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Broadcast Technology—Past, Present and Future: A Review

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Broadcast Technology - Past, Present and Future: A Review

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The broadcast technology is undergoing a phenomenal change in recent times. The advent of digital technology, with possibility of non-linear editing, virtual studios, disk-based storage, signal processing, multichannel transmission, multiple delivery systems, etc points to a very fascinating era. Research is also ongoing to devise a consumer receipt system which may be a lingua franca of education, entertainment, commerce, education, research and personal information. The "set-top" box shall dual as TV and a computer. This paper traces the broadcast development history and thereafter describes it's present status in India. The paper further discusses the new technology frontiers in the field of broadcasting with exciting possibilities of Direct to Home (DTH) service, Integrated Services Digital Broadcasting (ISDB) and broadcasting through Cyberspace.

OF all the functions performed by radio communications, none is more familiar to the general public than broadcasting. Radio and television broadcasts provide entertainment, information and education to the masses. Over the last ten years, sound and television broadcasting are undergoing a revolutionary change from the established analog to digital technology. New services, including high definition television (HDTV), digital audio broadcasting (DAB), and new direct broadcast satellite services (DBS) will augment, and in some cases compete with, existing AM and FM radio, VHF and a UHF television. Recently a new service, Cyberspace broadcasting, has emerged which is being tried by a number of broadcast organizations. The service provides flexibility of interactivity where listener /viewer can get the audio / video /animation etc on-demand. They can control the type and timing of viewing /listening.

This paper describes the history of broadcasting, it's development since its inception and the present status of broadcasting in India, in terms of technology, coverage and reach.

It is described later the concept of hierarchical quality structure for digital delivery. At present, there is one quality level of television. However, in future, when flat-screen televisions become available, there is distinct possibility of four types of televisions: High resolution big screen TV (HDTV), a higher resolution television systems for home use (EDTV), the present TV system (SDTV), a lower resolution mobile system suitable for viewing in the backs of cars, on trains, boats, planes and television version of a walkman using a head-up display to keep in touch with the latest news while walking down the street (LDTV). The second and third parts of the paper describe the digital delivery systems including Direct Satellite Service (DSS), Broadcasting through Internet and new services in the offing. The fourth part deals with the research being carried out in the receipt system where future concept is that of an interactive TV which may work as TV as well as a computer.

BROADCASTING SERVICE

The broadcast service deals with the point to multipoint communication. Broadcasting traditionally encompassed Radio and Television broadcasting. Thereafter the concept of data broadcasting as a value-added service was introduced. In recent times Multimedia broadcasting is being considered which consists of delivery of audio, video, data and text through a host of distribution system viz. terrestrial broadcast networks, satellite, ATM (Asynchronous Transmission Mode), SDH (Synchronous Digital Hierarchy), fibre cable and Internet.

History of Broadcasting

Radio

The era of radio broadcasting began in the year 1901 when G Marconi achieved a dramatic success in transmitting radio signals across the Atlantic Ocean. By

1921, Medium Wave (531 to 1602 kHz extended to 1700 kHz in North America) radio broadcasting of today had become a reality. Shortwave (3 to 30 MHz) broadcasting was further demonstrated by Marconi in 1922. The powerful impact radio can have on the imagination of listeners was amply proved on the evening of Oct 1938 when a direct broadcast of one hour play "War of the World" produced by Orson Wells from "Mercury Theatre" stunned the world[1]. The channel congestion led to the use of VHF frequency band for broadcasting. The first stereo broadcasting on FM was introduced in 1962 for high quality audio. The era of digital audio broadcasting started in 1995 with the regular transmission of Digital Broadcasting in Europe. The chronology of the events for sound recording and the broadcast history are given in Table 1.

TABLE 1 Brief history of sound recording and broadcasting technology

1864	Maxwell's electromagnetic wave theory for radio wave propagation.
1877	First description of recording sound onto a cylinder or disc described by Charles Cros in France and Thomas Alva Edison in the United States.
1878	Edison patents the recording of sound onto discs and cylinders.
1887	Heinrich Hertz transmits and receives radio waves over short distances.
1888	Emile Berliner shows first example of a working "phonograph" playback device.
1888	Basics of magnetic recording put forth by Oberlin Smith.
1889	Danish inventor Valdemar Poulsen patents the first magnetic recorder.
1895	Development of first wireless telegraph system by Guglielmo Marconi.
1905	First electron tube developed by Sir Ambrose Fleming.
1906	First wireless communication of human speech.
1919	KDKA in Pittsburgh is licensed as the first broadcast radio station.
1925	First electronic recording made with the use of a microphone.
1931	First experimental stereo recordings made by Bell Telephone Laboratories.
1933	Theory of frequency modulation (FM) for radio broadcasts by Edwin Armstrong.
1948	Introduction of Long Play (LP) record by Commercial Broadcasting Service (USA).
1954	Introduction of stereo tapes to the public.
1962	First stereo FM radio broadcasts.
1975-78	Early digital recording made.
1980	Sony introduces the "Walkman".
1983	First CD player made available by Sony and Philips.
1995	Digital Broadcasting starts.

Television

The Television era started with the video broadcasting in 1936 by BBC. Color was added to Television in 1950. NTSC, the US color standard, was adopted in 1953, with Europe following with the PAL standard in 1966. Television development continued with the introduction of UHF transmitters in 1952 to address the problem of spectrum limitation in VHF band. The launch of Sputnik in 1957 started the space race. With the formation of Intelsat by International Satellite organization, a new era of global connectivity started. In 1975, the delivery of video programmes to cable head ends via satellite started. The demand of video entertainment by viewers not served by cable, gave rise to direct to home (DTH) delivery system beginning in Australia in 1984 followed by Europe and US. In order to provide improved quality of service, PALplus (Box 1) standards were evolved. However, broadcasters decided to drop the introduction of the analog wide screen PALplus format in favour of digital system[2].

BOX 1 : PALplus standard

The PALplus standard generates for each TV frame, 432 (216 per field) main active lines in 16:9 format, plus 144 (72 per field) helper active lines. The main active line contain basically a conventional PAL image information, while the helper lines contain additional information transmitted in a way that a conventional PAL TV receiver will interpret them as "black" lines. Those lines are transmitted for each field in the sequence: *i*) a group of 36 consecutive helper lines, *ii*) 216 main lines; *iii*) the remaining 36 helper lines. When receiving such a signal, a conventional 4:3 PAL TV receiver will display the image in 16:9 format in the center of the screen (letterbox format, already widely used for broadcasting feature films). A Palplus TV set generates a full screen image by appropriately combining main lines with the helper lines.

In 1993, Europe began the project of digital television in the terrestrial 8/7 MHz channel. Digital satellite service (DSS) was introduced in 1995. A brief history of video and television technology is given in Table 2.

Broadcasting Service

The broadcasting service is used to serve both international and domestic audiences. International audiences are served by external service which are mostly short wave and medium wave radio transmitters. Domestic audiences are served by home service over-the-air radio and television systems. This service is also the major source of local news, sports, public affairs, etc.

External Service

External service by its very nature requires the

TABLE 2 Brief history of film, video, and television technology

1897	Development of the cathode ray tube by Ferdin and Braun.
1907	Use of cathode ray tube to produce television images.
1923	Patent for the iconoscope, the forerunner of the modern television picture tube.
Early 1930s	- RCA conducts black and white broadcasting experiments.
1936	First television broadcast made available in London.
1938	Initial proposal for color television broadcast made by George Valensi.
1949	System developed to transmit chrominance and luminance signals in a single channel.
1950s	3D and Cinemascope formats introduced by Hollywood.
1954	NTSC standard for color television broadcast introduced in the United States.
1966	PAL standard introduced in Europe.
1975	Sony markets the first Betamax VCR for home viewing and recording of video.
1976	JVC introduces the VHS format for VCR.
1976	Dolby Laboratories introduces Dolby Stereo for movies.
1978	Philips markets the first video laser disc player.
1984	The first Hi-Fi VCR is introduced.
1985	The broadcast of stereo television.
1994	Standard agreed upon for high definition television (HDTV) transmission.

generation of signals that are intended to be transmitted across international borders. Consequently, transmission of these signals is subject to the ITU (International Telecommunication Union) Radio Regulations. For decades, governments have made increasing use of the electromagnetic spectrum to conduct public diplomacy by broadcasting speech and music throughout the world. The external service stations are administered by All India Radio in India and these broadcast overseas on various Medium and Short Wave frequencies depending on the time of day and season of the year. These broadcasts are made in 16 foreign and 8 Indian languages, directly to receivers used by individuals throughout the world. The main external service transmitter at Bangalore has 6 nos. of 500 kW transmitters with slew aerials and rotatable curtains with 8 beams of 30^{o} width which practically covers whole of Asia, Africa and Europe. All India Radio uses 15 short-wave and 4 medium-wave transmitters for its External service

The analog high frequency transmissions suffer from distortion and fading in the ionosphere, from congestion in the bands and deliver an audio quality that can at best be described to be approaching medium frequency. Against this background, International broadcasters are examining the potential of delivering digital radio programmes in future to audiences world-wide as a direct to home (DTH) service using satellite. A consortium for DRW (Digital Radio World-Wide) set-up in 1994 is addressing this issue[3].

