5G Today

On the Road to 5G Broadcast

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A 5G Broadcast mode enables operators to distribute content across the cell boundaries of networks based upon classic mobile technologies and, using built-in convergence, establishes a back channel (uplink channel) using the same technology. This will create added value for 5G mobile terminals, from the seamless combination of linear TV broadcasts with on-demand offerings through to security-relevant information released to the wider public.

In the wake of the 5G rollout, an old idea could gain new traction; enabling television viewing on mobile devices. The idea of offering television on mobile devices is not new. Since 2006 there have been various attempts, mainly in European countries, to establish the DVB-H (H for handheld) standard based upon the DVB-T digital terrestrial television standard. However, these efforts proved to be in vain long before the last active service (Finnish DVB-H) was shut down in 2012. Developed before the smartphone era the system, with its screen resolution of 320 × 240 pixels, was outmoded and there were only a limited number of devices to support it.

Back to the beginning

Several mobile communication generations later, the situation is different. 4G systems can easily transfer high-resolution video, but the rapidly growing use of video-on-demand services and live streaming is pushing modern networks to their limits. 5G can help, but it can only provide significant support once 5G stand-alone networks in the mmWave bands become operational, which will take several years. However, overloading IP networks designed for point-to-point communications with multicast transmissions is a waste of transmission capacity. Classic broadcasting is still the best solution for delivering video content, provided it is brought to consumer devices in the best manner.

Standardised mobile communications technologies for multicast transmissions have been around since 2006 when the Multimedia Broadcast Multicast Service (MBMS) subsystem was specified in 3GPP Release 6 (UMTS). With Release 9, it made its way into LTE in the form of evolved MBMS (eMBMS), and in Release 14 (LTE-Advanced Pro) it reached the current development stage, called Further evolved MBMS (FeMBMS), which allows 100% of the available data capacity to be allocated to the broadcast payload. Further enhancements include the capability to receive broadcast content on mobile devices without the need for a SIM card, as well as support for larger transmitter cells in a single-frequency network.

Apart from all technical considerations, a relatively significant question remains. How can mobile network and TV network operators, chipset and device manufacturers, as well as content providers, be motivated to arrive at an agreed system rollout? All these parties are needed to launch the service.

The answer is a win-win situation for everyone involved. Mobile network operators benefit from offloading the data burden of broadcast content and TV network operators can boast a new, attractive field of applications for their transmitters in times of declining demand for terrestrial television. Content providers, e.g. internet broadcasters, can rely on full-coverage, high-quality supply. In addition, it will give the mobile device market – which has not seen any true innovations in recent years – a convincing reason for selling new products.

Entertainment is only one of the possible applications. The service can be used to transmit more than video e.g. data such as software updates for a large number of similar devices in the Internet of Things or in future vehicle fleets.

The Bavarian field trial

Currently, a major European field trial is underway as part of the 5G TODAY research project, which is funded by the Bavarian Research Foundation (BFS). Under the leadership of the German Institute for Broadcast Technology (IRT), Kathrein and Rohde & Schwarz have partnered in this project to create the required technology to enable the large-scale, efficient distribution of bandwidth-hungry media content to mobile devices. The project is supported by Bayerischer Rundfunk, the Bavarian state broadcaster, and Telefónica Germany as associated partners. The project aims to investigate and implement the opportunities that the FeMBMS specification offers for large-scale distribution of broadcast content over 4G/5G networks.

The project partners started with defining the technical and regulatory requirements necessary to make the project reality. They discussed potential use cases for the technology and defined a test method for carrying out quality measurements. In this context, the coverage forecasts by IRT and Kathrein play a major role as a reference for subsequent comparison to actual test results. Design and prototype implementation of the complete signal chain, comprising a broadcast transmitting system and a matching receiving system, started a year ago. Rohde & Schwarz developed the FeMBMS transmitter whilst IRT built the FeMBMS receiver. The receiver is based on software-defined radio (SDR) and OpenAirInterface (OAI) technology.

