Resolving the image of CCTV – Just the facts

by AndrewYoung, Intercon Security, Canada

Having been passionately involved in the Video and CCTV profession since 1976, I have seen the level of competence and technical knowledge in video gradually deteriorate and have heard many untruths and misconceptions. CCTV technology has come a long way, but does it serve us better? and has it improved? With the transition from fully analog based systems to digital hybrids and beyond, misconceptions and misrepresentations are rampant. All too often, representatives of companies or agencies involved in the CCTV business are making technically incorrect or misleading statements. How many people fully understand how to get the best performance from S-VHS recording? Or understand the answer to all our problems, the DVR. Unfortunately, in many cases, the poor customer is ill equipped to technically critique a proposal and resorts to evaluating mainly on price or exaggerated performance promises.

With Billions of dollars wasted annually on CCTV systems, I am presenting some basic information in the hope that:

A. Customers and end users get value from their systems instead of poor performance and inadequate images.

B. Inform future purchasers on some of the little known issues that can adversely affect system performance unnecessarily.

C. Share sound technical information that will dispel the many misconceptions and misinformation surrounding image quality in DVR's

D. Offer a system based perspective that will ensure your operational requirements are met in a manner that will save unnecessary expense and provide value for the dollars spent.

The evolving technology of digital recording and network transmission and the market understanding of it is riddled with marketing propaganda. Distinctions and claims where resolution, compression, file size, frame rate and perceived image quality are concerned are seldom based on "repeatable and quantifiable" performance, either in lab or in application. The new buzzwords in DVR marketing are "DVD quality". Writing information to the hard drive at speeds in excess of 5Mbps is the approximate bandwidth required for the quality and frame rate of picture we normally associate with a DVD. Very few DVR units are capable of this type of performance.

Regardless of the format or standard used, be it analog or digital, interlaced or progressive, one of the major characteristics of a CCTV system affecting overall picture quality is the ability of the system to reproduce fine detail found in the original image. This ability to resolve detail is determined by many factors such as overall response of the designed system, individual device design, recording or storage medium used, overall system bandwidth, sampling frequency, imaging device (camera and lens) and last but certainly not least, in the case of digital systems, compression algorithm. All these factors will have a measurable and considerable impact on the systems ability to maintain and resolve the detail found in the original image. The National Television Systems Committee (NTSC) developed the colour television specification for broadcast transmission and is bandwidth limited to conserve channel space for home entertainment purposes.

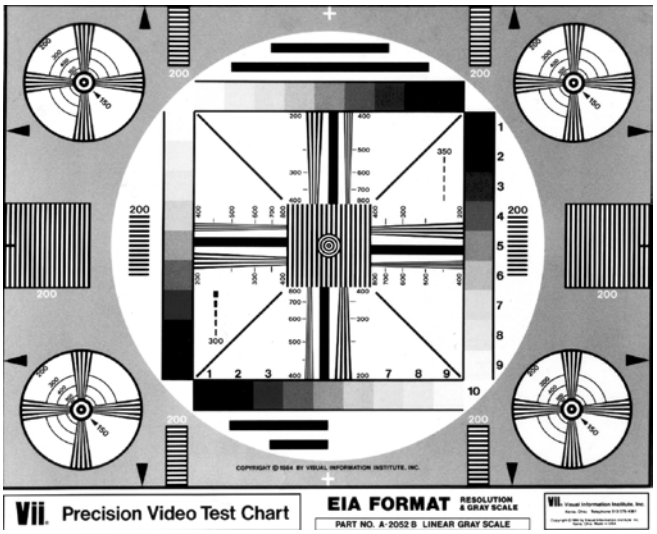

Fig.1 A scanned image of a Resolution Test Chart

However, NTSC has no upper bandwidth limitations for studio or CCTV use and can support horizontal resolution in excess of 700 lines (8.75Mhz) with a 4:3 aspect ratio. In the IEEE standard on video tech-

niques: Measurement of resolution of camera systems, they define resolution as follows:
"Resolution: A measure of the ability to delineate picture detail."

