

# Wideband Broadcasting: A Power-Efficient Approach to 5G Broadcasting

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## ABSTRACT

Efficient and flexible use of spectrum will be inherent characteristics of fifth-generation (5G) communication technologies with native support of wideband operation with frequency reuse 1, i.e. all transmit sites use all available frequency resources. Although not from the very first 5G release of 3GPP (Third Generation Partnership Project), it is expected that broadcast/multicast technology components will later be added and fully integrated in the 5G system. The combination of both wideband and frequency reuse 1 may provide significant gains for broadcast transmissions in terms of energy efficiency, since it is more efficient to increase capacity by extending the bandwidth rather than increasing the transmit power over a given bandwidth. This breaks with the traditional concept of terrestrial broadcast frequency planning, and paves the way to new potential uses of UHF (Ultra High Frequency) spectrum bands for 5G broadcasting.

This paper provides an insight into the fundamental advantages in terms of capacity, coverage as well as power saving of wideband broadcast operation. The role of the network deployment, linked to frequency reuse in the UHF band, and its influence in the performance of a Wideband Broadcasting system are discussed. The technical requirements and features that would enable such power-efficient solution are also addressed.

## INTRODUCTION

5G offers the prospect of high peak data rate download speeds for point-to-point transmissions. However, it is unlikely that these speeds are available everywhere due to both physical and cost limitations. Point-to-multipoint (PTM) capabilities are expected to be considered in the near future to meet the requirements of a wide range of use cases, including large-scale media distribution to mass audiences [1]. The development of 5G will offer new opportunities beyond the capabilities of eMBMS (evolved Multimedia Broadcast Multicast Service) or LTE (Long Term Evolution) broadcasting, which has already been enhanced in 3GPP Release 14 considering multiple requirements from the broadcasting industry. 5G is adopting new features for wideband operation with large bandwidth (BW) to meet the multi-Gbps data rate requirements of enhanced mobile broadband (eMBB). Support for a minimum large bandwidth of 100 MHz for operation below 6 GHz has already been adopted, which will be implemented thanks to a wide scalable numerology [2]. Moreover, bandwidth could be further extended by the aggregation of multiple carriers. The potential implementation of wideband operation is addressed from the perspective of the Digital Terrestrial Television (DTT) in the UHF band as one of the most powerful platforms for multimedia broadcasting. The technical concept explained in this paper can be applied to frequency bands allocated for 5G operation as well as for different use cases.

Wideband Broadcasting breaks with the traditional concept of frequency reuse employed in DTT [3]. With frequency reuse, the available frequency resources (RF channels) are orthogonally distributed across multiple stations. This fact limits available spectrum per transmitter area, and leads to the necessity of using high capacity transmission modes to compensate for the limited amount of spectrum. Reception of such modes requires very high Signal-to-Noise (SNR) thresholds, what also limits resilience against interference. Thus, stations operating in the same frequency need to be positioned far away (i.e. large reuse distance). As an example, the Geneva plan GE06 results in an average frequency reuse of around 5-6 in Europe [4]. High Power High Tower (HPHT) is the general topology in DTT networks, since high capacities can only be obtained by transmitting high power. Power grows exponentially with capacity, what also implies a high operational cost.

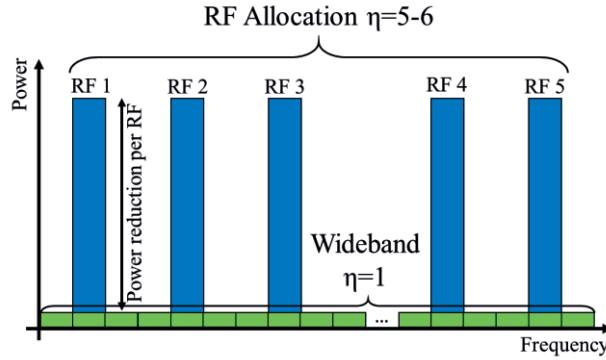


Fig. 1. Frequency and power allocation with current DTT systems and Wideband Broadcasting.

