PRACTICAL PERFORMANCE MEASUREMENTS OF LTE BROADCAST (EMBMS) FOR TV APPLICATIONS

David Vargas*, Jordi Joan Gimenez**, Tom Ellinor*, Andrew Murphy*, Benjamin Lembke** and Khishigbayar Dushchuluun**

* British Broadcasting Corportation (BBC), Research and Development, London, United Kingdom
** Institut für Rundfunktechnik (IRT) GmbH, Munich, Germany

ABSTRACT

The 3GPP Release-14 specification has enhanced LTE eMBMS to enable the provision of television services according to some of the requirements of the broadcasting industry. These improvements include radio interface enhancements such as support for larger inter-site distances in Single Frequency Network deployments and the introduction of more flexibility including a dedicated eMBMS carrier with 100% broadcast resource allocation. Although the performance of LTE eMBMS has been extensively evaluated by numerical computations, it is crucial to perform laboratory measurements that provide insights into the operation of the system in a practical setup. This paper describes the construction of eMBMS chains within the laboratory to carry out physical-layer measurements within a controlled environment and presents a methodology to measure the signal-to-noise-ratio (SNR) of eMBMS signals (that can time multiplex both unicast and broadcast parts). The SNR thresholds at different modulation and coding schemes are measured independently in the laboratories of BBC R&D and IRT and the results are compared with the results obtained with numerical evaluations.

INTRODUCTION

The 3GPP Release-14 specification includes new technical features designed to meet many of the requirements necessary for the distribution of Public Service Media content [1]. While maintaining the multiplexing and channel-coding processes included in previous releases, radio access enhancements in Release-14 include an option to have up to 100% of capacity allocated to broadcast, allowing stand-alone downlink-only operation in addition to the existing mixed unicast/broadcast mode. There is also an extended Cyclic Prefix of 200 μs to enable Single Frequency Network (SFN) configurations with larger cell sizes.

The performance of 4G Broadcast (eMBMS) has been extensively evaluated in literature by numerical calculation, however practical implementations can differ significantly from these [2]. Multiple eMBMS field trials have been carried out worldwide but, due to the complexity of these, it can be difficult to examine the performance of individual parts of the system in a detailed way.

Broadcasters have broad experience in practical performance measurements of DVB-T/T2 but the particular characteristics of eMBMS make it necessary to adapt and translate some of this experience to evaluate this new system.

This paper describes the construction of eMBMS chains within the laboratory to carry out physical-layer measurements within a controlled environment. It presents a methodology to measure the signal-to-noise-ratio (SNR) of eMBMS signals (that can time multiplex both unicast and broadcast parts). The SNR thresholds at different modulation and coding schemes are then measured in the laboratory and compared with the results obtained with numerical evaluations.

While Release-14 has enabled three different physical layer configurations (numerologies), practical equipment availability at the time the work was commissioned has meant that this paper focusses on one of those numerologies also available in earlier 3GPP releases.

The laboratory measurements are performed independently in the facilities of BBC R&D and IRT to compare and validate the proposed methodology and evaluations.

LTE EMBMS LABORATORY SETUP AND SYSTEM PARAMETERS

System Parameters

The experiments are carried out using a 3GPP Release-11 base station transmitting eMBMS signals that time multiplex, in the same carrier, unicast (Physical Downlink Shared Channel - PDSCH) and broadcast (Physical Multicast Channel - PMCH) transmissions. In particular 60% of the subframes (note that a subframe has a duration of 1 ms) are allocated to broadcast while the remaining 40% of subframes are allocated to unicast transmissions (cf. Figure 1).