The limiting visual resolution in any video system can be accurately specified in terms of a parameter called "TV lines" and is typically used to indicate horizontal resolution. However, the same technique can be used to measure vertical resolution. The limiting horizontal and vertical resolution of the video system chain and display combination is determined by observing

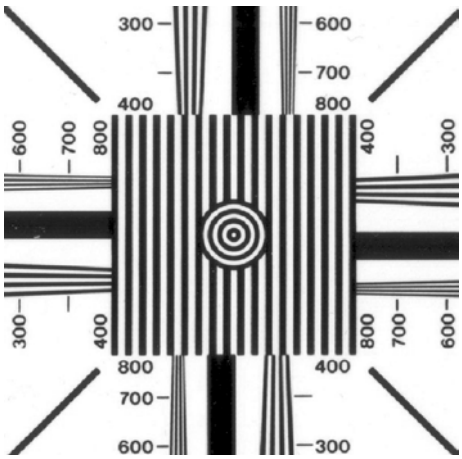

Fig.2 Centre of Resolution Test Chart

the point at which the individual lines of the graduated wedges are no longer discernable as separately defined images. Figure 2 shows the centre portion of a resolution test chart.

Methods of measuring resolution (visual and depth of modulation) are described in detail in the IEEE standard. 208-1995. The standard describes an accurate, quantifiable and repeatable way of specifying this often, and increasingly misunderstood, but extremely important measurement. Given a thorough understanding of the measurements to be performed, these methods can be applied to both analog and digital video systems.

The computer and DVR industry, in absence of formal video education in North America, have started referring to the number of horizontal and vertical pixels as the horizontal and vertical resolution. This is not only highly misleading but also completely wrong. A few years ago I was researching DVR's for an RFP. I had occasion to call an established manufacturer to determine the visual resolution of their DVR. I was connected with a software engineer in the technical/design department. I asked if he could tell me whether or not they had conducted any resolution tests to which he proudly replied that their DVR resolution was 352 x 288. Realizing that this designer was referring to format size, I clarified that I was inquiring about the actual recorded image detail remaining after compression.

What he said next was unbelievable… "how would we measure that?" I became somewhat frustrated. Based on the conversation to that point, I knew he had little or no video engineering experience and asked if they had any video engineers on staff? The reply was "No".

Sadly, but not surprisingly, this type of conversation is still the norm when talking to some DVR manufacturers.

It is a sad reflection on our industry that a large proportion of the security DVR's on the market today are little better (and in some cases worse) in terms of picture quality, than a VHS VCR. If poorly installed and specified some DVR's can be a very efficient way of finding mediocre images at best. What is worse is that in some cases customers have actually purchased high performance equipment, but due to a lack of knowledge and understanding of video engineering and CCTV system design are realizing only a portion of its true performance.

Outside of the broadcast and entertainment industry, I have yet to meet someone involved in CCTV that understands this extremely critical issue.

The most crucial aspect of any correctly installed CCTV system is the quality and quantity of the recorded images per camera per second. Good quality images are useless if they were not taken at the right time. Conversely, lots of recorded images are of no use if the image is blurred, dark or too small. Playback Image quality, normally determined by Horizontal Resolution (determined from overall system bandwidth) is something most people determine from a manufacturers specification sheet. It is normally the specification and performance of the Camera and DVR that most purchasers check, not the overall performance or bandwidth of the system itself.

A colour camera that has a Horizontal Resolution of 480 Lines recorded on a high performance DVR that is capable of recording 400+ lines of resolution is wasted if the camera is Line Locked and the DVR can not decode (separate luminance and chrominance) the incoming composite video correctly due to the incorrect vertical timing of the composite video signal. In some cases playback resolution can be reduced by as much as 50%. Sadly, this happens all too often, and the customer is unaware of what they have actually purchased. Even more alarming, is that a large number of CCTV dealers and so-called consultants are unaware of this. Line Locked Colour cameras do not comply with the timing specification SMPTE3 170M (formerly RS170A) SMPTE 170M originally defined by the EIA (Electronic Industry Association) as RS170A is the colour system and timing specification standard

for the NTSC format used in Canada and certain other countries including the United States.