Energy-efficient or green communications will be an indispensable pillar of 5G since power consumption for the information and communication technology (ICT) is forecast to increase in the next decade. Wideband Broadcasting can result in a more energy-efficient approach where potentially all RF channels from all transmit stations can be used. The concept is depicted in Figure 1. As an illustrative example, consider the terrestrial broadcast UHF band in Europe (470-694 MHz). With a frequency reuse factor of around 5-6, a capacity of about 200 Mbps can be achieved with the commonly used DVB-T2 (Digital Video Broadcasting Terrestrial Second Generation) mode 256QAM 2/3 (5.33 bps/Hz) using 5 multiplexes (8 MHz RF channels). On the other hand, a similar capacity could be obtained with QPSK 1/2 (about 1 bps/Hz) employing the whole frequency band (28 multiplexes). Table 1 shows a comparison of these two transmission modes. 256QAM 2/3 requires about 16-18 dB higher SNR threshold than QPSK 1/2. This represents the opportunity of transmitting about 17 dB less power (50 times) per 8 MHz channel although using more RF channels per station (28 instead of 5), which leads to a total transmit power saving of about 90%. Note that the ATSC 3.0 (Advanced Television Systems Committee) standard outperforms DVB-T2 providing spectral efficiencies closer to Shannon limit and even implements transmission modes with negative SNR threshold [5].

Table 1. Spectral efficiency, SNR threshold and potential power saving comparison between high and low rate transmission modes

Transmission Mode	Spectral Efficiency	SNR Threshold	Power per RF channel	Number of RF channels	Total Power
256QAM 2/3	5.33 bps/Hz	$\approx 17$ dB	50 W	5	$50 * 5 = 250$ W
QPSK 1/2	1 bps/Hz	0 dB	1 W	28	$28 * 1 = 28$ W

Whether the fundamental advantages of wideband operation can be implemented in a current network or not will mainly depend on the possibility of providing the same coverage levels as the current DTT platforms. Coverage for roof-top reception in the UHF 470-694 MHz band is mainly limited by interference due to the excellent propagation conditions of this band, combined with a high SNR threshold in relation to the applied frequency reuse factor. Decreasing frequency reuse down to 1 would result in coverage limitations due to severe co-channel interference. This may be dealt with by using ultra-robust transmission modes with SNR below 0 dB but resulting in very low data rates. Under certain conditions, the implementation of Successive Interference Cancellation (SIC) processes may improve coverage performance at the expense of increased receiver complexity [6]. With SIC it would be possible to cancel interfering signals that limit the coverage in the frequency reuse 1 scenario. This may allow reaching the same coverage levels as in current DTT system when frequency reuse 1 operation causes high interference levels.

## FUNDAMENTALS OF WIDEBAND REUSE-1 OPERATION FOR 5G BROADCASTING

### Concurrent Use of Spectrum and Frequency Reuse

Frequency reuse is implemented in DTT networks to decrease co-channel interference. In a Multi-Frequency Network (MFN), neighboring stations broadcast content using a different frequency. Although Single Frequency Networks (SFN) enable using the same frequency across multiple stations, frequency reuse is still necessary at borders between different regions or countries.

Figure 2 depicts a basic scheme with two transmitters in an MFN configured with a certain frequency reuse,  $\eta=4$ , and frequency reuse  $\eta=1$  (see the hexagonal patterns for reference). The bottom part of the figure shows

the Signal-to-Interference-plus-Noise ratio (SINR) experienced at the receiver located in-between the two transmitters.

The implementation of a certain frequency reuse limits interference at cell borders so that high capacity RF channels can be implemented with high transmit power. On the other hand, the high level of interference in the frequency reuse 1 scenario makes the SINR decrease at cell border. The total available spectrum gets confined as  $\eta$  increases. Following the initial example, with 224 MHz (UHF band in Europe) and  $\eta=5-6$  only about 40 MHz are available per station (5 RF channels). Decreasing the frequency reuse results in more available spectrum per station, but it also results in increased interference from co-channel stations. This suggests a required trade-off between the total capacity, coverage and potential power saving that wideband operation can offer in the context of a limited spectrum availability.

