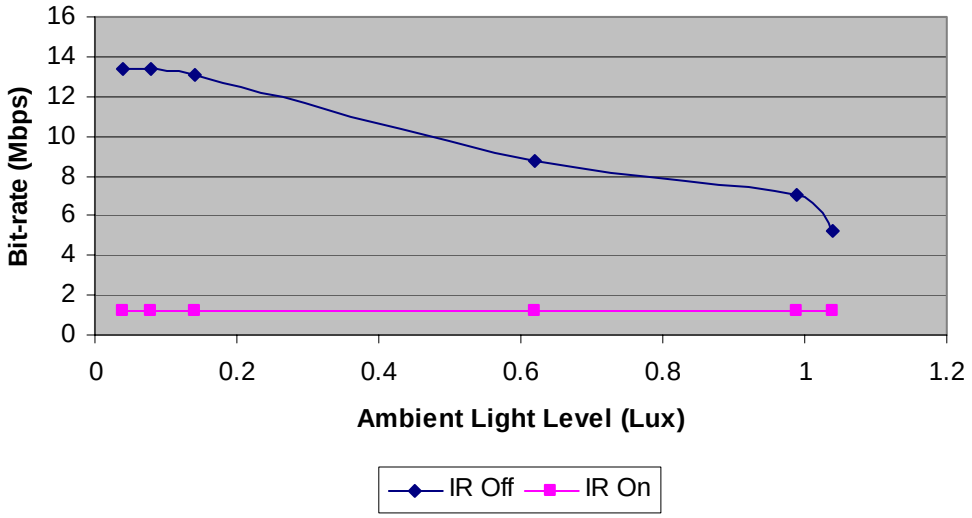
Executive Summary

IP surveillance presents problems of both image quality and bandwidth management in challenging outdoor conditions. The effects of infrared illumination on bandwidth were investigated to quantitatively demonstrate the benefits of implementing infrared illumination in an IP surveillance system. Testing showed that under a range of low-light conditions, infrared illumination decreased bit rate by a significant factor, ranging from 70% to 91% reductions. The results confirm that infrared illumination can help improve network performance by minimizing the bit rate-increasing effects of high-noise images. Reductions in bit rate are logically extended to reductions in required network storage.

Table 1: Overall Results



Introduction

At the Security Industry Association's 2007 International Security Conference in Las Vegas (ISC West), the "Best New Video Device" was awarded to Extreme CCTV for its Black Diamond infrared illumination technology. The award underscored the necessity of high quality images under any conditions, even in difficult nighttime and low-light environments.

Although infrared illumination is field-proven technology for high performance night vision, its use in today's surveillance video applications extends into a surprising realm: bandwidth management. Used today for its bit rate reducing effects, infrared illumination is a growing necessity for improving network performance in IP-based security systems. Infrared illumination can decrease both bandwidth and storage requirements, making it much more than a night vision necessity.

Our investigation aimed to confirm and quantify the effects of infrared illumination on bandwidth.

IR for IP – A Primer

Whether analog or IP, virtually all CCTV cameras produce usable surveillance images under well-lit daytime conditions. However, since today's security systems require 24/7 performance, it is the nighttime performance that determines overall system effectiveness. It is also precisely at night that most criminals will try to take advantage of weaknesses in security systems.

Extending our understanding even further, CCD and CMOS image sensors are designed to see light, making pictures or videos in the process. If there is no light, there can be no picture. Many cameras today have very low lux ratings, often in the range of 0.1 lux. And while these camera specifications suggest effective operation under low light, it is generally accepted in the security industry that low-light environments result in noisy, low-quality images.

When light levels decrease, there is a corresponding increase in the demand for bandwidth – often used synonymously with the term "bit rate" which is defined as the amount of space required by the network in one second. Generally speaking, and when all other factors are equal, daytime imaging will require less bandwidth than nighttime imaging.

To understand the reasons behind higher bandwidth in low light, we must consider automatic gain control (AGC), a camera technology which increases signal strength under low light conditions. AGC works simply by amplifying the image. However, the effect of the amplification is an increase in the video signal, and the noise. As a scene darkens, AGC is activated and image noise increases. As the scene becomes darker and darker, AGC increases in magnitude, creating more noise in the process. Eventually, the nighttime image is obscured by snow and graininess. Under these conditions, bit rates can be many times greater than the daytime bit rate for static, non-moving images.

