Implementing Closed Captioning for DTV

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ABSTRACT

The Federal Communications Commission (FCC) rules impose obligations on broadcasters for captioning of digital television (DTV) programs, but there has been some uncertainty over exactly what is required. This paper sets out the main requirements defined by the FCC rules, summarizes what broadcasters should be doing to meet those requirements, and provides guidance on implementing the various links in the chain from caption creation through to emission. A method for transport of DTV closed captions is described using data services in the vertical ancillary data space of serial digital video signals, and several methods for feeding caption data to the ATSC encoder are identified.

RULES AND REGULATIONS

FCC Rules

Since July 1, 2002, US broadcasters have been required to provide closed captioning on at least some of their programs transmitted on DTV channels. The core responsibilities of broadcasters were defined in the FCC Report and Order (R&O) issued July 21, 2000, regarding DTV Closed Captions (DTVCC) [9].

The FCC R&O amended Part 15 of the FCC rules, adopting technical standards for the display of closed captions on digital television receivers. It adopted into the rules Section 9 of industry standard EIA-708 (now CEA-708-B) [6], specifying the decoding and display of closed captioning for DTV systems. For informational purposes it also incorporated by reference the remaining sections of the standard, which specify the encoding, delivery and other aspects of DTVCC.

The R&O amended Part 79 of the rules to require transmitted closed captioning to reflect the changes in Part 15 and to require all caption data to be passed intact through program distribution facilities in a format consistent with Part 15, unless such programming is recaptioned or captions are reformatted.

The R&O also clarified the schedule for including closed captions in digital programming.

No distinction is made in the FCC rules between DTVCC for high definition or for standard definition programming; requirements are the same for both. The R&O makes clear that during the transition period to digital television, DTVCC in accordance with CEA-708-B may be derived from legacy CEA-608-B [5] (analog) captions as well as from native 708 authoring. It also confirms that to count captioned DTV programming hours towards the captioning total for each channel, the broadcast DTV signal must include both CEA-708-B and CEA-608-B caption data.

Receivers

The rules require all DTV set-top boxes and DTV receivers with a screen height of at least 7.8 inches (the height of a 13-inch 4:3 display) manufactured after July 1, 2001 to include a caption decoder complying with Section 9 of CEA-708-B. Such devices shall provide the user with control of caption font, size, color, edges, and background. Decoders must be able to decode the six standard services in CEA-708-B and allow users to choose at least one for display. Set-top boxes that have an analog NTSC output shall insert 608 caption data carried in the DTV signal into line 21 of the NTSC video output.

Cable Carriage

The rules require digital television programming with CEA-708-B caption data services to be delivered to digital cable subscribers with captioning intact.

Programming Requirements and Schedule

The FCC rules allow for a phased introduction of captioning as follows (note that at this time the term "channel" has not been clarified in relation to multicast broadcasting):

New Programming

For each DTV channel the schedule for captioned video programs for *new,* non-exempt, English language programming is as follows:

1/1/00 to 12/31/01	450 hours per calendar quarter
1/1/02 to 12/31/03	900 hours per calendar quarter
1/1/04 to 12/31/05	1350 hours per calendar quarter
After 1/1/06	100%, with some exemptions

New digital programming is that "*prepared or formatted for display on digital televisions that was first published or exhibited after July 1, 2002*". For Spanish language programming the schedule is somewhat delayed, leading to 100% by 2010.

Pre-rule Programming

For *pre-rule* non-exempt English language digital (and analog) programming, defined as "*first published or exhibited before July 1, 2002*", the schedule is:

1/1/03 to 12/31/07   30% of programming
After 1/1/08   75% of programming

Equivalent dates for Spanish language programming are 30% at 1/1/05 and 75% at 1/1/12.

Thus DTV services now have the same hourly captioning requirements as NTSC services. The programming requirements were re-confirmed in an FCC Public Notice issued January 6, 2004 [10].