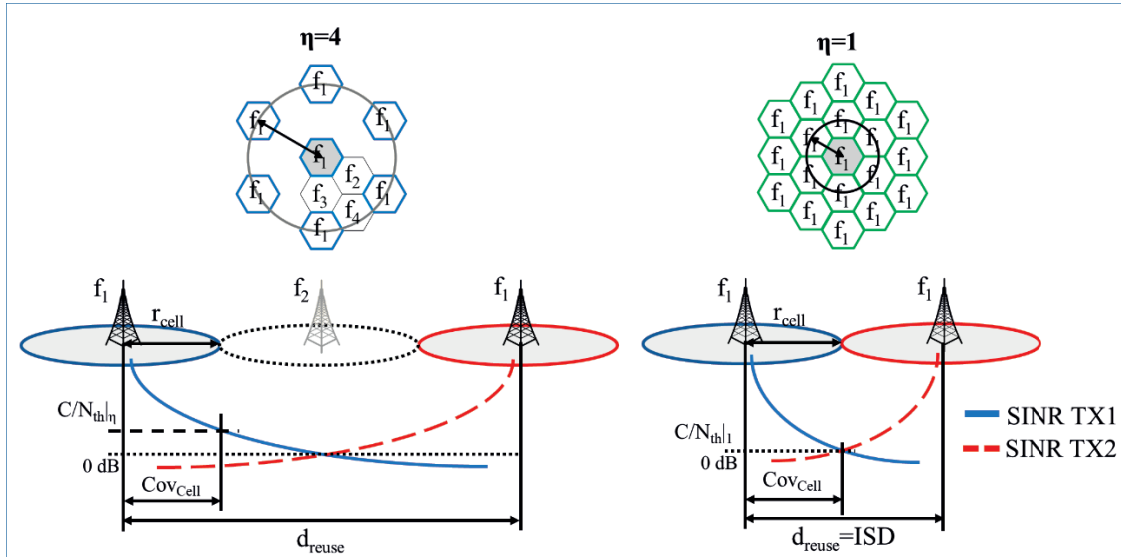


Fig. 2. Effect of the frequency reuse in decreasing SINR and coverage area.

### Capacity, Power Saving and Coverage Trade-Offs

Shannon's capacity formula provides a generalist tool to evaluate the relationship between capacity and power of a wideband signal in the AWGN channel. The capacity (in bps) provided by a generic communication system operating over a bandwidth  $B$  (in Hz) can be expressed as:

$$C = B \log_2 \left( 1 + \frac{P_{tx} |h(t)|^2}{N_0 B} \right)$$

where  $P_{tx}$  (in W) is the transmit power,  $h(t)$  is the channel impulse response of arbitrary duration, and  $N_0$  (in W/Hz) is the thermal noise power density. Bandwidth  $B$  is in front and inside the logarithm which means that the relationship between capacity and bandwidth is not linear. Even more, the term  $P_{tx} |h(t)|^2 / (N_0 B)$  inside the logarithm represents the SNR, which decreases in proportion to bandwidth. Figure 3 illustrates the resulting capacity and SNR when the bandwidth of three standard-BW signals of 5, 10, and 15 MHz is extended up to 400 MHz. The power of the standard-BW signals has been selected to initially provide SNRs of 0 dB and 10 dB.

