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WiB – A New System Concept for Digital Terrestrial Television (DTT)

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FOREWORD

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ABSTRACT

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A new system concept for DTT, called “WiB”, is presented, where potentially all frequencies within the Ultra High Frequency (UHF) band are used on all transmitter (Tx) sites (i.e. reuse-1). Interference, especially from neighbouring transmitters operating on the same frequency and transmitting different information, is handled by a combination of a robust transmission mode, directional discrimination of the receiving antenna and interference cancellation methods.

With this approach DTT may be transmitted as a single wideband signal, covering potentially the entire UHF band, from a single wideband transmitter per transmitter site. Thanks to a higher spectrum utilisation the approach allows for a dramatic reduction in fundamental power/cost and about 37 - 60% capacity increase for the same coverage compared with current DTT.

High speed mobile reception as well as fine granularity local services would also be supported, without loss of capacity. The paper also outlines further possible developments of WiB, e.g. doubling the capacity via cross polar MIMO, backward compatible with existing receiving antennas, and adding a second, WiB-Mobile, Layer Division Multiplexing (LDM) layer within the same spectrum, either as mobile broadcast or as mobile broadband.

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INTRODUCTION

Basic Principles of WiB

WiB is a new wideband reuse-1 based DTT concept, which builds on earlier work on Cloud Transmission by Wu et al [1], that is radically different from conventional DTT and seems to offer very attractive characteristics [2]. In a traditional High Power, High Tower (HPHT) DTT Multi-Frequency Network (MFN) or Single Frequency Network (SFN) a high capacity is typically transmitted per UHF channel, e.g. 33 - 40 Mbit/s with the Digital Video Broadcasting (DVB-T2) standard [3]. However, the high order modulation that is needed to carry the high capacity makes the signal sensitive to interference, which requires transmitters that operate on the same frequency to be positioned sufficiently far away and in a regular pattern. This way, their respective signals are attenuated so as not to cause harmful interference when they are received. When SFNs are used, the same principle of separation applies to groups of SFN transmitters.

A consequence of this approach is therefore that only a fraction (1:N) of the frequencies at a particular site are actually used, which is called reuse-N frequency planning (for DTT N is typically in the range 4 - 7). Unfortunately, since required power, according to Shannon [4], fundamentally increases exponentially with capacity, high-power transmitters are needed to obtain a high total capacity.

With WiB a far more power-efficient approach is employed, which is to use potentially *all* UHF channels from all transmitter sites (reuse-1) and spread out the transmitted power equally across these channels, potentially as a single wideband signal using a single transmitter, where also the existing 0.2 - 0.4 MHz (2.5 - 5%) spectral gaps between UHF channels could be exploited.

Using reuse-1 and, for example, QPSK modulation with code rate ½ allows for mobility and a spectral efficiency of about 1 bit/s/Hz. This is about the same as with an "all DVB-T2" implementation of DTT using existing types of frequency planning/reuse (assuming five 40 Mbit/s MFNs or six 33 Mbit/s SFNs). In both cases (taking overhead into account) about 200 Mbit/s can be offered within the 224 MHz of DTT spectrum (470 - 694 MHz) that remains after the 700 MHz-band release.

Simulations, however, indicate that WiB could be used with significantly higher spectral efficiency than 1 bit/s/Hz (1.37 - 1.60 ; see section on performance results, below). The use of a robust transmission mode, i.e. a transmission mode with a low required C/N, may also eliminate the need to use a Guard Interval/Cyclic Prefix (GI/CP) altogether, since at low C/N levels the gain of using a GI/CP seems to be lower than the overhead "pain".

A commonly employed DVB-T2 transmission mode is 256-QAM with code rate 2/3. However, with QPSK code rate ½ the required transmitter power (for a given coverage) is about 50 times (17 dB) lower per 8 MHz channel. The net effect of this is that a WiB signal would fundamentally only require about 10% of the *total* transmitter power (of all multiplexes) for DVB-T2, see Figure 1. There are however also other WiB gains that may further reduce the required power, see below.

