Navigating the Rapids of DTV Standards Conversion
By Peter Wilson

In the modern world of DTV we have, perhaps rashly complicated our lives beyond all reason. For various techno-political reasons we now have to deal with TV formats that come in an abundance of flavours. 702 worst case!! We have progressive or interlace, in a multitude of field or frame rates. You as users or originators of DTV programming may have to deal with all these formats.

Important DTV Issues

Many early adopters of DTV have come across difficult issues of quality caused by historical "Custom and Practice". An important thing to remember is that the end to end chain performance is very important.

Perceived sharpest and best picture quality, at the end of the studio chain does not always guarantee the best pictures at home any more. For example: super sharp enhanced UpConversion with motion adaption popping in and out, may seriously compromise your compression factor (coding gain).

The secret with DTV is smooth, smooth filter responses, smooth pictures etc…

The Strident call of “Progressive is easier to compress than Interlace” may be true in principle but the biggest bonus comes for example from using a lower temporal sampling rate (24 frames per second).

Another serious issue, which hit Europe many years ago, was standards conversion from discontinuous 3-2 sequences, and video inserts into film shot episodics.

For artistic reasons editors wish to cut on their preferred frame, with rushes transferred with a 3-2 sequence this means a sequence disruption, add video based inserts or titles and the compression factor is shot up real bad.
Mixed sequences without video inserts can be fixed with a good 3-2 detector which is followed by a re-sequencer or a 24p converter. Mixed film and video needs motion compensation, to convert all to 24p then it is a simple job to convert back to a continuous 3-2 sequence.

There are a host of high resolution, low resolution, progressive scan and interlace scan picture formats now in common use. We should also not forget the added dimension of 50Hz contributions from the 50 Hz countries.

In addition there are colorimetry matters to consider, SMPTE 170, 240, 274, EBU and REC 709 all have important meanings in the DTV era.

DTV cannot practically be a clean sweep, understanding legacy formats and their foibles becomes essential.

DTV Formats

If we multiply SDTV standards by HDTV for up and down conversion there are 19 SDTV variants * 37 HDTV variants, which equals 703 variations to program in Software and debug.

Industry Code	Total Lines Per Frame	Active Pixels per line/frame	Vertical Frequency (Hz)	Horizontal Frequency (kHz)	Sampling Frequency (MHz)	Samples per total line	Interlace	Film Rate (Hz)	Film Sequence	Industry Standard
SDI										
525i/60/2:1	525	720x483	60.00	15.750	13.514	858	2:1	-	-	ANSI/SMPTE 259M-1997/ITU-R BT.601-5
525P/60/3:2	525	720x483	60.00	15.750	13.514	858	2:1	24.00	3:2	?
525P/60/2:2	525	720x483	60.00	15.750	13.514	858	2:1	30.00	2:2	?
525i/59.94/2:1	525	720x483	59.94	15.734	13.500	858	2:1	-	-	ANSI/SMPTE 259M-1997/ITU-R BT.601-5
525P/59.94/3:2	525	720x483	59.94	15.734	13.500	858	2:1	23.98	3:2	?
525P/59.94/2:2	525	720x483	59.94	15.734	13.500	858	2:1	29.97	2:2	?
525P/24sf/2:2	525	720x483	48.00	12.600	17.325	1375	2:1	24.00	2:2	?
525P/23.97sf/2:2	525	720x483	47.95	12.587	17.308	1375	2:1	23.98	2:2	?
480P/60/2:2	525	720x480	60.00	15.750	13.514	858	2:1	30.00	2:2	?
480P/60/3:2	525	720x480	60.00	15.750	13.514	858	2:1	24.00	3:2	?
480P/59.94/2:1	525	720x485	59.94	15.734	13.500	858	2:1	-	-	ITU-R BT.601-5
480P/59.94/2:1	525	960x485	59.94	15.734	18.000	1144	2:1	-	-	ITU-R BT.601-5
480P/59.94/2:2	525	720x480	59.94	15.734	13.500	858	2:1	29.97	2:2	?
480P/59.94/3:2	525	720x480	59.94	15.734	13.500	858	2:1	23.98	3:2	?
625i/50/2:1	625	720x575	50.00	15.625	13.500	864	2:1	-	-	ANSI/SMPTE 259M-1997/ITU-R BT.601-5
625i/50/2:1	625	960x575	50.00	15.625	18.000	1152	2:1	-	-	ITU-R BT.601-5
625P/50/2:2	625	720x575	50.00	15.625	13.500	864	2:1	25.00	2:2	?
625P/48/2:2	625	720x575	48.00	15.000	20.625	1375	2:1	24.00	2:2	?
625P/47.9/2:2	625	720x575	47.95	14.985	20.604	1375	2:1	23.98	2:2	?
HD-SDI										
1080i/60/2:1	1125	1920x1080	60.00	33.750	74.250	2200	2:1	-	-	ANSI/SMPTE 292M-1996 - Format D/274M (4)
1080P/60/3:2	1125	1920x1080	60.00	33.750	74.250	2200	2:1	24.00	3:2	?
1080P/60/2:2	1125	1920x1080	60.00	33.750	74.250	2200	2:1	30.00	2:2	?
1035i/60/2:1	1125	1920x1035	60.00	33.750	74.250	2200	2:1	-	-	ANSI/SMPTE 292M-1996 - Format A/260M
1035P/60/3:2	1125	1920x1035	60.00	33.750	74.250	2200	2:1	24.00	3:2	?
1035P/60/2:2	1125	1920x1035	60.00	33.750	74.250	2200	2:1	30.00	2:2	?
1080P/60/1:1	1125	1920x1080	60.00	67.500	148.500	2200	1:1	60.00	1:1	ANSI/SMPTE 274M-1995 - Format 1
1080i/59.94/2:1	1125	1920x1080	59.94	33.716	74.176	2200	2:1	-	-	ANSI/SMPTE 292M-1996 - Format E/274M (5)
1080P/59.94/3:2	1125	1920x1080	59.94	33.716	74.176	2200	2:1	23.98	3:2	?
1080P/59.94/2:2	1125	1920x1080	59.94	33.716	74.176	2200	2:1	29.97	2:2	?
1035i/59.94/2:1	1125	1920x1035	59.94	33.716	74.176	2200	2:1	-	-	ANSI/SMPTE 292M-1996 - Format B/260M
1080P/59.94/1:1	1125	1920x1080	59.94	67.433	148.352	2200	1:1	59.94	1:1	ANSI/SMPTE 274M-1995 - Format 2
1080i/50/2:1	1125	1920x1080	50.00	28.125	74.250	2640	2:1	-	-	ANSI/SMPTE 292M-1996 - Format F/274M (6)
1080i/50/2:1	1250	1920x1080	50.00	31.250	74.250	2376	2:1	-	-	ANSI/SMPTE 292M-1996 - Format C/295M
1080P/50/2:2	1125	1920x1080	50.00	28.125	66.825	2376	2:1	25.00	2:2	?
1080P/50/1:1	1125	1920x1080	50.00	56.250	148.500	2640	1:1	50.00	1:1	ANSI/SMPTE 274M-1995 - Format 3
1080P/30/1:1	1125	1920x1080	30.00	33.750	74.250	2200	1:1	-	-	ANSI/SMPTE 274M-1995 - Format 7
1080P/29.97/1:1	1125	1920x1080	29.97	33.716	74.176	2200	1:1	-	-	ANSI/SMPTE 274M-1995 - Format 8
1080P/25/1:1	1125	1920x1080	25.00	28.125	74.250	2640	1:1	-	-	ANSI/SMPTE 274M-1995 - Format 9
1080P/24/1:1	1125	1920x1080	24.00	27.000	74.250	2750	1:1	-	-	ANSI/SMPTE 274M-1995 - Format 10
1080P/23.98/1:1	1125	1920x1080	23.98	26.973	74.176	2750	1:1	-	-	ANSI/SMPTE 274M-1995 - Format 11
1080P/24sf/2:2	1125	1920x1080	48.00	27.000	74.250	2750	2:1	24.00	2:2	?
1080P/23.98sf/2:2	1125	1920x1080	47.95	26.973	74.176	2750	2:1	23.98	2:2	?
1080P/24/1:1	1125	1920x1080	24.00	27.000	74.250	2750	1:1	24.00	1:1	?
1080P/23.98/1:1	1125	1920x1080	23.98	26.973	74.176	2750	1:1	23.98	1:1	?
720P/60/1:1	750	1280x720	60.00	45.000	74.250	1650	1:1	-	-	ANSI/SMPTE 292M-1996 - Format L/296M (1)
720P/59.94/1:1	750	1280x720	59.94	44.955	74.176	1650	1:1	-	-	ANSI/SMPTE 292M-1996 - Format M/296M (2)
720P/59.94/3:2	750	1280x720	59.94	44.955	74.176	1650	1:1	23.98	3:2	?
720P/59.94/2:2	750	1280x720	59.94	44.955	74.176	1650	1:1	29.97	2:2	?
480P/59.94/1:1	525	720x483	59.94	31.469	27.000	858	1:1	-	-	?
480P/59.94/3:2	525	720x483	59.94	31.469	27.000	858	1:1	23.98	3:2	?
480P/59.94/2:2	525	720x483	59.94	31.469	27.000	858	1:1	29.97	2:2	?
1080P/48sf/1:1	1125	1920x1080	24.00	27.000	18.563	1375	2:1	-	-	ANSI/SMPTE 274M-1995 - Format 12 (SONY Modified)
1080P/47.95sf/1:1	1125	1920x1080	23.98	26.973	18.544	1375	2:1	-	-	ANSI/SMPTE 274M-1995 - Format 13 (SONY Modified)
480P/30/1:1	525	720x480	30.00	15.750	34.650	2200	1:1	-	-	Proposed FOX Digital DTV Video Flags
480i/30/2:1	525	720x480	30.00	7.875	17.325	2200	2:1	-	-	Proposed FOX Digital DTV Video Flags
480P/24/3:2	525	720x480	24.00	12.600	34.650	2750	1:1	9.60	3:2	Proposed FOX Digital DTV Video Flags

