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Features of three-dimensional television video systems for broadcasting

BT Series
Broadcasting service (television)

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REPORT ITU-R BT.2160-4

Features of three-dimensional television video systems for broadcasting[1]

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[1] Radiocommunication Study Group 6 made editorial amendments to this Recommendation in November 2014 in accordance with Resolution ITU-R 1.

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Summary

The technology needed for a first-generation three-dimensional television (3DTV) two-channel stereoscopic system already exists, although so far there have been no announced plans for the general introduction of regular free-to-air broadcasting services. A number of broadcasting organizations nevertheless continue to carry out experiments in stereoscopic 3DTV production, while pay-television operator BSkyB introduced a stereoscopic 3DTV channel in the United Kingdom in October 2010. Several consumer electronics manufacturers introduced stereoscopic television receivers during 2010.

An essential aim of this Report is to present a framework for a study of the various aspects of digital three-dimensional (3D) TV broadcasting systems[2] as outlined in Question ITU-R 128/6. It is intended to identify the issues that need to be addressed, and to encourage further contributions to WP 6C.

1 Motivations for the introduction of 3DTV broadcasting

Interest in the possibility of 3DTV in the home may be due in part to a new wave of 3D movies reaching the cinema. In spite of the need to wear glasses, 3D movies have proved to be popular, attracting large audiences who are prepared to pay a premium for the 3D experience.

This in turn has created expectations of the imminent arrival of 3D movies in the home through packaged media[3], such as DVD and Blu-ray. Movies are an important part of television broadcasting, and so it is natural to consider whether 3D movies might in due course be made available through broadcast means.

On the other hand, while the need to wear glasses has not been an impediment to the success of 3D-cinema, questions are raised about the suitability of glasses in the home environment. The current state of development of autostereoscopic displays for glasses-free viewing leaves much to be desired, although it is hoped that ongoing research will eventually lead to improved or even new forms of glasses-free display.

So today's motivation to explore the possibility of the introduction of 3DTV broadcasting may be seen partly as exploitation of the natural evolution of the phased delivery chain used for movies where feature films are first screened in the theatre, then go to the home in packaged media, and finally are made available on broadcast television. In addition, a pay television operator may also have an interest in offering premium content in 3D, whether movies or live events.

Lastly, although 3DTV might not currently be seen a "future alternative" or development of high-definition television (HDTV), it is certainly possible that it could at least have a complementary role to other forms of 3D experience that are likely to become available in the home in the not too distant future.

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[2] Digital (3DTV) broadcasting is a television system that is designed to convey by broadcast transmission a more natural impression of depth to the scene that is being portrayed, by rendering spatially different views to each eye.

In its simplest form, the viewer is presented with a fixed or "static" stereoscopic view of the scene, while a more complex form of 3DTV enables the viewer to change the perspective of what is seen in discrete steps, by means of head movement. In its ultimate form, "holographic" three dimensional presentation would enable the viewer to change perspective through head movement in a continuous way that is comparable to natural sight in real life.

[3] A Blu-ray 3D specification has been introduced that encodes 3D video using the "Stereo High" profile defined by Multiview Video Coding (MVC), an extension to the ITU-T H.264 Advanced Video Coding (AVC). This is able to provide full 1080p resolution per eye, and can offer backward compatibility with existing 2D Blu-ray Disc players.

2 Background to possible 3DTV systems

The fundamental means by which a 3DTV broadcast system today is capable of enhancing the user's visual experience of three-dimensionality, compared to the broadcast of HDTV images, is by delivering stereoscopic image information to viewers in the home. 3DTV broadcasts must provide the signals necessary for generating images with different views of a scene to the two eyes of a viewer. By means of binocular fusion of the stereoscopic images, the 3DTV viewer can obtain an enhanced sensation of depth and an improved sensation of "presence" and "reality".

It is envisioned that the technology of 3DTV systems, as with all media systems, will develop and advance from one generation to the next, over a period of possibly many years. It may be anticipated that future generations will be likely to increase the amount of visual information provided, reduce the restrictive need for eyewear, and increase the freedom of movement allowed without negatively affecting the quality of the stereoscopic depth.

Thus, one method of classifying the various 3DTV systems is as follows:

Eyewear-based systems:

Those systems that are based on or targeted for "plano-stereoscopic" displays, whereby left and right eye images are presented independently to the two eyes using various methods that require eyewear to isolate the two views of a given scene.

Multiview autostereoscopic systems:

Such systems that are targeted for "plano-stereoscopic" (or non-volumetric) displays whereby left and right eye images are presented independently to the two eyes, using various methods that allow two views of a given scene to be isolated without the need for eyewear. In addition, this generation of systems may provide multiple views of a scene such that viewers can freely change their viewing angle and have access to visual scene behind objects.

Integral imaging or holographic system:

Those systems that are based on object-wave recording (holography) or integral imaging and are targeted at the simulation of a light field generated by an actual scene. Thus, freedom of viewing position without the hindrance of eyewear is provided. In addition, the light field provides the visual information (focus cues) for adjusting the ocular lens so as to focus correctly at the same distance as the convergence distance. This provides more natural viewing than the systems of the previous generations that requires maintenance of focus at the display screen irrespective of convergence distance.

3 A hierarchical structure

Current proposals for 3DTV signal formats can be seen as forming a hierarchical structure, which correspond to different constraints and requirements. This is given in diagrammatic form in Fig. 1. This hierarchy might be used in future for any draft Recommendation for 3DTV by the ITU-R found to be required.

FIGURE 1

Matrix of signal formats for 3DTV

Compatibility level ↓

Conventional HD Service Compatible (CSC) **Level 4**	**2D HD + MVC** [(1)] **(i.e. MVC)** (L, R formed by matrixing)	**2D HD + MVC** [(2)] **(i.e. MVC)** (Depth, occlusion, transparency data)	
HD Frame-Compatible Compatible (FCC) **Level 3**	Frame compatible plus MPEG resolution extension, for example SVC [(3)]		
Conventional HD Frame Compatible (CFC) **Level 2**	Frame compatible (L, R in same HD frame)		
Conventional HD Display Compatible (CDC) **Level 1**	Optimized colour anaglyph		
	Plano-stereoscopic profile **1st generation 3DTV**	Multiview profile **2nd generation 3DTV**	Object wave profile **3rd generation 3DTV**

Generation profile →

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(1) MPEG-4 AVC Stereo High Profile – a subset of MPEG Multiview Video Coding (MVC), Annex H to Recommendation ITU-T H.264.

(2) It is understood that ISO/IEC JTC/SC29/WG11 intends to address this form of extension to MVC.

(3) Annex G to Recommendation ITU-T H.264. Use of SVC would require a Level 5 decoder; Level 5 does not support interlace.

The principle of the hierarchy is that each box in the matrix in the diagram defines a type of signal, and this would correspond to the needs of a generic type of receiver. This is somewhat similar to the concept used for ISO/IEC JTC1 MPEG standards, though there are differences. Upper levels are intended to be “backward compatible” with lower levels, with one exception which is explained later.

Though different 3DTV display technologies today have different advantages and disadvantages, the hierarchy is essentially independent of the type of display used. Research and development, and market forces should allow 3DTV displays and technology to evolve and improve, while preserving the public interest for interoperability.

The hierarchy needs to cope with a range of circumstances, from where existing receiving equipment must be used intact (though glasses are used), to where some new elements (displays) are acceptable, to where both new receivers and displays are acceptable.

The quality of the 3DTV will be influenced by the quality of the individual left-eye and right-eye signals, and because of this, 3DTV may be most effective for the higher quality environment rather than the SD-TV environment.

