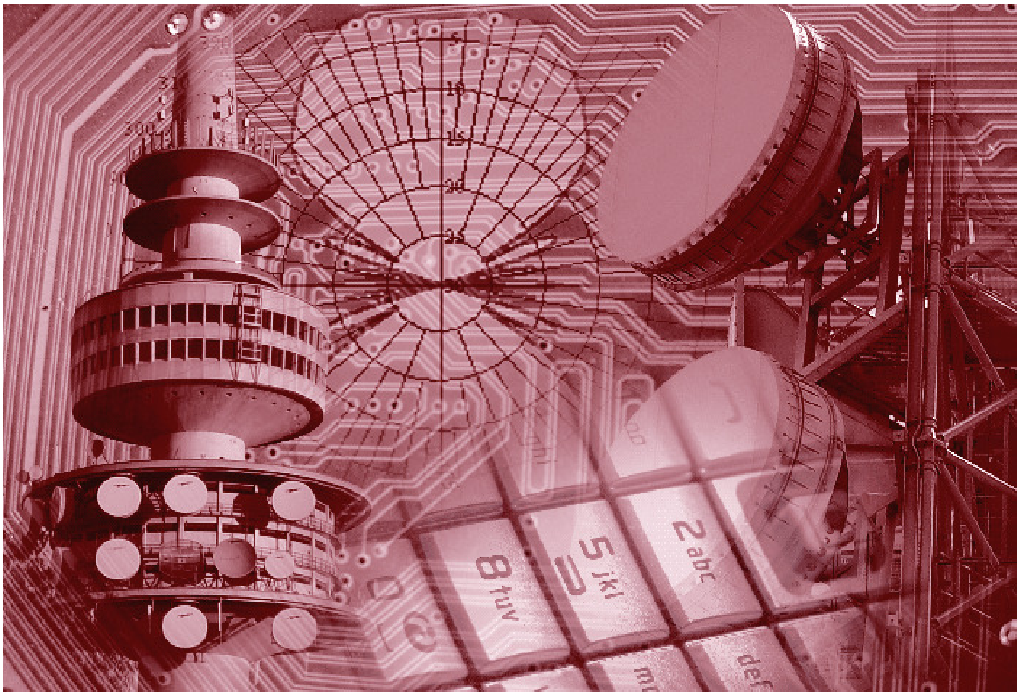
PLANNING DVB-T2

Advance and Challenge

This White Paper provides an overview of major techniques used in DVB-T2 and their impact on service planning and operation of this new transmission technology.



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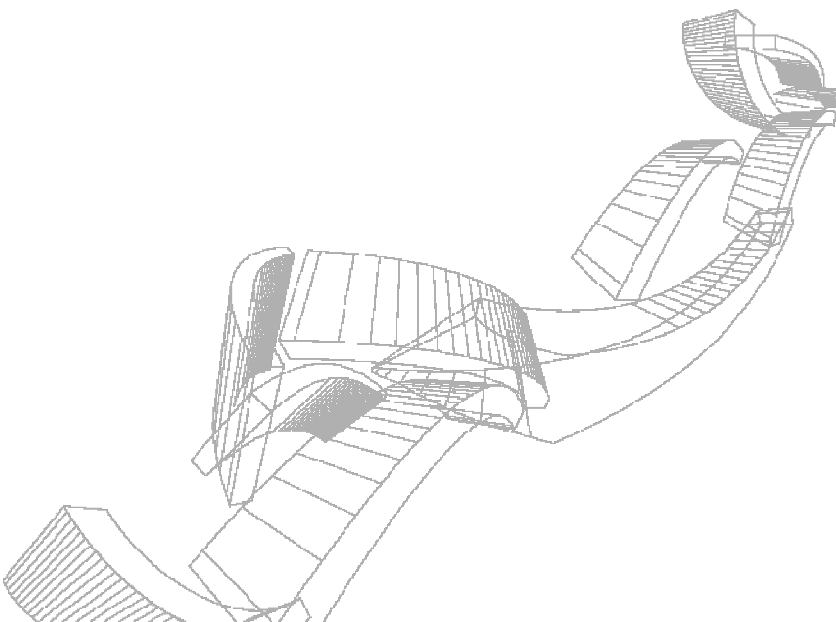

WHP01_3
Info@LStelcom.com
www.LStelcom.com

1 OVERVIEW

This White Paper provides an overview of major techniques used in DVB-T2 and their impact on service planning and operation of this new transmission technology. The first part outlines the increase in capacity through robustness gain achieved by rotated constellations and Q-delay. A study using the broadcast planning tool CHIRplus_BC illustrates the feasibility of large scale SFNs (Single Frequency Networks). The next part uses a simplistic example to show how MISO (Multiple Input Single Output) makes better use of the “SFN Gain” and how it can increase coverage. The paper closes with an evaluation of the new flexibility gained from the improved robustness when planning DVB-T2. It points out how DVB-T2 can reduce the transmission cost per program or how it can make delivery of HD services economically viable.