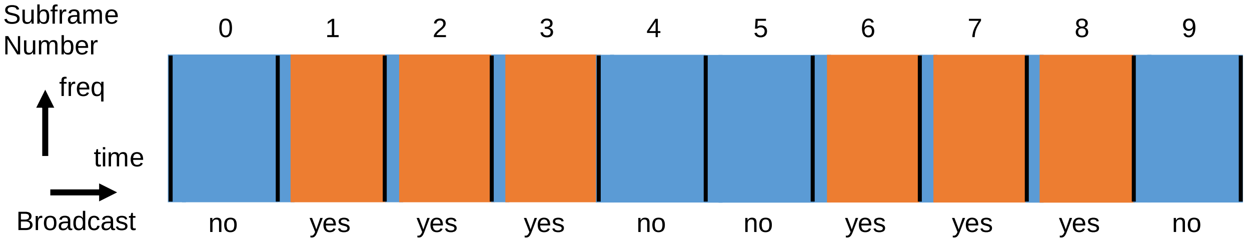

Figure 1: LTE eMBMS subframe allocation to unicast (PDSCH) and broadcast (PMCH) channels.

The devices used in the experiments are off-the-shelf tab lablets (at the BBC) and smartphones (at the IRT lab) with the necessary eMBMS middleware incorporated to allow reception of broadcast as well as unicast signals.

The selected bandwidth for the transmitted signal is 5 MHz (25 Resource Blocks) operating at band 28 with a downlink carrier frequency of 769.5 MHz and a paired uplink carrier with a carrier frequency of 714.5 MHz. The PMCH channel uses a subcarrier spacing of 15 kHz with the extended cyclic prefix of 16.7 us with the addition of one OFDM symbol in the non-MBSFN subframe region (i.e. OFDM symbols dedicated to control information and not available for data).

It is worth noting that although, in the context of eMBMS, the 3GPP Release-14 has introduced modifications to the physical layer (e.g. the introduction of a new cyclic prefix of

200 µs to enable SFN configurations with larger cell sizes and the possibility to use all subframes for broadcast), there have not been significant modifications from Release-11 to the main procedures in multiplexing & channel coding (i.e. CRC attachment, segmentation, channel coding, rate matching and concatenation as in TS 36.212 [3]) and physical channels and modulation (scrambling and modulation as in TS 36.211 [4]). This means that the evaluations conducted in this present paper are representative of performance results for the 3GPP Release-14 specification for the studied transmission modes.

Laboratory Setup

A block diagram representing the laboratory setup used for the experiments to evaluate the physical layer performance of LTE eMBMS is presented in Figure 2.

The transmitted LTE eMBMS is combined with an external noise source to conduct tests at different levels of received Signal to Noise Ratio (SNR). The resulting degraded signal goes through a splitter and the same signal is injected into the Device Under Test (DUT) and to a spectrum analyser. The tablet or smartphone is enclosed within a screened box to minimise interference to/from other nearby devices or transmissions operating on the same frequencies. Inside the screened box the user equipment is placed on a plate coupler. The spectrum analyser permits the measurement of the power levels of the wanted and interfering signals to estimate the SNR that is observed by the receiver that decodes the eMBMS services. The output power levels of the LTE eMBMS and noise sources can be controlled by variable attenuators. The signal levels measured in the laboratory for the LTE eMBMS signal at the spectrum analyser were in the order of -36 dBm. It is worth noting that the signal levels received by the tablet or smartphone will be lower than the ones measured at the spectrum analyser due to the losses of the plate coupler. However the SNR measured at the spectrum analyser is maintained at the tablet since both the wanted and interfering signals experience the same coupling loss and provided that the operating point is well above the noise floor of the receiver.

The transmit and receive ports of the base station are isolated by a duplex filter tuned to the relevant operating frequencies. While we have focused on the downlink in the set of experiments featured in this paper, the uplink signals coming from the user equipment can also be displayed on a spectrum analyser for monitoring purposes.

Selected Error Criteria for the Experiments

The evaluation of the performance of the physical layer of a candidate communication system is commonly assessed in the research literature in terms of bit-error-rate (BER) or block-error-rate (BLER) at the output of the channel decoder at the receiver. However, with the off-the-shelf equipment used in the experiments conducted in this paper, it is not possible to gain direct access to the output of the channel decoder and hence the only output available to evaluate errors that occur during the transmission is the final output video.