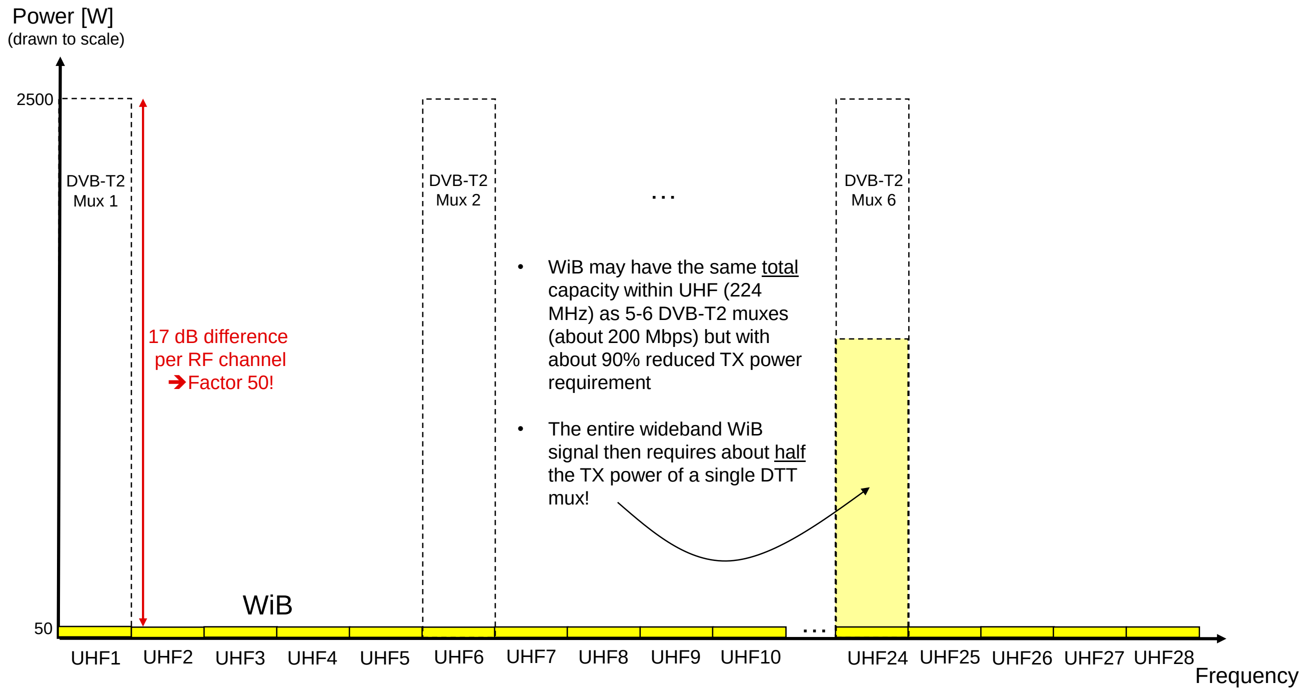

Figure 1: Required power for DVB T2 and WiB

Peak Service Data Rate and Tuner Bandwidth

Since the basic coding/modulation is restricted with WiB, due to the reuse-1, the capacity within a *single* 8 MHz UHF channel will be limited, in the order of 7 - 10 Mbit/s. To compensate for the lower capacity within a particular UHF channel it is instead assumed that a service can be spread across *several* UHF channels.

Assuming the basic tuner bandwidth is increased by e.g. a factor of four, i.e. from one UHF channel (8 MHz) to four UHF channels (32 MHz), the peak data rate could also be increased by a factor four to about 28 - 40 Mbit/s within this wider bandwidth. This should be sufficient for 4k-UHDTV services, also with features such as High Dynamic Range (HDR) and High Frame Rate (HFR).

A side-effect of the increased tuner bandwidth is an increased frequency diversity, which generally improves performance, assuming the service is appropriately interleaved across the whole bandwidth. This effect can be maximised by interleaving a service across the whole used spectrum, e.g. by using frequency-hopping techniques such as Time-Frequency Slicing (TFS), see [3] and Giménez et al [5].

It is then possible to extend the frequency diversity to involve all 28 channels within the 470 - 694 MHz UHF band (224 MHz wide), but still use a comparatively low tuner bandwidth (e.g. 32 MHz), which keeps complexity limited. The resulting TFS transmission scheme is depicted in Figure 2.

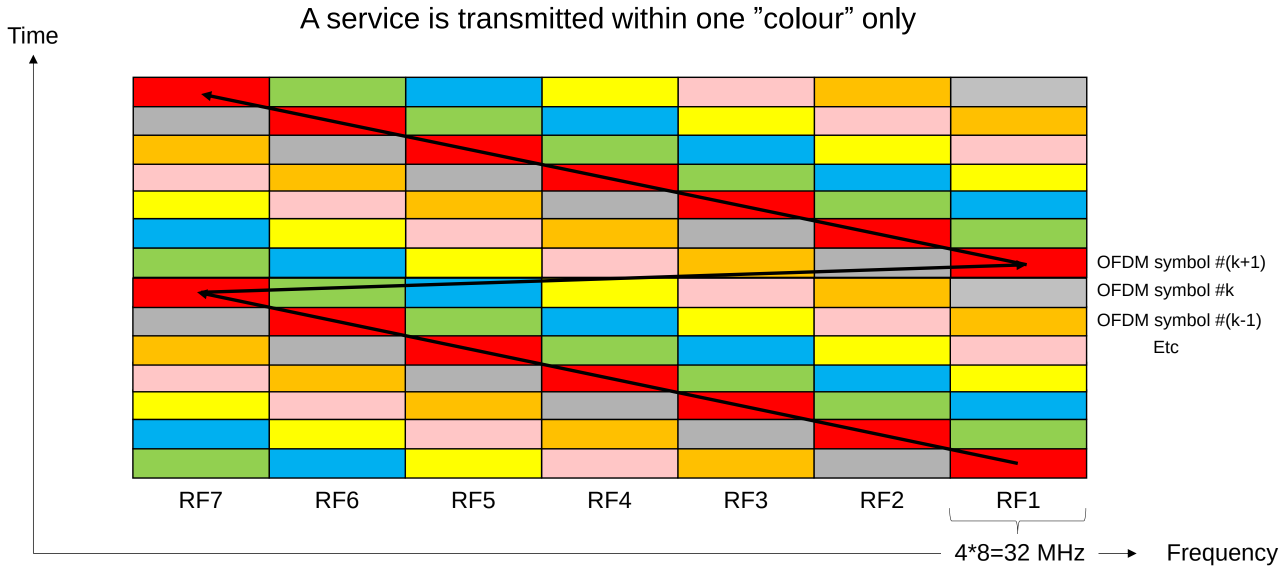

Figure 2: A possible TFS transmission scheme

Interference Considerations

With reuse-1 the receiver will experience a much lower Carrier-to-Interference ratio (C/I) than is usual for DTT and this issue must of course be seriously considered. The first tool to handle interference is the robust transmission mode (e.g. 17 dB more robust than current DTT) which, for example, may allow a C/I close to 0 dB.