The appendix provides a table comparing DVB-T and DVB-T2.

2 CAPACITY IMPROVEMENT THROUGH ROBUSTNESS GAIN

DVB-T2 introduces a new technique to improve performance in channels with frequency selective fading.

The IQ constellation diagrams are counterclockwise rotated to achieve constellation points with unique values on the I and Q axis (Figure 1). The information is therefore present on both axes.

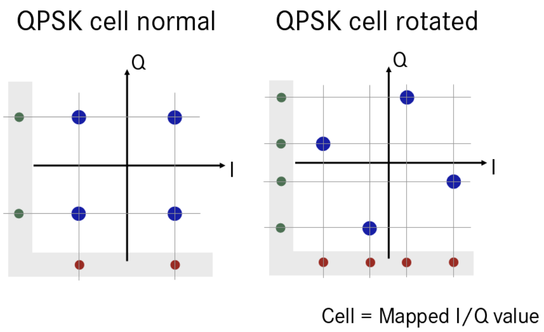

Figure 1: Non rotated and rotated QPSK constellation

But what is the practical use of this technique? In DVB-T the data bits from carriers which are severely degraded (e.g. due to fading) are lost. The FEC has to recover those lost bits. This can lead to a significant increase in the minimum field strength required to decode the signal.

Rotated Constellation is a way to significantly relieve the FEC. This technique results in more accurate detection of the data bits and therefore less errors that have to be corrected by the FEC. As a result it can use its capability for other channel impairments, e.g. noise. The trick is that the rotated constellation comes with Q-delay. After the constellation mapping (bits → QAM) the Q axis is delayed. Delay means in this context that it is shifted to the next cell as depicted in Figure 2. Therefore the information is split into I and Q values with both carrying full information but being transmitted on different carriers.

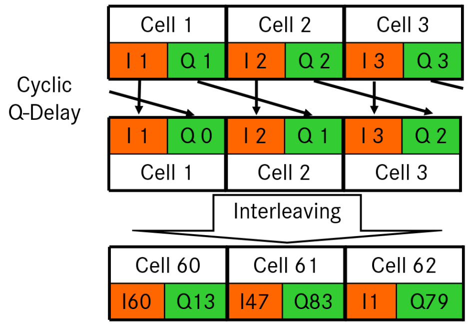

Figure 2: Q-delay (exemplary)

With the multitude of interleaver stages following this stage of the modulator both axes are transmitted on well separated carriers.

If some carriers get severely degraded only one axis is erased but the other axis is more likely to be still present. Of course, splitting the information in two parts makes each part slightly less robust than the combination of the parts. But overall the mechanism provides a significant increase of the robustness of the signal in severely degraded channels.

A worst case channel is the 0 dB Echo channel which consists of two paths with equal level and the second arriving later than the first as shown in Figure 3 below.

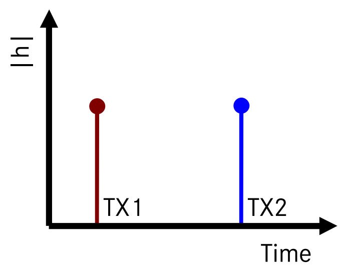

Figure 3: Channel impulse response of a 0 dB echo

Figure 4 shows the frequency selective cancelling that occur in a 0 dB echo channel.

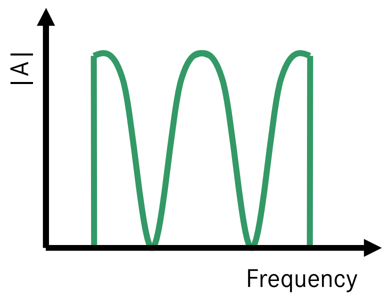

Figure 4: Frequency response of a 0 dB echo channel

The data bits on such affected subcarriers are very likely to be lost. Only the FEC can recover those bits unless the rotated constellation technique is used. Instead of requiring a 2 to 5 dB higher minimum C/N than a

Rayleigh channel it is about the same when using rotated constellations.

