UNRAVEL AND UNDO THE UNREAL CCTV CAMERA SPECIFICATIONS

- We owe it to our customers and the society that depends on us for security

By David Elberbaum, President of Elbex Ltd.

The law enforcement professionals, the security experts and the public at large cannot understand why the picture quality of terrorists in actions, bank robberies and other security breaches, generated by CCTV systems, are always noisy with no details and show unrecognizable faces. This persisting state of CCTV affairs is a continuous on going state at a time when the consumer's DVD, TV receivers and TV stations are all in the midst of transformation into digital high definition. It is perplexing why what we perceive to be a professional CCTV industry shows no creativity in picture generation and recording quality, but ample creativity in sales pitches, slogans and ...specifications, most of which brink on the illusionary and the misleading.
It is time to bring back the realities of CCTV performances so that future recording of terrorists and other menaces in action will not be as bad as the 9/11 pictures we saw of Mohammad Ata or the London bombers of July 7.

The security industry is capable of providing good CCTV surveillance using current existing technologies to provide clear, high quality pictures throughout. This regretfully is not the state of affairs and the security industry should only blame itself for the unacceptable quality of CCTV pictures and recordings we see, which are very often a direct result of the published hype and plain wrong CCTV specifications. This path taken by the security and CCTV industry, was and is, self-destructive and it must be changed.
Security today is about protecting life. It is as important as the environment, traffic, health, housing, food and other regulated industries. The security industry is not regulated and the major players, the consultants and the dealers crowding the security market are proving wrong the theory that market forces will correct abuses. The security market is driven by distorted and "hyped" performances, just to get an order or win a tender. If this course of shooting our own foot does not change, it will be a question of time before the regulators move in to regulate the industry.
Regulation may include heavy penalties and other measures, such as jail terms, to deter the hype and misrepresentations which we all prefer not to see.
Even at the risk of being termed nostalgic, I cannot help but refer to the way performance specifications of CCTV cameras were published in the past. In the older days Vidicons were 10 lux, Newvicons 1 lux and the "hyping" was in the range of 10% ~ 20%.
Every security consultants specifying CCTV cameras knew that the sensitivity were either 10 lux or 1 lux. Good signal to noise ratio was 47dB and the bulk was 45dB ~ 46dB. Even though resolution figures of the past were exaggerated by 100 TVL or more, the resolution of the early days of VHS recording was less than 280 TVL and lower than camera performances of that time, thus the market was not greatly affected. In the early days IR (infrared) illuminators were not applicable and rarely used, but all this has changed with the arrival of IR sensitive CCD and MOS imagers.

Things have changed beyond what the newly arrived technologies offered - the transparencies and the reality simply vanished, replaced by ever escalating hype, distortion, sheer nonsense and the unrealistic.

Even though everyone in the security market knows that illumination, sensitivity, resolution and S/N are the most important performance items of a given camera, the public at large, and the security professionals in particular, do not understand what the specified CCTV performance figures mean and the way they are measured.
Moreover, even the few that do understand what the lux, IR or dB are and how they are measured, do not realize (or do not speak about) how these important performance values are transformed by the industry into a realm of hype and fiction. This is damaging not only professional manufacturers, but the industry in general.

So, it is high time for everyone to understand. Knowing what is going on will help change the CCTV state of affairs, viewed by some as a marketing ploy, forgetting that our own security is on the line.

Let's get the facts straight

Traditionally, as in former years, most specification items of CCTV cameras were measured and published in line with the broadcast industry standards known as SMPTE (Society of Motion Picture and Television Engineers). Sensitivity is the exception.
The reason for excluding sensitivity is the practical difference in the illumination level applicable to TV studios and the reality of the illumination of scenes observed by CCTV cameras. The difference is important - television studios are well lit and are provided with lighting control and management facilities for maintaining high illumination levels, such as 2000 lux at all times. For this reason the standard illumination level established by the broadcast industry is 2000 lux, in line with the actual illumination levels of TV studios. This enabled the Broadcast industry to link each and every camera performance parameter and the way it is measured to a standard 2000 lux, including S/N, sensitivity and resolution.
The tying of all the performances of a broadcast camera to a 2000 lux base gave the user a clear picture of the quality of camera A versus camera B, because all the elements of the measured performances are equal.

The exclusion, or the separation of the sensitivity and illumination standard of CCTV cameras from the measuring of S/N and resolution was and is wrong, because the user of a CCTV camera is not able to truly compare the S/N and the resolution of camera A versus camera B, at the camera's specified sensitivity. The S/N and the resolution are measured at 2000 lux, and are a world apart from the S/N and the resolution values at the specified sensitivity.

