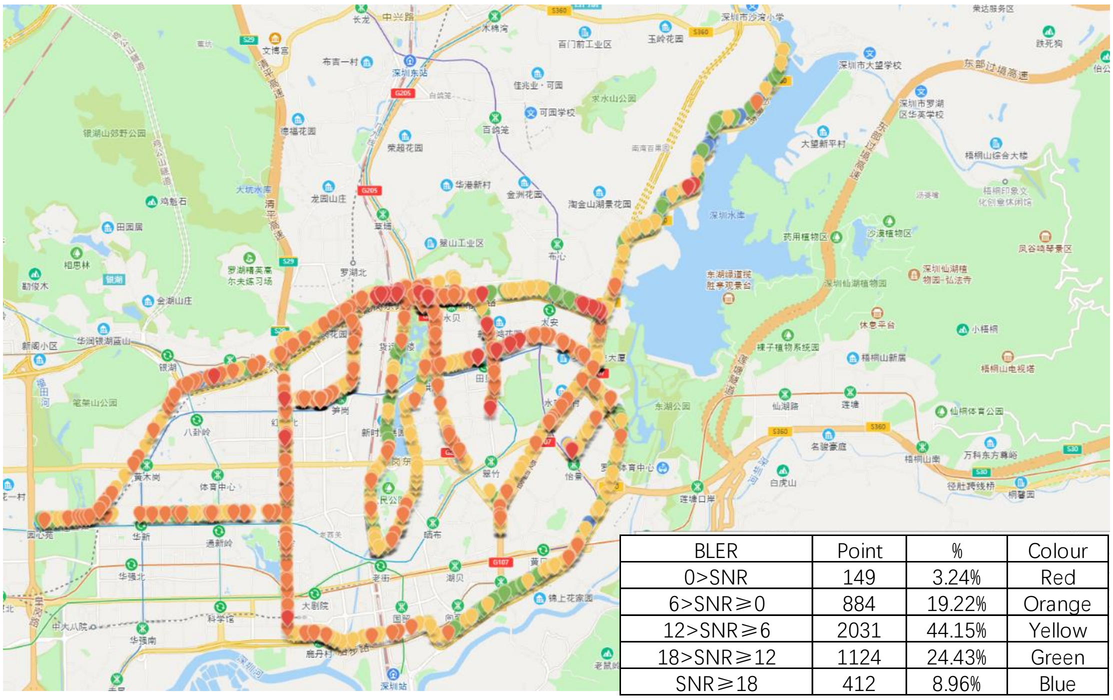
Item	Value
Bandwidth (MHz)	4.5
Modulation and coding scheme	MCS9
Cyclic-prefix (μs)	100
FFT length	3072
Subcarrier spacing (kHz)	1.25 / 2.5
Constellation	QPSK
FEC code rate	0.74
Payload data rate (Mbit/s)	3.908
Spectral efficiency (bit/s/Hz)	0.868

1) The performance of the subcarrier spacing of 1.25 kHz

When using MCS9 mode, the values of EQ_SNR measured by the System L receiver are essentially the same as those measured in MCS14 and MCS20 modes. Throughout the entire test sections, SNR below 6 dB is about 22% of the test sections (the SNR threshold of error free for MCS9 is about 4.4 dB under white Gaussian noise). The test results are shown in Figs 51 and 52.

FIGURE 51

EQ_SNR results for MCS9 with subcarrier spacing of 1.25 kHz



BLER	Point	%	Colour
0>SNR	149	3.24%	Red
6>SNR⩾0	884	19.22%	Orange
12>SNR⩾6	2031	44.15%	Yellow
18>SNR⩾12	1124	24.43%	Green
SNR⩾18	412	8.96%	Blue

FIGURE 52

BLER results for MCS9 with subcarrier spacing of 1.25 kHz

BLER	Point	%	Colour
BLER⩾0.3	138	3.00%	Red
0.3>BLER⩾0.1	6	0.13%	Orange
0.1>BLER⩾0.01	23	0.50%	Yellow
0.01>BLER⩾0.001	201	4.37%	Green
0.001>BLER	4232	92.00%	Blue

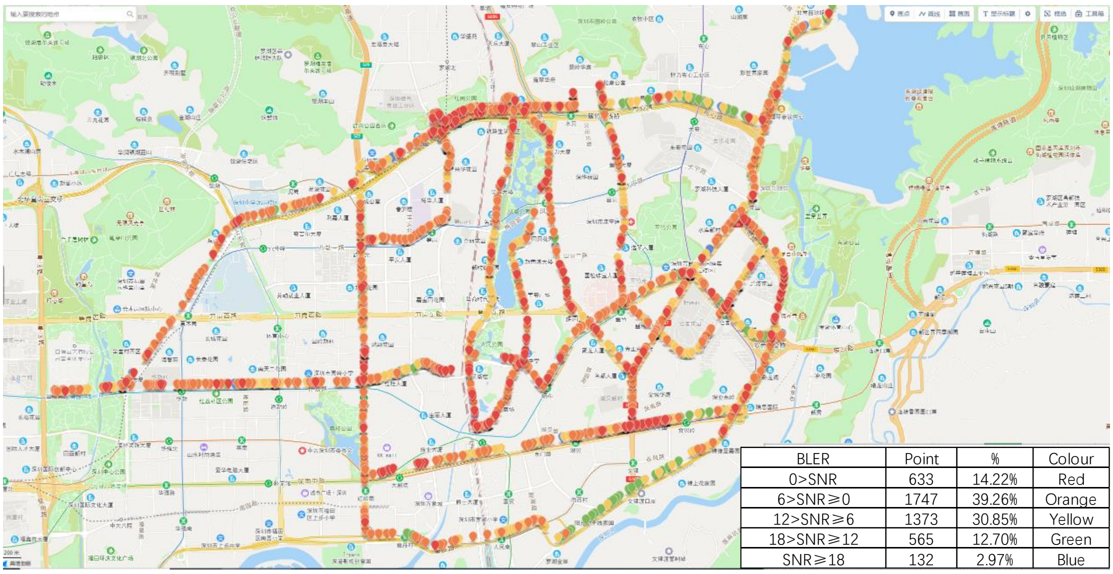
The BLER will be greater than 1% on only 3% of the test sections when using the MCS9 mode with the subcarrier spacing of 1.25 kHz. The video can be played smoothly in the remaining 96% test sections.

2) The performance of the subcarrier spacing of 2.5 kHz

As shown in Figs 53 and 54, the overall performance of the System L receiver shows a significant decline compared with the performance of subcarrier spacing of 1.25 kHz when using MCS9 mode with subcarrier spacing of 2.5 kHz.

FIGURE 53

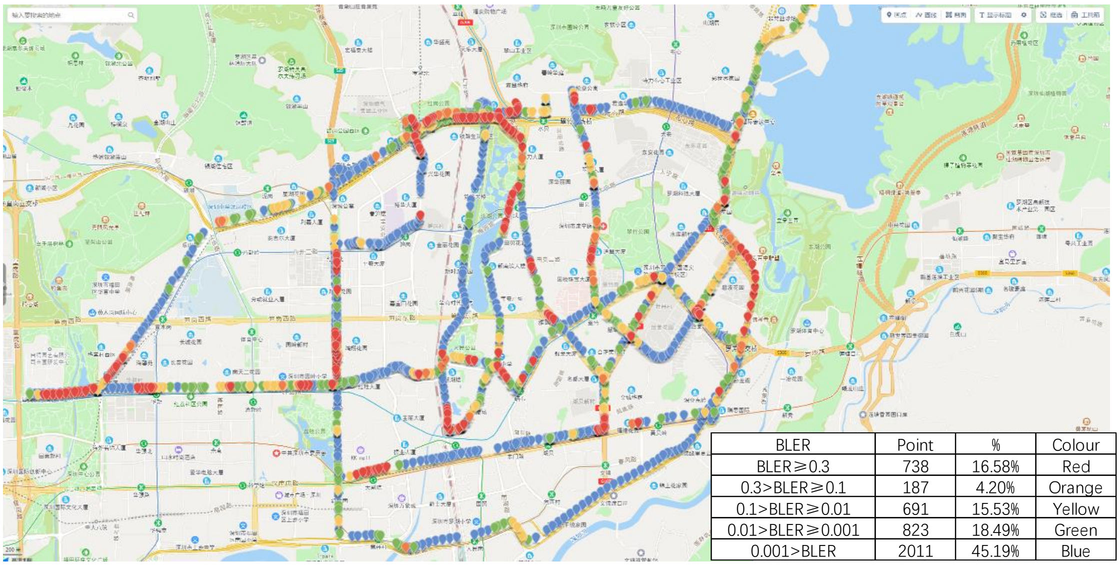
EQ_SNR results for MCS9 with subcarrier spacing of 2.5 kHz



BLER	Point	%	Colour
0>SNR	633	14.22%	Red
6>SNR⩾0	1747	39.26%	Orange
12>SNR⩾6	1373	30.85%	Yellow
18>SNR⩾12	565	12.70%	Green
SNR⩾18	132	2.97%	Blue

FIGURE 54

BLER results for MCS9 with subcarrier spacing of 2.5 kHz



According to statistics, the BLER greater than 1% is about 35% of the test sections, and the video will have obvious stuttering, which is much higher than the proportion (3%) at 1.25 kHz subcarrier spacing, and the proportion of completely error-free sections drops from 92% to 45%.

Annex 2

LTE-based 5G terrestrial broadcast of the Eurovision Song Contest 2022

1 Summary

A LTE-based 5G broadcast signal was transmitted during the Eurovision Song Contest 2022 event live and in high quality from sites in four European cities simultaneously. For now, only a select group of users with LTE-based 5G broadcast-enabled smartphones in Paris, Stuttgart, Turin, Vienna was able to see these transmissions. The aim is to change that, and to demonstrate, with those transmissions, the value this technology could bring to the media and millions of audience members.

LTE-based 5G broadcast is a complementary distribution technology that can add value in a number of use-cases – one of which is access to live content for mass audiences on the go, with the possibility to receive free-to-air content even without a SIM card, no need to sign up to third-party services, and in a way that delivers efficiency gains for distribution infrastructures.

For the purposes of the 2022 ESC LTE-based 5G broadcast trials, the EBU and its members (SWR (Stuttgart), ORS Group (Vienna), France Télévisions (Paris) and RAI (Turin)) teamed up with Eurovision services for the ESC signal logistics, Ateme for the encoding and streaming, Rohde & Schwarz for the transmission equipment, and Qualcomm for the prototype LTE-based 5G broadcast-compatible handsets.

1.1 Participants

– Ateme
– Qualcomm
– SWR (www.swr.de) – EBU member
– ORS/ORF (http://ors.at) (https://orf.at) – EBU member
– RAI (www.rai.it) – EBU member
– France Télévisions (www.france.tv) – EBU member
– Rohde & Schwarz (https://www.rohde-schwarz.com/ca/home_48230.html).

1.2 Start date and duration

– April/May 2022.

1.3 Location

– Geneva
– Paris
– Stuttgart
– Turin
– Vienna.

1.4 Technologies

– 3GPP Release 16 feature set.

1.5 Equipment and infrastructure

– Transmission equipment varied, depending on test-bed location
– Prototype LTE-based 5G broadcast-compatible handsets.

1.6 Spectrum and frequencies

– 600 MHz band – frequencies varied, depending on the test-bed location.

FIGURE 55

Eurovision Song Contest LTE-based 5G broadcast trials

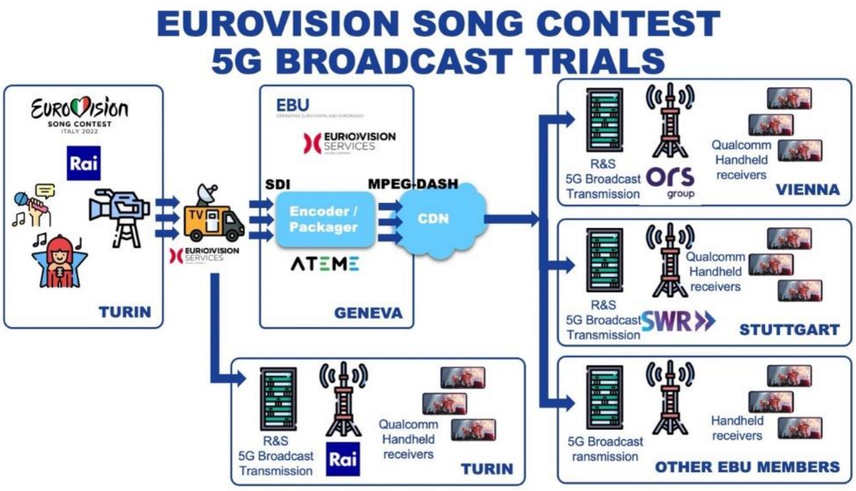


Figure 55 shows the diagram of the setup for the Eurovision Song Contest 5G broadcast trials involving the four sites. The signal was produced by RAI and delivered to the Eurovision Services headquarters in Geneva. A video encoder from Ateme was providing the signal to a CDN end-point where ORS, SWR and France TV were able to retransmit the signal to handsets using the LTE-based 5G Terrestrial Broadcast system.

FIGURE 56

A select group of users with compatible handsets in four cities was able to receive the LTE-based 5G Terrestrial Broadcast signal of the ESC 2022 live

2 Laboratory tests and field trials by Rai-CRITS in Turin

Over the last few years, Rai-CRITS has carried out extensive laboratory tests and field trials on LTE based 5G Broadcast functionalities (defined in Release 14 [1] and Release 16 [2]) to mobile devices, evaluating the coverage and quality of experience (QoE) in urban/dense urban and suburban environments. In particular, Rai successfully tested the LTE-based 5G Broadcast technology within the coverage of the metropolitan area of Turin with a single transmitter. Road measurement tests in both areas have been carried out to collect data about the achievable coverage and the required network configurations to guarantee a satisfactory quality of service (QoS).

The tests in the metropolitan area of Turin allowed an evaluation of the system's performance in a densely populated area characterized by the presence of tall buildings and other obstacles which often prevent a receiver from having the direct view of the transmitting site. The tests also concerned the Turin ring motorway, allowing the evaluation of the LTE-based 5G Broadcast's performance at rather high speeds.

2.1 Laboratory tests

Very extensive lab sessions allowed to gain a first-hand experience of the enormous potential of the system and to understand how mature the technology is for its rapid exploitation. The receiver tested during the laboratory session is the Software Defined Radio (SDR) receiver by Rohde & Schwarz. Different performance evaluations have been conducted for characterising the 'goodness' of both the technology and its implementation, such as the performance in presence of Additive White Gaussian Noise (AWGN) and the performance in case of a 0-dB echo channel to evaluate the resilience of the system in terms of reflections and SFN robustness. Finally, the performance within a mobile channel at different speeds (profile COST207-Typical Urban [3]) have been evaluated.