The second tool (for fixed roof-top reception) is that a directional antenna typically offers a very significant *discrimination*, i.e. “attenuation” of signals in unwanted directions or polarisation. Signals from directions other than the direction aimed for (normally the wanted transmitter), are thereby attenuated compared to the wanted signal. There is an established ITU model [6] for this antenna discrimination, according to which the antenna discrimination is 0 dB in a ±20 degrees sector in the direction the antenna is pointing, then gradually increasing up to 16 dB beyond a ±60 degrees sector.

For interfering signals with opposite polarisation, the antenna discrimination is assumed to be 16 dB, irrespective of angle of arrival.

Finally, there are methods for interference cancellation, by which unwanted signals may be cancelled under certain conditions, see Interference Cancellation chapter below. It should be noted that thanks to the inherent ability to cope with interference from adjacent transmitters, the WiB concept allows potentially all transmitters to transmit different content.

NETWORK COST SAVINGS WITH WIB

Savings in Capital Expenditures (CAPEX)

Perhaps the most striking (CAPEX) cost saving results because the total required transmitter power of the *equipment* could fundamentally be reduced by about 90%, thereby considerably simplifying the infrastructure. This could e.g. allow all existing transmitters to be replaced by a single wideband transmitter having a lower power (about 50%) than *each* of the traditional DTT transmitters. Some performance requirements, e.g. linearity, of the (single) transmitter could also be greatly relaxed thanks to the robust signal, which could simplify the design of the transmitter and contribute to a higher power efficiency.

Furthermore, since the complete WiB signal can be transmitted as a single wideband signal there is no further need to use RF combiners; there could be just a single exciter and a single wideband transmitter, with a Radio Frequency (RF) filter. A 90% reduced power also reduces the cooling requirements significantly and allows for simple battery back-up power solutions for many smaller sites.

Due to the lower power/cooling/volume/weight of the overall transmitter equipment it could more easily be installed in the transmitter mast, which would eliminate the need also for RF feeders. WiB also lends itself well to be used together with “active transmitter antennas”, i.e. a group of antenna elements (or even each antenna element) could potentially have its own, very low power, wideband “mini-transmitter”, which could enable an electronically-controlled *phased array antenna*, whereby the antenna diagrams could be tailor-made and optimised to the desired characteristics.

Savings in Operational Expenditures (OPEX)

Similar to the CAPEX case, the reduced *power consumption* would be the most striking OPEX advantage, but in this case the cost reduction would lie in the reduced electricity bill. In addition to the fundamental 90% power reduction there are also other possible factors that could allow for a further reduction in consumed power, such as elimination of the attenuation in (now superfluous) combiners, feeder, RF split etc., which may amount to a total of about 3 dB and a consequent further power reduction of 50%. On top of that: increased frequency diversity may offer further power consumption gains, due to a better link budget. Depending on the type of transmitter there may also be power efficiency gains in the actual transmitter implementation due to lower linearity requirements. From a service perspective, the overall complexity of the system would be reduced since there are fewer system components and the sensitivity of these is also reduced thanks to a far more robust operation mode. Lower power may also in general increase transmitter lifetime and reduce failure probability. Furthermore, there will be less need (or no need?) for frequency changes or frequency re-planning once the network is in operation.

INTERFERENCE CANCELLATION WITH WIB

Successive Interference Cancellation (SIC)

When a target signal S1 is interfered by an equally-modulated but stronger signal S2, Successive Interference Cancellation (SIC) can be implemented by 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 signal S1 can then be demodulated. This process is possible if the actual Carrier-to-Noise+Interference ratio (C/(N+I)) of the signal to be demodulated (here S2 followed by S1) is larger than the required C/(N+I). For a 1 bit/s/Hz spectral efficiency (e.g. QPSK code rate ½) the required C/(N+I) is close to 0 dB.

The described process can be generalised and be used for any number of signals if the C/(N+I) requirement is fulfilled for every demodulated and subtracted signal. One example scenario is shown in Figure 3, where the received powers from Tx1, Tx2 and Tx3 are C1, C2 and C3 respectively and with N being noise power. The weakest Tx3 signal can be demodulated if the C/(N+I) is fulfilled in the cancellation process of the two stronger signals and the required C/N is fulfilled for Tx3.