Exempt Programming

There are exemptions to the above captioning requirements for some types of programs, examples include:

- most programs shown between 2 a.m. and 6 a.m.;
- local non-news programming with no repeat value;
- commercials no more than five minutes long;
- some instructional programming that is locally produced by public television stations;
- programs in languages other than English or Spanish;
- programs shown on new networks for the first four years of the network's operations;
- public service announcements and promotional announcements shorter than 10 minutes, unless they are federally-funded; and
- programming provided by program providers with annual gross revenues under $3 million (although such programmers must pass through video programming that is already captioned).

In addition, a video programming provider or distributor may file with the FCC a petition for an exemption for specific programming.

ENT and Real-Time Captions

Electronic Newsroom Technique (ENT) automatically creates captions from a news script computer or teleprompter used for live newscasts. However live reports and other non-scripted items are not then captioned. FCC rules prohibit ABC, CBS, Fox and NBC and their affiliates in the top 25 television markets from counting news programming using ENT towards their captioning requirements. Rather these networks and stations must provide real-time captioning using a stenographer to convert the entire audio portion of the live program to captions. Others may use ENT to meet captioning mandates.

STANDARDS AND TERMINOLOGY

Although broadcasters may not need to know every detail of the complex standards involved for DTV captioning, it is necessary to be aware of the terminology used. Knowledge of the standards will certainly be useful in trouble-shooting and helping determine compliance of installed equipment and systems.

CEA-608-B

This standard defines the coding of data, including captioning, which is carried in line 21 of an analog NTSC video signal. It allows for up to four caption services per program and provides the familiar limited range of white characters (color is allowed but rarely used) within a box-like black background field. Captions generated in accordance with CEA-608-B are generally referred to as "*608*" captions.

CEA-708-B

This standard defines the coding of DTVCC as they are delivered in an ATSC emission bitstream as specified in ATSC A/53B [3], and is applicable equally to high definition and standard definition video formats, and to both terrestrial broadcasting and cable distribution. The captioning data is carried in the video user bits of the MPEG-2 bitstream, illustrated diagrammatically in Figure 1.
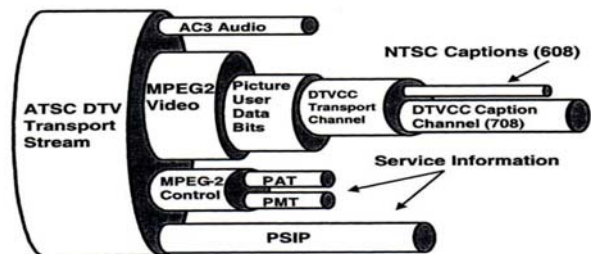

Figure 1 – Structure of the ATSC Transport Stream

DTVCC captions have greatly enhanced formatting and display capabilities compared to 608, with up to 63 services per program (only 16 can be announced in PSIP), eight independently controlled display windows, and an extended range of characters and multiple fonts, sizes and background and character colors and edges. The standard specifies how caption information is to be coded and processed, minimum implementation recommendations for DTV closed caption decoders, and recommended practices for caption encoder and decoder manufacturers. It also requires that decoders give users control over caption font, color, size and location that may override the parameters as transmitted. Document CEA-CEB-10-A [7] provides many clarifications and implementation guidance.

Captions generated in accordance with CEA-708-B standard are generally referred to as "*708*" captions.

608 Legacy Data

In addition to the actual 708 caption data required for use by a DTV set-top box or integrated receiver to display DTV captions, the CEA-708-B standard allows for, and requires, carriage of equivalent data for a subset of the captions coded in the 608 format. This legacy 608 data, also known as the *608 compatibility bytes,* is required for use by DTV set-top boxes so that line 21 data can be inserted in an analog composite video output (if provided) to feed a legacy NTSC TV set. Some DTV receivers may use the 608 data when 708 data is not available for providing closed captioning on the DTV display, but this is not mandatory and is not implemented in many receivers.

Caption Distribution Packet

CEA-708-B defines the Caption Distribution Packet (CDP) consisting of a specific sequence of bytes that can hold: the actual 708 DTV caption data, the 608 caption data, caption service information, and optional time code for synchronization (not needed with transport methods where the CDP is directly associated with video frames). The CDP is the basic unit of data that is transported through the professional portion of a DTV caption distribution chain.

Caption Service Descriptor

Caption service information comprises the caption service descriptor (CSD) as defined in the ATSC PSIP standard. It is used in the ATSC transport stream EIT (event information table) and PMT (program map table) to announce the presence and format of captions being carried.