In March 2019, a field trial was launched in the Bavarian Oberland to implement, test and evaluate an FeMBMS-based broadcast system. Two high-power, high-tower (HPHT) Rohde & Schwarz transmitters with 100kW of output power (effective radiated power, ERP) were installed at the transmitter sites of Bayerischer Rundfunk at Ismaning (near Munich) and on top of Mount Wendelstein (1828m high). Kathrein developed an innovative antenna for the Ismaning site and optimised it for mobile device reception. The two test transmitters operate in a single-frequency network (SFN) on channel 56 (750MHz to 758MHz).

FeMBMS functionality was added to the Kathrein Signal Analyzer test platform to enable performance verification of the FeMBMS trial broadcast system as well as comparison to coverage forecasts. Field measurements started in May 2019.

LTE-based 5G Broadcast TX system

An LTE-based 5G Broadcast TX system basically comprises a data contribution and control network (Evolved Packet Core, EPC) and one or several transmitters. The EPC, delivering

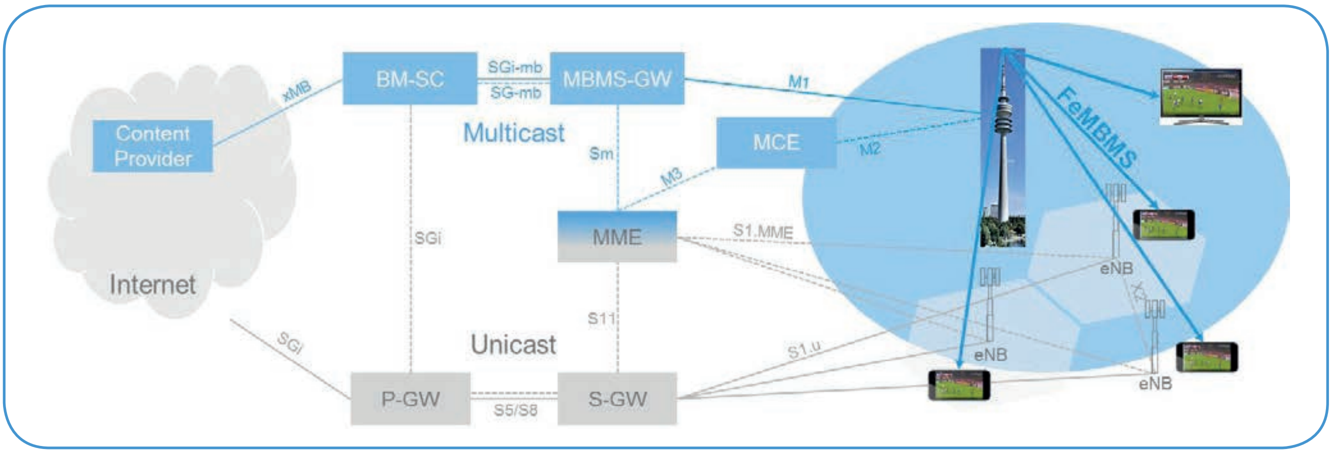

Fig. 1: Evolved Packet System with Evolved Packet Core (EPC) and transmitters (FeMBMS functional units are highlighted in blue)

purely unicast functionality to date, is extended with a number of functional units to provide broadcast functionality i.e. a Broadcast Multicast Service Centre (BM-SC), a Multimedia Broadcast Multicast Services Gateway (MBMS-GW) and a Multicell Coordination Entity (MCE). The payload is routed to the transmitters from the MBMS-GW using the M1 protocol; the control data is routed to the transmitters from the MCE using the M2 protocol.

For the physical layer, FeMBMS uses COFDM signals, as do all modern digital terrestrial broadcast standards (e.g. DVB-T2).

EPC functional units for FeMBMS

Rohde & Schwarz combines the BM-SC, MBMS-GW and MCE functional units in a Broadcast Multicast Service and Control Centre. The BM-SC receives broadcast services from the content provider. In the 5G TODAY project, the Bayerischer Rundfunk delivers its broadcast services as a Transport Stream over IP (TSoIP). The BM-SC re-combines the data of the services into new packets and adds a timestamp (SYNC) to the packet headers. The timestamp enables the transmitters to form a single-frequency network (SFN). From the BM SC, the data packets are routed to the MBMS-GW where they are taken to the transmitters as multicast signals.