Broadcasters may choose to use available 3DTV technology, and find the limitations acceptable, bearing in mind the gains, or they may prefer to wait for future technology which will have fewer limitations. It seems desirable that ITU-R should provide guidance for both.

3.1 Technology generations

In Fig. 1, the x-axis relates to the **system “generation”**. We may expect basic 3DTV technology to evolve in the decades ahead. The pattern of evolution is that we move from viewing a single stereo view with glasses, then to viewing with greater freedom for head movement, finally to viewing as we do normally (“natural vision”).

Broadcasters may decide to begin broadcasting with earlier technology generations (with its limitations), or to wait for future generations.

First-generation technology is based on the capture and delivery of two views, one for the left eye, and one for the right eye. There is a single “binocular disparity” or binocular parallax. There are limitations with such systems, compared to “natural vision”. With careful production, delivery, and display, effective results can be achieved. Usually, special glasses are used for viewing, though viewing without glasses (auto-stereoscopic) viewing is also possible.

Second generation technology is based on capture and delivery of multiple views. This allows multiple binocular disparities which makes the viewing experience closer to “natural vision”. Normally viewing will be done without glasses on auto-stereoscopic displays.

Third generation technology is based on the capture and delivery of the “object wave”, as is done in a simple way today with holography. The development of such systems is many years away at the moment.

We cannot predict with certainty whether, when, or if, the higher generations will be developed. But, we may note that often generation steps occur about every ten years or so, and that there can be a long lead time from idea to commercial exploitation.

3.2 Compatibility levels

The levels, or y-axis, in Fig. 1 relates to **compatibility levels**.

Level 1 relates to signals which provide for a system which does not require any new equipment by the viewer with the exception of glasses. This level is said to be HD conventional display compatible (CDC).

Level 2 relates to signals which provide for systems that require a new display but not a new set top box. This level is said to be conventional HD frame compatible (CFC). The 3DTV signal appears as a single HD signal to the set top box, which passes it through to the (new) display, where it is decoded and displayed as left and right pictures. If a 2D service of the same channel or programme is needed, it can in principle be provided as a conventional HD signal simulcast, provided there is sufficient spectrum. The left-eye and right-eye signals do not have the same “spectral occupancy” as conventional HD signals – some has to be sacrificed.

Levels 3 and 4 relate to systems which require a new set top box and a new display, but which offer a normal HD spectral occupancy left-eye and right-eye 3D service. Level 3 is said to be frame–compatible compatible (FCC), because it is an extension of Level 2. Level 4 is said to be conventional HD service compatible (CSC) because an existing 2D set top box will find, in the incoming multiplex, a conventional 2D HD signal which it can pass to a conventional display as a 2D picture.

3.3 Matrix points

Level 1/first-generation profile

The generic receiver here, for which the signal is intended, is a conventional HDTV receiver. The signals transmitted are based on a wavelength division multiplex and matrixing of the left-eye and right-eye signals, and a choice of complementary primary colour separation. For example, the "ColorCode" system has been broadcast in Europe and North America using Red/Green in one eye, and Blue for the other eye. Other sets trialed have been Red vs. Green/Blue, or Green vs. Red/Blue. The exact matrixing and choice of complementary colours can be left to market developments because a conventional receiver and 3-primary display is used, though in the light of experience ITU-R may be able to report on options.

Level 2/first-generation profile

The generic set top box here for which the signal is intended is a conventional HDTV set top box. But the 3D display needed is new and must have the capability to interpret an HD frame as left-eye and right-eye pictures. There are alternative ways to arrange the left-eye and right-eye signals to appear to the STB to be a single frame. The three principal methods (which involve sub-sampling) are the side by side (SbS), the over and under method (OaU), and the interleaved sample (IS), checkerboard or Quincunx method (of which there are variants). BSkyB in the United Kingdom uses the SbS method (2x1080i/960). It would be very valuable to the public to identify a single CFC method for broadcasting. At minimum, a common method of signaling the format is needed, such as has been developed by DVB.

This matrix point may be of particular value to broadcasters who manage a large existing population of set top boxes which must not be disenfranchised by the 3DTV broadcasts, and for whom additional delivery channels are available which can be used for 3DTV.

Simultaneous delivery of a 2D version of the same programme, if needed, requires a simulcast of a conventional HDTV signal.

For this and other Levels, the issue of "creative compatibility" of a 3DTV signal and a 2D TV version needs to be considered.

Level 3/first-generation profile

The generic set top box (or IRD) for which the signal is intended here is a new set top box which is able to decode a Level 2, frame compatible image, and also decode a resolution enhancement layer, using for example, MPEG SVC (scalable video coding), yielding normal spectral occupancy L and R HD images for output to the display. This approach would allow existing Level 2 transmissions to be compatibly improved to normal HD spectral occupancy, with the improvement becoming available by replacing the population of conventional set top boxes with the new set top boxes that include a Level 5 H.264 decoder; interlace content would not be supported. Note that unless all set top boxes are replaced, it could still be necessary to simulcast a 2D version of the programme for the 2D audience. Set top boxes (or IRDs) for this level would decode Levels 1 and 2 also.

Level 4/first-generation profile

The generic set top box here is also a new set top box (or IRD) which is able to decode an MPEG MVC signal conforming to the ISO/IEC JTC1 MPEG specification. The signal is arranged so that a conventional set top sees a single 2D HD signal which can be passed to a conventional display as a 2D service. New set top boxes (or integrated receiver/displays) recognize the additional information in order to decode a second view and provide two output signals L and R, to the display. Set top boxes for Level 4/first-generation profile include capability for Level 2 decoding (but, depending on market conditions, not complete Level 3 decoding including extension).

This matrix point may be particularly valuable to operators of terrestrial broadcasting services, where channels are scarce, and where it is necessary to provide both a 3D and 2D service from the same channel.

Level 4/second-generation profile

The generic receiver here for which the signal is intended is also a new set top box which is able to decode the 2D HD plus depth format as specified by the IEC/ISO JTC1 MPEG specification. The display is normally a multiview auto- stereoscopic display. Such set top boxes would also decode Levels 1, 2, and 4 of the first-generation profile.

Other matrix points are left empty for the time being.

4 First-generation 3DTV

It is not currently envisaged that a complete transition from 2D to 3DTV broadcasting will take place in the foreseeable future.

Rather, there is a need to first properly assess the viability of first-generation 3DTV broadcasting. This might perhaps take the form of various 3DTV programme content being made available to the public in a limited ad hoc manner, perhaps just a few hours per week. This could align with other research that is required, such as on the possible effects of eye strain and to assess whether there is acceptance of prolonged stereoscopic viewing. This may be considered as a test phase.

The business models are not the same for pay television and for free-to-air broadcasters, and so the acceptable solutions for first-generation 3DTV broadcasting are anticipated to be different, as explained in § 3 above.

Two variants of first-generation systems may therefore be required for use in different situations: where a service is to be delivered only to viewers with 3D displays; secondly, where the primary audience continues to be viewers receiving an existing 2D service, and it is wished to make use of the same transmission channel to deliver at least some programmes in 3D.

Two techniques are available to satisfy the above conditions:

1 A “frame-based” approach: package the left and right images into an existing HDTV frame.

There are several possible permutations of placement of the left-eye and right-eye images within the frame:

- side-by-side;
- over/under;
- line/column interleaved;
- checkerboard/quincunx.

There is also the potential to add layering techniques to restore the resolution that would otherwise be lost by the placement of two images within a single frame.

A frame-based service would not be directly viewable by existing 2D viewers.

For a multichannel pay television operator, the priority is likely to be to exploit the existing infrastructure in order to deliver 3DTV content to a group of subscribers. Indeed, such an operator could be in a position to do so without impact on services already being delivered to viewers. In this situation, a frame-based solution may be attractive.