Let's take the concept one step further and see how rotated constellations relieve the FEC. The higher the code rate of the T2-system (i.e. the less protection it has) the larger is the decrease of the required minimum C/N achieved by using this technique. The additional robustness can be used to increase the data rate by choosing a higher code rate (e.g. for a portable reception scenario) while keeping the same minimum field strength. The additional capacity can be used to improve picture quality or to provide additional services.

3 PLANNING EXAMPLES

The following section covers three areas of DVB-T2 planning. The first part evaluates the possibility of large scale SFNs which can be significantly larger than DVB-T SFNs. The next part presents MISO operation which enlarges the coverage area. A discussion about the operational scenarios that are possible due to the improved efficiency concludes this section.

3.1 Large Scale SFNs

DVB-T offers a maximum transmitter distance in a SFN of 67.2 km. This assumes an 8 MHz channel using the 8K carrier mode and guard interval 1/4. For SISO (Single Input Single Output) operation of DVB-T2 which means each transmitter emits the same signal the maximum transmitter distance can be up to 159.6 km (8 MHz channel). At this distance significant earth curvature is present which further increases the opportunity to include more distant transmitters in the SFN.

A planning exercise using the broadcast planning tool CHIRplus_BC for a SFN to cover the two southern German states Baden-Wuerttemberg and Bavaria (470 km x 360 km) using the current DVB-T transmitter network was performed. A common propagation model as specified in Section 4 was used. Only "coordination" antenna patterns were applied, real antenna patterns would however result in more accurate coverage predictions and less interference. The power is the same as it is currently used for DVB-T. To put it into context the coverage for DVB-T is presented first. The parameters are shown in Table 1 and Table 2.

	Fixed reception	Portable outdoor reception
Modulation	16-QAM	16-QAM
Guard Interval	1/4	1/4
Max. TX distance	67.2 km	67.2 km
Code Rate	2/3	2/3
Capacity	13.3 Mbit/s	13.3 Mbit/s
Number of Programs (MPEG4)	6 SD / 1 HD	6 SD / 1 HD

Table 1: DVB-T parameters for large scale SFN planning exercise

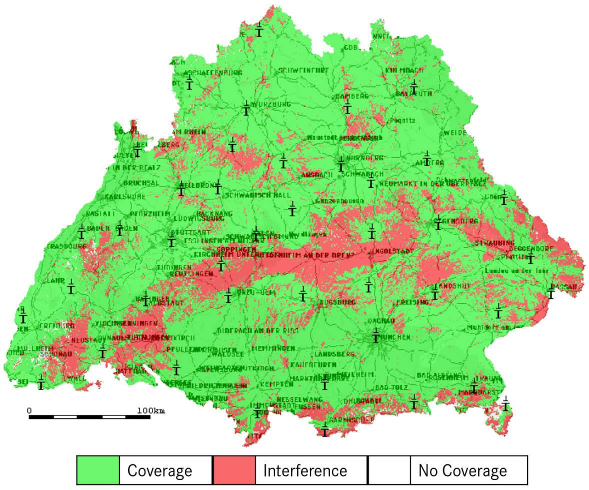

Figure 5: DVB-T coverage for fixed reception for a SFN covering southern Germany

Figure 5 shows the predicted fixed reception coverage for a large scale DVB-T SFN. Widespread interference is predicted over large parts of the coverage target area to the extent where modifications of the transmitter antenna would be insufficient to eliminate it.

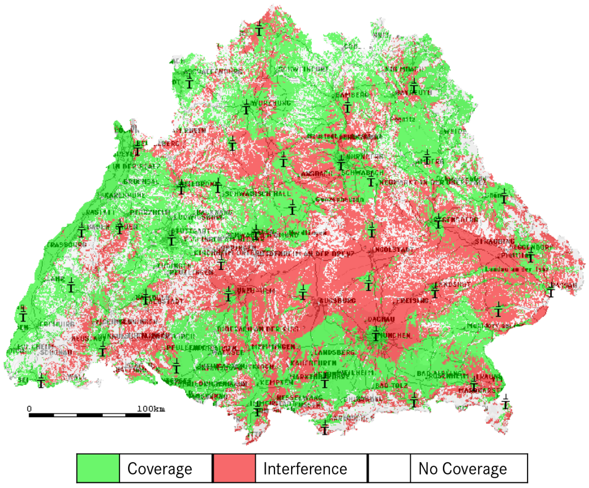

Figure 6: DVB-T coverage for portable outdoor reception for a SFN covering southern Germany

Figure 6 shows the portable outdoor reception coverage for a large scale DVB-T SFN. For portable reception even worse than for fixed reception interference dominates in the coverage target area. These coverage calculations prove that the use of DVB-T SFNs is limited to smaller areas.