The BM-SC informs the MCE on the number and data rates of the services to be broadcast simultaneously. The MCE uses this information to control the subframe allocation in the transmitter i.e. the allocation of payload to the radio subframes to be transmitted. In addition, the MCE assigns each service a Modulation and Coding Scheme (MCS), which determines the robustness and error protection for that service. The MCE will always attempt to make the best use of a data channel and transmit each service as robustly as possible.

FeMBMS transmitter

Since FeMBMS uses the same signal form as classic digital broadcast standards, FeMBMS can also be radiated via broadcast transmitters. The 5G TODAY project uses two high-power transmitters to broadcast FeMBMS.

The transmitters communicate with the EPC using the M1 and M2 protocols. The physical layer in the FeMBMS encoder is fully software-implemented, encompassing error protection, modulation, framing and inverse FFT. The software was developed in cooperation with the Institute for Communications Technology (IfN) of TU Braunschweig.

The I/Q data delivered by the FeMBMS encoder is taken to the exciter via an IP path in the transmitter. In the exciter, linear and nonlinear precorrection for the bandpass filter and the power amplifiers takes place, and the analogue FeMBMS signal is generated in the desired RF channel. The RF signal is distributed to the power amplifiers via RF splitters. The amplified RF signals from the individual power amplifiers are combined via a coupling network to a sum signal and taken to the transmitting antenna via a harmonics and bandpass filter.

5G Broadcast as seen from the antenna

Generally, the requirements on the transmitting antenna for radiating an FeMBMS signal are similar to those for a DVB-T(2) signal. Since both signals are OFDM-modulated, the same considerations for power/voltage load and VSWR apply. It should be noted that bandpass filters and combiners must be adapted to the 5MHz or 10MHz bandwidth usually deployed in LTE.

Consequently, an existing UHF transmitting antenna may be used for 5G Broadcast in the UHF band if it is a broadband antenna or can be re-tuned to the specific operating channel and has sufficient power/voltage capacity.

An important planning aspect for 5G Broadcast transmitting antennas is the coverage of mobile terminals. Services, such as Mobile TV, require a stable signal level to avoid interruptions. For portable reception outside buildings (portable outdoor), a location probability of 95% at 1.5m above ground is specified for "good" coverage. The modulation and coding parameters selected for the 5G TODAY project, together with typical values for the receiving antenna gain and C/N requirements for the receiver, yield a minimum field strength of 80dBµV/m for FeMBMS coverage.

Antennas for mobile reception

Serving onboard entertainment systems of cars with 5G Broadcast when using common HPHT transmitter parameters should not be a problem since, at least for mid-range and luxury cars, there are powerful Maximum Ratio Combining

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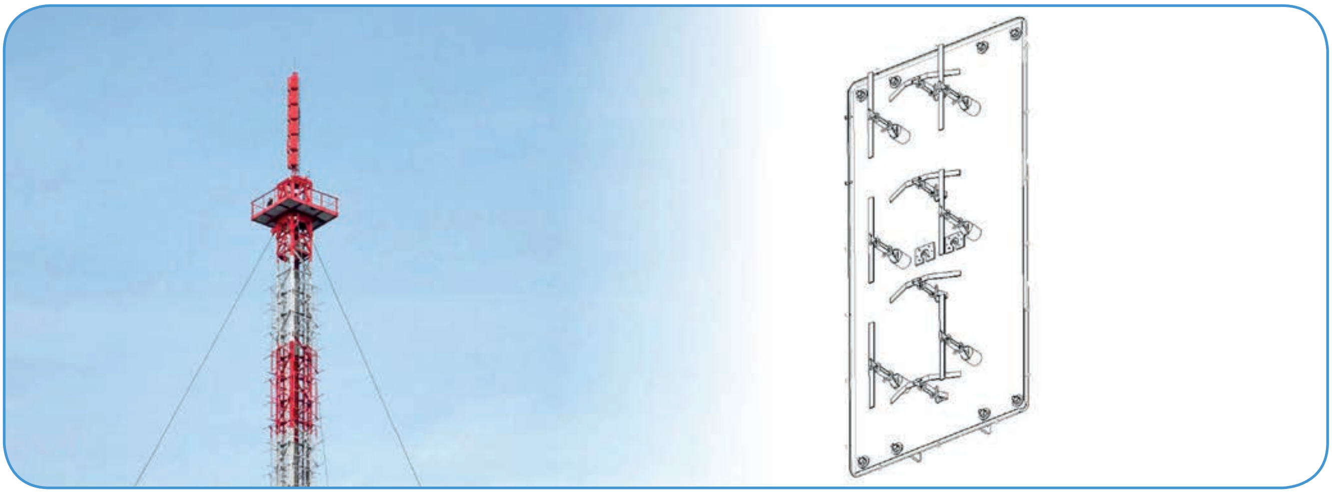

