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TECHNICAL REVIEW

Receiving Antenna Alignment in Hexagonal Grid Simulations:

A Study for LTE-based 5G Terrestrial Broadcast

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1. Introduction

Over the last few years EBU members have been collaborating with the mobile industry in order to make the enhanced Multicast Broadcast Multimedia Service (eMBMS), defined in the Third Generation Private Partnership (3GPP) mobile communication system standards, more suitable for delivering broadcasters' content. The collaboration has so far been very fruitful, with eMBMS being further evolved in the Enhanced TV (enTV) Work Item of Long-Term Evolution (LTE) Release 14 (Rel-14) specifications.

Rel-16 has further enhanced eMBMS with greater support for conventional broadcasting in the LTE-based 5G Terrestrial Broadcast[1] [1, 2] work item. A longer Cyclic Prefix (CP) has been added to support single frequency networks (SFN) with inter-site distances (ISD) more typically found in high power high tower (HPHT) broadcast networks. In addition, a shorter CP for greater mobility up to 250 km/h has been introduced, and the cell acquisition subframe (CAS) has been made more robust. EBU members continue to contribute to 3GPP.

3GPP makes extensive use of Monte Carlo based network simulations in order to evaluate the benefits of any potential enhancements before they are standardised. The enTV Work Item permitted the simulations to use several different methodologies for the alignment of directional receiving antennas to transmitter sites and for determining which signals are permitted to contribute to the useful signal.

This article investigates several different methodologies that are commonly used in these two aspects of the simulations and, using 5G broadcast as an example, illustrates how the different methodologies affect the results. Detailed worked examples are also provided for clarity.

2. 5G Broadcast: Background

LTE Rel-14 is the first 3GPP specification targeting the delivery of TV services in a similar way to conventional terrestrial broadcast standards [3]. For example, Rel-14 introduces carriers with 100% downlink capacity for broadcast services for which SIM-free reception without uplink is possible, and additional OFDM parameters (numerologies) for the support of fixed rooftop reception in SFN with an ISD of 15 km or more in low power low tower (LPLT) networks.

An extensive analysis of the broadcast related features introduced in Rel-14 can be found in [4] and [5]. A Rel-16 study [1] identified gaps between LTE Rel-14 eMBMS and the 5G requirements for dedicated broadcast networks in [3]. Rel-16 added further enhancements to make 5G Broadcast suitable for deployments in large area SFN with ISDs of around 100 km or more, increase mobility up to 250 km/h, and make the systems signal acquisition and synchronisation mechanisms more robust.

1 LTE-based 5G Terrestrial Broadcast is here referred to as 5G Broadcast

2.1 Numerologies for SFN Deployments

LTE Rel-14 introduced two new numerologies for the MBSFN (multicast-broadcast single frequency network) radio bearer of eMBMS. The sub-carrier spacings of the new numerologies are 7.5 kHz and 1.25 kHz, with CP durations of 33.3 µs and 200 µs, respectively.

LTE Rel-16 introduced an additional two numerologies with sub-carrier spacings of 2.5 kHz and 0.37 kHz, with CP durations of 100 µs and 300 µs, respectively [2]. The wider carrier spacing of the 2.5 kHz numerology supports greater mobility up to 250 km/h. The 300 µs CP numerology is designed to support fixed rooftop reception in SFN with large ISDs typically found in HPHT broadcast networks.

Table 1 sets out the sub-carrier spacing (Δ_f), CP duration (T_{CP}), useful symbol period (T_U) and equalisation interval[2] (EI) for the numerologies in 5G Broadcast. The longest CP permitted in Rel-14 was 200 µs (OFDM symbol duration $T_S = T_U + T_{CP} = 1$ ms). Rel-16 includes a 300 µs CP with an OFDM symbol duration of 3 ms.

While the MBSFN subframes (containing data) can only be configured with large "Extended CP" configurations, the cell acquisition subframe (CAS), containing control and synchronisation information, are restricted to the "Normal" and "Extended" CP configurations with a sub-carrier spacing of 15 kHz.

The 1 ms CAS, configured with normal CP, has 14 OFDM symbols and the CAS configured with extended CP has 12 OFDM symbols. For the rest of the paper we assume the extended CP configuration for the CAS due to its ability to tolerate echoes with longer delays.

Table 1: Rel-14/16 eMBMS Numerologies

	Δ_f (kHz)	T_{CP} (µs)	T_U (µs)	CAS EI (µs)	EI (µs)
Normal CP	15	4.7/5.2	66.7	-	-
Extended CP (Rel-14)	15	16.7	66.7	22.2	66.7
	7.5	33.3	133.3	-	66.7
	1.25	200	800	-	267
Extended CP (added in Rel-16)	2.5	100	400	-	200
	0.37	300	2,700	-	900

[2] The equalisation interval (EI) is the Nyquist limit of the receivers channel equalisation filter. The EI denotes the maximum echo delay for which a receiver may correctly equalise a transmitted signal. It is dependent on the effective frequency separation of the reference signal (RS) [6].

2.2 Framing and Cell Acquisition Subframe (CAS)

The introduction of a 100% broadcast mode required changes to the conventional frame structure of LTE. The new 100% broadcast radio frame is 40 ms in duration (Figure 1). It is made up of the new CAS with a duration of 1 ms followed by 39 MBSFN subframes each with a duration of 1ms for numerologies with 7.5 kHz, 2.5 kHz and 1.25 kHz sub-carrier spacings. With the 0.37 kHz sub-carrier numerology (300 µs CP), the frame structure consists of one CAS subframe with a duration of 1 ms followed by 13 MBSFN subframes, each with a duration of 3 ms.