The reality is that users of CCTV cameras (unlike broadcast studios) do not have the know-how and the means to measure the lumen. The unit of luminous intensity is the candela. One candela of radiated light is approximately equal to the light radiated by a common candle.
The illumination, on the other hand, is a measure of how much light is radiated upon an object, or how much of radiated light is "reaching" an object, a book for example.
We all know that a book will be highly illuminated when we use, for example a 100W bulb, or when the book is near the bulb, while the book will be insufficiently illuminated if we use a 20W bulb or when the book is far from the bulb.
Simply summarized, the illumination is dependent on the intensity of the radiated light and the distance between the bulb and the illuminated object. The unit of illumination is lux. One lux is equal to one candela illuminating an object at a (point to point) distance of one meter.
The lux value decreases inversely with the square of the distance and can be calculated by a simplified, yet practical formula:
S/N and the resolution. They therefore believe that the values are valid for the specified sensitivity or the minimum illumination of a given CCTV camera.
The users are not given a clear picture of what the combined camera performances are, and as will be understood later, render the S/N and the resolution figures meaningless and unimportant. This is because the users see little or no difference in the recorded or displayed pictures by cameras specified with 320 TVL or 480 TVL. The result of all this is the very poor resolution (50 TVL or less) and noisy pictures (3dB or worse) of terrorists and criminals that we see.
The disconnecting of the sensitivity and minimum illumination from the other performances enabled some "smart" CCTV marketers to take short term advantages by hyping the sensitivity and the illumination and by pushing the limits to an escalated black hole of totally fictitious unrealistic figures.
The irony is that these false figures became mandatory to comply with in order to stay in business and thereby spread throughout the industry.
The fictitious figures are in more than one way responsible for the proliferation of the low quality of pictures observed and recorded.

About the illumination

Since it all started with the illumination values, it is obvious that to comprehend the performance of a CCTV camera we need to come to terms with what is illumination - so here it is, in a simple to understand story.

For most people illumination means "how much light", the majority will say that the lux is a measure of light strength or power. This is an incorrect understanding of light. Illumination is not a measure of "light strength" or "light power". The measure of "light power", such as how much light is radiated, for example by a 100W bulb, is termed luminous flux and luminous intensity. The unit of luminous flux is the lumen and the unit of luminous intensity is the candela. One candela of radiated light is approximately equal to the light radiated by a common candle.
The illumination, on the other hand, is a measure of how much of light is radiated upon an object, or how much radiated light is "reaching" an object, such as a book.
We all know that a book will be highly illuminated when we use, for example a 100W bulb, or when the book is near the bulb, while the book will be insufficiently illuminated if we use a 20W bulb or when the book is far from the bulb.
Simply summarized, the illumination is dependent on the intensity of the radiated light and the distance between the bulb and the illuminated objects. The unit of illumination is lux.
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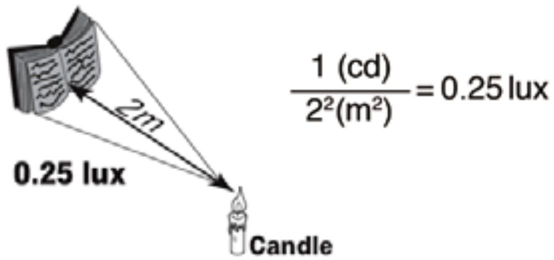
wherein

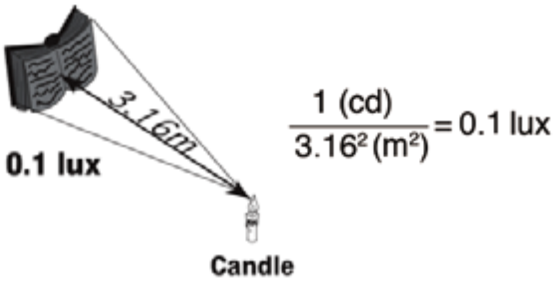
The lux value decreases universally with the square of the distance and can be calculated by a simplified, yet practical formula:

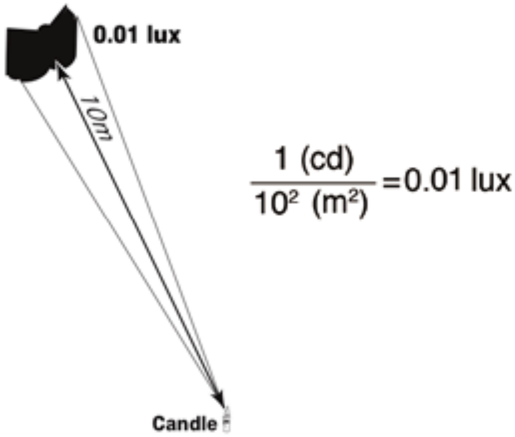
$$\text{point to point illumination} = \frac{\text{candela (cd)}}{\text{distance (m)}}$$

When 1 candela light source is positioned at 2 meters distance from an object, the object will be illuminated by only

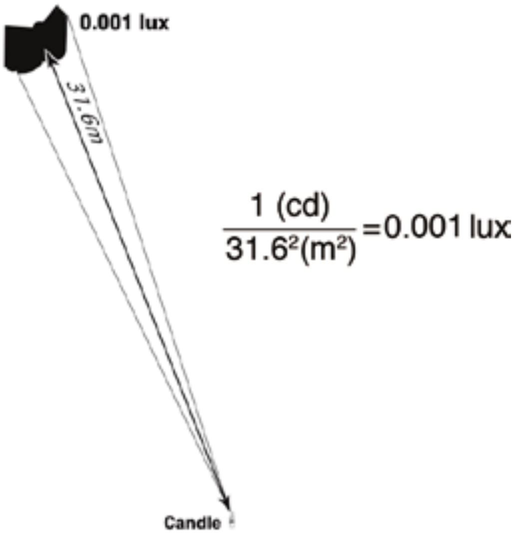


0.25 lux, At 3.16 meter distance the illumination falls to 0.1 lux.





