DTT Systems Comparison Study

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Abstract – Digital Terrestrial Television (DTT) is a digital technology that refers to the transmission and reception of video and audio information by means of digitally modulated signals over land. DTT provides different interactive services, better quality picture and sound in the same amount of frequency bandwidth required by analog television. In 2006 South Africa's Minister of Communications gazetted a policy for applying a switch over to the European system, DVB, which has already been adopted by over 120 countries over the world. However, a renewed debate recently revealed that the adoption decision has to include the Japanese and Brazilian ISDB-T standard. There have been some concerns raised as a result of this revision which include: South Africa possibly failing to meet the agreed ITU switch over dates, and local industry potentially writing off over R700million they have invested in producing DVB set-top boxes, plus other infrastructure investments. This is a lamentable situation, and industry stakeholders in South Africa and across the SADC have expressed their concerns and dissatisfaction. In this article we present an analytical comparison of the two standards in terms of their architecture, parameters and the costs related to set-top boxes. We also detail our recommendations as academia regarding the factors to be considered for the standards to be adopted.

Keywords: OFDM, DTT, SFN, DVB-T, ISDB-T, DVB-T2, STB, ITU, SADC, FFT

I. INTRODUCTION

The purpose of digital terrestrial television (DTT), similar to digital versus analogue in other platforms such as cable, satellite, telecoms, is characterised by reduced use of spectrum and more capacity than analogue, better-quality picture, interactive capabilities and lower operating costs for broadcast and transmission after the initial upgrade costs. A terrestrial implementation of digital television technology uses aerial broadcasts to a conventional antenna (or aerial) instead of a satellite dish or cable connection. Competing variants of DTT technology are used around the world. Advanced Television Standards Committee (ATSC) is used in North America and South Korea. ISDB-T is used in Japan, with a variation of it Brazil, Peru, Argentina, Chile, Venezuela, Ecuador and most recently, Costa Rica and Paraguay. DVB-T is the most prevalent, covering Europe, Australia, New Zealand, Colombia, Uruguay and some countries of Africa. DMB-T/H is China's own standard (including Hong Kong, though Hong Kong's cable operators use DVB). The rest of the worlds including South Africa, remain mostly undecided with many countries evaluating multiple standards. ISDB-T is very similar to DVB-T and can share front-end receiver and demodulator components. The United States of America has switched from Analogue to Digital terrestrial television, as have several European countries, with the rest hoping to have completed the switchover by 2015. In South Africa there is need for the government, industry and citizens to make a decision on which standard they will be adopting. At the moment the two standards under consideration are ISDB-T and DVB-T. There have been preliminary investigations and tests of the two systems in South Africa over the years and according to the available information, the standard of choice would have been DVB-T, before the recent announcement of a new standards review. In this report we present a descriptive technical comparison of the ISDB-T and DVB-T standards. We also look at the set-box costs to the general population and detail our recommendations. In Section 2 we present a technical comparison of the two systems by in terms of spectral efficiency, data throughput and network implementation. In Section 3 we look at an alternative to the two standards and introduce a second generation DVB-T2 advanced DTT option. In Section 4 the costs of the set-top boxes are compared and the impact it would have. In Section 5 some recommendations are presented, based on our findings.

Analysis was done focusing only on the 8 MHz channel bandwidth, as South Africa and the rest of the SADC countries are all signatory members to Geneva 2006 (GE-06) and has to conform to the international coordination of ITU Region 1, which has a UHF broadcasting frequency plan based exclusively on a 8 MHz channel bandwidth.

II. OFDM PARAMETERS AND SFN IMPLEMENTATION

Unlike pathloss or shadowing, which has large attenuation effects due to distance or obstacles, fading is caused by the reception of multiple versions of the same signal. The various received signals are caused by reflections referred to as multipath. Depending on the phase divergence between the received signals, the interference can either be constructive or destructive.

The basic idea of multicarrier OFDM modulation is quite simple and follows naturally from the competing desires for high data rates and Inter-symbol Interference (ISI) free channels. ISI occurs different transmitted signals/symbols overlap. To achieve an ISI free channel the symbol time has to be larger than the channel delay spread ($T_b > \tau$). To avoid this problem OFDM modulation divides the high-rate bit stream into lower-rate substreams ($\frac{T_b}{L} \gg \tau$) and adds a guard period to each symbol. This redundancy, also called adding a cyclic prefix (CP), allows the receiver to receive and demodulate the signal for a longer time. Since the OFDM symbol is a linear combination the cyclic prefix is added once, after the IFFT operation. In OFDM based Digital Terrestrial Television (DTT) systems, the length of this interval is usually variable and depends on the maximum expected delay spread time or channel response. Longer reflection paths require larger guard intervals. However, as the size increases, the data throughput decreases.

