Forensic Examination of CCTV Digital VTR Surveillance Recording Equipment

Approximately two years ago I authored a paper entitled, "The Forensic Examination of Video Recordings" which discussed some of the more conventional forensic techniques for examining questioned analog videotapes regarding their originality and for possible evidence of tape alteration. This paper specifically addressed the various mechanical and electrical signal anomalies that occur when editing of videotape is present or if different analog VCR 's had been used in the production of composite videotapes. The videotapes examined included conventional two-hour VHS which were continuously recorded on the original VCR. The instruments utilized in the examination of these continuously recorded two-hour videotapes included an oscilloscope, a waveform monitor, cross pulse monitor, spectrum analyzer, and other analytical equipment. Whenever editing/tampering did occur on a evidential videotape, invariably the above listed equipment was successful in identifying various timing differences that produced visible variations in the horizontal, vertical, and color synchronization pulses which makeup the video waveform. Portions of the audio signal are also often adversely affected because of the editing process. This paper will focus on the operational characteristics of both analog and digital CCTV time lapse VCR's and the forensic tools utilized in their testing and evaluation. (1)

CCTV Surveillance Equipment

Security VCR's have a number of additional features specifically designed for the industrial marketplace or for those institutions that require 24 hours a day video/audio surveillance. Some of the primary differences between a two-hour domestic VCR and a time-lapse VCR for the security industry include; TL VCR's can record up to 960 hours on a 120-minute tape; they can further record either continuously or in time-lapse modes between 6 and 960 hours; a conventional VCR records continuously in real-time with 25 frames per second while a time-lapse recorder has selectable recording intervals depending upon the amount of elapsed time recorded by the VCR; the recordings in time-lapse mode are periodic rather than continuous and there will always be a certain amount of information loss during the discontinuous recording process; time-lapse VCR's can also be triggered by external alarms which will cause the recording unit to switch from time-lapse mode into real-time for a preset duration or until the alarm is cleared; the time-lapse recorders also can be programmed to recycle and rerecord which is extremely useful when there is no operator to replace the 24-hour tape. It is also important to remember that time-lapse recorders do provide 2, 6, and 24 hour videotape recording but the original tape has to be played back in the same or similar time-lapse recorder set at these particular recording speeds to permit review of audio information. Although sometimes the audio signal is weak and has poor intelligibility, there is a host of audio enhancement software and other audio filters that can improve the audio signal intelligibility even if recorded in 12 or 24-hour time-lapse mode. (2)

Switchers and Splitters

It is common in many industrial sites to require multiple camera and monitor viewing during the playback process. A simple analog video switcher can accommodate several different camera inputs and by selectively pushing buttons on the monitor can activate particular fields of view. The next form of video switcher is known as a QUAD which allows a simultaneous display of four cameras onto a single monitor by splitting each view into quarter size samples. QUAD's are capable of viewing single or multiple cameras in a sequence or can individually provide for a single view. The resolution unfortunately for QUAD processors is normally marginal and the recorded image does degrade further with the copying process. A recent innovation by the security industry is the development of a multiplexer which can display typically from 4 to 32 camera images into a single monitor. Multiplexing of the cameras result in their output being recorded in sequence onto single videotape. The recorded images are captured in full screen thus insuring good resolution. The rate at which they are recorded can vary depending upon the initial setup of the time-lapse recorder and the multiplexer's ability to process the information. The disadvantages of mulitplexers are that recording of each camera is not continuous and when played back the system decodes whatever is on the tape. The mulitplexer further encodes the time date and camera number in the vertical blanking interval of the video waveform following each recorded field. If you attempt to playback the tapes without a multiplexer the decoding process does not occur and you see exactly what was recorded on the tape which is normally observed as an extremely rapid rate of change of the different camera fields. Further, if a worn video head is involved, the signal strength will be reduced and the digitization process will be degraded and possible not capable of proper playback. (3)

Time-Lapse Recorders

The forensic examination of time-lapse recordings invariably require that attempts be made to obtain the original videotape as any tape copy would necessarily bear some of the electronic and mechanical signatures of the copy VCR and not that of the original recorder. It is within the vertical blanking interval of the video waveform that a waveform monitor or oscilloscope can view important data information that is stored by the time-lapse VCR during the recording process. It normally consists of 20 blank lines and it gives the recorder an opportunity to store important information about camera, date and time of recording, store information, etc. for each line of video that has been recorded. Often times a monitor that has under-scan capability can visualize the vertical blanking interval and some of the data produced during the time-lapse recording process.