Topics

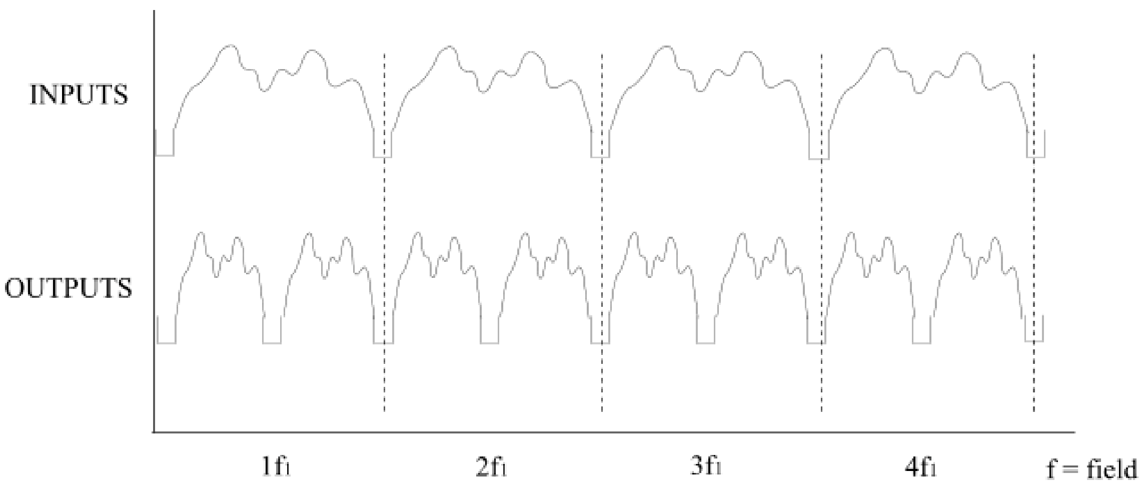
In this short presentation I will cover the various issues of conversion between formats including the most relevant technologies for each conversion.

Conversion Technologies

Line Doubling or Field Doubling?

Line Doubling

Line doubling is often used in large screen display systems.
A basic line doubler is not able to perform any geometric modifications to the picture. Line doublers take the incoming standard definition video with a nominal line rate of 15KHz and a field rate of 50Hz or 60Hz. They clock the incoming video into a store and clock it out at twice the speed, (31.25Khz). The perceived result is a big picture without visible line structure. They can work really well on film or frame based material due to the high level of information correlation of a scanned film. To be effective with NTSC film they need some form of 3:2 pull-down detection.



2:2 Film Sequence both fields from same temporal sample

Line doublers do not perform quite as well with interlaced video pictures with a temporal off set between fields.
Although they have no place in Broadcast they have held the main part of the home theatre market for several years.

Field Doublers

In Europe the 625 (PAL) System has 576 active lines. This is nearly 20% more active lines than NTSC. As these extra lines substantially reduce artefacts due to undersampling and alias many TV sets made for the European market have built in field doublers. In Europe we have 576 lines but more flicker so we tend to field double.

Quadruplers

There are also in the home theatre market line quadruplers.

Note: Direct view CRT displays have a potential to scan one octave economically. This means that a range of 15KHz NTSC to 31KHz is reasonably

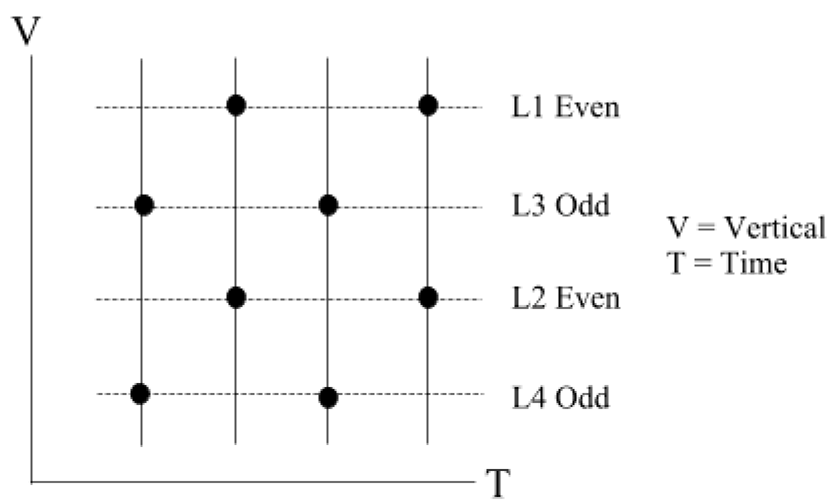
cheap to implement. Quadruplers have a line scan rate of 62.5Khz which can be accommodated on Pro CRT projectors with small, low deflection angle tubes (6"-9" diagonal).
Large (32") 16-9 direct view tubes consume large amounts of scanning power and need very large cathode drive voltages (150Vp-p+). Spanning approximately one octave for DTV receivers (15KHz to 33KHz 1080i) is practical. Higher scan rates are problematic.