A free-to-air operator with access to only limited transmission capacity might require to continue to use existing transmission channels to reach the general 2D audience. In this situation, a frame-based approach would not be suitable.

2 A 2D compatible method

This approach requires that additional information be conveyed in order to reconstruct the second image for suitably equipped 3D receivers.

There are several possibilities for making available the additional information needed to reconstruct the second image:

– simulcast;
– 2D + "delta" (data coded to represent the difference information between left eye and right-eye images);
– 2D + DOT (data to represent depth, occlusion and transparency information).

A "2D + depth" coding scheme could allow multiple views to be generated for presentation on autostereoscopic displays.

The 2D compatible approach allows existing viewers to continue to watch a 2D service. Those viewers wishing to receive 3DTV transmissions would need specially equipped receivers.

As an example, Korea's terrestrial broadcasters, KBS, MBC (Munhwa Broadcasting Corp.), SBS and EBS (Educational Broadcasting System), have prepared for 3D trial broadcasting from October 2010 using dual stream coding (left image with MPEG-2, right image with AVC/H.264) at a resolution of 1 920 × 1 080 interlaced 30 fps. Unlike some countries that have already tested 3D TV broadcasting, they will offer the service through terrestrial networks. Furthermore, Korea will be the first country in the world to offer a full HD 3D broadcasting service. In addition, cable broadcasters CJHelloVision and HCN and Korea Digital Satellite Broadcasting, will also take part in the 3D trial broadcasting service.

5 Future generations of 3DTV

Advanced forms of autostereoscopic display in conjunction with multiple camera systems are under study with the intention of allowing viewers to set their preferred viewpoint and to change it continuously in a range determined by the number of cameras and their allocation, for example so called "free viewpoint television", see Annex 3. This approach can retain backwards compatibility with the displays used for first-generation 3DTV.

There are also studies on possible new forms of "object wave recording" that could allow three-dimensional television images to be presented in a way that represents viewing the physical light in a virtual a space, perhaps using an advanced "integral" method or a holographic system. Such schemes are in the research phase. These studies are to be encouraged, as they promise to lead to the eventual realization of the ultimate goal of presenting images to viewers that are virtually indistinguishable from natural real-world surroundings. To achieve this, new types of advanced volumetric display will be required. It is currently uncertain when this technology might become available: it is likely to be many years in the future.

6 Expected bandwidth requirements for a first-generation system

In the case of a first-generation “2D compatible” system of broadcasting, some additional bit rate will certainly be required. In the extreme, 100% extra would be required for a second simulcast video channel. In practice this would be likely to be somewhat lower using a supplementary data stream for reconstruction of the second video image.

In the case of a “frame compatible” system, if it is accepted that the L and R images contain less spatial resolution than for a 2D system, then in principle no extra bit rate is required compared to the transmission of a normal 2D service. In practice, it is understood that operators plan to use broadcast bit-rates which are at the high end of current practice. It may nevertheless be argued that because this approach does not provide a 2D-compatible service, a completely new transmission channel is required, i.e. 100% extra capacity. However, in the circumstances of a multichannel operator this might not necessarily be a constraint.

It is currently unclear what the quality differences would be between these approaches, and there will inevitably be a trade-off between bit-rate and quality. Independent testing would be desirable.

The human visual perception can be exploited to reduce bandwidth requirements. For example:

– filtering (blurring) in one eye (switching on scene cuts);

– asymmetrical coding.

The 2D + depth approach offers the prospect of considerable bit-rate saving. However, a cost-effective method for depth map creation is not easy to obtain and is still an active area of research.

In the case of more advanced multiview schemes, multiview coding requires multiple synchronized video signals to show the same scene from different viewpoints. This leads to large amounts of data, but typically a larger amount of inter-view statistical dependencies than for stereo.

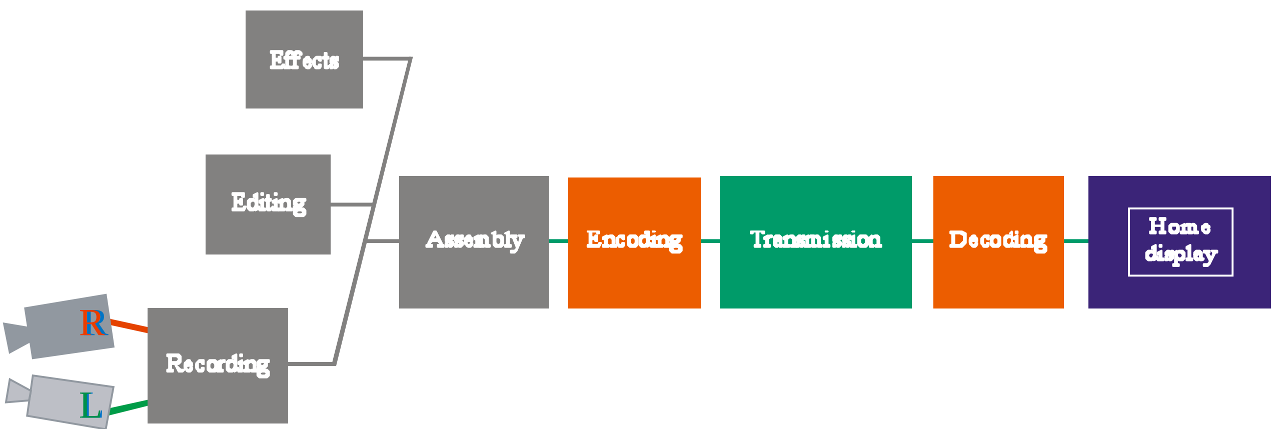
Last, but not least, independent testing using a standardized testing methodology is needed in order to accurately quantify how much extra bit rate would be needed, using a range of representative 3DTV source material.

7 The 3DTV broadcasting chain

The end-to-end broadcasting chain from image source, programme production, delivery and display may be illustrated as follows:

FIGURE 2

The broadcasting chain (indicative)



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The implications for the following individual elements of the broadcasting chain should be considered:

7.1 Image source methods

There are three main approaches to sourcing 3D programme material in use today. These are: stereo camera, CGI, and conversion from 2D video.

Most 3D video captured presently use stereo camera rigs. Some test footage has been captured using stereo cameras coupled with a rangefinder. Rangefinders are usually laser or infrared-based and attempt to provide depth maps for a given scene. The depth maps are prone to numerous errors due to a number of issues, such as poor accuracy, speculars, translucent objects, transparent objects and reflections. Another capture method that has had some testing is multi-camera rigs. These have a large number of cameras that provide a number of views. This method works well for capturing several views. However, the complicated rigs plus the large amounts of data currently prohibit widespread use of multi-camera rigs.

Computer generated content is typically considered the easiest method of stereo generation. The rendering system can either render one or more related views depending on the application. In addition, the Z buffer, which represents the distance to the screen of various objects, can be exported as a depth map. In either case, computer generated data can be used for stereoscopic production or for multiview production.

Finally, 3D video can be created by taking conventional 2D video and adding depth information. The normal process is to deconstruct the 2D image into a series of objects (also known as segmentation), assigning relative depth to each object, then filling in occluded areas. Human visual perception can also be exploited in the processes for converting from 2D to 3D. The creation of a depth map from 2D allows for the creation of multiple views, through a rendering process that incorporates techniques of covering disoccluded regions.

7.2 Characteristics of signals in the studio

Without coding or compression, the baseband required for a two-channel 3DTV system, with HD resolution for each eye, is twice that required for a HDTV system. However, the actual requirements will depend on the format of the signals of the 3DTV system.

– How much information is involved?
– Can signals be handled by existing equipment and interfaces?
– Would new interfaces be required?

The answers to the above questions can be expected to vary according to the form of the 3DTV system.