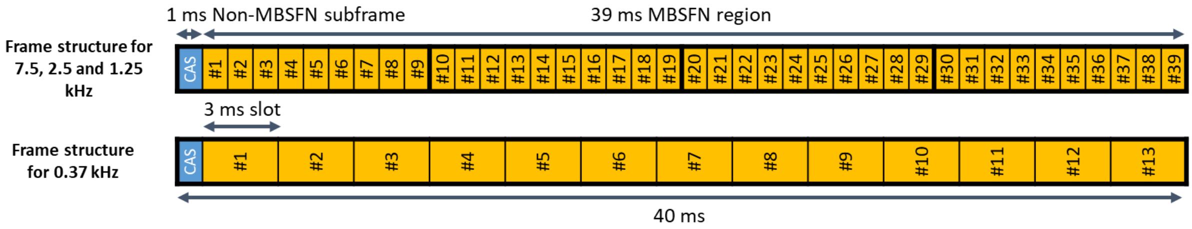


Figure 1: 100% Broadcast Radio Frame.

The CAS contains the essential signalling for demodulating the user plane data [5]. The physical channels comprising the CAS are shown in Figure 2.

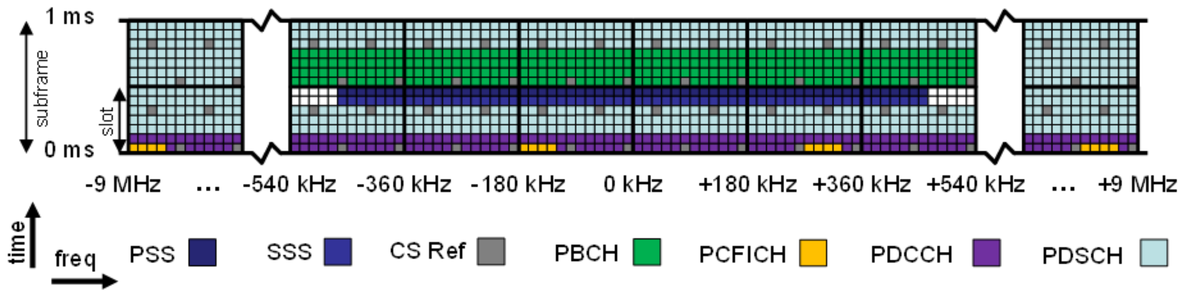


Figure 2: Channels comprising the CAS

The CAS uses CS-RS (Cell Specific Reference Signals) that are inherited from the unicast design, meaning that the CAS can only achieve a maximum 22 µs EI, as shown in Table 1. A numerology mismatch between the CAS and the MBSFN subframes therefore arises as the MBSFN subframes can be configured with CPs of 33.3 µs, 100 µs, 200 µs and 300 µs, while the maximum CP duration for the CAS is 16.7 µs.

The CAS must be correctly decoded before the PMCH (Physical Multicast Channel), which conveys the MBSFN subframes, can be received. It is therefore essential that the CAS is designed to be sufficiently robust so as to ensure adequate reception of the PMCH in locations where the CAS is not protected by the longer CP of the MBSFN subframes.

Rel-16 made the CAS more robust by different methods, including greater repetition of the information in the sub-channels, to increase detection probability. The changes do not include modifications in the numerologies as this would have needed a re-design of the control channels already defined for LTE.

3. Network Simulation Background

A framework for performing Monte Carlo based network simulations for 5G Broadcast in Rel-16 is set out in [1]. It describes the network topology, such as the locations of transmitter sites, their effective heights and radiated powers, the propagation model, the receiver's noise floor, receiving antenna patterns, etc.

The simulation network comprises 61 transmitters configured as shown in Figure 3.