At 10 meter distance the illumination drops to 0.01 lux.



And, at 31.6 meters it goes as low as 0.001 lux.

It is impossible to see a book illuminated by a candle at 10m or 31.6m distance, yet the many CCTV cameras specified with minimum illumination of 0.01 lux or 0.001 lux, claim in fact to observe dark scenes, illuminated by only one common candle, at a distance of 10 m (33 ft) or 31.6 m (103 ft) respectively away from the scene.

For those who believe that such specifications can be real, the simplest way to check it is to light a candle and see.

No conventional CCD or MOS camera, be it colour, B/W or both, can possibly generate a "usable picture" from a scene illuminated by 0.001 lux. In fact, the camera will generate nothing but noise, unless we apply tricks and ploys.

One trick is the long exposure, which is represented by the exposure time, adjacent to the sensitivity figure, such as 0.5S which identifies the exposure as 0.5 sec. duration. The long exposure, also known as "frame integration", is similar to taking a picture of a dark scene, by exposing a film in a still camera for a long period, such as 0.5 sec., 1 sec. or 8 sec.

This does not improve upon the camera's inherent sensitivity. It is creating a still (freeze) display, wherein no intruder or moving person can be recorded or identified, because they appear wholly smeared. Long exposure is a solution for registering unlawful parking in dark alleys, but it is useless for observation of moving people including criminals and terrorists in action.

The ploys are the introduction of IRE value, the reflection factor and the F-number of a lens which provide "limiting terms", restrictions and protection from claims by disgruntled users. I will explain later how these terms are manipulated, but let us look first at another outright wrong committed by so many, involving day-night cameras, lux and IR.

Visible light and IR

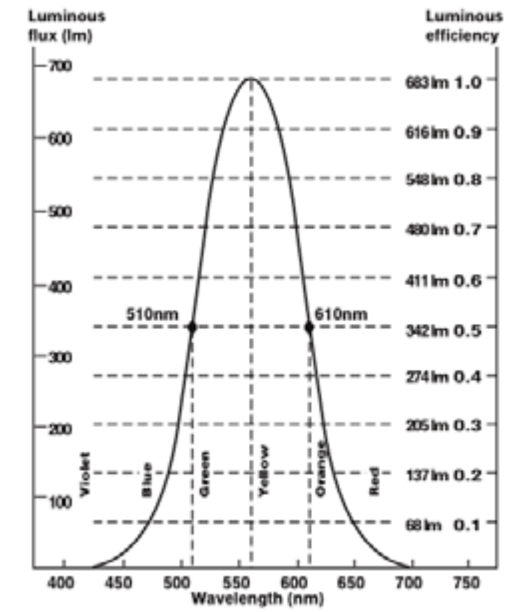
Over the past several years we have seen continued introductions of day-night CCTV cameras, all featuring a "magical" ability to increase by many hundred fold the camera sensitivity and/or the "minimum illumination" by removal of the IR cut filter and by switching off the chroma (colour) circuit. Typically, the camera's specified day mode sensitivity ranges from 3 lux to 0.25 lux and leaps to 0.01 ~ 0.001 lux for the night (B/W) mode.

This "magic" leap is not real, it is a measurement ploy by exposing the CCD to high IR radiant intensity and specifying it improperly in a very low lux value.

Lux and IR are not one and the same. Lux is a unit of illumination (illuminance) - a photometric unit. IR is a radiometric unit - measured in Watts. Illumination makes it possible for our eye to see, as opposed to darkness. IR irradiation belongs to "darkness", which is invisible to the human eye.

The light that illuminates things we see is an electromagnetic radiation, similar to the electromagnetic radiation of microwaves. The difference is in the frequencies, or the wavelength. The wavelength of the visible frequencies, known as the visible spectrum, ranges from 400nm (violet) to 700nm (red). This spectrum is divided into a rainbow of colours from red to orange to yellow to green to blue and to violet as shown in the CIE graph that follows.

CIE stands for the International Commission on Illumination (Commission International de l'Eclairage), which defines the



CIE luminous efficiency curve and the luminous flux of 1W of radiant power at the given wavelength.

measurement of light. The measurement of light, known as photometry, ***applies only to the visible portion of the optical spectrum***. Photometric units of light include terms and items such as talbot, lumen, nit, candela and lux.

The CIE curve represents the human eye's sensing ability versus the different wavelength (colour) within the visible spectrum, wherein the human eye sensitivity is highest to green colour (100% efficiency at 555 nm).

The eye sensitivity declines to 50% efficiency near the orange (610 nm) and the green/blue regions (510 nm) and to less than 10% efficiency in the red (650 nm) and blue/violet (470 nm) regions.

Human eyes do not sense or see radiated waves in the ultra violet (below 400 nm) or the infra red (above 700 nm) regions.

Similarly, the CIE curve also provides the basics for the luminous intensity standard, which is different for each and every colour.

To avoid the complex CIE standards, it will be sufficient to understand that the value set for a green (555nm) light bulb - having 1W of luminous flux, is equal to 683 lumen, which for a point to point measurement equals 683 Candela .

In comparison, 1W of red luminous flux (650 nm) equals only 68 lumen and 68 candela. 1W of IR radiant flux (over 700 nm) equals zero lumen, zero candela and ... zero lux.

