Emerging Trends in Audio Technology & its Impact in the Broadcast Industry

Roland K. C. Tan & Asaad S. Bagharib
MediaCorp Technologies Pte Ltd, Singapore

Abstract

Perhaps the introduction of CD in the 1980s marked the dawn of the digital audio revolution. Before the turn of the new millennium, analogue based audio system from the home entertainment to the pro-audio industries was fast becoming a rare entity with digital audio emerging as the dominant technology. From standard definition digital audio at 44.1 kHz/16-bits stereo format to higher definition multi-channel formats with resolution at up to 192 kHz/24-bits, analogue to digital studio console, and even FM to digital radio broadcast, the trends in audio look set to continue in the 21st century. This paper presents the current research trends in audio such as audio coding & high resolution audio, loudspeakers & microphones, audio recording, processing & storage, network audio systems, and transmission & broadcasting, and how these may influence the future of the broadcast industry.

1.0 INTRODUCTION

It has been almost three decades now since the launch of music CD (Compact Disc) in the consumer industry which marked the dawn of the digital audio revolution. With digital audio technology, a modestly priced consumer hi-fi system could now reproduce sound with such high quality that it would have created much envy to our forefathers who would need a much bigger budget to match in the analogue era. Once touted as the "perfect sound forever", several shortcomings of the Red-book audio CD format – a two channels, 16-bits LPCM (Linear Pulse Code Modulation) [1] audio sampled at 44.1 kHz, were soon discovered. Motivated by the quest for an even higher reproduced sound quality, a myriad of DSP (Digital Signal Processing) based technologies was developed and had also found its way into the pro-audio and media industries [2].

In the past 30 years, there have been incredible advances in DSP technology in digital audio. From digital stereo to higher definition multi-channel audio with resolution at up to 192 kHz/24-bits, digital console and digital audio workstation (DAW) with software-based audio processors, computer-based data storage medium to digital audio broadcasting, it was probably the audio renaissance. As innovation continues to make further headway in audio technology, will it continue to create an impact in the broadcast industry in the 21st century?

This paper presents an overview of the evolution in the broadcast industry in Section 2 and discusses under Section 3, the current research trends in audio and how it may influence the future of the broadcast industry. Several areas will be highlighted in this paper such as audio coding & higher resolution audio, loudspeakers & microphones, audio recording, processing & storage, network audio system, as well as transmission & broadcasting, before drawing a conclusion on its likely impact in the future of the broadcast industry.

2.0 EVOLUTION IN THE BROADCAST INDUSTRY

This section presents a brief overview of the evolution in the broadcast industry since the advent of music CDs in the consumer hi-fi industry in the early 1980s and how digital audio has created a major impact with its many benefits. This section also discusses some audio coding standards for two-channels (stereo) and also covers multi-channel audio formats, besides digital broadcasting.

2.1 Digital Audio

It is stating the obvious that the introduction of digital audio had created a quantum leap in audio technology. Digital audio offers increased sound quality and greater signal processing flexibility than its analog counterpart. Although high sound quality production is possible with both analog and digital systems, the studio and other broadcast equipment actually cost much less with digital for the same quality. There are also several advantages of digital systems that are of practical value. For example, digital copies can be reproduced with mathematical perfection and indefinitely without any degradation. This is certainly not the case with analog dubbings. Digital media also allows non-sequential (random) access, making audio editing with software tool on a computer workstation a very user-friendly and non-laborious process. It also offers greater flexibility in playback and recordings. Digital audio can be stored in computer-based data storage server and scheduled ahead for playback automatically. Digital systems also allow non-audio data to be inserted into the database together with the audio such as the artist's names, track titles, plus other useful information. These can be easily retrieved by the disc-jockeys (DJs) and audio engineers from theoretically almost anywhere such as the production studio, on-air studio, including office and even home computer.

