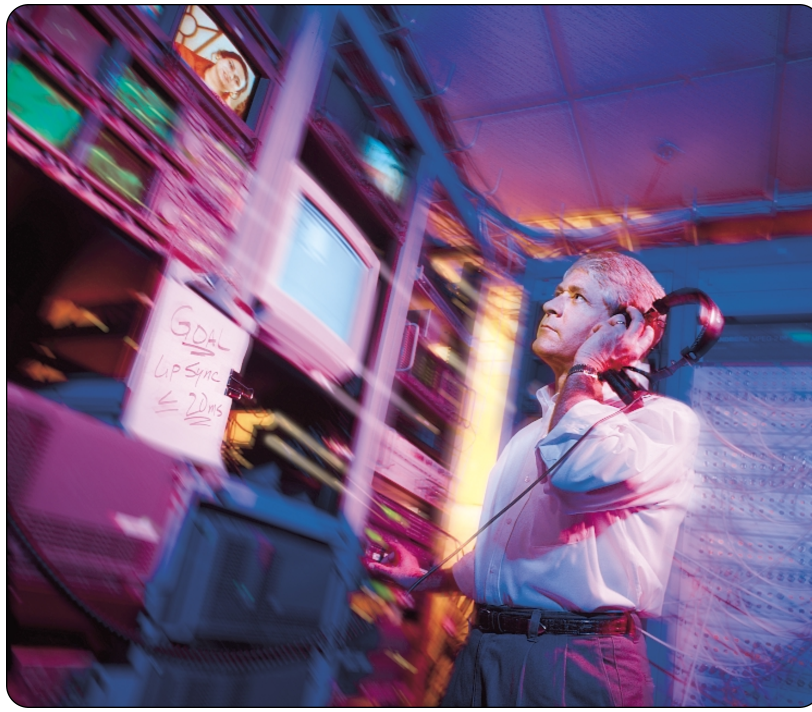

COMPUTING
COMMUNICATIONS
VIDEO

Audio-to-Video Delay Solutions within the Broadcast System

▶ A New Approach to an Old Problem...

Synchronization of audio and video has always been a challenge in the video plant. Rather than going away with the advent of digital television, it has become even more of a challenge. But now, a new technology from Tektronix, Inc., based on digital video watermarking, promises an entirely new approach to this problem.

The Nature of Audio-to-Video Delay

We have come to expect much of television over the last decade, including increased channel capacity and video/audio quality improvements, largely due to new digital processing capabilities. However, one factor of television program quality has remained constant: the proper and consistent synchronization of the visual and audio signal elements, otherwise referred to as lip-sync timing. But while lip-sync error has presented challenges to broadcast engineers in analog plants for years, it presents even greater challenges in digital plants where digital processing is becoming a common step in the production and distribution process of television programming.

The increasing complexity of routing, distributing, and digital signal processing of multiple channels of video and audio signals has caused increasing problems in maintaining audio-to-video synchronization within the broadcast plant. Small, unnoticeable audio-to-video delay errors within parts of the plant eventually accumulate to produce a noticeable error at the end of the distribution channel. It is therefore important to monitor and measure audio-to-video synchronization at several points within the system.

Usually, audio-to-video delay is introduced within the broadcast network whenever audio and video signals are processed separately. The processing of high bandwidth, digital video signals can take several fields to produce an output signal, whereas audio has a significantly lower bandwidth than video signals and takes less processing time to produce an output. Therefore, it is necessary to consider processing time differences within the system design of the broadcast plant and insert fixed delays in the audio path to remove the audio-advanced-to-video condition.

Typically, a skilled operator manually watching and listening to the program material has to determine the presence of an error. In order to do this, the operator must look for visual clues within the picture to determine if the sound heard corresponds to the picture and that they are indeed synchronous. The most obvious method is to listen to a person speaking while watching their lip movements to verify audio-to-video

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"lip-sync." When there are no visual clues in the picture to determine synchronization, such as a voice-over, it is difficult for an operator to determine a lip-sync error.