The EIA (Electronic Industry Association) is the standards body that originally defined the color TV standard used in North America, Japan, and a few other parts of the world.

As adopted by the FCC for broadcast use, the standards are precisely adhered to and carry the force of law for broadcast purposes. For non-broadcast use, SMPTE standards are not enforced. However, it is good video engineering practice to adhere to the SMPTE 170M standard when designing any video system. If video standards are not adhered to, image quality and integrity will suffer in the final video product.

This is by no means an exhaustive list of the problems that can lead to drastically reduced resolution in a system. High performance colour camera systems should be designed to alleviate any interference between the Luminance (Y) and Chrominance (C) signals, which will cause reduced resolution when recorded.

The correct frequency of the vertical synchronization signal in colour cameras is critical to maintain correct timing and separation of the Y and C signals and hence maintain system resolution during the Y and C decoding process. True high performance analog and digital equipment should utilize high quality comb filtering of the Y & C signals to maintain signal bandwidth. It should be noted that equipment that utilizes simple notch filtering dramatically limits signal bandwidth either side of the 3.58MHz region. Notch filtering effectively kills horizontal resolution in the 250 – 310 line region.

The way a system is designed and configured usually has a far greater impact on overall performance. A Colour camera that is Line Locked (Vertical frequency locked to AC zero crossover point) does not comply with the SMPTE 170M (formerly RS170A) standard for system and timing specification because the correct vertical frequency, as specified by SMPTE 170M must be 59.94005994 Hz. The nominal 60Hz generated by the local utility, which can actually deviate from 59.95Hz to 60.05Hz, is simply not accurate enough and should not be used as a system synchronization method in a high performance colour CCTV system. This would appear to be of no consequence, however, the vertical frequency must stay within a very tight tolerance. Otherwise, the correct relationships to all other signals in a composite video waveform will not be maintained. It must be understood that most of the signals that make up a complete NTSC composite video waveform have a direct phase, frequency and amplitude relationship to each other. Even minor deviation from these relationships can have a huge affect on video performance. As an example, the colour sub carrier frequency must be maintained at 3.597545MHz +/- 10Hz. If the AC power frequency in a line locked colour CCTV system drifted to 60.3Hz (+0.6%) the colour sub carrier would change by approximately + 20KHz (20,000Hz).

Comb filters are very good at maintaining luminance bandwidth, whereas Notch filters are not and are normally associated with lower performance equipment (below 250 lines of resolution). However, lets go back to the high-resolution cameras (480-lines) connected to the DVR that has the capability of recording 400 lines. The technician installs the cameras and as is normally the case he or she sets them all to line lock (59.95Hz to 60.05Hz) to prevent vertical picture roll.

He installs the DVR and connects up the composite video cables from the cameras and all would appear fine, after all it's digital, so it must be good – WRONG.

What the technician and virtually all of the CCTV industry does not realize is that the comb filter in the DVR (if so equipped) or S-VHS VCR can not operate correctly when presented with an unstable composite video signal that is of the wrong frequency anyway and certainly does not conform to SMPTE 170M standards.

In layman's terms, the internal circuitry of the comb filter is designed to revert to simple notch filtering when the composite video signal is unstable and phase relationships within the signal breakdown. Line and field based comb separation cannot be used on PAL or NTSC signals unless they are perfectly stable. Fig. 3 shows what happens to horizontal resolution when a line locked colour camera is recorded on a high performance DVR. There is noticeable degradation in horizontal resolution starting at 250 lines. This illustrates the effect notch filtering has on luminance bandwidth. Conversely, the image in Fig.4 shows the performance gain in resolution when the camera is correctly synchronized and the comb filter operates as intended. The recorded horizontal visual resolution from the DVR shown in Fig.4 is better than 400 lines.