This should be understandable, because lux is something we see, while IR is invisible to the human eye! IR irradiation therefore cannot be termed illumination nor specified in lux, or in any other standard photometric unit of light. Lux values can only apply to measurements within the visible spectrum as defined by CIE, but never to IR.

There are many established terms and units of measurements in our world, such as a meter, inch, gram, ounce, Celsius, volt, and ... lux.

In most countries it would be illegal, or sheer fraud, to label a 50 cc (cubic centimeter) container of a medical ointment as containing one litre of the substance, when in fact it contains only one gram. The sheer difference between the units of measurement, litre is volume, and gram is weight, would be sufficient to bring charges against the offender. The other important question, of course, would be - how can one gram of a substance be equal to one litre of it, in a 50 cc container that is far smaller (in volume) than the specified one litre.

An argument by the ointment manufacturer that the reference to one litre is in fact a measure of the substance foamed (or vaporised) into gas during the ointment production process may get the manufacturer off the hook, but it would be hard to sell it to the public because we all know what is a litre and what is a gram.

The problem is that most of us do not know what lux and IR are, nor how illumination, radiation and other light and IR items are measured.

As with the well known measuring devices for measuring standard units of weight, length, temperature or electricity, such as scales, rulers, thermometers or voltmeters, the illumination meter, known also as an exposure or light meter in photographic circles, is one of the devices or test equipment for measuring illumination in lux units. The light meters and other light measuring devices include a CIE pass filter and are calibrated to measure only light units within the visual spectrum as defined by CIE. The CIE pass filter, similar to the IR cut filter, prevents any and all IR radiation from passing onto the light sensor and from influencing the measuring accuracy.

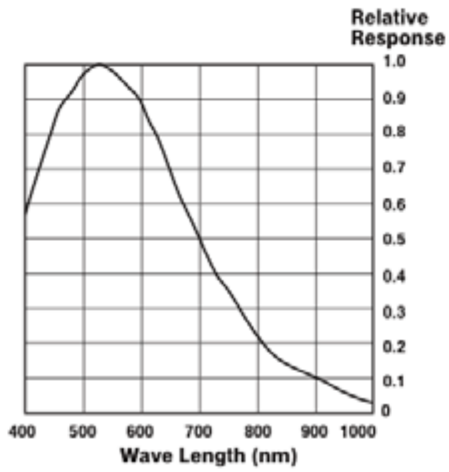
Based on this all the known light meters, exposure meters and other light measuring equipment will read ZERO lux or some residual value when exposed to IR radiation.

Light meters can, should and are used to measure the scene illumination observed by a CCTV camera. However, a light meter should never be used to measure IR irradiation, for which its reading will be zero lux, or a residual reading such as 0.01 lux, even though the scene may be exposed to substantial IR radiation.

To get a clearer picture here is the CCD side of the story.

CCDs are designed and manufactured to resemble the human eye, with color sensing efficiency as close to the graph of the visual spectrum as defined by CIE. Thereby CCDs are most sensitive to the green/yellow band of 550nm and drop to zero sensitivity in the ultra violet region (below 400nm). CCDs however do sense IR radiation beyond 700nm and up to 1000nm (some CCDs can sense up to 1200nm).

Typical CCD efficiency graph



The CCD sensitivity, however, is far lower in the IR region and drops to only 50%~5% efficiency or less, as shown in a typical CCD efficiency graph above.

Even though the CCD's sensing efficiency in the IR region is low, IR radiation must be prevented from reaching the color CCD. This is because IR is heavily radiated by the sun, by hot bodies and by many standard light bulbs, such as incandescent or halogen bulbs and if such IR is radiated into the optical path of a color CCD, it will cause havoc with the processing of color pictures. For this and other reasons every color and B/W CCD (or MOS) must be fitted with an IR cut filter that cuts or blocks the IR radiation from reaching the CCD. From here it should be simple to understand how day-night cameras are wrongly tested and specified.

As explained above, CCDs are far less sensitive to IR than to visual spectrum. In fact CCD sensitivity to IR is 2~20 times lower, (100% efficiency in the green region versus 50%~5% efficiency in the IR region). Therefore the notion that the removal of the IR cut filter increases the camera sensitivity by a hundred fold the other way, is a simple case of misrepresentation, induced by the improper use of a light meter for measuring IR irradiation.

The common incorrect test for the night mode of a camera is carried out by introducing a high power IR radiator (erroneously known as IR illuminator) for irradiating IR onto a dark scene. The test is performed by connecting a camera (with its IR cut filter removed) to a waveform monitor for measuring the video output signal. Placing the camera to observe an IR irradiated scene and positioning the light meter into the scene for measuring the IR irradiation...in lux!

This is a fallacious test that generates an IR induced B/W signal into the waveform monitor for measuring the video signal in IRE* units, such as 20 IRE, while the light meters, as explained above, will read zero lux or some residual value, such as 0.01~0.0001 lux, which is used for specifying the camera's sensitivity or its minimum illumination.

Readers should be aware that IRE is a unit of signal level and ***not an infrared item***, IRE is explained on the next page.