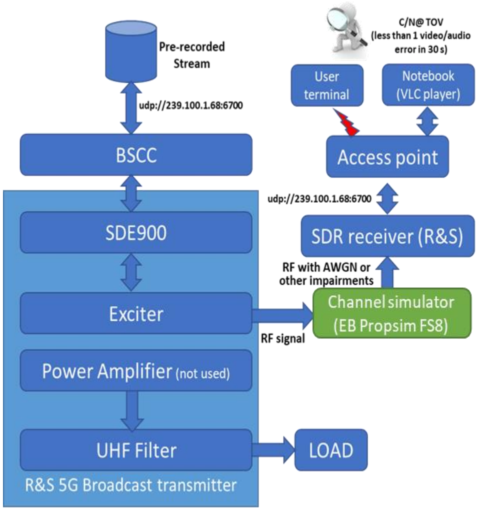
The block diagram of the adopted test bench is reported in Fig. 57. Alongside the classic laboratory equipment used for RF measurements (e.g. attenuators, bolometers), the fundamental devices used during the measurement session were the following:

– Spectrum analyser: Agilent E4443A
– Channel simulator: EB Propsim FS8.

The measurement procedure adopted in all the tests carried out was to add up the selected degradation (AWGN, echoes, Doppler shift, etc.) and to observe the video until reaching the threshold of visibility (TOV), which corresponds to less than one video/audio error in 30 s.

FIGURE 57

Laboratory Set-Up

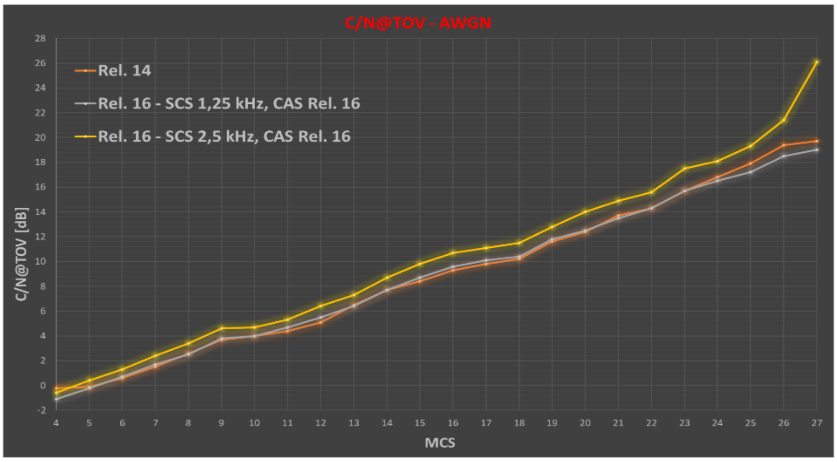


A huge amount of data has been collected during the lab tests. In this Report, only the results which can be considered as preparatory for the subsequent tests in a real service area are shown.

The performance of LTE-based 5G Broadcast in terms of *C*/*N* at the TOV are shown in Fig. 58. The obtained values are quite in line with what is expected from a theoretical point of view, with a limited implementation margin, especially for the more robust MCSs.

FIGURE 58

Additive White Gaussian Noise test results



More in details:

– With a Subcarrier Spacing (SCS) of 1.25 kHz, the results are in line with what has been already found in a previous measurement campaign based on former Release 14 of the standard; these data were already aligned with the expected theoretical ones.

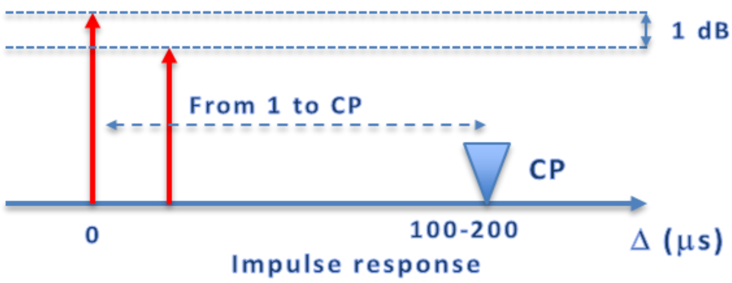
– With a SCS of 2.5 kHz, a slight degradation has been observed ranging from 0.5 dB using the most robust MCS up to about 2 dB with the most efficient MCS.

The "0 dB echo test" has been used to evaluate the robustness of the system in presence of an echo which can be either natural (reflection against an obstacle) or artificial (signal coming from another transmitter operating at the same frequency, SFN). Typically, a "robust" echo (equal to or slightly below the main signal) causes a degradation in performance compared to the presence of AWGN only; this degradation can be quantified between a few dB fractions and a few dBs as long as the delay is within the cyclic prefix (CP). Outside the cyclic prefix, on the other hand, the echo behaves as an interference, thus making the system quickly to collapse.

During these tests, the echo delay, having a power of 1 dB lower than the main signal (C/I = 1 dB), has been varied from 1 µs up to over the CP (see Fig. 59): 100 µs for SCS = 2.5 kHz, 200 µs for SCS = 1.25 kHz.

FIGURE 59

Impulse response for "Single echo test"



For each delay, noise was added until reaching the TOV. The results for MCS12, reported in Fig. 60, indicate that the behaviour of the receiver, was generally in line with what is theoretically expected. The following observations can also be made:

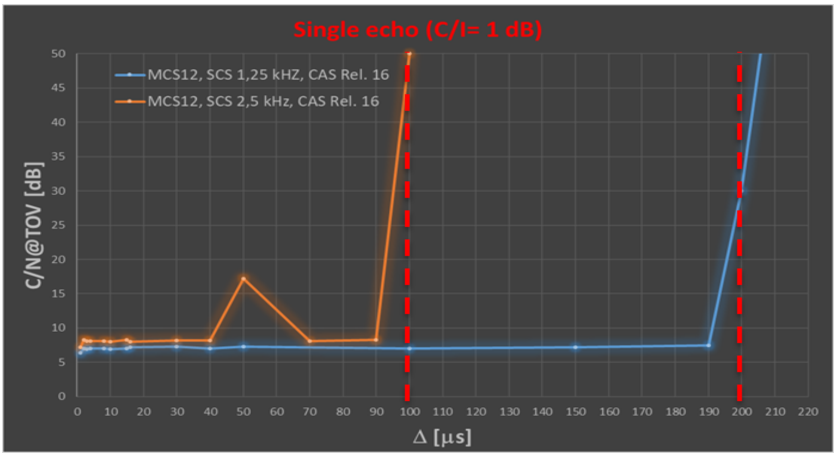
– With SCS = 1.25 kHz the results are in line with what expected (unsynced receiver at about 200 µs).

– With SCS = 2.5 kHz the results are in line with what expected (unsynced receiver at about 100 µs).

– New CAS defined in Rel-16 do not introduce any appreciable differences compared to those of Rel-14.

FIGURE 60

"Single echo test" results for MCS12

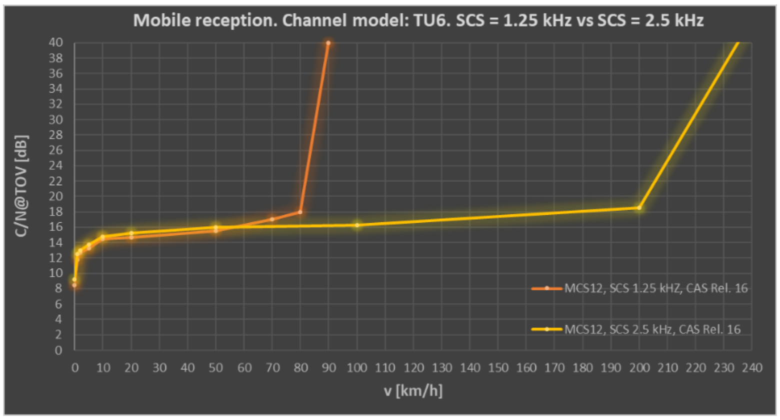


Other laboratory tests simulating the mobile channel aimed at verifying the maximum speed achievable by the system without compromising the reception. Echo profiles, typical of a mobile outdoor reception, have been generated using a channel simulator. These profiles are defined in COST 207: in the tests, a six-echoes profile representing a Typical Urban scenario (TU6) has been used.

The graphic in Fig. 61 reports the estimated *C*/*N* at TOV versus speed in km/h for the UHF channel 53 (f = 730 MHz), which is the test frequency generally used for Rai field trials in the Aosta Valley.

FIGURE 61

Mobile reception performance, TU6



Taking into account that the receiver was not specifically designed for the mobile channel, the results in the labs looked promising. In particular, the maximum achieved speed at 730 MHz was around 80 km/h with SCS = 1.25 kHz and about 200 km/h with SCS = 2.5 kHz, acceptable for most mobile use cases.

Using SCS = 2.5 kHz seems to be the best compromise between robustness against the Doppler effect and the length of the CP (100 µs, for an ISD between transmitters of up to 30 km).

2.2 Field tests

Road measurements with an omnidirectional antenna mounted on the top of the van in the area around Turin have been carried out to collect data about the achievable coverage and the required network configurations to ensure the service, to record the RF signal in different conditions for off-line evaluations on the mobile reception availability, to evaluate the electromagnetic field (EMF) availability and to identify an operating “threshold” for the mobile reception.

To obtain these results, a van was equipped with the following instruments:

– LTE-based 5G Broadcast receiver: Rohde & Schwarz SDR receiver;
– RF recorder: Lumantek Weiver 2.0;
– receiving antenna positioned on the top of the van;
– GPS antennas for georeferencing of measurements;
– monitors positioned in the headrests for observation of the received video;
– notebook with software designed by Rai CRITS for error detection and data logging of the EMF, van speed and geographical position.

The modulation parameters used during these measurement campaigns are based on the results of the preliminary laboratory tests and are a trade-off between the required robustness in a mobile reception context and the available capacity. Table 18 shows the transmission parameters adopted and the frequencies used in the testbed.

TABLE 18

Transmission parameters

Transmission parameters – Turin test bed	
Modulation scheme	MCS12 (16-QAM, rate 0.42)
Subcarrier spacing (SCS)	1.25 kHz (cyclic prefix = 100 µs)
Bandwidth	5 MHz
CAS	Release 16
Available bit rate	4.83 Mbit/s
Frequency	VHF ch. 11 (CF = 219.5 MHz)

2.2.1 Turin testbed

In October 2021, Rai CRITS activated a LTE-based 5G Broadcast Rel. 16 testbed in Turin on VHF channel 11 (f = 219.5 MHz) in vertical polarization. Despite this is not in the typical frequency range addressed for future LTE-based 5G Broadcast services, channel 11 was the only available experimental frequency in the Turin area. However, the reliability of the experiment was not compromised.

The set-up included the activation of one transmitter (see parameters in Table 19) at about 6 km in line of sight from the city centre. A pre-recorded signal has been played in the Rai Production Centre premises of Turin (CPTO). The SDI signal coming from the playout has been used to feed an encoder generating a Transport Stream over IP (TsoIP) at a desired bit rate. The multicast IP has been sent to the transmitting site via an optical fibre connection. At the transmitting site both the Broadcast Service and Control Centre (BSCC) and the transmitting chain by Rohde & Schwarz have been placed. The set-up of the testbed is reported in Fig. 62.

FIGURE 62

Turin testbed set-up

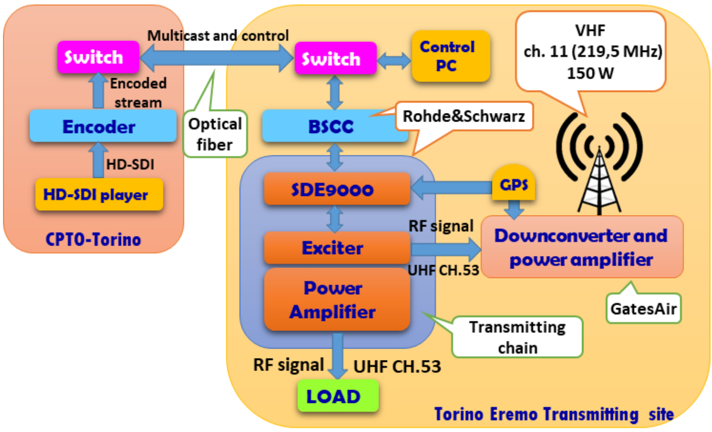


TABLE 19

Turin site parameters

Transmitter	Coordinates	Height	Frequency (CF)	Pout
Torino-Eremo	45°02’30’’N – 7°44’08’’ E	626 m (asl[1]) – 400 m (agl[2])	219.5 MHz (ch. 11)	150 W

(1) Above sea level.

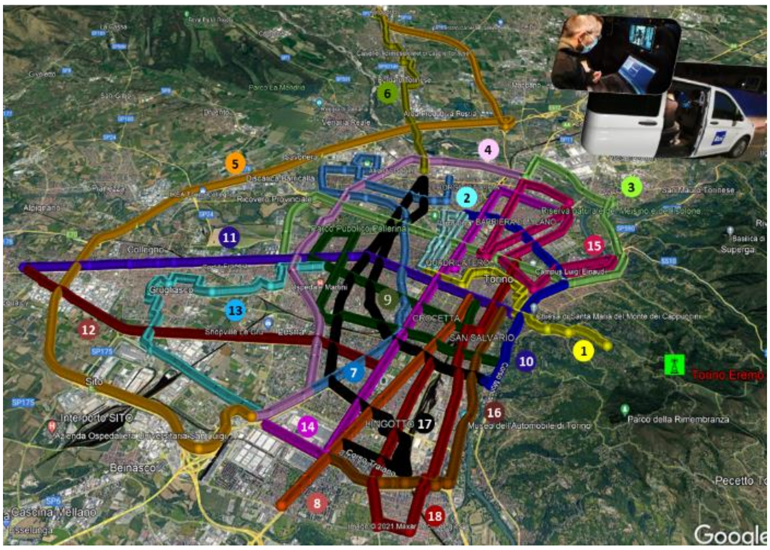
(2) Above ground level (Torino city).

The measurements, mainly carried out in the night to avoid the city traffic, have been divided into “routes” including both the urban and suburban parts of the Turin area, trying to include the most significant and popular places (city centre, airport, stadiums, railway stations, ring road, etc.). This way, 18 routes have been identified for a total of almost 250 km travelled, as illustrated in Fig. 63.

The post-processing of all this huge amount of acquired data made it possible to evaluate the available coverage of the LTE-based 5G Broadcast service transmitted from the Torino – Eremo site.