Although the majority of time-lapse recorders and corresponding videotapes are of the analog variety, there is an increasing demand for both digital video recorders and related equipment which would require different forensic examination techniques. One of the primary advantages of digital recording is it is more immune from electronic and other forms of interfering noises. A digital signal as an electronic waveform which is comprised of the numeric values of zeros and ones. This results in less signal degradation and a better picture quality for the surveillance industry. The signal can also be digitally processed and stored and this would aid in such factors as image enhancement, compression and other forms of correction. Lastly, there is no degradation between the originally recorded video signal and the copy tape.

Other signals that can be analyzed during the testing of time-lapse tapes include the audio signal which is recorded normally along one edge of a conventional VHS tape as either a single or stereo channel. Often times a separate erase head is mounted next to the audio head to facilitate a dubbing of a new audio signal onto the original videotape. In addition there is a control track which normally is a 30-hertz square wave signal which synchronizes the video frames on the tape with the monitor during playback. Full track-erase heads are normally seen on the video drum and are available for erasing any prerecorded material on the tape including audio\video or control track information.

The way in which time-lapse recording works in practice is best explained by example. A standard domestic VCR records continuously in real-time, with 25 frames per second, 2 fields per frame (a total of 50 images in all). An industrial machine, on the other hand, has selectable recording intervals allowing you to reduce the amount of information you tape depending on your requirements. If the record rate is dropped to 8.33 frames per second (16.66 images in total), for example, the VCR can span recordings to 24 hours worth of information. In this instance the VCR is said to be running in 24-hour time-lapse mode.

As the recording in time-lapse mode are periodic rather than continuous, there is a loss in the information taped in any single sequence, that can give a stroboscopic effect on replay. Consequently, the configuration of time-lapse recording is very much dependant on the practical needs of the particular security installation. It should also be borne in mind that when Time Lapse VCRs are used in conjunction with multiplexers the frames recorded would be divided between the number of cameras being viewed. There has been a notable shift in the last five years from the use of black and white surveillance cameras to color equipment and likewise there has been a dramatic change in both size and low light capabilities of CCTV cameras. Correspondingly there has also been a dramatic drop in the prices of CCTV cameras and time-lapse recorders and a surveillance system today costs significantly less then it did several years earlier. There has been increasing change in digital video recording equipment which is transmitted not only over local/wide area networks but also the Internet. At Sanyo Security Products in California the latest digital recording device (DSR-C100) includes a hard drive which allows continues recording of 17,000 high quality digital images on an internal 10.2 GB hard drive. The surveillance cameras connect directly to a PC and can record on compact flash cards for transportation and backup. During playback the operator can choose a zoom capability of up to 21 times normal enlargement and a "water marking" capability further ensures that digital editing does not occur. (4) (page 3 of 5)

Measuring The Video Signal

Institute of Radio Engineers (I.R.E.), units were established as the true measurement medium for video back in the late forties. It wasn't until the sixties and the increased availability of the oscilloscope that we started measuring the video signal in Peak-to-Peak voltage measurements. A video signal is made up of three important parts. They are video, pedestal or black level, and synchronization (sync) pulses. Color signals have the above as well as a color burst. Composite video is the combination of all three pieces measured together. Each portion of the video signal has it's own separate level. Video should measure at 100 I.R.E. (0.7143 volts peak-to-peak). Sync should measure 40 I.R.E. (0.2857 volts peak-to-peak). In color cameras, the color burst will measure 40 I.R.E. (1.000 volts peak-to-peak). A good hand held video meter will give you the ability to measure sync, luminance (video white level), composite video, and color bursts individually. In addition, you should be able to set the focus and/or back-focus of the camera, upon the video signal. (5) Charlie Pierce, Section 14.1

A good hand held video meter will give you the ability to measure sync, luminance (video white level), composite video, and color bursts individually. Another feature that a good quality digital video meter offers is focus, which is, accomplished through the high frequency levels of the video signal. A good quality hand held digital video meter can set the focus of a camera without a monitor. In addition to the aggravations of viewing an out of balance system are the technical problems including picture rolling, horizontal tearing, jumpy playback, and poor resolution. Signal losses are quite often attributed to; partial or complete short circuits between center conductors and shields; double terminations of the video cables; lack of termination of the video cable; or improper impedance connectors.

