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# Digital Terrestrial Broadcasting Technologies and Implementation Status

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***Abstract*—**Digital broadcasting has been an area of active research, development, innovation and business models development in recent years. This paper presents a survey on the characteristics of the digital terrestrial television broadcasting (DTTB) standards, and implementation status of DTTB worldwide showing the standards adopted. It is clear that only the developed countries and some in the developing ones shall be able to beat the ITU set analogue to digital broadcasting migration deadline because of the challenges that these countries faces in digitizing their terrestrial broadcasting. The challenges to keep on track the DTTB migration plan are also discussed in this paper. They include financial, technology gap, policies alignment with DTTB technology, etc. The reported performance comparisons for the different standards are also presented. The interesting part is that the results for many comparative studies depends to a large extent on the objective behind such studies, hence counter claims are common.

***Keywords*—**Digital terrestrial television broadcasting (DTTB) technologies, DTTB standards comparison, DTTB implementation.

## I. Introduction

DEVELOPMENT of terrestrial digital broadcasting has revolutionarised the broadcasting industry changing its perception that has existed for decades, increasing extensively the carrying capacity of a frequency channel for broadcasting stations, introducing mobility and facilitating convergence of data transmission, broadcasting and telephony. Hence, the business models and broadcasting value chain have changed. Digital broadcasting offers a number of new business opportunities and challenges. The broadcasting industry that was fragmented in the analog broadcasting era with PAL standard used in Europe, Asia and Africa; NTSC standard used in Japan, America and South Korea; while SECAM standard used in France and Africa has been repeated again in the digital era with DVB-T standard used in Europe, Asia and Africa; ATSC standard in Northern America; ISDB-T standard used in Japan and Latin America while DTMB being used in China. The fight for digital broadcasting standard adoption worldwide has already closed down. It is apparent that political and economical alliance, geographical proximity and historical ties played a significant role in the choice of standard adopted. The rest of this paper is organized as follows: section II describes DTTB technologies, section III presents deployment status of DTTB worldwide. Performance comparison of DTTB´s technologies is in section IV and conclusion is drawn in section V.

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## II. The DTTB Technologies

Digital broadcasting faces similar challenges in terms of fragmentation that were observed in the analogue broadcasting era with respect to broadcasting standards. The main problem is business dominance and influences in the broadcasting value chain, in particular the issue of royalties.

The various digital television standards differ significantly in the video and audio format, and conversion of the MPEG stream to a TV broadcast signal, however, there are also significant similarities / overlaps.

There are four basic standards of digital terrestrial broadcasting: Japanese standard (ISDB-T), U.S. standard (ATSC), the Chinese standard (DTMB) and European standard (DVB-T). The U.S. standard was the first to be announced, and was applied mainly in North America, while the European standard that followed has prevailed among European countries. The Japanese standard was the third to be developed and standardized followed by the Chinese standard.

### A. Advanced Television System Committee (ATSC)

ATSC is a broadcasting system for digital television transmission over terrestrial, cable, and satellite networks developed early 1990 aiming at high definition television (HDTV) but also covering standard definition television format. It offers three basic display sizes for ATSC; the basic and enhanced NTSC and PAL image sizes. It is based on A/53 standard of 1995 [1], then A/63 [2] and later A/72 [3], [4]. The ATSC Standard A/72 was adopted by the Federal Communications Commission of USA in 2008 that introduced H.264/AVC video coding to the ATSC system. In standard-definition, the ATSC system allow up to six programmes to be broadcast on a single 6 MHz frequency channel. ATSC system includes elements of the MPEG video coding, the AC-3 audio coding, and the 8-level vestigial sideband (8VSB) modulation. ATSC system maintained the use of 6 MHz channel as in the analog NTSC system and the terrestrial broadcasting use 8VSB modulation with a maximum transfer rate of 19.39 Mbit/s, to transmit coded and multiplexed signals. The standards’ characteristics extract is shown in Table I. ATSC is for fixed transmission/reception mode. It is argued to perform better in rural areas with low population densities requiring large transmitters and resulting in large fringe areas. The ATSC however, had difficulty even with