A. OFDM Carriers

The following section describes the differences between the DVB-T and ISDB-T technologies, specifically focusing on the subcarrier utilisation in the OFDM symbol structure. Using more OFDM carriers reduces the carrier spacing within the channel bandwidth which results in a larger symbol duration. Since the estimated delay spread time or cyclic prefix is a fraction of the symbol time, it is clear that larger symbol durations increases the ISI propagation distance (d_{delay}). ***Eq. 1*** formulises the theoretical relationship between the distance an electromagnetic wave will travel, as a function of the utilised subcarriers (L) in an OFDM symbol assuming c ≈ 3 x 10^8.

$$\Delta f = \frac{BW}{L} \qquad \text{(frequency spacing)}$$

$$T_b = \frac{1}{\Delta f} \qquad \text{(useful symbol time)}$$

$$T_g = G \times T_b \qquad \text{(guard interval time)}$$

$$d_{delay} = c \times T_g \qquad \text{(guard interval delay distance)}$$

$$d_{delay} = c \times \left(\frac{G \times L}{BW}\right) \quad \text{with} \quad d_{delay} \propto L \quad (eq.1)$$

Using ***eq.1*** and the OFDM parameters in ***Table 1***of Appendix A the coverage distance resilient to ISI for ISDB-T is calculated and the results presented in ***Table 2*** of Appendix B. The same calculations were done for the DVB-T standard and the results are shown in ***Table 3*** of Appendix B.

For longer guard intervals the maximum distance between transmitters in a single frequency network (SFN) increases without risking the effect of ISI. As previously argued, DVB-T defines longer guard interval durations as ISDB-T, which allows the deployment of more SFNs over larger coverage areas. Results indicate that DVB-T has a 19% larger SFN network area than ISDB-T.

In the most robust configuration available for both standards, DVB-T outperforms ISDB-T by 1.9db regarding transmitter power efficiency. Looking at the maximum net data rate configuration, it is also clear that DVB-T has a 2.9db transmitter power advantage over ISDB-T. [1]

B. Data Throughput Performance

DVB-T has a 2% data throughput performance edge over the ISDB-T technology. These performance values and parameters are given in the respective tables from the ITU-R BT.1306-4 documentation. [1]

A comparison between the Shannon limit for the three standards also validates this argument indicating that DVB-T has a slight edge over ISDB-T and that DVB-T2 outperforms both in extended mode. The Shannon formula used to calculate the upper limit is shown in ***eq.2***. The results are shown in ***Figure 1*** below.

$$C = B \log_2(1 + S/R) \qquad \text{(eq.2)}$$

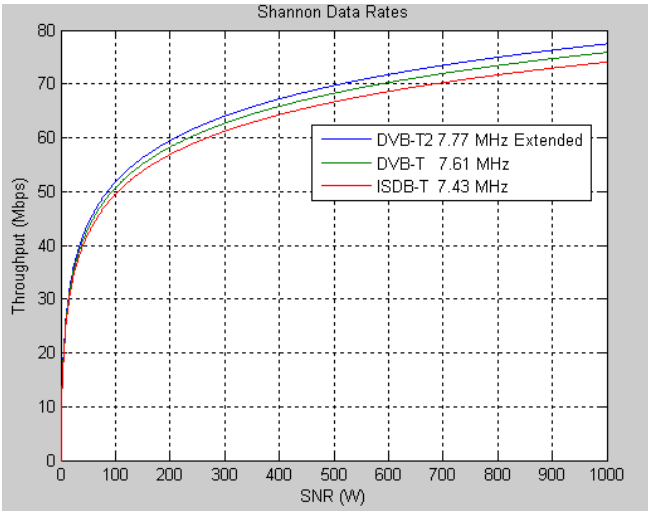

Figure 1: Shannon upper limit comparison between DVB-T2, DVB-T and ISDB-T

In conclusion, these results indicate that DVB-T is more efficient regarding transmitter power and delivers greater data payload over larger ISI free distances. While larger guard interval durations have the disadvantage of affecting data throughput performance, DVB-T still outperforms ISDB-T. DVB-T also allows for the roll out of more efficient SFNs, which entails the deliverance of substantially better coverage at a lower network infrastructure cost.