	Fixed reception	Portable outdoor reception
Modulation	64-QAM	64-QAM
FFT Size	32K	16K
Guard Interval	19/128	1/4
Max. TX distance	159.6 km	134.4 km
Code Rate	2/3	2/3
Carrier Mode	Extended	Extended
Capacity	24.5 Mbit/s	22.4 Mbit/s
Number of Programs (MPEG4)	14 SD / 2 HD	12 SD / 2 HD

Table 2: DVB-T2 parameters for large scale SFN planning exercise

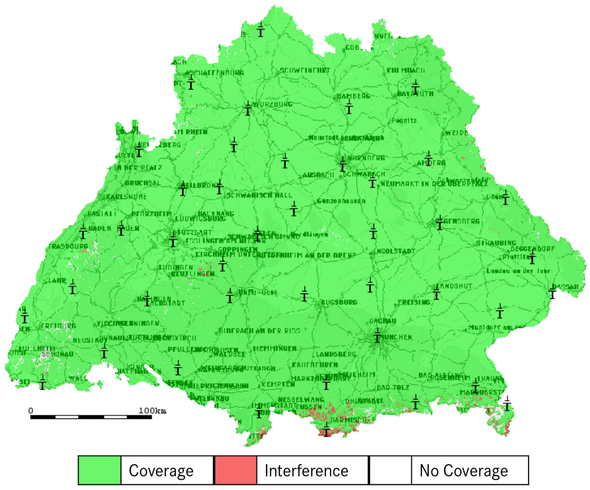

Figure 7: DVB-T2 coverage for fixed reception for a SFN covering southern Germany

Figure 7 shows the coverage for a large scale DVB-T2 SFN for fixed reception. Most areas have interference free coverage with only some very small areas showing predicted interference.

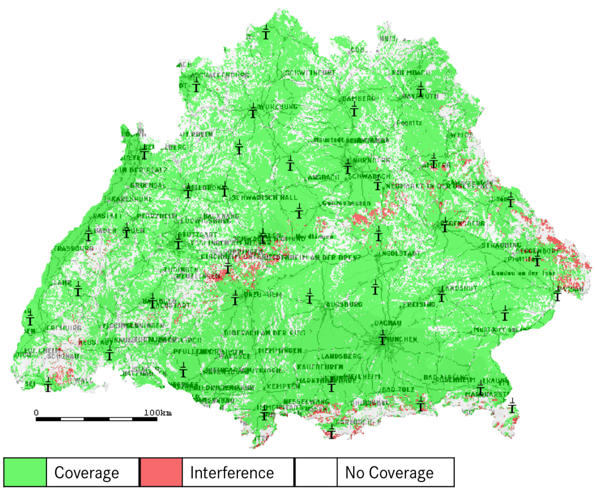

Figure 8: DVB-T2 coverage for portable outdoor reception for a SFN covering southern Germany

Figure 8 shows the portable outdoor DVB-T2 reception case. It shows that predicted interference only on some mountain ridges. As noted previously elevation antenna pattern data (down-tilts) was not used in this analysis, in general that would improve the predicted interference situation in those areas. This example points out that large scale SFNs, which are sometimes called nationwide SFNs, are a viable option. This was not the case for DVB-T.

But as coverage is just one side of the planning, coordination has also to be considered. In ITU Region 1 GE06 DVB-T Plan entries can be used for DVB-T2 as it fits under the GE06 DVB-T spectrum mask. An optimum SFN size for DVB-T2 as indicated in the example would mean larger allotment areas than the standard size in the GE06 Plan and require coordination with affected administrations. In this example the coordination is required with 14 administrations. Some of them do not even have a common border with Germany.

These large scale SFNs are available in DVB-T2 SISO mode. In MISO mode the maximum transmitter distance is limited to 79.8 km which is only slightly more than what DVB-T offered. SFN size and the use of MISO have to be carefully evaluated depending on the reception mode.

3.2 MISO Mode

During the period when technical concepts were evaluated for DVB-T2, one group of BBC engineers looked into using MIMO techniques for DVB-T2 [5]. They analyzed a dual polarization MIMO system. The results were quite promising from a technical viewpoint but to achieve the potential benefit the receiver antenna needed to be properly adjusted to use its complete potential. Unfortunately that is far from the reality that exists on most viewer's rooftops, let alone the requirement to change every television antenna in the country! Finally the commercial module of DVB-T2 set the limits by requiring that the viewer's antenna installation should be left untouched. For the receiver side it is the single antenna again, but using two antennas with different polarization or two separate transmitter locations for a multiple input system is still a valid option on the broadcaster side.