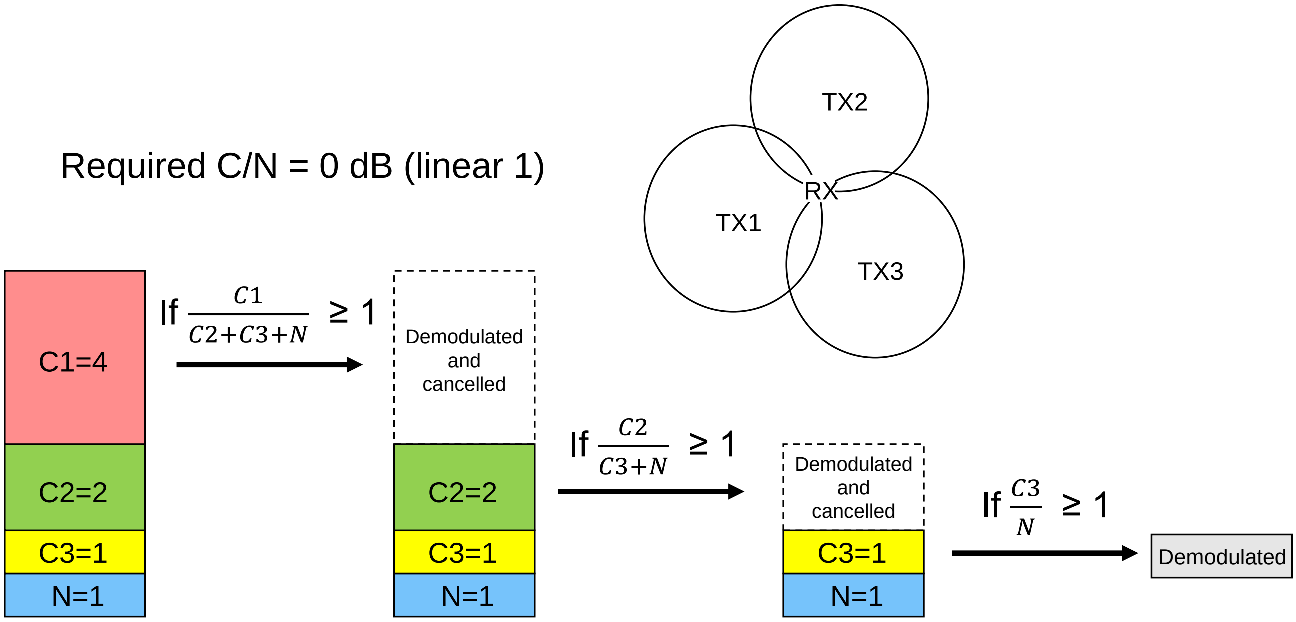

Figure 3: Example of SIC; the weakest Tx3 signal (received with power C3) is demodulated in three steps

For SIC to work in WiB (with reasonable receiver complexity), all the involved transmitted signals need to be fully synchronised with aligned Forward Error Correction (FEC) blocks, i.e. the reception situation needs to look like a traditional SFN, but with the different transmitters transmitting *different* content. To allow for SIC each received transmitter also needs to include scattered pilots that are orthogonal to all other received transmitter signals involved in the interference cancellation, i.e. there need to be at least three orthogonal pilot patterns.

The orthogonality ensures that received pilots, originating from adjacent transmitters (Tx1, Tx2, Tx3), do not interfere with each other. This is important, since it allows the receiver to properly estimate each of the channels, the result of which is then used for the following interference cancellation. One simple way of achieving orthogonality is to let each transmitter use a dedicated set of pilot pattern cells, which are unused (zero power) from neighbouring transmitters, which in turn use other sets of pilot cells. When all transmitters emit different information the required pilot density for an individual signal would only need to cover channel estimation of natural echoes, i.e. it could be very low. Then, to allow for interference cancellation, the density of pilot cells (including reserved positions to allow for orthogonality) would need to be, for example, a factor three higher than the basic very low density, i.e. still quite low.

Example: using a carrier spacing corresponding to the DVB-T2 16k mode a pilot density of 1:96 allows for the handling of natural echoes up to about 30 us. A factor three increase, to allow for interference cancellation, would imply a density of 1:32, i.e. still quite low. Even a further doubling, due to, for example, MIMO, would result in a density of only 1:16, which is also the overhead caused by these pilots.

In an SFN context a similar approach could also often be used, whereby each transmitter could transmit a sparse pilot pattern. The receiver would then assemble a joint channel estimate for relevant SFN transmitters, based on the channel estimates of the individual SFN transmitters. Thanks to the robust transmission mode it is likely that only a limited number of SFN transmitters would need to be involved.

Interference Cancellation via Beamforming (Beam-IC)

A completely different approach to interference cancellation is to use multiple receiving antennas, e.g. arranged as a phased-array antenna. Even in the simplest case, with two dipoles, these could have an electronically-controlled beam, which could dynamically maximise the C/(N+I) of the signal to be received. It should be noted that the C/(N+I) is not always maximised by employing full cancellation, due to noise amplification – but by a partial cancellation.

By extending the number of receiving antennas (and associated processing) more than one received signal (e.g. two) can be cancelled. It should be noted that this kind of interference cancellation reception can be seen as a kind of MIMO, with N transmitted signals received by N antennas and with potentially any of them (or all) being demodulated. Similar to MIMO each received signal needs a pilot pattern that is orthogonal to pilot patterns in other signals involved in the interference cancellation process.

Combination of SIC and Beam-IC

The most powerful, so far identified, approach for interference cancellation is to combine the two described variants of interference cancellation, SIC and Beam-IC, in such a way that for each signal to be demodulated the C/(N+I) is maximised by appropriately adjusting/optimising the electronically-controlled antenna for this particular signal. When this signal has been demodulated/cancelled the antenna beamforming may be re-optimised so that the C/(N+I) can again be maximised, this time for the next signal to be demodulated. All this can be performed by pure signal processing, based on a stored part (e.g. a number of OFDM symbols) of the received signals.

