The Final Word on SC/H and Color-framing

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Anyone editing with 1" Type-C VTRs and today's complex interformat systems has experienced the unwanted appearance of a **horizontal shift** in the picture, and the ensuing search for the cause. While the terms "SC/H phase" and "color-framing" are used regularly, they continue to be sources of confusion and misunderstanding to users of VTRs and editing equipment. Although at times we are tempted to attribute problems to the "gremlins" that we know live in our facilities, there really are answers to most color-framing issues!

This article is intended to help explain and de-mystify the principles of color-framing in the hope that solutions become more obvious. It will cover a small amount of SC/H phase technical theory, and then explore TBC operation, 1" VTR color-framing and editing, Betacam and MII operation, framestores, and setting up an SC/H timed system. Emphasis has been placed on both the theory and its practical ramifications.

SC/H BACKGROUND BASICS

The term **SC/H phase**, short for "subcarrier-to-horizontal" phase, describes a phase (time) relationship between colorburst and horizontal sync in a composite video signal. Because of the relationship between the frequencies of horizontal rate, subcarrier, and number of lines per frame, the phase of **colorburst** changes 90 degrees every field, while the phase of **picture subcarrier** (chroma) changes 180 degrees every two fields. Consequently, every two fields the chroma and burst are in phase, but 180 degrees reversed from the previous frame.

The RS-170A spec states that SC/H phase is measured at line 10 (the first line with colorburst), and that the subcarrier and horizontal sync should be locked together such that the **zero crossing point** of subcarrier, extrapolated from colorburst, will align with the 50% amplitude point of the leading edge of H-sync. Because the colorburst phase changes each field, there are four possible subcarrier-to-sync phases, thus it takes four **color-fields** to complete the SC/H phase cycle. The spec further states that **Field #1** is defined by the subcarrier being positive going when it crosses H-sync, on even lines. *(Figure 1)*

Based on these definitions, it can be said that SC/H is "out of phase" when the subcarrier zero crossing is "so many degrees of subcarrier" away from the leading edge of H-sync. Further, if the subcarrier is 180 degrees out of phase with H-sync, it may cause ambiguity as to which field is actually occurring. The four fields are grouped into **color-frames**, with fields 1 and 2 considered the "A" color-frame, and fields 3 & 4 being the "B" color-frame. The color-frames must always be in an alternating sequence. *(Figure 2a)*

Equipment that meets the RS-170A spec always produces sync and burst **locked** in the relationship described above. This being the case, certain constraints are put upon the video passing through this equipment in order for correct hue to be maintained.

TBC OPERATION

Horizontal shifts due to color-framing problems are ultimately traceable to **timebase correctors**. For practical purposes these shifts can be divided into two types, which I will call "recorded-in" and "mismatched edit". In both cases a picture shift is caused when a TBC encounters an SC/H phase inconsistency on a tape. The difference is that the first type occurs in the TBC of a source playback tape, and so is permanently "recorded-in" as part of the video on the edit master tape. The other type occurs when a recorder is allowed to make a **mismatched color-frame edit** (also referred to as an "inverted" or "wrong color-frame" edit), thus causing a shift to be seen when the tape is played back through a TBC. *(Figure 2b)*

RS-170A timebase correctors are designed to output video in color-frame phase with the reference signal they are locked to. With the TBC genlocked to house sync, the TBC's internal sync and SC (burst) generators are always producing the same SC/H relationship as the house generator. In other words, the TBC makes odd color-frames at the same time the house sync generator makes odd color-frames. The TBC is faced with a dilemma when the video color-frame at its input is opposite to the color-frame of the TBC's reference. In this circumstance the burst, and related picture subcarrier information, off the tape is 180 degrees (1/2 cycle of subcarrier) out of phase from the burst that the TBC is generating. If the TBC passed the video through as is, the picture hue would be inverted.

There are several ways that a TBC can produce correctly color-framed video at all times, while keeping the picture hue correct. One method is to delay the readout of digitized video from the TBC memory by **140nS** when wrong color-frame video comes in. This places the picture burst and subcarrier back in phase with the TBC burst (converting the picture information to the same color-frame as the TBC sync generator), but also **shifts the picture horizontally by 1/2 cycle of subcarrier**. TBCs which process “direct color” video use this method, which is why horizontal shift problems are so common with 1” VTRs.

Another method for dealing with color-frame errors in TBCs is to invert the subcarrier of the video before it is locked with H-sync. This method is quite useful and will be explained further in the following sections.

COLOR-FRAMING WITH 3/4” VTRS AND TBCS

There are actually very few color-framing problems with 3/4”, so it will serve as an example to introduce some basic concepts. Because 3/4” (heterodyne) VTRs unlock the SC and H relationship, no SC/H or color-frame information is retained in the recorded signal. When a 3/4" tape is played back through a TBC, the TBC must generate fresh subcarrier to replace the jittering SC from the tape, and also must establish an **SC/H** relationship for the video before the subcarrier and H-sync are locked back together.

In single-path TBCs designed specifically for use with 3/4” VTRs, the TBC only attempts to lock off-tape H-sync to its reference, so the new subcarrier can always be generated in phase with house. In this way, the output video always has the same SC/H as the output sync and burst, no matter what comes off the tape. An example of this type of TBC is the Sony BVT-800.

3/4" TBCs that handle the chroma and luminance in separate paths (so-called “dual-path” or "component" TBCs) also ensure that the hue is correct, without shifting the picture, by establishing the phase for picture subcarrier before it is recombined with the luminance. Whether the signal is sent to the TBC via the Y-688 (dub) input or the composite input, the chroma is stored in memory as R-Y and B-Y signals. After reading out of memory it is converted to luminance and subcarrier, which is where the TBC determines and locks the SC/H phase. One TBC of this type is the Fortel Y-688.

With either of these designs, the TBC will not introduce a horizontal shift. On the other hand, shifts can occur when a TBC that was designed for direct color is used for 3/4” playback. These TBCs want to lock off-tape subcarrier, as well as H-sync, to reference. But when the TBC locks the subcarrier from a 3/4” VTR it locks arbitrarily. This means that each time the tape is played there is a 50% chance that the newly established SC/H will be out of phase with house when it enters the memory, and the TBC must shift the picture information horizontally. Since the TBC cannot control the SC/H relationship that is established, it cannot guarantee that the same relationship, with its resultant picture position, will occur each time a given frame is played. This becomes apparent on **match-frame edits** (where two adjoining edits are made within a continuous scene) which have a 50% chance of showing a visible horizontal shift if the reconstructed SC/H phase happens to be different on the second playing of the tape.