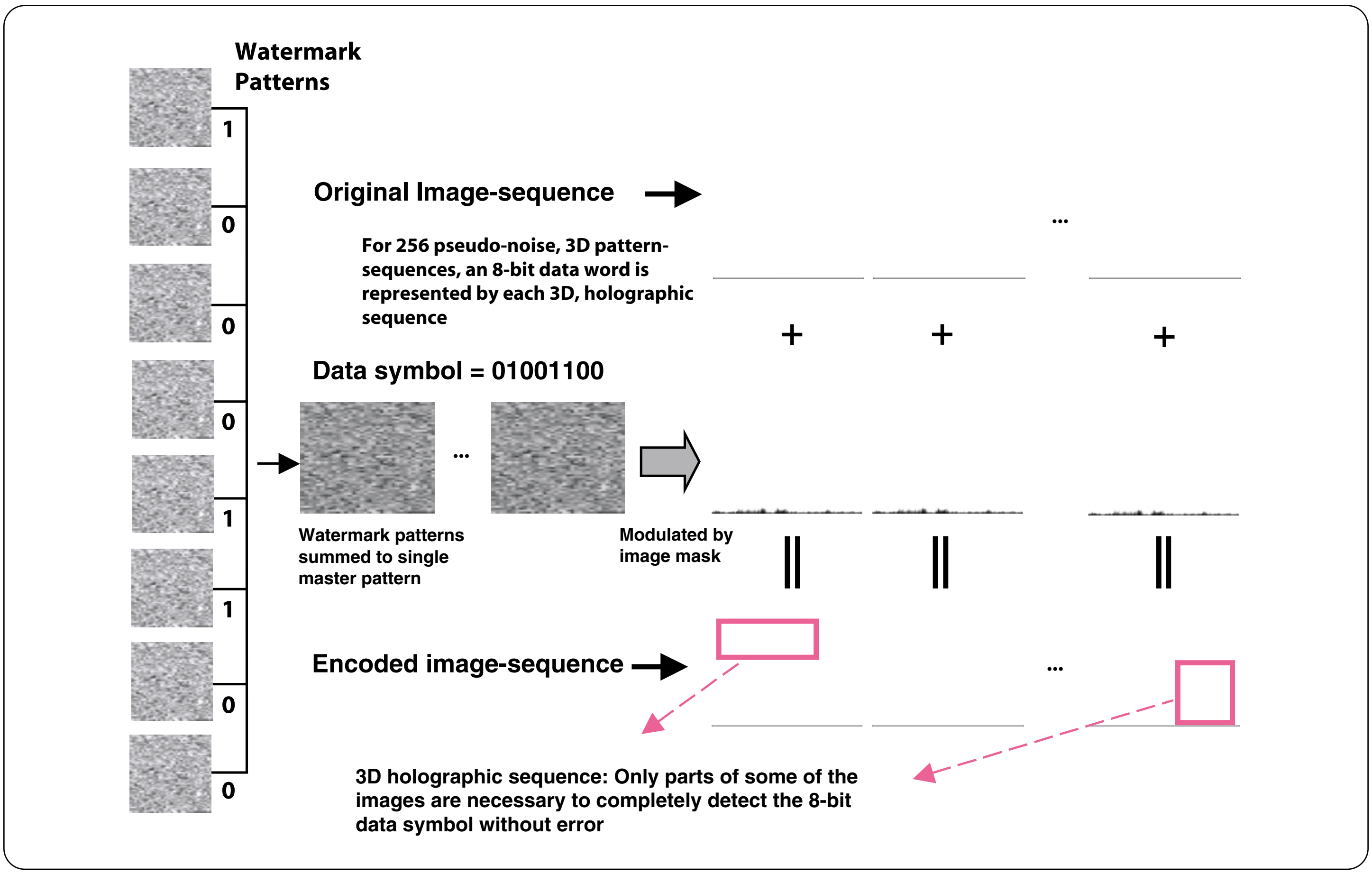
Traditional Methods for Measurement of Audio-to-Video Delay

Traditional automatic measurement of lip-sync error is a fairly complex problem. The solution requires the simultaneous generation and acquisition of both video and audio signals and an analysis of their relative timing. However, because of the random and dynamic nature of live video and audio programming, traditional testing is achieved only out-of-service, using specialized video and audio test signals inserted "upstream" into the program chain for later analysis of relative timing. The test signals required for this out-of-service method consist of a full-field video pedestal signal which is cycling between picture black and peak white synchronously with an audio tone which is "chirping" on during picture white and off during picture black, providing a good audio-to-video correlation reference.

Limitations of traditional automated lip-sync error measurements are well known. They include the following:

1) reliance on skilled, subjective analysis of the audio and video timing
2) out-of-service use
3) reliance on technologies which must pass data embedded within the television signal vertical interval or ancillary data space

However, a new technology developed by Tektronix, Inc., based on digital video watermarking, promises an entirely new approach to monitoring and correcting audio-to-video delay errors.

