Multi-layer Confidence Monitoring in Digital Television Broadcasting

Digital Video Primer

COMPUTING COMMUNICATIONS VIDEO

Tektronix
Enabling Innovation

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As television broadcasters transition from analog to digital technology, fundamental differences in these technologies are leading to new approaches for ensuring broadcast quality and reliability. In this primer, we describe quality control and system management challenges digital broadcasters face and the monitoring devices that have been developed to address these challenges.

Confidence Monitoring in Digital Television

Analog television signals represent video and audio as a continuous range of values that can assume an infinite number of states. Minor imperfections in the channels that distribute or transmit these signals can produce noticeable errors in the picture or sound. Quality decreases steadily with increased degradation in the channel.

Analog broadcast engineers can recognize the onset of channel impairment by simply watching the television broadcast. With experience, they can classify the type and level of impairment and take corrective action before quality degrades to an unacceptable level. Monitoring instruments add precision to this basic quality control approach.

Digital television signals represent video and audio information as a discrete set of values that can assume only a finite number of states. Minor imperfections in the channels that distribute or transmit these signals generally have no noticeable effect on picture or sound quality. Quality remains high as channel degradation increases until the impairment level reaches a threshold point. At this “digital cliff,” quality decreases to an unacceptable level.

Thus, digital system engineers *cannot* detect the onset of channel degradation by watching the broadcast; they can only *react* to severe quality problems once they appear. Digital broadcasters need monitoring approaches that let them *proactively* address channel degradation *before* it leads to noticeable quality problems.

Monitoring instruments that can detect impairments before they impact quality help broadcasters achieve the same level of confidence in digital television that they achieved in analog. These monitoring instruments are called *confidence monitors*. Systems built from these instruments are called *confidence monitoring systems*. Requirements for confidence monitoring instruments and systems for digital television facilities are based on quality control and system management challenges that broadcasters face.

Digital Television System Management

By supporting the convergence of video, voice, and data distribution systems, the transition from analog to digital technology also affects digital television system management. Digital telecommunication network operators gain new sources of revenue by offering distribution services to broadcasters, and broadcasters can use these services to reduce operating expenses. However, this complicates the process of maintaining quality by introducing additional transitions in the distribution chain. As one company hands content off to another, broadcasters must rely on other companies to meet contractual quality of service obligations.

Technology convergence has also facilitated new approaches to system management. Many broadcasters are considering management techniques that resemble the centralized monitoring and management systems seen in telecommunication facilities. These systems will rely on network-capable confidence monitoring devices that can report status and send alarms to a central Video Network Operations Center via standard network communication protocols.

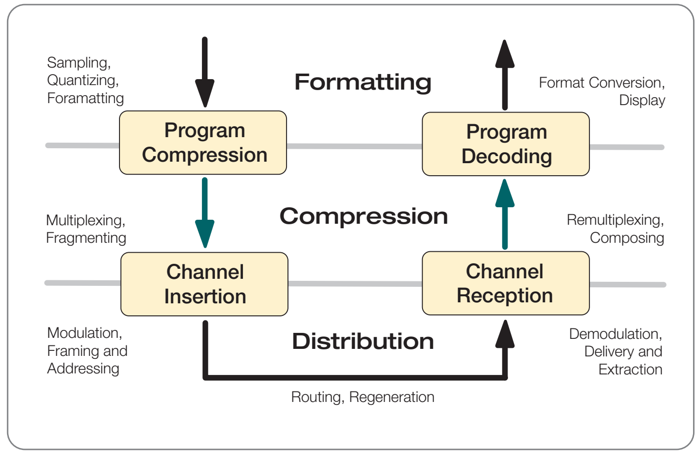
The digital cliff effect, the increase in the number of handoffs, and new centralized management approaches are factors driving the characteristics of confidence monitoring systems in digital television. Confidence monitoring solutions must also address the quality control challenges arising from the layered structure of digital television systems.

Confidence Monitoring Examines Multiple Layers

In an analog television system, distribution and transmission channels can be viewed as a sequence of analog signal processing steps. With the transition to digital technology, broadcasters can now use digital signal processing and digital data processing techniques to improve quality and efficiency in their broadcast networks. Hence, distribution and transmission channels in digital television systems contain sequences of *signal processing* and *data processing* steps.