A major technical deficiency of the hand held meter is its inability to determine the nature of the “video noise” or the Rf anomalies in the recording system. It is the oscilloscope that can resolve these questions. (4) Section 14.2

Oscilloscope (Analog)

A time analysis of any electrical signal can be conducted with an electronic instrument called an oscilloscope. The oscilloscope works on principles similar to those of a TV monitor, only in this case the scanning of the electron beam follows the video signal voltage in the vertical direction, while horizontally, time is the only variable. With the so-called time-base adjustment, video signals can be analyzed from a frame mode (20 ms) down to the horizontal sync width (5 s). Oscilloscope measurements provide the most objective measurement of the video signal and it is strongly recommended to anyone seriously involved in CCTV. With an oscilloscope it is very easy to see the quality of the signal bypassing any possible misalignment of the brightness/contrast on a monitor. Sync/video levels can easily be checked and can confirm whether a video signal has a proper 75-OHM termination together with how far the signal is (reduced in signal amplitude or the loss of the high frequencies).

Peak-to-Peak: This term relates to how much of a signal is being used for a measurement. Peak-to-peak means that the entire video signal is to be read from the top most point, and positive or negative is irrelevant.

Composite Video: Composite video is the complete video signal including the Raw Video Information Pedestal, and Sync Line. Composite video is measured form the sync line to the peak of the raw video average composite video with any camera system should be 1 volt peak-to-peak. Composite video signals may have high peaks of as much as 1.4 volts, which represent hot spots or very bright points within the video picture.

Raw Video: Raw video is the signal created by the tube or imager of the camera. Raw video on an average, measure .6 volts peak-to-peak with high peaks of .8 volts.

Pedestal: The pedestal appears to b a straight line and is below the raw video information. The pedestal is used as the black reference fro the raw video. All measurements of the video start form the pedestal and go up. The farther away from the pedestal that the video is, the whiter it will be. The closer to the pedestal that the video signal is, the blacker it will be.

Sync Line: The sync. Line of the video signal is the bottom most point of the signal and is used as the zero reference point for all peak-to-peak measurements of the composite video signal. (6) Section 14.6

Digital Video Recorders

Soon digital video broadcast (DVB) will become widely accepted as a new television standard. In fact it is already recommended by various countries' broadcast regulatory authorities. Closed circuit television will definitely follow suit with similar advancements, although the majority of the video devices are still analog.

One of the most important differences between an analog and digital signal, is the immunity to noise. A digital signal, having an electronic form, is also affected by noise, however, can only have two values: zeros and ones. Noise will only affect the digital signal when it's value reaches levels that may interfere with the digital circuit margins that decide whether a signal is zero or one. (7)

Digital vs Analog Recording Fact Sheet

Digital	Analog
Records directly to hard drive.	**R**equires VHS tapes to record.
Records only when motion is detected So it won't fill up your hard drive with unnecessary information.	**C**onstantly recording except during playback.
Constantly recording any detected motion even during playback.	**C**an't record while reviewing tapes.
Depending upon the amount of constant motion and the size of your hard drive, you can record approximately 30 days to 180 days of information or more. Plus no tapes!	**I**f you'r like most, you must change tapes weekly if not every couple of days.
Your hard drive will begin to recycle itself over the oldest information once it fills up.	**Y**ou'r still responsible for changing and archiving tapes
With a High Res Digital unit and High Res cameras, you can record 450 lines of resolution which will deliver sharper, cleaner images.	**T**ime-Lapse and Real Time recorders will only record 300 to 330 lines of resolution.
	Very limited flexibility at best.
	Remote capabilities are available at a significantly higher price. (Often, it's even more costly than a unitized Digital system)

Each Camera is individually addressable wich provides the ability to prioritize any camera in your system. IE: camera 1 - 2FPS, camera 2 - 5FPS,etc.

You can moniter events at your facility from a remote location if you have a static IP address at your facility and are viewing over a high speed modem line.

12 to 15 life expectancy

3 to 5 year life expectancy.

Still limited to 300 to 330 lines of recording resolution.

Separate remote system available at an axtra cost. Live viewing only no recorded play back.