Some form of metadata for first-generation systems are required to ensure that the left-eye and right-eye views are correctly identified. This may be based on either explicit or implicit information. For example, in the side-by-side format, whether the image on the left consists of the left-eye or right-eye view, and the sampling structure used, has to be known. Synchronization of the left-eye and right-eye views is also needed to ensure that there are no errors in timing, such as with the above-below format. Some of these signals might be able to be handled by existing equipment and interfaces but others might not.

Also, control signals are required for active eyewear that has to synchronize its operation with the view that is being displayed on the screen.

7.3 Programme production

Equipment is required that must handle recording, editing, effects, and postproduction.

The effect of the introduction on first-generation 3DTV on existing Recommendations that apply in the studio production environment will need to be considered.

Suitable provision will need to be made for monitoring the quality of the 3DTV at the point of origination and at appropriate points in the production chain.

One UK satellite broadcaster's technical guidelines, the prime objectives of which are to deliver content of both a high technical quality and of high production values may be found at http://introducingsky3d.sky.com/a/bskyb-3d-tech-spec/

http://www.sky.com/shop/tv/3d/producing3d.

In the UK, the BBC has issued interim delivery requirements for programmes made in stereoscopic 3D. See: http://www.bbc.co.uk/guidelines/dq/pdf/tv/tv_delivery_to_network_programmes_v1.2-2011.pdf

Further study is required.

7.4 Emission

3DTV signals may need to be encoded in ways that are appropriate to their transmission within the existing 6/7/8 MHz terrestrial transmission channels, and also by existing broadcast satellite services.

Different techniques are likely to be required that are appropriate to each of these situations, and according to the requirements of the broadcaster as indicated in §§ 4 and 5.

7.5 Display

There are known to be three fundamental approaches:

– viewer wears glasses;

– without glasses (auto-stereoscopic);

– headmounted display.

With a headmounted display, the left and right eyes are presented with the left-eye and right-eye images of a stereo pair. This may be appropriate for video games, but is unlikely to be appropriate for viewing of broadcast television. It is an individual viewing experience and is not suitable for collective (e.g. family) viewing of broadcast television.

Within these broad categories, various approaches may be possible. In many cases, 3DTV presentation relies on some form of eyewear or headgear that the viewer must wear in order to discriminate between left-eye and right-eye images:

– Anaglyph: a stereoscopic effect can be obtained by displaying images in which the presentation screen simultaneously displays two differently-filtered coloured images, (typically red for the right-eye image and cyan for the left-eye image). These are viewed through correspondingly-coloured glasses. One difficulty with this solution is that the viewer may feel compelled to remove the coloured glasses when looking away from the presentation screen. In addition, the programme presentation will necessarily provide an inferior colour rendition.

– Polarized glasses: this solution makes use of cross-polarizations for the right-eye and the left-eye images of a stereo pair; the images are watched through correspondingly cross-polarized glasses. One solution to display such cross-polarized image uses a "tiled" display of alternating tiles for the first and second image of a stereo pair. The tiled display is covered by an identically tiled polarized mask, with alternating tiles being cross-polarized. When viewed through cross-polarized glasses, separate views will be presented to the left and right eyes of the viewer. One problem with this solution is that the presentation of stereo images at HDTV resolution requires a more expensive display providing at least twice the horizontal resolution of HDTV.

– Shuttered glasses: the two images of a stereo pair are time-interleaved on the screen, and viewed through special glasses in which the left and right eye lenses are shuttered in turn, following the switching cycle of the left and right images on the screen.

While it seems inevitable that, at least to begin with (and possibly for many years) 3DTV viewing would require that viewers to wear glasses, first-generation 3DTV broadcasts could nevertheless continue to be viewed on more advanced improved forms of autostereoscopic display as the technology progresses.

8 Production grammar

Poor quality stereoscopic television could "poison the water" for everyone. There is a risk that 3DTV becomes associated with eye strain if stereoscopic content is poorly realized – whether due to inappropriate production grammar or due to inadequate technology for delivery. This has happened before in the cinema in the 30s, 50s, and 80s.

The production grammar of 3D often differs to 2D productions. Special care has to be taken in order to achieve a good 3D viewing experience. This can lead to some compromises for the 2D viewer. In some cases, a production might be optimized for 3D, with no intention that the 3DTV version be used for conventional standard- or high-definition television presentation.

It is understood that various recent trial 3DTV productions have provided useful learning experiences, and it is expected that further knowledge will be gained through ongoing trial productions and from services that have recently become available to the public. Live 3DTV production presents particular challenges. Live production nevertheless forms a regular part of the schedule of the recently introduced 3D service from United Kingdom pay television operator BSkyB.

9 The viewing environment

The effect of the viewing environment is fundamental on the perception of depth and to the quality of the overall viewing experience. The following situations should be considered:

– the studio environment;

– the home environment.

In particular, in conjunction with viewing distance, picture size and subtended viewing angle play a role in the three-dimensional effect as perceived by the viewer. This might have implications on the way in which 3DTV should be produced and displayed.

10 Principles for comfortable viewing of stereoscopic three-dimensional images

The increasing interest in stereoscopic three-dimensional (3D) content services has raised concerns about the comfort and safety of viewing stereoscopic images. As a result, it has become important that adequate information and guidance is available to producers of stereoscopic 3DTV content in order to assist with the production of programmes that are comfortable to watch.

Report ITU-R BT.2293 details some of the key issues and provides information and guidance to those involved with producing and broadcasting stereoscopic 3D programmes.

11 User requirements

These are currently not fully understood.

At its May 2009 meeting, WP 6C decided to carry out a survey on the aspirations of the ITU Membership on 3DTV broadcasting. The survey was carried out between July 2009 and October 2009. All those who responded considered that there is a need to discuss with standards bodies, such as the IEC, the provision of minimum requirements for 3DTV receivers which match a future 3DTV broadcast system. In addition all responders considered it very important/essential for a 3DTV system to have the same format as packaged media (e.g. HDTV capacity discs).

12 Performance requirements

The overall performance requirements need to be identified in sufficient detail in order to orient the choice of the appropriate technologies for a new 3DTV system.

A list of requirements is listed in Recommendation ITU-R BT.2023.

It is hoped that future contributions will provide clarifications and/or additional factors that should be considered.

13 Organizations with initiatives in 3DTV

A wide range of research, standardization, and trade associations are currently active in investigating aspects of 3DTV. A non-exhaustive list is attached in Annex 1.

14 Conclusions

Without an orderly approach to the standardization of 3DTV broadcasting systems, even for an initial test phase, various *de facto* standards will become established. There is a risk that subsequent implementation of 3DTV broadcasting could become more difficult.

Furthermore, actions likely to be taken by the gaming and optical media (Blu-ray) industries could have a significant impact on the capabilities of widely deployed consumer equipment.

It is also not known what the consequences might be of decisions on the future 3D-capabilities of interfaces to displays if these are taken in the absence of agreed requirements for 3DTV broadcasting systems.

It is anticipated that guidance will be desirable covering the following:

– quality assessment methods for 3DTV systems;
– reference 3DTV source materials for use in subjective tests;
– requirements for the broadcasting chain;
– requirements for production and production grammar;
– psychophysical aspects related to viewing of stereoscopic images;
– requirements first-generation 3DTV systems.

In addition, an important issue for further study is an understanding of bit-rate requirements for first-generation 3DTV broadcasting systems, for both the frame-based and compatible 2D approaches.

Referring to the matrix of signal formats described in Fig. 1, the most critical matrix points that might need to be standardized are the first-generation Levels 2 and 4 points to the maximum extent possible, but certainly regarding signalling.

Another critical issue is to try to align the matrix with the formats used for packaged media.