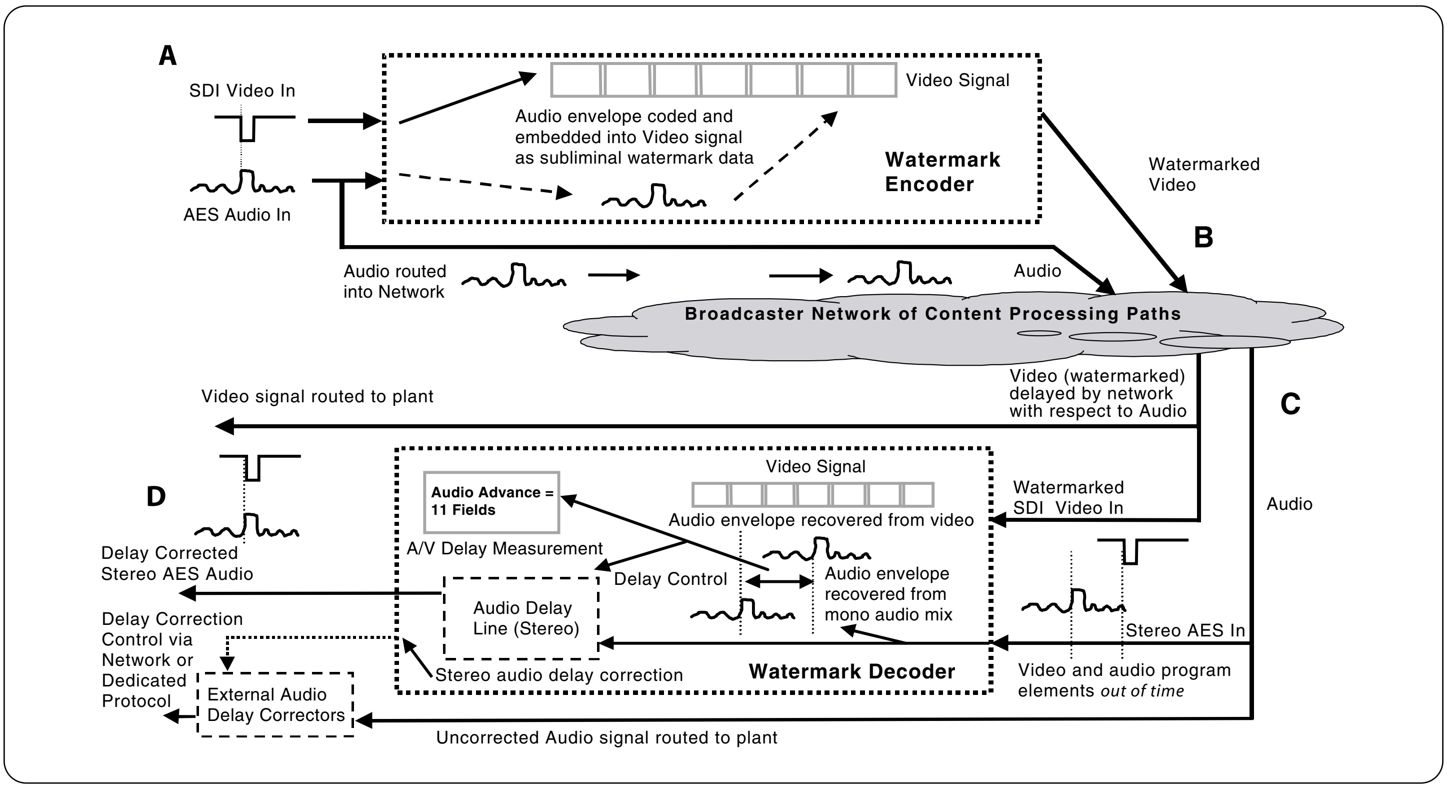


▶ ***Figure 1.*** *Conceptual illustration of the Tektronix "Intra-video" data channel technology. In this example, eight watermark patterns per video frame can provide for a 200-baud (25 frames/sec x 8 watermark patterns per frame). The watermarked data channel is encoded with the transformed facsimile of the audio-envelope variation for later decoding and comparison with the original program audio envelope. Additional data capacity is available for source identification coding.*

A New Method Proposed

Tektronix's digital watermarking encoder, the AVDC100, is optimized to embed a heavily compressed, transformed facsimile of the audio-envelope variation for coding into data words. The data words are then encoded into the video signal, frame-by-frame, as part of a permanent watermark pattern, creating a record of the audio-envelope variation at that point in time. The audio envelope itself is not encoded, only the variation within the envelope. In addition to the audio-envelope variation, the AVDC100 watermarking technology provides additional payload capacity to encode a permanent source ID that can be detected by additional AVDC100s anywhere in the program distribution chain. This allows program distribution for fulfillment of program play-out obligations to be tracked. Figure 1 illustrates the process of digital watermarking.