Fig. 2: FeMBMS UHF transmitting antenna at Ismaning near Munich, and a view inside an antenna array

(MRC) receiving systems available. By using multiple side window antennas for UHF band IV/V, a linear average active gain of typ. +10dBi for vertical polarisation and +5dBi for horizontal polarisation can be achieved. The minima in the radiation pattern of the MRC signal do not fall much below –10dB of the maximum.

One challenge, however, is the integration of UHF antennas into handheld terminals, such as smartphones, with typical dimensions of 120mm x 60mm x 8mm. Receiving antenna designs offering adequate efficiency and radiation properties, such as planar antennas or monopoles, are a min. ¼ wavelength in size. That means that, at a frequency of 750MHz (wavelength 400mm), the corresponding antenna would be a similar size as the handheld itself. Placing diversity antennas inside the housing of a handheld would be even more difficult.

In planning guidelines, a gain of –9.5dBd is specified for mobile terminals [2]. Theoretical examinations and measurements prove that this value can be achieved. However, the minima in the radiation patterns also need to be taken into account. They depend upon the handheld position and the influence of the human hand, and may be as deep as –10dB to –15dB below the maximum.

Transmitting antennas used in the 5G TODAY network

The 5G TODAY transmitter network consists of two high-power, high-tower stations i.e. on top of Mount Wendelstein near Rosenheim and at Ismaning, north of Munich.

At Mount Wendelstein, the existing vertically polarised DVB-T2 UHF transmitting antenna is used also for FeMBMS. Although the site is 1400m above ground level, and despite the high ERP of 100kW, the signal from Mount Wendelstein alone is too weak to provide portable outdoor FeMBMS coverage in the city of Munich, 50km away.

For this reason, a second FeMBMS transmitter has been installed at Ismaning, 15km northeast of Munich. The Mount Wendelstein and Ismaning transmitters are configured as a single-frequency network (SFN).

For the Ismaning transmitting antenna, horizontal, vertical or right-hand circular (RHC) polarisation can be selected. The antenna arrays are optimised so that the radiation properties in the operating channel are nearly identical for all available polarisations. This makes it possible to run measurement campaigns that are not influenced by the antenna behaviour.

Back in the 1970s, the use of circular polarisation for FM radio broadcasting was investigated for mobile and portable applications. The tests resulted in an improvement of received signal level and fading depth, equivalent to an increase in ERP of approx. 5dB to 7dB. Unfortunately, in FM radio, this improvement is accompanied by signal distortions due to multipath propagation. For this reason, circularly polarised FM radio could not establish itself in Europe, but did in other parts of the world.

In today's digital broadcasting world with multicarrier modulation and powerful error correction, multipath propagation is not an issue any more. In densely built-up areas, multipath propagation effects may even fill coverage gaps. Another benefit of circular polarisation is that it enables good reception, independent of the position of the receiving antenna.