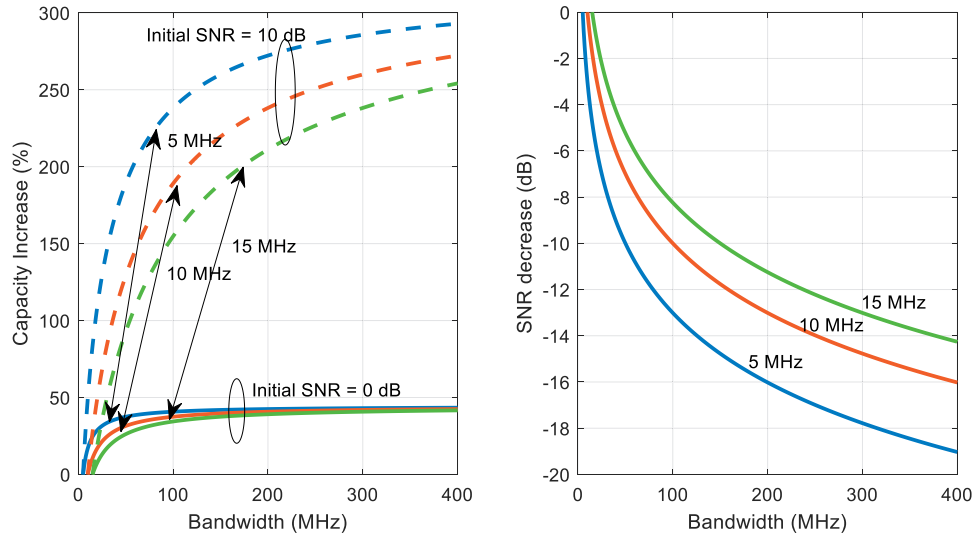


Fig. 3. Capacity increase (left) and SNR decrease (center) when extending the bandwidth up to 400 MHz with signals of 5 MHz, 10 MHz and 15 MHz. Power is kept constant for a system that initially achieves SNR equal 0 dB and 10 dB.

The maximum achievable capacity in all cases is bounded because of the non-linear behavior of capacity with bandwidth. The reason for this modest capacity growth is the fact that the SNR reduces inversely proportional to the bandwidth. Thus, just increasing bandwidth does not provide a proportional increase in terms of capacity. It can be shown that  $C \rightarrow (P\beta/N_0) \log_2(e)$  as  $B \rightarrow \infty$ , which is proportional to the transmit power. In conclusion, achieving a linear capacity growth is only possible if the SNR is kept fixed as the bandwidth increases but this can only be achieved by increasing transmit power proportionally to the bandwidth. That is, ten times more power is required when operating over a ten times wider bandwidth.

From the point of view of current DTT networks, it may be possible to maintain capacity while extending bandwidth from dozens of MHz to e.g. the whole frequency band. This would result in decreasing SNR threshold, which would bring important power saving and the possibility to set up ultra-robust transmission modes to cope with interference. However, the effects in coverage should be carefully studied since the increased interference levels may limit the coverage of the system for delivering the same total capacity. In case reuse 1 fairly approaches an available SINR of 0 dB, what may limit the coverage of the system, it may be possible to further extend performance by introducing interference cancellation methods. The received signal consists of an aggregation of several independent signals, each one with a different power level according to propagation and channel characteristics (transmit power may also be different). This situation resembles the initial Cloud Transmission concept [7], in which two different signals are combined but not necessarily synchronized.

Successive Interference Cancellation (SIC) may be useful when the desired signal is not at the top and the interfering signal can be demodulated and cancelled. This situation may happen either within the service area, causing that the cell edge is not fully covered, or beyond it. In the latter case, the SIC process may be used to extend the coverage area of the signal if it is transmitted with high enough power (with a certain power excess). Note that if the system is designed so that the coverage is limited to the cell area it may not be possible to extend its coverage.

Figure 4 depicts the basic idea of the SIC process and its comparison with the standard reception without cancellation.

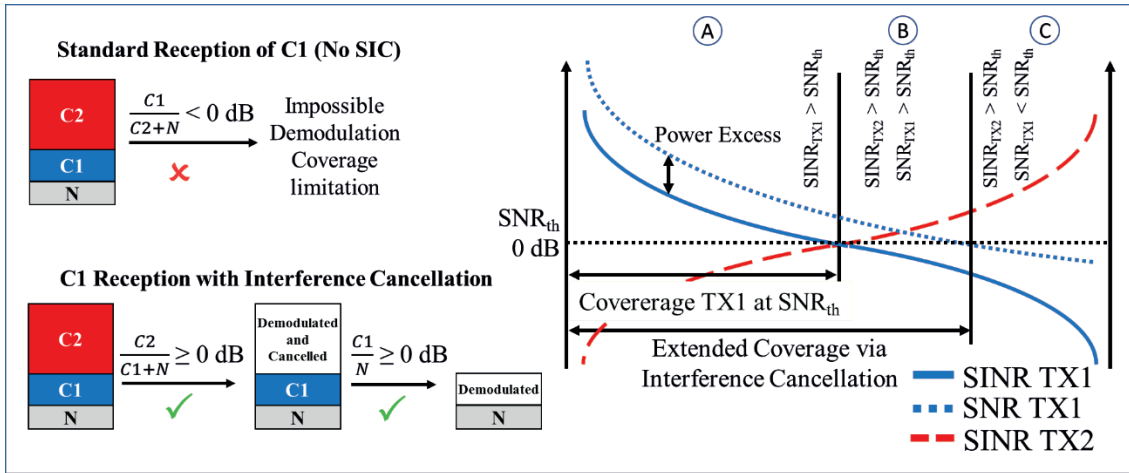


Figure 4. The received powers from TX1 and TX2 are C1 and C2 respectively and with N being noise. The targeted signal is C1. It can be demodulated as long as the SINR is fulfilled. In the cancellation process, the stronger signal C2 can be cancelled as soon as the required SNR is fulfilled. The cancellation process may be used to extend the coverage area of the targeted signal.

