# White Paper: Understanding Image Resolution

by Dr Bob Banerjee

This brief white paper demystifies analog video resolutions and their relationship to their digital counterparts. By understanding the relationship, we can optimize the use of our original camera video, without wasting effort compressing, transmitting, and storing parts of the image that can never be seen.

NTSC Analog Video

An NTSC analog video picture is composed of 480 active horizontal lines. When the picture is sent to a monitor or another receiving device, the first field of 240 even-numbered lines is sent, and then the second field of 240 odd-numbered lines is transmitted. This occurs at a rate of 60 fields per second.

The odd and even fields are offset one line apart, so when they are viewed in rapid succession (60 fields per second), they slot into one another to give the illusion of the complete picture – also called a frame, which is made up of 2 x 240 (or 480) lines. This is called interlaced video.

240 lines

Field 1

Field 2

480 lines

2 Interlaced Fields (1 Frame)
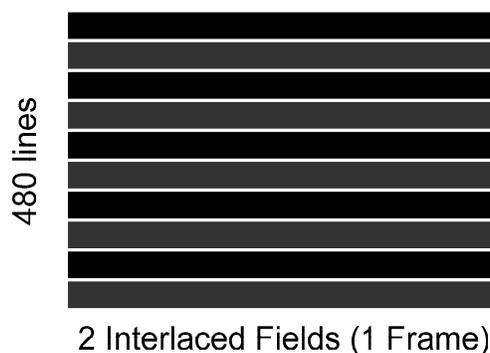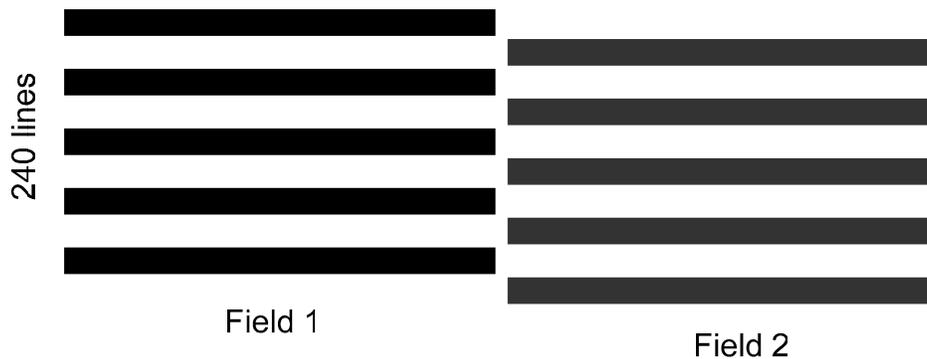
Resolution (TVL – or TV Lines) is a monochrome specification that states how many black and white lines can be seen in a given area. With 480 active scan lines, we can see how the theoretical maximum vertical TVL resolution is directly affected by the number of scan lines. (Note: TVL is not equal to scan lines, but vertical TVL is affected by the number of scan lines.)

Now that we understand the vertical resolution, we need to understand the horizontal TVL resolution (the number of vertical sampling points). This number varies by camera manufacturer, but they all follow the same definition.

As you can see in the drawing above, the picture is wider than it is high. This is called a 3x4 aspect ratio. (3 units high by 4 units wide). Horizontal resolution is defined as **the amount of vertical black and white lines you can see in 3 of the 4 units**. In other words, how much detail you can measure in 75 percent (3/4) of the picture's width.

This resolution number varies by camera type and camera manufacturer – many "standard" CCTV cameras have 380 TVL, but high-resolution cameras have more, typically 540 TVL.

Assuming all things are equal, if you were to connect an analog CCTV camera via coax to an analog monitor, you would see everything. However, when you digitize the analog video, compress it, transmit it across an IP network, and then decompress it again, the video changes. To understand how it changes, we need to understand CIF – resolution in the digital world.

Analog to Digital

In the analog world, 480 active scan lines and 75 percent of the horizontal area identify resolution. With digital, we still have a 3x4 aspect ratio, but pixels or sensing points now take the place of scan lines. Like cameras, these digital "picture grabbers" (digitizers) come in different levels of resolution (e.g., 176x144, 352x240, or 704x480). Like a steel chain, the picture quality of your system will only be as good as your weakest link.

What is CIF?

CIF and derivatives of this word are terms used to identify the level of resolution that the "picture grabber" can produce. CIF (pronounced "SIF") stands for "Common Interchange Format" or "Common Intermediate Format." It ranges from: CIF 352x240, 2CIF 704x240, or 4CIF 704x480.