ATSC A/65B [4]

ATSC A/65B defines information in the Program and System Information Protocol (PSIP) that describes the contents of an ATSC broadcast. It defines the caption service descriptor to be carried in the transmitted bitstream, providing metadata that may be used by the DTV receiver to display information about captioning in an electronic program guide, and may be needed to properly decode and display the closed captions. It states that for terrestrial broadcast transport streams the CSD must be present in the EIT, and that for transport streams delivered on cable the CSD must be present in the PMT for captioned programs and, if an EIT is sent, must also be present in the EIT.

Native Captions, Translation and Transcoding

Native Captions

Captions that are encoded and transmitted in the 608 or 708 format in which they were authored may be referred to as "*native 608*" or "*native 708*" captions.

Translated 708

It possible for captions to be encoded in the 708 DTVCC format by conversion from 608 legacy captions already encoded on line 21 of an analog NTSC video feed. This method can be used when the program was created primarily for NTSC transmission but is being encoded for DTV transmission, either as an SD program or with up-conversion to HD. For new programming this is expected to be an interim solution until native 708 caption authoring is generally adopted, but may persist indefinitely for legacy material that is already captioned.

There is no standardized algorithm for 608 to 708 caption conversion, but CEA-CEB-10 provides some guidance and says that the goal is "to produce captions with an appearance as close as possible to the appearance of the original data on a CEA-608-B decoder". Several manufacturers have implemented 708 encoders fulfilling this goal

The resulting DTV captions are usually known as "*translated 708*". They are also referred to in the FCC R&O as "upconverted captions" but this term should be deprecated because of the connotation that the process is related to video upconversion, which it is not. CEA-CEB-10-A and some manufacturers use the term "transcoded" in this regard, but that should preferably be used only to refer to the 608 compatibility bytes transcoded from 608 caption sources.

Transcoded 608

Where 708 captions are produced by translation from existing 608 line 21 data, the same data may be "*transcoded*" to fill the required 608 compatibility bytes.

RECOMMENDED IMPLEMENTATION

In accordance with CEA-708-B, ATSC A/65B, ANSI/SCTE 43 [1] and ANSI/SCTE 54 [2], DTV signals for broadcast and cable distribution, both for HD and SD program material with closed captions, need to carry:

- 708 DTV caption data
- 608 compatibility bytes
- Caption service descriptor in the EIT and PMT

To enable ATSC encoders and PSIP generators to generate signals that meet the above requirement, 708 caption encoders should produce the 708 DTV caption data, the 608 compatibility bytes, and caption service information.

CAPTION ORIGINATION AND ENCODING

CEA-608-B Line 21 Captions for NTSC

608 caption encoding for recorded material is shown in Figure 2. The program video is typically analog NTSC or digital SDI.
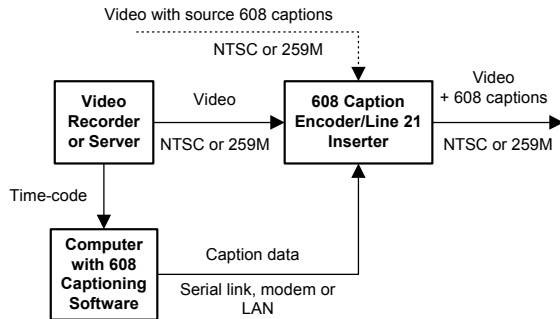

Figure 2 – Typical 608 Caption Encoding

The data from the captioning computer is processed and inserted in line 21 of the video to produce a signal that complies with CEA-608-B for NTSC transmission.

It is generally straightforward to insert, extract, or re-encode Line 21 captions at any point where the video program is available as an analog NTSC or SDI signal.