To understand why we see this rise in bit rate, it is necessary to have some basic understanding of how compression algorithms work. The basic principle of compression is to eliminate superfluous information to reduce file size. All compression requires a compromise between image quality and file size. Higher compression ratios deliver smaller file sizes but lower quality images. Lower compression ratios produce higher quality images but larger file sizes.

Today's popular compression engines typically incorporate JPEG, MPEG or M-JPEG, each known as lossy compression algorithms. They use one of two reduction principles:

- irrelevancy reduction which removes parts of the video signal not noticeable by the human eye, such as subtle color changes

- redundancy reduction which removes duplicated information either from the same frame or between frames, such as large uniform areas of color or stationary objects

Therefore, noise caused by AGC interferes with compression algorithms used in today's IP cameras. More precisely, compression algorithms interpret the snow and graininess of AGC-enhanced images as useful information (such as image details or motion) which cannot be reduced by either irrelevancy or redundancy. Consequently, nighttime images are less compressed and generally larger in file size. From this understanding, it is clear that there is a direct relationship between nighttime performance, compression and bit rates.

At first, it seems that the quickest fix would be to disable AGC. The strategy would indeed reduce bit rate, but at the expense of image detail. Doing so would result in very poor – if not useless – nighttime images. Clearly, nighttime performance of a surveillance system is essential to effective security.

The best solution to ensure effective nighttime performance of IP-based systems is to apply infrared illumination to a scene. Providing the IP camera with the right amount of infrared illumination will ensure that nighttime images are high signal, low noise. Under these conditions, AGC becomes unnecessary and compression functions work efficiently.

In most applications, frame rates and resolution are typically altered to suit the application requirements. For example, if either network bandwidth or storage space is insufficient, a common strategy is to reduce the frame rate, resolution or both.

However, there are disadvantages to this approach. Sacrificing frame rate and resolution result in low-quality "choppy" video that may miss critical moments in a security event. Additionally, low frame rate and resolution often defeat video analytics software. For high-level critical security projects, the better strategy is to upgrade storage and bandwidth capabilities to retain the integrity of the surveillance video.

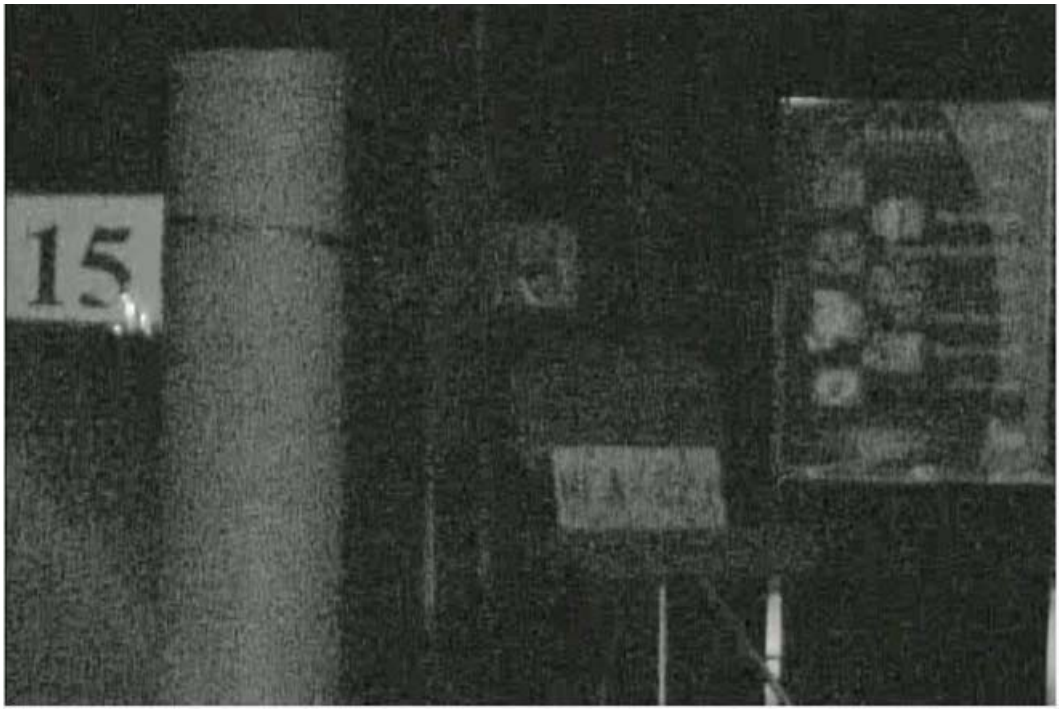
The addition of active-infrared replaces noisy nighttime images with high-fidelity night vision by providing "invisible" light for the camera to see. Gain mode is not triggered and bandwidth requirements remain similar to day-time levels.