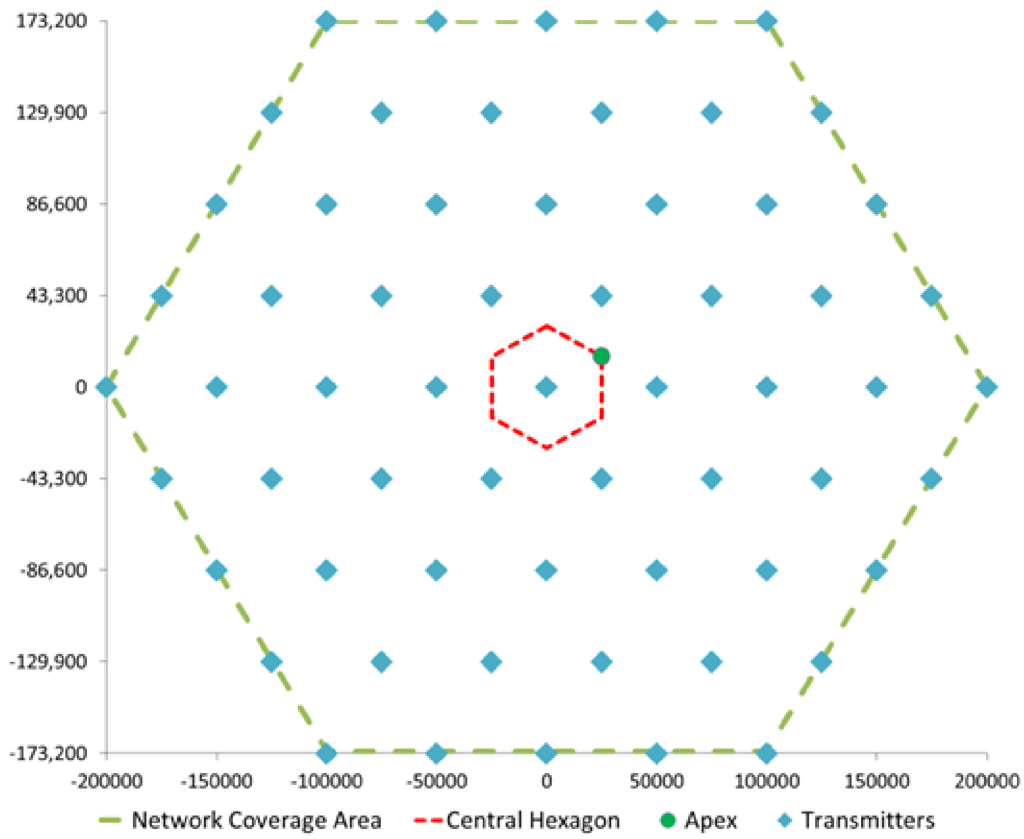


Figure 3: Hexagonal Network Layout and Coverage Area for the MPMT Network.

All 61 transmitters are allocated the same frequency and belong to a single MBSFN area. Multiple frequency networks (MFN) are outside the scope of the framework. Other key simulation parameters are shown in Table 2.

Table 2: Main Simulation Parameters

Parameter	Value
Inter-site Distance	50 km
Transmitter Effective Height	100 m
Transmitting Antenna	Omni-directional
Effective Radiated Power (E.R.P.)	40.5 dBW EIRP
Receiving Antenna Height	10 m
Receiver Noise Figure	6 dB
Rx Antenna Pattern	ITU-R BT.419/Omni-Directional
Rx Antenna Gain (Omni/Directional)	0 / 13.15 dBi
Antenna Cable Loss	4 dB
Implementation Margin	1 dB
Noise Bandwidth	9 MHz
Frequency	700 MHz
Propagation Model	ITU-R P.1546-5 over land
Wanted Signal Time Value	50%
Interfering Signal Time Value	1%
Location Variation (μ/σ)	0 dB/5.5 dB (log-normal distribution)
Simulation Methodology	Monte Carlo
Pixel Size	100 m x 100 m
Tx/Rx Error Vector Magnitude (EVM)[3]	8% / 4%
Handover Margin	None
SFN Signal Summation	SFN weighting function [6]

Measurements show that, due to variations in terrain and ground cover, the signals from transmitters will vary from one location to another throughout a small area e.g. a square ‘pixel’ with sides of 100 m. This location variation is modelled by a log-normal distribution with a mean of 0 dB and standard deviation of 5.5 dB. Location variation is a crucial concept in this document – it plays a key role in the network simulations.

All the simulations in this study have been carried out within a single square pixel of side 100 m, centred at the apex of the central ‘red hexagon’ marked by the green dot in Figure 3. Within this pixel, 10000 realisations of location variation were generated for each transmitter. The SINR was then computed from these realisations using the receiving antenna alignment methodologies described below.

The selected pixel is representative of the coverage area with interference from multiple distant transmitters and although coverage will vary over the entire network, restricting the analysis to a single representative pixel is a convenient way to

[3] In this document the EVM of the transmitter and the receiver has been set to 0% i.e. both are ideal.

compare the effects of different simulation methodologies. The examples in the Annex provide more detail on the SINR calculations within such a pixel.

3.1 Receiving Antenna Alignment for Roof-top Reception

Three methodologies have been considered when determining how to align directional receiving antennas (no alignment is necessary for omni-directional antennas):

- **Wanted Transmitter**: the main lobe of the receiving antenna is aligned to a specific transmitter, defined as the wanted transmitter, before the simulation begins. This option is commonly used for pixel-based simulations.

- **Closest Transmitter**: the main lobe of the receiving antenna is aligned to the closest transmitter. Due to the regular nature of the transmitter networks used herein, and the monotonic decay of the ITU-R P.1546-5 field strength with distance, this alignment is equivalent to aligning the receiving antenna with the transmitter that provides the strongest field strength before location variation is applied.

- **Strongest Transmitter**: the main lobe of the receiving antenna is aligned to the transmitter that provides the strongest field strength at the receiving location, after location variation has been applied.

3.2 Contributing Signals in SFN and ASFN Network Configurations

Several different options may be used to determine which signals may contribute constructively to the wanted signal. The options depend on the network configuration. Two different networks have been considered in this document: conventional SFN and Asynchronous SFN (ASFN), as described below.

- **SFN**: a conventional SFN in which the content from all transmitters is synchronised in both time and frequency so that signals from multiple transmitters may contribute to the wanted signal, the extent of which is determined with the well-known SFN weighting function [6].

    - **All Transmitters Contribute to the Wanted:** in the case of SFN, all transmitters may contribute to the wanted signal. In the examples herein there is only one MBSFN area, so all 61 transmitters may contribute to the wanted signal.

- **ASFN**: all transmitters transmit on the same frequency as in a conventional SFN, but their content is not synchronised. In these networks the signals from each transmitter would interfere with one another, regardless of the CP duration and the signals' relative delays. At each receiving location it is therefore necessary to define a single transmitter that provides the wanted signal within ASFN. Three options have been considered:

- **Wanted**: at all receiving locations, only the wanted transmitter, defined before the simulation begins, is permitted to provide the wanted signal. All other transmitters are defined as interferers.
- **Closest**: at each receiving location, only the closest transmitter may provide the wanted signal. All other transmitters are defined as interferers.
- **Strongest Transmitter**: only the signal from the transmitter providing the strongest field strength at the receiving location, after the application of location variation and the receiving antenna pattern (based on the alignment strategy above), contributes to the wanted signal. All other transmitters are defined as interferers.