Home Service

In India, domestic audiences are served by AM, FM, and TV broadcast stations employing analog radio transmissions designed for direct reception by home receivers. Indian households are well served with 180 million radio sets and 55 million television sets in 152 million households. The coverage by population is 97.5 % for radio and 85.8 % for TV. This is done by 144 MW, 52 SW, 101 FM and 923 TV transmitters in the country as on 20.8.1997. All India Radio also operates a national channel with a 1000 kW transmitter at Nagpur supplemented by 2 × 10 kW medium wave and 2×3 kW FM transmitters. The national channel is an attempt to cover the country for a unified programme. The coverage by national channel is 80% by population and is shown in Fig 1.

AM Broadcast Stations

AM broadcast stations operate on a channel in the 531-1602 kHz AM broadcast band. This band consists of 120 carrier frequencies beginning at 531 kHz and progresses in 9 kHz steps to 1602 kHz. The modulation of the radio carrier wave is amplitude modulation; hence, the AM reference. There are 144 AM broadcast stations operating in India. The operating power ranges from 1 kilowatts to 1000 kilowatts. Propagation in the AM broadcast band involves both the ground wave and skywave modes. The ground wave and skywave modes of AM broadcasting stations serve local and distant audiences, respectively. A disadvantage in AM broadcasting is its limited audio fidelity, relative to FM.

FM Broadcast Stations

FM broadcast stations in India are authorized for operation on 80 allocated channels, each 180-kHz wide, extending consecutively from 100 MHz to 107.9 MHz with standard deviation of 75 kHz. The effective radiated power ranges from 6 kilowatts to 10 kilowatts. 101 commercial and noncommercial FM stations are currently being operated by All India Radio. Better audio fidelity is a distinct advantage of FM radio over AM radio broadcasting; however, FM radio does not normally have the extensive service coverage areas that AM radio broadcasting enjoys. In India, the FM stations are normally operated to serve a small area of about 35-50 kilometers and they are termed as Local Radio Stations (LRS). The distribution and the coverage areas of LRS in India are shown in Fig 2.

Television Broadcast Stations

Throughout India, commercial and educational television broadcast stations comprise the broadcast

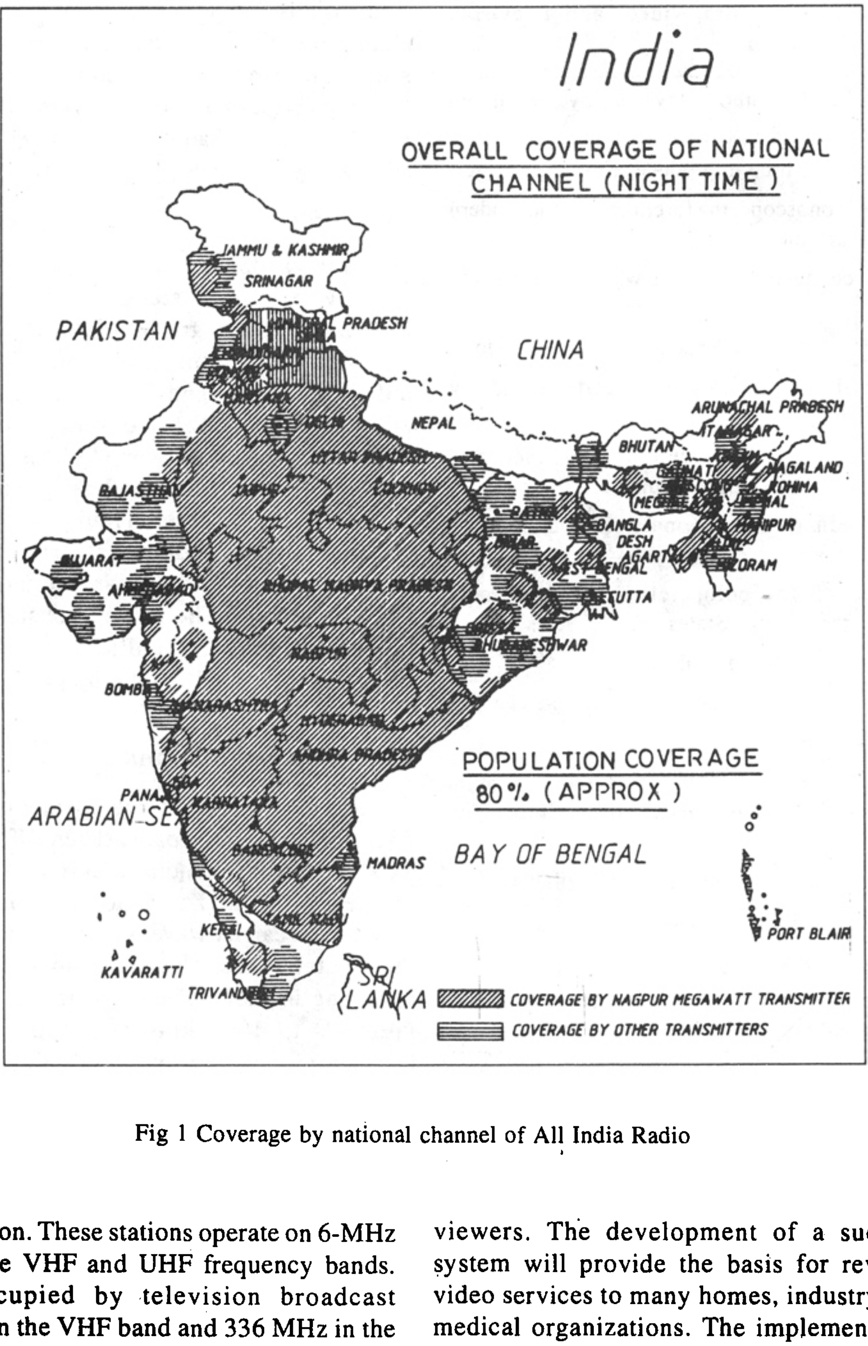

Fig 1 Coverage by national channel of All India Radio

television organization. These stations operate on 6-MHz wide channels in the VHF and UHF frequency bands. The spectrum occupied by television broadcast comprises 72 MHz in the VHF band and 336 MHz in the UHF band.

NEW TECHNOLOGY FRONTIERS IN BROADCASTING

Developments in digital coding, modulation, and compression have made the transmission of digital audio commonplace and digital video feasible. These technologies are gradually making their way into the conventional broadcasting scene as digital audio and ATV (Advanced TV). The potential exists for an enhancement to AM and FM broadcast stations where the sound quality can equal or nearly equal that of CD-technology. Also, HDTV is being developed in the United States, Europe, and Japan as a means of providing greatly improved picture quality to television viewers. The development of a successful HDTV system will provide the basis for revolutionary new video services to many homes, industry, scientific, and medical organizations. The implementation of HDTV is difficult and expensive for broadcasters, but it appears essential for broadcasters to find a way to upgrade their facilities to provide HDTV to consumers and remain competitive with the virtually certain introduction of HDTV by cable, VCR's, and DBS. International broadcast stations will experience improved spectrum efficiency with the planned single-sideband implementation and with satellite-sound broadcasting potentially representing a supplemental delivery system to international audiences. The technology has reached to the point where digital sound and picture are broadcast quality and economical. A technology demonstration of all digital production and transmission was done in the International Broadcasting Convention (IBC) - 1995, held at Amsterdam[4]. The DDS (Digital Delivery System) was capable of