Cameras and TVL (Horizontal) Resolution
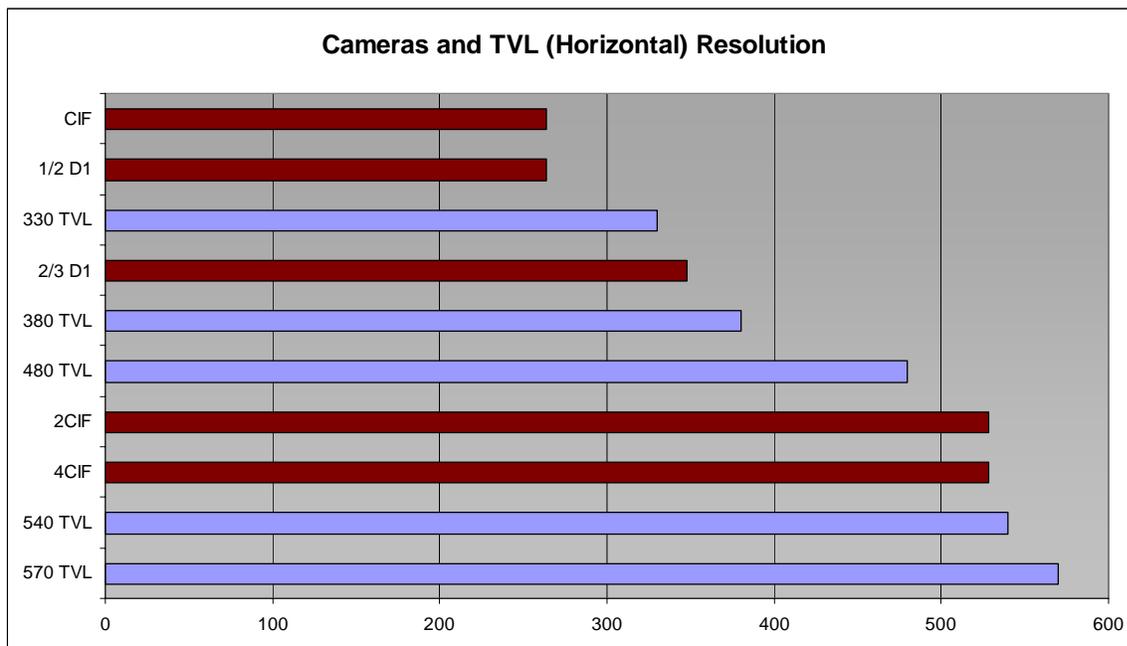
Camera	CIF	1/2 D1	2/3 D1	2CIF	4CIF
330 TVL	Good	Better	Best	*Unnecessary*	*Unnecessary*
380 TVL	Good	Good	Better	Better	Best
480 TVL	*Acceptable*	*Acceptable*	Good	Better	Best
540 TVL	*Acceptable*	*Acceptable*	Good	Better	Best
570 TVL	*Acceptable*	*Acceptable*	Good	Better	Best

The table above shows cameras and their CIF recommendations. Note that statements such as 'Good, Better, Best' are subjective and you are encouraged to try the settings for yourself:

- *Acceptable: significant image quality loss, but still usable depending on application*

- *Good: respectable, yet efficient image*

- *Better: optimized image (default recommendation)*

- *Best: as perfect as possible*

- *Unnecessary: compressed image contains wasteful/redundant information since the camera's resolution is lower*

CIF is Economical, But Does Not Bring Out the Best in Your Camera

Digitized NTSC video at CIF resolution is an image that is 352x240. It intentionally matches the NTSC 240 horizontal lines in a field so that there is a one-to-one conversion from analog to digital CIF. However, the 352 only produces a theoretical 264 TVL (remember 75 percent of 352), which does not match the 330, 380, 480 ,or 540 TVL from the cameras – so what happens to the extra vertical lines of resolution? They are lost. At CIF, any camera capable of delivering over 264 TVL will not appear superior: 264 TVL and 1,000 TVL cameras will produce identical images.

When compression solutions use CIF resolution, they typically use every other field and simply discard the others – so a CIF system throws away half the video information from the camera. Because the eye is good at averaging things, it's not that noticeable, but this cuts the vertical resolution in half, and makes the resulting video "jerky" and less smooth.

2CIF is an Effective Solution for High-Resolution Cameras

To benefit from higher resolution cameras, 2CIF (704x 40) can be used. Once again, the 240 matches the 240 horizontal scan lines in a single field and the 704 will give us 528 TVL. In the case of 330, 380, and 480 TVL cameras, we have an excess of vertical lines – if we have a 540 TVL camera, we can see almost all of the detail.

In other words, 2CIF is the lowest setting that maintains the horizontal resolution of the cameras. But note that the vertical resolution is reduced (because again, we discard alternate fields).

4CIF is the Ultimate Choice for High-Resolution Cameras

A 4CIF picture has 704x480 pixels. Like 2CIF, the 704 provides 528 TVL horizontally – **but** 4CIF provides 480 pixels in the vertical direction. This improvement supports the **full** 480 vertical resolution provided by the NTCS analog signal.

480 *scan lines* corresponds to 480 pixels. 4CIF systems use both fields. However, some 4CIF systems combine pairs of fields into frames (through a process called de-interlacing) and then code these frames as images. This leads to "zippering" artifacts on objects moving horizontally through the scene and can be very distracting to watch.

4CIF (similar to D1) contains substantially more horizontal and vertical data. Consequently, the data streams and data files are large.

2/3 D1 and ½ D1

There is a very effective compromise setting offered by some manufacturers called 2/3 D1 (pronounced "two-thirds D1").

2/3 D1 is 464x480. Its 464 horizontal resolution is a near-perfect fit for most cameras and the benefits in bandwidth and disk space savings can be very substantial.

½ D1 is another option: at 352x480, it has the width of CIF and the height of 2CIF. But as discussed earlier, the eye is less discerning in the vertical direction, which makes ½ D1 a less popular option.

Summary

Cameras have specific resolution capabilities that are measured in TVL, while digital and IP encoders measure in CIF. It's important to understand the relationship between camera TVL and horizontal resolution for digital systems so that you're getting the most out of your camera, but not storing extra and completely redundant data thinking that your final image will look better. In the vertical direction, the number of scan lines (240 or 480) is also a quality factor, but due to the nature of the human eye, it's less important than horizontal resolution.

Remember why this is so important: if you are about to spend $10,000 on storing video for a week at CIF resolution, you will need $20,000 at 2CIF or $40,000 at 4CIF.

Bosch Security Systems encourages you to get the best image possible out of your camera, and hopes that this white paper will help you understand the difference between what you think you're getting and what you're *actually* getting. You want to be sure you're selecting the right equipment *and* the right configuration.