III. DVB-T2 Advancements

This subsection focuses on the fundamental technological differences between DVB-T and DVB-T2 second generation terrestrial television broadcasting. This second generation standard is significantly more complex and structured differently in comparison to the DVB-T technology. Essential improvements of the new DVB-T2 specification compared to DVB-T include high order modulation modes, improved error correction strategies, pilot overhead reduction, addition to preambles for synchronisation and signal detection enhancement. Furthermore, it has the benefit of spectral and capacity efficiency, since the extended mode allows for an increased number of utilised carriers. The outer end of the OFDM signal spectrum can be extended, since the rectangular part of the spectrum rolls off more quickly for higher FFT-size options. The DVB-T2 group has focused on designing an advanced physical layer in order to have increased bit-rates, targeting HDTV services. This resulted in an improvement of more than 40% over DVB-T. [7]

A new complex I/Q plane rotated constellation technique gives an added advantage of component recovery, since theI and Q components are interleaved and transmitted on different frequencies at different times. Each axis on its own can determine which point was sent. Long sequences of data will not be disturbed by impulse noise or frequency selective fading, since bit, cell, time and frequency interleaving protects the signal from these occurrences.

The DVB organisation defined a set of commercial requirements which acted as a framework for the T2 developments, which are compatible with the provisions of GE-06 agreement and provides high flexibility in system configuration, increased broadcasting interactivity and a wide-ranging trade-off of minimum C/N levels and transmission capacity. Other DVB-T2 Advancements include:

- Increase in capacity through robustness gain achieved by rotated constellation and Q-delay.
- Improving SFN coverage gains by implementing MISO.
- Increased transmission data rates
- Bandwidth and frequency flexibility.
- Enhanced PARP reduction techniques in order to reduce transmission costs.

Features added to the COFDM principles include:

- Frame structure with preambles for signalling
- Flexible pilot structure
- MISO
- Rotated constellation
- LDPC + BCH coding
- PHY layer Time Slicing and Frequency Slicing
- Flexible FFT, GI and Modulation combinations
- Per service coding and interleaving

A. *Extended carrier mode*

The rectangular part of the spectrum rolls off more quickly for a larger FFT-size, which extends the outer ends of the OFDM signal's spectrum. This in effect produces spectrum gains between 1,4% (8 K) and 2,1% (32 K). The extended-carrier option has the added advantage of increasing data capacity. However, it is only applicable to the 8k, 16k and 32k FFT modes.

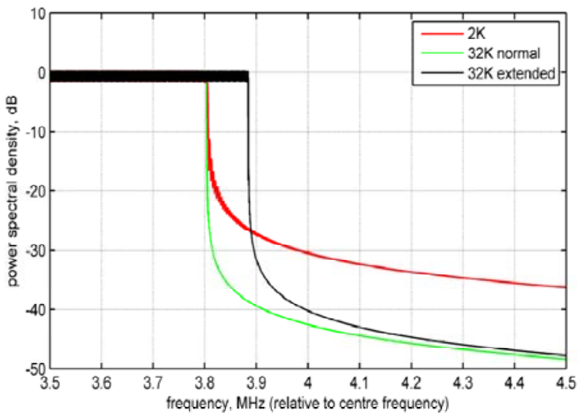

Figure 2: DVB-T2 Extended Carrier Mode

B. *Choice of Guard interval*

DVB-T2 offers additional guard interval options in order to support a range of broadcasters' needs. A larger number of available guard-interval cases in DVB-T2 allows for use where the maximum guard interval is wanted while using a particular FFT size and pilot pattern. These additional cases push the frequency-interpolation process (used in channel estimation in the receiver) closer to the fundamental Nyquist limit and allows for more efficient operation.

C. *Conclusion*

The analysis of the ITU-R BT. 1306-4 documentation confirms that DVB-T outperforms ISDB-T by some margin making DVB-T superior to ISDB-T. DVB-T2 is clearly superior to both and requires virtually the same transmitter power than DVB-T (or ISDB-T) to deliver a net data rate 50% greater than what can be delivered via DVB-T and ISDB-T in the same 8 MHz channel bandwidth (1.7 dB greater C/N required to deliver 59% more net data rate). DVB-T2 can be deployed in much larger SFNs providing for even greater spectrum efficiency. DVB-T2 second generation technology is far more superior to both ISDB-T and DVB-T.