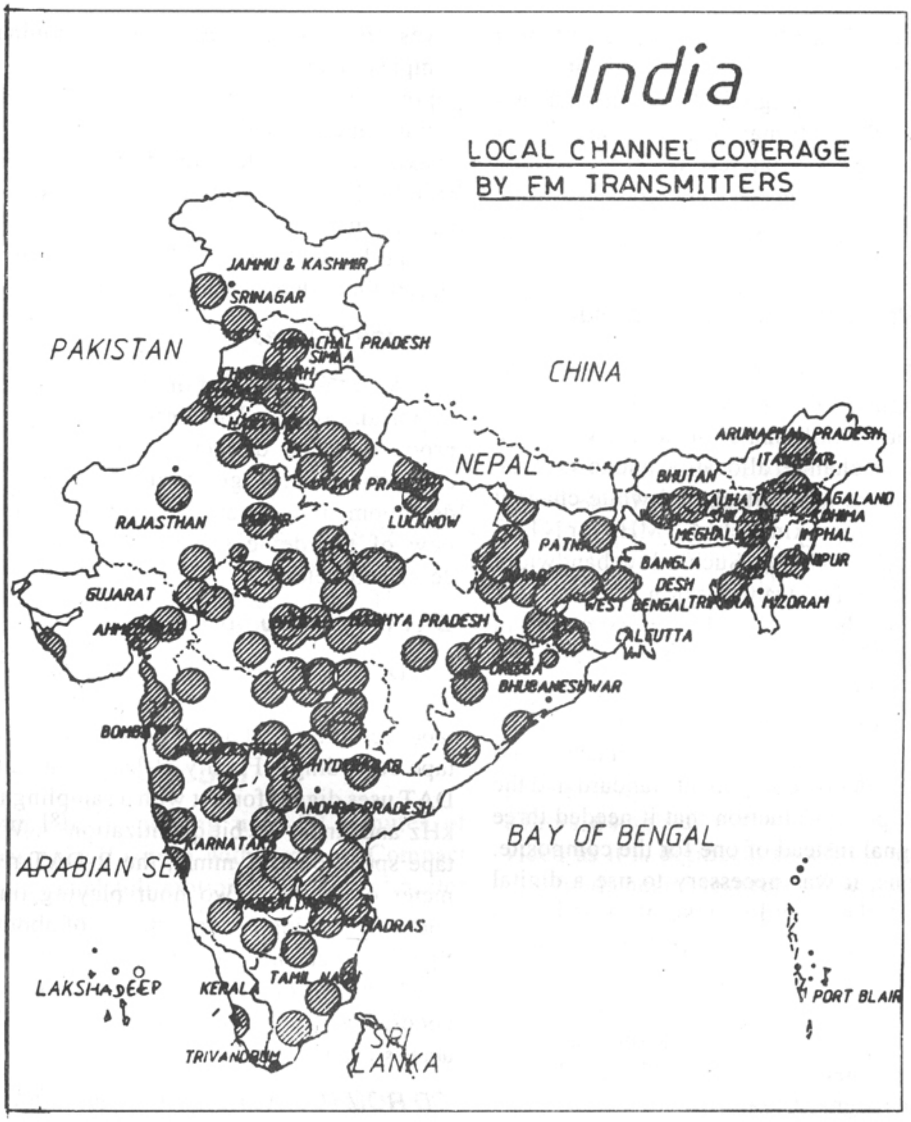

Fig 2 Coverage of FM local channels of All India Radio

providing up to 16 simultaneous stereo replay channels in either linear or MPEG-2 format.

Thus broadcasting in recent times is undergoing a phenomenal change. It will be worthwhile to have a brief review of the technological trends towards the new broadcasting system.

Studio Technology

The broadcast process consists of initial recording/ shooting, post production and distribution. Initial production involves shooting in studios, OB (outside broadcast) coverage etc. Post production consists of editing, layering, modification of picture contents and adding audio/video effects while distribution consists of actual delivery via terrestrial transmitter, satellite or cable (Fig 3). The limitation of analog technology with regard to the number of copies and layers is not the only drawback. The tape recorder needs time to play, record, wind and rewind the tape to find the desired clip. The digital video/audio server and disk recording technology provide random access, ease of editing and post production. As such the trend is towards a digital production system.

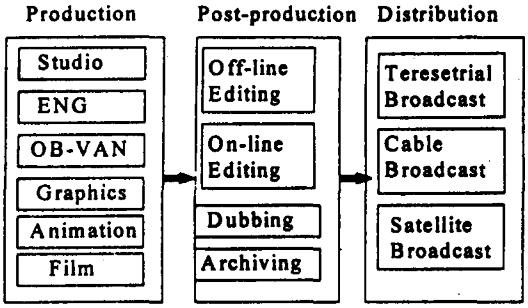

Fig 3 Broadcast processes

In most digital broadcast installations, the system is built around a central signal distribution unit. This equipment receives various signals from internal and external resources. The internal resources are live / recorded material. The external resources are outside broadcast (OB) vans, databases, value-added signals, networks etc. These are processed digitally to eliminate the generation loss.

Evolution of digital broadcast signal formats

PAL, SECAM, and NTSC were adopted for composite color signals in 1960's for maintaining a compatible reception by millions of black and while TV sets. To keep the same channel allocation and to save the frequency spectrum, the same black and white channel bandwidth were used; approximately 4.2 MHz for NTSC and 5.5 MHz for PAL/SECAM. Such a low bandwidth were found adequate for transmission to the TV receivers, albeit with drawbacks like "cross color' in specific conditions[5]. However, these were not sufficient for processing in the studios; i.e. for chroma keys. This led to the evaluation of component standards in 1981 which are commonly known as "Betacam" and the "M" format. This analog component standard had the disadvantage in the post production that it needed three cables for every signal instead of one for the composite. For all these reasons, it was necessary to use a digital television standard that would make it possible to preserve the original quality whatever the processing complexity. CCIR 601 (usually referred to as 4:2:2) was defined as an international standard for component coding of TV signals[6]. It specified orthogonal sampling at 13.5 MHz for luminance (Y) and 6.75 MHz for the two color difference signal Cb and Cr.

Some extended definition TV (EDTV) systems use a higher resolution format called 8:4:4 which has twice the bandwidth of 4:2:2. The choice of sampling frequencies gives 720 samples / active line for luminance Y and 360 samples for color differences and also includes space for representing analogue blanking within the active line. A serial digital signal for carrying the signal on a single coaxial line was developed in 1984. The system was standardized for 243 Mbits/sec based on 8/9 bit transcoding. Subsequently a serial digital component standard based on 10 bit was developed[7]. Figure 3 shows the video format summary.

Storage Devices

With the advent of digital era, storage devices play important role. The entire concept of digital post production and delivery is based on the quality and capacity of storage devices. There has been fast development in the storage devices during last 10 years. Few of the devices being used in broadcasting are described below.

DAT (Digital Audio Tape)

Developed in 1985, digital audio tape had two recording methods viz. R-DAT (rotary head digital audio tape recording) and S-DAT (stationary head digital audio tape recording). Finally R-DAT was standardized. R-DAT uses digital format with a sampling frequency of 48 kHz and linear 16 bit quantization[8]. With an absolute tape speed of 8.15 mm/s, the R-DAT requires only 60 meter of tape for two hour playing time. The digital audio signals yield a data stream of about 1.5 Mbits/sec. Special sections within the track are reserved for auxiliary information viz. programme titles and time-codes. The main disadvantage of DAT is lack of random access capability.

CD ROM (Compact Disc - Read Only Memory)

Introduced in 1983, CD ROM is cheap in quantity, durable, unaffected by magnetic disturbance and free of most hazards that prey storage media. Ultimate in audio

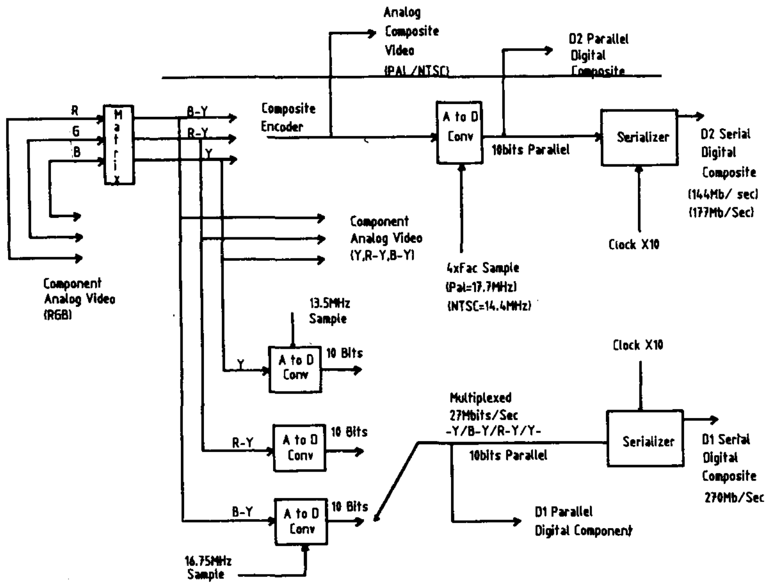

Fig 4 Video formats summary

excellence, the CD format is a real time, 16 bit linear pulse code modulation (PCM) process and supports a wide bandwidth of 20 kHz. Compact Discs are 12 cm in diameter, just over a mm thick, weigh about 16 grams and store upto 680 MB of data consisting of text, images, sound and graphic. The data is stored in the form of microscopic pits about half a micron wide, arranged in a single spiral track starting from inside to outside (total length of about five kilometers). A CD contains about 5 billion pits[9]. It's principal limitation is read only nature and the enormous amounts of storage space (Physical) and circuit bandwidth it occupies. The technical specifications of CD is given in Table 3.