An audio-envelope signature characterizes the audio input signal (see Figure 2). This envelope is digitized and added to the video signal by means of the Tektronix digital watermark technology that hides the data within the picture. The watermark can be thought of as a pseudo-random pattern that is added to a full-frame picture. The pattern is modulated into the picture dependent on the scene to allow the pattern to be invisible to the viewer. Now we have a synchronizing reference embedded in the video signal that is going to be processed with the video signal as it is distributed throughout the network. At some point in the network, the separate processing of audio and video signals will be combined and another AVDC100 can be used to decode and measure any audio-to-video (A/V) synchronization error. This is accomplished by extracting the audio signature from the SDI video signal and comparing it to a newly generated audio signature at the measurement



▶ ***Figure 2.*** *Audio-to-Video Delay Correction System Diagram. Synchronized audio and video programming enter the encoder at point A. The program audio envelope is coded and embedded into the video signal as subliminal watermark data (B). The watermarked video and program audio are routed to the normal distribution network (C). The program video and audio leave the network with video delayed relative to the audio; i.e., audio-to-video delay. At this point, the program audio and video are applied to the decoder/corrector which detects and decodes the audio envelope from the watermarked video (D). The timing shift between the recovered audio reference and the original audio signal is measured and used to control an audio delay block which continually re-times the audio to the video signal.*

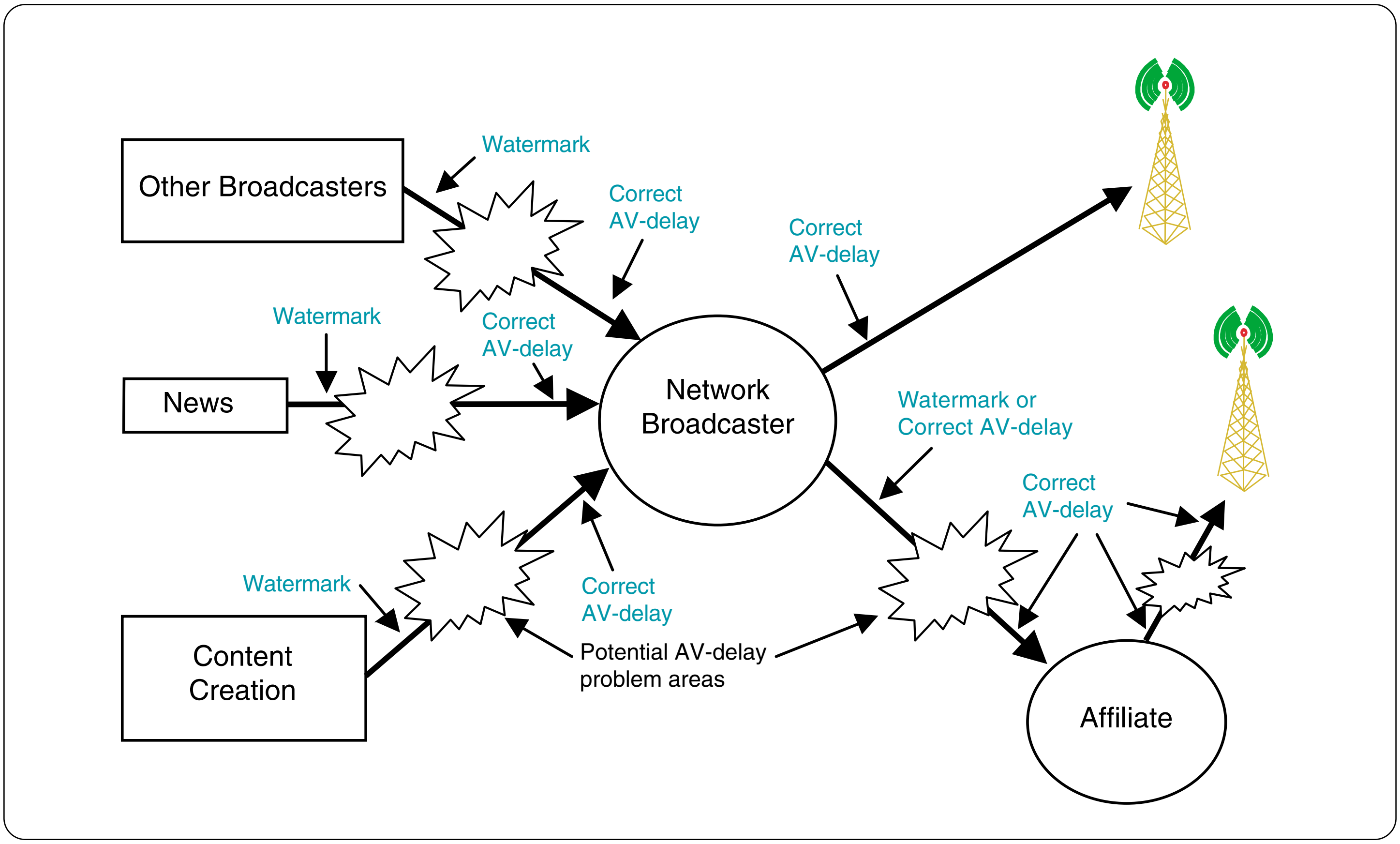


Figure 3. *The AVDC100 is used to watermark programming content at their origination points, where the audio and video are judged to be in time. Then, anywhere in the program distribution chain, another AVDC100 can be used to decode the embedded watermark and recover the encoded audio timing information. Constant monitoring and correction of the audio-to-video delay, which develops in the network, is possible.*