One way to avoid this problem is to **invert the phase** of the SC before the composite video goes into RAM. If the direct color TBC contains a **heterodyne processor**, it will separate the luminance and chrominance from the VTR, and invert the subcarrier if necessary, before sending the video to memory. This guarantees that there will be no color-frame conflict with house, and no need for a shift. The downside of heterodyne processing is that the analog filters used to separate luma and chroma cause high frequency roll-off above about 2.5Mhz, limiting the picture bandwidth, but this is not a significant problem with 3/4" video. If **subcarrier feedback** is used, the TBC can provide correctly phased subcarrier to the VTR, to lock the VTR’s internal heterodyne oscillators, thus precluding the need to perform Y/C separation and subcarrier inversion in the TBC. This avoids the use of separation filters, and the picture resolution will be better.

A simple test should be done to determine if a given TBC is capable of processing 3/4" video with consistent picture position. Play a Bars tape through the TBC, and carefully note the exact location of a convenient vertical edge (a fingernail will mark it sufficiently). Momentarily start and stop the tape several times. If the horizontal position of the noted spot is different on any trial, then the TBC is shifting the picture. Since this is a 50% probability occurrance, quite a few trials should be done. The bottom line is that if the correct type of TBC is used, 3/4" editing sources will never produce shifts.

COLOR-FRAMING WITH 1" VTRS

To discuss 1" color-framing, it is necessary to understand how color-frame information is recorded on a 1" tape, and how the VTR plays it back in relation to house sync. It is also important to recognize that although shifts in the picture are caused by TBCs, the VTR's servo system plays a major role in determining if the TBC will shift the video.

Because 1" VTRs use direct color recording, the actual SC/H phase of the input signal is retained. These VTRs have color-frame detection circuitry, on their video and reference inputs, that can differentiate the four color-fields. When video is recorded on a 1" VTR, in hard record or assemble, a **CF pulse** is added to the control track (CTL) at every Field #1, thus identifying the start of the sequence that is now on tape. In addition, while 3/4" VTRs have **2-field** ("framing") capstan servos, capable of slewing the tape to a given frame, 1" VTRs have **4-field** servos, meaning that they can tell not only where the beginning of each frame is, but also whether it is color-frame A or B. The VTR can then slew the tape so that a specific color-frame is being played at the same time that house sync is on that color-frame. The combination of color-frame detection and 4-field capstan servo is often referred to as the 1" VTR's **color-framer**. When the VTR is in "4-field servo mode", the color-framer is ON.

Also, note that 1" TBCs do not use subcarrier inversion to fix color-frame errors at play speed because they reference to the off-tape subcarrier, as well as H-sync, so subcarrier phase cannot be changed. However, these TBCs do use SC inversion when processing non-play speed video (such as slo-mo) because the off-tape color-frame is continuously passing in and out of phase with house, so compensating by shifting horizontally would produce constantly shifting pictures. The TBC instead uses **digital decoding** to separate luminance and chroma, inverts the subcarrier, and recombines them. Digital decoding is explained further in the later section on Framestores.

1" color-frame playback

When put in PLAY, with the capstan servo in **4-field** mode, the 1" VTR determines the color-frame sequence coming from the tape (generally by using the CTL CF pulse), and slews the tape position so that this sequence matches house sync at the VTR's reference input--which, of course, is also the same SC/H relationship that the TBC is generating. Consequently, the TBC receives video that is in color-frame phase with house sync, and it is not necessary to shift the picture. In this scenario, picture position will always be consistent, as long as the "color-frame playback adjustment" has been optimized (more on this later).

However, if the 1" VTR is in **2-field** mode, when put in PLAY the capstan servo does not attempt to align the off-tape color-frame with house reference, and the color-frame phase that reaches the TBC may be randomly in or 180 degrees out of phase with house. Consequently, the TBC will have to shift the picture position 50% of the time. In this case, a good tape can play back with inconsistent horizontal position because the capstan servo is in 2-field mode.

In addition, if a 1" tape has video SC/H inconsistencies from scene to scene (or if the SC/H phase of a scene is at an ambiguous value), an H-shift may occur even if the source VTR is in 4-field mode. In this case, the capstan servo may lock fine, but if the SC/H of the video changes the picture may be shifted if the TBC sees a mismatch to house. If this tape is used as an **editing source**, the shift could be permanently recorded-in to the master. This is the first kind of horizontal shift problem mentioned earlier; the recorder receives constant sync from the source TBC (or switcher sync inserter), but in some scenes the source video has been horizontally shifted with respect to its position in an adjacent scene.

1" VTR edit recording

When insert or assemble edits are made in 4-field servo mode, the VTR slews the tape, prior to the edit, so that the color-frame sequence is not broken. This is accomplished because a recorder always references its playback lock to the video at its input. Therefore, whenever the recorder is told to punch-in, it has slewed the tape to be in position to record the next legitimate color-frame; if it begins recording on color-frame A, it will be receiving color-frame A at that moment.

If video edits are made on a 1" tape in 2-field servo mode, the VTR will not attempt to slew the tape to make the new video consistent with the previously recorded color-frame sequence. Thus there is a 50% chance that a **mismatched color-frame edit** will be recorded, in which two "A" or two "B" color-frames are adjacent. This is the second type of H-shift problem mentioned. In this case the recording was made incorrectly, and the mismatched edit will cause a horizontal shift at the edit point, where the color-frame sequence is broken, every time the tape is played back through a TBC, regardless of the capstan lock of the VTR. The shift will be noticeable if it occurs between related material. *(Figure 2b)*

Video, CTL and timecode relationship

At this point we must define some conditions for the relationship between video, control track and timecode, as they affect 1" color-framing. On a correctly recorded tape, when the video is on field #1, the CTL contains a CF pulse. In addition, the RS-170A spec proposes a standard for the recorded **timecode** whereby the even timecode numbers represent color-frame "A" (fields 1 & 2), and the odd timecode numbers represent color-frame "B" (fields 3 & 4). The correctly made tape contains video, CTL and timecode in **color-frame phase** with each other. *(Figure 3a)* With 1" VTRs (after about BVH-1000 vintage) this will automatically be accomplished by hard recording a signal that meets RS-170A specifications (using the VTR's internal timecode generator).