The simplest MISO technique considering the calculation power is the Alamouti coding - a two-transmit antenna system as shown in Figure 9 [9].

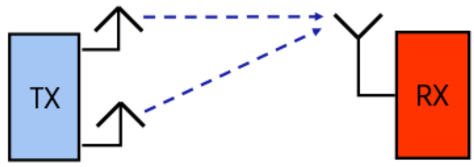

Figure 9: Alamouti MISO system

It is also called Space-Time Block Coding. The information is coded via two antennas separated in space and time. Two adjacent symbols build one block where the coding is performed. DVB-T2 uses a modified Alamouti coding transferring the concept from space-time with adjacent symbols to space-frequency with two adjacent carriers.

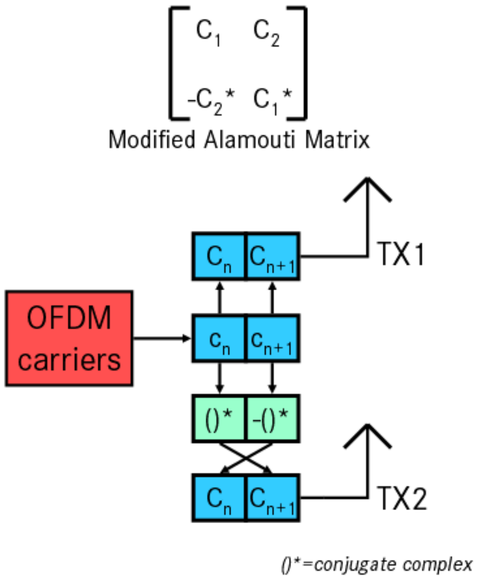

Figure 10: DVB-T2 modified Alamouti coding

Figure 10 shows that the coding is performed in pairs. Two data carriers are transmitted unmodified on TX1 while they get mathematically adapted and change position for transmission on TX2.

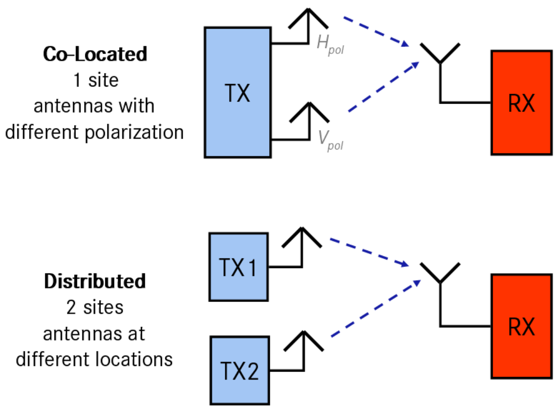

Figure 11: Co-located and distributed MISO

Figure 11 shows the possible configurations for MISO operation. The two signals can either be transmitted from the same mast on antennas with different polarization or from 2 different transmitter sites.

If the two signals correlate (DVB-T2 SISO SFN or DVB-T SFN) it leads to severe degradations of the signal which need to be compensated by higher field strength.

Areas with similar signal levels show a statistical "SFN Gain". But this gain is insufficient to compensate for this increase in the required minimum field strength. When removing this correlation using MISO the "SFN Gain" contributes fully to the coverage. Another effect also improves the coverage range of the transmitters. In areas with similar levels and a short delay between the echoes, MISO lowers the required minimum field strength relative to the non-MISO case. The total effects are shown in the following simplistic coverage planning example, based on a calculation with a statistical propagation model as described in Section 4 with the broadcast planning tool CHIRplus_BC.

Figure 12 shows that in areas with similar field strength both effects lead to an increase in coverage. The blue area results from the SFN Gain and the red area from the gain operating in MISO mode. As coverage is displayed on a "yes or no" basis the figure does not show that the SFN Gain area is also subject to some MISO gain. Therefore some extra reliability for the coverage is also added.