point. A correlation process takes the two audio signatures and calculates the measurement of A/V Delay, displaying the value on the device. The user can then automatically select to correct for audio advance conditions by using the internal audio delay. This produces a properly re-timed audio and video output.

The AVDC100 can also be used to insert a content ID within the watermark process as part of the data carried within the picture. The user can program that a specific set of characters be used for identification of the program material. At various points in the network, the watermark decoder can extract this information and display it on the AVDC100 as a scrolling message (see Figure 3).

The audio-to-video delay correction system is a point to multi-point system. It is therefore important to perform the watermarking process at certain originating points within the network where no audio-to-video delay exists to ensure correct timing throughout the rest of the system. The originating material should be watermarked to provide the desired reference of audio-to-video, otherwise there is the potential for error within the system by embedding a watermark with a significant audio-to-video delay error. However, this point-to-point system can correct any further error that accumulates throughout the system.

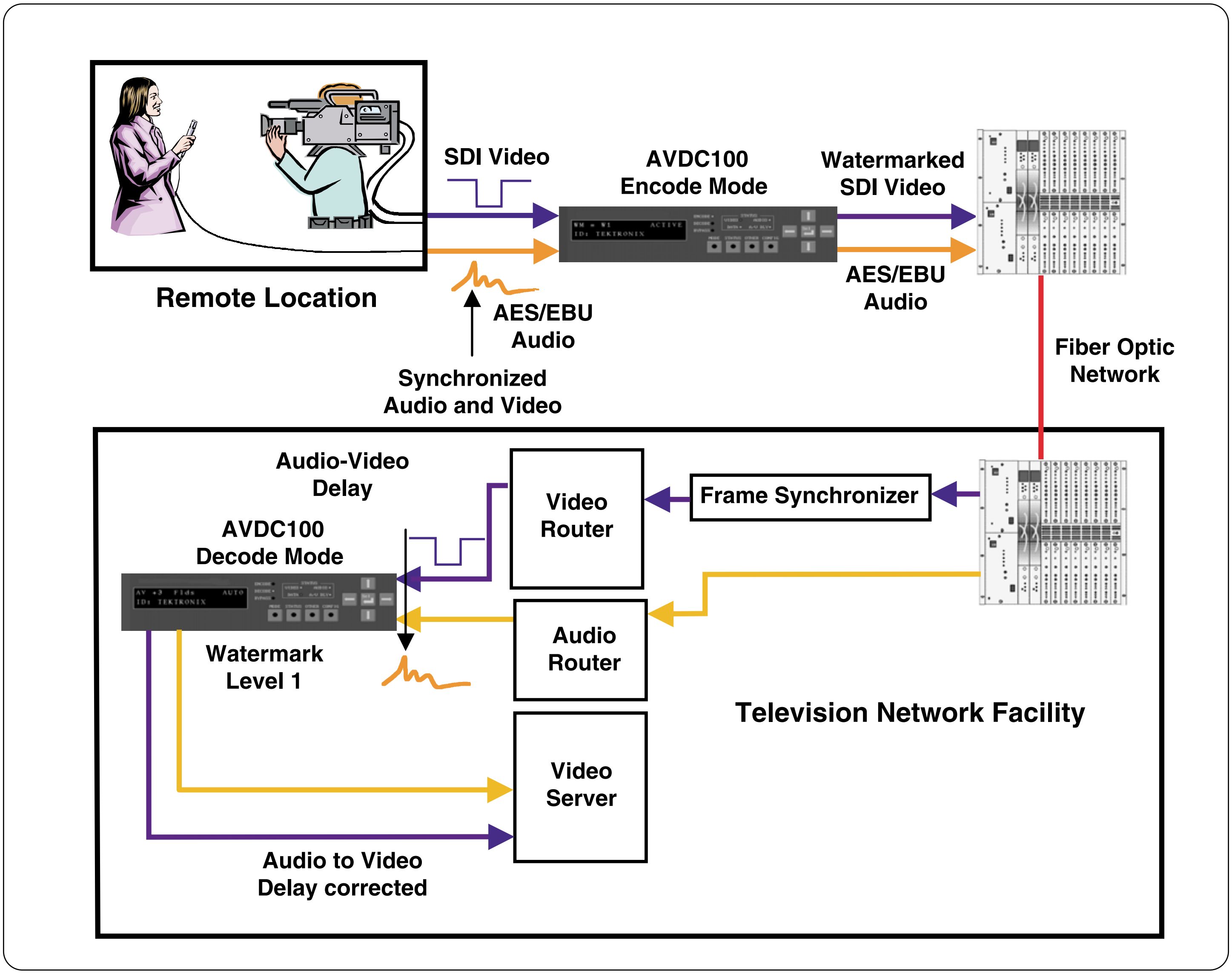


Figure 4. *How to use the AVDC100.*

Practical Solutions

The originating video production either happens at a remote location or within a television studio. It is at this point that audio and video are properly timed and the video should be watermarked. An AVDC100 is set to the watermark encode mode to add the audio signature data to the video signal. The AVDC100 is capable of inserting one of three different watermark energy "levels." The lower the energy level used, the less watermark energy is inserted; however, large amounts of video processing could remove the low-energy watermark so that it could not be successfully decoded. Therefore, a higher energy watermark should be used in these transmission paths if watermark-decoding errors are to be avoided.

Figure 4 shows a typical contribution of video production from a remote location using a 270 Mb fiber optic link to the television network. The transmission link is a high quality system and does not degrade the signal; therefore, watermark level 1 should be used for contribution-quality video in the origination phase of the program.

The processing of the audio and video signals within the transmission channel could have introduced delay within the system. By setting an AVDC100 to watermark decode mode at the point within the television network where the audio and video signals are combined, the propagation delay between audio and video through the system can be measured and corrected by the AVDC100.