CEA-708-B VANC Caption Encoding

Where 708 captions need to be carried in a video signal, as shown in Figure 3 the architecture for encoding is similar to the 608 arrangement. This technique is independent of production format and equally applicable to captioning HD and SD program material. The program video is HD-SDI or SDI.
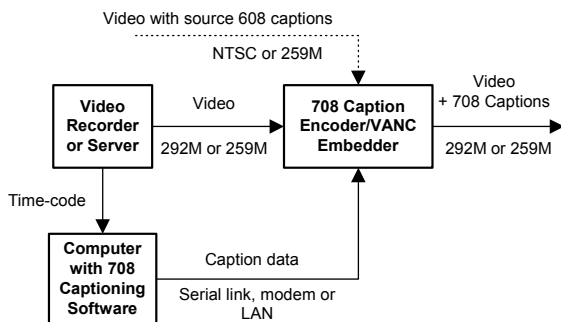

Figure 3 – Typical 708 Caption Encoding

For native 708 captioning, the data from the captioning computer is processed and inserted as caption distribution packets (CDP) embedded in VANC packets in the video signal in accordance with SMPTE 334M, Vertical Ancillary Data Mapping for Bit Serial Interface, [12]. Alternatively, as indicated by the dotted line input in the drawing, 608 captions from an NTSC video feed may be used as a source of captions to be

translated to 708. The two video sources must, of course, have identical program content.

The VANC packets are transported as an integral part of the digital video signal, however, special arrangements have to be made at any point in the distribution chain where VANC data may be removed.

Authoring for 708 Captions

708 Authoring Implementation
At this time, work is in progress by US national captioning organizations for an agreed 708 caption intentions format. In the meantime some 708 caption encoders can accept data from files configured with data in native 708 format – i.e. exactly as defined in CEA-708-B. It is also possible for 708 caption encoders to accept data derived from a 608 "caption intention" files. The resulting DTVCC are limited to the authoring capabilities of CEA-608-B and cannot exercise all features of a 708 caption decoder.

For full implementation it is recommended that CEA-708-B caption authoring systems should produce both 708 and the associated 608 caption data types, and provide appropriate data for the caption service information.

RECORDING, PROCESSING, DISTRIBUTION

Embedding DTVCC in VANC, whether for HD or SD program material, allows them to automatically follow the video through most standard routing and switching, and some types of processing and recording equipment, similar to the principle of carrying 608 captions in line 21 of an analog signal. However several issues must be considered as discussed below:

Recording
For recording systems, the integrity of the DTVCC data should be ensured by selecting a tape format and equipment or video server technology that preserves the SMPTE 334M data in VANC. This function may be integrated into the recording system; in other cases it may be by use of external bridges. Current recording equipment is generally not capable of recording and passing all VANC data from input to output and care is needed to ensure that the relevant data packets needed to implement DTVCC are preserved by the selected equipment.

Processing
Various video processing equipments in the broadcast plant may delay, repeat or drop video frames and/or delete the VANC part of the video signal. Wherever possible, system design should minimize the use of equipment that disrupts the flow of VANC data, or special provision should be made for bridging around

it. The bridging equipment should preserve the relative timing between captions and video as far as possible.

Compression Distribution Systems

If the program is distributed through a medium that involves MPEG compression, such as a satellite link, VANC data is not carried directly with the compressed video, therefore the CDPs must be bridged from the VANC packets of the input HD-SDI or SDI video signal to a data channel in the MPEG multiplex. In general, there are three different ways to do this:

1. The VANC data is packaged into the transport stream multiplex as a private data service on dedicated PIDs (packet ID).

2. For captions generated direct from a 708 caption encoder, a serial representation of the captions can be packaged into a private data service.

3. The uplink MPEG encoder takes the caption data and packs it into the video user data according to CEA-708-B and ATSC A/53B.

It is possible for all three of the above methods to be implemented at the uplink system, and the most useful one(s) selected for use at the downlink site. All will equally support 708 captioning data and the 608 compatibility bytes at the same time.

All these methods are supported with MPEG transmission at bit rates including, and higher than, the 19.39 Mbps ATSC emission standard, such as the 45 Mbps rate typically used for network distribution. Method 3 is similar to the arrangement used for emission station captioning and ATSC encoding. It is usually used for network distribution at 19.39 Mbps as implemented by some networks, but may also be used when the bitrate differs from the ATSC nominal, using the video outputs from the receiver/decoder with caption data in VANC or feeding caption data via serial link to an MPEG encoder.

In each case the equipment bridging the caption data through the MPEG process should preserve the relative timing between captions and video.