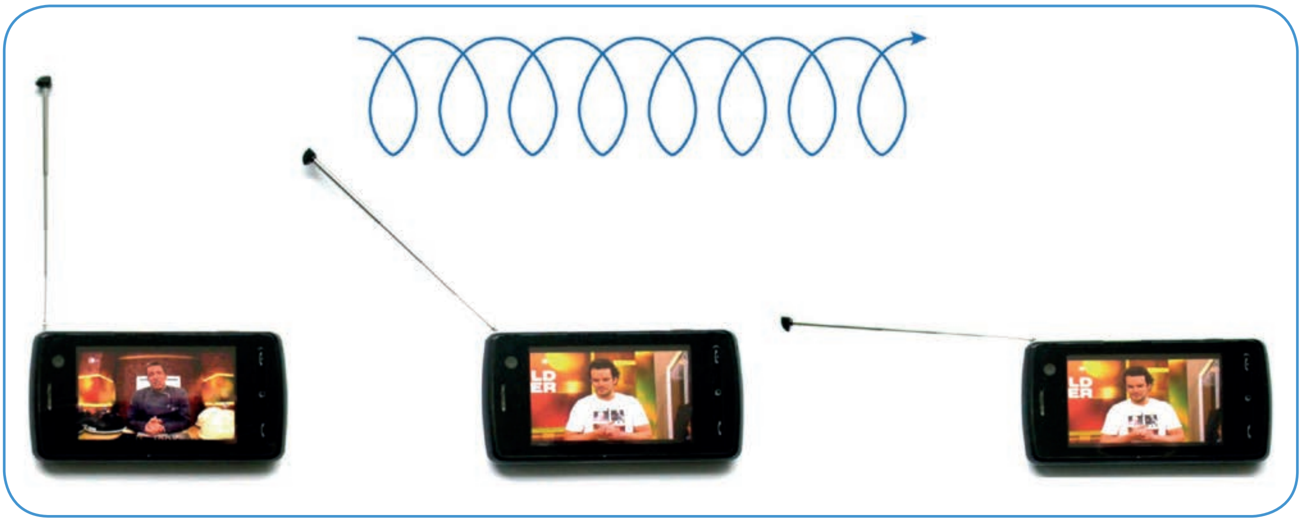

Fig 3: Circular polarisation enables good reception, independent of the position of the receiving antenna

Consequently, circular polarisation may be able to compensate for the inadequate receiving antenna properties of mobile terminals in the UHF band, particularly in difficult radio environments.

Investigating and quantifying the potential for improving coverage, when using circular polarisation, is part of the 5G TODAY project.

Measurement equipment for FeMBMS

For the 5G TODAY project, dedicated measurement software for FeMBMS was created, based on the Kathrein Signal Analyzer platform which relies on software-defined radio (SDR) technology. The system consists of:

- FeMBMS decoder software.
- RF receiver and digitiser.
- GPS and other position detectors.

The RF receiver digitises the radio signal and supplies I/Q data to the decoder software. Signal level and signal quality on dedicated FeMBMS channels are evaluated and linked with the GPS and positional detector data. The system works in snapshot mode, which means that data is acquired and decoded package by package. To achieve measurement cycles of acceptable length and complexity, the signal is not decoded down to picture and sound level.

The measurement software was created independent of any existing chipset or software. This enables the validation of other platforms as well as the functionality of the standard itself.

In the 5G TODAY project, this system is used to measure signal level, signal quality and receiver robustness. It has been integrated into various vehicles for stationary, portable and mobile measurements.

Field measurements: first results

Initial field measurements have been performed within the framework of the 5G TODAY project, and many more measurements are planned until the end of the project. Based on the results of these measurements, the opportunities and the limitations imposed by FeMBMS networks will be assessed. The field trial puts the system through its paces to explore and evaluate its viability und performance in practice, focusing on specific broadcasting requirements.

Software from Kathrein was used for the measurements. In a first step, mobile measurements were performed using an external car roof antenna, and measured data were analysed on field strength and carrier-to-interference-plus-noise ratio (CINR).

To evaluate the network design, both the Multimedia Broadcast Single Frequency Network (MBSFN) data signal, with a cyclic prefix (CP) of 200µs, and the Cell Acquisition Subframe (CAS) signal, with a CP of 16.67µs, were examined. The CAS signal contains the control information required for 100% MBSFN broadcast resource allocation and is carried by subframe #0. It is transmitted at intervals of 40ms, i.e. it is transported in every fourth radio frame. The CAS signal is required for both signalling and synchronisation. As a result, to decode the data signal, the CAS signal must first be decoded correctly. This means that MBSFN coverage is ensured only if both the data signal and the CAS signal can be received.