VARIABLE BIT RATE (STATMUXED) SERVICES USING MULTIPLE PLPs

Variable bit rate (VBR) services may be transmitted over DVB-T2 using variable bit rate Physical Layer Pipes (PLPs). With WiB, however, §Successive Interference Cancellation would not generally work with variable bit rate PLPs, since the signals from involved transmitters (varying independently) would then not be synchronised, as required.

With WiB, all PLPs have an equal and constant bit rate, and the VBR aspect is catered for by dynamically mapping a VBR service to *a variable number* of PLPs, the number being dependent on the instantaneously required bit rate of the service.

The efficiency of the statistical multiplexing would not be significantly affected by this. With WiB a large number of VBR services could thereby share a common statmux pool consisting of the 200 - 300 Mbit/s total capacity of the UHF band. This would allow for close-to-ideal statmuxing of UHD services, each having a peak data rate of up to 28 - 40 Mbit/s.

PERFORMANCE RESULTS FROM SIMULATIONS

Spectral Efficiency Limits with HPHT Network Modelling

The achievable spectral efficiency of WiB in a HPHT network was estimated via Monte Carlo simulations. The network was modelled by a homogeneous reuse-1 hexagon lattice, see Figure 4, with 60 km distance between adjacent transmitters and with an effective antenna height of 250 m.

Spectral efficiency was evaluated in the assumed worst point of the network, i.e. the mid-point between three adjacent transmitters, at 10 m above ground level, see Figure 4.

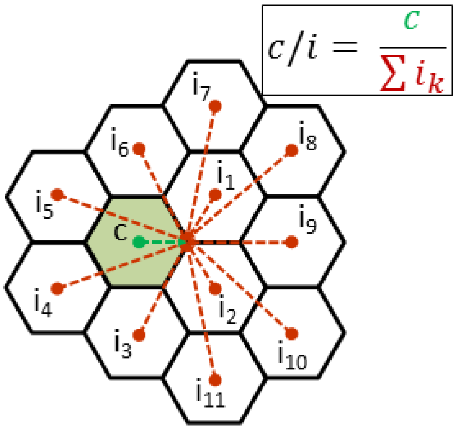

Figure 4: Hexagon Lattice

The assumed Effective Radiated Power (ERP) was 1 kW per 8 MHz UHF channel and the receiving antenna gain was 11 dBd, with discrimination according to ITU Recommendation BT.419 [6].The assumed down-lead loss and receiver noise figure were 4 dB and 6 dB respectively. The propagation model was according to ITU Recommendation ITU-R P.1546 [7] over land.

Time variations of the propagation was statistically modelled by fitting two log-normal distributions to the propagation curves given for 50% and 10%, and 10% and 1% of time, respectively. This allowed three different correlation models to be used: full inter-site as well as intra-site correlation (C), no inter-site but full intra-site correlation (U1), no inter- or intra-site correlation (U2).

Fading was statistically modelled by means of two processes. A frequency- independent but location-dependent fading was modelled as a log-normal random variable with 0 dB mean and 5.5 dB standard deviation. A site-to-site correlation model is applied to account for location-dependent fading dependence on angular position and distance between stations [8]. A frequency dependent fading process with 2 dB standard deviation was added to model potential frequency-dependent variations of the received field strength, according to Giménez et al [9]. The coverage criterion was to require reception with 95% location probability and for 99% of time at the worst point in the network. For each realisation, the C/(N+I) determined the maximum Shannon capacity that can be transmitted. In order to account for ideal frequency interleaving, the average spectral efficiency over all RF channels was calculated.

Two application cases were considered. *Best transmitter* models a receiver pointing to the best transmitter in each realisation. *Wanted transmitter* models a receiver pointing to a desired (not necessarily the best) transmitter among the three closest transmitters. The Best transmitter case corresponds to reception of e.g. national services *within* a country, or to reception of regional services, when it is considered “acceptable” to receive any of the regional services from one of the closest transmitters.

For a large proportion of the receiving locations the “Best transmitter” case may be representative, but at country borders the “Wanted transmitter” case is normally the relevant one, for natural reasons. The spectral efficiency that the WiB system can provide is calculated so that layers above the desired one can be cancelled. Since all layers (transmitters) provide the same capacity, the minimum of all of them is selected. Table 1 shows the achievable spectral efficiency with 95% location probability for 99% of time.

Table 1: WiB spectral efficiency

Time correlation type	Best Tx	Wanted Tx
Inter/Intra site (C)	3.41 bit/s/Hz	1.55 bit/s/Hz
Intra-site (U1)	3.38 bit/s/Hz	1.37 bit/s/Hz
No correlation (U2)	4.07 bit/s/Hz	1.60 bit/s/Hz

Thanks to the relatively large antenna discrimination (16 dB) the “wanted transmitter” is almost always also the strongest one, which means that interference cancellation only increases performance marginally for this use case. It is however expected that with lower antenna discrimination (e.g. a simpler roof-top antenna, portable or mobile reception) the gain by interference cancellation will be much more important.