IV. Set Top Boxes Prices

The price and costs related to set-top boxes is of great interest when considering which DTT standard to adopt. The expenditure on receivers far exceeds expenditure on transmitter networks in all scenarios. The receiver cost is the most important criteria, particularly for developing countries like South Africa and other Southern African countries. Receivers must be affordable otherwise, digital transition will fail. Low cost receivers mean higher early penetration and rapid transition. Even if all new TV sets have built-in digital terrestrial TV, the replacement cycle for TV sets is typically 10 years or more. Set-top boxes offer a crucial way to kick-start the transition to digital TV and consumers like low-cost STBs, because they avoid the need to replace TV sets. Affordable STBs are the key to rapid adoption of digital TV. Users can benefit from mass-deployment in other countries, which drive the price of STBs down. For several years, Brazilians have acknowledged that ISDTV-T STBs are too expensive, whilst also predicting that STBs "will soon cost $50" [8]. In 2010, ISDB-T STBs in Brazil still cost $160 or more [8]. DVB-T2 STBs are now available in the UK at retail prices starting at £80 (US $120) [9]. This price differential is puzzling because DVB-T2 is much more complex than DVB-T and is a brand new technology. However, one can reasonably assume that the very wide deployment of DVB-T has a significant influence and the same chipset manufacturers would be looking at the DVB-T2 market as well.

At the SADC meeting in Luanda, the Brazilians explained that *"there was no demand for set-top boxes – and that is why they are expensive* [8]*"*. In practice as other parties explained, the demand is probably so low because set-top boxes are too expensive. At the Lesotho meeting, the Brazilians admitted that in 2007 there were more than 20 suppliers of STBs for Brazil, but now there are only 2 suppliers (clearly a "failed" market) [12]. The Japanese TV market is already saturated (and dominated by expensive HDTV sets). Hardly any STBs are sold in Japan. Digital TV has not yet become a major success in Brazil, but it is also dominated by HDTV sets. Hardly any STBs are sold in Brazil too. It is argued that if you adopt an 8 MHz variant of ISDB-T, you will lose the economies of scale because the receivers would not be compatible with those used in Japan or Brazil (both use 6 MHz channels). It is difficult to exactly match the economies of scale offered by DVB's mass markets around the world. However, the number of DVB-T receivers in use in Europe totals about 200 million and the global total is likely to exceed 250 million this year. DVB-T has already been implemented in more than 40 countries, including: Botswana, Mauritius, Namibia, Kenya & Tanzania [11].

We have frequently heard claims that *"ISDB-T is free to the world"*. The truth is that ISDB-T receivers necessarily include several patents that require payment of royalties to the patent owners, such as OFDM (the basic modulation system) and MPEG-2 and/or MPEG-4 AVC video compression. The developers of ISDB-T cannot give away the rights to patents owned by others. DVB-T receivers are subject to the same patents and ISDB-T is subject to the same royalties as DVB-T. DVB's success is based on open markets and hundreds of suppliers serving mass markets around the world (not just Europe). Intense competition ensures lowest prices for consumer equipment and for professional equipment, such as transmitters, modulators, multiplexers, etc. Mass markets benefit manufacturers because it gives them more opportunities for export. A manufacturer in South Africa (Altech UEC) has already apparently exported 4 million DVB-T set-top boxes (without any domestic market) [10]. There is also need for governments to invest in subsidies for manufacturers and citizens to promote the migration. Technical expertise also needs to be assembled or trained in order to facilitate for the migration and the continued maintenance and operations of the equipment for which ever standard is to be adopted. South Africa has quite a lot of experts in DVB-T who are currently working for most of the manufacturers and broadcasting companies. ISDB-T expertise is not very much pronounced within South Africa, although the Brazilians and Japanese suggested that they would offer South Africans training of their standard.

V. Recommendations

We would like to propose that the following be considered to assist with clarification of the present SA situation:

- Detailed testing and analysis of the two standards over set parameters and scenarios.
- Consideration of the set-box pricing and availability (economies of scale).
- Considerations of government subsidies for stakeholders within this market.
- Vision of potential growth of the South African electronic manufacturing companies through manufacturing of the set-top boxes.
- Harmonisation of the standards within the SADC member states.
- Consideration of previous investments by business and government stakeholders.
- Consideration of available local and international expertise to manage the transition and maintain the new system or standard.
- The current situation and relative prevalence of standards adoption in the rest of the world cannot be ignored. Issues such as availability of equipment from multiple, competitive sources and associated expertise, should be considered in any rational decision making process.