At first sight the ASFN may appear to be a curious arrangement with no practical application, but it is an appropriate model for the CAS in MBSFN networks where its content is not completely synchronised across all cells e.g. when CS-RS are used.

Selected combinations of the above receiving antenna alignment and contributing signal options are set out in Tables 3 and 4. Table 3 shows that no antenna alignment methodologies have been considered for omni-directional receiving antennas as, by definition, it is not possible to align them in any particular direction. The combinations shown in these two tables form the basis of the following study.

Table 3: Receiving antenna alignment and contributing signal combinations for SFN

SFN		
Rx Antenna	**Rx Antenna Alignment**	**Contributing Signals**
Directional	Wanted	All Transmitters
	Closest	
	Strongest	
Omni	N/A	

Table 4: Receiving antenna alignment and contributing signal combinations for ASFN

ASFN		
Rx Antenna	**Rx Antenna Alignment**	**Contributing Signals**
Directional	Strongest	Strongest
	Wanted	Wanted
		Strongest
	Closest	Closest
		Strongest
Omni	N/A	Wanted
		Strongest

4. Simulation Results

4.1 Single Frequency Networks (SFN) with Directional Receiving Antennas

This section presents and discusses the results for SFN in which all transmitters may contribute to the wanted signal. Figure 4 shows the complementary CDF of the SINR achieved at the apex of the central hexagon for the receiving antenna alignment options in Table 3 and two different CP durations. The 300 µs numerology achieves a higher SINR than the 200 µs numerology as the longer CP reduces SFN self-interference.

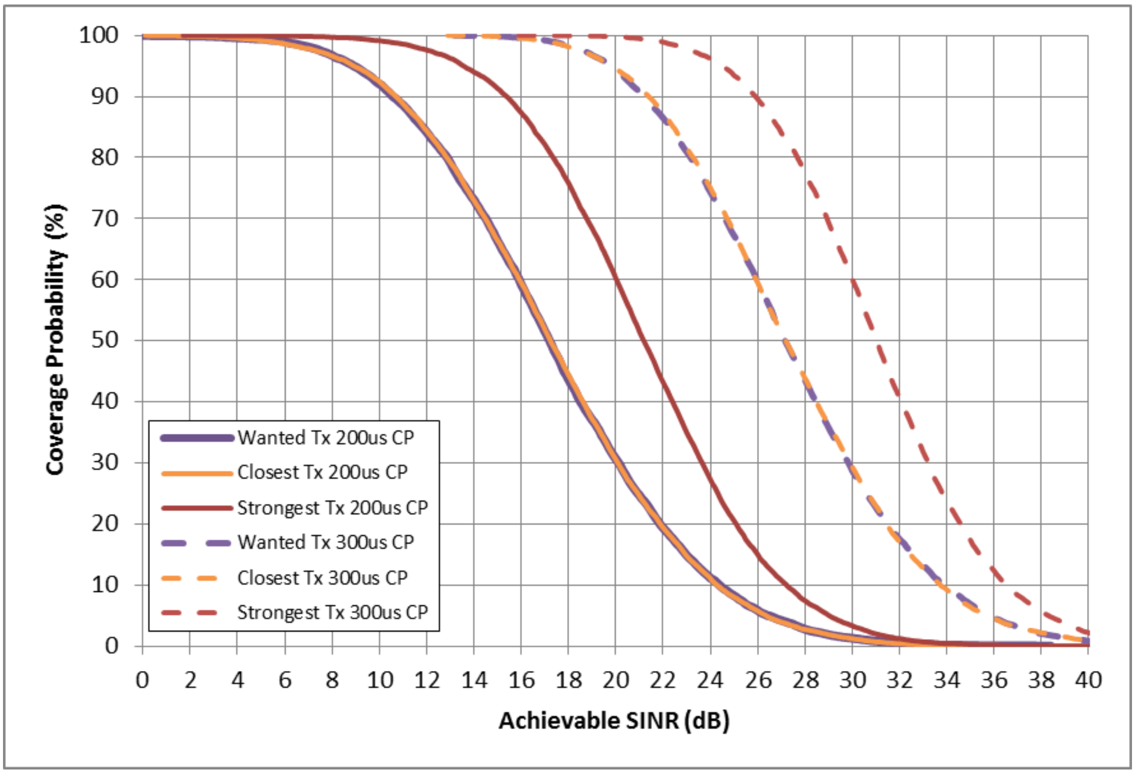


Figure 4: Achievable SINR for different directional receiving antenna alignment strategies in SFN

Due to the symmetry of the network and the location of the pixel that is being considered, aligning the receiving antenna to the wanted and closest transmitters at each location achieves identical SINRs.

Aligning the receiving antenna to the strongest transmitter at each location produces a markedly higher SINR than the other two methods for both CPs. With this method, at every receiving location the receiving antenna is aligned to the strongest signal after location variation has been applied. The wanted signal level is thus maximised, as well as the SINR.

It is worthwhile noting that the shape of the curves may change from one receiving location to another; at some locations there will be a greater or lesser effect of one antenna alignment method over the other. Nevertheless, the principle remains that different methodologies may significantly affect the coverage results. It is therefore important to know, and to clearly state, which methodologies were used when results are presented.