LOCAL STATION ARRANGEMENTS

Figure 4 overleaf shows a possible configuration of captioning-related equipment in a local station with ATSC and NTSC transmission. This is intended only to illustrate some of the captioning arrangements discussed below and is not a full system diagram.

The drawing shows a DTV system for HD only. A similar arrangement could be used for SD DTV using SMPTE 259M in place of SMPTE 292M. In that case

up and down conversion to and from the NTSC feeds is not required.

NTSC Station Output

For the NTSC station output there are two main arrangements, it may have:

1. A legacy NTSC station master control with legacy network distribution and local sources, or

2. A standard definition (possibly down-converted) feed from one of the DTV program services.

For the first case, NTSC caption arrangements will be unchanged from the legacy arrangement. For the second case, 608 caption data will usually need to be retrieved and inserted into line 21.

ATSC Station Output

For the ATSC station output there are three main arrangements, it may have:

1. A dedicated DTV (possibly HDTV) station master control or simple switcher with a (H)DTV network distribution and local live and recorded sources. The DTVCC should already be present on the live network and recorded sources but need to be added to the live local sources;

2. A feed (possibly upconverted) from the NTSC network distribution and master control. In this case the line 21 captions will need to be translated/transcoded to 708;

3. A bitstream received from the network already encoded in ATSC transmission format (at 19.39 Mbps) and ready to send to the DTV transmitter with local content spliced in and new PSIP information added. In this case, DTVCC should already be present in the incoming bitstream.

Some stations may have combinations of these arrangements, depending on network DTV distribution arrangements and the number of DTV program services.

Local Live DTV Captions

Live programming may be captioned using a 708 caption encoder with SMPTE 334 VANC embedding, as discussed above but with live video and with caption intentions generated in real-time, with authoring from a stenographer or with Electronic Newsroom Technique as mentioned above (where allowed). This is shown at the upper-left side of Figure 4. Alternatively the 708 caption encoder may feed the ATSC encoder directly as shown in Figure 5. If the local programming originates as an NTSC source, existing legacy arrangements for

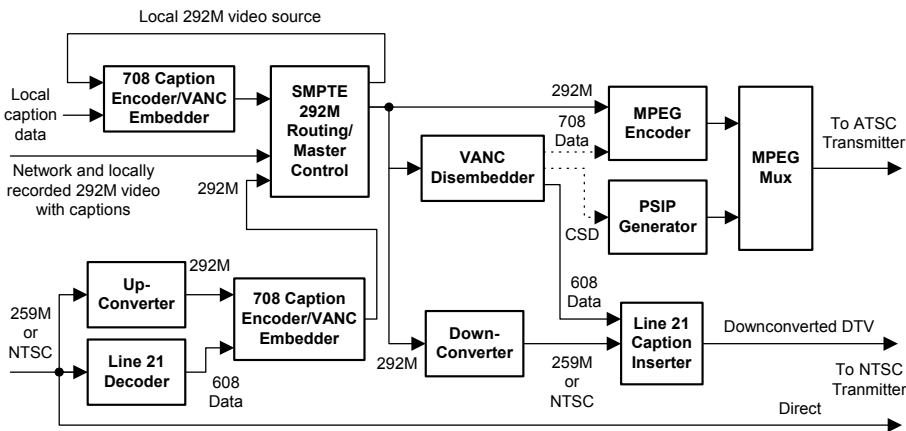live 608 captioning arrangements may be used, with bridging to DTVCC.

Figure 4 – Emission Station Captioning

NTSC – DTV (up-conversion)

Some HD DTV programs may be produced by up-conversion from an analog or SDI program intended for NTSC transmission. In this case, the captions must be bridged from the analog NTSC or SDI line 21 to CDPs in the VANC of the HD-SDI stream. This can be accomplished by having a decoder extract the 608 data from line 21 and feed it to a 708 caption encoder/VANC embedder, as shown at the lower-left side of Figure 4. Similar techniques can be used to insert DTVCC in the VANC of SD programs for DTV transmission, without up-conversion.