This is the reason that DTV receivers display at 1080I with built in scan conversion. In due course silicon devices for the video drive and deflection circuits will be available to scan at 720p (45KHz) reliably. There is still the safety issue of the higher power dissipation and higher deflection voltages.
In the longer-term non-CRT displays will fix this problem.

Linear Interpolators

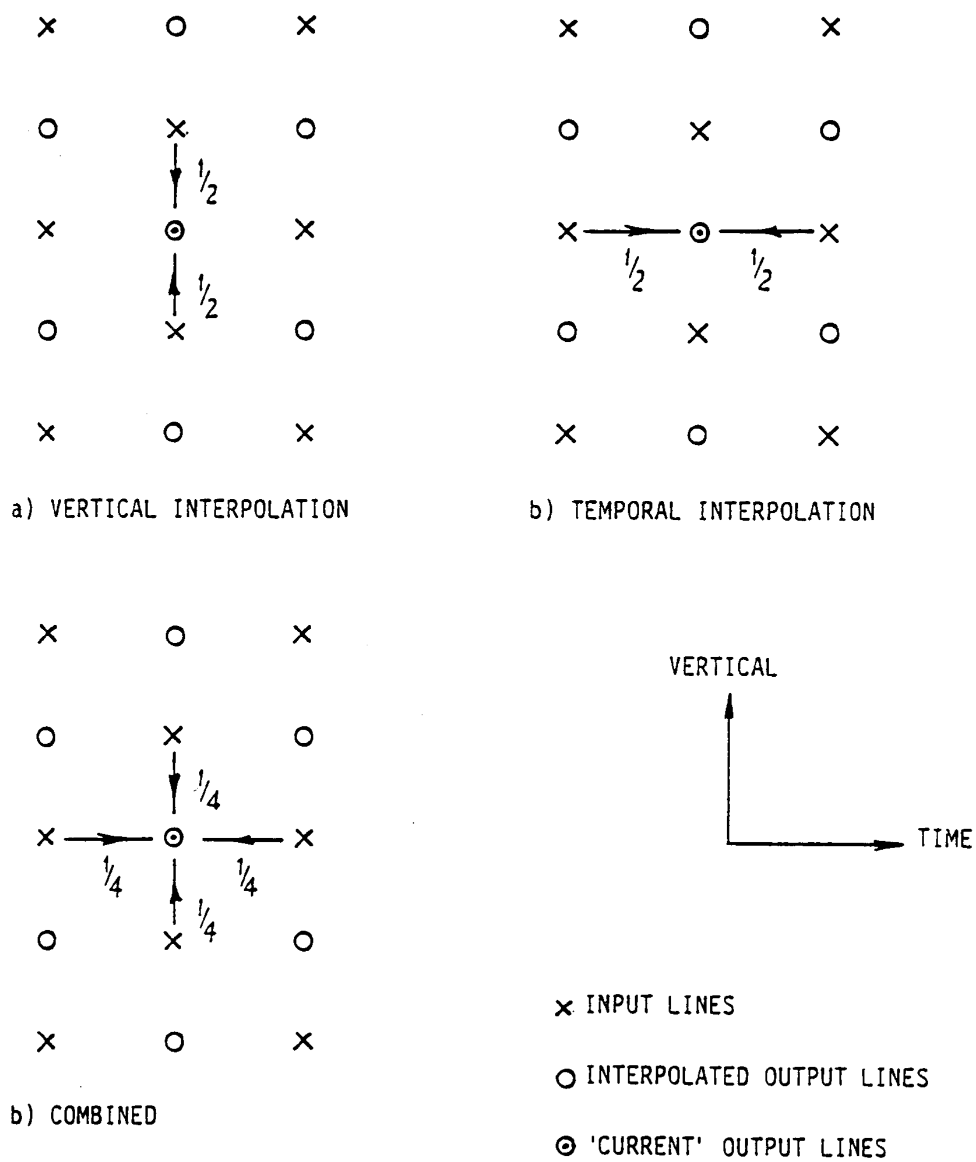
Linear conversion is the core of the mainstream standards converter market. Linear Interpolators can work in vertical and temporal space simultaneously. When combined with a horizontal sample rate converter you can simultaneously convert interlace to progressive, 50Hz and 60Hz and modify the aspect ratio. A rule of thumb is the more taps in the Interpolation filter the more precisely tailored the frequency response can be.

The normal description of a linear standards converter in a sales brochure has a reference to how many taps (12, 16, 24) or how many lines and fields e.g. 4 lines 3 fields (12), 4 lines 4 fields (16), 6 lines 4 fields (24).

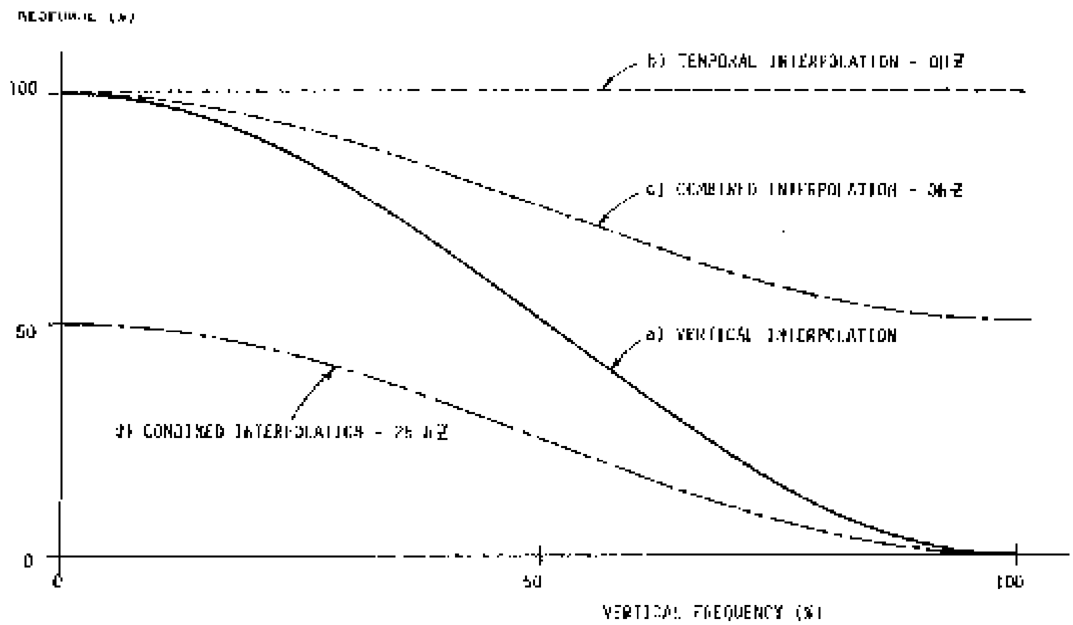


INPUT SAMPLES IN VERTICAL TEMPORAL SPACE

The basic task of the interpolator is to accept the input sampling grid and generate a new output set of samples according to the output sampling grid required.