When a target signal C1 is interfered by an equally-modulated but stronger C2 signal SIC consists in first demodulating the stronger signal, then re-modulating it and subtracting it from the incoming signal, which is possible since it is perfectly known after the (assumed successful) demodulation. In a final step the target C1 signal can then be demodulated. This process is possible if the actual SINR of the signal to be demodulated (here C2 followed by C1) is larger than the required SNR threshold. For a 1 bps/Hz spectral efficiency (e.g. QPSK rate 1/2) the required SNR is close to 0 dB. The described process can be generalized and be used for any number of signals if this requirement is fulfilled for every demodulated and subtracted signal.

Note that the SIC mechanism will benefit from high power imbalances between the different received signals. If e.g. 3 signals are received with equal power none of them will be demodulated since the SNR threshold 0 dB will not be accomplished. Thus, the advantages of the system are severely linked to the network deployment and reception conditions.

Figure 5 depicts the available SINR at cell edge<sup>1</sup> as a function of transmit ERP (equivalent radiated power) considering ideal hexagon-based networks (60 km inter-site distance and 250 m effective antenna height) with different frequency reuse factors. Field strength is calculated with ITU-R P.1546 model assuming roof-top reception conditions with a receiving antenna based on ITU-R BT.419 recommendation with 11 dBd gain. The assumed down-lead loss and receiver noise figure are 4 dB and 6 dB respectively. The calculations are obtained by means of Monte Carlo simulations with SIC for reuse 1 which is modeled by selecting the maximum available SINR of the system as the minimum between the SINR of the first signal considering the other as interference and the SINR of the subsequent signal having removed the first one. The process is repeated until the wanted signal is reached.

Note that this illustrative example is provided for comparison with an MFN approach so that different transmitters broadcast signals with different content. It is possible that stations transmit signals of the same content in a synchronized fashion as in a traditional SFN, what may reduce interference.

<sup>1</sup> SINR is the minimum to achieve a coverage criterion for 95% location (location-dependent fading with standard deviation 5.5 dB) and 99% of time (both wanted and unwanted signals vary uncorrelated in the time dimension).

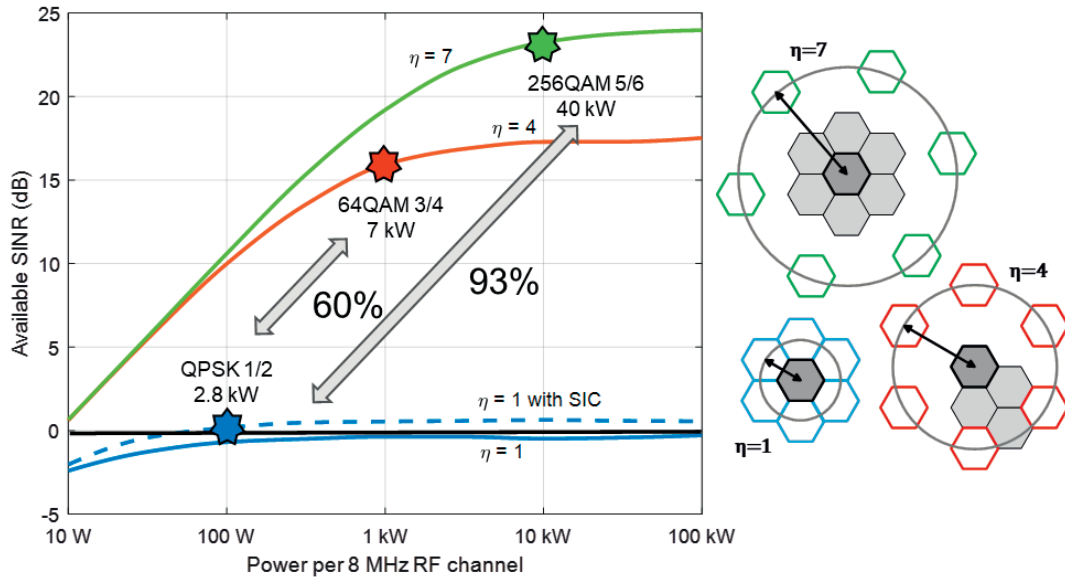


Fig. 5. Basic hexagon-based simulation with different frequency reuses. Available SINR as a function of the power per 8 MHz RF channel.