4.2 Asynchronous Single Frequency Networks (ASFN)

In ASFN networks it is necessary to define at each location which transmitter provides the wanted signal. It should be expected that defining the wanted transmitter in different ways will affect the simulation result. The combinations of receiving antenna alignment and permitted contributing signals set out in § 3.2 are investigated below.

4.2.1 Directional Receiving Antenna

Figure 5 shows the results for the directional receiving antenna simulations.

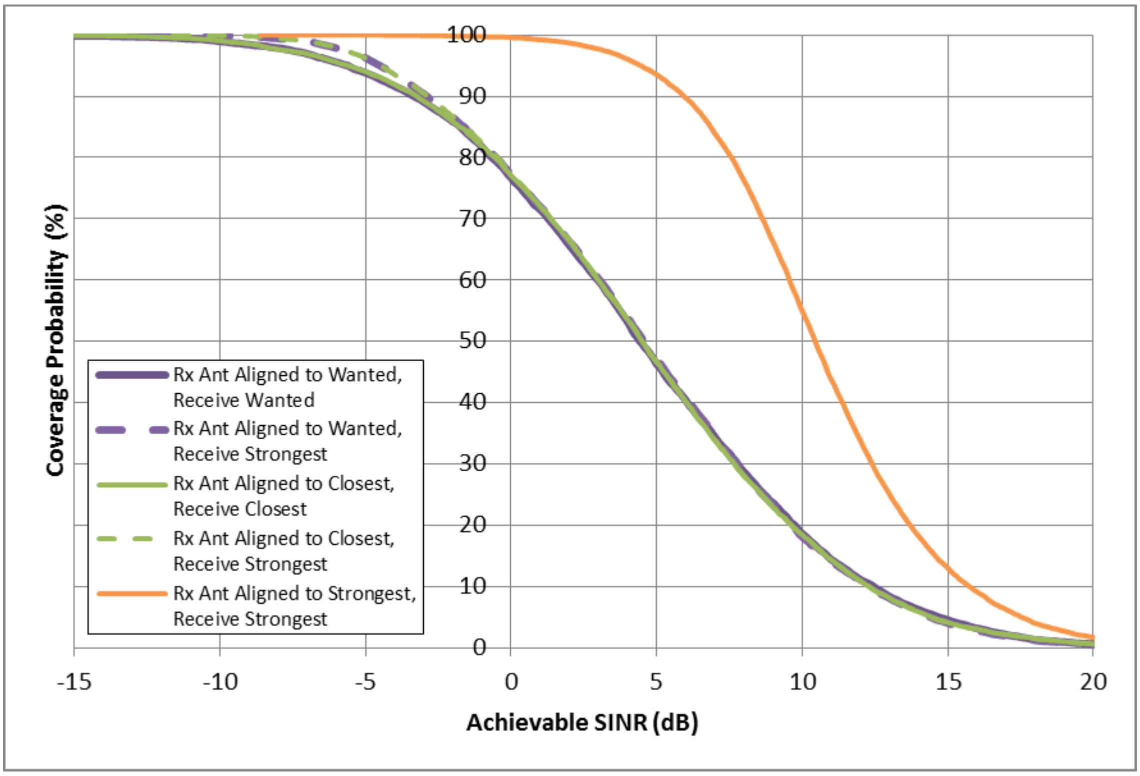


Figure 5: Achievable SINR with a directional receiving antenna in an ASFN

In this example, due to the symmetry of the network, the SINR curves are identical for the receiving antenna aligned to the closest transmitter, receive the signal from the closest transmitter methodology and receiving antenna aligned to the wanted transmitter, receive the signal from the wanted transmitter.

Similarly, the curves are identical for the receiving antenna aligned to the closest transmitter, receive strongest signal methodology and receiving antenna aligned to wanted transmitter, receive strongest signal methodology. However, at high coverage probabilities (e.g. >95% locations), defining the wanted signal as the strongest signal (after location variation and receiving antenna alignment) marginally improves the

SINR compared with restricting the wanted signal to the one originating from the transmitter to which the receiving antenna has been aligned.

A significantly higher SINR is achieved by aligning the receiving antenna to the strongest signal at each receiving location (after the application of location variation), and to defining the strongest signal as the Wanted.

4.2.2 Omni-Directional Receiving Antenna

This section investigates reception of an ASFN with an omni-directional receiving antenna – a network configuration suitable for modelling the CAS, which may not be fully synchronised, for reception with mobile devices (assumed to have omni-directional antennas). The results for the Wanted and Strongest transmitter methods are shown in Figure 6.

Defining the strongest signal as the wanted signal, as opposed to only permitting the wanted signal to come from a pre-defined wanted transmitter, significantly improves the achievable SINR. In this example the difference between the two methodologies for the 95th percentile is approximately 13 dB.

Allowing the mobile device to receive the strongest signal at each location in the model is appropriate as these devices have no receiving antenna pattern to align to any particular transmitter. This model is therefore considered to be more appropriate for mobile reception than restricting the device to consider a pre-defined signal as the wanted signal, particularly in the cases where there is no requirement to deliver regional content at border regions.