FIGURE 63

LTE-based 5G Broadcast “subway” in Turin

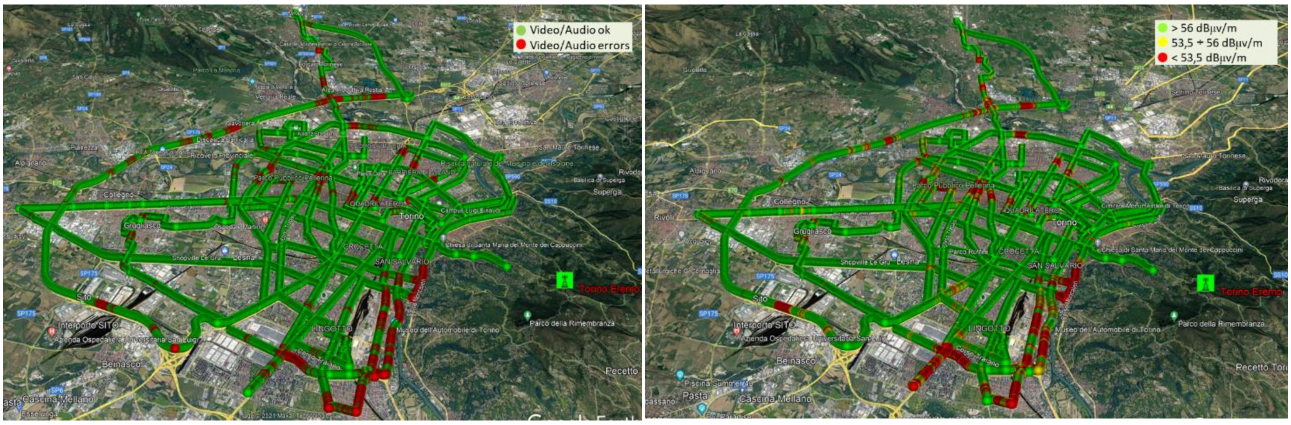


The estimated overall coverage in terms of QoE is 92.2%: this means that every 100 s, more than 92 s were correctly received while 8 s showed some video and/or audio errors. This coverage estimation also includes some areas generally considered outside the service area (e.g. the south-east area of the town, which is located at the basis of the hill hosting the HPHT and for this reason is affected by shadowing effects).

Starting from the power measurements at the input of the receiver and taking into account the antenna parameters, the EMF at approximately 2 metres (height of the van) has been calculated.

FIGURE 64

Turin testbed: coverage and EMF



Looking at the maps in Fig. 64 (right side), it should be noted that the traffic lights colours system has been chosen in order to fix a kind of operating threshold in mobile reception. The idea was to find an EMF value granting over-threshold values in a percentage comparable to the measured available coverage. This operation makes sense since available coverage and EMF values are strictly correlated. Data processing established that using a threshold of 53.5 dB(μV/m) provides the 92.3% of over-threshold values, very similar to the 92.2% of measured coverage. In Fig. 64 it is evident the very close geographical correlation between the points where it was not possible to receive the signal (left side) and those where the EMF is less than 53.5 dB(μV/m) (right side).

The threshold is also useful for off-line simulations: in fact, changing the modulation scheme, the transmitting power or other parameters (i.e. the receiving antenna) it is possible to "forecast" the service coverage for a certain area.

The Turin testbed has been used on the occasion of two important demonstrations. The first one took place as part of the 5G-TOURS project [4]: Rai-CRITS experimented the delivery of high-quality linear TV services to 5G mobile phones in broadcast mode, using the most recent implementation of the 3GPP-Release 16 standard.

The second demonstration took place during the Eurovision Song Contest 2022 event, hosted in Turin from 10 to 14 May 2022. During ESC2022 Rai, simultaneously with other EBU partners in other European countries, tested the LTE-based 5G Broadcast mode adopting a LTE-based 5G Broadcast smartphone prototype provided by Qualcomm (see Fig. 65).

FIGURE 65

ESC2022 demonstration

References

[1] 3GPP TR 38.913 v14.3.0, "Study on scenarios and requirements for next generation access technologies", August 2017.

[2] 3GPP TR 36.976 v16.0.0, "Overall description of LTE-based 5G terrestrial broadcast", March 2020.

[3] Cost 207 digital land mobile radio communications final report, September 1988.

[4] https://5gtours.eu/

Annex 3

Field trials in Germany

1 5G Media2Go

1.1 Introduction

The next generation of mobile telecommunication technologies (5G) comes with a promise of various new applications. This also applies to the media and entertainment sector for the production of new forms of content and for its distribution. There seems to be an opportunity to target in particular smartphones, tablets and vehicles with both linear TV and radio programmes and nonlinear offers such as media libraries or podcasts. Future autonomous cars are considered a new very important use case for media consumption.

The broadcast, automotive and telecommunication industry have a common interest to offer users access to attractive media content and services while in a car or on public transport. The combination of linear and nonlinear content on the integrated infotainment system of contemporary cars constitutes an important step into this direction. The location or the route of the vehicle taking into consideration the expected duration of travel could be used in the future to generate recommendations thereby offering additional value for mobile media consumption.

1.2 Participants

– Südwestrundfunk (SWR, www.swr.de) – EBU member
– DFMG Deutsche Funkturm GmbH
– Dr. Ing. h.c. F. Porsche AG
– Hochschule Mainz
– Kathrein Broadcast GmbH
– Media Broadcast GmbH – BNE member
– Mercedes-Benz AG
– Rohde & Schwarz GmbH & Co. KG
– Technische Universität Braunschweig – Institut für Nachrichtentechnik
– Telekom Deutschland GmbH.

1.3 Services

– linear TV programmes
– linear radio programmes
– ARD / SWR Mediathek
– geo-referenced content recommendations (“Travelguide”).

1.4 Start date and duration

– 1 October 2020 to 30 September 2022.

1.5 Location

– Greater Area Stuttgart / Heilbronn (Germany).

1.6 Technologies

– FeMBMS (Release 14) and LTE-based 5G Terrestrial Broadcast (Release 16), LTE Unicast.

1.7 Equipment and infrastructure

– 2 HPHT transmitter sites in Stuttgart and Heilbronn
– 4 LPLT transmitter sites at mobile base station sites
– SWR signal contribution system for HPHT sites
– On-channel repeaters for LPLT sites
– LTE mobile network.

1.8 Spectrum and frequencies

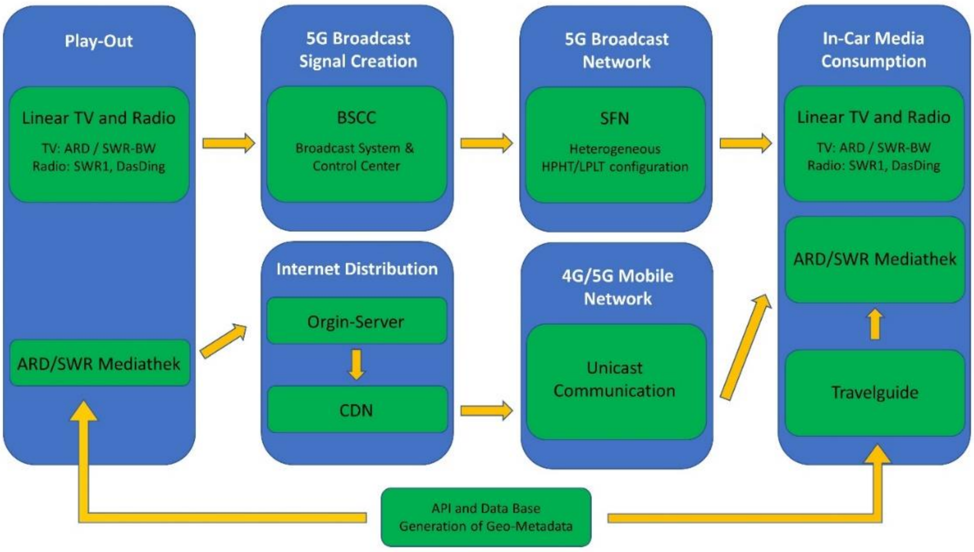
– 5 MHz / 8 MHz carrier in TV channel 40 (622-630 MHz)
– Commercial LTE spectrum.

1.9 Main goals

– Verification of LTE-based 5G broadcast as a system being capable of delivering linear media services to in-car infotainment systems.
– Deployment of a LTE-based 5G broadcast network in the wider Stuttgart area consisting of two high-power-high-tower transmitters (HPHT) and a set of low-power-low-tower stations (LPLT).
– Integration of different media services in the infotainment system of a car.
– Execution of measurement campaigns to assess quality of service and coverage of the 5G broadcast transmissions.

FIGURE 66

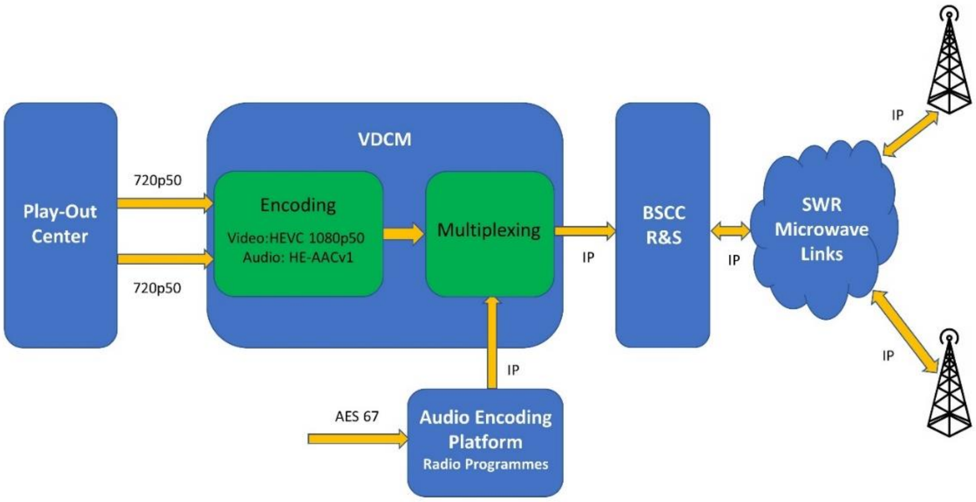
Overview of the entire distribution and usage chain



– Execution of mobile measurement campaigns in order to investigate availability of services with regards to coverage and quality of service.

FIGURE 67

Generation of LTE-based 5G broadcast signal



In order to distribute linear services by means of LTE-based 5G broadcast, a dedicated transmitter network is deployed in the 5G Media2Go project. As the project focuses on media services for infotainment systems in vehicles, the selection of the transmitter sites was guided by the intention to cover the city of Stuttgart, the highway A81 between Stuttgart and Heilbronn and highway A8 from Stuttgart westwards. Moreover, both the premises of Porsche in Weissach and the campus of Mercedes-Benz in Sindelfingen were to be covered as well.

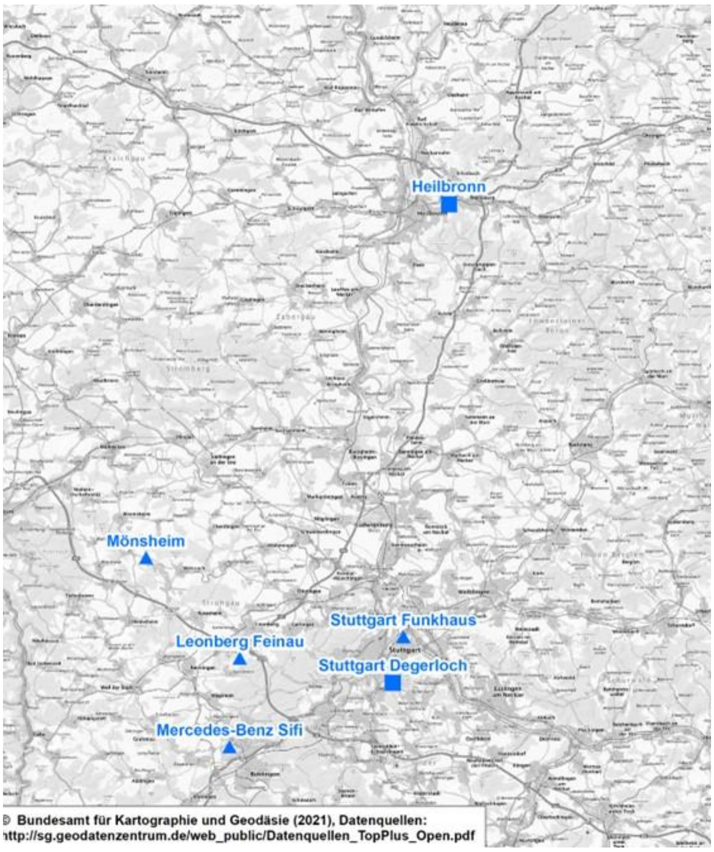
The network consists of two high-power-high-tower (HPHT) stations of SWR (Stuttgart-Degerloch and Heilbronn-Weinsberg), a small transmitter at the SWR premises in downtown Stuttgart (Stuttgart-Funkhaus), a trial station on the Mercedes-Benz campus in Sindelfingen and two mobile network sites of DFMG in Leonberg-Feinau and Mönsheim L1177. The transmitters Stuttgart-Degerloch, Heilbronn-Weinsberg, Leonberg-Feinau and Mönsheim L1177 were put into operation during the first months of the project while Stuttgart-Funkhaus was on air since December 2021. The transmitter Sindelfingen followed in April 2022.

The two main transmitters of the network in Stuttgart and Heilbronn are operating at ERPs of about 73 kW and 20 kW, respectively. The small transmitter Stuttgart-Funkhaus uses 1 kW ERP. Sindelfingen has an ERP of 743 W, while Leonberg-Feinau and Mönsheim L1177 are transmitting signals with an ERP of 288 W and 218 W, respectively. All stations are operated as a single frequency network, i.e. all stations are transmitting the same LTE-based 5G broadcast signal on the same frequency. This is an option naturally offered by all COFDM systems.

Figure 68 shows the geographical layout of transmitter network.

FIGURE 68

Geographical layout of transmitter network



1.10 Results and conclusions

The results of comprehensive measurements show that LTE-based 5G terrestrial broadcast is fundamentally suitable for the distribution of (linear) content to fast moving receivers. In 5G Media2Go particular focus lay on the examination of how the modifications introduced by 3GPP Release 16 affect the robustness of the CAS, and whether a wider subcarrier spacing used for the MBSFN subframes ensures more robust transmission at high movement speeds. In addition, the performance of the system using the wider bandwidth introduced by 3GPP Release 17 was evaluated.