Two error criteria are used in this paper to evaluate the performance of LTE eMBMS in the laboratory. The first one is the “onset of failure”, i.e. the operating point at which errors start appearing at the decoded video stream. The second one is “complete failure”, i.e. the operating point at which the decoded video stream is completely corrupted.

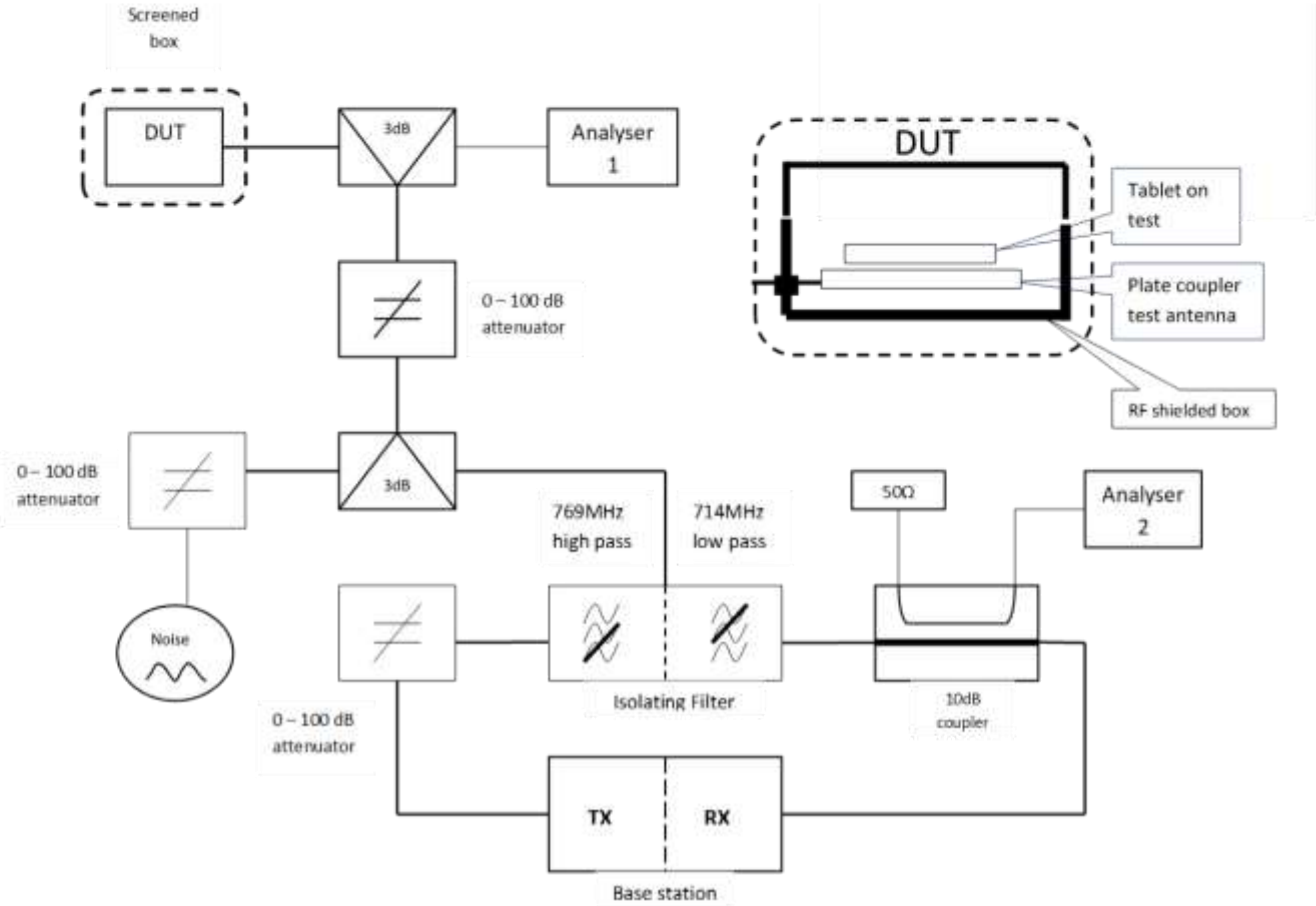

Figure 2: LTE eMBMS laboratory setup

It is worth noting that it is not the goal of this paper to design suitable quality measures for TV delivery using LTE eMBMS targeting mobile devices but to provide first insights on the practical performance of the physical layer of LTE eMBMS. The design of suitable quality measures for TV delivery needs to take into consideration many aspects e.g. type of devices, receiving environment, type of content, etc. and hence is out of the scope of this paper.