TABLE I
CHARACTERISTICS OF DIFFERENT DTTB STANDARDS

| Factor | ISDB-T | DTMB | ATSC | DVB-T | DVB-T2 |
|---|---|---|---|---|---|
| Modulation scheme | 64QAM-OFDM, 16QAM-OFDM, QPSK-OFDM, DQPSK-OFDM | 4QAM-NR, 4QAM, 16QAM, 32QAM, 64QAM | 8-VSB, 16VSB | QPSK, 16QAM or 64QAM | QPSK, 16QAM, 64QAM, 256 QAM |
| Transmission modulation | BST-OFDM; Segmented, 13 segments; 2k, 4k, 8k | TDS-OFDM and 8-VSB | | COFDM; 2k, 8k | COFDM; 1K, 2K, 4K, 8K, 16K, 32K |
| Frame rate [fps] | 25, and 50 or 30 and 60 or 15 and 30 | | | 25, and 50 or 30 and 60 | |
| Bandwidth [MHz] | 6, 7, 8 | 6 | | 6, 7, 8 | 1.7, 5, 6, 7, 8, 10 |
| Compre-ssion | MPEG-4 | | | | |
| Multip-lexing | MPEG-2 | MPEG-2 | | MPEG-2 | |
| middleware | BML, Ginga-NCL | | | | |
| FEC | Convolution codes 7/8,3/4,2/3,1/2; Outer coding: RS(204,188) | LDPC; codes 0.4, 0.6, and 0.8; BCH codes; RS (204,188,8) | TCM 2/3; RS (207,187, 10) | Convolution 1/2, 2/3, 5/6, 7/8; RS (204,188,8) | LPDC + BCH 1/2, 3/5, 2/3, 3/4, 4/5, 5/6 |
| Interleaving | Time, Frequency, bit, byte | | | | bit, cell, time, frequency |
| Guard interval | 1/16,1/8,1/4 | | | 1/4, 1/8, 1/16, 1/32 | 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4 |
| Audio coding | MPEG-4 AAC@L2 or MPEG-4 HE-AAC v1@L2 | | | | |
| Data bit rate [Mbps] | 3.65 – 30.98 | 4.81 - 21.96 | 19.39 | 4.98 - 31.67 | Up to 40.2 |
| carriers | 1405, 2809, 5617 | 1, 3744 | 1 | 1705, 6818 | |

Note: RS is Reeds Solomon, DTTB is Digital TV Terrestrial Broadcasting, LDPC is Low Density Parity Check, BCH is Bose-Chaudhuri-Hocquenghem, CC is convolution Code.

fixed reception due to multipath up to 2008 when MediaFlow was being developed [5] to accommodate mobility. MediaFlow streams were limited to 200-250 kbit/s which was enough for small screens whose improvement is realized through the development of the standard ATSC-M/H.

ATSC system has been criticized as being complicated and expensive to implement and use. The ATSC signal is more susceptible to changes in radio propagation conditions than DVB-T and ISDB-T. It also lacks true hierarchical modulation, which would allow the SDTV part of an HDTV signal to be received uninterrupted even in fringe areas where signal strength is low. To address this, additional modulation mode, enhanced-VSB (E-VSB) has been introduced [5].

COFDM modulation scheme is better than the 8VSB at handling multipath propagation and ATSC is incapable of true single-frequency network (SFN) operation. It is necessary to use distributed transmission mode, using multiple synchronized on-channel transmitters to reduce frequency requirement of ATSC to the level of DVB-T SFN networks.