2.2 Audio Coding

Before the turn of the new millennium, digital storage medium was largely handicapped by its limited capacity and prohibitive cost. These had generated much research and development interests in the area of data compression algorithms for digital audio which had strong economic and design consequences in the storage and transmission areas. It had also created a major impact in the pro-audio and broadcasting industries, leading to the development of NICAM stereo for television programme [3], ISDN (Integrated Services Digital Network), computer-based digital music storage devices and workstations, portable MD (MiniDisc) recorders, digital audio broadcastings, and the highly controversial but nevertheless thriving MP3 (MPEG-1 Layer III) podcast via the Internet, among many others. Without advanced DSP techniques that incorporate psychoacoustic theory [4] such as MPEG audio [5], digital audio may not have grown beyond the consumer hi-fi industry.

2.3 Multi-Channel Audio

In the late 1990s, the popularity of DVD (Digital Versatile Disc) saw the proliferation of 5.1 multi-channel audio which can practically be found in almost every home cinema system set up. It was therefore only logical for digital television broadcast standards to adopt multi-channel audio transmission such as the Dolby Digital (AC-3) [6] in the American's ATSC (Advanced Television Systems Committee) and the European's DVB (Digital Video Broadcasting) standards.

2.4 Digital Audio Broadcasting

The ability to transmit or broadcast information digitally soon became a reality with the introduction of perceptual audio coding. In 2005, the authors have presented a paper on the revolution of digital radio in the last decade and how it would succeed the role of its

predecessors [7]. In 1986, the European Eureka-147 Digital Audio Broadcasting (DAB) [8] was launched with the objective to replace analogue FM radio. Designed to operate in the VHF Band III and L-Band region, it can also carry data services beyond audio. This was followed by iBiquity Digital in the USA with the launch of HD Radio (High Definition Radio) [9]. Based on the IBOC (In-Band On-Channel) technique, it is primarily designed to operate in the VHF Band II spectrum and co-exist with analogue FM. In Japan, the ISDB-T (Integrated Services Digital Broadcast-Terrestrial) [10] was designed to deliver both radio and television programmes. For AM broadcasting in the short-wave (SW) and medium-wave (MW) bands below 120 MHz, there is the Digital Radio Mondiale (DRM) [11]. Besides terrestrial digital radio, several digital satellite radio services were also launched that include WorldSpace [12], XM Radio [13] and Sirius Radio [14].

3.0 EMERGING TRENDS IN AUDIO TECHNOLOGY

As innovation continues to make further progress in the new millennium, this section looks into the emerging trends in audio technology [15][16] and the potential impact in the future of the broadcast industry. Current emerging trends include higher resolution digital audio, advanced audio coding, loudspeakers & microphones, audio recording, processing & storage, as well as network audio systems.

3.1 Higher Resolution Digital Audio

An extension of the Red-book CD audio format at 44.1 kHz/16-bits to a higher definition digital audio format at up to192 kHz/24-bits is theoretically necessary in order to reproduce sound that is closer to that of the original musical performance. Introduced by Sony/Philips since 1999, the SACD (Super Audio CD) adopts a 1-bit DSD (Direct Stream Digital) format at 2.8224 MHz. On the other hand, the DVD-A (Digital Versatile Disc – Audio) introduced by Toshiba in 2000 adopts a multi-bits format at 192 kHz and 24-bits resolution. Although both formats have been around for about 8 years, sales have been sluggish and album releases are still limited. In fact there has been a steady decline in CD sales in recent years due to a lessened consumer interest in formal listening which explains the niche market status now accorded to audiophiles and their expensive hobby. With the exception of TV, it is difficult to comprehend radio listening like an audiophile who would remain seated in the home on a couch at one designated "sweet spot" in order to derive the full benefits of a higher resolution multi-channel radio broadcast. There is no doubt the entertainment priority has changed over the years. Coupled to the popularity of portable devices that are geared towards convenient casual consumption, the authors have remained skeptical of the potential of any higher resolution format within the realm of radio, including multi-channel audio.