The Live Video Streams

In the laboratory experiments at BBC R&D three live MPEG-DASH video streams of the same content are used that are encoded at different bit rates. The bit rates of the aggregated video and audio streams used in the experiments are 452, 715 and 1427 kbps and the same segment duration of 3.84 s.

At IRT, three different MPEG transport streams with 500 kbps, 800 kbps and 1 Mbps are used. In this case, the streams are delivered using RTP (Real Time Protocol) encapsulation.

The three live video streams are mapped to different LTE eMBMS system configurations that provide different physical layer transmission capacities.

PERFORMANCE EVALUATION

In this section, we first present a methodology to measure the SNR of the broadcast part of LTE eMBMS signals that does not rely on specific LTE demodulation software. Secondly we show performance results by numerical computations and finally compare these with the experiments conducted in the laboratory.

SNR Measurement in LTE eMBMS Signals

The goal is to obtain a methodology to measure the SNR of a LTE eMBMS signal with a spectrum analyser with standard frequency and time domain processing but that does not rely on specific software to demodulate the complete (or part of the) received LTE eMBMS signal (e.g. using the reference signals or other specific channel or signals in the specification). Since the 3GPP LTE eMBMS specifications orthogonally multiplex unicast and broadcast subframes in the time domain, the spectrum analyser is configured in zero span as shown in Figure 3. In this paper we are interested to measure the signal power of the MBSFN subframes i.e. the ones carrying the broadcast content. Since the base station is not serving users with unicast content, those subframes dedicated to unicast are mostly idle and therefore have lower power levels.

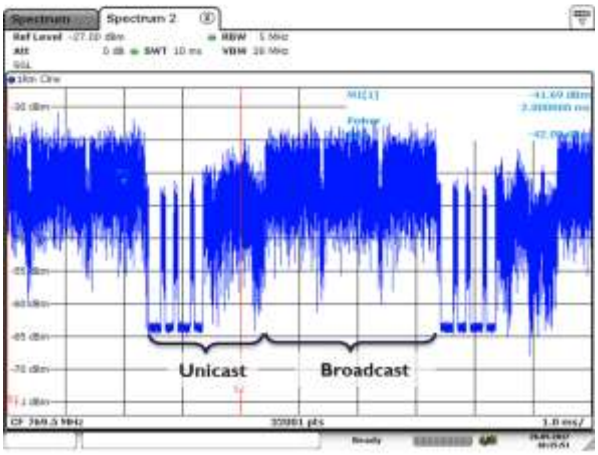

Figure 3: Measured time domain LTE eMBMS signal showing time multiplexed unicast and broadcast subframes.

Before any performance measurements are done the output power levels of the LTE eMBMS signal and the external noise source need to be configured to a known value that provides a reference SNR (e.g. SNR equal to 0 dB). To obtain a reference SNR value, the signal power of the MBSFN frames is first measured in zero span mode (time domain) without the external noise source (Figure 4). Secondly the power of the external noise source in the data carriers (e.g. 4.5 MHz for 25 resource blocks) without the presence of the LTE eMBMS signal is measured in the frequency domain (Figure 4). For the measured power levels of both the LTE eMBMS signal and the external noise source, the powers can be adjusted with the variable attenuators to obtain the same level which then provides the reference value of SNR=0 dB. If the transmission system is configured to use all the subframes for broadcast (as it is specified in 3GPP Release-14), the powers of both LTE eMBMS signal and the external noise source could both be measured in the frequency domain (or in the time domain with adequate resolution bandwidths adapted to the transmitted signal bandwidth).