### B. Integrated Services Digital Broadcasting - Terrestrial

The Integrated Services Digital Broadcasting - Terrestrial (ISDB-T) is a Japanese standard that uses H.262/MPEG-2 Part 2 [6], [7]. The standard has a variant that use H.264/MPEG-4 AVC compression standard which is known as ISTD-T International used in Latin America. It uses band segmented Transmission (BST) OFDM modulation scheme and frequency, time, bit and byte interleaving. It applies time interleaving to control susceptibility to interference. The standard divides the frequency band of one channel into thirteen segments, twelve of which are received by fixed receivers and one is used for mobile receivers such as cell phones. This allows broadcast stations to simultaneously transmit single-frequency signals to fixed and mobile terminals which enables mobile devices display high-definition images by receiving twelve-segment signals, even when in motion. The standard incorporates disaster-related functions as a standard feature. Hence, this standard uses the same channels and transmitters for fixed and mobile TV [8]. Test conducted on various digital broadcasting systems in Brazil showed that ISDB-T presented superior performance in indoor reception and flexibility to access digital services and TV programs through non-mobile, mobile or portable receivers [9] compared to its rivals. It also supports complex interactive TV programs, and quality mobile TV. However, these claims have been heavily contested by rival standards who also considered the single segment allocation in a channel for mobile TV as a limitation. This standard has multiprogram feature that allows one to watch up to three different programmes at once. Brazil was the first after Japan to adopt the standard in 2006 followed by Peru, Argentina, Chile and Venezuela in 2009.

The standard offers 25/50 or 30/60 frames/sec. for fixed reception or 15-30 frames/sec. for mobile and possible channel bandwidth of 6/7/8 MHz. MPEG2 and MPEG4 compression schemes are used in this standard for the Japanese and international standard respectively. Multiplexing uses MPEG-2 system. This standard's characteristics extract is shown in Table I.

The channel coding stage in ISDB-T is based on a concatenated coding system. The coding system has (204,188) Reed-Solomon (RS) code as outer code and convolutional code (CC) with constraint length 7 as inner code. A byte-level interleaver is used between outer code and inner code.

### C. Digital Video Broadcast - Terrestrial

The Digital Video Broadcast Terrestrial (DVB-T) is a European developed technical standard that specifies the framing structure, channel coding and modulation for digital terrestrial television (DTT) broadcasting that was first published in 1997 although its development started in 1993. It allows delivery of a wide range of services, from HDTV to multichannel SDTV, fixed, portable, and even handheld mobile reception. The second generation of DVB-T is DVB-

T2. Some believe however that the necessity to upgrade to second generation over such short period is a result of principle weakness in the first generation. This standard's transmission system uses orthogonal frequency division multiplex (OFDM) modulation which uses a large number of sub-carriers and capable of handling very harsh conditions. DVB-T has 3 possible modulation options (QPSK, 16QAM, 64QAM), 5 different forward error correction (FEC) rates, 4 Guard Interval options, Choice of 2k or 8k carriers and can operate in 6, 7 or 8MHz channel bandwidths (with video at 50Hz or 60Hz). These characteristics have been strongly enhanced in the second generation, the DVB-T2. Table I shows the standard's characteristics extract. This standard allows, with use of appropriate guard band in OFDM modulation, deployment of Single Frequency Networks countrywide and whole enhances indoor reception with simple gap fillers. The standard has also Hierarchical Modulation capacibility allowing two completely separate data streams to be modulated onto a single DVB-T signal by embedding a "High Priority" (HP) stream within a "Low Priority" (LP) stream. DVB-T belongs to the DVB standard family that includes DVB-T2, DVB-S, DVB-S2, DVB-C and DVB-H/SH that are designed to meet specific broadcasting environment/delivery platform. DVB-T2 has adopted different FEC schemes and increased significantly the number of sub-carriers, broadened the modulation schemes, transmission modulation and bandwidth options hence enhancing the capabilities of the standard in digital terrestrial broadcasting.