In certain systems, the audio signal could be embedded in the SDI signal within the transmission path. Normally, audio embedding equipment is not a source of audio-to-video delay error. However, in many cases it is still desirable to monitor and correct for audio-to-video delay error that could have occurred within the program distribution chain. Such errors could be caused by equipment that processes video with embedded audio or after repeated audio de-embedding and re-embedding cycles. In this case, the user should choose to watermark the video before the initial audio embedding process. Note that when using embedded audio, the AVDC100 watermark decoders located within the television network need to be routed to the appropriate embedded audio signals in order to correlate the same selected pair of audio channels used by the AVDC100 watermark encoder. Therefore, the television network needs to standardize on the two channels it will use for the audio signature. If the signal will pass through several different broadcaster networks, the user could select the watermark ID data to carry information regarding which embedded audio channels are being used for watermarking. With appropriate audio de-embedding, the AVDC100 can measure the audio-to-video delay. The two selected audio channels will be re-timed to the video signal. If the user wishes to correct all the embedded audio channels, an external audio de-embedder and re-embedder with appropriate delay unit is required. The AVDC100 can be used to drive the delay of the external devices, providing a solution to controlling audio delay on multi-channel audio sources.

Application In a Broadcast Distribution System

A practical application of the Tektronix watermark encoder/decoder technology for monitoring and correction of audio-to-video delay is demonstrated within a television-broadcasting network. This television network employs a number of Tektronix watermark encoders for watermarking of outgoing network distribution feeds with associated audio envelope information. Watermark decoders are installed at regional network reception sites to monitor the watermarked network feeds and, if necessary, correct for audio-to-video delay error, which may have occurred during the program distribution process. In this typical application, the potential of audio-to-video delay from the output of network master control to archival at the regional re-transmission sites is of particular interest. Areas of concern include 1) output of the MPEG-2 encoders at the network uplink and 2) output of the MPEG-2 decoder at the regional downlink and subsequent video processing at the regional transmission sites including program synchronization to studio reference and program archival. Any one point within the distribution and archival chain may contribute fixed or even variable amounts of audio-to-video delay, making set-and-forget audio delays difficult to use or entirely inappropriate.