Errors can basically happen in three ways. If the timecode is from a non-color-framed external generator it may be **reverse phased** to the video and CTL on the hard recorded tape. *(Figure 3b)* Or, as mentioned previously, if video inserts are made with the recorder in 2-field mode a **mismatched color-frame edit** may occur and the video after the edit will then be opposite phase from the CTL and timecode. *(Figure 3c)* Lastly, if an assemble edit is made in 2-field mode, the video and CTL may change phase at the edit point.*(Figure 3d)* The ramifications of these relationships will become clearer when computerized editing is discussed.

H-shift predictability

The RS-170A spec allows an SC/H window of +/-40 degrees from 0. This is usually an acceptable range for the TBC to determine which color-frame is being played. However, SC/H phase variations beyond this range may be treated as the opposite color-frame, or be ambiguous. Generally an SC/H error greater than 90 degrees will cause the TBC to shift the video. But, **the amount of the shift will always be 140 nS** (1/2 cycle of SC), regardless of the actual error value.

The direction that a 1" TBC shifts the picture can be either right or left of the true recorded position. This is principally determined by the direction (from 0 degrees) that the SC/H phase is off. 1" TBCs will always shift a given SC/H error in the same direction, unless the error is near 180 degrees, in which case it may be ambiguous and subject to a shift in either direction on each playing.

To clarify the conditions that can result in a horizontal shift we will make a distinction between errors of **color-frame inversion** and errors of **SC/H phase**. In the first case, since the VTR's color-framer is using the control track CF pulse to determine which color-frame the tape is on, the servo locks the tape so that the CF pulse matches field #1 of house. If the tape happens to have reverse color-frame video (as might happen if an insert had been made in 2-field mode) the VTR will still lock based on the CTL, and the TBC will receive video that is opposite to house color-frame. In the second case, the relationship between the video, CTL and timecode is not even an issue, because the TBC looks solely at the SC/H phase of the off-tape video. If the SC/H is too far from 0 degrees, the TBC may think that the color-frame has changed and shift the picture, even though the color-frames and CTL are in phase with each other.

Both of these errors can occur independently or simultaneously. So, for example, if a tape is played which contains video that has a 30 degree SC/H phase error, the TBC should not shift the picture at its output. But if the video is out of color-frame phase with CTL, the TBC will end up shifting the picture. Simply, mismatched color-frame edits force the TBC to pass video that is a different color-frame from the TBC's output sync and will always result in a shift. Conversely, if the video and CTL are in phase, but the video's SC/H is 95 degrees, shifts may occur.

All 1" TBCs have a connection between the TBC and the VTR's color-framer which provides a means for the color-framer to verify the color-frame entering the TBC in cases where the TBC cannot accurately detect it. If the video's SC/H is outside the TBC's window, and it cannot determine the color-frame, the signal from the VTR's color-framer (derived from CTL) will "back up" the TBC by indicating the correct color-frame for which the SC/H phase is valid. This link is still present on modern TBCs, but was primarily of use with older TBCs which had smaller windows of SC/H detection.

Color-frame playback adjustment

The **color-frame playback adjustment** centers the off-tape color-frame detector of the TBC so that playback of a tape with imperfect SC/H phase will not be ambiguous. The control is usually accompanied by some type of indicator to tell when the optimum point is set. If this adjustment is not set at the start of playback, a tape that contains video with SC/H phase at the edge of the determination window may cause the TBC to shift the picture position back and forth randomly (sometimes known as "cycle-jumping"). In this situation, the horizontal shifts may not occur in the same place on each playing, thus making it impossible to match-frame with that source tape.

The color-frame playback adjustment should be set routinely each time a new tape is put up, just as with TBC levels. It should be adjusted while playing the program video to be used (not BARS), and the VTR's color-framer must be ON. Also, remember that this adjustment is a playback only function. On VTRs with highly visible SC/H phase meters, such as a VPR-3, it may appear that the "SC/H Adjust" knob is doing something during recording. It is not. The VTR cannot change the SC/H phase of the video being recorded!

Often a tape with SC/H or color-frame problems can be identified by watching the **PB color-frame indicator** on the TBC. If the tape is exhibiting shifts, and the indicator goes on and off at scene changes, or flickers, chances are the tape has a problem (in the case of a VPR-3, the meter reading will vacillate). If the tape has adjacent segments with widely different SC/H phases it may be possible to find a compromise setting of the CF PB adjustment for both segments, thus eliminating the H-shift. (A typical cause of this problem is a multi-camera shoot where the switcher being used does not replace the blanking of the outgoing video, thus allowing different SC/H from each camera to be passed on to the recorder.)

COMPUTERIZED EDITING WITH 1" VTRS

It becomes clear from the preceding discussion that when editing to a 1" VTR the recorder must synchronize off-tape color-frame phase with input video so that the sequence is not broken at edits. This applies to any editing done with a 1" recorder, regardless of the source VTRs. Even if the recorder is editing in a stand-alone pair with a source VTR, it will slew the source machine so that it is in sync for the edit, but it will slew itself to match the **color-frame sequence** of the video it is recording (in this case, the output of the source TBC).

In a properly setup plant, any source used in editing will be locked to house sync and correctly SC/H phased, whether it is a TBC or a switcher with a blanking inserter. Consequently, the recorder will always be receiving processed sync that is in-phase with the house color-frame sequence, regardless of what the actual color-frame of a given source tape (and its consequent horizontal position) may be.

With all this in mind we can now approach the problems that arise in computerized editing with 1" VTRs, which is the most complicated situation as far as color-framing is concerned. For the following discussion we will consider computerized editors to be of two classes: those that do not address how the VTRs are color-framed, such as Convergence, CMX and Paltex, and those that color-frame for the 1" VTRs, such as Grass Valley and certain Sony editors.

For the time being, assume that the recorder is always in 4-field mode to make correctly color-framed edits. As a starting point, the basic sequence of events leading up to an edit is as follows:

1. The editor cues all machines to the pre-roll point, and then starts them in PLAY.
2. The 1" recorder (4-field servo) locks its off-tape color-frame phase to the color-frame phase at its input (presumably from a switcher).
3. The editor slews the source VTRs to the desired sync relationship with the recorder, based on timecode or control track counters. This is done by bumping (slowing) the lead machines momentarily.
4. Once synchronized, the sources are released and continue to run locked to house reference. The recorder punches in at the desired frame.