The CAS investigations revealed that the 3GPP Release 16 modifications led to a robustness gain of individual physical channels of around 2 dB in comparison to what was possible in earlier 3GPP releases. A dependence of the CAS robustness on the movement speed could not be observed in the test where the highest speed driven was 180 km/h. Since the subcarrier spacing used by the CAS (15 kHz) is far wider than the Doppler shifts in that speed range, this is in line with expectations.

When examining the MBSFSN subframes, a subcarrier spacing of 1.25 kHz and 2.5 kHz was used. The subcarrier spacing of 2.5 kHz is intended to enable more robust data transmission at high movement speeds, compared to a subcarrier spacing of 1.25 kHz. However, the performance at both subcarrier spacings showed no significant dependency on movement speed. For the data encoding, mainly two different MCS values were used. MCS9 uses a QPSK with a code rate of 0.67 while MCS16 uses a 16-QAM with a code rate of 0.64. With a signal bandwidth of 5 MHz, up to 3.8 Mbit/s can be transmitted by using MCS9, while up to 7.4 Mbit/s are possible with MCS16. However, this gain in data rate comes at the price of a less robust signal, so the MCS16 needs approximately 3 dB more SNR than MCS9. Extending the channel bandwidth from 5 MHz to the newly defined option of 8 MHz, the required SNR can be reduced by up to 3 dB. This is due to two effects. Firstly, more frequency resources are available leading to a more efficient frequency-domain interleaving, which in turn increases the frequency diversity gain. Second, as the bandwidth increases, so does the individual codeword length. This enables more effective encoding by the coding algorithms, which reduces susceptibility to errors. If possible, the largest possible bandwidth should therefore be used for data transmission, as this not only enables a higher data rate, but also increases robustness.

Under the Travelguide service thread of 5G Media2Go a system was developed which offers geo-referenced recommendations for content in the ARD/SWR Mediathek. To this end, a corresponding interface was developed.

In order to geo-reference Mediathek content, the available videos were processed in different ways both manually and automated based on analysing audio track, video description, metadata and image data. By combining the transcribed audio track and the metadata associated with a video such as title, synopsis, keywords, a prototype process was implemented that automatically geo-references the content.

A location score that maps the quality of the location reference of a specific video was prototypically designed. Using the Travelguide service developed, content from the media library can be searched, filtered and retrieved depending on location data. In addition, a Web app was developed that uses this API and provides further functionalities.

In total, more than 52 000 videos could be geo-referenced. Due to playout rights constraints, only around 28 000 videos are currently available in the database. The core of the project was the realization of a Web API, through which the service is made available to the automotive partner and can thus form the foundation for applications based on it. Using the Porsche infotainment system as an example, video content can be queried around the current location of the vehicle or along a possible travel route. It can then be displayed in the integrated player on the passenger panel.

In summary, the following major conclusions can be drawn from the investigations carried out in 5G Media2Go:

– LTE-based 5G broadcast is capable to deliver linear TV and radio services to smartphones and infotainment systems in vehicles.
– LTE-based 5G broadcast supports delivering linear services at high speeds of up to 180 km/h.
– LTE-based 5G broadcast can be configured to distribute different data stream formats, e.g. MPEG Transport Stream and MPEG DASH.
– LTE-based 5G broadcast supports network operation in single frequency mode including both HPHT and LPLT transmitters.
– The integration of LTE-based 5G broadcast transmissions alongside with unicast communication on infotainment systems of vehicles to grant access to non-linear services is straightforward. This allows to offer hybrid services which combine linear and non-linear elements.
– A particular spin-off of the project is the Travelguide application. The relevance of geo-referenced recommendations will increase as mobile media consumption will grow.

Further technical details can be found in the GMedia2Go Report[2].

2 LTE-based 5G broadcast in Hamburg

2.1 Summary

The pilot project comprises of two SFN transmitters (5- and 10-kW ERP respectively) and a corresponding playout centre. The impact of the parameters (like MCS and cyclic prefix) on the

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[2] https://drive.google.com/file/d/1CznXRhhNboNVvXVI6oTqiF2f6brlONxb/view.

reception will be measured in order to get a better basis for network planning. It is not a funding project. Thus, it is open for any other testing and development in the context of video distribution for broadcasters.

2.2 Participants

– Norddeutscher Rundfunk (NDR) (www.ndr.de) – EBU member

– Media Broadcast (MB) BNE member.

2.3 Services

– 1 TV service

– 2 audio services

– Internet Link Service (ILS)

– HbbTV

– *(open for changes and extensions)*.

2.4 Start date and duration

– Show case started in October 2021

– Pilot project planned until end of 2023.

2.5 Location

– Hamburg (Germany).

2.6 Technologies

– LTE-based 5G broadcast.

2.7 Equipment and infrastructure

– Virtual Digital Content Manager – VDCM (Synamedia)

– Broadcast Service and Control Centre – BSCC (R&S and Enensys)

– Transmitters (R&S).

2.8 Spectrum and frequencies

– 5 MHz at channel 34 (to be extended to 8 MHz).

2.9 Main goals

– The main goal is to clarify open questions for preparing decisions with respect to an introduction of LTE-based 5G broadcast, e.g. analysis of reception conditions depending on different parameters, further measurements, interoperability tests, foundations for frequency and network planning, experiences with receiving devices and development/test of possible applications (open for any other question that will come up during the project).

2.10 Highlights

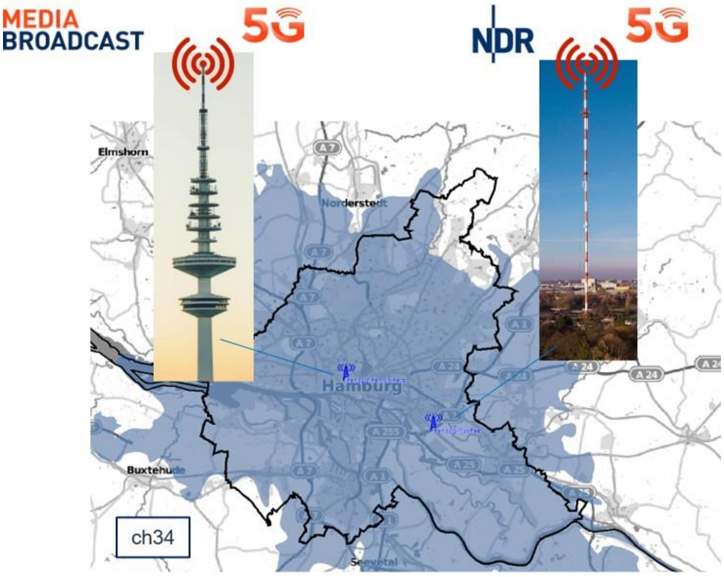
– Project is in the starting phase

– Tests were carried out with different core components

– The network is now prepared for an operation of 8 MHz wide signal.

FIGURE 69

Intended service area of trial



Annex 4

Vienna (Austria) field trials

1 Summary

Assessing the performance of FeMBMS (Release 14) and LTE-based 5G broadcast (Release 16) in comparison with DVB-T2 and DAB+. Studying product maturity of infrastructure and receivers with close cooperation to manufacturers. Evaluating hybrid use cases and applications (e.g. combining LTE-based 5G broadcast with broadband networks to provide a seamless switch experience to the user) and evolving the 5G broadcast ecosystem.

2 Participants

– Austrian Broadcasting Corporation (ORF) – Public Broadcaster, Content Provider TV and Radio (http://orf.at – EBU member)

– Austrian Broadcasting Services (ORS) – Broadcast Network Operator (http://ors.at) – BNE member)

– Servus TV – Private Broadcaster, Content Provider TV

– ProSiebenSat.1 PULS 4– Private Broadcaster, Content Provider TV for Puls24

– KroneHit – Private Broadcaster, Content Provider Radio

– Vienna University of Technology Institute for Telecommunications – Link Level Simulations.

3 Services

– Linear TV and Radio (RTP, HLS, DASH in various configurations[3])
– Emergency Warning Tests.

4 Start date and duration

– Phase 1: 2020-2021 – Comparison DVB-T2 vs LTE-based 5G broadcast
– Phase 2: 2021-2023 – Investigation of hybrid applications and further development of the 5G broadcast ecosystem.

5 Location

– Vienna (Austria)

6 Technologies

– FeMBMS (Release 14) and LTE-based 5G Terrestrial Broadcast (Release 16)

7 Equipment and infrastructure

– Commercial equipment and Infrastructure:
  • 2 HPHT Transmitter Sites
  • 2 Core Systems
– Open-source receiver (OBECA/5G-MAG Reference Tools)
– Open-source transmitter (5G-MAG Reference Tools)
– Smartphone-formfactor devices with LTE-based 5G broadcast receiving capability.

8 Spectrum and frequencies

– 739 MHz, max bandwidth 10 MHz before 1.7.2020
– 667 MHz, max bandwidths [8 MHz (Kahlenberg transmitter), 10 MHz (Liesing transmitter)] from 1.7.2020
– 640.5 MHz, max bandwidth 5 MHz (Liesing transmitter) from 1.2.2022.

9 Main goals

– Open testbed for Broadcast Network Operators, Mobile Network Operators, Set Top Box and chip manufacturers
– Study product maturity of infrastructure and receivers with close cooperation of manufacturers
– Support the evolution of a LTE-based 5G broadcast ecosystem by developing and providing an open-source receiver for own and other trials and application developer

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[3] Use-Case defined settings for Modulation Coding Scheme, Bandwidth and Services.

– Phase 1:
  - Compare simulation and measurements of FeMBMS Rel.14 (and Rel.16) with DVB-T2 and DAB+
  - Technical evaluation of LTE-based 5G broadcast use-cases and applications.
– Phase 2:
  - Hybrid use-cases LTE-based 5G broadcast and Broadband
  - Further development of the LTE-based 5G broadcast ecosystem.

10 Highlights

– Results from phase 1 of the trial have been summarized in a CEPT input paper[4]

Development of the world's smallest open-source LTE-based 5G broadcast receiver "OBECA" 2021

– First reception tests and measurements within a high-power-high-tower testbed with a smartphone-formfactor device with LTE-based 5G broadcast reception capabilities in February/March 2022

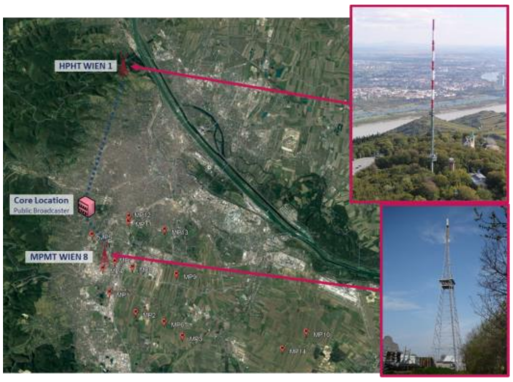
– Nakolos: a solution for Broadcaster, Content Provider and Broadcast Network Operators to offload traffic from Content Delivery Networks (CDNs) utilizing LTE-based 5G broadcast. It helps Broadcasters and Content Providers to keep their CDN distribution costs under control[5]

– Resilient PNT based on LTE-based 5G broadcast (testbed for a joint project of the European Space Agency and Rohde & Schwarz)[6]

– First tests with a commercial research device, i.e., a commercially available phone which was re-configured as a research device for LTE-based 5G broadcast reception in January 2023.

FIGURE 70

Vienna testbed overview with the two transmitters (Wien Kahlenberg, Wien DC Tower and Wien Liesing), the LTE-based 5G broadcast core location at the public broadcaster



[4] https://www.ors.at/fileadmin/user_upload/ors/5G_Broadcast/PTD_21_012_Technical_implementation_status_of_5G_Broadcast_-_Vienna_Field_Trial_.pdf

[5] https://nakolos.com

[6] Field test support for a project by ESA and Rohde & Schwarz: https://navisp.esa.int/project/details/167/show.

FIGURE 71

Mimicking mobile users with the self-developed measurement setup using a bicycle trailer in 2020 (~80 kg, containing battery packs, 2 measurement systems and laptops for up to 3 hours measurements)

FIGURE 72

LTE-based 5G broadcast reception platform OBECA, by February 2021 the world's smallest open-source receiver for LTE-based 5G broadcast. Now part of the 5G-MAG Reference Tools

Annex 5

LTE-based 5G terrestrial broadcast trials in Italy

1 LTE-based 5G terrestrial broadcast trial in Italy/Aosta Valley

1.1 Summary

The main scope of this trial is:

– Provide LTE-based 5G broadcast delivery to massive audiences with HPHT infrastructure;

– Study the performance of a LTE-based 5G broadcast signal in mobility (in-car scenario) and urban outdoor (coverage analysis);

– Improve video user’s experience;
– Distribute of audio-visual (A/V) content and services to a potentially unlimited number of users.

1.1.1 Participants

– RAI (Public Service Media Organization – TV Content Provider – Broadcast Network Operator) (www.rai.it) – EBU member
– Rai Way.

1.1.2 Services

– Provide high-quality video media content and service to mobile devices using conventional terrestrial broadcast network infrastructure.

1.1.3 Start date and duration

– November 2021 to June 2022.

1.1.4 Location

– Aosta Valley (Italy).

1.1.5 Technologies

– LTE-based 5G Terrestrial Broadcast (Release 16).

1.1.6 Equipment and infrastructure

– Two HPHT transmitter sites in SFN (Single Frequency Network) mode
– EnTV/EPC core by Rohde & Schwarz
– hardware/software defined receiver (SDR) by Rohde & Schwarz and iFN
– hardware/software defined receiver (SDR) by OBECA.

1.1.7 Spectrum and frequencies

– UHF channel 53 (730 MHz centre frequency).

1.1.8 Main goals

– Implement a standalone-dedicated broadcast mode deployed on terrestrial broadcast network infrastructure
– Setup and experimentation of a single frequency network (SFN)
– Distribution of live TV broadcast over a dedicated broadcast network to mobile devices
– Mobile reception (in vehicles)
– Free to air reception.

1.2 Field tests

Road measurements with an omnidirectional antenna mounted on the top of the van in Aosta Valley have been carried out to collect data about the achievable coverage and the required network configurations to ensure the service, to record the RF signal in different conditions for off-line evaluations on the mobile reception availability, to evaluate the EMF availability and to identify an operating “threshold” for the mobile reception.

To obtain these results, a van was equipped with the following instruments:

– LTE-based 5G Broadcast receiver: Rohde & Schwarz SDR receiver;

- RF recorder: Lumantek Weiver 2.0;
- receiving antenna positioned on the top of the van;
- GPS antennas for georeferencing of measurements;
- monitors positioned in the headrests for observation of the received video;
- notebook with software designed by Rai CRITS for error detection and data logging of the EMF, van speed and geographical position.

The modulation parameters used during these measurement campaigns are based on the results of the preliminary laboratory tests and are a trade-off between the required robustness in a mobile reception context and the available capacity. Table 20 shows the transmission parameters adopted and the frequencies used in the testbed.