We can best understand how these steps interact and impact broadcast quality by organizing them into a layered model. Specifically, we can use three layers to model a digital television broadcast system (Figure 1):

- In the *Formatting* layer, television content producers create and format the video and audio that the broadcaster will deliver to the end consumer. Signal processing in this layer includes:
  - the sampling, quantizing, and formatting steps needed to create digital television signals
  - conversion between digital formats, and
  - displaying a digital signal on a television set or picture monitor
- In the *Compression* layer, content producers and broadcasters compress and aggregate content for storage, distribution, or transmission. Signal processing in this layer includes video and audio compression. Data processing in this layer includes:
  - multiplexing programs and system information into a single data stream
  - fragmenting this stream into a packet protocol, and
  - recomposing programs from packets for decoding
- In the *Distribution* layer, broadcasters process content for distribution over internal networks or delivery to the end consumer through digital television transmission systems. Signal processing in this layer includes techniques for modulating digital signals onto RF carriers. Data processing includes:
  - error correction algorithms for transmission, and
  - the formatting needed to embed content into the network communication protocols used in internal distribution



▶ ***Figure 1:*** *Layered model of digital television system.*

Quality Control Challenges Within the Layers

Adding digital signal and data processing to broadcasting introduces new sources of error, with different types of errors in each system layer.

At the Formatting layer, broadcasters face challenges in dealing with the wide array of new formats for both standard and high-definition digital television. As in analog television, they need to ensure correct colorimetery and verify conformance to standards. In addition, they may need to convert from one format to another, e.g., down-converting HD content for broadcast on an SD system. These format conversions can introduce quality errors. Also, separate processing of digital video and audio can lead to synchronization problems.

At the Compression layer, broadcasters deal with technology that is significantly different than anything they encountered in analog television. Compression introduces new types of quality defects, e.g., blockiness. Errors can occur during the complex process of multiplexing programs and system information into a single data stream. Errors in timing and synchronization parameters can compromise the decoding process and lead to noticeable content quality errors.

At the Distribution layer, broadcasters encounter familiar RF technology in the transmission networks; however, these systems use different modulation techniques and offer new challenges in understanding coverage and interference problems. For internal distribution, broadcasters increasing rely on telecommunication technology, introducing problems with latency, packet loss and synchronization.

From source to consumer, program content typically moves through these system layers many times. Transitions between layers can dramatically alter the nature of the digital information, e.g., moving between uncompressed digital video at the Formatting layer and compressed digital video at the Compression layer. The additional processing needed to move across layers increases the probability of quality errors at these transitions.

Moreover, errors in one layer can cause errors in a different layer, in some instances masking the original error source. For example, blockiness errors can arise from problems in a compression step (Compression layer), or as a consequence of uncorrected bit errors in the receiver (Distribution layer). Similarly, transmission errors can occur due to failures in the modulation steps (Distribution layer), or from variations in the data rate from the multiplexer feeding the studio-to-transmitter link (Compression layer).

Distributed Multi-layer Confidence Monitoring

To meet the quality control and system management challenges described above, confidence monitoring systems should have the following characteristics:

– Layer-specific probes that detect the different types of errors seen in digital television systems

– Extended monitoring capability to give broadcasters advanced notification of system degradations before they become quality problems

– Multi-layer monitoring that lets broadcasters quickly isolate the root cause of a quality problem

– Network control that supports the new system management challenges

Layer-specific Probes

In a confidence monitoring system, we can think of each monitoring device as a probe, monitoring quality at a particular point and layer in the distribution and transmission chain. Broadcasters will need to use different probe types for quality control at different layers.

At the Formatting layer, digital waveform monitors help broadcasters detect many quality problems. Like their analog counterparts, these probes monitor characteristics of the digital video signal. They belong to a larger collection of Formatting layer probes which includes digital audio monitors, picture quality monitors for detecting blockiness and other picture impairments, and probes for detecting audio/video delay.

The MPEG-2 standard defines the basic processing steps and techniques used at the Compression layer. Broadcasters need MPEG protocol monitors capable of detecting problems in basic MPEG processing, as well as the additional processing defined in the DVB, ATSC, or ISDB broadcasting standards based on MPEG.

At the Distribution layer, broadcasters need probes to detect quality problems in a wide variety of distribution and transmission channels. Probes in this group include devices to monitor RF transmissions in DVB, ATSC, or ISDB formats. They also include probes for monitoring information sent through either cable or fiber telecommunication networks.

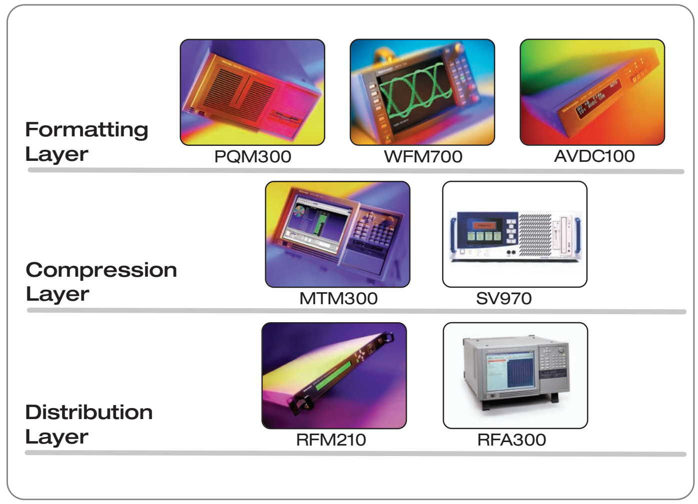
Extended Monitoring Capability

We can also distinguish confidence monitoring probes by the level of monitoring they offer. *Basic confidence monitoring* probes track a small set of key quality parameters. They act as an "indicator light," telling the broadcaster when something *has gone* wrong.