This sequence works without trouble when using any type of 2-field servo VTRs as source machines (3/4", non-SP Betacam, early MII). Since they are incapable of color-framing themselves, they will simply be slewed so that the desired frame is being played when they reach the edit point. Their TBCs will take care of picture position. The only machine concerned with color-framing in this scenario is the recorder, since it is the only 4-field machine. Even if the recorder is bumped during preroll, it will relock to color-frame phase with input video.

With 1" source VTRs, if they are left in 2-field servo mode their color-framers will not attempt to slew the off-tape sequence to match house. Although playback picture position will not be maintained for a given scene, consistency during **match-frames** will be assured by virtue of the editor controlling the source tape position via timecode. Since the editor will always cause the source machine to be on the desired frame at the edit point, the source VTR will have the same timecode relationship to the recorder, and thus the same color-frame relationship, on the continuation of a match-frame as was established in the first half of the match-frame. If the desired frame happens to be the opposite color-frame from house in the first edit, the source TBC will shift the picture position. But this will not matter since the exact same color-frame relationship (with the same picture shift) will be established for the continuation of the match-frame.

Leaving the 1" sources in 2-field is not recommended, however, for two reasons. The simplest is that there is a chance that a machine will accidentally be left in 2-field when next used for recording, with potentially troublesome results. The other reason is that there are instances when **absolute picture position** is required (where TBC output is the same position as off-tape, not shifted either direction). A good example of this is when editing graphics; where scenes from several sources will be combined and they contain a common picture element, such as a fixed background. In this case, the source VTRs must be in 4-field, so that their servos will assure that the TBC will not shift the position of any selected scene.

Here is where complications begin to arise. With both the recorder and source VTRs in 4-field servo mode, there will be a conflict if the editor requests a source VTR to sync up on a frame that is the opposite color-frame from house at the edit point. As just described, once the recorder is locked the editor bumps the source machines to the correct relationship for the edit and lets them loose. If the source VTR was bumped so that its off-tape color-frame does not match house, when the VTR is released by the editor its own color-framer will re-slew it so that it does match house. The editor will then bump the machine back to the desired frame for the edit, the VTR color-framer will slew it back into phase with house, and the battle will continue until the edit aborts (sound familiar?).

Color-frame conflicts and timecode

Obviously 4-field record and source VTRs cannot be left to their own devices, so it becomes necessary for the editor to determine when there will be a conflict between the source color-framers and the record edit points. But the editor has no direct knowledge of the color-frame sequence on any of the tapes. The only color-frame information available to the editor must be derived from the **timecode** on the tapes.

By comparing the timecode numbers of the record and source edit points, the editor can determine when a color-framing conflict will arise. If the recorder is to edit-in on an odd timecode number, the source VTR must also be on an odd timecode number so that the source VTR's color-framer will not fight the editor. It now becomes clear why the color-frame relationship between video, CTL and timecode is important!

Many editors control the source in-points by using a software "round-off routine" (sometimes called “Source Color-frame” or “Source TC Adjust”). This routine looks at the timecode numbers chosen for the edit point, and if the source number is mismatched to the recorder (odd against even) it changes the source in-point by one frame so that they match. Essentially, the round-off routine prevents the editor from having the source VTR sync on a frame that will be opposite to house color-frame, and consequently opposite to its own color-framer, at the time of the edit. **This routine must be used anytime there are 4-field source VTRs.** If not, any edit that mismatches source and record timecode numbers will abort continuously.

Actually, it may be advisable to use the round-off routine <u>anytime</u> there is a 1" source, even if it is in 2-field. The reason for this is, again, the requirement of **consistent picture position**--in this case as applied to "end-over-end" edits of identical material. For example, if a static scene must be extended by editing the same shot to itself, the picture position must remain constant. With the round-off routine working, simply matching to the record in-point automatically makes the source point correct, avoiding a conflict. However, without the round-off routine, it is possible to arbitrarily make the source in-point opposite from the recorder. Since there is nothing to prevent the source VTR from locking to the opposite color-frame as requested (it is in 2-field mode), the source TBC will shift the picture position of the new segment. This shift will be “recorded-in” on the edit master, as the two segments have been layed down with H-positions that do not match.

In this situation a match-frame is <u>not</u> being performed, so picture position cannot be assured solely by virtue of the editor establishing the same color-frame relationship twice. By using the color-frame round-off routine at <u>all times</u> with 1" sources, it will be impossible to place the source on the opposite color-frame to house, thus avoiding an H-shift in this particular scenario.

It should be noted that some editors (the human kind) do not like using the TC round-off routine, as it may make precise action or audio cutting difficult, and choose to work with the routine off. They should be aware the of aforementioned pitfalls.

Reversed Phase Timecode

With the 1" sources in 4-field, and the timecode round-off routine ON, there is one last conflict that may arise. If the timecode and color-frame sequence on the source tapes are **reverse phased**, (as could happen from using a non-color-framed generator) the editor will inadvertently sync the VTR so that its color-frame sequence is <u>opposite</u> that of house sync. When the editor releases the VTR it's color-framer will re-slew it so that the off-tape color-frame matches house, the editor will slew it back out of phase, and again the fight will continue until the edit aborts. This conflict can be resolved on some editors by instructing the round-off routine that the particular VTR has "reversed phase code". Now the editor will ensure that the source timecode numbers are <u>opposite</u> from the recorder.

With editors that do not color-frame for the recorder, using a <u>record</u> tape with consistently reverse phased code will cause the source VTRs to lock on the opposite color-frame to house all the time, thanks to the round-off routine. If they are in 4-field mode they will fight the editor. The fix is to instruct the editor that <u>all</u> source VTRs have reversed phase code! Having done so, the edits will work. However the source video will <u>always</u> be shifted by the TBCs. This is generally not a problem because H-shifts are only visible when some video is shifted and some is not, so absolute color-frame phase is usually unimportant as long as it is <u>consistent</u>. But its something to keep in mind.