Further contributions to WP 6C are invited on the above and related topics.

Annex 1

Organizations with current initiatives in 3DTV

1 ISO/IEC JTC1/SC29/WG11

In July 2009 it was planned to finalize the specification of carriage of MVC over MPEG-2 systems, as well as extensions to the file format specifications to accommodate multiview video.

Work is also proposed to begin on a new 3D video (3DV) format that aims to support advanced stereoscopic display processing and auto-stereoscopic displays.

An amendment to ISO/IEC 14496-10 includes a spatially interleaved frame supplemental enhancement information (SEI) message to signal the type of interleaving in a frame-based scheme.

2 ITU-T Study Group 9

ITU-T SG 9 has recently initiated work items to develop draft new Recommendations on subjective assessment methods for 3D video quality and on display requirements for 3D video quality assessment. In addition, studies are being progressed on scalable view-range representation for free viewpoint television (FTV).

3 ITU-T Study Group 16

The multiview coding extension of Recommendation ITU-T H.264 | ISO/IEC 14496-10 MPEG-4 AVC has proceeded to AAP Consent under ITU-T Recommendation A.8 approval process.

4 3DTV – Network of Excellence

See: www.3dtv-research.org.

5 3D4You – Content generation and delivery for 3D television

3D4You was a project funded by the European Union under the information and communication technologies (ICT) Work Programme 2007-2008, a thematic priority for research and development under the specific programme "Cooperation" of the Seventh Framework Programme (2007-2013). Project website: http://www.3d4you.eu/.

6 SMPTE

The activities of the Society of Motion Picture & Television Engineers (SMPTE) include standardization work related to stereoscopic 3DTV in the production environment. SMPTE's work is distributed among its various Technology Committees, Working Groups and Ad Hoc Groups.

One such activity has been completed and has resulted in a published standard (SMPTE ST 292-2:2011 Dual 1.5 Gb/s Serial Digital Interface for Stereoscopic Image Transport) that defines a method of transporting stereoscopic images using two streams of 1.5 Gbit/s in conjunction with the means to identify each stream.

For each current activity related to stereoscopic 3DTV, the table below identifies the responsible SMPTE group, the scope of work, and its status as of September 2011. See also: https://www.smpte.org/.

Overview of SMPTE standardization activities related to stereoscopic 3DTV (September 2011)

Standards Committee Group	Name	Scope	Status
Technology Committee 35PM, Working Group on 3D Home Master	ST 2061 Stereoscopic Distribution Master	The Stereoscopic Distribution Master (formerly known as the '3D Home Master') is intended to provide a standardized means for interchange of 3D content amongst mastering facilities, and between a mastering facility and the ingest facility of a distribution system. The Stereoscopic Distribution Master may feed various distribution outlets for 3D content to the home, including (but not limited to): mobile, Blu-ray/DVD, streaming, terrestrial, and cable/satellite broadcast. The document includes a Glossary, and covers Image Structure, Subtitles, Captions and Graphical Overlays, and Metadata	FCD Final Committee Draft

(*continued*)

Standards Committee Group	Name	Scope	Status
Technology Committee 10E Essence: AHG	ST 2066 Disparity Map Representation for Stereoscopic 3D	Identify requirements for a data representation of disparity maps relevant for production, post-production, and distribution of 3D content.	Work in progress
	ST 2068 Frame Compatible	This document categorizes and enumerates the various methods to transport a pair of stereoscopic frames within single video frames. Unique identification codes are assigned to these methods in order to facilitate interchange of 3D Frame Compatible signals. The information contained can be used to confirm that proper encoder/decoder pairs are used. It can also set the H.264/MPEG-4 AVC Frame Packing Arrangement SEI message prior to delivery to end user terminal devices. One purpose of this document is to carry the frame packing information necessary for the MPEG-4 AVC Frame Packing Arrangement SEI message. A second purpose is to carry information describing the frame packing arrangement that may be used in the production workflow. The document will not enumerate the filtering used prior to sub-sampling, but optional suffix coding may be provided in some implementations in order to identify unique filtering on the basis of specific implementations.	Work in progress
Technology Committee 32NF Networks and Infrastructure	SMPTE ST 2063. Stereoscopic 3D Full Resolution Contribution Link – MPEG-2 TS	This document specifies how a stereoscopic 3D video system based on the MPEG-2 Transport Stream (TS) that is codec agnostic (i.e. any codec for which there are defined methods for transport via MPEG-2 TS is permitted) performs coding, multiplexing, and decoding. It defines constraints for the input image pair, the bit stream, the multiplexing, timing synchronization, and signalling, as well as for the video coding and decoder behaviour. The input image pair must have the same image structure (horizontal and vertical pixel count, scanning system, colorimetry, and frame rate) and be coincident in time.	Final Committee Draft

(end)

Standards Committee Group	Name	Scope	Status
	ST 292-2 Dual 1.5 Gb/s Serial Digital Interface for Stereoscopic Image Transport	This standard defines a means of transporting stereoscopic images (Left eye and Right eye images) using an interface consisting of two links based on the SMPTE ST 292-1 data structure. The Left eye images are carried on one link of the interface and the Right eye images are carried on the other link. The stereoscopic image formats to be transported using this standard are the 4:2:2 10 bit image formats defined by SMPTE ST274, ST2048-2 and ST296, which can be transported by a single SMPTE ST292-1 serial interface. Audio and other associated ancillary data may also be transported. This standard also defines a payload identifier.	Published standard
	ST 425-2 Source Image Format and Ancillary Data Mapping for Stereoscopic Image Formats on a single-link 3Gb/s Serial Interface	This standard defines a means of transporting a stereoscopic image pair consisting of a Left Eye and Right Eye image (Le and Re) using an interface consisting of a single 3Gb/s (nominal) link. The stereoscopic image formats to be transported using this standard are those 4:2:2 10 bit image formats having a sampling frequency of 74.25 MHz, or 74.25/1.001 MHz. Audio and other associated ancillary data may also be transported. This standard also defines a payload identifier. It is not necessary for implementations to include support for all formats defined in this standard to be compliant. Implementers should indicate supported formats in commercial publications.	Final Committee Draft
	ST 425-4 Dual 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport	This standard defines a means of transporting stereoscopic images (Left eye and Right eye images) using an interface consisting of two streams based on the SMPTE ST 425-1 data structures. The Left eye images are carried on one stream of the interface and the Right eye images are carried on the other stream.	Work in progress
Technology Committee 31FS	3D interleaved in MXF OP 1a	File format to standardize the transport of left and right eye images in frame interleaved MXF files for use in TV acquisition, contribution, distribution, station operations, and archives.	Work in progress

7 The Digital Video Broadcasting Project

Technical work in Digital Video Broadcasting Project (DVB) is driven by commercial requirements. Following completion of a study mission to investigate the possible need for 3D activities, further activity led to the publication of "DVB commercial requirements for DVB-3DTV" (DVB Document A151, July 2010). This addresses "frame compatible" 3DTV services over HD broadcast infrastructures. Work has started on considering a second phase of "2D service compatible" commercial requirements.

On 17 February 2011 the DVB Steering Board approved the DVB-3DTV specification, which has been published as BlueBook A154 – Frame Compatible Plano-Stereoscopic 3DTV, (DVB-3DTV). The specification has been sent to the European Telecommunications Standards Institute (ETSI) for formal standardization.

The specification specifies the delivery system for frame compatible plano-stereoscopic 3DTV services, enabling service providers to utilize their existing HDTV infrastructures to deliver 3DTV services that are compatible with 3DTV capable displays already in the market. This system covers both use cases of a set-top box delivering 3DTV services to a 3DTV capable display device via an HDMI connection, and a 3DTV capable display device receiving 3DTV services directly via a built-in tuner and decoder.