A more “sophisticated” laboratory test of camera sensitivity places a standard 2000 lux light box with a test chart in front of the camera under test (connected to a waveform monitor) for measuring the video signal generated by the camera with its IR cut filter removed. The test is carried out by inserting several ND filters into, or in front of, the light box for reducing the illumination until the measured video signal falls, for example, to 20 IRE, and specifying the minimum illumination in lux on a basis of the illumination calculated reduction.

A Neutral Density filter (ND filter) is a precise filter for reducing light. It is commonly known for reducing intense light from entering the optical path of a camera, such as the ND filter (spot filter) used in auto iris lenses. The ND filters, made of dark charcoal black glass (like that used to protect a welder's eyes) or films, are available in different transmittance factors for reducing the luminous intensity by ratios such as 1/2; 1/16; 1/50 or 1/100 etc, for the entire visual spectrum equally. Hence the term Neutral Density. However, even though the spectrum of the ND filter can be extended into the IR region, commonly used ND filters reduce IR radiation, such as IR radiated by a light box only slightly. In fact, many of the commonly used ND filters pass some 50% of the IR radiation on the average.

The calculation of the combined transmittance factor of, for example three filters, each with a transmittance factor of 1/100, calls for a simple multiplication of the individual filter factors, e.g. 1/100 x 1/100 x 1/100 = 1/1,000,000. The combined 1/1,000,000 transmittance factor will reduce the 2000 lux of a light box to a calculated value of 0.002 lux. However, the IR radiated by the bulbs of the light box will be reduced by some 50%, e.g. 50% x 50% x 50% = 12.5%. Since standard light boxes are powered by well over 200W bulbs, it means that the CCD will be exposed to intense IR radiation (over 25W).

Using a calculated illumination reduction of the transmittance factor within the visual spectrum (such as the above example of 1/1,000,000) to specify the camera's minimum illumination as 0.002 lux at 20 IRE, does not consider the 25W of IR radiation that passes onto the CCD of a night mode camera (having its IR cut filter removed). Measuring IR induced video signal levels, as low as only 20 IRE, cannot be termed transparent representation of camera performance, nor truthful business, to say the least. The IRE is a term that needs to be understood, so here is the IRE story.

The IRE story

The internationally established standard for composite video signal level is a 1.0 Volt peak to peak, commonly written in camera specifications as 1.0Vp-p.

The 1.0 Volt composite signal actually combines two signals, a fixed sync signal of 0.3Vp-p and a video signal of 0.7Vp-p (max). The composite video signal has many signal components and its video level is dependent upon the scene content and the illumination. Because the components of the video signal are inter related it was necessary to establish an arbitrary reference unit to the levels of the different video signal elements and this was established by the *Institute of Radio Engineers* from the early days of television, hence the IRE unit. The IRE as related to CCTV camera specification concerns only the level of the luminance signal, i.e., the B/W picture signal. Therefore, without going into the details of the IRE standard, it will be sufficient to understand that the internationally established 0.7Vp-p video signal is divided into 100 IRE units, wherein each IRE unit is equal to 1% of the 0.7Vp-p. From this, it should be simple to understand that the 20 IRE the camera is generating at the specified minimum illumination will be only 20% of the 0.7Vp-p video signal or 0.14Vp-p, 50 IRE is only 50%, i.e., 0.35V p-p and 10 IRE is 10%, or 0.07Vp-p.

The 20 IRE~50 IRE (0.14Vp-p ~ 0.35V p-p) are reached with the camera amplifiers at full gain and the noise they generate at full blast. This is against a signal that is specified as composite 1.0V p-p in the same camera data sheet to begin with! Moreover, as specified in many camera data sheets, 20 IRE will be realized only for an unrealistic 75% or 89% object reflectance, or reflection.

Light reflection

The terms reflection and reflectance are similar, but they are not the same. Reflection is a general term in optical geometry, used in the formation of images in smooth surfaces, such as mirrors (specular reflection) or in granules or rough surfaces (diffuse reflection). Reflectance is a term used in the field of multi layers of films or multi coating of lenses and filters, for providing controlled reflectance and transmittance within the visual spectrum and beyond, such as the LPF (Low Pass Filter) used in colour CCD cameras.

The vague and mixed use of such basic optical terms as specified in the data sheets of different CCTV cameras suggests that the reflection values (75% or 89%, etc.) are not

a result of testing procedure, but an intentional inclusion of reflection ratios that are outside the realm of our day-to-day security observation. Moreover, such reflection ratios are impossible or difficult to realize, to say the least, even in broadcast television studios. The practical term should be reflection (diffuse reflection) which tells how much (in percentage) of the illumination (in lux) will be reflected from objects within the illuminated scene. In the example of night mode, specified at 0.002 lux, the value in n% tells us how much of 0.002 lux will be reflected from a person trying to break through a backdoor of a poorly illuminated warehouse. A reflection from white plain paper is in the range of 60~80%, while a black opaque wall reflects nothing or 0%. The reflection of dark brown or black human skin is approximately 15% and the reflection of a Caucasian human skin is approximately 30%.
Altogether, the above mentioned reflection values are approximate reflection within the visual spectrum. They cannot apply to IR radiation, which is different and which was the basis for specifying the night mode of a camera.
It should be obvious to any CCTV consulting engineer that no person's face can reflect 75% or 89%, etc., and that at best a playback of a recorded event under very low illumination, will reveal noisy, dark or shadowy images with no details, making it practically impossible to identify the recorded person.
Regardless of all this, we are witnessing time and again serious tender specifications calling for day-night cameras, reciting the minimum illumination, as presented by CCTV camera suppliers in their data sheets and forcing potential bidders to comply with such fictitious specifications.