Movie and video sound productions have progressed beyond 5.1 multi-channel audio format. There are higher definition audio formats in movie production at up to 6.1 or 7.1 multi-channel sound such as the Dolby Digital+/TrueHD, DTS 24/96 and even MPEG-4 (AVC). It must be emphasized, however, that the cost of home cinema to the consumer is no longer an issue with the price of an average 5.1 multi-channel system having dropped to less than US$200. The price of a higher definition multi-channel home cinema system should be considered affordable to most consumers. Moreover to ensure TV's survival amidst the many home entertainment options that are available today, broadcasters are beginning to offer HDTV (High Definition TV) programme transmission. It would not do HDTV programme any justice if the accompanying audio should fall below TV viewers' expectation.

3.2 Advanced Audio Coding

Although digital storage capacity is no longer a big issue, advanced audio coding technique [17] still has an essential role to play in broadcast transmission. There is a tendency for broadcaster to squeeze as many digital services as possible on a single multiplex, hence trading sound quality with quantity. The same goes with the high bit-rate associated with a higher definition digital audio format. It must be substantially reduced without compromising the subjective sound quality [18][19]. Higher efficiency perceptual audio coders, such as the multi-filterbank parametric coding approach first proposed by one of the authors in [20][21][22], has continued to generate much research and development interest. Recognized as an international standard in April 1997, the MPEG-2 AAC (Advanced Audio Coding) was developed to reach indistinguishable audio quality at very low bit-rates [23]. It has since evolved into the MPEG-4 aacPlus (ver 2) standard based on a combination of three technologies: AAC, SBR (Spectral Band Replication), and PS (Parametric Stereo) [24]. aacPlus (ver 2) has already found widespread applications in broadcasting such as DVB, DMB (Digital Multimedia Broadcasting), HD Radio and XM Satellite Radio. In February 2007, it was approved by the ETSI (European Communication Standards Institute) as an additional codec for the Eureka-147 DAB standard and was named DAB+. Australia has since announced its plans to rollout DAB+ in January 2009. Once the right marketing strategy and business model are identified, current DAB broadcasters and listeners could stand to gain much more with DAB+.

3.3 Loudspeakers

The fundamental technology behind loudspeaker design has remained very much the same since the first electro-acoustic transducer was invented by Alexandra Graham Bell in 1876. Today, passive speakers have made way for amplified speakers, or more commonly known as the active studio monitors, and have dominated most studios. The advantages of a dedicated amplifier-speaker match were further enhanced with active digital crossover filter design instead of a passive filter topology. However, the ability to obtain a good response is often marred by the non-linear distortion in loudspeaker drivers and the less than ideal listening room acoustic. The task is even more challenging in a typical broadcast studio and outside broadcast environment. When applied carefully, adaptive DSP-based digital equaliser techniques [25] can provide a viable and inexpensive solution. First adopted in the consumer hi-fi industry several years ago, it is envisaged that the technique would also find its way into the broadcast arena.

3.4 Microphones

Like in the loudspeaker design, there has been no major breakthrough in microphone technology except for the adaptation to the digital domain. The AES 42 standard, published by the Audio Engineering Society (AES), defines a digital interface for microphones. Microphones conforming to this standard directly output a digital audio stream through an XLR male connector, as opposed to producing an analog output. Such digital microphones can be used either with new audio equipment which has the appropriate input connections conforming to the AES 42 standard or by use of a suitable interface box. Studio-quality microphones which operate in accordance with the AES 42 standard are now appearing from a number of microphone manufacturers.

3.5 Audio Recording, Processing and Storage

Although various storage systems are available for audio recording, hard disk systems are still widely used in audio productions due to their huge recording capacity and reliability. Within the broadcast industry, solid-state audio recorder using flash memory storage medium

is beginning to replace all optical disk medium. Network and server storage systems will be a major trend which will be discussed in the following section. With the increasing amount of audio data that are accessible online, the ability to search information will become more critical. Metadata-based systems to support such tasks have emerged such as MPEG-7 and MPEG-21.