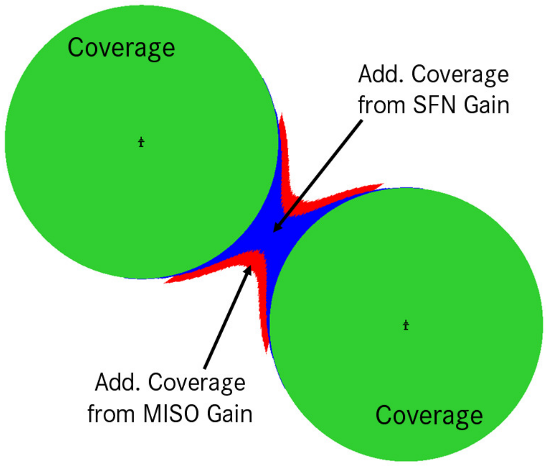

Figure 12: Coverage improvement through SFN gain and MISO gain (distributed MISO)

The Alamouti coding is based on two transmit antennas (two sites) but it can also be used with more than two transmitters. These are then divided into two groups.

Extending the MISO planning to more than two transmitters will be more of a challenge. Research is still underway to find a suitable planning model that will result in an optimum network topology i.e. assigning the transmitters to MISO group 1 or 2.

3.3 Larger coverage or higher capacity or both?

A multitude of techniques makes DVB-T2 more efficient than DVB-T. In DVB-T2 the minimum required SNR per bit (E_b/N_0) is significantly decreased. There are two possibilities to make use of it.

The first option is to hold the data rate fixed and lower the minimum field strength values. This results in a larger coverage while reducing the network costs per program because the number of transmitters can be reduced. Otherwise it can be used to provide the same coverage while reducing transmitter power and therefore reducing the network costs per program.

The second option is to use the additional robustness for increasing transmission capacities while keeping the minimum field strength the same. For the same power more data can be transmitted and therefore the costs per program are reduced, which may also improve the viability of introducing HD services.

Using the broadcast planning tool CHIRplus_BC, an example with three transmitters in the southwest of Germany was performed. The parameters are given in Table 3 and Section 4.

	DVB-T	DVB-T2 same Emin	DVB-T2 same data rate
Modulation	16-QAM	64-QAM	16-QAM
FFT Size	8K	16K	16K
Guard Interval	1/4	1/8	1/8
Code Rate	2/3	2/3	3/5
Carrier Mode	Normal	Extended	Extended
Capacity	**13.3** Mbit/s	25.0 Mbit/s	**15.0** Mbit/s
Number of Programs (MPEG4)	6 SD 1 HD	14 SD 2 HD	6 SD 1 HD
E_{min} (500 MHz; 1.5 m)	**68.4** dBµV/m	**68.6** dBµV/m[1]	62.4 dBµV/m[1]

Table 3: DVB-T and T2 portable indoor reception parameters for same E_{min} and same data rate

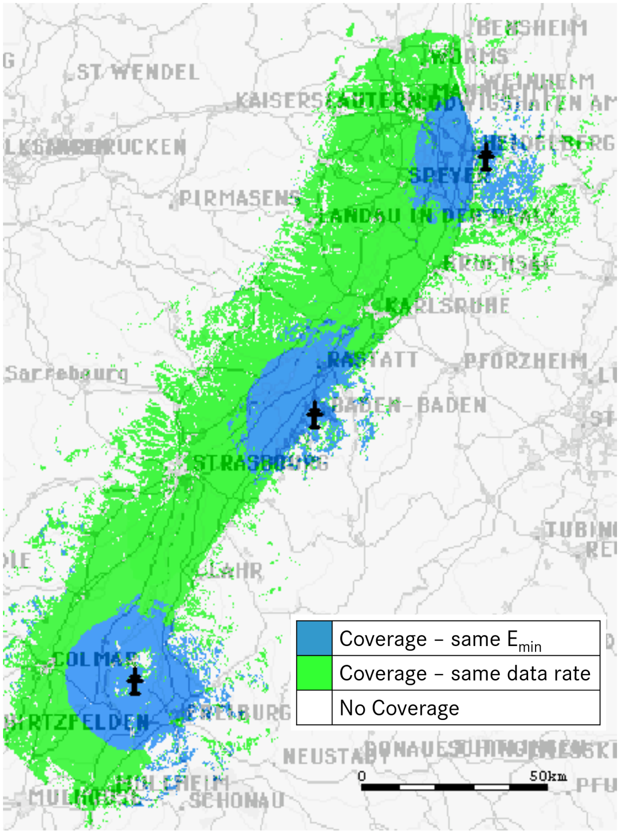

Figure 13: Coverage portable indoor reception for same E_{min} and same data rate

Figure 13 shows that a significant coverage increase for portable indoor reception can be gained when keeping the data rate constant but lowering the minimum field strength. DVB-T2 allows the noise to be 6.2 dB higher while providing slightly more data capacity than DVB-T.