DTV – NTSC (down-conversion)

There may be a need to derive an NTSC broadcast signal from an HD-SDI stream. The CDPs carried in SMPTE 334M VANC packets in the HD-SDI stream should contain CEA-608-B data, which can be embedded into line 21 of the analog NTSC or SD- SDI video. This can be achieved by having a 334M VANC disembedder extract the data from the HD-SDI stream and feed the 608 caption data via a serial port to an analog NTSC or SDI line 21 closed caption inserter, as shown in the lower-right portion of Figure 4.

SERVER BASED CAPTIONING

The techniques described above for carrying captioning data in VANC of the video signal are appropriate for many applications of DTV caption distribution. An alternative server-based captioning architecture, where the caption data is distributed separately from video may have advantages for some station operations, and is particularly applicable in facilities using video-servers for program origination.

In this type of system, instead of inserting caption data into the video at some upstream point for distribution

with the video program, caption files are generated and then distributed separately from the video, typically over a computer network. A separate caption file for each program is stored on a captioning computer (server) at the emission station that runs software to manage the various caption files and playout. Software running on the captioning server, or on other networked computers, allows a program playlist to be established. As programs are played out, time code from the video server triggers captions from the caption server to be fed to the caption encoder and inserted into the transmission feed. Information on specific features and arrangements for server-based captioning is available from the manufacturers.

Server-based captioning is applicable to both 608 captioning for NTSC and 708 captioning for DTV. Such systems use basically the same interfaces between the captioning computers and caption encoders and between caption encoders and ATSC encoders as systems using captions embedded in video streams.
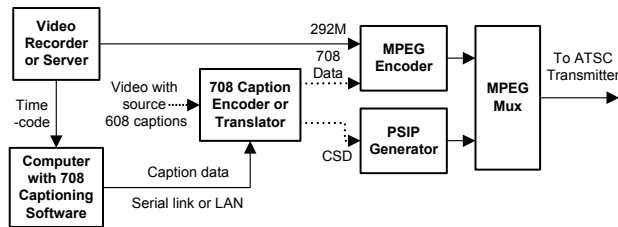
CAPTION INPUT TO THE ATSC ENCODER

The task of embedding the caption data into the ATSC stream in accordance with A/53 and CEA-708-B falls to the ATSC encoder. Several different methods may be used for getting the caption data into the encoder, depending on system configuration and manufacturer and the source of the caption data, as follows:

1. As shown in Figure 4, a SMPTE 334M VANC disembedder can extract the CDP stream from VANC in an HD-SDI or SDI video feed and transform it to the data format expected by the ATSC encoder. Most ATSC encoders have a caption input serial port. This port accepts data in one of two documented formats: SMPTE 333M [11], which is known as the "pull" protocol; or the so-called "Grand Alliance" format, also known as the "push" protocol.

2. For ATSC encoders that themselves have the capability of extracting CDPs from SMPTE 334M VANC packets, the "708" connection shown dotted in Figure 4 is not required.

3. Alternatively, as shown in Figure 5 overleaf, a local 708 caption encoder without VANC

embedding can be used to feed the ATSC encoder using a serial connection and taking caption data from a captioning computer or live authoring workstation. Figure 5 does not show the video routing and arrangements that may be needed for switching captioning data signals for different sources.

Figure 5 – Alternative Captioning Feed to Emission Encoder

4. As shown in Figure 5, a 608 to 708 translator/transcoder unit without VANC embedding can also be used to feed the ATSC encoder, with captions originating from a legacy line 21 caption source.

5. Some ATSC encoders can accept analog NTSC or SDI video and generate the 708 DTVCC captions for transmission from 608 legacy captions present on line 21 of the video, without using an external 708 caption encoder. Note that some early ATSC encoders inserted only the 608 compatibility bytes.

A combination of the above methods may be used. This requires that special switching (not shown in the drawings) is used to route to the ATSC encoder the appropriate caption data for DTV network, local sources, or NTSC converted sources.

PSIP AND THE CAPTION SERVICE DESRIPTOR

Caption service information is required to be carried in the DTV bitstream as set out in ATSC A/65B, ATSC A/53B, CEA-708-B, and ANSI/SCTE 54. For systems using CDPs carried in VANC, the caption service descriptor should be extracted from the CDP when the VANC data is disembedded and should be fed to the PSIP generator and, where appropriate, the ATSC encoder as shown in Figure 4. That equipment should enter the CSD into the PMT and current program EIT table entries. Local 708 caption encoders feeding the ATSC encoder and PSIP generator directly without using VANC, as shown in Figure 5, should also generate the caption service information.