Editors that color-frame the VTRs

The previous discussion assumed that the 1" recorder would be in 4-field servo mode at all times. This is necessary to prevent mismatched color-frame edits from being recorded, but it forces the recorder to be the "lead" machine during preroll. Consequently the editor must wait to synchronize the source VTRs until the recorder has locked. Some later editor designs, such as the Grass Valley, use a system in which the VTRs are left in **2-field** mode and the editor acts as the color-framer for them. The editor receives color-frame ID (CFID) from the house sync generator so that the it knows house color-frame at all times. This method decreases the time needed to synchronize the VTRs because they can all be locked simultaneously.

Again, these editors must get their information on the color-frame of the VTRs via timecode. At the outset, it is assumed that the timecode on the record tape is in color-frame phase with the video. If the timecode is not in phase with the video, mismatched color-frame edits will be recorded since the editor is locking the recorder to house--based only on the timecode. This is basically only an issue when cutting into an existing edit master, and will become apparent if the TBC's color-frame indicator changes when the first edit is played back. Grass Valley editors provide a selection, in the INIT menu, to choose which timecode phase (odd or even) is considered color-frame "A".

In addition, the GVG editors will also act as color-framers for the 1" source VTRs if they are left in 2-field mode. This precludes the need for the timecode round-off routine, since the source color-framers will never fight the editor. However, absolute source picture position (no shift from off-tape) may not be maintained.

Using VPR-3s, which can detect color-frame from **recorded video** (instead of CTL), does not affect synchronizing or choice of the recorder's timecode phase. And, because the color-framer is not being used, there is nothing to prevent recording a mismatched color-frame edit on an existing master with reversed phase code (this would be prevented if the color-framer were on). The only way to tell that this has occurred is by keeping an eye on the VTR's "Wrong Field" indicator. One caution about the VPR-3 and GVG editors: the VTR color-framer is turned off automatically via the serial remote port, but the editor does not turn it back on after the edit session.

The Sony 900 and 9000 editors can also color-frame for the VTRs based on house color-frame (in this case derived from composite video). The 9000 adds the additional feature of accepting a signal that is derived directly from the VTR's color-framer. There are several modes of operation: **CF pulse**, in which the derived pulse is used to determine the color-frame of VTRs; **TC**, in which the timecode is used (as with the GVG); and **VTR**, which allows the VTRs to color-frame themselves (like the previous editor class). There is also a "**Learn**" mode which momentarily plays the tapes in 4-field, to find out where they want to lock, then bases its synchronizing routines on that. If a VPR-3, set to determine tape color-frame from video, is used with the Learn mode the editor will learn the actual video color-frame and thus prevent mismatched color-frame edits, even while color-framing for the recorder based on TC.

Some CMX editors fall between these two categories because they do not color-frame for the recorder, but will cause edits to abort if the recorder is locking opposite to the editor's own internal reference oscillator. The main problem with this arrangement is that the internal oscillator will lock randomly each time the editor is powered on, making its identification of "color-frame A" different half the time. In any case, the recorder should be in 4-field mode so that it will not record a reverse color-frame edit at any time!

In summation, to eliminate the possibility of horizontal shifts in 1" to 1" timecode editing:

1. If the editor does not control VTR color-framing directly, the 1" recorder should be in **4-field** servo mode so that it can slew itself to match the color-frame of the incoming video. If the editor does color-frame the recorder there may be a "Record CF" option to choose the assumed color-frame phase of the timecode.

2. The 1" source VTRs should be left in **4-field** if absolute off-tape picture position is required (or to prevent accidentally leaving them in 2-field when used as recorders) but may be put in 2-field if the editor controls their color-framing.
3. The **color-frame playback adjustment** should be checked whenever a new source tape is mounted.
4. The **"color-frame round-off routine"** should be used anytime there is a 4F 1" source machine--this applies even if the recorder is a 2F VTR. It may also be desired if the sources are in 2-field mode to guarantee consistent picture position during certain edits.
5. Excessive aborts with 4F sources may indicate that one or more source tapes has **"reversed phase timecode"**, and this may be entered into the editor's color-frame round-off routine.

Refer to your editor operation manual for further recommendations.

BETACAM "COLOR-FRAMING"

Since Betacams are **component** video recorders, they were originally designed as 2-field servo machines (component has no "color-framing" as it has no subcarrier, and hence no SC/H relationship). At some point it was realized that they were being used for composite recording and playback as well, and a system was added to help improve the picture quality of composite source material.

Briefly, the reason for this system is that the luminance and chrominance separation done before component recording is imperfect on certain transitions (diagonal lines, for instance), causing the separated signals to contain some residual amounts of the opposite component. When the luma and chroma are re-encoded for the NTSC output, encoding subcarrier is generated locked to the reference input (house sync). If the encoding subcarrier happens to be the opposite phase from the original subcarrier of the recorded signal, artifacts may be visible. However, if the composite signal is reconstructed with its original SC/H relationship the artifacts are minimized.

To accomplish this SC/H reconstruction, Sony added what I like to call "**pseudo color-framing**". The way this system works is to add a "color-frame" indicator (CF pulse) to line 15 of the B-Y channel on tape. On playback the CF pulse is used to tell the TBC which color-frame is occurring, thus establishing what phase the subcarrier should be during encoding. Since the VTR only has a 2-field servo, it cannot slew itself to correct a mismatch between the off-tape subcarrier (as indicated by the CF pulse) and the current house subcarrier. However, when the encoder detects such a mismatch it instructs the TBC to delay the video readout by 140 nS, thus inverting the subcarrier and making it match house, eliminating the potential artifacts. Of course, this causes a horizontal shift.

Without editor control, there is a 50% probability that the capstan will lock on a frame in which the off-tape CF pulse is out of phase with house, causing a shift 50% of the time. Under control of a timecode editor, if the same frame is requested twice, say for a match-frame edit, the H-position will be consistent (just like a 1" VTR in 2-field servo).

None of this would be particularly problematic except that continuity of the CF pulses is not guaranteed during recording. That is, they may be recorded adjacent to one another causing the TBC to shift the picture back and forth irregularly.

The following applies to regular (non-SP) Betacams:

On studio recorders (BVW-40), when a recording is made from the composite input, with the "Video" switch in STANDARD mode, the color-frame pulses are recorded based on the color-frame of the incoming video. However, if the recording is stopped and restarted, there is a 50% chance that there will be a discontinuity ("mismatch") in the sequence at that point because the VTR is not able to slew the tape for a continuation of the sequence. Again, it behaves like a 1" VTR in 2-field mode, and the composite output will have a horizontal shift whenever there is a recorded CF pulse discontinuity. When a recording is made from the component inputs (YRB or CTDM) the color-frame pulse is not recorded.