The results show that the achievable capacity becomes limited due to interference when reducing frequency reuse. The selection of the possible transmission modes is limited to those offering a maximum SNR threshold. The required ERP has been calculated for certain DVB-T2 modes that offer similar capacity to that targeted by the Wideband Broadcasting with ideally 1 bps/Hz. For a fair comparison,  $\eta=7$  and  $\eta=4$  have been chosen which offer 4 and 7 RF channels (8 MHz), respectively, of the total 28 in 224 MHz. The mode 256QAM 5/6 can fit in the reuse 7 scenario offering a capacity of about 50 Mbps with a required ERP per RF channel of 10 kW (about 200 Mbps with 40 kW for 4 RF channels). The mode 64QAM 3/4 can fit in the reuse 4 case with a capacity of about 30 Mbps and required ERP of 1 kW (about 210 Mbps with 7 kW for 7 RF channels). With QPSK 1/2 using all RF channels a total ERP of 2.8 kW is required. This supposes a total power saving of about 93% and 60% with respect to the  $\eta=7$  and  $\eta=4$  cases.

#### Data Rate Advantages: Guard Bands Removal and Increased Peak Data Rates

Wideband operation provides benefits in terms of data rate thanks to the potential suppression of guard bands, which are used to decrease the impact of OOB (Out-of-Band Emissions) between different RF channels. The guard band in LTE is defined to be 10% of available bandwidth. For instance, in a 20 MHz channel, 1 MHz of each side band are not used. In state-of-the-art DTT systems the guard band overhead is about 3% (e.g. in ATSC 3.0 and DVB-T2 7.77 MHz of 8 MHz can be used). The overhead can be further reduced by extending bandwidth. For instance, extending a 20 MHz LTE signal bandwidth by 5 times would free up 8 MHz.

Wideband operation with robust transmission modes may also enable the reduction of the cyclic prefix overhead in SFN operation, as the use of ultra-robust transmission mode may cope with degradation due to ISI (inter-symbol interference). Note also that increased frequency diversity can be achieved by transmitting data across multiple frequencies. This would improve resilience against field strength variations between frequencies or co-channel and adjacent channel interference, what could be exploited in terms of more capacity.

Wider bandwidth operation enables higher peak data rates. For instance, a Wideband Broadcasting system with 1 bps/Hz would not offer more than approximately 8 Mbps (using 8 MHz channels). Using instead a wider bandwidth with 32 MHz would allow the peak data rate to be increased to about 32 Mbps.

Another important aspect for media broadcasting is the possibility to enhance Statistical Multiplexing (StatMux) when transmitting variable bitrate services by exploiting a total higher data rate StatMux pool. This could enable the transmission of extra services, as introduced in [8].

#### Network operator perspective: CAPEX and OPEX cost saving

Potential CAPEX (Capital Expenditure) cost savings are directly related to the reduction of the total required transmit power in a Wideband Broadcasting system since the equipment could be simplified. For

example, all existing transmitters per station could be replaced by a single wideband low-power transmitter. Some performance requirements such as linearity could also be relaxed thanks to the configuration of more robust transmission modes. Furthermore, the nature of wideband operation would eliminate the need of RF combiners by their replacement by a single exciter and a single wideband transmitter, with an RF filter. Reduced power also reduces the cooling requirements significantly and may allow for simple battery back-up power solutions for many small sites. The reduced power, cooling requirements, volume and height may allow the possibility of install transmitter equipment directly in the site mast.

From the OPEX (Operational Expenditure) perspective, the reduction of power consumption would be the most advantage, with a direct cost reduction in electricity. In addition, other factors could even allow further reduction in consumed power, such as the elimination of the attenuation in combiners, feeder, RF split etc., (about 3 dB) which may not be required.