TABLE II
DTTB IMPLEMENTATION DATA EXAMPLES

| Country | penetration | | | | coverage | | | |
|---|---|---|---|---|---|---|---|---|
| | Actual [%] | Year | Projected [%] | year | Actual [%] | year | Projected [%] | Year |
| Japan | 43.7 | 2008 | 100 | 2011 | | | | |
| France | 62.5 | 2011 | 89 | 2008 | 97.3 | 2011 | 91 | 2011 |
| Germany | 100 | 2008 | | | | | | |
| Ireland | | | | | | | 98 | 2011 |
| Italy | 84.7 | 2011 | | | 81 | 2011 | | |
| Spain | 79 | 2009 | | | 98 | 2011 | | |
| Rumania | | | 18 | 2012 | | | | |
| Columbia | | | 42 | 2009 | | | | |
| Netherlands | 16.4 | 2010 | | | | | | |
| Sweden | | | | | 70 | 2010 | 90 | 2012 |
| Finland | 74 | 2005 | 85 | 2011 | 99.9 | 2005 | | |
| Norway | | | | | 85 | 2007 | | |
| Australia cities | 89 | 2011 | | | | | | |
| Austria | | | | | 97.7 | 2011 | | |
| Greece | | | | | | | 60 | 2010 |

### *D. Digital Terrestrial Multimedia Broadcasting*

Digital Terrestrial Multimedia Broadcasting (DTMB) is a Chinese standard for terrestrial digital television broadcasting, whose development started in 1994, was published in 2006 as GB206002006 and became a mandatory Chinese national standard in 2007. This standard for DTTB handles also modern supplementary services. DTMB is a combination of a single carrier modulation (C = 1) proposal; the Advanced Digital Television Broadcasting-Terrestrial (ADBT-T) and the multicarrier modulation (C = 3780) proposal; the Digital Multimedia/TV Broadcasting-Terrestrial (DMB-T). The standard is a result of developments from two Chinese universities, Tsinghua University in Beijing and Jiaotong University in Shanghai. DTMB has similarities to both DVB-T and ATSC derived from its predecessors DMB-T similar to DVB-T and ADTB-T similar to ATSC. It uses the OFDM transmission modulation scheme, 8 MHz analog bandwidth and signal constellation and has novel signal processing techniques integrated in it [10]. The standard uses Time-Domain Synchronous OFDM (TDS-OFDM), concatenation of Low Density Parity Check (LDPC) and Bose-Chaudhuri-Hocquenghem multiple error correction binary block code (BCH) and adopted long time interleaver instead of Cyclic Prefix-OFDM (CP-OFDM), concatenated RS and convolutional code used in other standards. BVB-T2 has adopted this approach. DTMB can facilitate HDTV, interactive television and data casting in one SFN multiplex with transmission parameters being 64QAM, C=3870, PN945 and CR 0.6 providing transmission capacity of 21.658 Mbps net data rate [11]. Table I presents an extract of the standard's characteristics. Enhanced Digital Terrestrial Multimedia Broadcast (E-DTMB) [12] system has been developed to provide embedded transmission of multiple services over existing DTMB system including mobile TV [13].

## III. DTTB DEPLOYMENTS

The deployment of digital broadcasting varies widely from region to region with economic and technology capacity contributing heavily to the rate of success. Currently all standards incorporate MPEG4 compression scheme in their systems while transmission streams use MPEG2. The number of carriers varies from 1 to 27,265 while FEC used are CC plus RS and/or LDPC plus BCH. Guard interval range from 1/4 to 1/128 while bandwidth in MHz range is 1.7 to 10 depending standard and code rate of between 1/2 and 7/8.

In regard to deployments, Europe, North America and some Asian countries have done very well. For Africa however, by the end of 2011, over 75% of TV households were still receiving analogue terrestrial TV signals. It is important however to take into consideration not only penetration of digital broadcasting but also coverage. In developing countries where TV broadcasting reception is primarily in cities, coverage in two of the most populated cities may show a very good penetration while geographical coverage being very low like the case for Tanzania. The reverse can also be true as can be observed in Table II. Hence, penetration and coverage are both equally important politically when it comes to analogue switch-off.