Optimised Performance for QPSK Interfered by QPSK

In the HPHT network simulations above, all interfering signals that are weaker than the one currently being demodulated have been treated as noise. This is however a *pessimistic* assumption since the constellation is known, and this side information can be exploited to improve performance.

From an information-theoretical point of view, based on the concept of Mutual Information, one can derive the theoretically optimum performance for a general case where a QPSK signal is interfered by another QPSK signal, having an added random phase. The random phase will usually arise naturally as a result of different path delays in the network combined with interleaving, but can be added intentionally at the transmitter to avoid destructive superposition of cells at the receiver under highly correlated Line-of-Sight (LoS) propagation conditions.

This has been done and the required C/N for a given power relation of the two signals (C/I) is given in Figure 5 for a number of different spectral efficiencies (bit/s/Hz). For 1 bit/s/Hz, with required C/N=0 dB, adding a noise-like interferer at C/I=0 dB would leave no room for noise so would make the required C/N approach infinity. However, when the QPSK constellation is taken into account in an optimum way (ideal demapping) with 2-dimensional log-likelihood ratios (2D-LLRs), the required C/N becomes 6 dB.

Exploiting the knowledge of the constellation therefore seems to allow very large gains in performance. Network performance is expected to be further improved when this behaviour is exploited. Figure 6 depicts for a fixed C/I=0 dB the achievable rates assuming optimal and suboptimal de-mapping.

Depicted also for example are rates for Advanced Television Systems Committee (ATSC) 3.0 [10] with QPSK and different code rates (CRs) based on the presence of a random phase, optimal de-mapping and sum-product FEC decoding. As can be seen, ATSC codes follow closely the ideal curve.

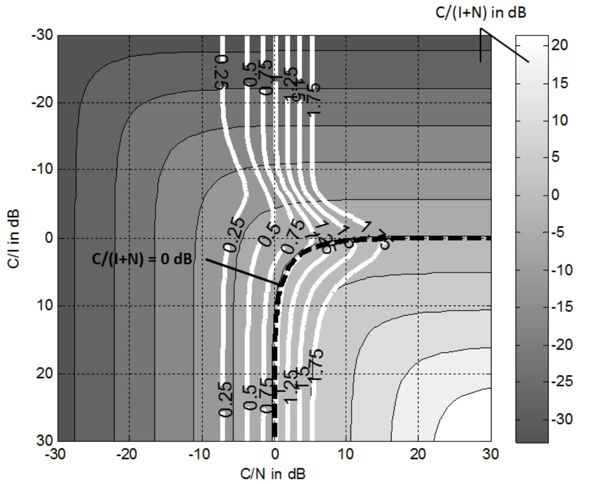

Figure 5: Achievable rates 0.25…1.75 bit/s/Hz for a two-Tx system with an applied random phase and optimal detection

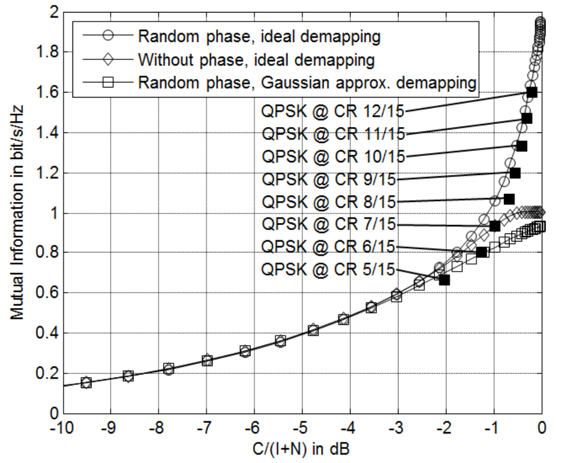

Figure 6: For C/I=0 dB, achievable rates for various de-mappers. Included is the performance with ATSC 3.0 CRs (■)

Channel selectivity considerations

It is well-known that for a given total signal power over a bandwidth B, subject to Added White Gaussian Noise (AWGN), the channel capacity is maximised when the received power is also constant over B; any time and/or frequency selectivity reduces the overall capacity.

Since real channels are often selective to some extent this could lead one to believe that the simulation results above are optimistic. However, this is not necessarily the case. One may typically assume that selectivity will appear not only on the wanted signal but also on relevant unwanted signals.

Assuming, for example, a selectivity that follows the statistic of a Rayleigh distribution, and with independent realisations for the different signals, the resulting capacity of the Rayleigh vs Rayleigh channel is actually *increased* compared to the classical AWGN case; for a spectral efficiency of 1 bit/s/Hz the required theoretical C/I is reduced from 0 dB to -3.0 dB.

When imperfect channel coding & modulation and implementation loss are also considered the required C/I will increase, but is unlikely to exceed 0 dB for 1 bit/s/Hz. If needed, an optimised selectivity could be artificially applied already on the transmitted signals in order to maximise the capacity for interference-limited reception.

RECEIVER ASPECTS

The receiver could basically be a single-tuner Orthogonal Frequency Division Multiplex (OFDM) receiver (or other Multi-Carrier system) with at least 32 MHz tuner bandwidth. The wider *virtual* bandwidth (up to e.g. 224 MHz) is either handled by TFS (frequency hopping) or by sampling at a higher rate and then performing the frequency hopping in the digital domain.