We have discussed in the earlier sections above that digital audio can be easily manipulated using DSP, avoiding many of the disadvantages found in analog processing. The authors believe this trend would continue and have noticed, for example, several recent research interests and patents filed on the subject related to audio time-scale modification. A high-quality modification algorithm for broadband digital audio and speech recordings, which will not alter the pitch of musical instruments or characteristics of the singer's voice as the tempo is changed, can be useful in the broadcast industry [26]. Radio DJs can vary the tempo of music without introducing audible distortion. In TV production, there is no need for the audio engineer to re-record an actor's voice for lip synchronization in voiceover work. As another example, news scripts can be automatically converted to speech for news broadcast. The same can be applied for traffic news. Natural sounding text-to-speech synthesis can also be achieved by using time-scale modification techniques to alter prosody [27].

3.6 Network Audio Systems

Wireless networking, using radio frequency links instead of wires such as Bluetooth [28] and WLAN (Wireless Local Area Network), is becoming increasingly popular as a means of connecting digital devices and computers. It provides greater flexibility and mobility to the user and does away with the messy tangled strands of wires which can be quite a headache in a typical studio environment. The transfer of audio data has also become more common over the networks instead of dedicated digital interfaces or analog cabling.

Improvements in networking technology, storage media, and audio coding, promise the delivery of extremely high-quality audio over the Internet. Founded in December 2000 comprising of members from more than 23 companies, the ISMA (Internet Streaming Media Alliance) aims to accelerate the market adoption of open standards for streaming and progressive download of rich media including MPEG-4 audio, video and associated data, over Internet Protocol (IP) networks. Ongoing works in ISMA also deal with digital rights management [29] and quality of service (QoS). To overcome bandwidth limitation and network traffic congestion, broadcasters are also considering multi-point networked or P2P (Peer-to-Peer) distribution for online streaming services. Many in the broadcast industry are also exploring remote monitoring and diagnostic, as well as file-based audio transfer [30] via IP networked audio systems.

4.0 CONCLUSIONS

There is no doubt that digital audio has created a quantum leap in audio technology over the past three decades with increased sound quality that cost much less than analog system and the added flexibility in signal processing using software editing tools on computer workstation. It had caused a major impact that has both practical and economic values which led to the development of digital terrestrial and satellite broadcastings such as the DVB, ATSC, Eureka-147 DAB, HD Radio, ISDB-T, DRM, WorldSpace, XM Radio and Sirius Radio. Broadcast contents can also be transmitted online using MP3 podcast. Digital copies can now be generated indefinitely without degradation and non-audio data such as the artist's names and track titles can be included together with the audio. The gap between broadcast

and home entertainment based on CD and DVD in terms of its sound quality has been narrowed by quite a huge margin.

As innovation continues to make further progress in the new millennium, digital audio has moved beyond 44.1 kHz/16-bits stereo to higher resolution multi-channel formats at up to 192 kHz/24-bits. With the exception of TV, it remains to be seen of the potential of the higher resolution multi-channel audio format within the realm of radio. With advanced audio coding techniques, broadcasters can now offer more contents without trading sound quality such as the DAB+ in digital radio. Although the basic technology behind loudspeaker and microphone designs have remained unchanged for many years, its performances have been digitally enhanced using advanced DSP. In the area of audio recording, solid-state recorder based on flash memory medium is beginning to replace all optical disk medium. Network and server storage systems will be a major trend in the broadcast industry. The ability to search information using metadata-based systems such as MPEG-7 and MPEG-21 will become even more important. The combination of advanced digital audio processing algorithms and fast IP-based networking systems with powerful, portable, low-power computation and flash memory-based storage medium promises a new era in broadcasting. With wireless network such as Bluetooth, most wires and cables can be eliminated. Rich media including MPEG-4 audio, video and associated data can be streamed over IP networks using multi-point networked or P2P distribution.