Methods for originating caption service information are not standardized, and different users and manufacturers

may have different arrangements for generating the caption service descriptor. It cannot be assumed that all caption encoders generate complete and correct caption service information for the caption services as required for insertion in the PSIP tables.

Caption service descriptors to be entered in PSIP tables for future events have, of necessity, to be generated and distributed separately from the captioned video service. Arrangements for this will vary depending on the equipment and system design

Data Interface to the PSIP Generator

A proprietary message format has been developed by one manufacturer to allow the CSD and also the content advisory descriptor to be provided from a caption encoder or VANC disembedder to a PSIP generator upon request

However, ATSC candidate standard CS/75, Programming Metadata Communications Protocol, defines an XML-based open standard for communication of PSIP-related metadata between equipment in the facility, when it is not bound with associated video or audio. This facilitates transfer of both current and future program metadata (including the caption service descriptor) to the PSIP generator, and when approved as a standard (expected later in 2004) will be the preferred method of PSIP metadata communications.

MONITORING

Monitoring of 608 and 708 caption encoding and content should be carried out at appropriate points in the distribution chain to check for:

*   Presence of captioning information
*   How captions will be displayed on a consumer receiver (basic caption functionality)
*   Video/caption synchronization
*   Regulatory compliance

Caption data should be checked when the captions are generated and when programs are delivered. Master control facilities should be provided with monitoring for closed captioning data and functions, both for incoming program material and for transmitted broadcast signals. Points to note for 708 caption monitoring include:

1. Where 708 captioning data is carried in VANC, a VANC disembedder with appropriate caption decoders should be used to examine the 708 and 608 captioning and associated data. Some 708 encoders themselves provide the capability for monitoring and verifying embedded caption data

2. Verify correct insertion of the 708 and 608 caption data in the outgoing DTV bitstream. Presence of the caption data and the caption service descriptor in the ATSC transport stream should be checked using an MPEG stream monitor.

3. Monitor the broadcast 708 captions using an off-air DTV receiver with 708 closed captioning decoding capability. Professional receivers usually have more comprehensive functionality for this than typical consumer receivers and may also provide a bitstream output (typically ASI) derived from the demodulated RF, which can feed an MPEG stream analyzer. In addition, professional receivers may have a transport stream input that can be used to monitor the bitstream output from an ATSC encoder prior to sending to the transmitter. This capability will assist in system trouble-shooting.

4. DTV caption monitoring should include the associated 608 caption data using the derived NTSC signal generated by the DTV receiver to feed 608 monitoring equipment.

5. Monitoring of cable television captioning will require use of a suitable cable television interface unit or integrated receiver able to select and display the DTV captions.

Verification

Consideration needs to be given to arrangements for proving captions were correctly broadcast in the event that a complaint of non-compliance is received. One possible arrangement would be to maintain an off-air recorded log of station output with a bitstream recorder – disk-based server or tape-based system.

CONCLUSIONS

While there have been some uncertainties over requirements and methods for implementing DTV closed captioning, the situation is now becoming much clearer. A range of products for encoding, distributing and transmitting DTVCC is now available from several manufacturers and fully compliant DTV captioning is possible. Program producers have still to take advantage of the capabilities of CEA-708-B caption authoring, and standards work still remains to be done to ensure compliant captioning is transmitted under certain complex service scenarios.

FURTHER INFORMATION

Some of the information in this paper is taken from an SMPTE Engineering Guideline on Implementation of CEA-708-B and CEA-608-B Closed Captioning Implementation [13] currently in preparation and expected to be issued for trial publication in the near future. That document provides more detail on many of the techniques mentioned here. Additional information may also be found on the following web sites:

FCC
http://www.fcc.gov/cgb/consumerfacts/closedcaption.html
NCAM
http://ncam.wgbh.org/dtv/
ATSC
http://www.atsc.org/faq/faq_closed.html

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