VI. Conclusion

The adoption of the next standard for South Africa and whether South Africa will make it in time to meet the 2015 deadline, is a decision involving all role players, such as government, industry, academia and the broad community, but the ultimate responsibility lies squarely with government. This article is an attempt to clarify the fundamental differences within the OFDM structures of both ISDB-T and DVB-T, and to explain the impact on data throughput and network infrastructure. Results indicated that DVB-T slightly outperforms ISDB-T. The latest DVB-T2 system is, however, far more superior.

Digital broadcasting and digital migration is all about content, communication and a service to the greater public. If this service is poor and access to the service too expensive, South Africa is most likely to end up in a situation where the uptake is low with little public interest. It is fundamental to the citizens of the SADC that the next 40 years or so of digital terrestrial broadcasting, are driven by sound decisions.

VII. References

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VIII. AUTHORS

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Appendix A

Table 1: Comparison between ISDB-T, DVB-T and DVB-T2 Parameters

	Parameters	**8 MHz DVB-T multi-carrier (OFDM)**	**8 MHz DVB-T2 multi-carrier (OFDM)**	**8 MHz ISDB-T multi-carrier (segmented OFDM)**
1	Used bandwidth	7.61 MHz	7.77 MHz (extended) 7.61 MHz (normal) (extended mode for FFT 8k and higher)	Bw × Ns + Cs 7.434 MHz (Mode 1) 7.431 MHz (Mode 2) 7.430 MHz (Mode 3)
2	Number of radiated carriers	1 705 (2k mode) 3 409 (4k mode) 6 817 (8k mode)	853 (1k mode) 1705 (2k mode) 3409 (4k mode) 6817 (8k mode) 6913(8k mode extended) 13633 (16k mode) 13921(16k mode extended) 27265 (32k mode) 27841(32k mode extended)	1 405 (Mode 1) 2 809 (Mode 2) 5 617 (Mode 3)
3	Modulation mode	Constant coding and modulation (CCM)	CCM/ACM See DVB Document A122 [3]	Band segmented transmission modulation (BST)
4	Modulation method	QPSK, 16-QAM, 64-QAM, MR-16-QAM, MR-64-QAM(4)	QPSK, 16-QAM, 64-QAM, 256-QAM	DQPSK, QPSK, 16-QAM, 64-QAM
5	Channel occupancy	See Rec. ITU-R BT.1206 [2]	See DVB Document A122 [3] and DVB Document A133 [4]	See Rec. ITU-R BT.1206 [2]
6	Active symbol duration	224 µs (2k mode) 448 µs (4k mode) 896 µs (8k mode)	Depends on number of carriers and bandwidth mode	189 µs (Mode 1) 378 µs (Mode 2) 756 µs (Mode 3)
7	Carrier spacing	4 464 Hz (2k mode) 2 232 Hz (4k mode) 1 116 Hz (8k mode)	Depends on number of carriers and spectrum mode	Bws/108 = 5.271 kHz (Mode 1) Bws/216 = 2.645 kHz (Mode 2) Bws/432 = 1.322 kHz (Mode 3)