Digital broadcasting will continue to exist in the 21st century as a more efficient and cost-effective means of reaching its audience *en masse* [31]. However, broadcasters can no longer afford to rely solely on terrestrial or satellite transmission. It would have to place equal emphasis on its services through the other alternative delivery platforms that include Internet streaming [32]. Perhaps traditional programming format that is still so deeply entrenched in the mindset of many broadcasters requires a paradigm shift, moving towards the concept of niche, on-demand and interactive content programming. With digital technology, its role and applications will grow beyond traditional radio and television broadcasts [33][34]. If the progress of digital audio technology and its impact in the broadcast industry in the past three decades are any indication, it is clear that we are in for another very exciting future ahead!

5.0 REFERENCES

[1] **S. P. Lipshitz & J. Vanderkooy**, "Pulse Code Modulation – An Overview", *Journal Audio Eng. Soc.*, Vol.52, No.3, (Mar 2004), pp 200-215.

[2] **Roland K. C. Tan**, "Digital Signal Processing (DSP) in Professional Audio (Part I & II)", *Sound.Works magazine*, (Jan/Feb 1997), pp 43-45 and (Mar/Apr 1997), pp 45-47.

[3] **C. R. Caine, A. R. English & *et al***, "NICAM 3: Near-Instantaneously Companded Digital Transmission System for High-Quality Sound Programmes", *The Radio and Electronic Engineer,* Vol.50, No.10, (Oct 1980), pp 519-530.

[4] **B. C. J. Moore**, *An Introduction to the Psychology of Hearing*, publisher Academic Press Limited, London, England, (1991 edt)

[5] **K. Brandenburg & M. Bosi**, "Overview of MPEG Audio: Current and Future Standards for Low Bit-Rate Audio Coding", *Journal Audio Eng. Soc.*, Vol.45, No.1/2, (Jan/Feb 1997), pp 4-21.

[6] **M. F. Davis**, "The AC-3 Multichannel Coder", presented at the 95th Convention of the Audio Engineering Society, (7-10 Oct 1993), New York, preprint 3774.

[7] **Asaad S. Bagharib & Roland K. C. Tan**, "Digital Radio Revolution – The Future is Here!", *Radio Asia Conference 2005 on "Asian Radio at the Cross Roads: A New Paradigm in the Digital Age"*, (15 Jun 2005), Singapore.

[8] **Roland K. C. Tan**, "Eureka-147 Digital Audio Broadcasting", *Sound.Works magazine*, (Jan/Feb 1998), pp 22-26.

[9] **C. Kelly**, "iBiquity Overview", *ABU-AIR Regional Symposium on Digital Radio Broadcasting*, (17-20 Nov 2003), New Delhi, India.

[10] **S. Nakahara**, "ISDB-T SB Overview", *ABU-AIR Regional Symposium on Digital Radio Broadcasting*, (17-20 Nov 2003), New Delhi, India.

[11] **P. Gordon**, "DRM Overview", *ABU-AIR Regional Symposium on Digital Radio Broadcasting*, (17-20 Nov 2003), New Delhi, India.

[12] WorldSpace Satellite Radio website at http://www.worldspace.com/

[13] XM Satellite Radio website at http://www.xmradio.com/

[14] Sirius Satellite Radio website at http://www.sirius.com/

[15] "Emerging Technology Trends in the Areas of the Technical Committees of the Audio Engineering Society", *Journal of the AES,* Vol.55, No.11, (Nov 2007), pp 1004-1020.

[16] **F. Rumsey**, "High Resolution Audio", *Journal of the AES,* Vol.55, No.12, (Dec 2007), pp 1161-1167.

[17] "New Developments in Low Bit-Rate Coding", *Journal of the AES,* Vol.53, No.3, (Mar 2005), pp 235-241.

[18] **Roland K. C. Tan & M. O. J. Hawksford**, "Data Compression Algorithms for High Definition Digital Audio using Multi-pulse Adaptive Sub-band Coding (MASC)", *Proc. Institute of Acoustics (UK)*, Vol.13, Part 7, (Nov 1991), pp 207-218.