To maintain the same OFDM symbol time and carrier spacing in this 32 MHz bandwidth as with the DVB-T2 32k mode in 8 MHz, a Fast Fourier Transform (FFT) size of 2^{17} (128k) would be required. For channel estimation three different channel estimates (one for each received transmitter signal in a 3-transmitter environment) need to be handled and passed through the (cell-based) de-interleaving chain, so that the Successive Interference Cancellation process can be performed after a single “once-and-for-all” de-interleaving step, see Figure 7.

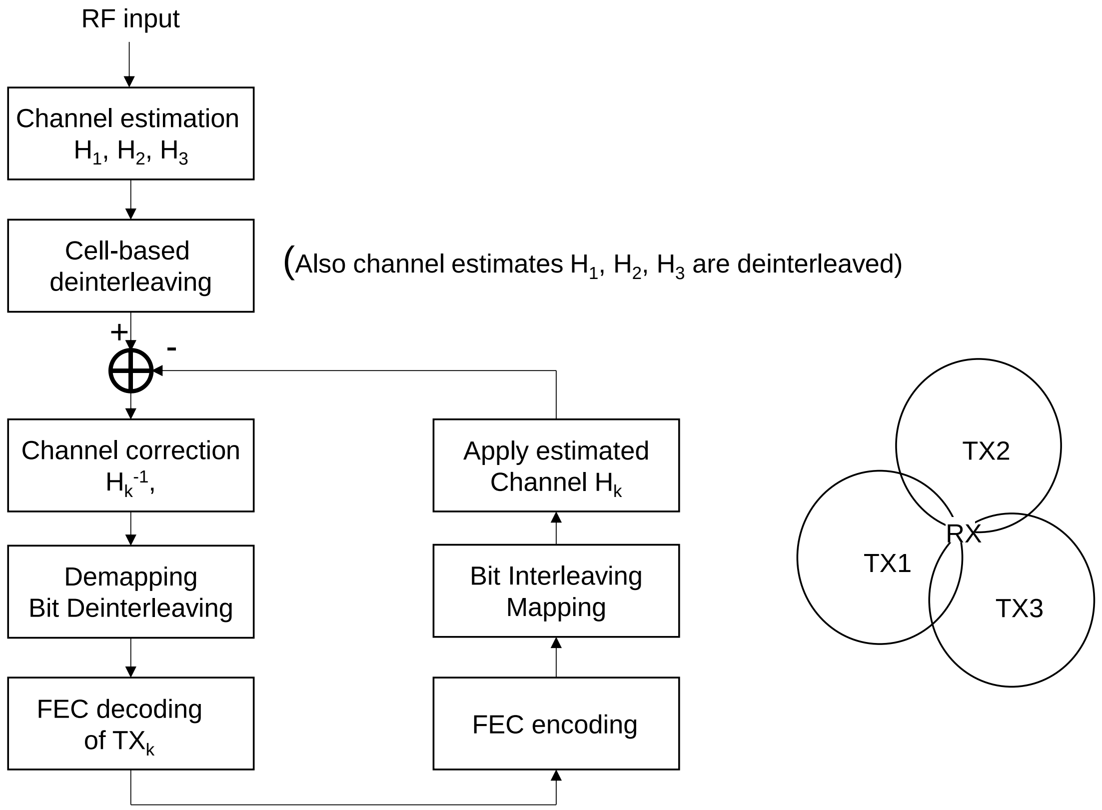

Figure 7: Simplified diagram of receiver processing of channel estimation and interference cancellation

The complexity of the fundamental FEC-decoding itself could be similar to DVB-T2 or ATSC 3.0 (or maybe lower, because of the lower expected peak bit rate) but the interference cancellation would require the basic FEC decoding to be done at a higher rate (or with more parallelism).

Considering that Moore’s law has been in action since the specification and implementation of DVB-T2 in 2009 and that it is expected to be in operation until the implementation of WiB sometime in the 2020s, the overall WiB receiver complexity does not appear to be overly high.

INTRODUCTION SCENARIOS

All migrations to new standards are more or less painful and can normally not be achieved in “one shot”; a gradual approach is typically preferred. With an *interleaved approach* WiB would be introduced in much the same way as DTT was introduced in an analogue TV context, i.e. current DTT would still be used and WiB would be transmitted with *some* power from potentially all frequencies that are not used by current DTT. The transmitted WiB power would be adjusted, for each transmitter site/frequency individually, so as not to cause harmful interference.

In a transition phase, it might be necessary to accept some degree of degradation of existing DTT, although this may also be compensated for by using a somewhat more robust transmission mode for DTT. Alternatively, WiB could be introduced by using the alternative polarisation (normally vertical), in which case interference into current DTT should be very limited or negligible.

It is possible to design WiB to allow the use of an arbitrary subset of UHF channels (the particular subset varying across transmitter sites), still allowing for interference cancellation, see Figure 8. This subset could first be small and then grow until WiB eventually might replace DVB-T/T2 altogether.