8 The Blu-ray Disc Association (BDA)

See: http://www.blu-raydisc.com.

9 HDMI Licensing, LLC, has announced the release of HDMIspecification 1.4

See: http://www.hdmi.org/index.aspx.

10 Consumer Electronics Association

The Consumer Electronics Association (CEA) has established a 3D Task Force. This is considering interfaces between consumer sources, sinks, repeaters, converters, and glasses. They are also considering what is needed for "3D READY" products. It is proposed to develop standards for 3D glasses, including interface, signalling, setup, control and polarization. A project is being considered to update CEA-861 to carry 3D content.

11 The 3D@Home Consortium

This comprises around 40 members, with the aim of speeding the commercialization of 3D video into homes worldwide.

See: http://www.3dathome.org.

12 Association of Radio Industries and Businesses

The Association of Radio Industries and Businesses (ARIB) has established a working group for researching 3DTV broadcasting in 2008.

See: http://www.arib.or.jp/.

13 Ultra-realistic communications forum

The Ultra-realistic communications forum (URCF) is a forum established by the organizations from industries, government and academies, with the aim of promoting the R&D of ultra-realistic communications.

See: http://www.scat.or.jp/urcf/.

14 3D Consortium

The 3D Consortium was established in 2003 and comprises 47 members from 3D industry. Its main focus is on stereoscopic 3D.

See: http://www.3dc.gr.jp/.

15 Consortium of 3-D image business promotion

The Consortium of 3-D image business promotion was established in 2003 and comprises 49 members.

See: http://www.rittaikyo.jp/.

16 Japanese Ergonomics National Committee

Japanese Ergonomics National Committee (JENC) is in charge of the national preparation for ISO TC159.

See: http://www.ergonomics.jp/.

17 Telecommunications Technology Association

In Korea, Telecommunications Technology Association (TTA) has established a 3DTV Project Group (PG806), with the aim of development of 3DTV broadcasting specification and viewing safety guideline. 3DTV PG consist of two Working Groups; WG8061 for the development of 3DTV broadcasting specification and WG8062 for the development of 3DTV viewing safety guideline.

TTA subsequently published "3DTV Broadcasting Safety Guideline" in December 2010 (see ITU-R Report BT.2293 Annex 2).

See: http://www.tta.or.kr/.

18 European Broadcasting Union (EBU)

The EBU (http://www.ebu.ch) has produced a 3D briefing document for senior management. This is reproduced in full in Annex 4.

In addition, EBU Recommendation R 135 "Production & Exchange Formats for 3DTV Programmes" (August 2011) provides interim recommendations for EBU Members who are required to produce, exchange, archive and distribute 3D programmes using 2D infrastructure and transmission technologies, see: http://tech.ebu.ch/docs/r/r135.pdf.

19 MUSCADE

MUSCADE is intending to create major innovations in the fields of production equipment and tools, production, transmission and coding formats allowing technology independent adaptation to any 3D display and transmission of multiview signals while not exceeding double the data rate of monoscopic TV, and robust transmission schemes for 3DTV over all existing and future broadcast channels. MUSCADE is a collaborative project co-funded by the European Commission's Seventh Framework Programme – ICT under the theme "Networked Media and 3D Internet". See: http://www.muscade.eu/index.html.

20 3D VIVANT

The 3D VIVANT project is investigating the generation of a novel true 3D video technology, based on mixed 3D Holoscopic video content capture and associated manipulation, and display technologies. This project, is supported by the European Commission through the Information & Communication Technologies programme. See: http://www.3dvivant.eu/.

Annex 2

Historical background on the development of stereoscopic and 3D television systems

Document 6C/92 describes the present state of three-dimensional (3D) TV broadcasting studies in the Russian Federation:

6C_92.doc

Annex 3

Introduction to free viewpoint television

See Document 6C/69:

069N06e.doc

Annex 4

Technical Report 10

3D Briefing Document for Senior Broadcast Management

EBU TECHNOLOGY AND DEVELOPMENT

Your reference in media technology and innovation

3D TV - Its importance to EBU Members

Geneva
December 2010

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Contents

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3D TV Briefing Document
for Senior Broadcast Management

Keywords: 3D television, Stereoscopy, Displays, Glasses, 3D Production.

3D TV Synopsis – What is important for EBU Members?

The value of 3D to the audience

The perception of the public towards 3D is predominately determined by cinema experiences. In spite of this, the consumer electronic manufacturers are promoting 3D as the next big desirable viewing experience in the home.

The EBU believes that public service broadcasters (PSBs) must take a pragmatic approach to 3D services and they should be aware of the value of an event or programme to its audience when making decisions about producing and broadcasting in 3D.

Programmes such as the Olympics and Eurovision Song Contests can be regarded as an "appointment to view" where an audience will be prepared to use glasses and watch 3D content instead of a 2D simulcast. This may not be the case with day to day viewing where the 2D version will just seem easier to watch.

Certain content genres such as wildlife documentary, especially macro and animation elements and some live events in smaller size areas can deliver a very immersive 3D viewing experience.

The display market

It is expected that all larger displays will be 3D capable in the future. For PSBs it is important to understand the potential number of households that are equipped with 3D capable displays.

GfK figures (Oct. 2010) suggest:

It is expected that by 2014 about 42% of all purchased display devices will be 3D capable.

The number of 3D devices in Europe is expected to be 600 000 by the end of 2010, and by the end of 2011, about 3 Million devices.

The primary question is whether consumers will accept 3D at all and whether they will invest in additional glasses (usually the displays are sold with one or two pairs of 3D glasses).

Content

Creating good 3D content requires special equipment and skills.

The current position of 3D rights is unclear, and public service broadcasters must pay close attention to developments in the discussions of 3D rights.

PSBs should grasp their responsibility to inform and educate the public about 3D for Television (in a way similar to that done for HDTV).

3D content is best produced with a particular range of screen sizes - home (30" to 70"), cinema or IMAX in mind.

Stereographers use different depth budgets for cinema and TV. Disparity (see glossary) that produces a good but large 3D effect on TV could cause extreme 'pain' as your eyes try to look in opposite directions in the cinema!

Making 3D that is OK on all screen sizes may be just that; OK but not stunning. This means that 3D content produced for the cinema requires post-processing to work adequately on consumer sized displays (and vice-versa). Not following this guideline will generally lead to unsatisfactory results.

3D and Health Issues

Poor stereoscopy *is* responsible for headaches, eye strain and nausea!

Estimates[1] of the number of people who suffer from 'stereo blindness' vary from 5% to as many as 15% of the population!

Note: *Stereoscopic 3D-TV displays call on the eye-brain to work in a way they do not normally do by separating the functions of focussing and pointing. This can cause eye discomfort, and may cause eye fatigue or other symptoms. The ITU-R is considering these 'health-related' issues. There is generally a shortage of information about the potential short or longer term effects of viewing S3D. The ITU-R, prompted by the views of the Italian administration, also recognizes that for environments such as the 3D cinema there may be health related effects in the use of the same glasses by multiple viewers. The ITU-R is asking the World Health Organization for information on all these issues.*

What can the EBU do to help?

The EBU technology group will continue to monitor market developments and those in the production, distribution and consumer domains. In particular, the following areas will be covered:

- 3D content availability from the industry at large (Blu-ray, gaming, acquisitions);
- Production technology, training and operational guidelines;
- Distribution and consumer technologies;
- Recommendations to standards bodies;
- Representing PSBs' positions;
- Monitoring and disseminating information about the physiological effects of 3D viewing.

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[1] See for example, http://www.telegraph.co.uk/science/steve-jones/7451130/When-watching-3D-can-fall-flat.html and http://www.settheory.com/stereo_blindness_test.html.