	Parameters	8 MHz DVB-T multi-carrier (OFDM)	8 MHz DVB-T2 multi-carrier (OFDM)	8 MHz ISDB-T multi-carrier (segmented OFDM)
8	Guard interval duration	1/32, 1/16, 1/8, 1/4 of Active symbol duration 7, 14, 28, 56 µs (2k mode) 14, 28, 56, 112 µs (4k mode) 28, 56, 112, 224 µs (8k mode)	1/4, 19/128, 1/8, 19/256, 1/16, 1/32, 1/128 Active symbol duration depends on number of carriers utilised and spectrum mode.	1/4, 1/8, 1/16, 1/32 of Active symbol duration 47.25, 23.625, 11.8125, 5.90625 µs (Mode 1) 94.5, 47.25, 23.625, 11.8125 µs (Mode 2) 189, 94.5, 47.25, 23.625 µs (Mode 3)
9	Overall symbol duration	231, 238, 252, 280 µs (2k mode) 462, 476, 504, 560 µs (4k mode) 924, 952, 1 008, 1 120 µs (8k mode)	Depends on number of carriers and spectrum mode.	237.25, 212.625, 200.8125, 194.90625 µs (Mode 1) 472.5, 425.25, 401.625, 389.8125 µs (Mode 2) 945, 850.5, 803.25, 779.625 µs (Mode 3)
10	Transmission frame duration	68 OFDM symbols. One super-frame consists of 4 frames	Super-frame is composed of many T2 frames in the hierarchical structure depending on scheduler and configuration of frame structure.	204 OFDM symbols
11	Inner channel code	Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8	LDCP Code Code rates : 1/2, 3/5, 2/3, 3/4, 4/5, 5/6	Convolutional code, mother rate 1/2 with 64 states. Puncturing to rate 2/3, 3/4, 5/6, 7/8
12	Inner interleaving	Bit interleaving, combined with native or in-depth symbol interleaving	Bit interleaving, Cell interleaving, Time interleaving, Frequency interleaving Interleaving depth from 70ms 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.	Intra and inter segments interleaving (frequency interleaving). Symbolwise convolutional interleaving 0, 95, 190, 380, symbols (time interleaving)
13	Outer channel code	RS (204,188, *T* = 8)	BCH Code	RS (204,188, *T* = 8)
14	Outer interleaving	Bytewise convolutional interleaving, *I* = 12	See DVB Document A122 June 2008 [3]	Bytewise convolutional interleaving, *I* = 12
15	Data randomization/ energy dispersal	PRBS	PRBS PRCI	PRBS
16	Time/frequency synchronization	Pilot carriers	Pilot carriers scattered 1%, 2%, 4%, 8% of total and continual 0.35% of total	Pilot carriers

	Parameters	8 MHz DVB-T multi-carrier (OFDM)	8 MHz DVB-T2 multi-carrier (OFDM)	8 MHz ISDB-T multi-carrier (segmented OFDM)
17	IP outer channel code Reed-Solomon (RS) code	MPE-FEC RS (255,191)	See ETSI TS 102 034 document [5] [6]	RS (204,188, *T* = 8)
18	Receiver power consumption reduction	Time-slicing	ACE PAPR algorithm and Tone Reservation techniques	One-segment service
19	Transmission parameter signalling (TPS)[(9)]	Carried by TPS pilot carriers	PP1-PP8 PP1 : Identical to DVB-T (~8% overhead) PP7 : 1/12 of DVB-T (~1% overhead)	Carried by TMCC pilot carriers
20	System transport stream format	MPEG-2 TS	MPEG-2 TS / GSE	MPEG-2 TS
21	Nett data rate	Depending on modulation, code rate and guard interval (4.98-31.67 Mbit/s for non-hierarchical modes)	Depending on modulation, code rate and guard interval (7.49-50.34 Mbit/s absolute maximum bit-rates in PP7 mode)	Depending on number of segments, modulation, code rate, hierarchical structure and guard interval 4.87-31.0 Mbit/s
22	Carrier-to-noise ratio in an AWGN channel	Depending on modulation and channel code. 3.1-20.1 dB	Depending on modulation and channel code. 3 dB (QPSK 1/2) to 24 dB (256QAM 5/6)	Depending on modulation and channel code 5.0-23 dB

Appendix B

Table 2: Theoretical Delay Spread Propagation Distance for ISDB-T 8MHz

Formula:	Mode (2k):				Mode(4k):				Mode(8k):			
BW (MHz)	7.434				7.431				7.430			
L	1405				2809				5617			
Δf (kHz)	5.29				2.64				1.32			
T_b (µs)	189				378.78				757.57			
G	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
$T_g = G \times T_b$ (µs)	47.3	23.6	11.8	5.9	94.7	47.3	23.7	11.8	189.4	94.7	47.3	23.7
$d_{delay} = c \times T_g$(km)	14.2	7	3.5	1.7	28.4	14.2	7.1	3.5	56.8	28.4	14.2	7.1

Table 3: Theoretical Delay Spread Propagation Distance for DVB-T 8MHz

Formula:	Mode (2k):				Mode(4k):				Mode(8k):			
BW (MHz)	7.61				7.61				7.61			
L	1705				3409				6817			
Δf (kHz)	4.46				2.23				1.12			
T_b (µs)	224				448				896			
G	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32	1/4	1/8	1/16	1/32
$T_g = G \times T_b$ (µs)	56	28	14	7	112	56	28	14	224	112	56	28
$d_{delay} = c \times T_g$(km)	16.8	8.4	4.2	2.1	33.6	16.8	8.4	4.2	67.2	33.6	16.6	8.4