TABLE 20

Transmission parameters – Aosta Valley test bed

Modulation scheme	MCS12 (16-QAM, rate 0.42)
Subcarrier spacing (SCS)	1.25 kHz (cyclic prefix = 100 μs)
Bandwidth	5 MHz
CAS	Release 16
Available bit rate	4.83 Mbits/s
Frequency	UHF ch. 53 (CF = 730 MHz)

1.2.1 The Aosta Valley testbed

The Aosta Valley region has very often been the scenario for RAI Research Centre experiments, especially since the advent of digital technologies in the 90s. The reason for using the Valley lies in its peculiar topography which is particularly complex from a signal propagation and reception point of view. The numerous side valleys and the large number of required transmitter sites to cover the area, also make the Aosta Valley perfect for testing SFN. Furthermore, the possibility of travelling along a dense secondary road network, close to the main valley which often climbs up steep mountain slopes frequently hidden from the transmitters, provides a demanding test case for the reception of mobile TV.

Furthermore, transmitting the LTE-based 5G Broadcast signal from two different HPHT sites, with partially overlapping coverage areas in the region of Aosta town, has made it possible to experiment with a SFN in a realistic operational environment. For these reasons, the Aosta Valley testbed has been an excellent test bench for LTE-based 5G Broadcast technology.

Rai CRITS activated the testbed in the Aosta Valley in November 2021, transmitting signals on UHF channel 53 (730 MHz) in horizontal polarization. The set-up included the activation of two transmitters (see parameters in Table 21):

- Transmitter 1: Aosta – Gerdaz, located in the south of Aosta, on the mountains surrounding the town, at about 5 km in line of sight from the city centre.
- Transmitter 2: Saint Vincent – Salirod, located close to the town of Saint Vincent, at about 4 km in line of sight from the city centre.

TABLE 21

Aosta Valley sites parameters

Transmitter	Coordinates	Height	Frequency (CF)	Pout
Aosta-Gerdaz	45°42'08'' N – 7°18'35'' E	1 366 m (asl [(1)]) – 770 m (agl [(2)])	730 MHz (ch. 53)	50 W
Saint-Vincent-Salirod	45°44'38'' N – 7°40'41'' E	1 114 m (asl [(1)]) – 550 m (agl [(3)])	730 MHz (ch. 53)	100 W

(1) Above sea level.

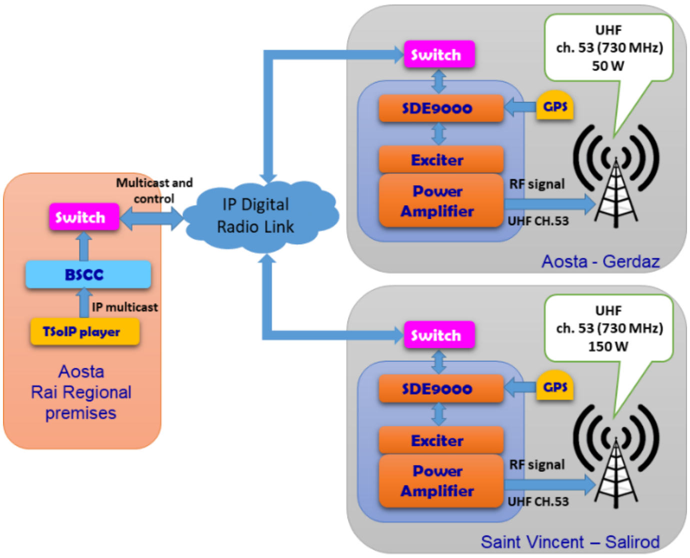
(2) Above ground level (Aosta city).

(3) Above ground level (Saint-Vincent city).

A pre-recorded TsoIP at a desired bit rate has been played in the Rai Regional premises of Aosta where it was located the BSCC, connected to the two transmitter sites by means of an IP digital radio link. The set-up of the testbed is reported in Fig. 73.

FIGURE 73

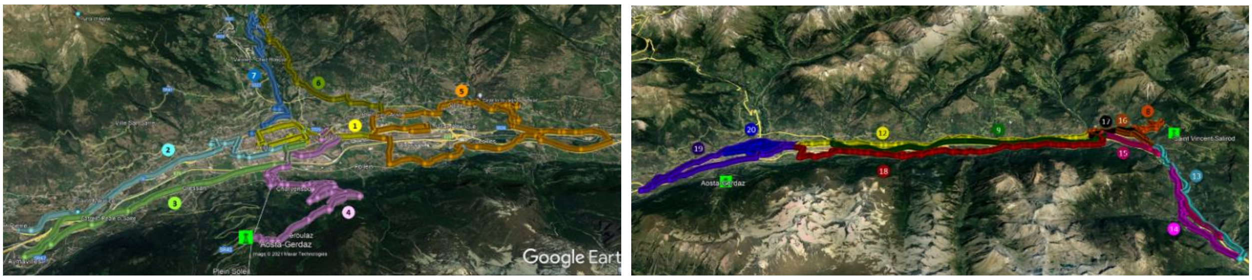
Aosta Valley testbed set-up



After checking the radiant systems, the coverage of each single transmitter has been analysed, in order to have an exhaustive picture of the overlapping areas. These data are of fundamental importance to set up the SFN properly and to carry out coverage measurements in the most significant areas. As done in the Turin testbed, the measurements have been carried out on routes in the main towns in the SFN service area, the highway running through the main valley and the suburban areas that often lie in the lateral and narrower valleys. Thus, 18 routes have been identified for a total of more than 250 km travelled, as illustrated in Fig. 74.

FIGURE 74

The Aosta Valley routes, (a) Aosta - Gerdaz, (b) Saint Vincent - Salirod



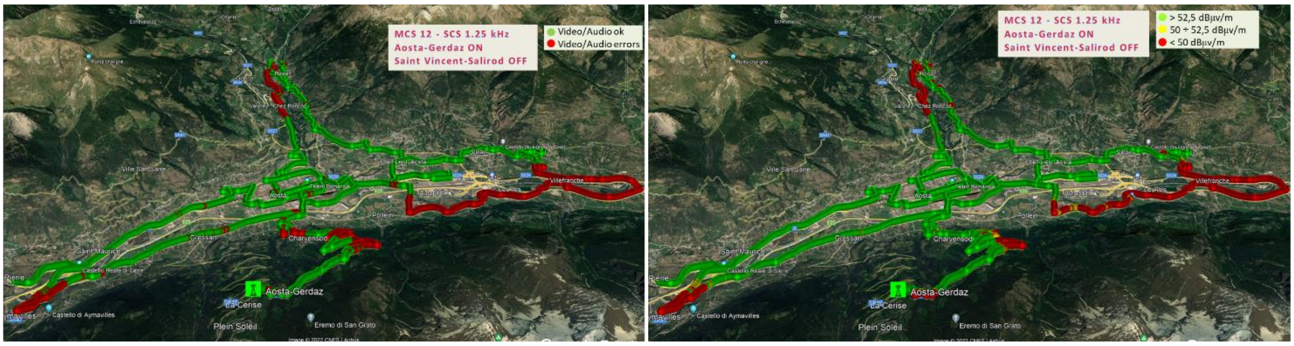
(a) (b)

For each route, coverage has been evaluated by monitoring the audio/video and reporting the points where errors were detected; then, such errors have been acquired and georeferenced by using a special software developed in our laboratories. In addition, the power values at the receiver input and the RF signal were recorded for subsequent off-line analysis. From the power values and on the basis of the characteristics of the receiving antenna (i.e. antenna factor) the EMF at a height of 2 metres has been extrapolated.

The processing of the acquired data allowed us to obtain the coverage maps for each single transmitter and an EMF value threshold. As an example, the coverage relating to the Aosta – Gerdaz transmitter and the EMF map are shown in Fig. 75.

FIGURE 75

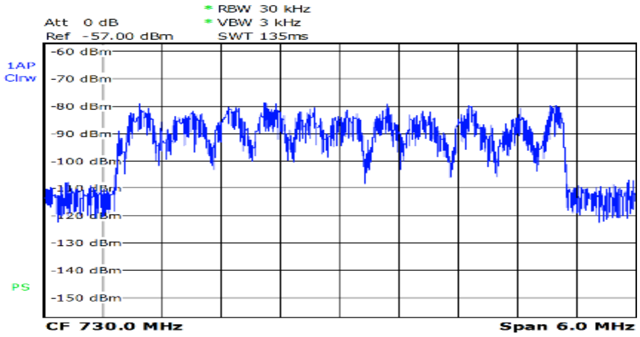
Aosta – Gerdaz coverage and EMF



Considering a threshold of 50 dB(μs V/m), the number of measured seconds during which the EMF has been over-threshold is quite similar to the coverage percentage; as in the case of the Turin testbed, there is a very close geographical correlation between the points where it is not possible to receive the signal and those where the EMF is under threshold, as it is clearly visible in Fig. 76. The difference between the threshold value identified in the Turin testbed (53.5 dB(μs V/m)) and the one obtained in the Aosta Valley is due to a different sensitivity of the receiver in VHF band compared to the UHF band performance used instead in the Aosta Valley. Another reason that justifies this difference is that in the Aosta Valley, differently from the Turin testbed, the urban area is quite limited compared to the suburban area where the mobile reception is simpler because very often the transmitter site is in line of sight with the receiving antenna.

FIGURE 76

Spectrum at Aosta airport

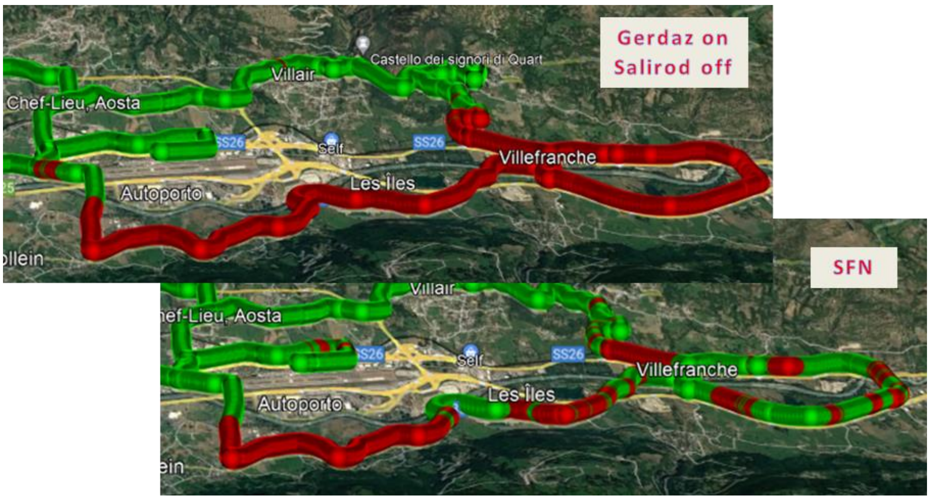


The following step has been to set up and verify the correct behaviour of the SFN network. Therefore, after verifying all the network parameters set by means of the BSCC, some test points were identified in the overlapping area of the two transmitters, where measurements were carried out using a vehicle equipped with a 10 m telescopic pole. For each of these measurement points, a static delay has been set on the Aosta – Gerdaz transmitter to get a relative delay between the two transmitters equal to 1 µs. This way, using a spectrum analyser and rotating the antenna so that the received power from the two transmitters were as similar as possible (i.e. C1/C2 = 0 dB), it was easy to observe "holes" (typical in an SFN context) within the spectrum at a distance of about 1 MHz (1/1 µs). As an example, Fig. 76 shows the measurement point of Aosta – Saint Christophe. Similar results were obtained in other three selected points. These preliminary measures allowed us to verify the synchronization of the SFN.

Once the correct functioning of the SFN had been verified, hence keeping both transmitters switched on, coverage has been measured again in the service area: we have focused on the overlapping area of the two transmitting systems, namely the urban area of Aosta and the west suburban area of the city. Basically, the paths shown in Fig. 74 (a) were retraced, in order to further validate the SFN and to appreciate the improvements in coverage thanks to the combined effect of the two transmitters. For example, route 5 (see Fig. 77), one of the most subject to the combined effect of the two transmitters, sees an increase in coverage from 58% to over 68% when operating in SFN mode. The relatively low value of the coverage is due to the fact that the route includes some areas, especially in the south of Aosta, where both transmitters are shielded from the surrounding mountains.

FIGURE 77

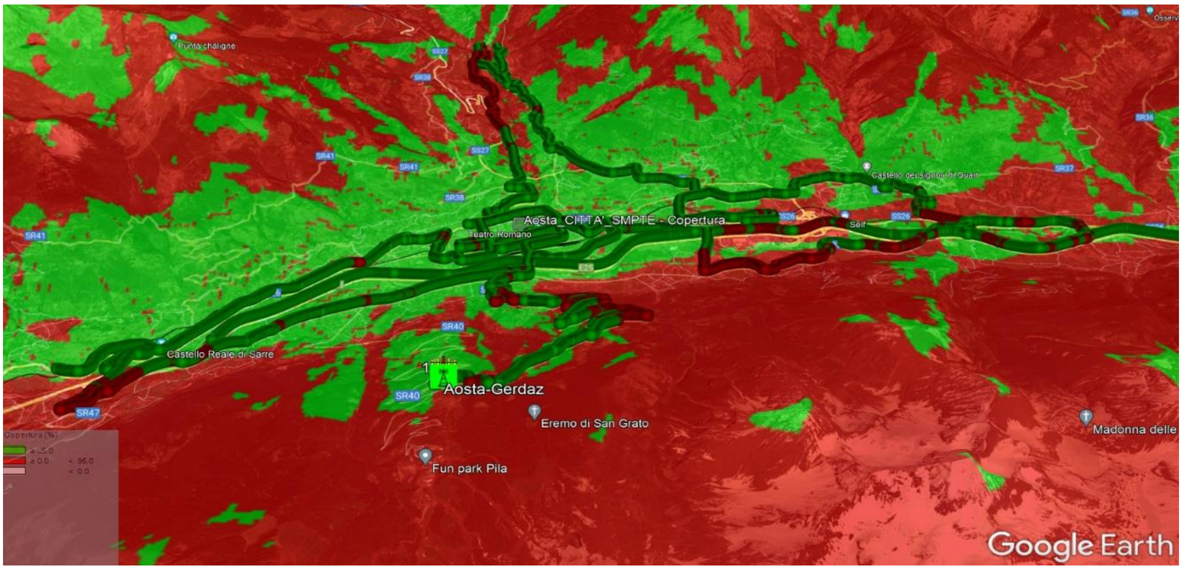
SFN coverage increasing in Aosta



As a further element of comparison, an attempt was made to compare the predicted values of the simulative analysis considering a single threshold value placed at 95% of the covered locations, with the field measurements, finding a very good agreement as can be easily verified in Fig. 78. Of course, such an approach needs to be further investigated: if confirmed, it would indicate that mobile reception is reliable in areas where the simulations provide a coverage rate of over 95%.