Sony devised various combinations of field recorders and cameras which are capable of adding the CF pulse. This is to provide an SC/H "starting point" so that the composite output will look the same each time the tape is played. I have been told that Betacam system cameras later than the BVP-300 will generate a CF pulse based on the actual SC/H of their encoded output, and this pulse will be added to component recordings on both standalone and piggyback recorders. Problems arise when an early or adapted Sony camera is used, or a camera from another manufacturer. In this case the results may be unpredictable; no pulses recorded or random ones.

The solutions for dealing with H-shift problems in non-SP Betacams are two-fold. In actual practice, the artifacts caused by inaccurate composite reconstruction are only visible on colorbars or critical graphics material, and only when a color-frame mismatch occurs (causing a change in the appearance of encoded video at the edit). So, to prevent a mismatch from occurring, composite recording on the BVW-40 should be done in "NON-STANDARD" mode, in which the CF pulse is not recorded at all.

In addition, **SWITCH 801** on the EN board should be left in the ON position (called "no field" or "field off", depending on the manual). In this position, the encoder will not produce H-shifts and will put out essentially normal video. This will prevent H-shifts when playing tapes with discontinuous CF pulses. I recommend this switch remain in the ON position at all times! Also, note that this switch affects only the functioning of the EN board, and is not connected to the servo system. By setting these switches as described you forfeit any quality benefits from the pseudo color-framing system, but generally the H-shift problems are far more noticeable! (Note: in some early BVW-10 players the EN board may not have this switch. In this case unplugging CN-1 from the piggyback (DU) board on the EN board will disconnect the CF pulse detection circuit.)

Caution should be taken when setting these switches, as some combinations can cause confusing results. For example, if a BVW-40 is left in STANDARD mode, and SW 801 is ON, any edits made from a composite source may have CF pulse mismatches recorded--but they will not be visible on that deck because the shift circuit is disabled!

My experience with BVW-15 studio players was ambiguous at best. Apparently some were built during an interim phase in production and they have a switch beneath the control panel that is intended to select 2 or 4-field operation (some may even have a 2/4/8-field switch). Some actually appear to have 4-field servos as well. In any case, the servo switch should probably be left in the 2-field position (with SW801 ON), for the previously stated reasons.

Betacam SP machines do have true 4-field servos. This being the case, they behave just like a 1" VTR. If the Betacam tape has CF pulses recorded, an SP playback machine will attempt to servo for a match to house when in 4-field mode. In 2-field, it will ignore the CF pulses and off-tape color-frame will be random, with picture position different 50% of the time. However, since some recorded tapes may have inconsistent CF pulses, it is probably advisable to leave SP **playback** decks in 2-field mode, thus avoiding any problems with unpredictable horizontal position. On SP studio recorders, CF pulses are also added to component recordings. Fortunately, if the deck is in 4-field mode it will slew the tape to produce coherent color-frame pulses at edits, with either component and composite inputs.

Actually, SP Betacams have a 3-position switch which controls both the capstan servo mode and the encoder “shift” circuitry. In the position labeled **2F** the capstan acts like a 2-field servo, but the encoder will not produce an H-shift when playing over a CF Pulse mismatch. In **2/4F** the capstan acts like a 2-field servo, and the encoder will show an H-shift. Finally, in **4F** the capstan uses a 4-field servo, and the encoder will produce H-shifts at color-frame mismatches. Also, the setting of this switch can be overridden by a selection in the software Setup Mode, as well as through the serial port, and changing the switch position while in REMOTE will have no effect. Whew!

If you have a correctly SC/H phased system, it is probably best to leave the SP recorders in 4F mode. This way they will color-frame correctly and produce the best quality composite output (but remember, these must now be treated as **4F servo** machines when editing). If a particular tape is exhibiting shifts on playback, temporarily switch to 2F mode to disable the shift circuit. The same cautions apply here as with the non-SP Betacams, since the **2F** switch position will record mismatched color-frame edits, but at the same time make them invisible. **See Addendums at end of article.**

Sometimes it is useful to view the actual color-frame pulses on a Betacam tape when trying to track down problems. These appear as flickering “blue lines” in the vertical interval, but are normally not visible because the TBC replaces the vertical interval on playback. One way to see them is by linking a B’cam recorder to another B’cam through the **component dub cable**. If the tape is played in the source deck of the pair, and the signal is viewed through the recorder in CTDM mode, the “blue line” can be seen on a cross-pulse monitor. This is because the CTDM signal does not pass through the player’s TBC, and the recorder’s TBC can be bypassed in E-to-E mode.

(For accuracy’s sake, I will mention that Sony added a Vertical Interval Subcarrier system (described in the following MII section) to the SP Betas. As far as I know the original CF pulse still affects the servo and encoder circuits, so the previously mentioned behavior applies.)

MII COLOR-FRAMING

Like the original Betacams, early MII decks also have only 2-field servos. H-shift occurrences are the result of the operation of the Vertical Interval Subcarrier (VSC) circuit which, as with Betacams, is used to improve the quality of the composite output by removing residual cross-components leftover from Y/C separation.

When a composite recording is made on a studio deck, one line of incoming SC is sampled and recorded at line 15 of the vertical interval on tape. On playback, new subcarrier is generated in the Encoder locked to the reference input (house sync). The VSC circuit compares the previously sampled subcarrier on line 15 with the fresh subcarrier being generated. If they are not in phase, the VSC circuit causes the TBC to delay the video readout from memory by 140 nS to bring them in phase. This shifts the picture! Again, this is not really color-framing, but it behaves as though it were. The same results hold true when editing with timecode as for Betacams; picture position will be consistent during match-frames, but not otherwise.

It is possible to disable the VSC circuit by setting S3-1 on the L6 board to ON ("vertical phase inhibit"). With the VSC system defeated, there will be no reason for the picture position to change. As with the Betacam, any picture quality benefits are also lost, but these are not as onerous as the H-shifts. When a component recording is made, or the "Video" switch under the front panel is set to NON-STANDARD, the VSC is not recorded, thus avoiding the problem. MII field decks also do not record any VISC information.