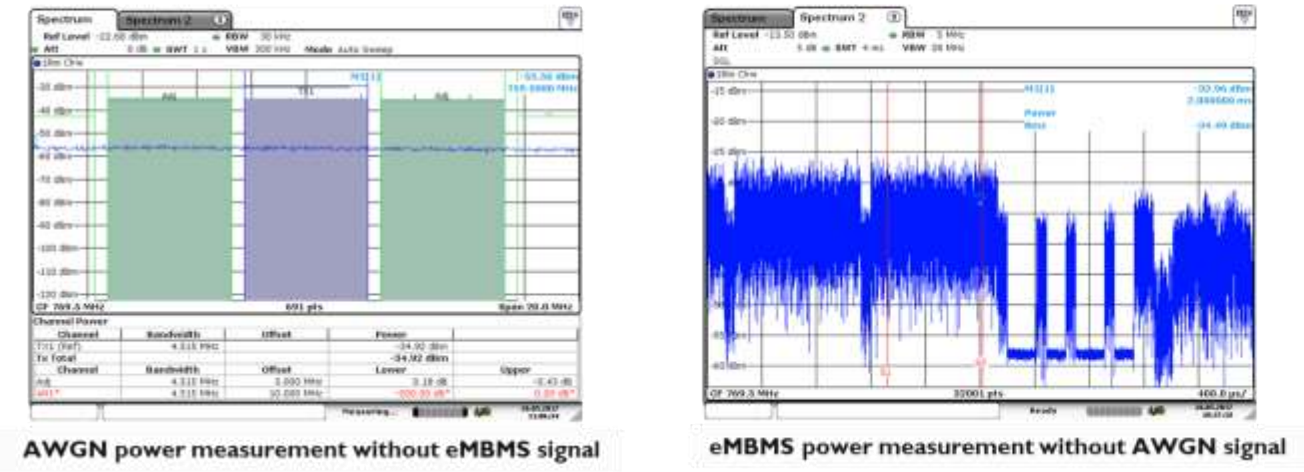

Figure 4: LTE eMBMS SNR measurement procedure – separate power measurements of MBSFN subframes and noise.

Simulated Performance in AWGN Channel

The performance of LTE eMBMS has also been evaluated by numerical calculations with a physical layer simulation platform that has been developed following the 3GPP technical specifications TS 36.211 (Physical Channels and Modulation) [4], TS 36.212 (Multiplexing and Channel Coding) [3] and TS 36.213 (Physical Layer Procedures) [5].

Figure 5 shows the BLER vs. CNR (in dBs) obtained with the system parameters specified in the first section of this paper in an AWGN channel model. The MCS settings selected are based on table 7.1.7.1-1 of TS 36.213 which does not include a 256QAM constellation. A representative set of MCS is selected, in particular MCS 5 & 9 correspond to QPSK, MCS 9 & 11 correspond to 16QAM and MCS 18 & 24 correspond to 64QAM. The effective code rates after channel coding and rate matching (given the system parameters used in this paper) are 0.39, 0.71, 0.39, 0.68, 0.47 and 0.80 for MCS 5, 9, 11, 16, 18 and 24 respectively. The receiver uses a maximum likelihood demapper and the algorithm used for the turbo decoder is a true a-posteriori probability decoding with a maximum of eight iterations and the assumption of ideal channel estimation.

As can be seen, in the simulation results that the MCS values with higher effective code-rates have higher error floors than the MCS configurations with a stronger effective code-rate.

Laboratory Experiments in AWGN Channel

Table 1 shows the results of the laboratory experiments done at BBC R&D and IRT to evaluate the performance of LTE eMBMS for different MCS values. For each measurement, two SNR values are reported in the table corresponding to the two error criteria specified in the first section of this paper, namely “onset of failure” and “complete failure”. The results are compared with the simulation results at a BLER equal to 10^{-4}, which can be considered as a transmission with a low percentage of errors and we expect this BLER criteria to be close to the “onset of failure” error criteria.