1. 3D history

What we currently think of as 3D is more accurately described as 'stereoscopy'. A true 3D image would allow you to see around objects in the picture. Also, as you moved, the image would look different viewed from different angles.

Stereo TV, on the other hand, follows 2D television rules i.e. the image follows you around the room and you can't look around objects. Stereo is more about providing additional depth rather than an additional dimension.

Stereoscopy experiments began in the 19th century, starting with still images but rapidly following the movies into the early cinema.

Stereo camera rigs were patented around 1900 and the earliest confirmed 3D film (*The Power of Love*) was shown in the Ambassador Hotel Theatre, Los Angeles, in September 1922!

Over the past 90 years, 3D has come and gone. After each decline there have been various attempts to revive the technology.

The 1950s were described as the golden age of 3D with the now-infamous '*House of Wax*' released in April 1953 with stereo sound!

The 1980s saw a run of 'Part III' films with the addition of a "-D" at the end of the title (e.g. '*Jaws Part IIID*'). Each revival was usually the result of a technical advance or a technique that seemed to make 3D better or more compelling, but it was never enough to catch a mass sustainable market.

2. Current situation

The latest revival of 3D is slightly different. It is being driven by a combination of factors:

- a run of very good 3D animations in the cinema that has whetted the public's appetite;
- the availability of affordable domestic flat screens capable of displaying several different 3D formats (prices starting from around 1400 €);
- in the near future, all HD Ready displays will be 3D capable;
- 3D content (feature films, gaming, US series) will be available direct to home via 3D Blu-ray disks and high speed internet (HBBTV, VoD, etc.);
- consumer cameras (stills and video cameras) are available that interface directly with the 3D displays.

3. Stereoscopy for Television

3.1 Acquisition

Traditional 2D camera positions for an event may not be good enough for 3D. If the cameras are too far away from the action, for example, the 3D depth effect is lost.

Mini Camera
Side by Side Rig

2 eyes = 2 cameras. But it's not quite as simple as strapping two cameras side-by-side.

The theory suggests the centres of the lenses should be about the same distance apart as human eyes. It's this distance that makes the depth 'seem' about right. Cameras are placed on a rig in different ways.

Only mini-cameras with small lenses are narrow enough for **side-by-side** rigs.

Studio cameras and field camcorders with high quality lenses are usually too large for side-by-side mounting (the lenses would be too far apart). Larger cameras therefore use 3D **mirror** rigs.

Full Size
Mirror Rig

The most common mirror rigs mount the cameras at 90° to each other with one looking through a 45° mirror.

Good mirror rigs can cost over 30 k€ and they are big!

Notes:

- *Lenses are matched as closely as possible for left eye and right eye cameras.*
- *Cameras are aligned and tracked as closely as possible.*
- *Zooms do not necessarily work well and some camera moves destroy the 3D illusion.*

Camera Positions for 2D and 3D coverage of football

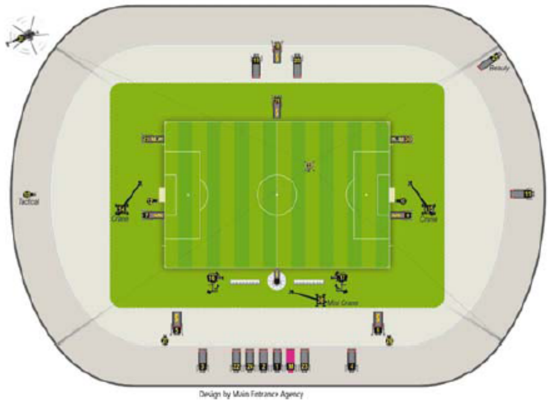


Figure 1a: Camera positions for 2D production

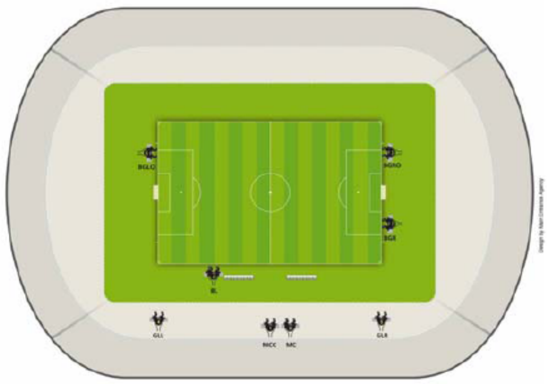


Figure 1b: Additional cameras required for 3D production
(courtesy of HBS [http://www.hbs.tv/orientation])

The additional cost of producing 3D content is difficult to calculate accurately.

Until there is a lot more experience of 3D acquisition, using one (typically the left eye) view of a 3D production for 2D HDTV is normally not advisable. In consequence of this, events for 2D HD and 3D will require two production crews.

Studio infrastructures based on 3G-SDI are being developed and can be used both for 3D and for next generation HDTV (1080p/50).

3D single camera productions usually need a longer time to set up and light and they may in fact need separate 2D and 3D cameras on the same shots if they are to be used for 2D and 3D services.

Each programme type will need to be assessed for 3D suitability against cost and value to the audience. Estimates vary from 20 - 50% increase over 2D HD.

Is has been observed that there is now a trend for integrated 3D cameras (combining left and right image capture in one camera housing; various technologies are employed).

Several manufactures are developing production tools to make set-up and alignment for 3D productions easier.

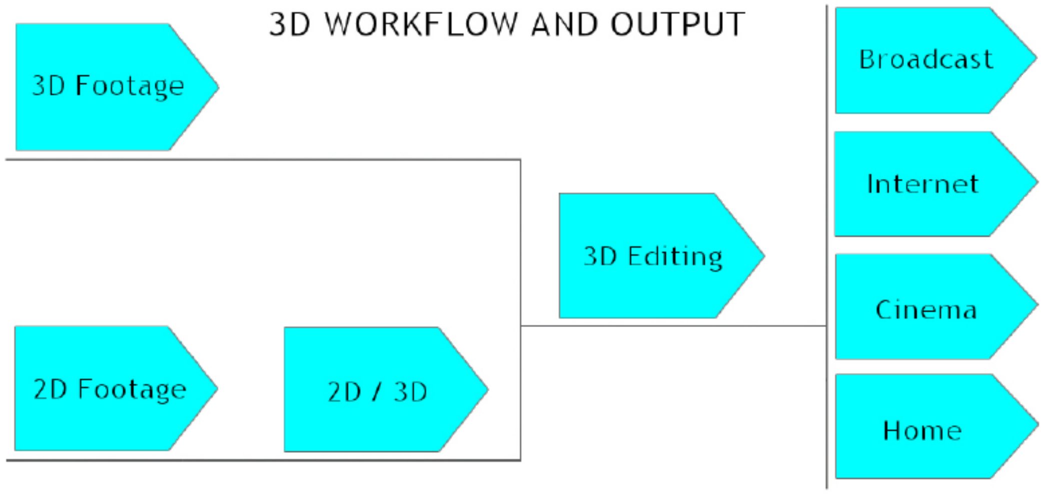


Figure 2: Simplified production route

3.2 Postproduction and Processing

If the cameras are set up properly, live and as-live programmes with simple cut editing are relatively straightforward. If the 3D depth of a programme needs to be adjusted in postproduction (with special 3D capable equipment and trained staff), this can take longer than editing the programme itself!

All major manufactures for postproduction equipment such as AVID, DVS, EVS, GV, Quantel and Sony are providing or updating their products to become 3D capable.

Getting things right in postproduction is a very time consuming and expensive thing to do. The shortage of skilled 3D editors will only add to the time and expense.

Storage requirements for 3D are double that of 2D and two images have to be moved around existing infrastructure and also archived.