(8) Freeze Frame I/Net Article

Digital VTR Theory

The main differences between analog and digital VTR's are in the signal system. If analog video is input into the system, it is converted to digital. Four or more channels of analog audio is also converted to digital. In addition, most professional digital formats also have analog longitudinal audio cue and time code tracks to go along with the digital audio. If a format uses video compression, the video is compressed at this time. Tiny imperfections in the tape that would produce unnoticeable dropouts in an analog system would seriously "trash" a digital signal. The digital video data is therefore encoded using an error correction system, that can replace some lost data completely. (9)

Because of the wide bandwidth of the digital signal, it is recorded on the tape by several heads at once. The head drum spins much faster in most digital machines than in an analog one, with 6,000 RPM being about average. There are more tracks per scan, and they are narrower than any analog format. The servos have to work very hard in a digital machine to keep data errors down. Audio data is also recorded by the rotary heads, usually in a special area at the center or ends of the video track. Since audio errors are generally more objectionable than video errors, most digital VTR formats record each audio segment twice. The audio is recorded in separate segments from the video to allow editing of just he video or just the audio, or any combination of both.

Digital video recorders (DVRs) give you the ability to record perfect quality pictures and replay them at the touch of a button. Digital recording also make it possible to record video on a computer disk. DVRs are able to record much more information in wither real time or time-lapsed mode.

DVR vs. Analog VCR

- VCRs use standard VHS tape, while digital information can be stored on digital audio tape (DAT), digital versatile disc (DVD), or hard disk drive (HDD).

- DVRs have the ability to search for recorded information based on time/date/second as well as camera input, allowing for much faster retrieval times.
- DVRs can save images with very little background picture noise and higher stability, and are generally of higher quality.
- With DVRs, the image quality does not deteriorate during storage or frequent viewing.
- DVRs require less maintenance.
- DVRs offer many additional features such as remote video retrieval, integral multiplexing, pre and post-image enhancements, and networking capabilities.

Types of DVRs

Basic DVRs are a replacement for traditional VCRs. They are typically single-channel devices capable of recording up to one or two weeks of information. Basic units offer little or no setup capability. The recorder usually determines the playback quality, storage capacity, and reviewing characteristics.

Multiplexed DVRs combine multiple video inputs with the recording unit, eight or 16-channel multiplexing unit with the digital recording device. The time-sharing of video inputs operates the same way as standalone video multiplexers. Multiplexed DVRs typically have a storage capacity of about 480GB to 600GB.

Multi-channel DVRs are designed for high-end applications. Requirements such as month-long storage, real-time video recording of all video inputs and unlimited video channels can be obtained with multi-channel DVRs. Multi-channel DVRs allow all images per camera to be recorded, whereas, in a multiplexed unit, video inputs are divided between the images.

DVR and Remote Video Monitoring

DVR allows remote viewing of video systems through LANs, WANs and Web-based systems. One major advantage of a network is the ability to receive video signals anywhere using equipment ranging from a simple Internet browser to special client-based application software. Another advantage is that it eliminates the need to run new cabling and provides easier solutions for future system expansion. (10)

Measuring the Digital Serial Signal

When viewed on an appropriate scope or monitor, several times sweeps (overlaid by the CRT persistence or digital sample memory) produces a waveform that follows a number of different paths across the screen. The waveform that results is known as an eye pattern as displayed on a monitor. Analog measurements of the serial digital waveform start with the specifications of the transmitter output. Specifications to be measured are amplitude, risetime, and jitter, which are defined in the serial standard, SMPTE 259M. Frequency, or period, is determined by the television sync generator developing the source signal, not the serialization process.

Requirements for a basic operational monitor include display of the program signals carried by the digital signal with features and accuracy consistent with today's analog baseband signal monitors. An operational monitor should also include information about the serial digital signal itself, such as data available, bit errors, and data formatting errors.

Program signal measurements are essentially the baseband video and audio measurements that have been used for years. An important aspect to these measurements is that the accuracy of signal representation is limited by the number of bits-per-sample. In analog systems there's been a small amount of digital data present in video signals in the form of Vertical Interval Time Code (VITC); but the serial data stream has much more capacity for data other than video. Hence, more complete measurement methods are desirable.

In addition to the traditional television system measurements there's a new dimension for test and measurement to quantify the various parameters associated directly with the serial waveform. The result is several categories of monitoring and measurement methods to be considered: program signal analysis, data analysis, format verification, transmitter/receiver operation, transmission hardware, and fault reporting. (11)

Conclusion

The increasing usage of both analog and digital surveillance cameras, recorders and different transmission/storage mediums requires the forensic expert to continually update his analytical tools.

The detection of audio and video edits will be more problematic in the digital age which will necessitate on-going research into development of appropriate test measurement equipment/protocols for forensic video examinations.

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