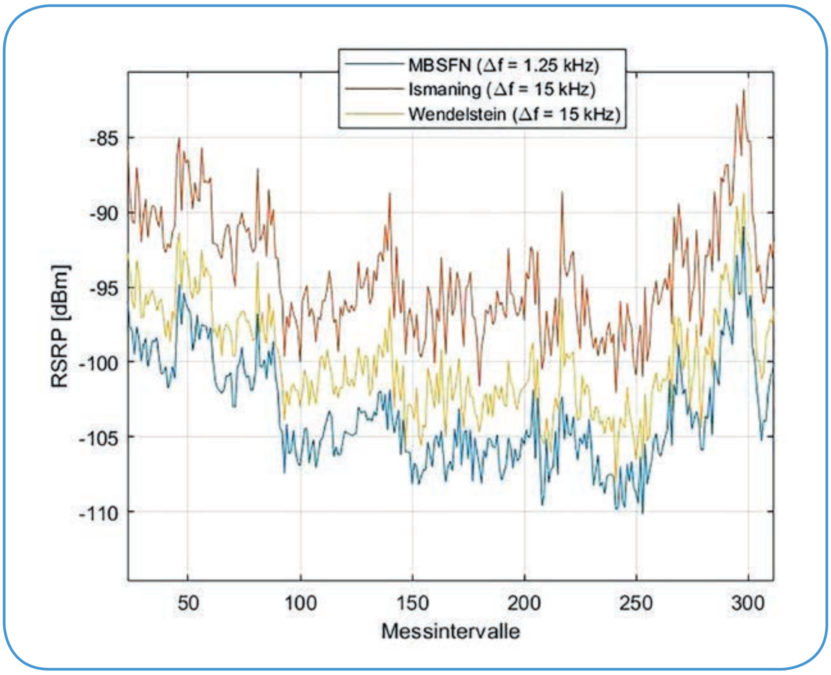

Fig. 4: Measured RSRP values for CAS signals and MBSFN signal

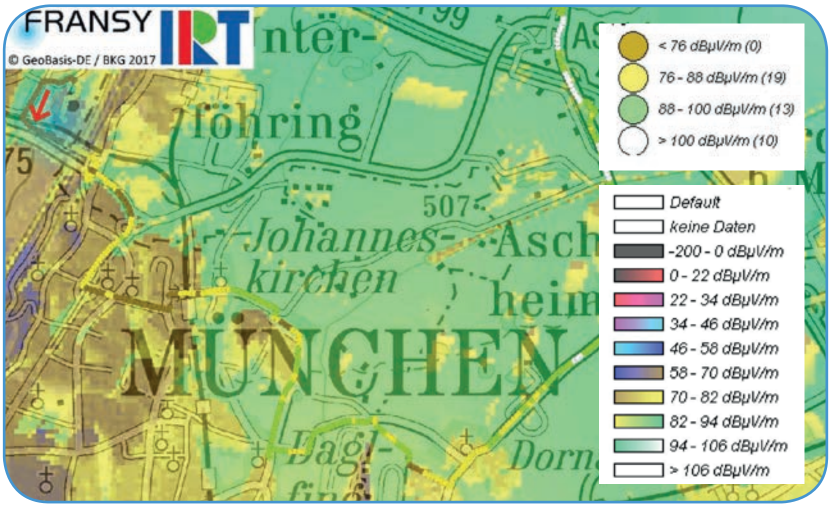

Fig. 5: Forecast field strength versus measured MBSFN signal field strength

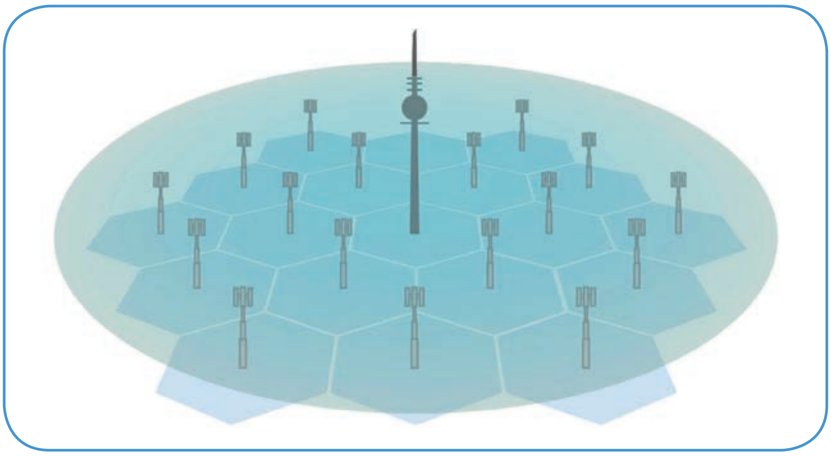

Fig. 6: Efficient distribution of broadcast content across cell boundaries

The CAS signal has a very short CP, which makes it unattractive for single-frequency operation in HTHP networks. On the other hand, it is clearly more robust and requires a considerably lower carrier-to-noise (C/N) ratio than the corresponding data signal. A study conducted by Nokia [1] has shown that, depending upon the channel profile, a signal-to-noise ratio (SNR) of –4.8dB, or –6.6dB, respectively, is required for the signal to be decoded correctly, observing an error criterion of 1% PBCH BLER. Whether the stated values are sufficient for receivers in real-life operation remains to be established in laboratory tests.

During initial mobile measurements, the two transmitters at Ismaning and Mount Wendelstein were operated with a vertical transmitting antenna and 100kW ERP. Delay optimisation did not take place during these measurements. The MCS9 transmitter network configuration was used.

Fig. 4 shows, as an example, the measured Reference Signal Received Power (RSRP) for the selected network configuration. The Figure displays a section of the test route circled with a red frame in Fig. 5; the arrow indicates the direction of travel. The test route is located near the Ismaning transmitter. The power levels measured along the test route are consistently higher than those for the Wendelstein transmitter which, while installed at high altitude, is a significant distance away from the test route. The measured power levels relate to the associated reference signals. For this reason, the CAS signals have a different reference bandwidth than the corresponding MBSFN data signal, which is reflected by lower power levels of the MBSFN signal.