All this will add to the cost and time taken to postproduce a 3D programme. Current thinking indicates that costs will increase by 25 - 30% over 2D programme costs.

3D postproduction costs will nevertheless fall as 3D options become standard in equipment.

Computer animation is ideal for 3D - hence the recent glut of 3D animated feature films. The rendering and postproduction computing power already required for (2D) animation is quite capable of handling the 3D element.

Animation has one other advantage as far as 3D is concerned; as everything in a computer animation is synthesised, if anything looks wrong, it can be changed to look right! The perspective or horizon or any part of the image can be adjusted until the 3D works properly.

3.3 2D to 3D conversion

It is technical possible to generate low quality 3D images from 2D images.

This process can be used where 3D cameras were not available for acquisition or for archived content to be included in 3D programmes.

Extreme caution should be used for converting 2D to 3D.

3.4 Displays and glasses

How can 3D work when it's displayed on a 2D screen? There are currently four primary technologies:

3.4.1 Colour separation

Anaglyph and Colorcode (and other colour variants) work by showing both left and right images at the same time on screen, the left eye image in one colour and the right eye image in another. This was the 'original' 3D technology used in cinemas in the past ('*House of Wax*' etc.).

Anaglyph Glasses

Colorcode Glasses

The viewer uses coloured glasses to make sure that the images go to the appropriate eye.

Figure 4:
Red/Cyan anaglyph image as it is transmitted and appears on all TVs

Whilst this is an inexpensive technology that works on any available display, the resulting 3D image quality is very unsatisfactory. It is no longer competitive in face of newer technologies and it is possibly the reason why 3D was never accepted in the past.

Consequently, EBU Members are advised not to use this technology.

3.4.2 Polarised / Passive

This technology demands a new 3D TV display with a polarised screen. The left and right eye images are lined up behind the polarising screen and each image is given a different polarisation.

To see the 3D image, polarised glasses are needed. These are similar to polarised sun glasses but the lens of each eye has a different polarisation to make sure the correct image goes to each eye.

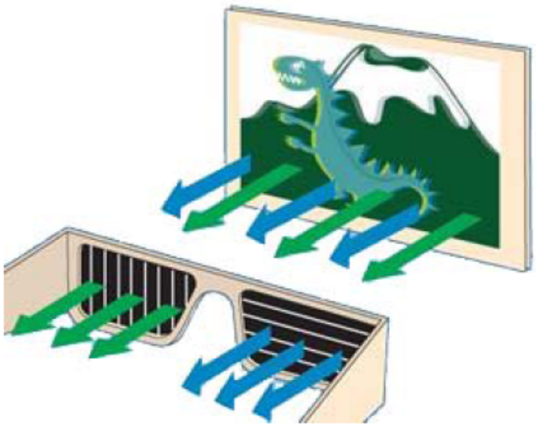
The glasses include no active electronic elements and are therefore termed 'passive'.

Advantages

- Good 3D;
- No colour or picture distortion as with colour separation;
- Glasses are very cheap;
- Used in displays for the professional market.

Disadvantages

- Requires a new 3D TV display;
- Both images are reduced resolution (no longer HD resolution);
- Technology in the display is more complex than for displays with shutter glasses (see below), thus they are not very common in the consumer display market;
- Variants of polarisation technology (e.g. linear orthogonal, circular) mean that glasses may not be compatible between different displays.



3.4.3 Shuttered / Active

Shuttered technology requires two active components - the screen and the glasses.

Shuttered LCD glasses are controlled by an infra-red signal sent from the TV. The left and right images are displayed alternately on the screen at a high frame rate (100 or more frames per second). When the left eye image is on screen the right eye lens of the glasses is made opaque and vice-versa.

Advantages

- Good 3D;
- Full resolution images;
- This is the primary format chosen by display manufactures for the new consumer 3D TVs.

Disadvantages

- Glasses are expensive e.g. from 80 € a pair;
- The Infra Red signal has not been standardised (e.g. glasses of one display will not work on another manufacture's display);
- Interference of the infra red signal can cause flickering.

3.4.4 3D TV with no glasses

The screen is covered with tiny lenses, arranged to send viewing zones of left/right images to the viewer.

The lenses direct the left/right images out of the screen in zones. If you sit in a zone at the correct distance and angle you see 3D - if you move out of a zone you lose the 3D image.

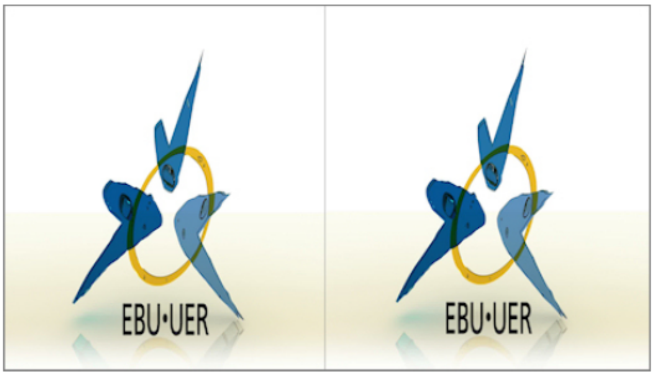
Lenticular screen technology is still very new. Displays for the consumer market are expected from about 2014 onwards.

4. Distribution and receiver

4.1 Current options

This involves using current HDTV distribution technologies and current set top boxes (STBs) in the home, but a new display is required.

The left and right signals are combined in a HDTV frame with the consequence that both images are reduced in resolution. This is called ***Frame Compatible*** 3D. Various ways of combining the signals are possible, the most prominent are:



Side-by-Side

Top and Bottom

The STBs pass these images through and it is the new 3D displays that stretch the reduced resolution left and right eye images to full frame to create the 3D image.

Note: Current 2D HDTV displays (not new, 3D displays) would show a side-by-side (or top-bottom) image as illustrated in the above figure, which is of course unusable for the viewer.

4.2 Future technologies in distribution and production

The limitations in 3D image quality inherent with Frame Compatible technology have triggered several working initiatives in the standards organisations such as DVB (for distribution) and the SMPTE (for production). Some of the aims of these activities are:

- Improved 3D image quality;
- More features such as depth control on the receiver or display (consumer side);

- 2D HD backwards compatibility to avoid the need for simulcasting, called ***Service Compatible*** 3D;
- 3D subtitling;
- Contribution links;
- Broadcast equipment interoperability standards.

5. Glossary of important terms

These are some of the more common terms used in 3D production; many more are used by experts.

Convergence:	Is where an object within a frame appears as a single image (both left and right images sit perfectly on top of each other). It is the position or plane of the TV screen and objects in front will appear to be out of the screen and objects behind will appear to be into the screen.
Depth budget:	This is the amount of 3D that is established for the 3D production. Typically it is referred to as a percentage. For some 3D productions of live events, depth budgets of less than 4% are used, e.g. 2.5% into the screen 0.5% out of the screen have been used.
Disparity:	Distance of the same object between the left and right eye view.
Inter Ocular / Inter Axial:	Commonly termed IO this refers to the physical distance between the centre of 2 frames, or loosely how far the cameras are apart. Note: it is the relationship between the Convergence and Inter Axial that determines the amount of 3D.
Positive & Negative Parallax: ("Inies" and "Outies")	Positive parallax means the object appears behind the screen, hence the term "Inies". Negative parallax means the object appears in front of the screen, hence the term "outies". Zero parallax means the object appears on the screen and the left and right eye images are exactly overlaid (exactly like a 2D image)
S3D:	Stereoscopic 3D
Stereographer:	New role in a 3D production team. He or She takes responsibility for the quality of the 3D.
Z-axis:	The axis from front to back of a 3D image, i.e. into and out of the screen.