It is possible to combine the two general options of larger coverage or higher capacity using the Physical Layer Pipe (PLP) concept. Using one PLP with a high capacity for HD services for fixed reception and another PLP targeting portable indoor reception with SD services is a viable option. Including mobile and fixed services would actually require a tradeoff between the services.

Especially in markets that are just commencing digital terrestrial TV (DTT) this issue should be closely evaluated.

For SFN operation the increase in data rate that can be achieved is shown in Table 4 and Table 5. The minimum field strength for DVB-T was used to find the matching DVB-T2 parameter set. The high carrier modes in DVB-T2 (8K, 16K or 32K) have the option of adding carriers on each side of the spectrum to make better use of the channel (extended carrier mode).

	DVB-T	DVB-T2
Modulation	64-QAM	256-QAM
FFT Size	8K	32K
Guard Interval	1/4	1/16
Code Rate	2/3	2/3
Carrier Mode	Normal	Extended
Capacity	19.9 Mbit/s	37.0 Mbit/s
Number of Programs (MPEG4)	9 SD 2 HD	20 SD 4 HD
E_{min} (500 MHz; 10 m)	52.5 dBµV/m	51.8 dBµV/m[1]

Table 4: Potential capacity increase of 86% for fixed reception SFN mode

	DVB-T	DVB-T2
Modulation	16-QAM	64-QAM
FFT Size	8K	16K
Guard Interval	1/4	1/8
Code Rate	2/3	2/3
Carrier Mode	Normal	Extended
Capacity	13.3 Mbit/s	25.0 Mbit/s
Number of Programs (MPEG4)	6 SD 1 HD	14 SD 2 HD
E_{min} (500 MHz; 1.5 m)	56.4 dBµV/m	56.8 dBµV/m[1]

Table 5: Potential capacity increase of 88% for portable outdoor reception SFN mode

Table 4 and Table 5 show the clear advantage of using DVB-T2. The fixed SFN mode here would allow the carriage of 4 HD (MPEG-4, 720p) services with reasonable picture quality while the portable option would allow distribution of 14 SD (MPEG-4, 576i) services. With DVB-T2 the terrestrial platform becomes a very good basis for competition with satellite or cable distribution.

[1] This value has been calculated based on GE06 Annex 3.4 and DVB A133 (Dec 09), a noise figure of 6dB and an implementation margin of 0.5 dB was used

DVB-T2 is not just limited to fixed and portable reception. Mobile reception will even be further improved as DVB-NGH (Next Generation Handheld) will be based on DVB-T2 Future Extension Frames and therefore has the possibility to share a multiplex with it.

4 PROPAGATION AND FIELD STRENGTH CALCULATION

The coverage calculations in Sections 3.1 and 3.3 are based on field strength calculations that use a propagation model based on digital terrain and land usage data. This model uses the Deygout diffraction algorithm with up to seven knife edges and empirical corrections depending on the morphology. This model is well proven with measurements [6]. The frequency is 722 MHz.

The coverage calculations on section 3.2 are based on field strength calculations performed with the propagation model specified in Recommendation ITU-R P.1546-4. This model is based on empirically derived field strength curves and the effective antenna height (h_{eff}) which takes into account terrain heights in a range of 3 to 15 km from the transmitting antenna. The calculations here used an equal h_{eff} for each direction. Terrain Clearance Angle was not used. A generalized model was preferred to provide a clear understanding of the described effect without mixing it up with propagation effects.

Minimum field strength (Emin) values in this document are for 50% time and 95% locations.

5 CONCLUSION

DVB-T2 provides data rates between 50% and 90% higher than DVB-T for the same level of robustness. The increase results from the following advances:

- Improved FEC
- Rotated Constellation and Q-delay
- Greater choice for guard interval
- Higher FFT modes (number of carriers)→ larger SFNs
- Flexible Pilot Pattern
- MISO

This definitely makes it the first choice when introducing DTT or adding HD services to the terrestrial platform.

However, accurate definition of the key parameters of the DVB-T2 system is more critical in planning DVB-T2 networks than it is for DVB-T.

The industry leading broadcast planning tool CHIRplus_BC is being constantly refined to provide accurate calculation for selection of the right SFN size and other DVB-T2 core parameters that will be vital for successful operation of DVB-T2 networks.

LS telcom offers consulting services to find the right parameter set to optimally match your business case.