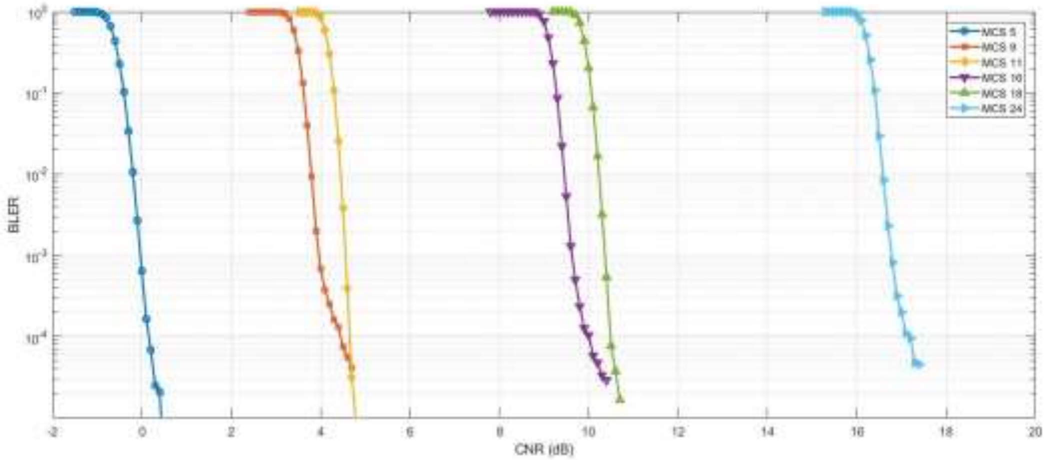

Figure 5: Simulated performance of LTE eMBMS in AWGN channel for the selected MCS configurations measured in the laboratory.

It can be seen that the results obtained at both laboratories are well aligned with differences of only around 0.5 dB for both error criteria. As expected the measured results are always worse than the simulated, particularly for the “onset of failure” criteria where the differences with simulation are around 1-2 dB. For the “complete failure” which requires higher error rates the differences compared with simulation are closer within 1 dB. This performance degradation of the laboratory experiments compared to simulation is expected due to implementation margins. The measured values for MCS 24 from BBC R&D have a significantly higher difference compared to simulation and this needs further exploration and verification with further measurements.

MCS Index	Data rate Video Stream BBC/IRT [kbps]	Simulated SNR at BLER 10^{-4} [dB]	Measured SNR at “On Set Failure” [dB]		Measured SNR at “Complete Failure” [dB]	
			BBC	IRT	BBC	IRT
5	452/500	0.1	1.7	2.3	-0.2	0.3
9	452/500	4.4	5.2	5.7	4.7	5.1
11	715/800	4.6	6.8	6.3	5.5	5.7
16	715/800	10.0	11.2	11.9	10.5	10.8
18	1427/1000	10.5	13.0	12.7	11.2	11.6
24	1427/1000	17.2	24.2	19.6	20.8	18.3

Table 1: Measured performance of LTE eMBMS in AWGN channel in the laboratory of BBC R&D and the laboratory of IRT and comparison with simulated results.

DISCUSSION AND FUTURE WORK

This paper has presented the construction of LTE eMBMS chains within the laboratory to carry out physical-layer measurements within a controlled environment and it has presented a methodology to measure the signal-to-noise-ratio (SNR) of eMBMS signals (that can time multiplex both unicast and broadcast parts). The SNR thresholds at different modulation and coding schemes have been measured independently in the laboratories of BBC R&D and IRT and the results have been compared with the results obtained with numerical evaluations. The measurement results show good alignment between BBC R&D and IRT and the differences with respect to simulation are in the range of practical implementation margins.

At the point of writing this paper further experiments are being carried out to evaluate the performance in mobile channels with multipath propagation. If time permits and the tests are successful these tests could also be presented in the conference to be held in September 2018. Other avenues to explore include the application of Application Layer Forward Error Correction (AL-FEC) to improve the performance in mobile environments.

ACKNOWLEDGEMENTS

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