Results

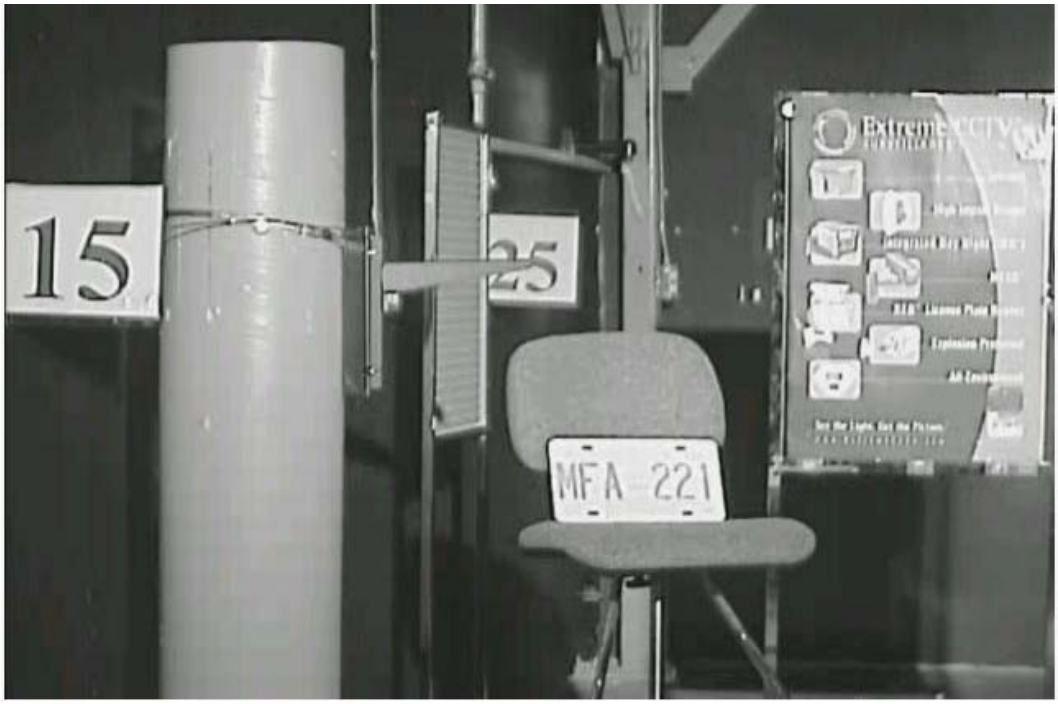
The following table summarizes our results.

TRIAL	Camera	Ambient Visible Lighting (Lux)	Infrared Illumination	Bit Rate (Mbps)	% Bit Rate Reduction
1	Dinion^{XF} LTC-0495	0.04	off	13.37	**91%**
2	Dinion^{XF} LTC-0495	0.04	on	1.21	
3	Dinion^{XF} LTC-0495	0.08	off	13.43	**91%**
4	Dinion^{XF} LTC-0495	0.08	on	1.21	
5	Dinion^{XF} LTC-0495	0.14	off	13.12	**91%**
6	Dinion^{XF} LTC-0495	0.14	on	1.21	
7	Dinion^{XF} LTC-0495	0.62	off	8.80	**86%**
8	Dinion^{XF} LTC-0495	0.62	on	1.21	
9	Dinion^{XF} LTC-0495	0.99	off	7.03	**83%**
10	Dinion^{XF} LTC-0495	0.99	on	1.21	
11	Dinion^{XF} LTC-0495	1.04	off	5.27	**77%**
12	Dinion^{XF} LTC-0495	1.04	on	1.20	

Sample images from the above trials are shown in the following pages.