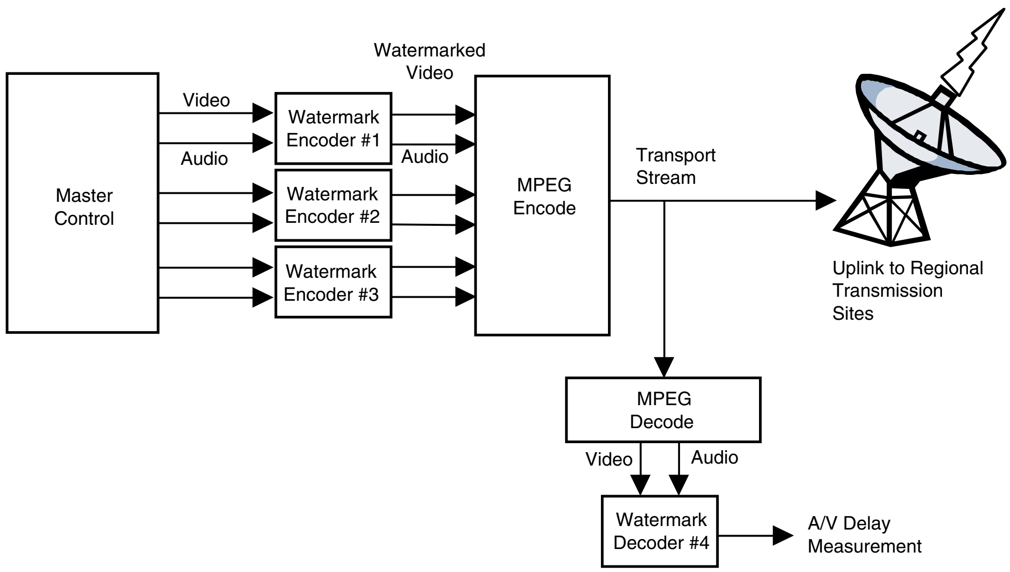


Figure 5. *Watermark Encoders #1, #2, and #3 watermark individual program feeds from Master Control prior to MPEG-2 encoding. In addition to encoding audio envelope data, each watermark encoder is configured with a unique source ID code which is added to the watermark data creating a permanent source ID tag within the video signal.*

Referring to Figure 5, watermark encoders #1, #2, and #3 are installed in the program chain at the output of network master control, assuring watermarking of the individual program video signals with known good audio-to-video timing relationship. In addition to watermarking audio envelope information for audio-to-video delay correction, each separate program feed is watermarked with a unique source identification code that can be later decoded by the regional transmission site or network control for confirmation that a particular program aired when scheduled. After processing, the watermarked video and program audio signals are MPEG-2 encoded and multiplexed into a transport stream for uplinking to network distribution. Note that MPEG-2 encoding and RF modulation during network distribution have negligible effect on the Tektronix watermarking technology ensuring stable watermark data decoding throughout the program contribution chain. At the output of the MPEG encoder, a test MPEG decoder and watermark decoder #4 is used to monitor audio-to-video timing through the primary MPEG encoder during live network programming.

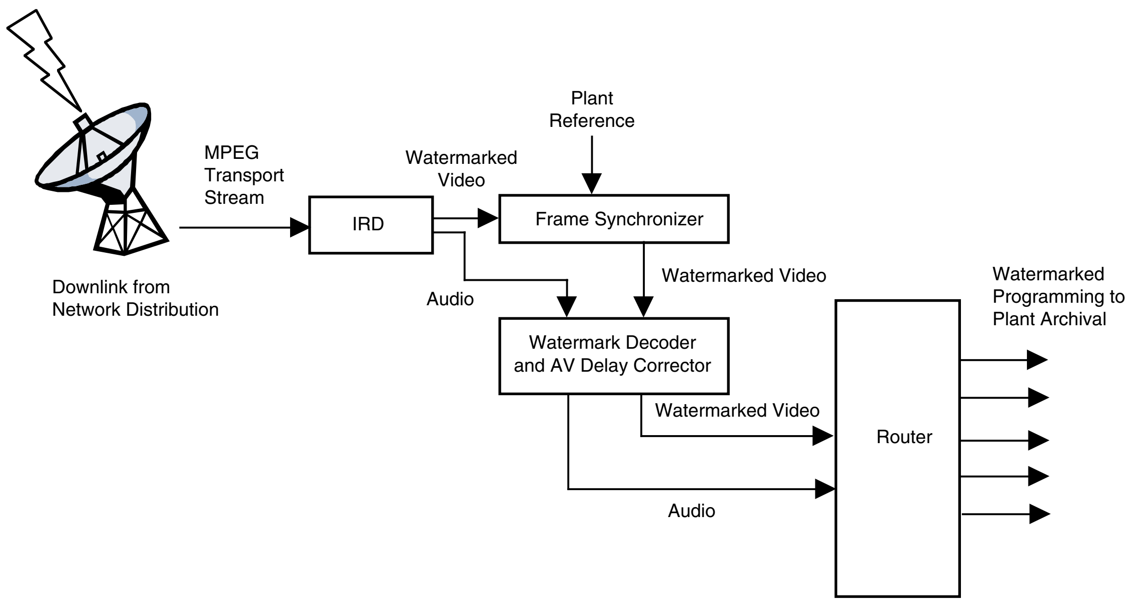


***Figure 6.** At the regional transmission downlink, additional watermark decoders, positioned just after the video frame synchronizer, are configured to decode the embedded watermark for monitoring and correction of audio-to-video delay. The Tektronix watermark decoder also decodes the unique source identification coded earlier at the network uplink site.*