Since a forecast of the expected field strengths in the MBSFN network was made before the actual field trial, it was possible, in a subsequent step, to compare the simulated values to the actual MBSFN field strengths derived from the measured RSRP values. To perform this validity check, the measured values were averaged every 50m of the test route, corresponding to the resolution applied in the forecast, which was created using the IRT2D propagation model.

Fig. 5 shows the measurement results for a given section of the test route. The results can be compared qualitatively with the forecast results depicted in the underlying area. In many areas, measured values correlate well with simulated values. In some areas or locations, the actual field strengths exceed forecast values; this is particularly true for suburban areas. The inverse effect also happens. In some areas, simulated field strengths are very high, whereas actual measured values are lower.

This comparison also demonstrates the limits of establishing forecasts based on coarse morphographical classification, relying on the assumption that there is often a uniform population density within a city or urban area, whereas outside this area a large, open landscape is assumed. This problem could be remedied by using high-resolution topographical/morphographical data as a basis for coverage forecasts.

The laboratory and field measurements, within the framework of the 5G TODAY project, are scheduled to be completed in late October 2019. They will trigger many discussions and lead to numerous analyses and findings that will provide a deeper insight into the opportunities and limits of the system.

The future of 5G Broadcast

A 5G Broadcast mode makes it possible to distribute content across the cell boundaries of networks based upon classic mobile technologies and, thanks to built-in convergence, enables the implementation of a back channel (uplink channel) using the same technology. This will create added value for 5G mobile terminals, from the seamless combination of linear TV broadcasts with on-demand offerings through to security-relevant information released to the public as a whole.

[1] R1-1611493, Performance results for cell acquisition subframe, Nokia, Alcatel-Lucent Shanghai Bell, 3GPP TSG RAN WG1 Meeting #87, Reno, USA, November 2016.
[2] ETSI TR 102 377 v1.1.1: Digital video broadcasting; DVB-H Implementation Guidelines, ETSI, Sophia Antipolis 2005.