CD-R (CD Recordable)

Compact Disc Recordable (CD-R) or CD-WO (Compact Disc Write Once) available since 1989, use a layer of organic dye and a very thin layer of reflective gold on a pre-grooved polycarbonate disc. The dye polymer, when exposed to a cutting laser beam, reacts with the polycarbonate to form a pit. The CD-R can be written in multiple session.[10,11]. Discs with storage capacity of 550 MB are now available.

Compact Disc Interactive (CD-I)

CD-I is capable of playing upto 72 minutes of moving pictures on full screen with audio of Compact Disc quality. A typical full motion CD-I disc allocates 1.2 Mbit/sec for video and 0.2 Mbit/sec for audio in stereo quality. In order to compress the audio/video to this bit rate (1.4 Mbit/sec), the MPEG coding is used. During playback, the audio/video is decoded. The main features are 50/60 Hz compatibility and high quality full motion play back of 72 minutes duration[12].

Digital Video Disc (DVD)

DVD are capable of storing about 2 to 10 GB data on a single disc. This is done by decreasing the size of the pits as well as the distance between them and utilizing advanced compression techniques. A single DVD of 12 cm can store two to five hours of high quality video.

It was desirable to have two or more hours of recording (one movie) on a 3Gbit DVD. With the requirement of 6 Mbit/s of MPEG-2 in constant bit rate (CBR), about one hour of recording is only possible. As a solution, a variable bit rate (VBR) coding which permits 3 Mbit/s with sufficient picture quality is used. Coding and multiplexing is still based on MPEG-2 method (ISO/IEC-13818-2) which supports VBR[13]. Main-Profile at Main-Level for video and Program Stream for Multiplexing is used. Audio signal is coded in CBR[14].

TABLE 3 Technical data for CD system

Disc	
Diameter	120 mm
Thickness	1.2 mm
Reading Speed	1.2 to 1.4 m/s
playing time	max. 60 min (stereo)
Signal	
sampling frequency	44.1 kHz
Quantisation	16 bit linear per L/R channel
Data rate from disc	4.3218 Mbit/s
Audio performance	
Frequency range	20 Hz to 20 kHz; ± 3 dB
S/N	>90 dB

Video Servers

The video server is the storage device which includes computer network and SCSI (Small Computer System Interface) to distribute and archive compressed video as data, avoiding generation losses and taking advantage of standard computer network and tape transports[15]. A server based broadcast system concept is shown in Fig 5.

A video server can be represented by five key components: (*i*) RAID disk array, (*ii*) a real time controller for traffic management on the bus, (*iii*) I/O cards, (*iv*) high speed internal data bus, and (*v*) disk scheduling that configure the video server for specific applications[16].

Video server must contain storage, and a common choice today is magnetic hard disk. While in nonlinear editors, a single disk may be used to store the compressed video as it is digitized, broadcast applications differ in two fundamental respects. One, broadcast applications demand multiple, simultaneous channels accessing the same material and two, data protection. Disk arrays with RAID satisfy both these requirements[17].

Robotic Tape Handling Systems

In a bid to automate the broadcast studios, the recent trend is to load the tapes into robotic tape handling systems including videocarts[18] (a device that stores a number of tapes and passes it to digital recorders for on-air transmission on the basis of program entered in a

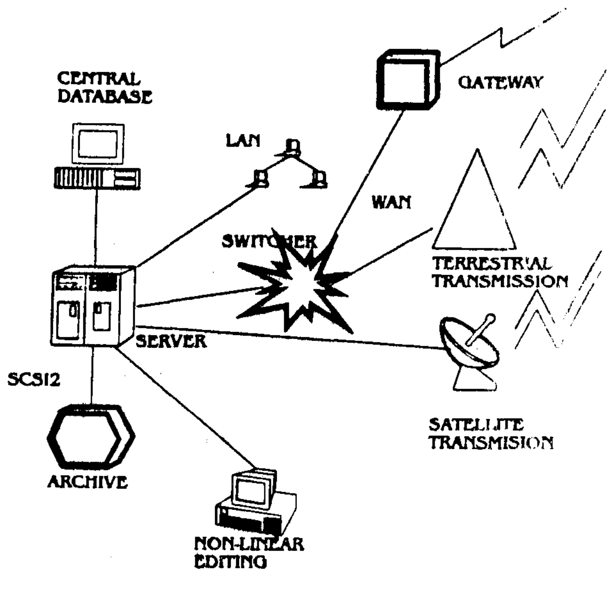

Fig 5 Distribution/transmission broadcast system

remote computer). Playback is triggered by a computerized signal sent from the broadcast automation system. Back-up videotape playback equipment ensures uninterrupted transmission at all times.

Non Linear Video Editing Systems

Non-linear system allows editing of a video by feeding the raw footage from tape on to the hard drive of the computer disk. Video clips on the disk can be manipulated using a software much like the text being edited by a word processor. With the help of a mouse, the clips can be moved and shuffled around a time-line. The provision for inserting digital effects including graphics, lighting, transitions such as dissolves, wipes, peels, page turns etc also exists. The latest high end editing suites allow real time transitions. The typical systems have high capacity hard disks for storing digital video effects and clips. These are stored in compressed form based on MPEG-2 coding. The system is capable of taking analog video, converting it in digital form, allowing editing and insertion of stored effects and clips and thereafter delivering the video either in analog or digital form. The main features are Windows editing system, true lossless compression of CCIR-601 video at the maximum quality setting (1.6:1)[19,20].

The Virtual Studio

Virtual reality (VR) is defined as an experience in which a person is surrounded by a three-dimensional computer generated representation, and is able to move around in the virtual world and see it from different angles, to reach into it, grab it, and reshape it[21]. The Virtual Studio attempts to integrate computer and information technologies into the very heart of architecture design. The virtual studio system combines live video with 3D computer generated graphics sets in real time, during live-to-air or live-to-tape shooting. The use of 3D computer generated graphic-sets eliminates the need for the physical props. These graphic-sets integrate broadcast quality images[22]. The system also permits insertion of video clips, interactive 3D effects and scenarios, visual and audio reactions and more[23]. Virtual studio is made up of rear-projection screens for walls and a down-projection screen for the floor. Projectors throw full color workstation fields (1280 × 512 stereo) at 120 Hz onto the screens, giving between 2,000 and 4,000 linear pixel resolution to the surrounding composite image. Computer controlled audio provides a sonification capability to multiple speakers. User's head and hand are tracked with electromagnetic sensors. LCD stereo shutter glasses are used to separate the alternative fields going to the eyes. High end workstations create the imagery (one for each screen) which are fed through a serial communication port to input. With the advancement of multimedia and 3D graphic supported computer systems, the virtual reality is being produced by mixing the stored scenes with the real actors or virtual actors with the real scenes[24]. Virtual Studios are opening very exciting possibilities where the shootings can be made in the studio and thereafter the scenes from the digital stores can be added. This will offer lot of economy in video production. A number of broadcast organizations have setup the virtual studios[25,26].

The Global Studio

The Global Studio is a collaborative exercise which involves the participation of a number of people distributed over the Internet. This allows artists located in different cities or countries to participate in programme production without really being present in the studio.