Referring to Figure 6, network programming is downlinked at the regional distribution site and processed through an IRD (Integrated Receiver-Decoder), which decodes the MPEG-2 transport stream into individual video and audio program elements. The video is then routed through a frame synchronizer that can add multiple frames of video delay to the signal path. The video signal and associated audio signal are routed to another Tektronix watermark decoder configured for A/V delay correction mode and positioned just after the video frame synchronizer. The Tektronix watermark decoder detects and decodes the watermark from the video, extracting the audio envelope data and unique source identifier, encoded at the network uplink facility. The watermarking hardware compares the audio envelope data, extracted from the watermark, with the program audio envelope data. Timing variations between the data points are calculated and reported as audio-to-video delay and used to control an internal audio delay for constant correction of audio-to-video delay errors. In the event the incoming network program feed lacks watermarking, the watermark decoder at the regional site either maintains the current audio delay setting or slowly slues to zero audio delay until a watermark is again detected on the incoming network programming feed and audio-to-video delay values can be updated.

Post Production of Watermarked Material

Within the television production environment, it is likely that the originating watermarked program will be recorded or archived for future use. Watermark level 1 will survive some digital processing and light compression and will therefore remain as part of the video program when recorded.

However, post-production offers a wide array of digital processing effects and the ability to manipulate the original program material. Digital manipulation of the watermarked video can clearly affect the ability of any watermarking system, including the AVDC100, to recognize and decode an embedded watermark. Therefore, it is critical to understand if a watermark is sufficiently present in the video program in order for the watermark decoder to function at the necessary level.

The user can configure the AVDC100 for two possible scenarios when watermark detection is not possible. The audio delay can be selected by the user to "flywheel" at the last successfully detected value until a watermark is again positively detected, or it can gradually slew to the minimum default audio delay value configured by the user.

Creation of titles and graphics over the watermarked picture should still allow the AVDC100 decoder to extract the watermarked data. The decoder only needs to detect a few lines of the watermark pattern in order for the watermarked data to be decoded provided no geometric distortions, such as picture squeezing or shifting, occur. Therefore, titles and logo bugs overlaid in the picture should have no effect on decoding the watermark from other areas of the picture.

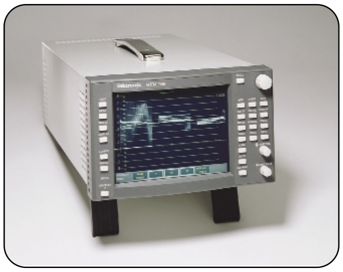
Further audio mixing during the editing process often adds a "voice-over" to the original audio (used for watermarking) or adds a background audio track. This audio editing process has the potential to change the audio envelope data from the original watermarked data and potentially affect the ability of the AVDC100 to successfully correlate an A/V delay measurement. However, if the background audio is at a low audio level and does not change the peaks of the original audio envelope, it is still possible for the AVDC100 to correlate the original audio watermarked data with incoming audio signal to the decoder. When a total voiceover which completely changes the audio track occurs, it is highly likely that there will be no visual reference between the audio and video program, thus eliminating the need for automatic A/V delay correction anyway. Essentially, because the voiceover audio envelope has replaced the original audio signal, there will be no correlation between the watermarked data and the audio signal.

Conclusion

Audio-to-video delay errors are an increasingly unpleasant fact of life for television broadcasters, content providers, and television network distribution engineers. While television viewers have come to expect increasingly higher quality of programming content, the complexity of understanding the causes of, and implementing corrections for, audio-to-video delay is actually increasing. To make matters worse, the typical audio-to-video delay error today is with video lagging audio, which is not only more noticeable, but is more unsettling and annoying to viewers.

While traditional audio-to-video delay measurement methods are proven and readily available, they are out-of-service technology due to the interfering nature of the required video and audio test signals. However, digital video watermarking technology provides a solution to this problem by enabling an in-service method for monitoring and correcting of audio-to-video delay, allowing a fresh approach and potential solution to an old problem.

WFM700 Multiformat Waveform Monitor



- Monitors and measures HD and SD signals in a single unit
- HD and SD eye pattern measurements and jitter displays
- Configurable/modular architecture
- Up to four input channels of digital video
- Digital processing ensures reliable and repeatable measurements
- Color display is 50% larger than standard displays

VM700T Video Measurement Set

- Measures NTSC, PAL, and SDI signals
- Waveform monitor, vectorscope, and picture display
- Three input channels
- Auto measure with user-definable limits
- Programmable functions
- Remote monitoring, measurement, and control

TG700 Multiformat Video Generator

- Multi-format analog and digital test signal generator
- Modular expandable platform
- Ideal channel configuration and performance to support reference generator needs

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