The lens F number

The F number of a lens is another item of importance governing the camera sensitivity. The F number such as F1.0, F1.4 or F2.0 represents the aperture of the lens with its iris fully open. The aperture of a lens tells how much of the reflected light (from the illuminated observed scene) passes through the lens onto the CCD. F1.0 will pass all of the reflected light through. The light passing through the lens decreases inversely with the square of the F number and is calculated by a simple formula shown:

$$\frac{1}{\text{aperture}^2\ (F)} = \text{Passing light}$$

wherein for various F numbers we have:

$$\frac{1}{1.0^2} = 1$$

$$\frac{1}{1.4^2} = 0.5$$

$$\frac{1}{2.0^2} = 0.25$$

The "minimum illumination" or the "usable picture" is therefore conditioned in camera data sheets upon the use of a lens having a low F-number such as F1.0, F1.2 or F1.4. While a low F number is needed to pass more light through the lens, the F number also governs the "depth of field" or how much of the scene will be in focus.

Here there is a conflict with the F number.
With bigger F numbers the depth of field is deeper and wider, the focus is better and the resolution is higher. Therefore, specifying a low F number for a "usable picture", will result in a very shallow depth of field (no focus) and poor resolution, or a "non usable picture". This is because with an F1.2 lens, for example, the depth of field of a 1/3" or 1/4" CCD is a few centimetres or millimetres respectively.
Simply explained, by using a lens with a low F-number most of the observed scene will be out of focus, reducing the resolution of a low illuminated scene to as low as 50TVL or less. This is an "unusable picture" because a person's face cannot be identified from a 50TVL picture.

What the CCTV industry has created is wrong!

A comparison with what are the basic sensitivity requirements in the broadcast industry will demonstrate how far the CCTV industry has drifted.

The sensitivity criterion for broadcast cameras are:

1. How high is the F number;
2. For a camera to generate 100 IRE;
3. With all amplifiers switched off; and
4. At 2000 lux.

Why can't the CCTV industry do the same, by changing for example the illumination to 100 lux or 10 lux?!

Two other items of paramount importance are the Signal to Noise ratio (S/N) measured in dB and the resolution, measured in TVL (TeleVision Lines).

The S/N

The S/N is measured with the camera exposed to 2000 lux of white light (light box) with its AGC amplifier switched off. The camera's peak to peak video signal (whole white) and the noise (RMS value) generated by the CCD and the camera's video circuits are measured and compared. The S/N ratio of CCTV cameras, under such test conditions, will read anywhere from 48dB to 52dB or better. At an average of 50dB (316 to 1 ratio) the measured RMS noise level is about 2.1mV and its peak to peak level is approximately equal to 0.5 IRE or higher.
At 50dB S/N ratio the noise does not affect the observed display nor the playback of a recorded picture.
But for cameras exposed to less than 3 lux, or at video level output such as 20 IRE and with the camera AGC amplifier at full gain (approx. 30dB), this is what happens: The noise is amplified 32 times (AGC gain of 30dB) to 16 IRE, which is 80% of the specified 20 IRE for the brightest objects, having 75% or 89% reflection. Therefore, the overall noise (p-p) will be higher than the video signal, rendering the picture useless and unrecognizable.
This is without considering the noises generated by the camera's processing circuits and the AGC amplifier operating at full blast, plus the noise generated by a recorder and by other peripheral equipment.
In the past, a lower video signal level and the S/N were not as critical to video recording (VHS) as it is today to digital recording for two major reasons. The first is that the DVR needs to convert the analog signal to digital and the DVR does it on the basis of 0.7Vp-p. When a camera generates only 20 IRE the signal is amplified again by the DVR input

amplifiers, which contribute additional noise. At this point the noise and the signal are either equal or the noise may be larger than the signal. Second, the noise generated by the camera is random noise, continuously moving throughout the screen, similar to the noise particles circling about the screen of a TV receiver when its cable or antenna is disconnected.

For JPEG, MJPEG or Wavelet recorders, compressing the whole picture, the noise simply increases the volume of the processed data and occupies most of the allocated Bytes (such as 20KB per field or frame), leaving the picture with useless resolution and plenty of noise.

For MPEG2 or MPEG4 DVRs in which compression is based on movements within the scene, the noise is "random moving objects" that keep the compression circuit busy as if there were never ending movements throughout the scene, reducing substantially the frame refresh rate and, here too, occupying the allocated capacity with noise, useless resolution and an unrecognizable picture.

If we want to benefit from our "digital future" it is vital that each and every one of us understand that realistic S/N values are so much more important and critical in the digital world than in the analog world. For such purposes it is necessary to specify the S/N value of a camera for its intended illumination environment - this, along with the minimum S/N value for the video input signal of a DVR, under which the DVR will record recognizable pictures. Anything short of that is inviting unusable surveillance in perpetuity, and it is shooting the security of our own societies in the knee.