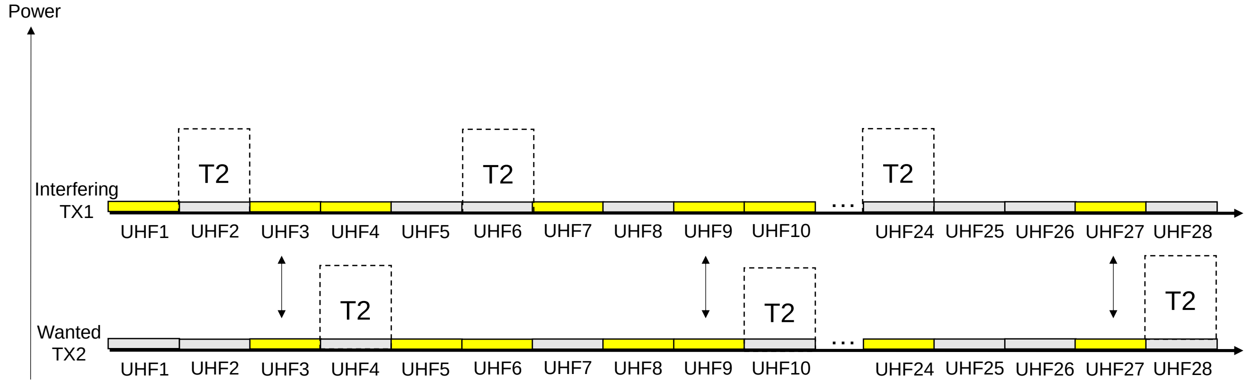

Figure 8: WiB interleaved with DTT

REPEATERS AND TRANSPOSER

In addition to the traditional HPHT stations a DTT network typically also consists of additional sites of different kinds. The main categories are:

1. Small SFN-synchronised transmitter sites with separate feeds (microwave link, satellite, fibre, …).
2. On-channel (SFN) repeater.
3. Frequency-shifting transposer.

From a WiB perspective there is nothing special with category 1 transmitter sites, above; they can be treated like the main transmitter sites and do not impose any special consideration.

On-channel repeaters should also be possible in the same way as today, although with a wider total bandwidth.

What needs special consideration is the use of transposers. These are a kind of repeater that takes a signal off-air, and retransmits it on a new frequency. Superficially it may seem impossible to use transposers in a system that already exploits all the spectrum (reuse-1). However, with special arrangements of the transmitted WiB signal it should also be possible to use transposers with WiB, provided no more than *half* of the total capacity (*category A services*) needs to be retransmitted (e.g. only public service).

When these conditions are fulfilled the transposer could retransmit category A services on frequencies originally (from the main transmitter) occupied by services not aimed for retransmission (*category B services*). The transposer could achieve this by a simple frequency shift and filtering.

FURTHER WORK, ADVANCED WIB

The basic WiB system outlined above could further be developed in a number of different ways. Here we will only mention two such directions, both of which could double the WiB capacity ; WiB-MIMO and WiB-LDM.

With WiB-MIMO, and assuming roof-top reception, one would add a second independent signal on the opposite polarisation and effectively have a dual-Single Input Single Output (SISO) signal, where one of the signals would be receivable by a legacy single-polarisation (typically horizontal) TV antenna, thanks to antenna polarisation discrimination, which is expected to sufficiently well attenuate the unwanted polarisation. By installing a new antenna both polarisations could be received. By frequency-transposing one of the two received polarised components, immediately after the antenna, the existing down-lead could be used for both components and the receiver could be a SISO receiver, which would pick a selected service from the relevant component.

In a more advanced variant it should, in some cases, be possible to receive the full MIMO capacity even with a single-polarisation antenna, provided the two signals use orthogonal pilots and the received signal strength is large enough on the weaker polarisation, taking into account the polarisation discrimination, which may however be limited on a simple antenna. In this case SIC between the two polarisations could be applied.

With WiB-LDM one would add a second, WiB-Mobile LDM layer superimposed on the WiB-DTT signal, and transmit this from the transmitters of a densified network providing mobile coverage of the WiB-Mobile signal. When the WiB-Mobile signal is a broadcast signal it would be transmitted with higher power than the WiB-DTT signal allowing a mobile receiver to receive it without demodulating the WiB-DTT signal. The weaker WiB-DTT signal would still be strong enough for rooftop reception, after cancellation of the stronger WiB-Mobile signal. However, when the WiB-Mobile signal is a unicast (point-to-point) signal, e.g. as part of 5G *New Radio*, the WiB-DTT signal needs to be demodulated first.

CONCLUSIONS

This article has presented a new DTT system concept called WiB that is based on wideband reuse-1, which allows for a potentially very large reduction of DTT network costs (both CAPEX and OPEX) whilst significantly exceeding the capacity and coverage that can be obtained with, for example, an optimised implementation of DVB-T2. In the most demanding "wanted transmitter" case, simulations indicate a possible capacity increase in the range of 37 - 60%, assuming the DVB-T2 reference can carry about 200 Mbit/s per site within the 470 - 694 MHz band.

The complexity of the receiver could be limited to that required to receive a particular service and not the entire transmitted WiB capacity. Furthermore, the WiB concept also allows for high-speed mobile reception without the need for handover or capacity loss, fine content granularity (no big SFN areas required) and a possible reduction (or even elimination) of GI/CP overhead. Finally, WiB can be extended in various ways, such as backward-compatible cross-polar MIMO, dual-layer LDM mobile/fixed reception and even with a WiB-DTT and WiB-Mobile broadband literally sharing the same spectrum.

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NOTE

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