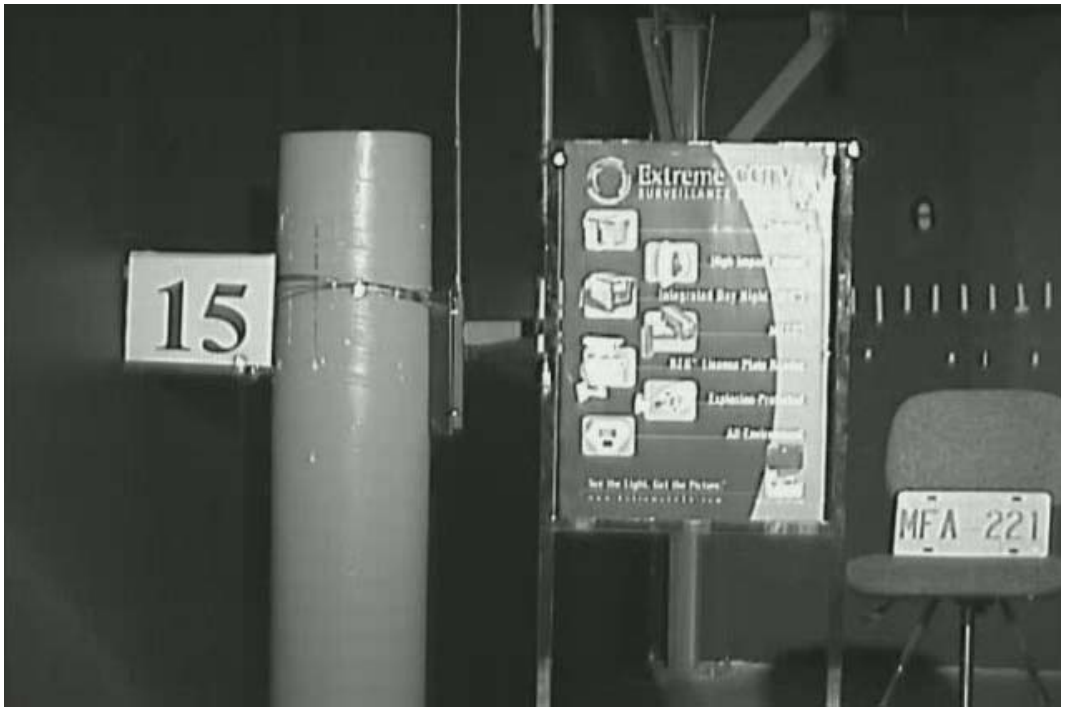


Trial 3: infrared off. Ambient visible lighting 0.08 lux. Bit rate = 13.43 mbps.



Trial 4: infrared on. Bit rate = 1.21 mbps. Bit rate reduction = 91%.

Trial 11: infrared off. Ambient visible lighting 1.04 lux. Bit rate = 5.27 mbps.



Trial 12: infrared on. Bit rate = 1.20 mbps. Bit rate reduction = 77%.

Conclusions

When comparing the effects of infrared illumination from a low light scene (<1 lux) to a scene well exposed to infrared illumination, our testing showed bit rate reductions ranging from 48% to 91%. The variation in magnitude of reductions may be attributed primarily to differences in ambient visible lighting levels. The results reveal a clear trend of less pronounced bit rate reductions as the ambient lighting conditions became brighter, making infrared illumination less important in video bandwidth. In the general case, the results obtained in our testing clearly demonstrate that infrared illumination is a bit-rate reducing tool under low light conditions.

At the most basic level, infrared illumination is light. Although invisible to the human eye – which would see a completely dark scene – infrared illumination is a form of light that modern surveillance cameras can use to create images. Precisely because it is light, infrared illumination prevents noisy images and subsequently the chain of events that cause high bit rates. As our testing shows, the low-noise (or what can be considered high quality) images require significantly less bandwidth than noisy (low quality) images.

From our investigation, we find we are back to basics, even in the world of IP. Good surveillance is grounded in good images, 24/7. As video security consultant Bob Wimmer wrote in a recent white paper series for *Security Sales and Integration* magazine, "All designs of networking systems start with the camera or lens assembly, which will control the performance of any networking system." Moreover, although the market is moving towards digital imaging platforms, the principles of good imaging remain the same and are in fact more important considerations when designing a CCTV system.

Although the preceding investigation focused on bit rates, the use of infrared illumination extends logically into storage as well. Since there is a direct correlation between bit rate and storage requirements, it may be concluded that infrared illumination can be an effective strategy for reducing storage demands in IP video applications. The issue is especially important because disk space is one of the most expensive components of CCTV security.

What is the relationship between bandwidth and disk storage?

Bandwidth and storage – one of the most expensive components of a video security system – are directly related. If video is being transmitted at a certain bit-rate across a network to be stored, then it will consume disk space at exactly the same rate. For example, a 1 Mbps video stream will use 1 Mb (Megabit) of space in one second, or about 1/8 = 0.125 Megabytes per second, which equates to 0.125 x 3,600 = 450 Megabytes per hour (about 11 GB per day or 75 GB per week).