FIGURE 78

Simulations vs measurements



2 5G audiovisual broadcast broadband network (Rai Way – Italy)

2.1 Trial in Turin and Palermo

2.1.1 Summary

On July 2022 Rai Way was awarded the “5G Audiovisual 2022” tender of the Ministero delle Imprese e del Made in Italy, former Ministero dello Sviluppo Economico, obtaining also 1 million Euro funding.

The one-year project had the main objective of experimenting with innovative technologies based on 5G networks in the sector of the production, distribution and broadcasting of innovative live audiovisual content.

2.1.2 Participants

– Rai Way S.p.A.
– Rai Radiotelevisione Italiana
– Municipality of Turin
– Rohde & Schwarz
– Politecnico di Milano
– OpNet
– MainStreaming
– Impersive
– Kinecar

– RETESETTE
– La Sicilia Multimedia
– Teatro Massimo (Palermo).

2.1.3 Start Date and Duration

– July 2022 to July 2023

2.1.4 Location

– Turin and Palermo

2.1.5 Technologies

– 3GPP Release 16 feature set and seamless switching broadband/broadcast

2.1.6 Equipment and Infrastructure

– Fiber Optic and Radio-Link network Rai Way and OpNet
– Two Rai Way HPHT sites, one in Turin and one in Palermo, based on Rohde & Schwarz LTE-based 5G broadcast technology
– CDN Broadband in Turin and Palermo and CDN local Edge (Dedicated Broadband MainStreaming in Turin)
– Prototype LTE-based 5G broadcast-compatible handsets
– SDR receiver with capabilities of seamless switching broadband/broadcast, developed by Politecnico di Milano on the basis of 5G MAG Reference Tools, also integrated on the infotainment system of a minicar, to allow for car mounted vehicular reception.

2.1.7 Spectrum and frequencies

– 5 MHz, 743-748 MHz band – SDL-B2.

2.1.8 Main goals

The main goal was experimenting with innovative technologies based on 5G networks in the sector of the production, distribution and broadcasting of audiovisual content.

2.1.9 Highlight

In the field of audiovisual production, innovative use cases were created through the use of 5G private networks like, e.g. a multistage live jazz concert with synchronous contribution from the musicians present in different locations and immersive live VR 360 shooting of cultural events.

FIGURE 79

5G broadcast trial in Turin

The trial provided a comprehensive overview of the extensive potentialities of the cutting-edge combination of LTE-based 5G broadcast and CDN technologies for the linear broadcast and broadband distribution.

Rai Way and the aggregation of partners created synergies between innovative audiovisual production, contribution and distribution networks, implementing an immersive and engaging live artistic content, even in teaching scenarios and demonstrating with the experimentation project the potential of the HPHT Rai Way broadcast network.

The use cases refer to specific "Live Events": TV contents, including live streams captured by means of a 5G remote production and VR360 content for full immersive experiences, have been distributed via LTE-based 5G broadcast to handheld devices, VR headsets and vehicular infotainment systems, implementing seamless switching between broadcast and broadband delivery to offer an uninterrupted viewer experience.

In the field of content production, the project exploited 5G Private Network technology to support distributed and remote television production of live events. The main objective was to reduce latency of a 5G Private Network and audio/video digital encoding systems (some tens of ms), so that a jazz band, with some components in distant places, could play together a jam session. At the same time, the network had to guarantee signals of adequate quality to the remote control room for live broadcasting on television channels.

In fact, in the context of Torino Jazz Festival 2023, a jazz improvisation of a 16-professional big band was shown, whose musicians, in addition to playing on stage, took turns in the different remote areas. With the contents of the same live performance different experiences were put in place: on smartphones and tablets, in the metaverse with headsets and live for an audience enjoying the show.

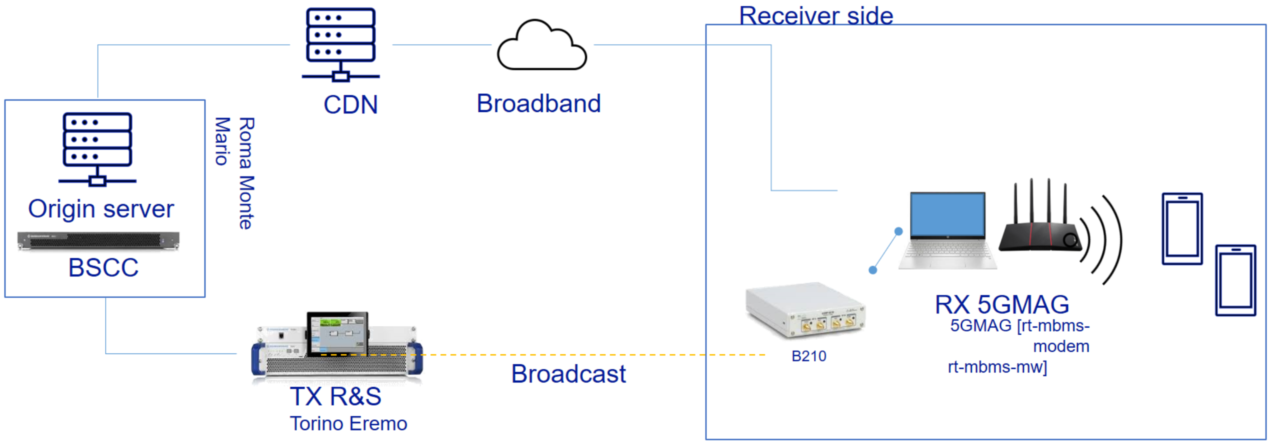
In the field of content distribution, in Massimo Theatre of Palermo, VR360 live signals were produced. The LTE-based 5G broadcast VR360° signal was received by a fixed rooftop antenna and the SDR prototype receiver, to be finally retransmitted via Wi-Fi6 to VR headsets with a high QoE. The reception place was both in a conference room inside Massimo Theatre where invited participants were present and at a Palermo school called "Convitto Nazionale Falcone" where many students were present with their teachers. A similar use-case has been realized at the Modern Art Gallery in Turin.

For the automotive use case, the prototype receiver has been integrated in the infotainment system of Kinecar, a highly connected minicar, to allow car mounted vehicular reception, with a good QoE along the streets of Turin: the multimedia live contents of the Italian broadcasters Rai, Antenna Sicilia and RETESETTE were used to feed the LTE-based 5G broadcast and broadband networks, to reach the vehicle infotainment system and via Wi-Fi mobile commercial devices (smartphones and tablets) used by the passenger.

The coverage, guaranteed by HPHT sites, was combined in deep urban areas with the usage of 5G data connectivity (OTT, unicast): the seamless switching between broadcast and broadband delivery allowed the uninterrupted service consumption for a satisfactory Quality of Experience.

FIGURE 80

Receiver-side integration and seamless switching



The integration between broadband and broadcast services was achieved by means of an additional application level, named Seamless Switching Application (SSA) running on the receiver and developed by Politecnico di Milano.

The trial was a combination of LTE-based 5G broadcast and CDN technologies and the high-level architecture of the application consisted of a HTTP server that responded to video streaming requests through three channels: the broadband (BB), the broadcast (BC), and the switching channel (BS).

The BC source was developed by Politecnico di Milano on the basis of the demodulator (version 1.2.2) and MBMS client (version 0.9.2) of the 5G-MAG Reference Tools.

The BS channel was managed by the application and enabled the manual or automatic switching between BB and BC according to specific commands or receiver conditions.

3 EI-Towers 5G field trial in Lissone (MB - Italy)

3.1 Summary

EI-Towers carried out a LTE-based 5G Broadcast "demo" field test in March 2023 in an area around its headquarters in Lissone (Lombardy).

The intention was to see the functioning of the system in practice, the characteristics of the equipment (BSCC, transmitters, handsets) and present the LTE-based 5G Broadcast system to a range of possible stakeholders in a future service. This includes, between others, broadcasters, content providers, IP carriers and consumer equipment manufacturers.

In particular, one of the achieved objectives was also to take a look at the quality of the radio coverage and the interference aspects with adjacent (downlink) channels used by Mobile Operators. Indeed, for this trial, EI-Towers used one of the three 5-MHz blocks in the 700 MHz duplex-gap band which, in Italy, are called SDL-B1, SDL-B2 and SDL-B3, and in particular, SDL-B1.

The reason for this choice was that these 5-MHz blocks in the duplex-gap of the 700 MHz band remained unsold in Italy after the auction made for the 700 MHz band and, therefore, are available today. Conversely, in Italy, all channels in the UHF band (at least those coordinated with neighbouring countries) are already used for broadcast, making extensive use of SFN networks also with national coverage. Only UHF channels currently assigned to neighbouring countries would be available and, in practice, even one regional coverage would be difficult to achieve.

As a follow-up, the idea would be the possible implementation of a LTE-based 5G Broadcast network with more extensive coverage in one or more Italian regions and/or a number of locations of interest (e.g. football stadiums). In addition, the QoE could also be evaluated with a selected group of users.

3.1.1 Participants

– EI-Towers (I)

– Rohde & Schwarz (D).

3.1.2 Start date and duration

– March 2023.

3.1.3 Location

– Lissone (Monza e Brianza – Lombardy).

3.1.4 Technologies

– 3GPP Release 16.0.

3.1.5 Equipment and infrastructure

– BSCC and TX 20 Watt (operating at 2.5 Watt and 1 Watt ERP) (Rohde & Schwartz)

– Prototype LTE-based 5G broadcast compatible handsets (3GPP Release 13.0)

– TSMA/TSMW 4G/5G receivers and SW ROMES (Rohde & Schwarz).

3.1.6 Spectrum and frequencies

– 5 MHz, 738-743 MHz band – SDL-B1.

3.2 Main Goals

The intention was to see the functioning of the system in practice, the characteristics of the equipment (BSCC, transmitters, handsets) and present the LTE-based 5G Broadcast system to a range of possible stakeholders in a future service. This includes, between others, broadcasters, content providers, IP carriers and consumer equipment manufacturers.

3.3 Highlight

Contents

The contents were prerecorded sequences in MPEG-TS format with H264 video coding (MPEG-4/AVC), live content (Channel 5, DAZN Zone, Cartoonito) in MPEG-TS over IP format with H264 video coding, or prerecorded content in DASH format with H264 video coding. Video signals were 720p or 1080p with 50fps.

The audio/video bit rate (in the live case) was identical to that transmitted on the DTTB or IP platform and of the order of 3 to 4 Mbit/s. For pre-recorded sequences it was of the order of 3 Mbit/s. Some live signals were also prepared with a reduced bit rate of 1 Mbit/s in order to be able to use MCSs with less capacity.

With regard to the unidirectional transport of the signal (via the ROUTE protocol, formerly FLUTE of DVB-H), the choice of mode was made taking into account first of all that the 3GPP standard provides for the following two types:

– file-based: this can be used by OTT services (DASH/HLS) for the distribution of videos or for the distribution of files (e.g. firmware updates or other);

– streaming: this can be used for the distribution of live video with low latency or other, and the RTP protocol is an example, not necessarily audio/video.

Note that file-based distribution per se does not introduce latency (apart from the time it takes to download the file), but it is then the video distribution protocol (DASH/HLS) that generates it. For example, the HLS player will not start playing the content unless it has downloaded at least three segments, and since a segment typically lasts 3 to 5 seconds, there will therefore be at least 10 to 15 seconds of latency. In the course of the experiment, the choice to use one mode rather than another was therefore constrained by the support of the phone and the resident video player app.

In this case, in addition to DASH/HLS, RTP was supported and therefore this protocol was chosen to have the minimum delay.

In conclusion, the LTE-based 5G Broadcast delay of live transmissions was in line with that of the DTTB platform and, compared to the equivalent OTT service[7], about 15 to 20 seconds earlier.

Figure 81 shows a picture of one of the phones used during the experiment.

FIGURE 81

Photo of the LTE-based 5G broadcast phone

Transmitter

The transmitter was used with 2.5 W of output power (before the filter) and 1 W ERP.

Figure 82 shows the spectrum measured at the output of the transmitter with a simple non-critical mask) four-pole filter.

It is a filter usually used in DTTB stations and re-calibrated for the occasion at 740.5 MHz centre band and 5 MHz bandwidth. In this case the attenuation is more than 60-63 dB on adjacent channels and also out-of-band, more than 100 MHz away from the 740.5 MHz centre frequency.

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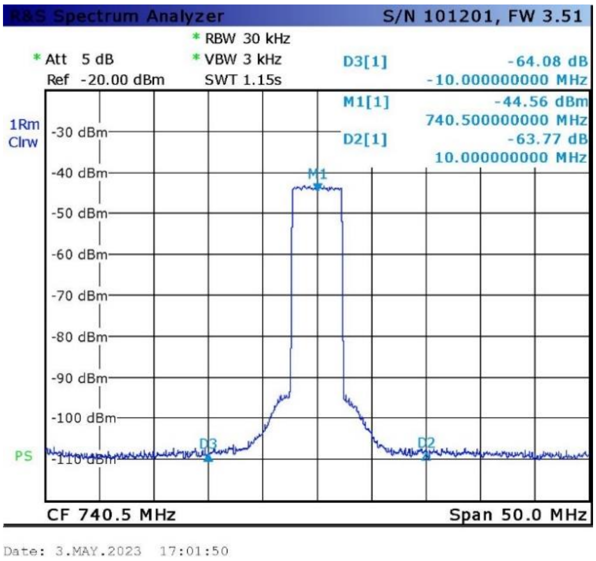
[7] OTT stands for 'Over the Top', a multimedia service offered directly to viewers via the Internet.

FIGURE 82

Example of TX spectrum with channel filter



For reception, the following equipment was used:

– 2 Qualcomm LTE-based 5G Broadcast phones supplied by R&S, capable of demodulating the LTE-based 5G Broadcast signal and presenting audio and video.

– R&S TSMW and TSME receiver with R&S ROMES software.

– R&S ETL spectrum analyser (and DTTB receiver).

– Omnidirectional antenna, Pol.V for mobile reception.

Measurements were conducted on the move, using the TSMW/TSME receiver with the Romes SW and the telephone (in-car reception) and also while stationary (out-door reception), using the telephone and checking the possibility of receiving the A/V signal.

Figure 83 shows an example of the spectrum of the signal received in the field. Specifically, the image includes the spectrum from 720 to 790 MHz.