A point of interest here is that although PAL systems are affected in the same way as NTSC, this is less noticeable in PAL systems due to the fact that the Pal subcarrier is at a substantially higher frequency than that of NTSC (4.43MHz as opposed to 3.58MHz), therefore chroma notch filtering under the same sce-

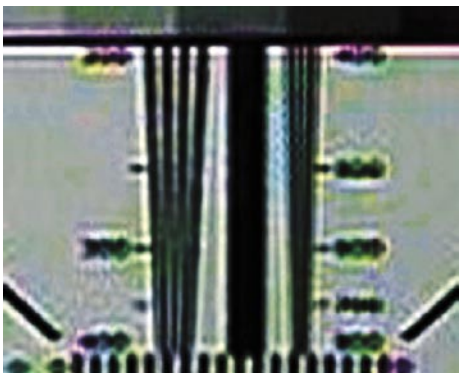

Fig.3 Line locked colour camera

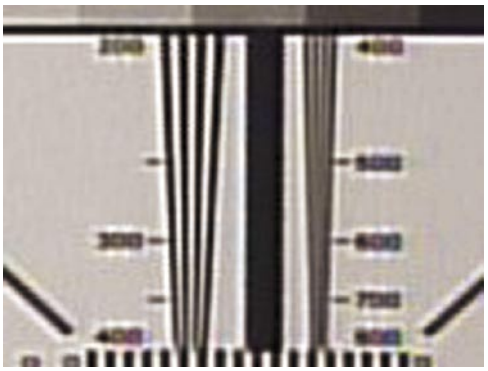

Fig.4 Colour camera locked to 59.94Hz

nario has less of a detrimental effect on the luminance response and hence resolution.

Therefore comb filtering is not as necessary for high luminance response in PAL systems.

For those of you who are interested in furthering your knowledge in this field, I suggest reading the excellent material written by John Watkinson on this subject.

John is considered a Guru in the field of Video Engineering and has many excellent publications.

A large proportion of the video equipment on the market today (analog and digital) still operates and conforms to all the basic principles of early television signals. These basic principles of video MUST be understood to evaluate a CCTV system. We say system and not equipment for a very good reason. Single pieces of equipment can be evaluated to some extent from its published specification. However, a CCTV system should not be evaluated only on equipment specification.

Although this article is discussing high performance Colour CCTV systems, so as not to cause confusion, it should be noted here that, line locking of monochrome cameras is acceptable and has no negative impact on recorded picture quality.

Our industry is almost totally unregulated and therefore performance standards are either ignored or totally misunderstood. Formal, published testing standards do exist. However, as an industry we need to embrace, comprehend and apply them vigorously when designing a high performance CCTV system. Only then will performance specifications of a system have a demonstrable and quantifiable meaning.

General Guidelines. Because of the vast differences in the size and complexity of CCTV systems, it is difficult to establish minimum specifications on each piece of equipment or system design, but it must be understood that cumulative build up throughout the overall system loop can and will cause problems where high performance is required. Most distortions and other degrading factors can be additive.

Designing and installing high performance video systems means adhering to the rules.

To do it right, you need good test equipment. More importantly, understanding how to use the test equipment correctly and in the right context is critical. Merely having good test equipment means nothing if you don't know exactly what you are doing or trying to achieve.

Summary. The hardware and design considerations for high profile CCTV systems in today's security environment are extremely complex. It is crucial that consultants, engineers and CCTV professionals educate themselves about the possible system problems and become more active in this end of the business.

We regularly see pictures retrieved from CCTV systems at crime scenes that are unnecessarily poor and provide only a fraction of the potential information had the systems been specified and installed correctly. I have been saying to colleagues and clients alike for many, many years that we all must take responsibility for the quality of the pictures generated by the systems we sell/purchase. Who takes responsibility or accepts the liability when a violent criminal was not apprehended due to poor quality video and then recommits a violent crime?

We must never forget that:

"A high quality image may assist in the investigation and arrest of a violent criminal and hence save future lives"

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