Signal Processing

Broadcast "signal" is a time or space dependent quantity that contains information. Examples of a time signal are music or the spoken word. An example of a space signal is a video (television) image. Signal processing comprises of implementing strategies for decomposing information into parts and for removing noise from information. Signal processing also includes channel equalization and echo cancellation. Channel equalization, which balances the channel response across all frequencies, is necessary to make high speed (megabits per second) transmission of data. New high speed modems are incorporating ever more sophisticated channel equalization algorithms[27] to enable higher transmission speeds. Furthermore, testing is on-going for ghost cancellation systems for broadcast television.

Array signal processing is entering the marketplace through proximity detectors for collision avoidance systems in cars and trucks. It is also used in systems where speech signals must be extracted from noisy environments for outside broadcast coverage and active noise cancellation for cars, airplanes and factories. Signal processing has dramatically improved in recent times due to availability of advanced technology viz. programmable hardware and software digital signal processors (DSPs), parallel machines, VLSI synthesis and advanced software environments[28].

Digital Quality

It is worthwhile to know the quality expectations for the digital system. The digital system will provide an increased signal to noise ratio of the order of 98 dB for 16 bit system { $SNR = (6.02 \times n) + 1.76$, where n is the number of bits per sample} as compared to 65 dB of analog audio[29] and no deterioration and multi-generation tape loss when it comes to long term archiving. However these data are for the uncompressed digital audio. The representation of digital image needs a vast amount of bit data. For example, with a sampling rate of 48 kHz and 16 bit linear coding, a stereo signal has a source data rate of about 1.5 Mbit/sec. Assuming a base bandwidth of 45 MHz, threefold sampling frequency and a resolution of 8 bits, a HDTV signal features a data rate of about 1 Gbits/sec. The direct transmission of such data rates for audio and video would not be viable economically. To solve these problems, new ways are being followed in R & D at the expense of perfectionism. At the destination (receiver), the signal is not reproduced but human ears and eyes are fooled, using results from the psychoacoustics and visual phenomena.

In a digital domain, a photo can be scanned digitally and transmitted as a serial bit stream. In order to reduce the time of transmission, it is desirable to transmit as few a bits as possible. Certain algorithms can be used to discard the transmission of redundant bits and reconstruct it at the receiving end. The Television signals have substantial redundancy in them. This means one frame looks much like the next in most cases. This is called temporal redundancy. Even within a frame the video samples are to some extent predictable. This is called spatial redundancy. Eliminating temporal and spatial redundancy in television results in less number of bits to be transmitted. This is called compression of video signal. The Motion Picture Expert Group defined MPEG-1 standard[30] in 1992 and MPEG-2 in November 1994[31] for moving video. MPEG-2 has been accepted as the world standard for digital broadcasting. The technology of video compression has been enabled by improvements in integrated circuits and by recently developed standards for inter-workability. In video compression, signal processing algorithms separate video signals into constituents, enabling digital encoders to efficiently represent these singles for transmission. Video receivers need similar systems to reconstruct the picture. In this way audio data can be reduced by a factor of eight without affecting the CD quality, and HDTV data by a factor of seven to fifty (140 to 20 Mbits/sec). Since the reception quality depends upon the extent of compression, a concept of hierarchical quality structure has emerged for digital TV[32]. HDTV or High Definition TV is for very high quality viewing in a big hall. EDTV or Extended Definition TV is also high quality viewing in home. SDTV or Standard Definition TV is the quality available today. LDTV or Low Definition TV is for mobile service viz. for a train or car. Table 4 shows the hierarchical quality structure for compressed digital TV signals.

Towards All Digital Studio

All these developments have led to the concept of all digital studios. DAWs (Digital Audio Workstations) and Video Cart becoming everyday broadcast production tools, non-linear editing coming to age and HDTV edging closer to consumer reality, all digital television production and distribution is not far away.

Transmission System

Transmission system in the broadcast scenario deals with the distribution of signal via terrestrial, satellite or cable. Till early 90, the main delivery of broadcast signals was through terrestrial analog transmitters. The satellites were used for linking of terrestrial transmitters. The development was mostly towards increase in efficiency and signal quality as compared to the physical links. The recent trend is towards digital broadcasting using terrestrial modes or direct satellite broadcasting for the direct to home (DTH) service. In the following sections, few of the latest developments taking in this area have been described.

Digital Audio Broadcasting

The prospect of sending higher quality audio to portable receivers is spurring development of digital audio broadcasting (DAB). Europe has led the way with its Eureka 147 project[33,34]. The project was launched in 1986 and continued up to 1994. The main emphasis of the project was to carry out test DAB transmissions and also consider the new communication services supplementary to the broadcast services (traffic information and management system, data transmission to specific group of users etc). The DAB was carried out using an OFDM (Orthogonal Frequency Division Multiplexing) packet in which six stereo programmes were transmitted with other data (Fig 6). The project led to the detailed and comprehensive system definition and specification of the standards[35]. Japan started DAB satellite services in 1992 for small fixed panel antennas. BBC started its introductory DAB service in September 1995 in the frequency range 217.5 - 230 MHz. All India

TABLE 4 Hierarchical quality structure for digital TV

Format	HDTV	EDTV	SDTV	LDTV
Quality	High	Enhanced	Standard	Limited
Comparable to	2XCCIR601	CCIR601	PAL /SECAM/NTSC	VHS
Data rate before Compression	1Gbits/sec	432Mbit/sec	216Mbit/sec	108Mbit/sec
Data rate after Source coding	30Mbit/sec	11Mbit/sec	4.5Mbit/sec	1.5Mbit/sec
Compression	MPEG-2	MPEG-2	MPEG-2	MPEG-1
Utility	Telepresence	Home viewing	Home viewing	Mobile TV

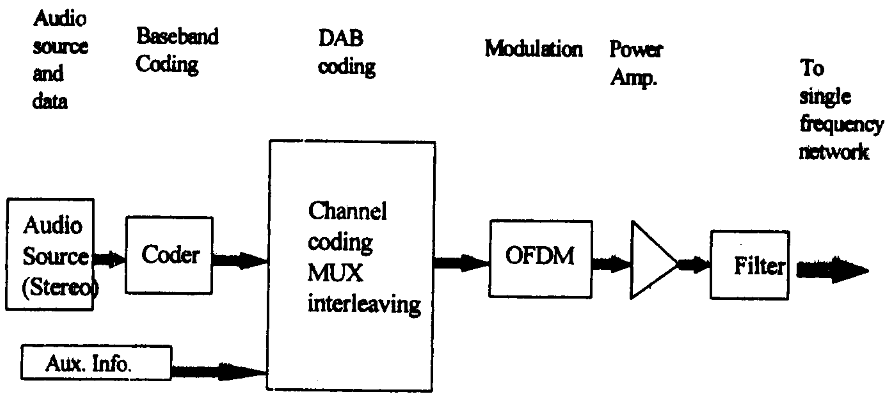

Fig 6 Block diagram of a DAB transmission system for mobile reception

Radio is conducting experiments with DAB in Delhi. A 125 Watt transmitter has been installed and the field trials have been made. Broadcasters are investigating technologies to enable digital transmissions to share the same spectrum with existing FM and AM broadcasts. The advantages to the listener of the DAB system over FM are very impressive. The sound quality is comparable to that of CDs and is relatively immune to multipath interference. Data such as lyrics and phone-in numbers can also be transmitted with the audio. Programme labeling, graphics and traffic messages are among the other enhanced features available. A block diagram of a DAB receiver is given in Fig 7. DAB is much more spectrum efficient since a single frequency can be shared for the whole of the national terrestrial network.

High Definition Television (HDTV)

Around the world, High Definition television (HDTV) systems are being brought to the fore. Similar to the quality of sound gained from the compact disc (CD), HDTV sets a standard, in which picture quality is comparable to the clarity of 35 mm film. The standard for analog HDTV was defined in 1970 with 1125 lines scanning rate, line interlacing, 5:3 aspect ratio and 60 Hz. field frequency. The trials were conducted in Japan using BS-2B satellite in 1989[36] and the experimental transmission started in 1991. Japan has begun limited satellite transmission but high receiver costs combined with lack of HDTV programmes are resulting in limited set penetration. In Europe and Japan, the emphasis is on analog satellite transmission. In the USA, the Japanese standard with 1125 lines / 60 Hz has been accepted. However, there is the problem of terrestrial TV channels having a bandwidth of 6 MHz and priority being given to terrestrial programme distribution over other transmission media. Analog HDTV certainly cannot be implemented in the 6 MHz channel and therefore US is focusing on digital terrestrial transmission systems using video compression.