However, basic confidence monitoring probes do not offer a complete solution. While they can enhance the broadcaster's ability to *react* to a quality problem, they do not offer the information needed to *proactively* address system degradation before it becomes a quality problem. *Extended confidence monitoring probes* use more sophisticated analysis to make additional measurements of quality parameters. They act as "indicator gauges," telling the broadcaster when something *is going* wrong.

RF transmission monitoring offers a good example of this distinction. Basic RF confidence monitors measure bit-error-rate (BER). BER will remain low until the transmission approaches the digital cliff, then increase dramatically as the transmission falls off the cliff. This gives broadcasters only slightly more time to react than they would have by watching the transmission on a picture monitor.

Extended RF confidence monitors add additional measurements like Modulation Error Ratio or Error Vector Magnitude. These measures will noticeably change as system performance degrades, giving broadcasters early warning of potential quality problems, and an opportunity to make adjustments or seamlessly transition to backup systems.



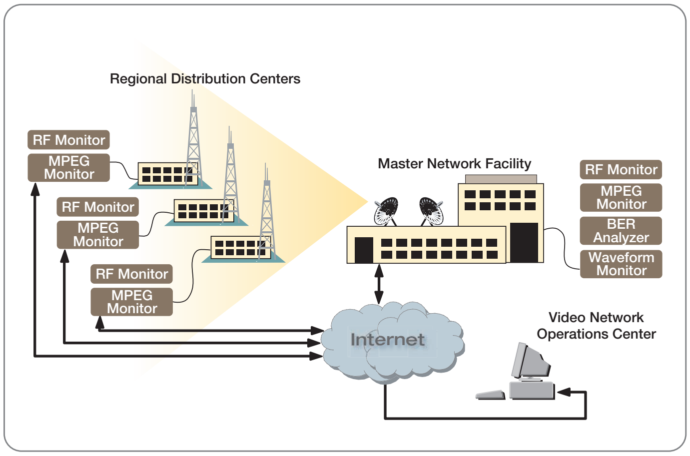
▶ *Figure 2: Tektronix' layer-specific probes used in multi-layer confidence monitoring.*

Multi-layer Monitoring

To have confidence that their facilities are operating correctly and efficiently, broadcasters will generally need to probe at all layers. Probing at only one layer can give a misleading picture of system health.

We began with a simple example of this problem. By watching the broadcast on a picture monitor, broadcasters are probing quality at the Formatting layer. While this offers significant information on system health in an analog system, it offers little information in digital systems.

Similarly, monitoring just the MPEG protocol or the RF transmission will only yield partial information. To gain a complete picture of system quality, and to quickly detect and isolate quality problems, broadcasters will need *multi-layer* confidence monitoring solutions (Figure 2).



▶ *Figure 3: Layer-specific probes, such as Tektronix PQM300 (used at the formatting layer), SV970 (compression layer), and RFM210 (distribution layer) enable distributed, multi-layer confidence monitoring.*

Network Control

System management concerns also impact confidence monitoring. Broadcasters often need to monitor at geographically separated locations. For example, a broadcaster accepting contribution feeds over a telecommunication network may want to install confidence monitoring probes at the network operator's points-of-presence.

These distributed probes will need network capability so they can report status and alarm conditions to a central location. Network monitoring software can correlate this information to help engineers identify the source of quality problems (Figure 3).

Physical and Economic Factors in Confidence Monitoring

Form factor and cost are additional considerations in developing a confidence monitoring system. Large, card-modular solutions may work well in central nodes with a large number of signals and multiplexes, while small single-channel probes may work better in remote locations like transmitter sites. Broadcasters involved in mobile television applications will want highly portable solutions, while installation and maintenance teams will need hand-held confidence monitoring probes.

Conclusion

Due to the digital cliff, broadcasters can no longer detect the onset of quality problems by viewing the broadcast and will need to use confidence monitoring systems. Combining analog and digital signal processing with digital data processing creates layers in digital television systems, driving the need for multi-layer confidence monitoring systems with layer-specific probes to quickly detect and isolate quality problems.

These systems need extended monitoring capability to help broadcasters proactively address performance degradations before they become quality problems. The systems also need network-capable probes in a variety of form factors to integrate effectively into emerging system management approaches.

As television transitions from analog to digital technology, broadcasters will increasingly rely on these distributed, multi-layer confidence monitoring systems to ensure optimal performance in their distribution and transmission systems.

For more information on Tektronix multi-layer confidence monitoring probes, please visit www.tektronix.com/Measurement/video_audio.

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