From a service perspective, the overall complexity of the system would be reduced thanks to fewer system components and less critical sensitivity requirements by using more robust operation modes. Furthermore, there will be less need for frequency changes or frequency re-planning once the network is in operation. Regulatory aspects for the deployment of Wideband Broadcasting should be carefully studied as well as the implication for the introduction of the system in terms of coexistence with other networks.

## **TECHNOLOGY REQUIREMENTS AND IMPLEMENTATION ASPECTS**

The basic Wideband Broadcasting system outlined here should be developed to achieve increased capacity or coverage performance in highly interference-limited scenarios. A series of transmitter and receiver requirements are briefly introduced in this section to discuss its implementation feasibility.

### **Wideband Operation**

A key component of the system should be the ability to configure wideband signals so that capacity gains due to the suppression of guard bands and increased performance thanks to extended frequency diversity can be exploited.

3GPP is discussing the adoption of a minimum large bandwidth per carrier of 100 MHz in Rel-15 together with a maximum number of 16 NR carriers for Carrier Aggregation (CA) [9]. Bandwidth extension presents implications in the FFT size and sampling frequency. 3GPP standards rely on a fixed sub-carrier spacing (SCS) so that increasing FFT size produces a proportional bandwidth increase. Candidates of the maximum number of subcarriers are 3300 or 6600 in Rel-15, with a candidate maximum FFT size of e.g., 4096 or 8192, respectively. The potential SCSs for below 6 GHz operation are 15 kHz and 30 kHz. With these assumptions, a maximum channel bandwidth of 100 MHz or 200 MHz could be achieved.

Conversely, traditional DTT systems are based on a fixed bandwidth with variable FFT and SCS. In the latter case, to maintain the same OFDM (Orthogonal Frequency Division Multiplexing) symbol time and SCS, additional computation complexity is added to the receiver. ATSC 3.0 already adopts the Channel Bonding (CB) method for bundling two standard-BW RF channels using two tuners (plain CB) and even extend frequency interleaving (CB with SNR averaging) [8].

If complexity could be increased to some extent, the receiver could basically be a single-tuner OFDM receiver with limited bandwidth (e.g 32 MHz) so that as with the DVB-T2 32K mode in 8 MHz, an FFT size of 128K would be required. The whole bandwidth could be exploited if a frequency hopping mechanism is used to cover the wider virtual bandwidth (up to e.g. 224 MHz). The concept of frequency hopping across the UHF band was introduced in DVB-T2 specification where temporal slots of a signal can be transmitted across different RF channels and recovered at the receiver with a single or multiple tuners.

### **Ultra-robust transmission modes**

The basic mechanism to cope with severe co-channel interference is the implementation of ultra-robust transmission modes offering SNR operation below 0 dB. A wide range of LDPC codes are expected in 5G for the data channels. ATSC 3.0 already provides transmission modes with SNR operation below 0 dB (e.g. QPSK 2/15 or 3/15). This may provide the opportunity of demodulating the strongest received signal at the expense of limited capacity due to the low rates of such transmission modes. Note also that the gap between the modulation and code rate efficiency to Shannon limit increases at high SNR regions as well as the penalty due to degradation for different channel models [5].

### **Successive Interference Cancellation (SIC)**

The interference management for a Wideband Broadcasting receiver is linked to the operations performed in power-domain MUST (Multi-User Superposition Transmission) in LTE and LDM (Layer Division Multiplexing) in ATSC 3.0 to retrieve information from different transmitted layers [10].

In MUST and LDM, the transmit signal consists of the overlapping of several signals (which may aim different capacity/coverage requirements) which are generated at the transmitter. The aggregation occurs at QAM-symbol level with a selected relative level between layers. Afterwards, the joint signal passes through a series of common blocks (e.g. waveform generation, pilot and reference signals insertion, ...). At the receiver, the signal is acquired as a single signal, regardless of the number of layers since the interference between layers is only present at symbol level. In ATSC 3.0, physical layer signaling does not undertake an LDM process. Moreover, the layers are synchronized since they share the same waveform parameters. The symbol components of the layers are time-aligned as they were jointly assembled at the transmitter. The number of layers as well as the relative power level between them are indicated in terms of signaling parameters. The reception of the layer with high SNR requirements is performed after the successful decoding, re-encoding and subtraction of the strongest layer. A buffer is needed to store the original signal and allow subtraction.