TABLE III
TERRESTRIAL DIGITAL BROADCASTING IMPLEMENTATION

| System | Continent | Country | Year Start | Commercial | Analog Switch-off planned | actual |
|---|---|---|---|---|---|---|
| DVB-T | Europe | UK | 1998 | 2004 | 2012 | |
| | | Germany | 2003 | | | 2008 |
| | | Denmark | | | | 2009 |
| | | Netherlands | 2003 | | | 2006 |
| | | Norway | 2007 | | | 2009 |
| | | Croatia | 2002 | | | 2010 |
| | | Finland | 2001 | | | 2007 |
| | | Sweden | 1999 | | | 2007 |
| | | Austria | 2006 | | | 2010 |
| | | Italy | | 2006 | 2013 | |
| | | Ireland | 2011 | | 2012 | |
| | | Poland | | | 2014 | |
| | | Slovakia | 2008 | | 2012 | |
| | | Lithuania | 2006 | | 2012 | |
| | | Slovenia | 2007 | | 2010 | 2010 |
| | | Switzerland | 2001 | | 2008 | |
| | | Spain | 2000 | | 2010 | 2010 |
| | | Malta | 2005 | | 2010 | |
| | | Luxembourg | 2006 | | 2006 | 2010 |
| | | Ukraine | 2006 | | 2015 | |
| | | Portugal | 2009 | | 2012 | |
| | Africa | Kenya | 2009 | | 2012 | |
| | | Tanzania | 2010 | | 2012 | |
| | | Uganda | 2010 | | 2012 | |
| | | Zambia | 2011 | | 2015 | |
| | | Algeria | 2009 | | 2014 | |
| | | Mauritius | 2005 | | 2011 | |
| | | Namibia | 2005 | | 2005 | |
| | | South Africa | 2008 | | 2013 | |
| | | Morocco | 2007 | | 2015 | |
| | | Nigeria | 2010 | | 2015 | |
| | | Ghana | 2010 | | 2012 | |
| DTMB | Asia | China | | 2007 | 2018 | |
| DVB-T | | Iran | | 2009 | 2015 | |
| | | Israel | | 2009 | 2011 | |
| | | Saudi Arabia | 2006 | | | |
| | | Brunei | 2008 | | 2014 | |
| | | Thailand | 2011 | | 2020 | |
| | | Sri Lanka | 2011 | | 2017 | |
| | | Indonesia | 2007 | | 2017 | |
| | | Malaysia | 2006 | 2009 | 2015 | |
| DVB-IPTV | | | | 2005 | | |
| ISDB-T | | Japan | 2003 | | 2011 | 2012 |
| | | Philippines | 2009 | | 2015 | |
| | | Taiwan | 2004 | | 2012 | |
| | | Vietnam | 2011 | | 2015 | |
| ATSC | | South Korea | 2001 | | 2012 | |
| ATSC | America | USA | | | 2009 | |
| | | Canada | 2003 | | 2011 | |
| | | Honduras | 2007 | | 2022 | |
| | | Mexico | | | 2015 | |
| | | El Salvador | 2009 | | 2018 | |
| DVB-T | | Panama | 2009 | | 2019 | |
| | | Columbia | 2010 | | 2020 | |
| DVB-T | | Argentina | 2005 | 2006 | | |
| ISDB-T | | | 2010 | | 2019 | |
| | | Brazil | 2007 | | 2016 | |
| | | Peru | 2010 | | 2020 | |
| | | Chile | 2010 | | 2017 | |
| DVB-T | Oceania | New Zealand | 2008 | | 2013 | |
| | | New Caledonia | 2010 | | 2011 | |
| | | French Polynesia | 2010 | | 2011 | |
| | | Australia | 2001 | | 2013 | |

Although the migration from analogue to digital broadcasting was planned to be accomplished in 10 years, a number of countries, particularly developing one, took long to initiate the actual implementation of migration as can be seen in Table III. Countries in Western Europe took 1year (Latvia) to 14 years (UK) in the transition process [14]. There are a number of reasons for this delay for developing economies:

- Initially the costs for end equipment were high that needed strategy to absorb part of the cost to facilitate consumers take-up. Only tax relief was a feasible option for developing counties with weak economies.
- Technical specifications for Set-top-box (STB) or integrated TV had to be specified while understanding the technology and the interoperability between MUX service providers is not a trivial issue and also handling free to air reception with a single STB from all MUX operators. The antennae used in analogue broadcasting do not necessarily work in digital frequencies, hence additional costs.
- Costs for installation of multiplexes, distribution network and transmitters to cover the whole country are very high to be done over a short period particularly for developing countries. Invited foreign firms' investment plans are dominated by their business agenda/interest rather than service provision.
- The concept and technology was new that called for change of mindset.
- Selection of technology to adopt from those available that are not compatible was dominated by pressure from interest groups and business interests while efforts were being made to cope with the rapid DTTB developments.
- Time was required to review rules of engagement under new broadcasting environment while the technology was still developing , decision makers and technocrats in evolving countries were not familiar with the technology.
- Developing strategies for public-private-partnership in deploying network facilities was not easy even for public broadcasters.
- Private broadcasters complacency and misconception (based on investment made in analogue systems) particularly for dominant broadcasters.
- Digital take up is mostly policy driven while governments did not have the required financial resources to support the migration process.

There are also delays in effective realization of planned rollout by different MUX operators. These were influenced by:

- Dual illumination in the transition period faced implementation difficulties because of perceived business interest protection by dominant analogue TV broadcasters leading to slower viewers' response.
- Mixed role of broadcasters and multiplex services offerings.
- MUX charges too high hence an entry barrier to some of the incumbent broadcasters to migrate and for new entrants. Therefore, Regulator's intervention essential.
- The TV market in most African countries (terrestrial and satellite) is dominated by free to air services which has

impact on attracting investors targeting primarily pay TV.

- The lack of capacity to develop attractive local contents in developing economies to meet the expanded needs for the increased broadcasting channels capacity.

The deployment period has taken shorter period in the developed countries in that most of them have beaten the 2015 ITU deadline. Some developing countries have reduced significantly the dual illumination period; e.g. Brazil managed to cover 50% of its huge territory in 16 months although consumers take up was much slower because of perceived cost benefit. However, in other countries it was problematic because of the lack of cooperation between the primary broadcasting stakeholders particularly the dominant incumbent analogue broadcasters and the licensed MUX operators.

The Digital Terrestrial Television Broadcasting allows incorporating return channel from televisions for interactivity. Most systems currently use mobile operators collaboration to provide return path.

It is significant to note that ITU had to extend the nominal switch-off date for analogue television broadcasting for some countries for five more years from the nominal date of 16 June 2015 because of various implementation challenges experienced by such countries [15]. The adoption of the different standards by various countries is given in Table III and summarized below.

*1) ATSC*

ATSC is deployed in respective years in the United States (June 2009) [1], Canada (Aug. 2011) [16], Mexico (Dec. 2015) [17] and El Salvador [18], [19], Dominica Republic (Sept. 2015), Honduras (Dec. 2010), Puerto Rico, Bahamas, Bermuda, South Korea (Dec. 2012), American Samoa and Northern Mariana Islands.

*2) ISDB-T*

ISDB-T has been deployed in Japan, Brazil (Dec. 2007), Peru (Apr. 2009), Argentina (Aug. 2009), Chile (Sept. 2009), Venezuela (Oct. 2009), Ecuador (Mar. 2010), Costa Rica (May 2010), Paraguay (June 2010), Philippines (June 2010), Bolivia (July 2010) and Nicaragua (Aug. 2010) [20] - [25].

*3) DVB-T/DVB-T2*

DVB-T has been deployed in Europe, many Asian and African Countries. In Africa all of the 15 Southern African Development Community (SADC) countries selected DVB-T through the 2006 ITU Geneva agreements and agreed to continue with this implementation if they have already started and migrate to DVB-T2 at a later date. Tanzania also has started with DVB-T and is migrating slowly to DVB-T2. This standard is the most widely adopted standard.

*4) DTMB*

This standard is deployed in China.

## IV. Performance Comparison

Comparison tests conducted by GEMNET from January 2008 for ISDB-T and DVB-T using same RF system (transmitter to antennae link) while ISDB-T used 64QAM, DVB-T used 16QAM. ISDB-T showed superior performance and coverage particularly in one segment feature [26].