Figure 8 shows the transmission chain for a HDTV broadcasting. The high quality video input is taken via a signal processing unit before applying to the source encoder. The output data rate of 20 to 30 Mbits/sec is subjected to forward error correction (FEC) channel coding. In the subsequent multiplexer, the audio, sink data and control signals are added to the coded picture signal, whereupon a gross data rate of 30 to 40 Mbits/sec is obtained.

The channel coded data are modulated onto the IF carrier and packed into a channel bandwidth of 7 to 8 MHz (6 MHz in US). A mixer upconverts to the RF carrier frequency, e.g. in Band I to Band V (47 MHz to 862 MHz) before the signals are applied to the terrestrial transmitter and antenna.

Direct Broadcast Service (DBS)

In the 1970's and 1980's satellite became the chief means of long distance radio-communication and facilitated worldwide TV programme distribution in real

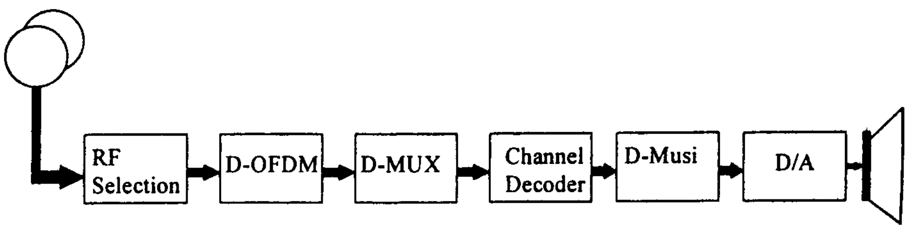

Fig 7 Block diagram of a DAB receiver

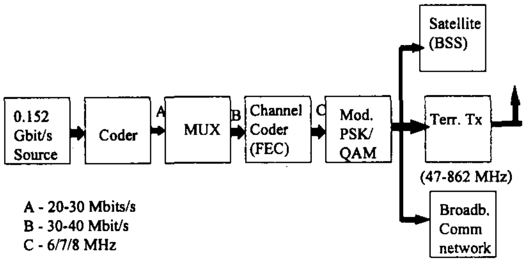

Fig 8 Transmission Chain for Digital HDTV

time. In rural areas not serviced by terrestrial TV broadcast stations and cable TV systems, satellite signals made possible direct reception of TV from satellites by TVRO (TV Receive Only) receivers equipped with parabolic antennas with diameters between 2 and 5 meters. For almost two decades, TV programme delivery by satellite was done in the 4/6 GHz and 11/12.4 GHz bands. Doordarshan, India is using this technique to provide centrally produced programmes to Low Power TV (LPTV) stations.

Development in advanced radiocommunications technologies and the offer of improved radio-based services paved the way for direct TV and audio broadcasts from satellites (also known as Direct to home - DTH service). Today, three technologies have been aggressively developed - the direct broadcast service (DBS), BSS-HDTV and BSS-Sound.

Direct broadcast satellite (DBS) was introduced in US in late 1993 for the delivery of conventional television programming directly to the consumer, using frequency of 12.2-12.7 GHz for the BSS. The DBS system consists of a small 18 inch satellite dish, a digital integrated receiver/decoder (IRD) which separates each channel, decompresses and translates the digital signal, and a remote control. The dish never has to track the satellite so there's no waiting for the picture to come in[37]. DBS programming is distributed in USA by three high power HS-601 satellites (DBS-1, DBS-2 and DBS-3), co-located in geosynchronous orbit, 22,300 miles above the earth at 101 degrees west longitude. DBS-1 features 16 no., 120 watt Ku band transponders with DBS-2 and DBS-3 each configured to provide 8 transponders at 240 watts. DBS-1 delivers upto 60 channels of programming and approximately 20 channels of programming is provided from USSB (United States Satellite Broadcasting). DBS-2 and DBS-3 are used exclusively to provide approximately 175 channels. Each one of the transponders on the DBS-1 satellite can send more than 23 Mbit/s. The DBS-2 and DBS-3 satellites are even faster, at around 30 Mbit/s each.

DBS employs MPEG-2 technology, the emerging world standard for digital broadcasts. DBS is fully digital and "forward compatible" so that consumers can take advantage of emerging technologies, such as interactive services, 16 × 9 wide screen and HDTV (digital) broadcasts.

Programming comes from various content providers (CNN, ESPN, etc.) via satellite, fiber optic cable and/or special digital tape. Most satellite (analog communication satellites used for programme delivery) delivered programming is immediately digitized, and uplinked to the orbiting satellite. The DBS satellites retransmit the signal back down to every earth station, or in other words, every little DSS receiver dish at subscribers' homes and business.

Broadcasting Satellite Service-HDTV is meant for HDTV but due to the problem of large bandwidth required for analogue HDTV, the service has not become operational. WARC-92 (World Administrative Radio Conference -92) have allocated two frequencies: 17.3-17.8 GHz for Region 2 (Europe); and 21.4-22.0 GHz for Regions 1 (America) and 3 (Asia) for this service. These new allocations will become effective from April, 1, 2007[38].

Broadcasting Satellite Service-Sound (BSS-Sound) is for high quality audio programming. BSS-Sound generally refers to the delivery of music, sports, news etc directly to consumers' radio via satellite. WARC-92 adopted three different allocations for BSS-Sound: 1452-1492 MHz, 2310-2360 MHz and 2535-2655 MHz. The service shall be received using portable radios. Such services will not be compatible with existing analog AM and FM radios and require consumers to purchase new radios to enjoy this new broadcast service.

New Services

A host of new services are being experimented and planned in the coming years. Few of these are being described.

Multimedia Broadcast Services

Multimedia system combines various information sources such as text, voice audio, video, graphics and images. The potential applications are Distance learning[39]. Multimedia mailing system[40], Collaborative work system[41], Multimedia communication system[42], Information and demand system[43] and Multimedia Broadcasting[44]. Multimedia broadcasting is defined as a suite of interactive digital services which combine to provide high quality, multi-channel, mobile reception. This is capable of providing digital audio, video, 3D TV, data, Near Video On Demand (NVOD), computer software delivery , multi -channel transmission, pay per view, value added Services viz. RDS (Radio Data System), paging, tele-music, tele-shopping, teletext etc. The multi-media broadcasting is based on the concept that the digital coding of audio, video and other signal results in a data stream. As such after digital conversion, the difference between audio, video and computer data ceases to exist. It is in this context that multimedia broadcasting assumes significance. Once the channel is digitized, more and more services including audio, video, voice, graphics, animation, computer data etc can be multiplexed[45] and put on a common delivery system which could be a fibre optic cable, terrestrial broadcast transmitter or a satellite in a Ku / Ka band capable of delivering signal directly to home using a 50 cm dish antenna.

Integrated Services Digital Broadcasting (ISDB)

Throughout the world, the trend is towards an Integrated Services Digital Broadcasting (ISDB). In ISDB, analog video, audio and test signals are digitized and these data alongwith other digital data for control and value added services are formed into a Transport Stream (TS) using fixed length packets. The conditional access is provided by multiplexing control signals into the data stream. It is used to address various services to each subscriber or to target programmes to a specific group / customer. This leads to virtual channel for pay per view or video on demand. The scrambling and encryption are provided using hardware embedded micro-processors or external smart cards. The digital video signal contains unused space during the line blanking period and carries no useful information. It is possible to insert compressed data into the video signal into these spaces. There is a maximum capacity of insertion of 270 megabit/s serial digital data stream which can carry 8 stereo pairs of 3.072 megabit/s (AES/EBU standard AES-1992) or 16 audio channels or equivalent computer data. This data can be a software code, graphics, still picture or any other value added service. In a country like India, it is possible to provide audio in multiple languages. The system configuration of an ISDB is given in Fig 9.