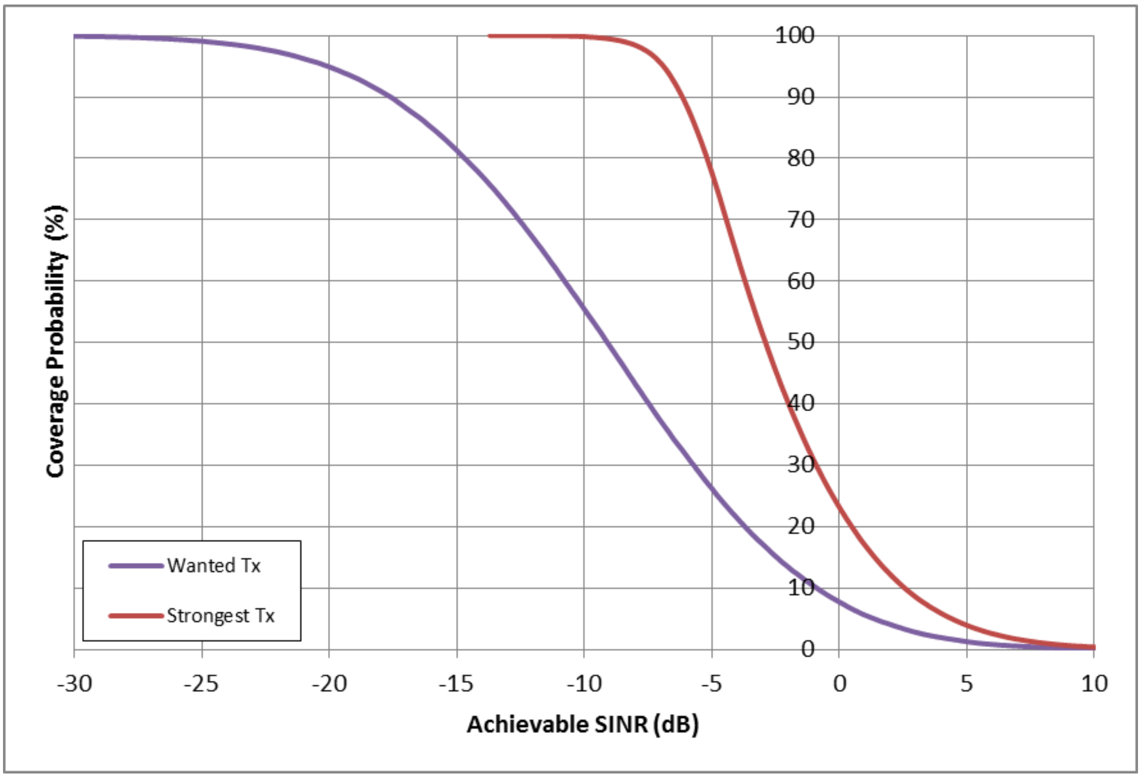


Figure 6: Achievable SINR with an omni-directional receiving antenna in an ASFN

5. Conclusions

This article has outlined several different methodologies that are commonly used in network simulations in order to align receiving antennas and to define the transmitters which may contribute to the wanted signal.

It is clear from the network simulation results that different methodologies may significantly affect their outcome. It is therefore important to clearly state the methodology that has been used when presenting such results so that they can be correctly interpreted.

With respect to 5G Broadcast, a critical topic has been to understand how robust the CAS would need to be in order to ensure that this essential signal is adequately received.

As shown in this article, different methodologies for determining which transmitters may contribute to the wanted signal in a mobile receiving environment can make a significant difference to the achievable SINR in the network (circa 13 dB).

When evaluating the performance of signals, such as the CAS, it is important to apply simulation methodologies that reflect the receiving environment so that the transmission standard may be appropriately designed. Over-designing the system may be too costly, while under-designing the system may lead to a poor user experience.

Annex: Antenna Alignment Examples

Three very simple examples are now presented in order to illustrate how different receiving antenna alignment algorithms may affect the results of otherwise identical simulations. The examples are based on the trivial three transmitter network shown in Figure 7 configured as an ASFN. Each transmitter is located at the centre of three regular hexagons whose apexes meet at the geographic centre of the network. For simplicity we focus on a square pixel of side 100 m located at this central point, but as the concepts involved here are general in nature, any other location could have been chosen.

All three transmitters have the same effective height, effective radiated power (ERP) and omni-directional antenna pattern. Due to the symmetry of the network, and the ITU-R P.1546 propagation model, which decays monotonically with distance, each transmitter generates the same median signal strength in the central pixel for any specific percentage of the time. In the examples below the median field strength generated by each transmitter in the pixel is taken to be 70 dB µV/m for 50% of the time. The 1%-time levels are 72 dB µV/m.

The convention of computing wanted and interfering signals at their 50%-time and 1%-time levels, respectively, has also been used. Thermal noise has been excluded for simplicity.

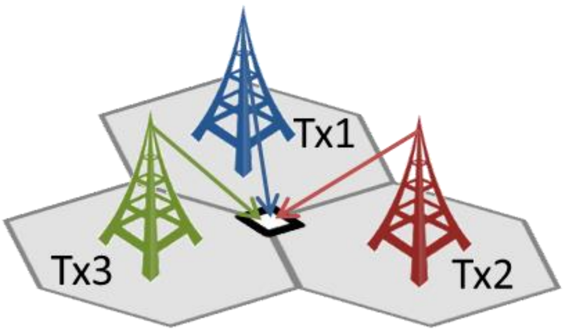


Figure 7: Three transmitter network and central pixel

Within the pixel the field strength from each transmitter will naturally vary from one receiving location to another due to location variation (e.g. signal blockage due to buildings, vegetation, etc.). Assuming there is no correlation in the signal levels generated by any of the transmitters at any location within the pixel, the field strength of each transmitter can be calculated at each location:

$$F_{ij} = \tilde{F}_i + L_{ij} \qquad (1)$$

Where F_{ij} is the field strength from transmitter i generated at location j within a pixel. $\tilde{F}_i$ is the median field strength within the pixel generated by transmitter i. L_{ij} is the value of the location dependant variation for transmitter i at location j. The location variation is approximated by a log-normal distribution of mean (μ) 0 dB and standard deviation (σ) 5.5 dB.