In the proposed Wideband Broadcasting system, conversely to LDM or MUST, single-layer signals are generated at the transmitter and broadcast from different stations. A series of requirements need to be considered for a successful SIC process. The number of received signals is, a priori, unknown since it mainly depends on the network topology and the propagation conditions. Moreover, the number of signals to cancel may change over time so that the position of the desired layer within the amount of received signals is not constant. Thus, the number of cancellation rounds to be performed is variable and the SIC process must be designed according to these characteristics. As well, the relative power level between signals is not a priori known but can be estimated. A proper channel estimation process, may help detecting the relative levels of the signals. As well, a transmitter identification (TxID) mechanism may help on the selection of the desired signal to be demodulated.

Channel estimation should ideally be performed for each received signal in order to account for each transmitter-receiver channel. As a first idea, this could be realized by using  $N$  orthogonal pilot (reference signals) patterns so that up to  $N$  channels may be estimated and the corresponding signals detected. Mechanisms such as Walsh-Hadamard or Null Pilot encoding may be used To limit pilot pattern overheads, the pilot patterns could be reused across different transmitters. Other operations that could require increased complexity such as those linked to the deinterleaving of the channel estimates and data signals as well as the demodulation/decoding of the different signals should be studied. The SIC process may also cause degradation that could limit the expected performance of the system. The non-ideal cancellation of the layers as well as the effects of noisy channel estimation may generate error propagation between layers, limiting the number of layer that can successfully be eliminated.

### **Signal Acquisition and Synchronization Aspects**

A series of mechanisms should be considered to ensure the proper acquisition of the signals. In this sense, the signal acquisition and synchronization are critical. In the Wideband Broadcasting system, all signals are interfered unless some orthogonality or constructive interference could be achieved at some point in order that the different signals can be treated as one from the synchronization perspective. For standalone operation, signal acquisition may be performed by transmitting the same kind of physical layer signaling from different transmitters. These data could be treated as SFN signals thus generating constructive interference.

Inter-symbol interference (ISI) inter-carrier interference (ICI) must be controlled at both preambles and data channels to avoid degradation of the layers. OFDM sub-carriers of the different layers need to be synchronized so that a single FFT operation can deliver symbols containing the interfered layers without additional degradation. This could be achieved by a similar mechanism as within SFN transmitters in which transmit signals share the same clock.

### **CONCLUSIONS**

This paper presents an illustrative approach to a Wideband Broadcasting system with ultra-robust transmission modes and frequency reuse 1 fully aligned with the expected capabilities of 5G. The approach may bring a series of advantages in terms of capacity, coverage and transmit power saving. The full integration of unicast and broadcast capabilities within the 5G system will also enhance user experience.



The main benefit of Wideband Broadcasting for current DTT networks implementing frequency reuse would come from the possibility to maintain the coverage and capacity of the system while considerably reducing transmit power. The potential power saving can be around 80-90%, which would be translated into a very positive impact reducing the network capital and operating costs.

Wideband operation also allows for capacity gains thanks to the elimination of guard band between RF channels, increased peak data rates and enhanced statistical multiplexing. The wideband signal may also benefit from increased frequency diversity. The implementation of ultra-robust transmission modes may also allow the reduction to a minimum of the cyclic prefix overheads.

On the other hand, the high level of interference in frequency reuse 1 networks may considerably reduce capacity and/or coverage at cell edge, although this depends heavily on the system design and the applied interference cancellation processing in the receiver. The functionality of the system is still to be analyzed in real networks. The coverage performance of Wideband Broadcasting requires a proper characterization of the interference in denser DTT networks which differ from the traditional scenarios where interfering stations often are many hundreds of kilometers away from the service areas. The coverage performance in portable and mobile reception also needs to be analyzed. With ultra-robust transmission modes, it may be possible to enhance receiving conditions in locations close to the transmit stations.

For enhancing system performance, a series of mechanisms and implementation requirements should be addressed. Interference Cancellation methods such as SIC may provide capacity and/or coverage advantages but also increases receiver complexity. The fact that several, mutually interfering, signals are available at the receiver may also be considered for an adequate implementation of the acquisition and synchronization mechanisms, channels estimation procedures and interference cancellation algorithms. The impact and complexity at the receivers are critical for a successful implementation of the proposed system.

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