Figure 84 shows the quality of LTE-based 5G Broadcast coverage. The position and direction of the cell are indicative. For the useful LTE-based 5G Broadcast service, it can be concluded that the extent of useful outdoor coverage (signal level at 1.5 m) for MCS10 is limited to about 400 m at most and is very similar to that envisaged at the application stage.

FIGURE 83

Example of (received) spectrum in the field

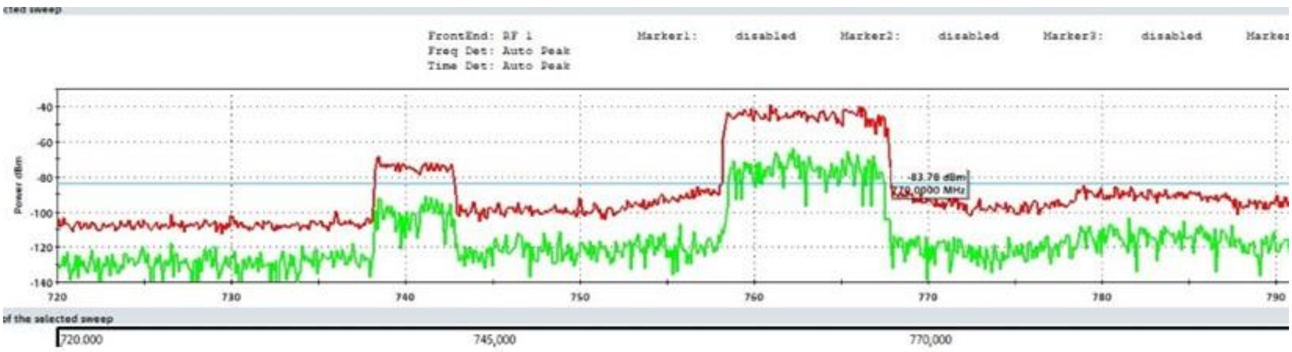


FIGURE 84

Quality of LTE-based 5G broadcast coverage

3.4 Summary of some results of the demo

– LTE-based 5G broadcast works properly and with low latency compared to the corresponding 'unicast' OTT service. In fact, live transmissions are in line with DTTB transmissions and about 15 to 20 seconds earlier than the equivalent OTT 'unicast' service when using the RTP protocol in the 5G broadcast system, as chosen during the DEMO.

– The LTE-based 5G Broadcast system was successfully presented to a good number of stakeholders interested in a possible future service. These included content providers, TV broadcasters, IP operators and equipment manufacturers.

– The coverage, in terms of received em. field E is as expected, based on the estimated characteristics of the measurement system (receiving antenna, drop cable and professional receiver):

  - Moreover, this coverage is very small, given the very limited transmitter power.
  - For real operation, a transmission power of an order of magnitude or more is appropriate (e.g. 20 W ERP instead of 1W ERP).
  - A greater height of the transmitting antenna, e.g. at least 30-40 m, would greatly facilitate the extension of coverage, especially in the presence of obstacles (clutter). This assumption is made on the basis of simulations performed by modifying this height.

– No difference in coverage quality was measured on the adjacent bands (Mobile Network Operator service in downlink, B28) in the presence of the LTE-based 5G Broadcast signal compared to when such a signal was not present.

– The phones used in the trial, at least for now, only work without a SIM i.e. as small ‘televisions’ but with all the functionality that a Wi-Fi can offer and, at least for the time being, still work only with an old release of the specification.

– It was possible to gain important experience with regard to the coding of audio/video content for portable and mobile services and also with regard to the measurement of the mobile radio service, both in terms of the level and quality of radio coverage of the individual frequency band and of each transmitting ‘cell’.

Annex 6

LTE-based 5G terrestrial broadcast field trials in Denmark

1 Copenhagen trial

1.1 Summary

In June-July 2022, during the opening week of the Tour de France 2022, a LTE-based 5G broadcast trial was established in Copenhagen.

The trial was realized through a collaboration between the Danish Broadcasting Corporation (DR), TV2 Denmark, Rohde & Schwarz, Qualcomm, Cibicom, Open Channel and Progira. The programme content was provided by the 5G RECORDS project through TV2, and was produced through a 5G-based live production chain. The trial therefore marked the first time that a full “glass to glass” 5G programme production/broadcast chain was in use.

One purpose of the trial was to test the viability of a LTE-based 5G broadcast implementation using as much existing infrastructure as possible. The LTE-based 5G broadcast transmitter was therefore installed at an existing DTTB-site BOA (Borups Allé) in Copenhagen, where it could be connected to the already established combiner and antenna system, running in parallel with the existing DVB-T2 network on a separate channel, however limited to 5 MHz due to limitations of the receiving device / 3GPP release 16/14. Since DVB-T2 coverage of Copenhagen is provided by four transmitter sites, while only one site was employed for LTE-based 5G broadcast, the power of the LTE-based 5G broadcast transmitter was increased to 8 kW ERP from the 2 kW ERP of the DVB-T2 transmitters on the same site.

Video: LTE-based 5G broadcast Trial in Copenhagen
www.youtube.com/watch?app=desktop&v=iV8l52leT9Q

1.2 Participants

– Danish Broadcasting Corporation (DR) – EBU member
– TV2 Danmark A/S – EBU member
– Rohde & Schwarz GmbH & Co. KG
– Cibicom A/S
– Open Channel ApS
– Progira Radio Communication AB
– Qualcomm Technologies Inc.

1.3 Services

– Linear tv programme.

1.4 Start date and duration

– June to July 2022.

1.5 Location

– Copenhagen.

1.6 Technologies

– LTE-based 5G terrestrial broadcast (Release 16).

1.7 Equipment and infrastructure

– Medium power/medium tower transmitter site in Copenhagen; ~10 dBd antenna system gain
– R&S TMU9evo LTE-based 5G broadcast transmitter
– R&S BSCC headend
– Ffmpeg based media converter
– Qualcomm UE devices (support rtp and DASH stream and 15 kHz subcarrier spacing)
– 5G MAG software-based receiver platform with SDRPlay RSP1a RF front end.

1.8 Spectrum and frequencies

– 5 MHz carrier in UHF channel 39 (617-622 MHz) – LTE band 71
– Centre frequency: 619.5 MHz
– 750 W RF output power
– 8 kW ERP
– Antenna height: 97 metres above ground level.

1.9 Main goals

– Verification of the capability of LTE-based 5G broadcast to provide indoor coverage of linear media services for handheld devices
– Proof of concept for reuse of existing DTTB antenna systems for 5G broadcast
– Trial of the 5G-MAG Receiver Reference implementation.

1.10 Highlights

A Rohde & Schwarz LTE-based 5G broadcast transmitter was installed at an existing DTTB site BOA in Copenhagen, sharing the antenna system with 5 DVB-T2 transmitters. The transmitter had an RF output power of 750 W, leading to a radiated power of 8 kW ERP from a height of 97 metres above ground.

The R&S BSCC headend at the Tx site BOA received a rtp stream via the Cibicom fiber network from a 5G production established by TV2 in Tivoli in Copenhagen and signalled through their playout centre from TV2's broadcast centre in Odense (Kvægtorvet).

FIGURE 85

The 5G production and broadcast chain, as implemented during the trial

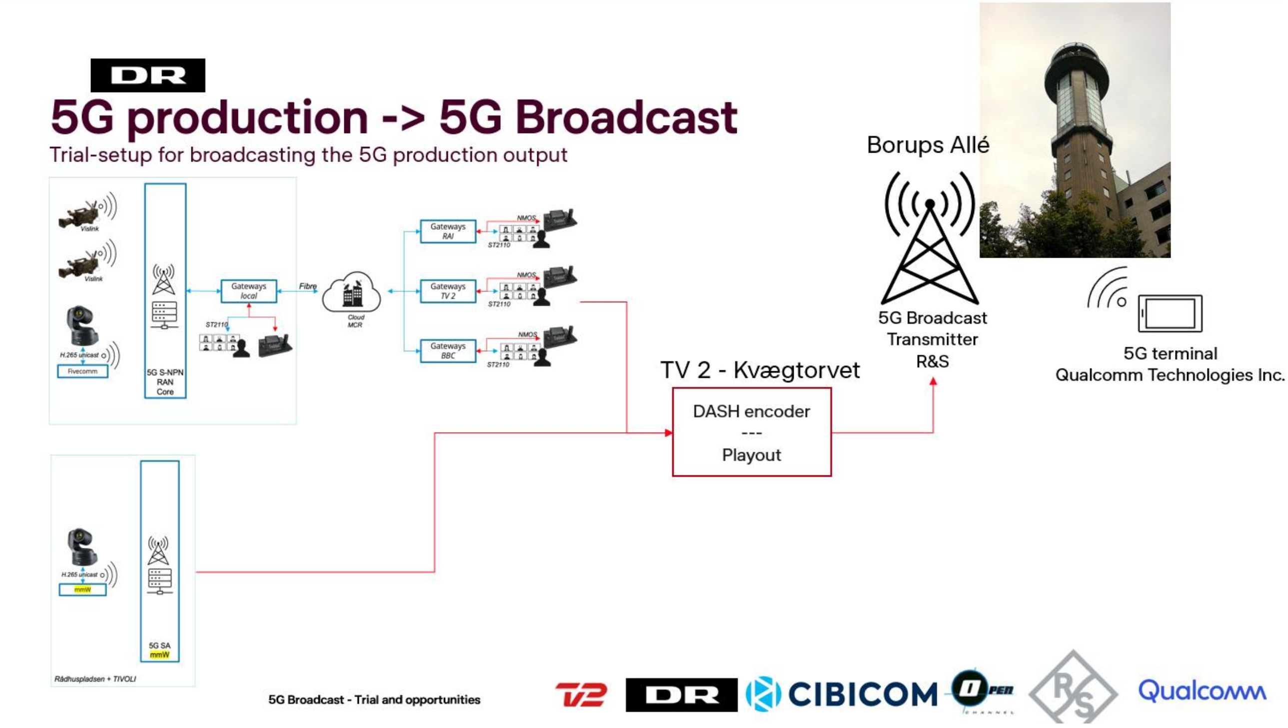


FIGURE 86

LTE-based 5G broadcast transmission site in Copenhagen

A variety of transmitter configurations were trialled. For the main event a robust modulation scheme (MCS6) was selected to achieve deep indoor coverage. In the 5 MHz channel employed, this gave sufficient bandwidth for a 1080p rtp-stream at ~1.5 Mbit/s.

The signal was received on Qualcomm prototype End User Devices, and the broadcast content was delivered from TV2 as part of the 5G Records-project, produced through a 5G Private Network production chain.

The intended reception spot was in the conference rooms of the Confederation of Danish Industry, a little over 2.6 km from the transmission site and immediately next to Tivoli, where the Tour de France team presentations were filmed and produced through the 5G Records 5G chain.

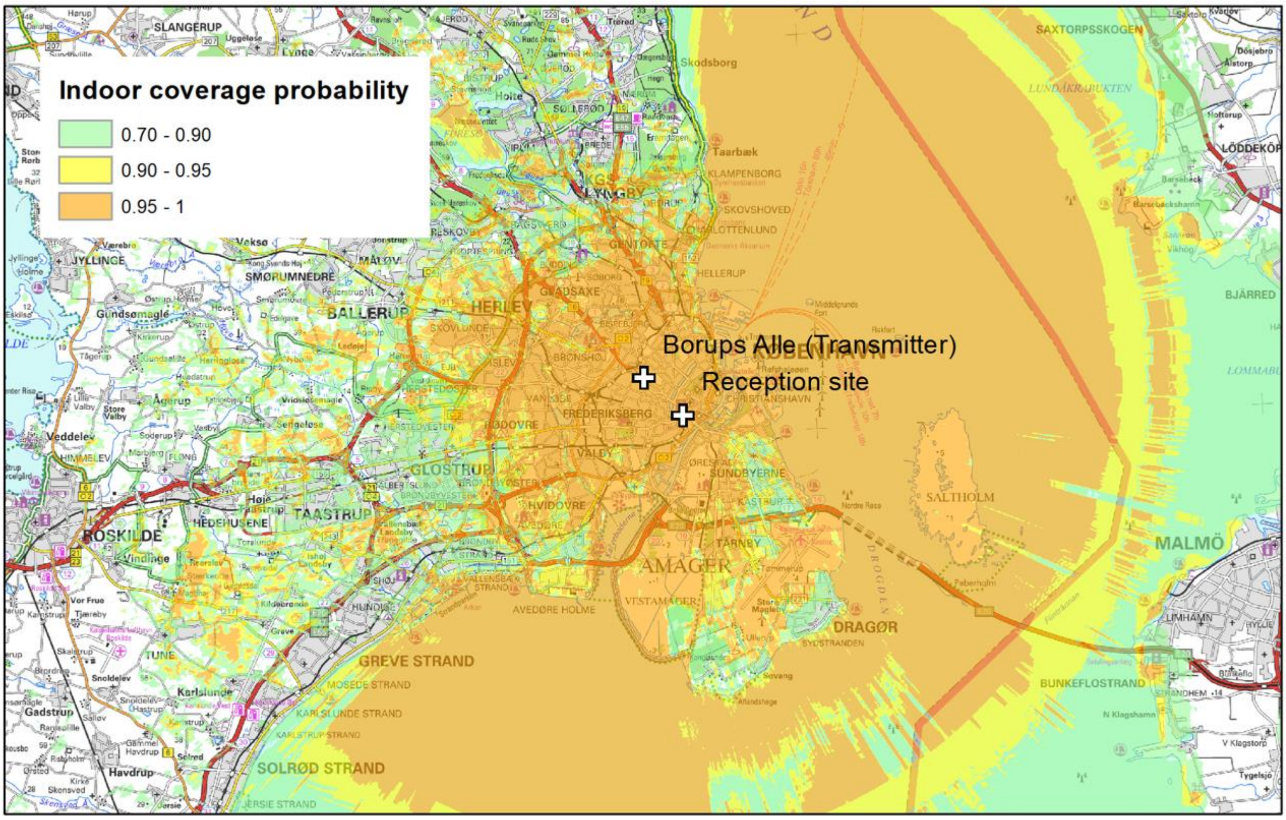
Reception conditions were difficult, since the rooms were on the ground floor of an 8-storey building of low-energy construction with very high building penetration loss. A successful demonstration was still achieved due to the robust modulation and coding scheme employed.

FIGURE 87

"Industriens Hus"; the intended indoor reception spot for the trial
Source: Orf3us, Public Domain https://commons.wikimedia.org/w/index.php?curid=25377497

FIGURE 88

Calculated coverage probability (indoor coverage) by Progira



1.11 Take aways from the trial

– Easy setup of LTE-based 5G broadcast transmitter with minimum impact on existing infrastructure.