Table 5 shows an example of the 50%-time field strengths from each of the three transmitters that could be found at three arbitrary locations inside the central pixel, and how they were derived from a median signal level. The location variation value (L) has been randomly drawn from the log-normal distribution previously described.

The 1% time-values are 2dB higher.

Table 5: Field strengths in the central pixel, for the 50%-time levels.

	Location 1			Location 2			Location 3		
	$\widetilde{F}$ (dBμV/m)	L (dB)	F (dBμV/m)	$\widetilde{F}$ (dBμV/m)	L (dB)	F (dBμV/m)	$\widetilde{F}$ (dBμV/m)	L (dB)	F (dBμV/m)
Tx 1	70	7	77	70	-9	61	70	-8	62
Tx 2	70	3	73	70	11	81	70	5	75
Tx 3	70	-5	65	70	-3	67	70	7	77

Figure 8 illustrates the situation within the pixel where the 50%-time signal levels have plain type and the 1%-time values are italicised.

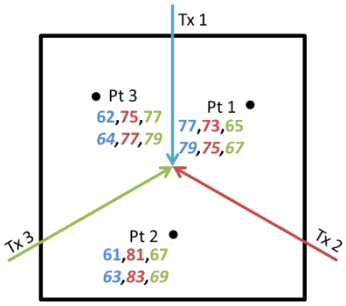


Figure 8: Field strengths in the central pixel

A1 Rx Antenna aligned with Wanted Tx; Only the Wanted Tx is Permitted to Provide Wanted Signal

In this example Tx 1 is defined as the wanted transmitter. The directional receiving antenna is then aligned to this transmitter, and only this transmitter may provide the wanted signal. Once these definitions have been made, the appropriate wanted (50%-time) and interfering (1%-time) field strengths (F_{ij}) at each location become those shown in Figure 9a. The receiving antenna, with the pattern in Figure 9b is aligned to Tx 1 at all receiving locations within the pixel. The effective field strengths ($F_{e\,ij}$) that would be received from each transmitter at each location after the receiving antenna pattern has been applied are then shown in Figure 9c.

$F_{e\,ij}$ is simply the sum of the appropriate field strength from each transmitter at each location (F_{ij}) and the appropriate attenuation of the receiving antenna pattern (A_{ij}) given the bearing between the wanted and interfering transmitters.

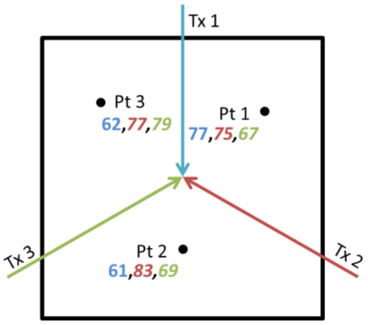


Figure 9a:

Field strengths at locations within the central pixel with Tx 1 defined as the wanted transmitter

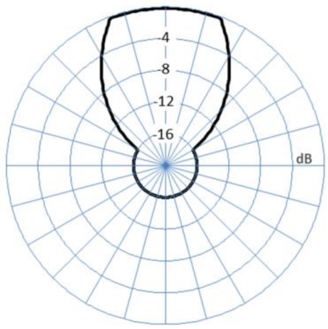


Figure 9b:

ITU-R BT.419 antenna pattern with 16 dB front to back ratio

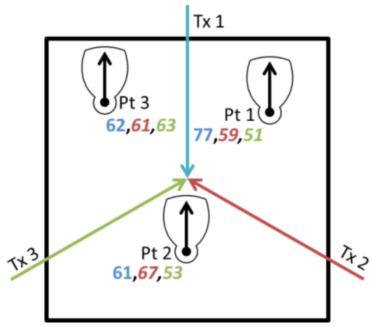


Figure 9c:

Effective field strengths (F_e) with receiving antenna aligned to Tx 1 (50%-time wanted, 1%-time interferers).

Table 6 sets out the derivation of the effective signal levels in more detail. In this example the wanted transmitter (Tx 1) would provide an SINR of 17.4 dB at location 1. At locations 2 and 3 the SINR of the wanted transmitter would be much lower (-6.2 dB and -3.1 dB respectively).

Even though other transmitters may provide a better SINR at these two locations, this methodology forbids them to contribute as wanted signals – they have been defined as interferers. In this trivial example the wanted transmitter method would conclude that the lowest SINR within the pixel would be -6.2 dB, at location 2.

Table 6: Rx Antenna aligned with Wanted Tx;
only the Wanted Tx permitted to provide Wanted Signal
Field strengths and SINR. 50%-time and 1%-time (italics) field strengths

	Location 1			**Location 2**			**Location 3**		
	F (dBµV/m)	**A (dB)**	**F_e (dBµV/m)**	**F (dBµV/m)**	**A (dB)**	**F_e (dBµV/m)**	**F (dBµV/m)**	**A (dB)**	**F_e (dBµV/m)**
Tx 1	77	0	77	61	0	61	62	0	62
Tx 2	*75*	-16	*59*	*83*	-16	*67*	77	-16	*61*
Tx 3	*67*	-16	*51*	*69*	-16	*53*	79	-16	*63*
SINR (dB)			**17.4**			**-6.2**			**-3.1**

Computing the SINR at more locations in the same way would permit a cumulative distribution of the SINR to be generated from which the desired percentile could be found.