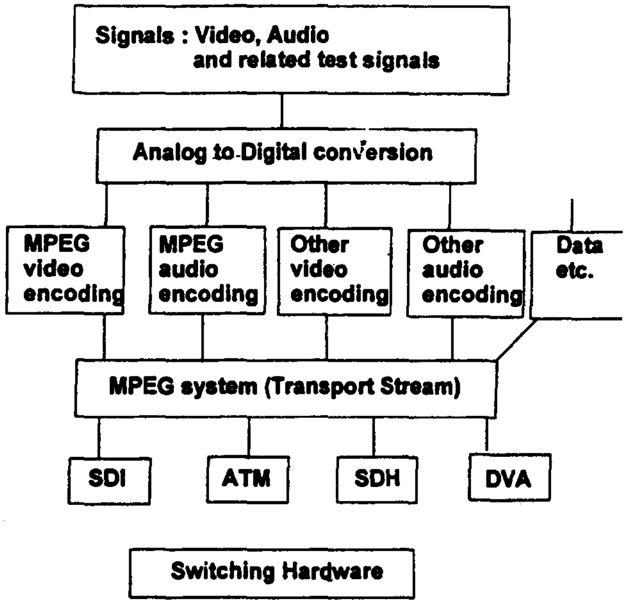

Fig 9 Concept of ISBD

The distribution of compressed signals without generation losses requires a broadband distribution network capable of interfacing with other video / computer / telecommunication equipment. A server with disk arrays (RAID), computer network and SCSI interfaces is used to store/ archive / forward compressed data. This server is the central hub for transmission, non-linear editing, connecting to central database / Ethernet / WAN etc. The packet multiplex system provides easy inter-connection to open networks viz. Serial Data Interface (SDI)[46] which is the CCIR 656 worldwide standard for serial digital video, Synchronous Digital Hierarchy (SDH) (Telecommunication method for multimedia MPEG2 transport stream), Asynchronous Transfer Mode (ATM), satellite or terrestrial transmitters. An interactive link through a telephone or a wireless system allows putting questions to the speaker from the comforts of a drawing room.

Video On Demand (VOD)

The VOD is a service where user selects the kind of video and the time of its viewing using a remote control[47-50]. Depending on the level of interactivity that the user enjoys, the VOD system (VODS) categorization is given Table 5.

TABLE 5 Category of VOD

Interactive VOD (I-VOD)	Full virtual VCR capabilities, including fast forward, reverse, freeze.
Staggered VOD (S-VOD)	Staggered start times allow individual viewer to choose their viewing time and even " pause and restart" their movies
Near VOD (N-VOD)	user is a passive participant except in the matter of choosing the programme.

Fully Interactive Video-On-Demand service is based on Video Server. Multimedia is placed on this server the Retrieval is done by the subscriber themselves[51].

Value Added Services

The mosaics of digital sound and TV broadcasting also contain data or value added services. The worlds of audio, video and data are rapidly converging. Digital sound and video signals may be considered as an anonymous data streams. The efforts are on-going to include one or more digital data channels along with the broadcast signals. These data channels can be used for various value added services. For example Video and Data Services can be used to obtain personal responses from television viewers and for use in conducting educational programming, conducting polls, downloading data, and ordering pay-per-view programming, services and products. There is a demand for transparent networks using different ways of transmission via terrestrial transmitters, satellite and cable with open interfaces to the various services. Digital audio broadcasting (DAB) and digital video broadcasting (DVB) are becoming digital integrated broadcasting (DIB)[52]. Broadcasters are attempting to reach standards and implement a system under the name Radio Broadcast Data Services. Few of the services introduced recently / being planned are given below.

Radio Data Services (RDS)

RDS system was introduced in 1984 to provide traffic information service for motorists in Germany[53,54]. RDS uses a free space in the stereo multiplex signal at 57 kHz for a 1187.5 bit per second wide data channel. The basic idea of RDS is to provide additional information for mobile reception. It can tell a receiver how to tune a station by format or call letters. Interactive Paging is one of the popular service of the RDS[55]. Today, RDS has been adopted in almost all European countries and also US, Japan and India.

Radio data are transmitted in the form of a continuous, binary data stream with 1.1875 kbit per second. In selecting the modulation carrier and type of modulation for the RDS signals, the existing occupancy in the stereo multiplex baseband has to be considered. Figure 10 shows the audio mid band signal (15 kHz), the stereo pilot tone (19 kHz), the sideband signal 23 to 53 kHz and the signal with station identification, area identification and an announcement identification. The RDS signal is superimposed on this signal. Principal of RDS data stream processing is shown in Fig 11.

Data Radio Channel (DARC)

ITU-RA (International Telecommunication Union - Radio Communication Assembly) approved the DARC system on October 1995 as a recommended system for large capacity FM multiplex broadcasting to stationary and mobile receivers[56]. The DARC system, which has been developed by NHK (Japan Broadcasting Corporation) can provide a variety of data services for mobile receivers[57]. The system is used for providing traffic information, news, weather forecast and information services related to the conventional FM programmes. The system can also be applied to DGPS (Differential Global Positioning System) and Radio Paging services. NHK started news, weather forecasts etc using DARK in March 1996.

The DARC system uses a specially developed modulation scheme called LMSK (Level Controlled Minimum Shift Keying) which maintains transmission quality and ensures compatibility with stereo sound signals as well as RDS by controlling the injection level in proportion to the stereo L-R signals. DARC uses the product code of the (272,190) shortened difference set cyclic code that can be decoded rather simply by using a majority logic circuit, and gives greater robustness in adverse environments. The data rate is 16 kb/s.

Teletext

The teletext service was introduced in Germany in 1970. Teletext is a service where use of vertical blanking space is made. During this blanking interval, a text in the form of digital data is transmitted. An encoder is used for inserting digital data and the text is transmitted along with the TV signal. At the receiving end, a decoder helps in recovering the digital data and displaying the text on the conventional TV receiver. The service suffers from the limitation of low data rate of the digital signal[58].

Information Superhighway

Information Superhighway is that ultimate communication network which will prove pervasive connectivity and sufficient bandwidth to allow digital media convergence and interactivity. With its growing ease of use and burgeoning popularity, the Internet is fast becoming the all purpose information superhighway[59].

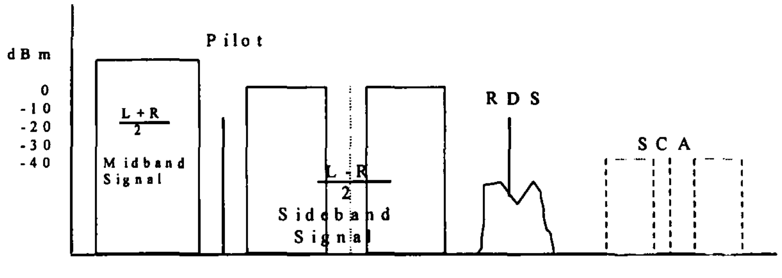

Fig10 Stereo multiplex baseband with RDS & SCA (subsidiary channel authorization)

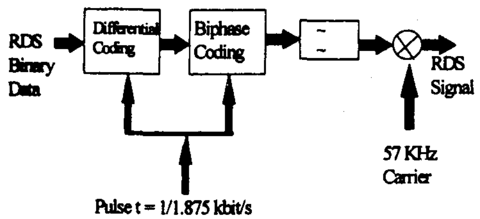

Fig11 Principal of RDS data stream processing

The predominant technologies for broadcasting on the Internet, use buffering, codec (compression/ decompression) and streaming. Buffering is provided to make up for transmission delays. By allocating portion of memory to store a few packets, usually a dozen or so of audio/video information, the player always finds data to play from buffer rather than waiting for receipt of data from server. Codec technologies compress the data using compression algorithms at the server end and then decompress at the receiving end. Stream technology allows for real time repositioning within a file as well playing files as they are downloaded. The main services using Internet are described below.

Audio On The Net

Until the advent of several lossy compression technique, large size of audio files coupled with the bandwidth limitations of the Internet made it impossible to use the World Wide Web for efficiently and reliably accessing large volumes of archived audio content. This was because an entire audio file had to be downloaded to the machine before the playback could begin. Buffering, codec and stream technologies have made it possible to deliver sounds on the web even using 14.4 Kb/s modem in a real time with controls for rewind, forward, pause and playback. The use of audio stream (continuous-delivery) technology permits playing of a single audio packet on receipt. The transfer communication being bi-directional, the player can request the server to send a specific audio packet[60].

Streaming audio technologies are designed to overcome the limited bandwidth of Web: a 14.4/28.8 Kb/s modem or 128 Kb/s ISDN connection. A 14.4. Kb/s modem has a throughput capacity of 1.8 kilobytes/sec, as against the requirement of 176 kilobytes/sec of CD quality audio (97 times the capacity of 14.4 Kb/s modem). For this reason all the streaming audio technologies compress the data drastically to match the throughput of the Internet connection. While CD quality audio requires a compression of 97:1, several audio codecs start with lower quality for example 8 kHz, 16 bit audio requires a compression of only 8:1.