– Deep indoor coverage in urban environment with LTE-based 5G broadcast to handheld devices (UE) and HD-quality streaming is possible.

– Removal of limitations in UE could probably improve both capacity and coverage (e.g. running 8 MHz block instead of 5 MHz).

– Highly capable SDR-based receivers are available as Free/Open Source software, and can be used with off-the-shelf hardware for receiving, characterizing and logging LTE-based 5G broadcast signals on air.

– Great willingness from industry partners to make the trial a success and a lot of interest in the trial in general.

Annex 7

Spain: LTE-based 5G broadcast trial in Barcelona

1 LTE-based 5G broadcast trial in Barcelona during MWC23

1.1 Summary

The efficient deployment of next-generation connectivity is essential to drive technological innovation and accelerate inclusive economic growth. One of the innovation pillars in broadcasting is the efficient transmission of audiovisual contents to mobile phones. LTE-based 5G broadcast will allow viewers to enjoy live content on their mobile phones with low battery consumption and without the need to consume data from the mobile operator commercial network.

During the events of ISE (Integrated Systems Europe) and MWC (Mobile World Congress) in Barcelona a LTE-based 5G broadcast trial was deployed using a 3 KW e.r.p. emission. This trial was the result of the effort of RTVE, Rohde & Schwarz, Qualcomm Technologies and Ateme in collaboration with Cellnex. Cellnex deployed a new transmitter in a location providing coverage to Fira Gran Via venue and its surroundings; the transmitter was provided by Rohde Schwarz; using ATEME encoding solution; and the receivers used for the demonstration had Qualcomm technology.

The configuration used eMBMS (Release 12) with MCS16 (16-QAM) achieved 4.5 Mbit/s of capacity. The capacity was limited to 60% due to performance of Qualcomm reception device.

The content initially included two TV services (including HD) and one Radio service, in a second stage three TV and two Radio services. The content to which there was access included programs from Radio Televisión Española (RTVE): the main channel "La1", "Canal 24h" and the regional radio channel "Radio 5" and from *Corporació Catalana de Mitjans Audiovisuals* (CCMA) with main channel "TV3" and radio channel "Catalunya Radio".

The main goal of the trial was to showcase how the full value chain works, from taking the signal to watching the content on a mobile device. The impact of the parameters like MCS on the reception was measured in order to get a better basis for network planning.

1.2 Participants

– Cellnex Telecom – Broadcast Network Operator – EBU member, (https://www.cellnex.com)
– RTVE – National Public Content Provider TV & Radio – EBU member (http://rtve.es)
– CCMA – Regional Public Content Provider TV & Radio (http://ccma.cat)
– Rohde & Schwarz (https://www.rohde-schwarz.com)
– Ateme (https://www.ateme.com)
– Qualcomm Technologies (https://www.qualcomm.com).

1.3 Services

– Linear TV and Radio services (DASH). Test with:
  - 2 TV services + 1 Radio service
  - 3 TV services + 2 Radio services
– Emergency Warning Tests.

1.4 Start date and duration

– 23 January 2023 – 17 March 2023.

1.5 Location

– Barcelona (Spain)

1.6 Technologies

– 3GPP eMBMS (Release 12) and FeMBMS (Release 14)

1.7 Spectrum and frequencies

– 5 MHz in TV channel 39 (617-622 MHz)

1.8 Equipment and infrastructure

– Emission from a rooftop urban site (total height of 30 meters)
– Satellite reception
– Codec & Packager (Ateme)
– Broadcast Service & Control Centre – BSCC (Rohde & Schwarz)
– 1 KW Transmitter (Rohde & Schwarz)
– UE devices (Qualcomm).

Figure 89 shows the scheme of the trial.

FIGURE 89

LTE-based 5G broadcast block diagram for MWC2023

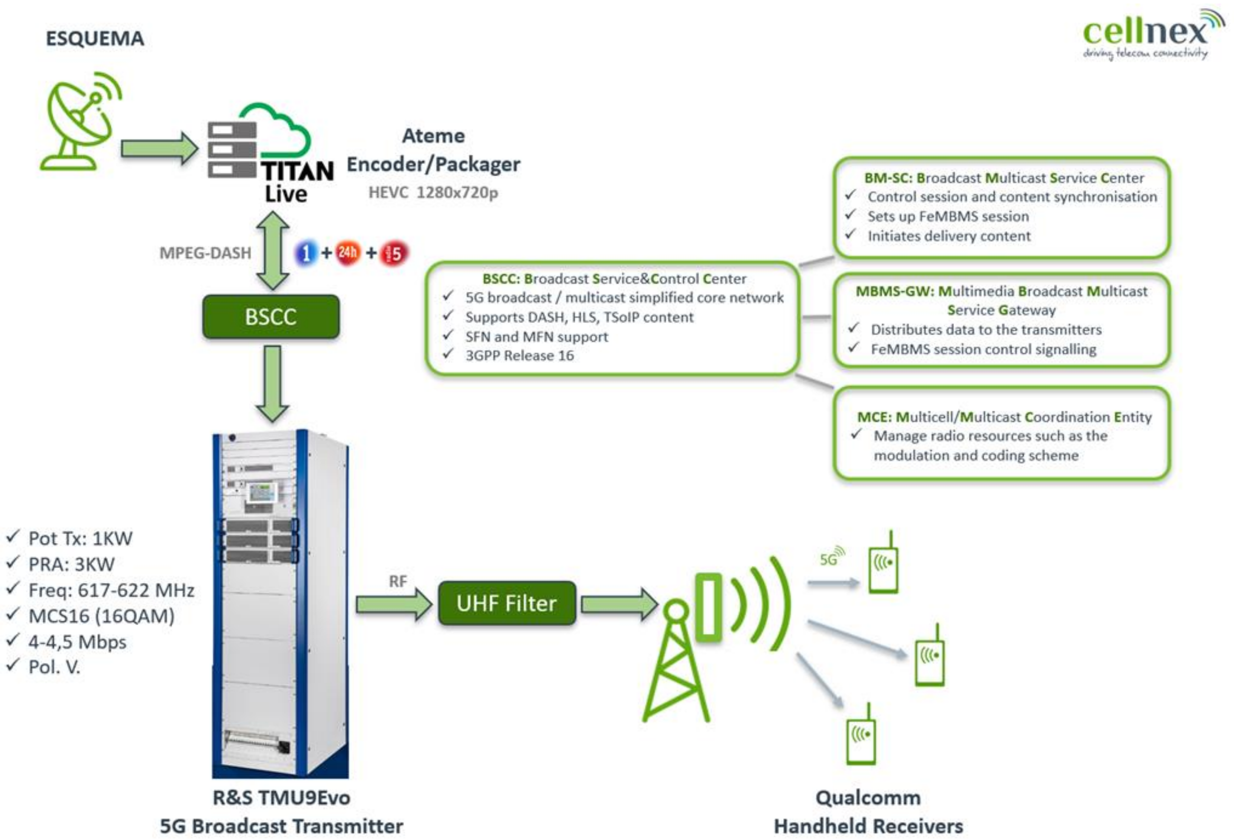


Figure 90 shows the urban site infrastructure, while Fig. 91 is a photograph of the transmission system of the trial.

FIGURE 90

Urban site infrastructure and equipment

FIGURE 91

Transmission system

Figure 92 shows the LTE-based 5G-Broadcast reception Qualcomm device.

FIGURE 92

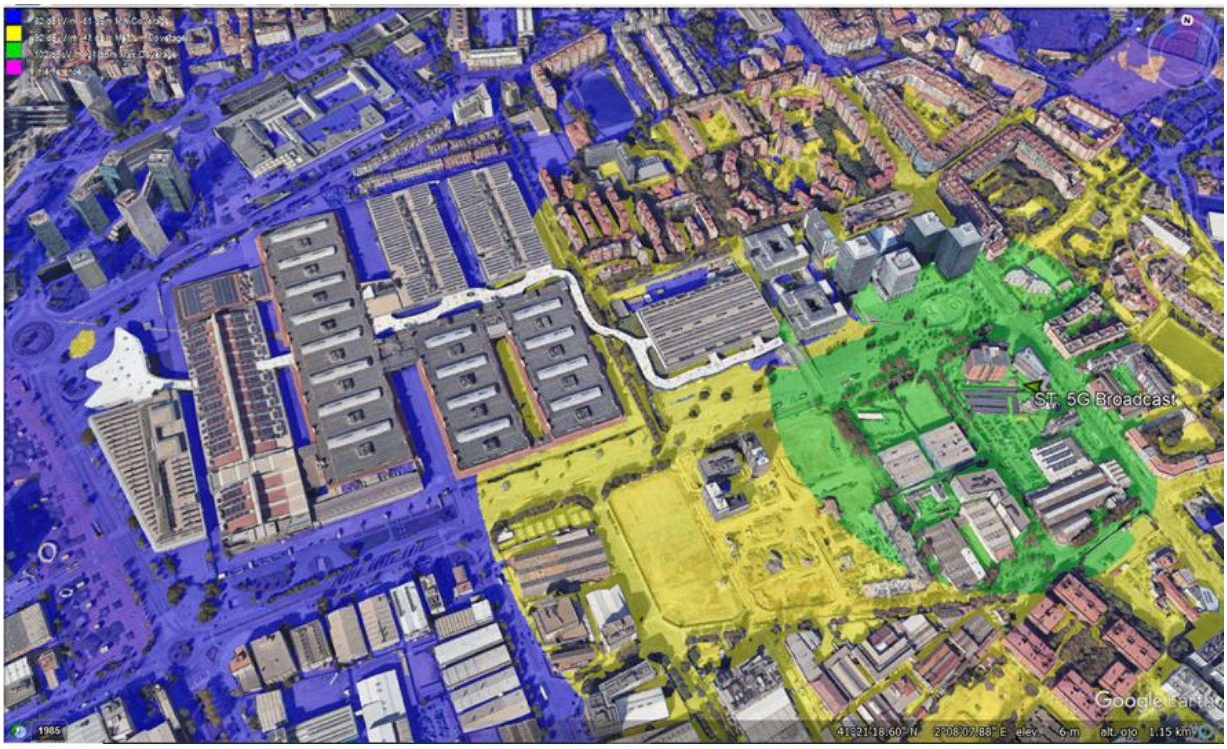
LTE-based 5G Broadcast reception Qualcomm device

Figure 93 shows the result of a simulation with Omni antenna and building only considered for indoor coverage.

Simulated results are OK for outdoor coverage but not yet satisfactory for indoor coverage. Indoor and outdoor measurements confirm this prediction.

FIGURE 93

LTE-based 5G Broadcast simulated results



1.9 Main goals

– Support technology evolution and next-generation connectivity. Show new technologies and opportunities offered by LTE-based 5G Broadcast to view content on the mobile.

– Study elements involved in the whole chain with close cooperation of manufacturers.

– Execution of measurements with different MCS to study the impact in coverage.

1.9.1 Previous trials

Several trials have been carried out in Spain to test and develop the LTE-based 5G broadcast ecosystem. In the following paragraphs some further information are given.

- **Trial 1, MWC20**

During the MWC in 2020 a LTE-based 5G broadcast trial have been carried out using a 50 kW ERP emission with a 1.5 kW Tx power.

The configuration was FeMBMS (Release 14) with MCS27 (64-QAM) and a CP of 200 μs, achieving a bit rate of 15.4 Mbit/s.

The emission was from Collserola tower, the main HPHT in the city of Barcelona covering about 4 M people, using the 750-755 MHz (BW of 5 MHz).

The content included two videos (including HD) and one audio.

The main goals of the trial were: Testing FeMBMS in 700 MHz band in a real environment and testing delivery of TV and radio channel providing information services. Some mobility measures (antenna on a vehicle) and at street level (pedestrian) have been carried out. The main conclusion was that such a high-performance configuration faces challenges for mobility and pedestrian reception.

This has been a result of the joint effort of RTVE, Rohde & Schwarz and Cellnex.

- **Trial 2, during the MWC22**

During the MWC in 2022 a second LTE-based 5G broadcast trial have been carried out using an indoor 1W ERP emission. It was the first worldwide real demonstration of devices with embedded LTE-based 5G broadcast chipsets.

The configuration was LTE-based 5G broadcast (Release 16) with MCS23 (64-QAM) and a CP of 66.7us, achieving a bit rate of ~12 Mbit/s.

The emission was from the Rohde & Schwarz MWC stand using the 617-627 MHz (BW of 10 MHz).

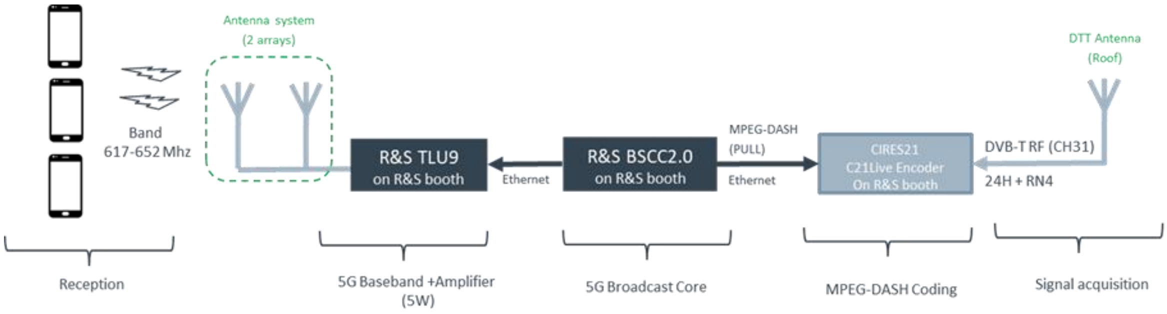
The content included 2 videos (including HD) and 1 audio.

The main goal of the trial was to showcase the first Qualcomm mobile devices embedding the LTE-based 5G broadcast decoder. It was for the very first time that a smartphone formfactor has been utilized in such demonstration without the need of SDR.

This has been a result of the joint effort of RTVE, Rohde & Schwarz, Qualcomm and Cellnex.

FIGURE 94

LTE-based 5G broadcast block diagram for MWC2022



In Fig. 94, content reception includes DTTB signal acquisition on MUX channel 31 in order to obtain RTVE public services RN4 (audio) and 24H (video). This content will be transcoded into HTTP MPEG-DASH multi bitrate protocol through C21Live Encoder and served in PULL mode to BSCC.

BSSC LTE-based 5G broadcast Core module will consume MPEG-DASH streams previously generated and will create the LTE-based 5G broadcast signal to be delivered to the transmitters. Finally, one low power transmitter (5 W) connected to a two antennas array system will send to mobile receivers LTE-based 5G broadcast signal from BSCC in order to cover R&S and Cellnex Booths on band 617-652 MHz.