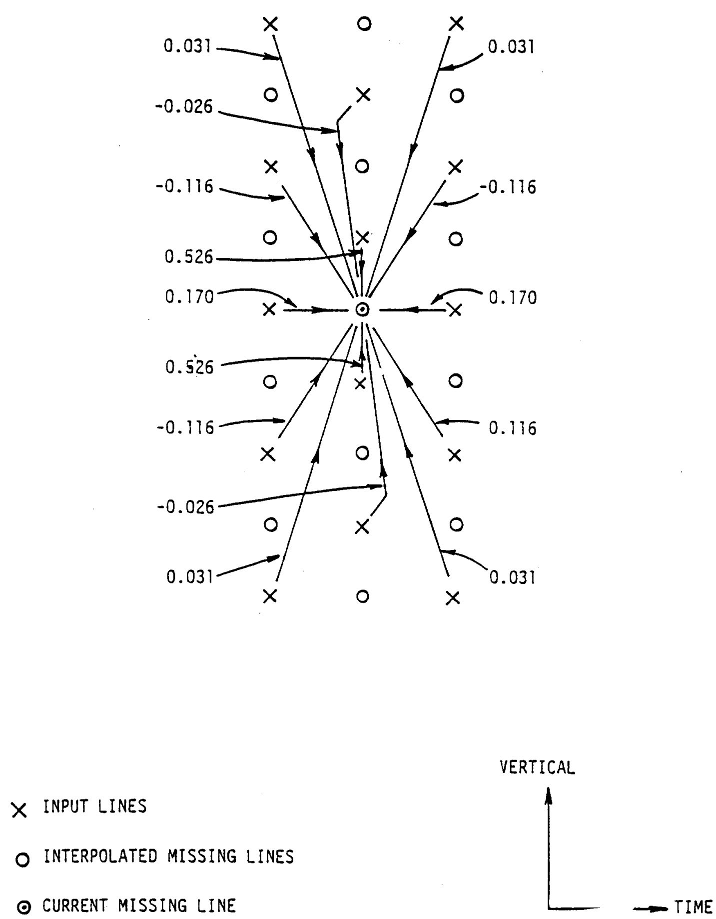


The example above is applicable for both interlace and progressive scan images. However the above example will have limited performance.



As you can see from the above graph the vertical frequency slopes away quite severely.

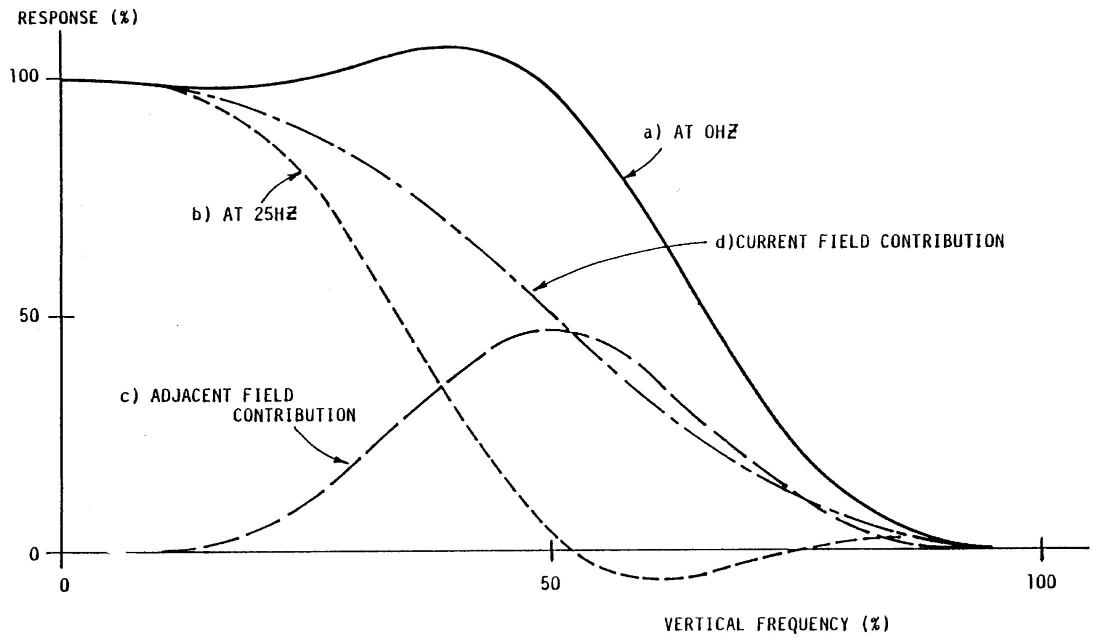
A more realistic implementation is the following:



This uses contributions from 9 lines and 3 fields. The amount of contributions from each available pixel to the desired pixel is generated by an algorithm which embodies a modified sin x / x function.

This algorithm generates multiplier coefficients for each contribution. Complex algorithms allow us to decide the vertical temporal response of the Interpolator. A typical algorithm will use hf and lf contributions from the center field (frame in progressive) and hf only contributions from adjacent fields.

This gives minimal temporal judder if frame rate converting and allows the interpolator to smoothly increase vertical resolution on stationary pictures.



As you can see from this graph the vertical response is smoothly boosted.

If a much smaller filter is used adaption may be needed to improve resolution on still pictures. Overt adaption is not recommended for compressed systems.

The use of hf contributions from adjacent fields can leave some Hf print through at cut points, this can be removed by CleanCuts™ Technology.

Motion Compensated Converters

Motion compensated converters have the same function as the above mentioned interpolators. That is they take the pixel data from the incoming sampling grid and convert it to the outgoing sampling grid.

The outgoing grid can be interlace or progressive, and at a different temporal rate.

The motion compensated standards converter measures the position of each pixel and them compares the position with the next field or frame. The measurement accuracy in the Alchemist series is +/- 1/16 of a pixel both horizontally and vertically. There are three basic methods of motion measurement.

Block Matching

Block matching is used by MPEG in a "much" lower resolution form. Block matching moves blocks around the frame at high speed and makes comparisons to identify where the pixel has moved to.

Gradient

Gradient estimators use a function of brightness with respect to distance. A moving object will have a spatial luminance gradient. By searching for similar slopes in the next image, motion can be tracked. The particular achilles heel of the gradient method is camera flash bulbs transiently distorting the gradient.

Phase Correlation Ph.C™

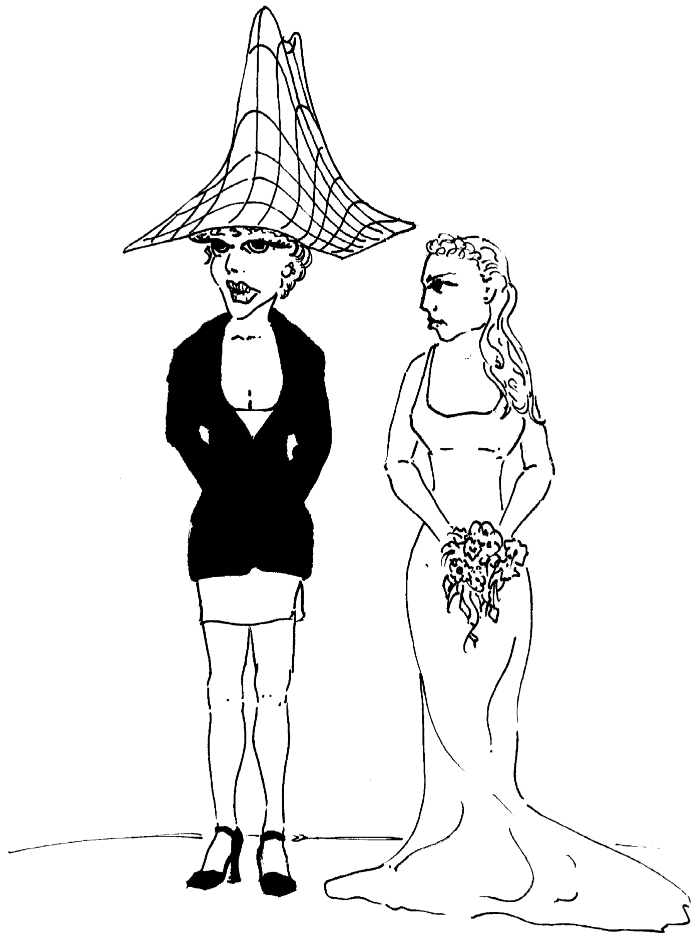
Phase Correlation is the most successful method to date. Phase correlation works by performing a spectral analysis on the two succession fields (frames) by using a very fast fourier transform.