TV resolution

It is well known and understood that CCTV cameras with higher resolution display finer details and recognizable images of people and faces. The question of what is higher resolution, however, is confusing to most people. For example, the resolution of any television channel we see in our everyday life is approximately 330 TVL (NTSC) and 400 TVL (PAL).

There is no question in anyone's mind that the images we see on TV news are far superior to what we see and record through CCTV cameras, where 752 or 768 horizontal pixel arrays are used, specified with 460 or 470 TVL. Even the playback of a movie through a standard VHS cassette is far superior to the playback of a CCTV recording, though the VHS resolution is only 240 TVL.

The repeated encounters with low resolution performances by CCTV systems makes the resolution figures, be it in TVL or pixels, meaningless in the eyes of users, because it is unexplainable how 470 TVL resolution can be as poor as can be, while 330 TVL of daily TV news are so clear.

Regardless, each and every new CCTV tender specification we see is calling for cameras with a resolution of 460 TVL or 480 TVL, etc., even though such high resolution values are simply impossible to reach at the illumination levels the cameras are specified for.

Such high resolution can never be reached in day-to-day practice, not even with scenes illuminated by 100 lux ~ 1000 lux. Therefore, each and every CCTV tender specifying a system with a resolution of 480 TVL is in fact transforming what is supposed to be a serious specification for a security system, into another hype or sheer nonsense.

The resolution specified in TVL tells us how many black and white dots we can see on a 75% stretch of TV's one horizontal line (TV resolution is measured per picture height). Most CCTV camera suppliers do not specify a measured resolution. The specified resolution in the camera's data sheet is a theoretical maximum resolution value, on the basis of the horizontal pixel array of a CCD such as 752 or 768 pixels. Without going into the complexity of the theoretical calculation in this article, it should be noted that the theoretical maximum (commonly available) high resolution for PAL is 460 TVL (752H pixel array) and for NTSC is 470 TVL (768H pixel array). The B/W resolution for CCIR and EIA is approx. 580 TVL. For other horizontal pixel arrays of a CCD, use 61% of the figure to get approximately the theoretical maximum resolution in TVL for colour CCDs and 75% for B/W CCDs.

The above resolution figures are the maximum theoretical figures, but in practice, as stated, even at 2000 lux, the measured resolution is never as high as the theoretical resolution. Among other factors, the resolution is dependent on the illumination and the lens used. Lenses reduce the theoretical resolution figure, particularly wide-angle lenses. The very important factor is the illumination; under low illumination, the resolution is dramatically reduced.

There are several methods to measure the resolution. The most subjective method is based upon measuring 40% signal level, known as aperture signal, versus the peak signal measured at 50 TVL level. 40% signal level measured against peak signal of 20IRE equals 6.4mVp-p and 6.4mVp-p is equal to noise. This means that to measure a resolution at 20 IRE signal (even if it does peak at 50 TVL) will read noise only. This renders the resolution to be less than the reference 50 TVL.

There should be no surprise then that the recording of Mohammed Ata's image on 9/11 and the images of the London bombers on July 7 had no chance of being any better.

The state of CCTV and the security market is no fun at all.

Unresolved bank robbery

Having to write this article proves that the mediocre and the "clever" marketers prevail. The endless pictures of unresolved bank robberies published on the Internet tell the rest of the story.

One cannot blame it all on CCTV manufacturers. It is not only the supplier's fault. The "cheapest bidder gets the job" is another leading reason for the "blindness" in this whole saga. For example, 1/2" CCD cameras that are far more sensitive than 1/4" CCD cameras and have far better S/N, depth of field and resolution may cost $200~$300 more per camera, which for a 50-camera system will increase the camera cost by some $10,000~$15,000, yet because of the better S/N ratio, the use of 1/2" cameras may reduce the cost of the DVR's HDD by many times that amount.

Another unresolved robbery

If all is equal, a CCTV system with 1/2” cameras may end up saving hundreds of thousands of dollars on large system costs, and provide far superior performance and recordings.

So how do we change all this?

The many articles I and others have written in the past made no dent and did not slow the way the CCTV market drifted into this state of ridicule that could have been the source for a comedy script. Yet because it is serious we at Elbex have decided to do more than write an article in CCTV and security magazines.

This time we, at Elbex, have developed the first ever portable camera analyser for measuring all the items of CCTV cameras, including illumination, S/N, resolution, IRE, colour accuracy and spectrum.

This camera analyser is supplied with a calibrated and controlled light source for generating a controlled light in candela units (0.1~1.0 cd) and a calibrated and controlled IR radiator in (what we elected to term) IR candela^{TM} units (0.1~1.0ircd^{TM}).

The camera analyser measures illumination from 0.01 lux up to 100,000 lux and IR irradiation in (what we elected to term) IRlux^{TM}, from 0.01 irlx^{TM} to 100,000 irlx^{TM}.

Further, the camera analyser superimposes onto a display of a stored picture of a scene under measurement with readings of illumination and IR irradiation, along with all the measured performances of the camera, including its output waveform.

The stored display can be printed via a PC to provide a test certificate for the CCTV camera, as measured at its intended location, under its intended illumination.

We have priced this patent pending amazing camera analyser, model EWM40 (WM stands for waveform monitor), to be affordable for every security officer, security consultant, security dealer, security installer and all suppliers of CCTV cameras. We hope that with such an affordable tool we may help change the CCTV market direction. We also hope that it will help many suppliers, consultants and dealers to reconsider and rewrite their data sheets, tender specifications and offers.