As with Betacams, precautions about mutually incompatible switch settings apply; if edits are made in the composite mode, with the “Video” switch in STANDARD, the VSC will be recorded. But the VTR cannot synchronize the VSC already on tape with the incoming subcarrier, so edits may occur in which the VSC reverses phase at the edit point. These will not be seen on playback if switch S3-1 is ON (VSC playback inhibited). For this reason it makes sense to leave the “Video” switch in NON-STANDARD at all times.

Later MIIs (AU-660, for example) do have full 4-field servos and color-framing capability (and must be treated as 4F VTRs in editing). The VSC information is still used to improve encoded picture quality, but a CF pulse is also added to the control track to guarantee coherent recording at edits. The CF pulse is added at every field #1 when recording composite or component recordings.

In addition a 3-position “Lock” switch provides various operating modes: in **2F** the CF pulse is not recorded, and the capstan servo is 2F. In **4F** the CF pulse is recorded and the capstan is 4F. **4F forced** is used when recording a signal that is not RS-170A and thus has no color-frame reference point. This mode forces the capstan servo, TC generator and VSC circuit to start at the same place. This does not guarantee they will all pick up the same at an edit, but the VSC should be coherent.

H-POSITION IN FRAMESTORES AND EFFECTS DEVICES

In addition to timebase correctors used with VTRs, H-shift problems can be caused by devices that capture video frames, such as framestores, synchronizers, stillstores, DVEs and graphics units.

A standard "2-field" framestore cannot store all 4 fields necessary for the complete color-frame sequence, thus it introduces an inherent SC/H phase problem. Assuming the framestore and the source passing through it are genlocked to the same sync, the picture information leaving the framestore will always be on the opposite color-frame from house, since it is delayed by 2 fields. When the video color-frame is opposite to house the video must be delayed 140nS in memory in order for output hue to be correct. This produces the familiar horizontal shift, when compared to the input video. Short of buying a 4-field framestore, there are a few ways to avoid this H-shift.

If a single video path is used, the H-shift can be avoided by the use of **digital decoding** circuitry. Decoding is the process of separating luminance and chrominance, using a digital filter, for the purpose of inverting the subcarrier phase as needed. Typically the filters used are either comb, notch or adaptive types. Comb decoding is generally best for vertical lines, while notch is best for horizontal lines. **Adaptive** decoding analyzes the picture information and switches between comb and notch modes as needed, thus providing the best match for the particular subject matter, though artifacts may still be visible on certain material. (Note that older 1" TBCs which process vari-speed playback use non-adaptive digital decoding, hence the reduced resolution on still-frames.)

Several 1" TBCs now contain adaptive digital decoders that can be switched on by the user at any time (Ampex Zeus, for instance). With decoding on, these TBCs are able to accomplish the novel function of playing 1" tapes that contain <u>mismatched color-frame edits</u> without producing an H-shift. In addition, the Zeus can be used as a 2-field framestore, and adaptive decoding provides an acceptable bandwidth freeze with no horizontal position change (unity picture position).

Another method for eliminating the H-shift is to use a 2-field framestore which handles chroma and luminance in **separate paths** (like the "component" 3/4" TBC). In this case, the subcarrier can be inverted without the need for shifting the entire memory contents. An example of this type is the Fortel Turbo 2.

If a single-path framestore is used, but it has a **heterodyne processor** (for use with 3/4" VTRs), it is possible to invert the chroma, if necessary, before the recombined signal is fed into memory. This will solve the H-shift problem, but does have the disadvantage of reduced bandwidth due to the separation filters.

The upshot is that there are some cases where it is not possible to achieve unity picture position in a unit used for straight freezes of full-bandwidth video. It depends on the unit being used. An additional problem is that some framestores and DVEs will lose their color-frame lock if the input video, or the burst, is momentarily lost. When they relock they may decide <u>not</u> to shift the video on the same input signal, causing an H-position inconsistency.

Finally, be aware that these devices may add a source of horizontal position inconsistency <u>not</u> related to SC/H phase: **H-position adjustment**. This adjustment may not be clearly identified (some common terms are picture position, video phase, or picture phase) and should NOT be confused with horizontal phase controls for output timing. In the interest of eliminating H-shifts, it is advisable to individually check each piece of equipment for “unity” horizontal picture position (no difference between input and output). If the device is precisely timed to a switcher, a horizontal wipe between the device (storing Bars) and house Bars will demonstrate if position is correct.

SC/H PHASE IN A FACILITY

All this color-framing knowledge is virtually useless if the video passing through a facility does not have acceptable SC/H phase. In a facility with no 4-field VTRs, this is of little consequence, but the use of 1" and 4-field 1/2" formats makes proper SC/H phase a necessity.

Basically, SC/H phase should be accounted for on **any device that generates new sync**. This includes central sync and test signal generators, all TBCs (including those <u>inside</u> a VTR), framestores, production switchers, cameras, character and graphics generators. It follows that the composite sync and black that all equipment is genlocked to must also have good SC/H phase, since many devices produce the same SC/H at their output that they receive as a genlock signal.

Devices, such as routing switchers, that do not replace blanking or sync, or otherwise separate sync and subcarrier, will not change the SC/H phase of the video passing through them! The same goes for cable, except when runs go well over several hundred feet. Care should be taken, however, when using the newer breeds of equalizing DAs, as the action of the equalizer circuit can introduce enough high frequency group delay to cause some SC/H change--on the order of a few degrees per 1000' of equalization. Also, regenerative pulse DAs can cause SC/H changes.

SC/H phase can be adjusted when a device is timed to the system. Unfortunately, it is not possible to see SC/H phase on conventional waveform monitors and vectorscopes. Two devices that I have successfully used to measure SC/H phase are the **Tektronix 1750** waveform monitor, and the **Lenco Videoscope**. With these the user is given a visual representation of the relative positions of the leading edge of H-sync and subcarrier at line 10. It is simply a matter of adjusting the particular device under test for the recommended visual alignment of these two components. The Videoscope is no longer available, but several other manufacturers including Grass Valley, Pesa, Leitch and Magni make devices that will measure SC/H phase directly.

One note about these devices is that they cannot realistically be held to extremely tight tolerances (particularly with regard to matching one another's measurements) due, at least in part, to differences in the way circuits handle the rise-time (slope) of the H-sync leading edge. However, they are all accurate enough to adjust a plant to reasonable specs.