The output of the FFT is then passed through an inverse FFT which generates a correlation surface.

The fourier transform analyses signals that change with respect to time. The signals can be broken down into frequency components. The incoming waveform is expressed as a number of discrete samples. The fourier transform analyses the signal in an equal number of discrete frequencies. This is a Discrete Fourier Transform (DFT). The fourier transform analyses the spectrum of a block of samples by searching separately for each frequency.

The spectral analysis on the signal is performed as above on two successive fields (frames), the resulting phase information is then subtracted field to field. The difference in phase between the two fields is then subjected to a reverse transform which directly reveals pixels whose positions correspond to detected motion between fields.

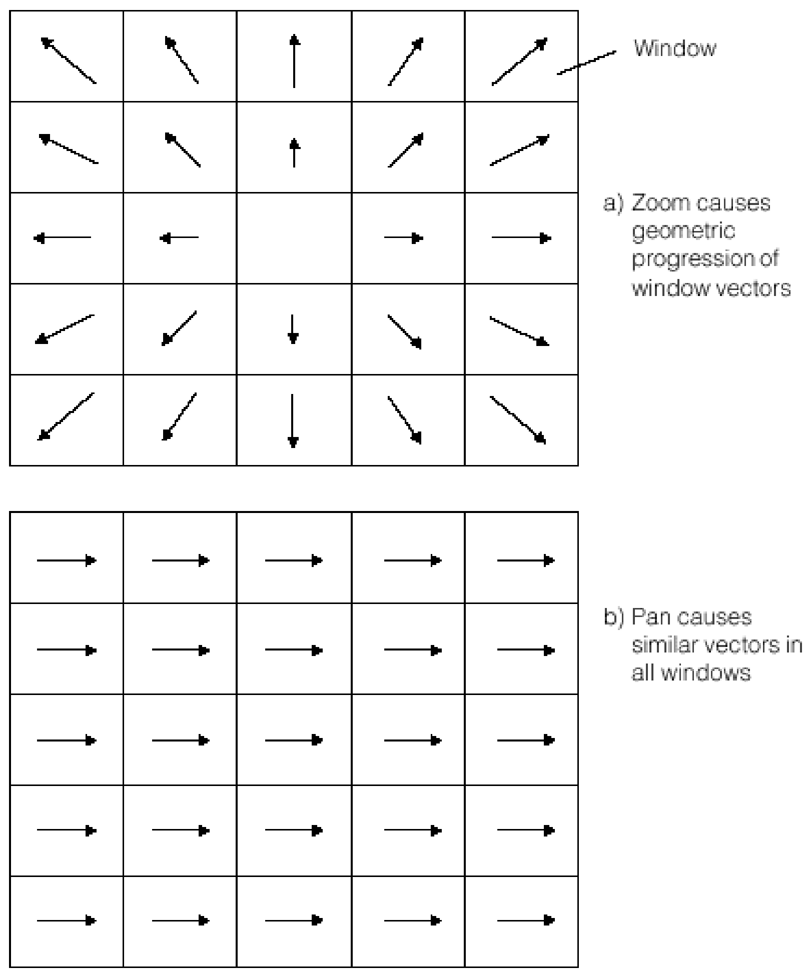
The nature of the transform domain means that if the distance and direction of the motion is measured accurately, the area of the screen in which it took place is not. In practical systems a steered block matching type process follows the phase correlation.



The bride was not impressed with her sisters choice of hat for the occasion. Phase Correlation is the height of fashion!!

The strength of phase correlation is that it actually measures speed and direction of moving objects rather than estimating extrapolating or searching for them.

The output of the phase correlation and object matcher is a vector field for each pixel.



The results of a) a zoom and b) a pan on the vectors in various windows in the field.

The key to this working, apart from the extraordinarily high computational speed (many billions of operations per second), is the complex filtering algorithm to identify the correct vectors to use for each pixel.

The processed vector data is fed to a picture builder which builds the target field or frame. The processing algorithm and picture builder also have to deal with complex, obscured and revealed backgrounds.

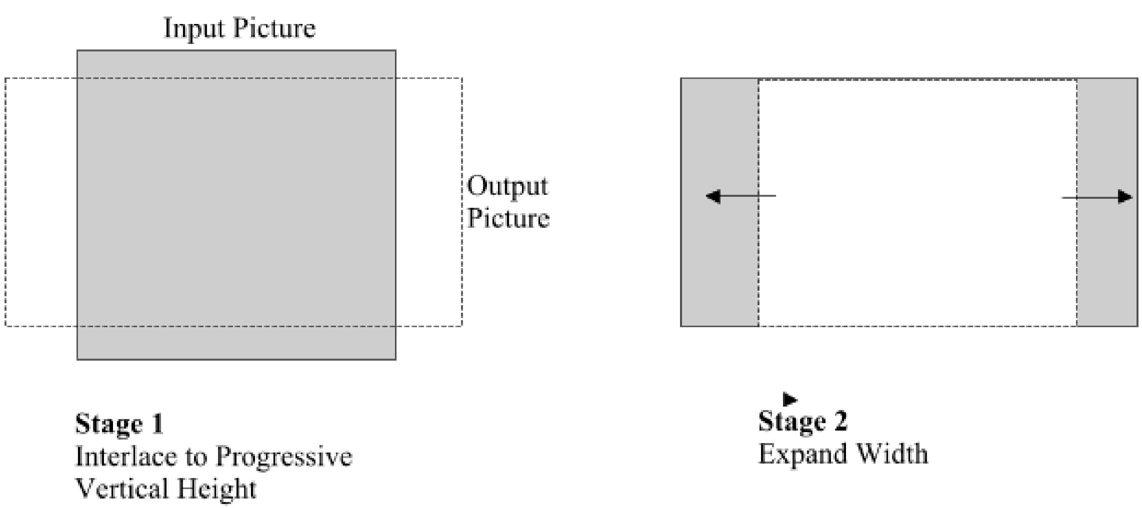
Conversion Types

Interlace to Progressive

Both the linear interpolators described before and the Ph.C systems are eminently suitable to carry out the conversion between interlace and progressive scan. Linear conversion carried out at the same field (frame) rate can give exceptional results although there can be issues with for example rolling captions.

<u>Example 1</u>
A typical conversion carried out by the S&W HD5050 might be:

- Accept an input signal of 525/59.94 2-1 interlace, this has an active line number of 483 lines and an active pixel number of 720 pixels per line. (digital blanking).
- If we wish to convert this to 1280x720 1-1 we carry out the following operations: In the vertical temporal interpolation we take the incoming sample grid and convert it to the outgoing sample grid in the vertical domain.
- Any vertical modifications required for the transmitted aspect ratio are carried out simultaneously. The output of this block is 720 pixels x 720 lines at 59.94 1-1.
- We then up sample the horizontal direction in a rate conversion interpolator to 1280 pixels.