[19] **J. R. Stuart**, "Coding for High-Resolution Audio Systems", *Journal Audio Eng. Soc.*, Vol.52, No.3, (Mar 2004), pp 117-144.

[20] **Roland K. C. Tan & M. O. J. Hawksford**, "Multi-pulse Adaptive Sub-band Coding (MASC) using Psychoacoustic Optimization Algorithm", presented at the 93rd Convention of the Audio Engineering Society, *Journal Audio Eng. Soc. (Abstracts)*, Vol.40, No.12, (Dec 1992), p 1041, preprint 3366.

[21] **Roland K. C. Tan & M. O. J. Hawksford**, "Dynamic Excitation Pulse Allocation in MASC Coder", presented at the 94th Convention of the Audio Engineering Society,

Journal Audio Eng. Soc. (Abstracts), Vol.41, No.5, (May 1993), pp 404-405, preprint 3567.

[22] **C. M. M. Tio, Roland K. C. Tan & *et al***, "Psychoacoustic Parametric Audio Coding Technique using a High-Order QM Sub-Band Filter Bank", presented at the 107th Convention of the Audio Engineering Society, *Journal Audio Eng. Soc. (Abstracts)*, Vol.47, No.11, (Nov 1999), p.1008, preprint 5046.

[23] **M. Bosi, Karlheinz & *et al***, "ISO/IEC MPEG-2 Advanced Audio Coding", *Journal Audio Eng. Soc.*, Vol.45, No.10, (Oct 1997), pp 789-814.

[24] **G. Moser**, "MPEG-4 aacPlus – Audio Coding for Today's Digital Media World", *A White Paper from Coding Technologies*, (Nov 2005), pp 1-13.

[25] **R. G. Greenfield & M. O. J. Hawksford**, "Efficient Filter Design for Loudspeaker Equalization", presented at the 86th Convention of the Audio Engineering Society, (7-10 Mar 1989), Hamburg, preprint 2764.

[26] **Roland K. C. Tan & A. H. J. Lin**, "A Time-Scale Modification Algorithm Based on the Subband Time-Domain Technique for Broad-Band Signal Applications", *Journal Audio Eng. Soc.*, Vol.48, No.5, (May 2000), pp 437-449.

[27] **M. W. Macon & M. A. Clements**, "Speech Concatenation and Synthesis using an Overlap-Add Sinusoidal Model", *Proc. of IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP),* Vol.1, (May 1996), pp 361-364.

[28] "Bluetooth and Wireless Networking – A Primer for Audio Engineers", *Journal of the AES,* Vol.50, No.11, (Nov 2002), pp 979-984.

[29] "Digital Rights Management", *Journal of the AES,* Vol.51, No.9, (Sep 2003), pp 855-860.

[30] "Moving Digital Audio: Part 2 – File Transfer", *Journal of the AES,* Vol.51, No.3, (Mar 2003), pp 180-187.

[31] **Asaad S. Bagharib & Roland K. C. Tan**, "Wireless Technology Battlefield in the 21st Century – Can Radio Survive?", *ABU Information Paper for the Annual Meeting of the ABU Technical Committee,* (20th-27th Sept 2004), Almarty.

[32] **F. Rumsey**, "Digital Broadcasting in the IP Age", *Journal of the AES,* Vol.55, No.11, (Nov 2007), pp 1021-1024.

[33] **Asaad S. Bagharib, Roland K. C. Tan & *et al***, "Beyond Radio in DAB: Awakening the Giant Within", *ABU Technical Review,* (Nov-Dec 2002), pp 13-20.

[34] **Asaad S. Bagharib & Roland K. C. Tan**, "Case Studies on New Services and Applications", *ABU Digital Radio Convention 2006,* (14-17 Aug 2006), Kuala Lumpur, Malaysia.