Above all we hope that this will challenge all of us to compete on quality and performance, regain our pride, the respect of the users and the society that depends on us for security (and possibly make a decent profit while doing so).

I wish to thank Mr. Vlado Damjanovski, the Editor of CCTV focus magazine and Mr. Glenn C. Weahner, Senior VP and chief technology officer at Pelco for their input and support with this article.

a square picture segment with a side of N readouts, i.e. about 30 operations per picture element will be needed to make an elementary high-frequency processing of an image segment 3 x 3. Therefore, at least 10 million readouts per second will be needed for a standard TV camera with a video-frequency bandwidth of 5 MHz to get a non-distorted display of the signal. The processor speed required for processing an image segment of 3 x 3 at the TV system operation rate will be 300 million operations per second. Increase of an image segment size will sharply increase the requirements processing speed. There are a few ways to decrease the requirements in hardware computing power. One is, for example, by means of parallel multi-processors. Another would be by extending the processing procedure for the time required for generation of all elements of an image segment. So far, most of these methods are too exotic to be applied in surveillance and security CCTV systems, which normally consist of tens or sometimes even hundreds of TV cameras.

One possible way to perform image processing consists in creating customized computing machine, at the cost of abandoning the advantages of a general-purpose computer. This seems to be the way security CCTV equipment developers and manufacturers have chosen to follow. We have to be aware though that there are essential limitations here. For example, to isolate low-frequency spatial components, the whole picture measuring 600 x 800 elements has to be processed as a whole, not by individual segments. This is, of course, unachievable at the TV system rate even at the cost of programmed control abandonment.

That is why "outdated" methods of analogue engineering are still used for image processing in security systems. Here, the pragmatic approach to selection a method proved to be justified, i.e. selecting the method that minimizes the cost under the circumstances when pre-set constraints have been applied to processing quality as well as to weight and size of the equipment. With this approach in mind, it turns out that the selection of a method depends on the physical details of the image transformed by this function. Then image parameters may be grouped into:

1. Spatial distribution parameters (e.g. spectral content, geometrical similarity, etc.);

2. Level distribution parameters (e.g. luminance, contrast, saturation);

3. Parameters of reciprocal statistical relationship between multi-dimensional signal components (e.g. segment wise inter frame correlation, reciprocal correlation of chrominance signals);

4. Parameters of image variation in time (e.g. shift rate, display lag, etc.).

If a processing operation transforms a parameter in such a way as to make up for hardware-originated distortions, the image restoration method will be applied. In this case known hardware-originated errors are considered (e.g. photoelectric transformation errors). If a parameter is brought to its optimal value, the normalization will be done OK. In this case the most essential thing is the criteria for image quality as seen by the TV recipient. If in this parameter the image distribution differs from noise distribution, this difference may be used for signal selection in the noise background, i.e. for achieving noise suppression and proper Signal/Noise ratio. If the distribution differences are result from the picture elements, processing of distribution in this parameter will permit to select picture elements for semantic analysis. During the semantic analysis the properties of the image itself are considered (e.g. sizes of the objects, relationship of contours, parameters of motion, etc.).

CCTV systems in security and video monitoring are characterized, as a rule, by the fact that the number of cameras is considerably larger than the number of monitors. Therefore, video signal processing hardware is traditionally embedded directly in the cameras. This allows: (1) to apply customized computing devices adapted to a specific photoelectric converter and (2) to perform the most important mission – normalizing the video signals as it comes from the camera. Indeed, it is practically impossible (and inappropriate) to arrange video data processing "on the fly" in a single customized digital device. It is much simpler and more reliable for the video switching, recording and displaying equipment to operate with normalized video signals in CCTV network.

Maintaining the stable video signal swing at the camera output under the conditions of varying illumination of a scene is the most important function of video signal normalization. To achieve this goal, special mechanisms are applied in the camera for controlling its sensitivity. It is important here that electronic devices of the CCTV camera and the CCTV operator together evaluate (measure) and set the video signal value, which ensures optimal conditions for displaying visual scenes on the monitor at the protected facility. This measurement is not easy, because a CCTV video signal is uni-polar by its nature and its form is quite different from the form of harmonic functions, whereupon the traditional notion of an amplitude loses its sense. It is also wrong to equate the value of a video signal with its average value or with the mean square (standard) deviation, as deviations of real video signals from the normal distribution law are very considerable.

Therefore, in actual practice we have to either limit the abnormal readouts prior to measurement, or to refer to stable (robust) response of the signal values. Any constrains of the signal and making it stick to a frame of specific parameters will always be faced with the risk of neglecting something that afterwards may turn out to be extremely important. In cases like these non-parametric evaluation of signals by plotting level distribution histograms is preferred. This can be done correctly only during the digital processing of video data of *the whole frame* – and as such is implemented in modern digital CCTV cameras. Besides, to ensure stable operation of automatic control loops used for controlling camera sensitivity, a sequence of video signal level evaluations made per frame is subject to statistical processing by means of a digital filter with the parameters adapted to varying input illumination. Thus, the traditional evaluation of video signal level in analogue cameras by means of peak- or quasi-peak detection, which was faced with inadequate selection of peak