Two Stage Conversion Process

<u>Example 1</u>
Another typical conversion might be:

- Input 625/50, actually 576/48Hz progressive from a telecine transfer
- UpConvert from 576/48Hz, (actually 720 x 576 x 24p:sf) to 1080p24sf or 1280x720p24

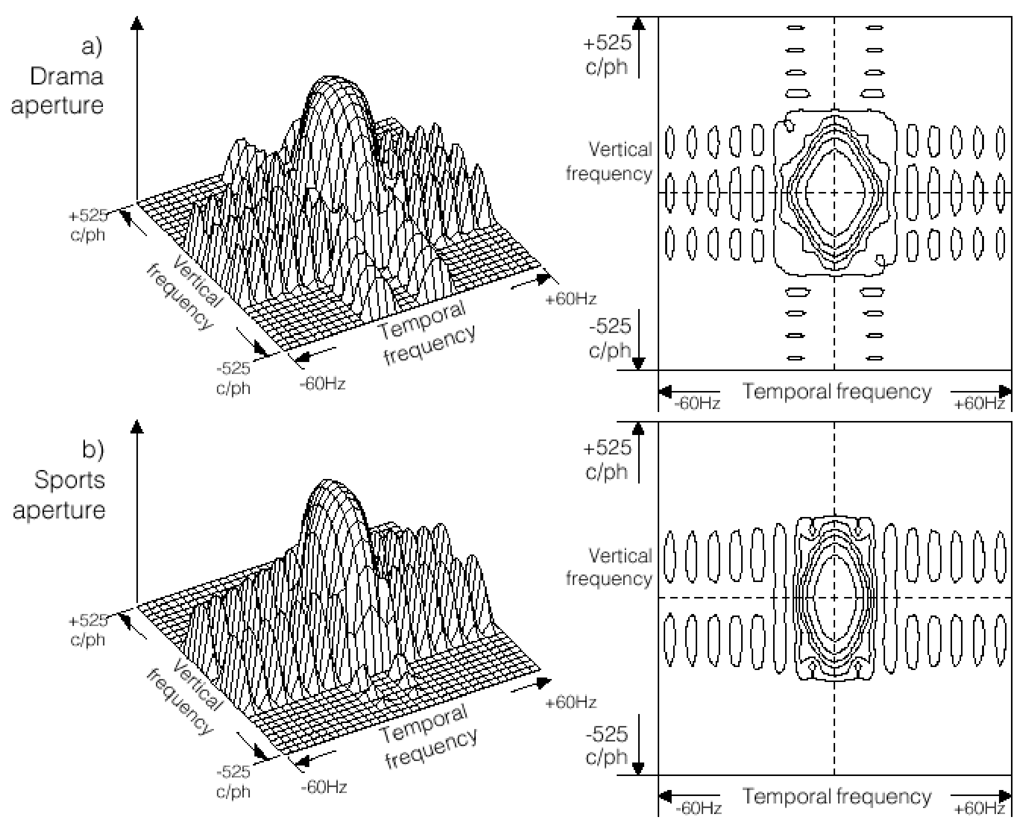
- An additional conversion mode inserts 3-2 pull-down for 1080i:60 3-2 or 720p:60 3-2

Progressive to Interlace

The inverse of the I-P converter is true
The interpolator can easily convert a P picture into an I space.
The key to good conversion is fully understanding how interlace works, there by allowing optimum coefficient generating algorithms to be made.

Frame Rate

If a frame rate conversion is also needed in the video domain (not film), then either a linear interpolator or a motion compensator converter can be used. The linear converter will have either a judder or blur artefact due to temporal beating. The user can choose for example a conversion algorithm which trades judder for blur for sports and blur for judder in drama.



The responses of the filter in the ACE converter.
a) The response optimised for drama,
b) The response optimised for pans to reduce judder.

A motion compensated converter is able to generate completely synthetic output pictures with no induced judder or blur.

When may you need this?

For example at the Olympics next year the main coverage will be in PAL.
If US networks or NHK want SD inserts for their HD programmes then they will need an UpConverter from 625(576)/50:2-1 to 1080i60:1-1 or 1280x720/60:1-1. Motion compensation is the only way to do this without conversion artefacts being visible.

Film V Video Comparison

Film and TV temporally sample the presented image.

Sampling theory states that a sampling system cannot properly convey frequencies beyond half the sampling rate. If the sampling rate for video is considered to be the field rate then no temporal frequency of more than 25Hz (PAL) or 30Hz(NTSC) can be handled (Film or Video at 24fps is 12Hz).

Old tube cameras had a temporal response similar to the Eye, the tubes were however a bit slow to match the eye perfectly well, so people complained about lag.

Modern CCD camera's mostly capture the full image and then generate a Pseudo interlace. The capture characteristics are much more like film but they look temporally smoother due to the 30Hz display rate (No 3-2 pull down).

Interlace is as I am sure you have all heard the first compression system. Interlace is a very clever idea considering it came from engineers in the 1930's.

What are the downsides to interlace?

1. The two biggest complaints are twitter and vertical alias if when captured the vertical resolution is too high, terrible on NTSC (483 lines), much improved in PAL (576 lines), not objectionable in 1080I (assuming the technical implementation is good).

2. Loss of perceived vertical resolution. (Approximately 40% due to kell and other factors)

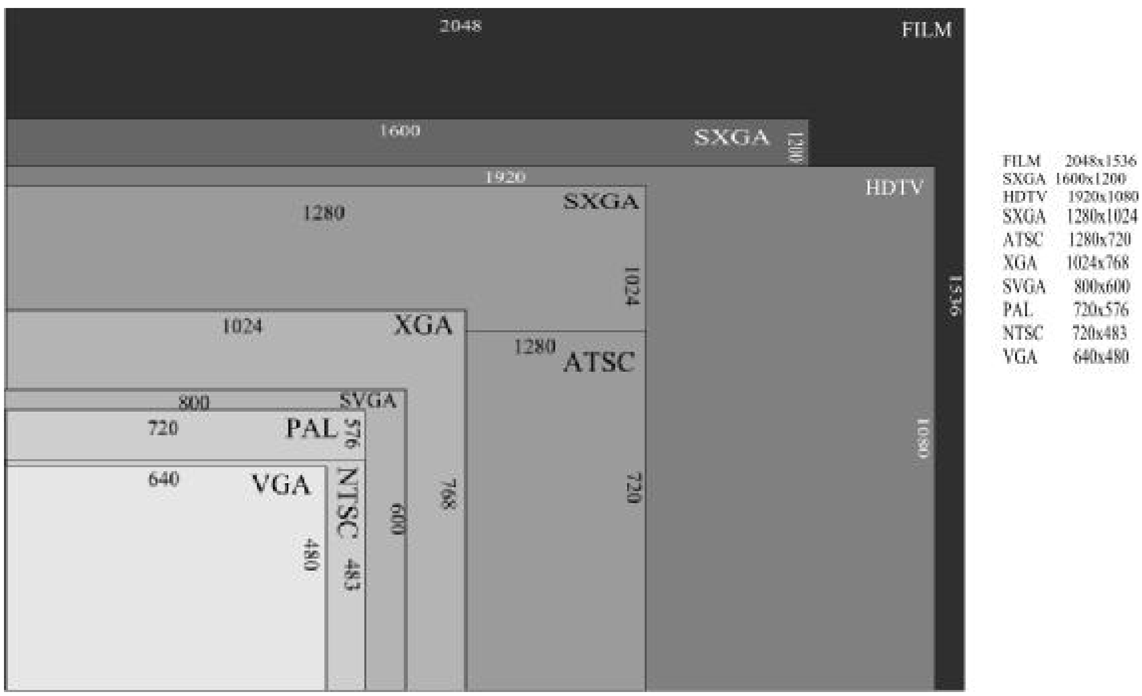
So are there cures for these problems?

1. Problem 1 also applies to progressive scan (alias) if the number of lines is insufficient (480). There is no substitution for more lines in the capturing device progressive or interlace.