6 GLOSSARY (ACRONYMS)

BCH	Bose, Chaudhuri, Hocquenghem Code
C/N	Carrier to Noise Ratio
DTT	Digital Terrestrial Television
E_{min}	Minimum Field Strength
FEC	Forward Error Correction
FEF	Future Extension Frame
GI	Guard Interval
HD	High Definition
h_{eff}	Effective Transmitting Antenna Height acc. to ITU-R P.1546-4
LDPC	Low-Density Parity-Check Code
MFN	Multi Frequency Network
MIMO	Multiple Input Multiple Output
MISO	Multiple Input Single Output
PLP	Physical Layer Pipe
PP	Pilot Pattern
SD	Standard Definition
SFN	Single Frequency Network
SISO	Single Input Single Output
SNR	Signal to Noise Ratio

7 REFERENCES

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APPENDIX T2 KEY FEATURES

The forward error correction (FEC) performance of DVB-T2 was greatly improved compared to its predecessor DVB-T It accounts for a 30% higher data capacity. Together with a multitude of new techniques an increase of the data rate of more than 50% is achieved. The table below shows the differences in detail.

	DVB-T	DVB-T2
Modulation	COFDM: QPSK, 16QAM, 64QAM	COFDM: QPSK, 16QAM, 64QAM, 256QAM
Used Bands	Band III, IV/V (VHF, UHF)	Band III, IV/V (VHF, UHF) + L-Band
Supported channel raster	6, 7, 8 MHz	1.75, 5, 6, 7, 8, 10 MHz
FEC Channel Coding	Convolutional Code + Reed Solomon Code Code Rates: 1/2, 2/3, 3/4, 5/6, 7/8	LDPC Code + BCH Code Code Rates: 1/2, 3/5, 2/3, 3/4, 4/5, 5/6
FFT Size	2K, 8K	1K, 2K, 4K, 8K, 16K, 32K
C/N range (Rice channel)	5 dB (QPSK 1/2) to 23 dB (64QAM 7/8)	3 dB (QPSK 1/2) to 24 dB (256QAM 5/6)
Pilot Pattern	1 Pilot Pattern	8 Pilot Patterns: PP1 to PP8 PP1: identical to DVB-T (~8% overhead) PP7: 1/12 of DVB-T (~1% overhead)
Guard Intervals	1/32, 1/16, 1/8, 1/4	1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4
Max. Tx Distance in SFN (8 MHz channel)	67.2 km (8K mode)	159.6 km (32K mode), 134.4 km (16K mode)
Signal Bandwidth	5.71, 6.66, 7.61 MHz	1.54, 4.76, 5.71, 6.66, 7.61 , 9.51 MHz (normal) 1.57, 4.86, 5.83, 6.80, 7.77 , 9.71 MHz (extended) Extended bandwidth used in 8K, 16K and 32K mode for higher bitrates through less guard bands.
Service Specific Robustness	Very Limited If using Hierarchical Modulation it is possible but not very flexible.	Physical Layer Pipes (PLP) Data is split in PLPs which can have different Modulation, FEC Code Rates and time interleaving depth.
Interleaving	Bit + Frequency Very small interleaving only within one OFDM Symbol is performed.	Bit+ Cell+ Time + Frequency Interleaving depth from 70 ms in Mode A (single PLP) up to more than 200ms in Mode B. In case of multi frame interleaving >500ms possible for low data rate PLPs.
Diversity	SISO, (SIMO if diversity receiver)	SISO, MISO, (SIMO, MIMO if diversity receiver)
Rotated Constellations	–	Significant robustness gain in channels with severe degradations (multipath, SFN operation, narrow band interference, ...)
Mode for Extensions	–	Future Extension Frame (FEF) Allows something completely different in between T2-Frames e.g. for Next Generation Handheld (DVB-NGH) or transmitter signatures.
Max Bit Rates (8 MHz)	31.7 Mbit/s (8K, 64QAM, CR=7/8, GI=1/32)	50.3 Mbit/s (32Ke, 256QAM, CR=5/6, GI=1/128, PP7)
Used Bit Rates (8 MHz)	Portable SFN: 13.3 Mbit/s Fixed SFN: 19.9 Mbit/s Fixed MFN: 24.1 Mbit/s	Portable SFN: 25.0 Mbit/s Fixed SFN: 37.0 Mbit/s Fixed MFN: 40.2 Mbit/s
GE06 compatible	GE06 planning based on DVB-T	Signal is under the mask of DVB-T (power level measured in a 4 kHz bandwidth)

Table 6: Parameter comparison between DVB-T and DVB-T2