ISDB-T and DTMB uses different FEC schemes. For ISDB-T, the convolutional codes are optionally punctured into 1/2; 2/3; 3/4; 5/6 and 7/8 data rates. In DTMB, the LDPC codes are constructed as three different data rates with 0.4; 0.6 and 0.8 respectively. In the two standards, the outer codes, RS codes in ISDB-T and BCH codes in DTMB, are constructed as fixed data rate. DTMB further utilize scrambler and time interleaver to harden protection for errors. The bit error rates (BER) performance comparison showed that the error decoding capability is similar for ISDB-T and DTMB when the data rate is low while the decoding performance of DTMB is better than ISDB-T when the data rate is high. However, decoding of DTMB is more complex than of ISDB-T [27]. It is claimed that the most significant feature of ISDB-T is its superior resistance to poor reception conditions, including interference caused by reflection of radio waves from buildings and mountains. Moreover, the standard embeds in a single frequency band both fixed and mobile broadcasts i.e. one channel is divided into thirteen segments, of which twelve are for fixed reception and one for mobile reception [28].

ATSC is claimed to be superior for impulse noise handling which is especially present on the VHF bands but does not support hierarchical modulation.

While DVB-T and DVB-H rely on the well-known coded orthogonal frequency division multiplexing modulation with cyclic prefixes (CP-COFDM), the multi-carrier system in DTMB uses a new scheme called time domain synchronous OFDM (TDS-OFDM), which inserts pseudo-noise sequences into the guard intervals. This allows the receiver to quickly synchronize with the signal and to estimate at the same time the subcarrier channel characteristics. Instead of the concatenated RS and convolution codes used in DVB-T, DTMB employs forward error correction based on concatenated BCH and LPDC codes, resulting in superior error correction and an improved sensitivity. The system is claimed to provide a bit error rate of less than $10^{-10}$ in typical receiver conditions, and supports high-speed mobile reception up to 130 km/h. Finally, DTMB uses a hierarchical framing structure that is kept synchronous to real time. This provides a precise time base to the receiver and supports automatic wake-up and power-saving functions [29]. ATSC is a single carrier standard while the others are multi-carrier.

The design of different standards had different main goals: ISDB-T was for HDTV, mobile TV and audio; DVB was for digital and mobile TV; and ATSC was for HDTV and to work in NTSC broadcasting environment. However, all standards have evolved to encompass all these features.

ATSC is for single transmitter (MFN) implementation and has limited on-channel repeater and gap-filler operation [30] while the other standards can handle both SFN and MFN operations. ISDB-T offers high reliability for transmission of data services (keys for CA).

Southern Africa Digital Broadcasting Association (SADIBA) had influence on the choice of technology adopted

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for African countries, south of the Sahara. Since South Africa, the key SADIBA stakeholder, had invested heavily on DTTB studies since the late nineties. Therefore, it was better positioned to support its arguments in 2009 on suitable standard for the region with its study results. It was claimed that many comparative studies published were biased, inaccurate and skewed towards a particular technology [31] since they were hardly supported by technical facts and scientific evidence. The report for the study was on comparison between ISDB-T and DVB-T that concluded in favor of the DVB-T standard. It is true however that the introduction of DVB-T2 has enhanced significantly the capabilities of DVB-T family standard but the other technologies are also enhancing theirs like ATSC 3.0 [32] and E-DTMB.

## V. Conclusion

The digital terrestrial television broadcasting (DTTB) technologies are as fragmented as the analogue versions being phased out with the regions of influence remaining similar and linked to economical, political and historical ties and geographical proximity. DVB-T has been the mostly widely adopted technology. Implementation of DTTB has been much slower than anticipated in developing countries/economies because of the high costs involved and the logistics involved prior to launching DTTB and a number of challenges provided in this paper. It is significant to note that the functionalities and capabilities of the different DTTB technologies have increasing converged although compatibility still remains an issue to be addressed.

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