2. Problem 2 can be vastly improved by de-interlacing to the original field rate. For example 1080I when compared in vertical resolution to 720p looks similar.

   If de-interlaced to 1080p it will have much better vertical resolution.

   The downside is that the base band sample rate just jumped from 74.25MHz (5.5 times D1) to 150MHz (11 times D1). In the short term this may only apply to the display.



ALL THESE IMAGES ARE PROGRESSIVE SCAN. REDUCE PERCEIVED VERTICAL RESOLUTION BY 40% FOR INTERLACE.

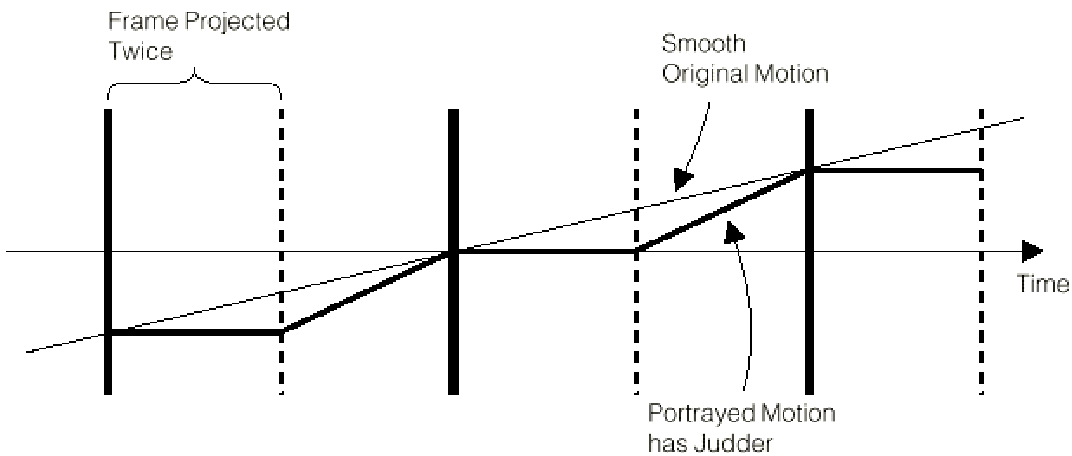
So let's move to film. Film is currently carried in a video wrapper.

I will not enter into the dynamic range (how many bits) debate. I will concentrate on the picture rate issues.

Film at 24Hz has an even sample period between frames so the motion is inherently smooth.

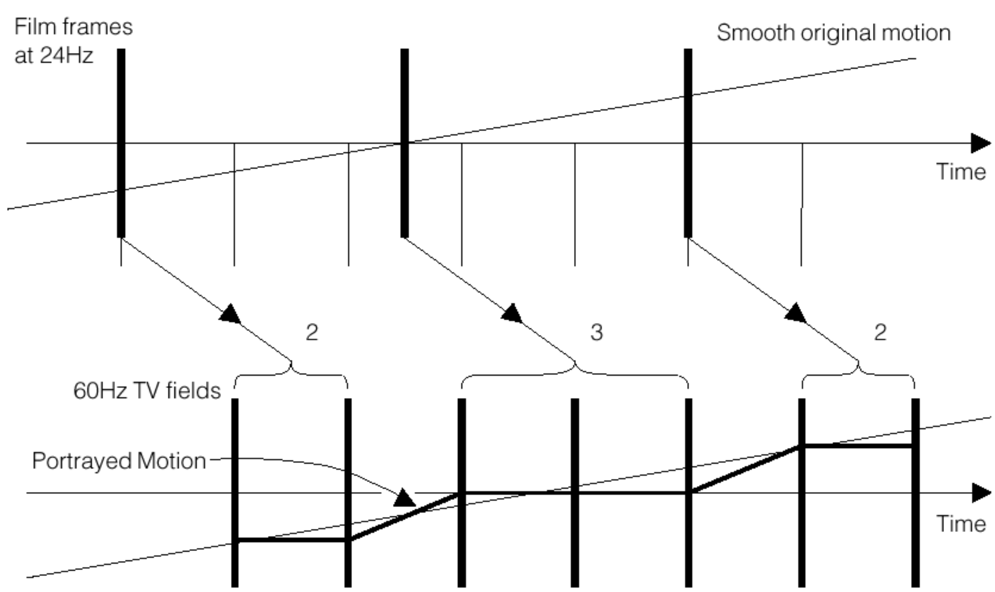
The big problem with displaying film is that 24Hz is subsampling the motion in many scenes and 24Hz as an image refresh rate is too low. The solution to this is to flash the film two or three times for each frame so that the eye does not perceive flicker.

The downside of this technique is judder.



The frame repeating results in motion judder as shown here.

In the current US TV system (NTSC) this problem is made worse by a technique called 3-2 pull down. This results in even more judder than is created by flashing the frame twice. Flicker V 3-2.



Telecine machines must use 3:2 pulldown to produce 60 Hz field rate video

Film and Video Conversion

24P
24P is not in principle a new idea, 720x576 25: 1-1SF has been in use since the beginning of television in Europe.

So what is 24P? 1920x1080x24:1-1 is the "purest" form.

A complete frame of film is captured on a sample grid of 1920 pixels by 1080 lines.

This format is very easy to manipulate as it has square pixels, so the software guys can miss out the line of code that is so perplexing to them.

The downside of this format is that it cannot be displayed in this form. The display device would have to have a refresh device built into it which would have to output 48Hz or 59.94 with 3-2 pull down to be able to view without terminal flicker.

1920 x 1080 x 24:1-1sf (segmented frame). As mentioned above this segmented frame system has been in Europe since the dawn of television in 720x576 form from TK transfers.

The camera or the TK machine captures a complete frame at 24 frames per second, this image is then scanned in an interlace format.

Due to the absolute vertical temporal correlation between field 1 and 2 there is no loss of vertical resolution or interlace twitter.

There can be twitter on the display unless UpConverted.

To display the pictures is easy as the interlace system is operating at 48Hz.

If you up-speed this to 50Hz (4%) it is suitable for transmission in Europe at 1080p25 over 48Hz.

Infact displaying at 50Hz makes a marked improvement in flicker visibility without introducing 3-2 judder in the post environment.

For transmission 1080p24 or 1080p24sf can easily be processed.

1080p24 can be converted to sf and speeded up 4% to 50Hz for 50Hz markets and 3-2 pull down can be electronically added for 60Hz markets.

The one we don't mention is the motion compensated conversion from 24p/24psf to 59.94Hz which smoothes out the motion and makes the film look similar to video.

24-60
This is an easy conversion to do. 24p pictures are fed into a processor that automatically inserts a 3-2 sequence in to the output. As the sequence is continuous it compresses easily.