If no special test equipment is available, a second choice might be the SC/H phase meter built-in to a 1" VTR. If it has not been changed since factory alignment, chances are the meter on a BVH-2000 or VPR-3 will be close enough. If nothing else, it will provide a means to make all the equipment within the facility consistent.

The last resort would be the "empirical" method; using an oscilloscope and some delay lines. This method is described in the Grass Valley publication cited in the Bibliography, and works fine for verifying the accuracy of SC/H test equipment, but it is too cumbersome for day-to-day maintenance on a whole facility.

Once the SC/H phase can be observed, adjustment is simple. Some devices, like the Zeus, have a separate control specifically for this parameter, apart from the usual SC and H phase controls. But these are really all that is necessary. After timing the device's H and SC phase by the method you prefer, connect the SC/H phase measurement equipment to the device output (sending through a routing switcher is perfectly acceptable). It should be quite close already if you have timed the device against a reference with good SC/H phase (such as a correctly adjusted Bar generator). To bring the SC/H phase as close as possible, adjust the **H-phase** control very slightly. A small change of this control will make a large difference in SC/H, but should be imperceptible as far as H timing is concerned, due to the relative scales of subcarrier and horizontal time periods. Attempting to tighten up SC/H phase by adjusting the SC phase control will only result in moving the device out of color time.

To minimize inconsistent SC/H recordings, I highly recommend that all production switchers have blanking inserters at their outputs. This provides constant, reliable SC/H phase to any record VTR, regardless of the sources selected. But remember that these switchers, which may be "the end of the line" in a timing chain and not subject to H and SC timing requirements, must have their **SC/H phase** correct because it is the sync and subcarrier of the switcher that the 1" VTR will be recording!

As for accuracy, obviously the closer to "0" degrees, the better. But I have found that as much as +/-30 degrees is acceptable. Although RS-170A only calls for +/-40 degrees, there is at least one obvious reason that this is far too wide. In the worst case, if one source device (say house black) was at +30, and the the output of a switcher was at -40, and these signals were recorded adjacently on a 1" tape, there would be a 70 degree variance between the two segments. That is asking for trouble! In a tightly adjusted plant I would consider +/-10 degrees to be acceptable. (There is really no reason to be any tighter than this for video recording, but I did encounter a situation--producing Level IV videodiscs with digital sound--which required "absolute 0 degree SC/H phase". Or so they told me.)

In summation, to produce a correctly SC/H phased and shift-free plant:

1. Use a high quality **RS-170A sync generator**, and make sure any back-up generators are correctly locked to it.
2. **Correctly genlock** all devices to signals which <u>retain</u> the SC/H relationship of the sync generator. Be careful when wiring devices that require individual sync and subcarrier (different path lengths can change their original relationship).
3. Periodically check and adjust the **SC/H phase** of any device that produces new sync, particularly production switchers. Always check SC/H phase when timing a device to the system.
4. Make sure house **timecode generators** are capable of producing RS-170A color-framed timecode.
5. Periodically check and adjust the **unity picture position** of devices that are capable of changing the H-position of video.

VOODOO AND BLACK MAGIC

Hopefully this article has provided some insight into the vagaries of SC/H phase and color-framing problems. To me, this is one of the hairiest areas of video system engineering, and continues to be a source of pain and anguish for all concerned. Unfortunately it shows no signs of going away, as digital VTRs also require color-framing (and the same principles apply).

While great pains were taken to assure the accuracy of this article, in the course of writing I discovered that even the equipment manufacturers are sometimes at a loss to describe how and why their equipment behaves as it does. My advice is: don't accept that there are no solutions to mysterious color-framing problems, and don't accept answers that sound downright <u>wrong</u> (though even the correct ones may be surprising). If you can't get satisfactory answers by asking, test it yourself!

GLOSSARY

2-field servo — A capstan servo circuit capable of locking on any frame, with no regard for the color-frame sequence.

4-field servo — A capstan servo circuit capable of locking on either of the two color-frames in the color-frame sequence. Synonymous with "color-framer ON".

Capstan servo — The circuit that controls a VTR capstan which drives the tape to lock in a certain relationship to a reference.

Color-frame — 1. *n.* One of the two possible arrangements of 4 fields that make up the complete SC/H phase cycle.
2. *v.* The process of aligning the color-frame sequence coming from a tape with a reference.

Color-framer — The circuit that detects the color-frame of a playing tape, and causes VTR capstan servo to lock on a specific color-frame with respect to a reference.

Mismatched color-frame edit — A video recording in which two "A" or two "B" color-frames are recorded adjacently. Also referred to as an "inverted" or "wrong" color-frame edit. Not to be confused with a "recorded-in" horizontal shift.

RS-170A — Specification which states the specific way in which subcarrier and horizontal sync should be locked in the NTSC color system.

SC/H phase — The relationship between colorburst and the leading edge of horizontal sync which produces 4 distinct color-fields in NTSC video.

BIBLIOGRAPHY

The following publications are recommended for further information on SC/H phase and color-framing:

1. "NTSC Studio Timing: Principles and Applications", Grass Valley Group
2. "Model 51 Editing System Installation Guide", Grass Valley Group
3. "110S Frame Synchronizer Operator's Manual", Tektronix
4. "The Television Engineering Handbook", K. Blair Benson, McGraw-Hill

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LATER ADDENDUMS

Color-framing with Betacam SP decks (BVW-60, 70, etc.) is actually slightly different than previously described. When recording from a composite source, using 4F mode is required for the previously described reasons.

However, when recording from a **component** source it is advisable to leave the servo in 2F mode. In 4F mode bad color-frame edits may be recorded because the color-frame servo is trying to match the off-tape pulses with incoming video which has no color-frame information. Using 2F mode in component recording forces the deck to ignore the incoming video and simply continue the pulse sequence already on tape.

This rule also applies to Digital Betacam.

Servo Mode	2F	2/4F	4F
Composite Input	Servo OFF Shift NOT visible	Servo OFF Shift VISIBLE	Servo ON Shift VISIBLE
Component Input	Servo OFF, pulses match sequence on tape Shift NOT visible	Servo OFF, pulses match sequence on tape Shift VISIBLE	Servo ON but no incoming reference Shift VISIBLE