This methodology is well suited to situations where different content is available from one or more networks in the area of interest, for example at borders between regional and national services, where it is necessary to ensure that certain content is available at particular locations.

A2 Rx Antenna aligned with the Wanted Tx; Wanted Signal Defined as Strongest Signal

In this methodology the receiving antennas remain aligned to Tx 1 (the wanted transmitter). However, the wanted signal is defined as the strongest signal at each location after the application of location variation and the receiving antenna pattern (i.e. the highest value of F_e).

Figure 10 shows what is now happening inside the pixel. Tx 1 would continue to provide the highest value of F_e at location 1 and its signal is thus defined as the wanted signal at this location. At location 2, Tx 2 would provide the highest value of F_e. The signal from Tx 2 is therefore defined as the wanted signal at location 2. At location 3, Tx 1 would provide the strongest signal. Table 7 provides more detail.

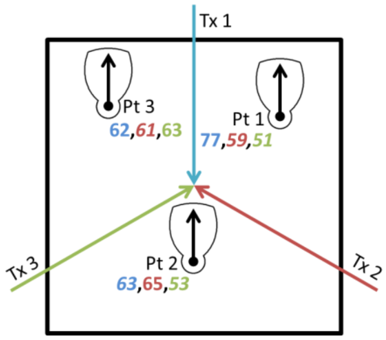


Figure 10: F_e within the pixel for the Wanted-Best Transmitter methodology

Table 7: Rx Antenna aligned with the Wanted Tx; Wanted Signal Defined as Strongest Signal Field Strengths and SINR.
50%-time and 1%-time (italics) field strengths.

	Location 1			**Location 2**			**Location 3**		
	F (dBµV/m)	**D (dB)**	**F_e (dBµV/m)**	**F (dBµV/m)**	**D (dB)**	**F_e (dBµV/m)**	**F (dBµV/m)**	**D (dB)**	**F_e (dBµV/m)**
Tx 1	77	0	77	*63*	0	*63*	*62*	0	*62*
Tx 2	*75*	-16	*59*	81	-16	65	*77*	-16	*61*
Tx 3	*67*	-16	*51*	*69*	-16	*53*	*79*	-16	*63*
SINR (dB)			**17.4**			**1.6**			**-3.1**

Defining the wanted signal to be the strongest after location variation and antenna directivity has increased the lowest SINR to -3.1 dB, an increase of 3.1 dB compared with the methodology in the previous section.

A3 Rx Antenna aligned to Strongest Tx; Wanted Signal Defined as Strongest

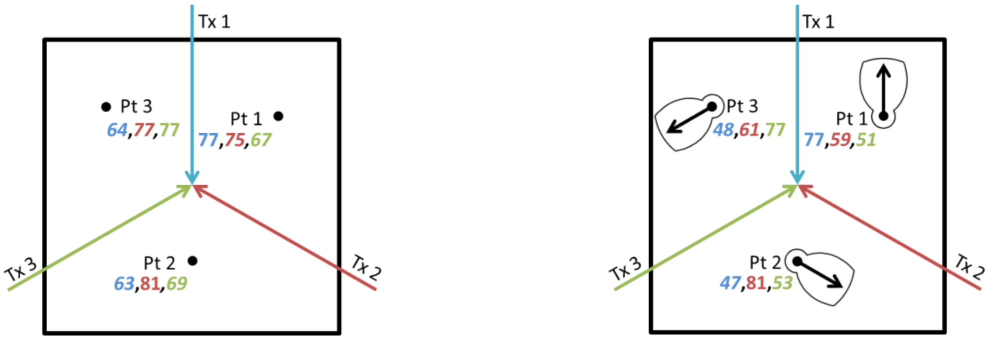
With this methodology, any transmitter may provide a Wanted Signal, and at each location the receiving antenna is aligned to the transmitter providing the highest 50%-time value of F. This is a significant additional degree of freedom, the effect of which is shown in Figure 11 and Table 8, where we can now see that a positive SINR may be achieved at all locations.

At location 1 the wanted transmitter remains Tx 1, which continues to provide an SINR of 19.4 dB as there is no better direction in which to align the receiving antenna.

At location 2 it is now possible to align the receiving antenna with Tx 2 and define this transmitter as the wanted. Doing so increases the effective field strength from this transmitter while simultaneously reducing the interfering signal from transmitter 1. The SINR at this location rises to 27 dB, up from 1.6 dB in the previous example.

Similarly, at location 3 it is now possible to align the receiving antenna to Tx 3 and define transmitter 3 to be the wanted. The SINR at this location therefore rises from -3.1 dB to 15.8 dB, even though it remains at location 3.

This methodology produces a significantly higher SINR than the other two methods considered above.



Highest value of F at locations within the pixel   Corresponding value of F_e

Figure 11: Strongest Transmitter Method

Table 8: Rx Antenna aligned to Strongest Tx; Wanted Signal Defined as Strongest Field Strengths and SINR. 50%-time and 1%-time (italics) field strengths

	Location 1			**Location 2**			**Location 3**		
	F **(dBµV/m)**	D **(dB)**	F_e **(dBµV/m)**	F **(dBµV/m)**	D **(dB)**	F_e **(dBµV/m)**	F **(dBµV/m)**	D **(dB)**	F_e **(dBµV/m)**
Tx 1	77	0	77	*63*	-16	*47*	*64*	-16	*48*
Tx 2	*75*	-16	*59*	81	0	81	*77*	-16	*61*
Tx 3	*67*	-16	*51*	*69*	-16	*53*	77	0	77
SINR (dB)			**17.4**			**27**			**15.8**

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