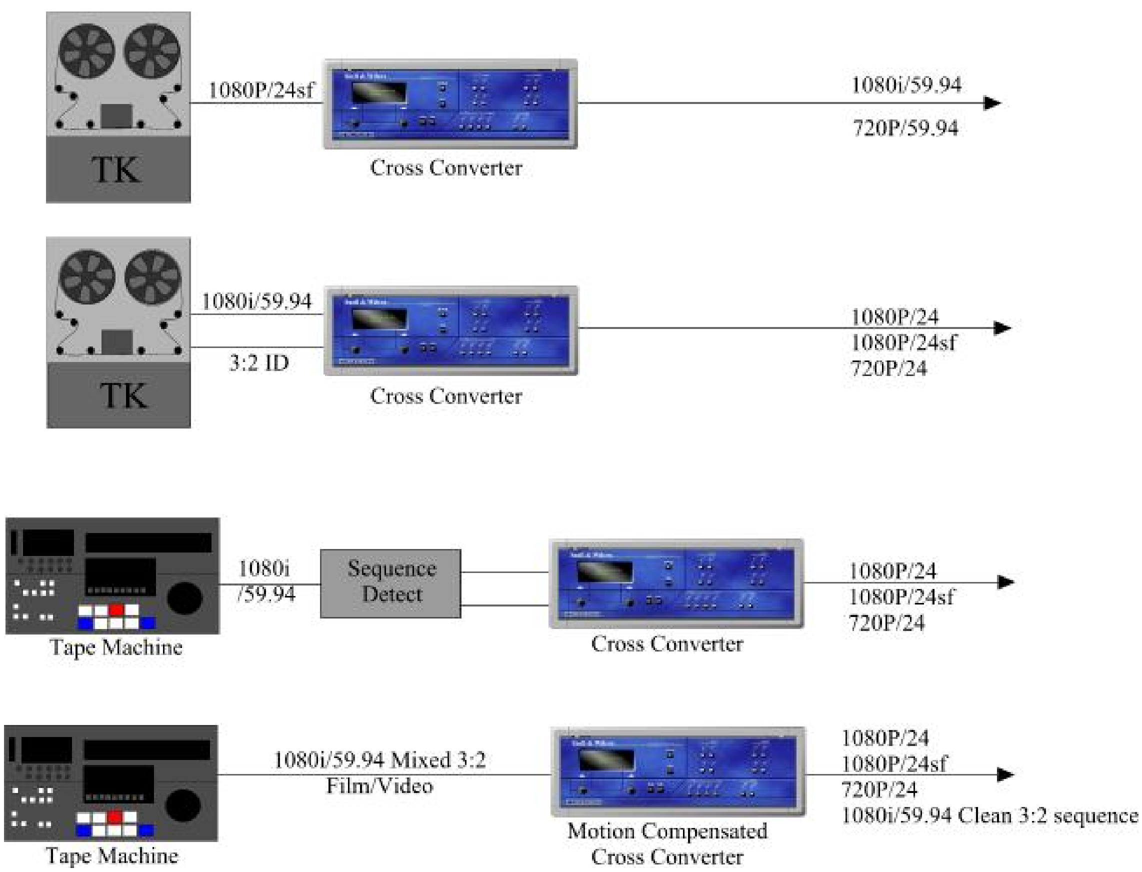
60-24
This is possible in two ways:

1. Film material: Detect the incoming 3-2 sequence and delete the repeated fields.

   There may be some delay in this process as the sequence detection needs to verify its sequence detection is correct. Video inserts would be converted as per linear interpolation

2. Mixed film and Video Material: The best solution to mixed material is a motion compensation system.

   This system would analyse the incoming pictures, detect 3-2 sequence disruptions and more importantly video segments. The video segments would be standards converted to 24p and integrated into a clean 24p sequence. This is particularly relevant for video captions with odd motion.



Possible Conversion Modes

50Hz-60Hz
This video based conversion can be carried out using linear interpolation with the afore mentioned trade off between judder and smear. Though the real solution is a motion compensated conversion. This HD to HD conversion will become a reality in the near future.

Summary of Conversion Types

None of the so called universal format translators on the market are truly universal. There is a significant cost penalty in having a universal box as most 'jobs' are of a specific type.

For example a post house or transmission facility may wish to convert a 1080I contribution feed to 720p for transmission, this may be all they wish to do.

A post house may wish to convert 1080p 24 masters to 1080 or 720 for distribution.

Another post house may wish to scan at 1080I 3-2 and release on 525/625/1080i. There will be ranges of converters available and although the universal motion compensated converter will exist in the future it will be limited in number as a more task specific solution will normally be found from Up, Cross or Down Converters.

Colorimetry

DTV colorimetry can appear to be a minefield to the new DTVer. Colorimetry is broken down into the following:

NTSC Primaries (Original)		Red	Green	Blue	White, CIE III. C
	X	0.67	0.21	0.14	0.310
	Y	0.33	0.71	0.08	0.316
	Z	0.	0.08	0.78	0.374
EBU Primaries		Red	Green	Blue	White, D_{65}
	X	0.640	0.290	0.150	0.3127
	Y	0.330	0.600	0.060	0.3290
	Z	0.030	0.110	0.790	0.3582
SMPTE RP 145 Primaries		Red	Green	Blue	White, D_{65}
(new NTSC/240m)	X	0.630	0.310	0.155	0.3127
	Y	0.310	0.595	0.070	0.3290
	Z	0.030	0.095	0.775	0.3582
Rec 709 Primaries		Red	Green	Blue	White, D_{65}
	X	0.640	0.300	0.150	0.3127
	Y	0.330	0.600	0.060	0.3290
	Z	0.030	0.100	0.790	0.3582

- Regular PAL NTSC 601. This includes normally 480p.
- 240m 274m and BT709 for HD
- 240m comes from the old analog Sony NHK days and is only present on some legacy material

274m is different from 240m but virtually identical to ITU-BT709. All professional converters should have a dial up conversion matrix.

The HD colorimetries are very different from PAL and NTSC, although similar to themselves.

If you do not convert correctly you end up with hue and saturation errors that cannot be eliminated with a traditional colour corrector.

Aspect Ratio

Using linear interpolation techniques this is technically viable. There are many hundreds of SDTV aspect ratio converters in Europe, all Up and DownConverters should have this feature as standard.

There are much more complex production issues to deal with. Garret Smith from Paramount has highlighted these issues in detail at SMPTE, IBC and Montreux. Technically it is easy, from a production point it is difficult.

Compression Issues

Recap on DTV issues that affect Compression.
"An important thing to remember is that the end to end chain performance is very important. Perceived sharpest and best picture quality at the end of the studio chain does not always guarantee the best pictures at home any more."

The secret with DTV is smooth, smooth filter responses, smooth pictures etc…
If UpConverting from NTSC, use the best possible decoder that you can afford.
Use adaption sparingly, overt pumping between modes can adversely affect your compression factor.

Another serious issue, which adversely affects compression, is discontinuous 3-2 sequences. When discontinuous 3-2 sequences and video inserts occur in film shot episodic's, much of the benefit of using 24 frame film is negated.
For artistic reasons, editors wish to cut on their preferred frame, with rushes transferred with a 3-2 sequence, this means a sequence disruption, add video based inserts and the compression factor is shot up real bad.

Another problem is video titles on a film background.

One of the biggest compression bonuses for 24P users is not that the pictures are frame based progressive scan, it is because the temporal rate is lowered from 60 to 24, there is just not as much picture information to transmit. Thus with current MPEG encoder implementations, the system is not as stressed transmitting 24 FPS as 30 or 60.

If we look at a couple of the practical compromises made by current DTV implementers we can see that the significant reduction of spatial resolution in the 720 P system can be turned into a temporal bonus. 720P at 60Hz is fantastic for sports, as seen by the Monday night football.

1080i has nearer to cine resolution with excellent motion rendition, but possible interlace artefacts depending on the implementation technology.

1080P 24 allows progressive pictures with full HD resolution with the restriction that it is not suitable for sports as the temporal rate is too slow.

In the future de-interlace from 1080I 30 to 1080P 60 will be possible in the consumer technology displays, giving the benefits of both worlds.

The same receivers will also be able to image scale to or from 720P without significant quality loss.

Conclusion

The computer fraternity have ensured that standards conversion is a major part of the future of DTV.
Try to work out the best conversion modes for you and there will be a range of specialised converters for you to use.

Thanks to:
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* available from Snell & Wilcox Website - www.snellwilcox.com