Video On The Net

As a medium, video is much more demanding than audio, both technically and aesthetically. Compressing television quality video, whose original bandwidth is about 27 megabytes per second, to a usable 28.8 Kb/s modem, requires an astounding 7500:1 compression ratio. This extreme compression, achievable only by lossy techniques, causes tremendous distortion in the form of pixelation, blockiness and gross artifacts. Using a 64 Kb/s -single line ISDN or 128 Kb/s - dual line ISDN, greatly enhances the quality of the video. A high bandwidth network or T-1 connection can play a stored file at full frame rate[61].

Music Archives on Web

Web has opened exciting new possibilities for the music industry. Many recording artists, recording studios and record companies now operate their own webs. Already several radio stations have gone on line and are broadcasting programmes over the Web. University of Miami has experimented with the distribution of real time music concerts over the Web (http.// www. Music.miami.edu/music). Examples of other progressive Web sites include following:

http.//www.realaudiocom/ contentp/abc.html -	American Broadcasting Corporation, USA.
http.//www. sony. com -	Sony Corporation, Japan
http.// www. bbcnc. - org. uk	BBC, UK
http.//www. msstate. - edu/movies	InternetMovie Database, Cardiff, UK

In the near future, Web connected fans could long on to hear their favourite musicians perform from the comfort of their own room[62,63].

Virtual radio

Virtual Radio is the non-stop user-definable music broadcast on the Internet that brings the latest in new music. Virtual Radio gives a wide variety of choices: where one can choose and listen the song on-line or download it to machine. This is not a sample, this is a radio-quality broadcast of the entire cut many times right off the band master's DAT. Each "Cyber Tune" (a fancy name given to the music being broadcast on the net) page contains band information, a description of the music, and images of the band. Virtual Radio is the new way to be exposed to today's music[64,65]. Many Broadcasting organizations viz. BBC (British Broadcasting Corporation), MRTV (Malaysia Radio and TV). ABC (American Broadcasting Corporation) etc are producing the programme and broadcasting them. The beauty is that an individual can be a broadcaster by taking a web site on rent[66, 67]. Two individuals have started " All India Internet Radio" in USA.

Interactive 3D TV network

A multimedia communication network which demonstrated the feasibility of 3D television transmission through satellite was demonstrated in ITVS (International Television Symposium) held at Montreux in 1995 (Fig 12)[68]. The bit rate was 30 Mb/s and the satellite was operated in the 20-30 GHz. Interactivity was supplied via a reverse feed modem allowing a robot arm in the Darmstadt studio to be controlled from the auditorium in Montreux. The demonstration was aimed to show the viability of a viewer controlled robot device via Internet to select the programme or interact with the broadcast.

Multicasting

Multicasting is yet another service, which involves broadcast of multiple service viz. video, audio, and data consisting of software (computer), tele-shopping, 3D viewing etc. This type of service comes under Integrated Services Digital Broadcasting (ISDB). The idea behind such digital services is that once the digital domain consists of pure data only, multiple type of data can be multiplexed and sent through the same delivery system. The diverly system can be of any type viz Satellite, ATM, SDH etc. Another popular delivery system is Internet which is capable of delivering multimedia/ hypermedia data.

Receipt System

With the growing trend towards merger of broadcasting, communication and computers, the search for a receiver which can double as a computer and TV is ongoing. The development of digital interactive technology for domestic and personal use is arguably the phenomenon of the decade. Interactive television has been hyped and more recently disputed as the means by which digital services will be introduced to the home. Regardless of its title, Interactive Television is set to address the core issues which continue to face new media: how will the cultural and business success of conventional television be linked to the possibilities of digital networks and information technology[69,70]? Future generation of television receiver would prove more than entertainment. It would pave the International Information Highway and build the common ground for communicating diverse high density, synchronous data. As digital video merges with the Internet, it can become the lingua franca of commerce, education, research and personal information. Few important R&D works are described here.

TVOT (Television of Tomorrow) Project

A TVOT (Television of Tomorrow) can be viewed as an extension of the Internet and the World Wide Web into entertainment or it could be viewed as an alternative model for television - Internet Video[71]. This TVOT would be capable of decoding of sound and picture, understanding the formats, archival retrieval, and a work station for personal creative expression. With this view, a forum by the name, "TVOT" has been set up as an internationally funded research consortium to address worldwide digital television and media. Short term objective is to develop an open architecture television, and longer term goal is a three dimensional TV set.

National Interactive Communications Project

The National Information Infrastructure (NII) program is to provide consumers throughout the United States, with an in-home system for entertainment, education, business, and even shopping, using the widely publicized digital interactive communications system[72]. The focus of the study is on the viewing requirements, consumers needs, technical considerations for interoperability and scalability for a receiver set that can provide for HDTV viewing, computing and connecting

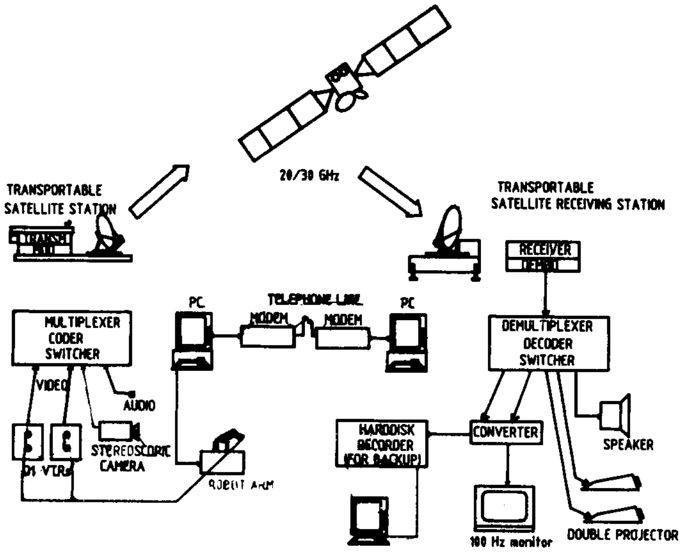

Fig 12 Interactive 3D TV experimental setup

to the information superhighway.

Demonstration at NAB 96

For years, analysts have said PCs won't succeed as a family entertainment devices until they exist in configuration that fit into the family entertainment center and double as a TV. Now systems aiming to achieve that marriage are on the anvil[73]. In NAB 96, products have been released, which not only deliver PC staples such as application software, Internet access and CD ROM titles, but which also function as stand-alone TVs. An MPC3 (Multimedia PC) compliant, system can operate as an ordinary TV while the computer is of. The system can split the screen to display upto 12 TV channels simultaneously, or display a TV and PC image at the same time, by digitizing signals coming from cable or a VCR. It has video, computer and audio RCA input, and output jacks for integration into home theater system. There's also a 125- channel cable ready TV tuner and a Broadcast Channel Lockout feature for parents to control children's viewing[74]. Several "ghost" cancelling systems have been proposed to enable modified television receivers to cancel multiple reflected signals and improve picture quality .

Direct TV Link Up

Research is being carried out to provide video broadcasts and related interactive data services for personal computers using Digital Broadcast Satellite (DBS) System. Users will be able to download large files in seconds using the broadband delivery system. Microsoft plans to build support for TV reception directly into Windows 95. The Direct TV set-top box will basically be shrunk down to a card that will fit in the PC and enable users to watch the regular video channels, either on the PC or on a connected TV, but data services will be available only on the PC. The service will also provide multimedia magazines with downloadable interactive programs and other services targeted at home consumers, including sports scores. There may also be tie-ins between video programming and related data services[75,76].

CONCLUSION

It is an exciting age we live in and each day new technologies are developing to make broadcasting more efficient, cost effective or just easier to administer. The combination of MPEG digital data compression and broadband fiber optic cable networking raises the prospect of almost limitless number of fast communication channels between broadcasters and consumers. Distinctions between broadcasting and narrowcasting will dissolve within a loose three tier structure of satellite based delivery system, terrestrial broadcasting and local- cum-minority interest fiber optic cable. As 20th century gives way to the 21st, much broader range of programme will have to be delivered to cater to so many channels. The studios will go digital with non-linear disk based editing allowing crystal clear production of TV programmes. The virtual studio shall let broadcasters turn almost any room into a very usable television studio. Digital technology in the Broadcast Satellite applications shall allow small dishes to be used for receiving limitless channels. Interactive broadcasts through cyberspace shall allow users to define their own channels. And tomorrow holds even more for us to see[77].

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