HELICAL VIDEO TAPE INTERCHANGEABILITY REQUIREMENTS

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BACKGROUND

In the initial applications for helical video tape recording and playback equipment, the necessity for recordings to be playable on any number of players in a variety of locations generally was not a serious consideration. In most cases recordings were made off-air or of local originations, either of entertainment or educational programming, for subsequent playback on the same VTR equipment used for the recording. Although there were some exceptions, such as regional or state educational organizations where video tape was used to avoid the expense of intercity transmission and the scheduling limitations of network programming release from a central location, these were in minority and thus not a major factor at the time in forcing development of technical improvements and standards dictated by interchangeability requirements.

More recently, however, with the increased use of helical color video tape in fully automated cable and hotel pay-TV origination systems, for advertising and sales promotion, and for expanded educational non-interconnected networks, all requiring quality competitive with that of television broadcasting, the need for optimum interchangeable performance has become acute. The problems have been compounded, first by the large number of organizations providing a recording service in a manner not unlike that of a film processing laboratory producing prints for distribution to theaters and other exhibitors, and second by the increasing number of manufacturing sources for equipment and tape.

Apart from technical quality, another complication which results in increased cost of duplication and distribution, is the large number of different recording formats. In fact, not only are there a variety of tape widths, but in addition, a variety of formats exist for any one width. The problem is considerably more complex than in motion-picture film where the gauges are limited to Super-8, 16mm, and 35mm; and the formats to two types of wide-screen and the traditional 3-by-4 aspect ratio.

To cite a few of the cassette or cartridge formats in use, in 1/2-in. there are the EIA-J and Philips, in 3/4 in. the U-Matic and in 1-in. the IVC and Ampex. The problem has grown to such proportions that it is no longer amenable to standardization through the work of industry technical committees. Instead, the question of the best format for each application undoubtably will be answered in the marketplace by the user. Therefore, industry activity appears likely to be the development of recommended practices for each of the different formats which are available from two or more manufacturing sources.

The following review of the interchangeability requirements, for the most part will be general in scope; in the interest of brievity, where specifics regarding parameters and tolerance are discussed, the 3/4-inch U-Matic or 1-inch IVC formats will be used as examples.

SURVEY OF INTERCHANGEABILITY FACTORS

It is the obvious conclusion from the foregoing that interchangeable performance has to be developed to a level where no operating or set-up adjustments are required in order to accommodate tapes made on different recorders or head assemblies. In order to achieve such highly desirable operational flexibility, rigorous control must be exercised over many parameters. The scope and magnitude of the design and operational problems is indicated by the following tabulation of the most significant factors to be taken into account:

Video Head
Dihedral alignment
Head-to-Tape speed
Gap azimuth alignment
Tape guiding
Recorded track dimensions

Magnetic Tape
Physical dimensions and properties
Magnetic properties
Cassette dimensions
Humidity and temperature effects

Video Signal
Carrier frequencies for sync level
Carrier frequencies for reference black level
Carrier frequencies for reference white level
Luminance and chrominance bandwidths
Color carrier signal
Pre- and post-emphasis

Control Track
Recorded level
Signal phasing to video signal
Track dimensions and placement
Gap azimuth alignment

Audio Head and Track
Recorded level
Track dimensions and placement
Gap azimuth alignment

As will be evident in the subsequent discussion, several of the items listed cannot be adjusted or corrected except during manufacture. For these parameters, the user's control is limited to a periodic check in order to determine if the equipment remains within the permissable limits of tolerance. However, many of the factors are subject to set-up or operating adjustment and must be held under careful control if interchangeable performance is to be comparable to that achieved in non-interchangeable operation.

VIDEO HEAD
One of the objectionable degradations in helical video tape playback results from timing errors in the playback signal. These can be caused by misalignment in the head assembly, or more frequently, differences between recording and playback, head-to-tape speeds.

Dihedral Alignment: If the two video heads are not precisely 180-degrees apart on the head drum, following the switch between heads the television fields from each of the heads will be displaced horizontally. This will be apparent as dual images of vertical lines at the top of the picture. The longer the receiver horizontal sync time-constant, the further down from the top of the picture the split of vertical lines will be present. Adjustment tension by the skew correction control will have no effect on this error. Normally dihedral errors are corrected by factory alignment. However, in the event it is required, an adjustment can be made in the field using an alignment tape provided by the manufacturer as a test reference.

Head-to-Tape Speed: A difference in recording and playback speeds will result in a cumulative error in signal timing. This will be evident as a horizontal shift of the video immediately following the switch between heads, and differs from dihedral errors in that both fields shift identically rather than in opposite directions. The effect is commonly known as skew. On receivers with a short horizontal sync time-constant, the effects of such time-base errors do not cause a serious degradation in picture geometry, since the shift in horizontal positions is usually limited to a few lines at the bottom of the picture after head switching and is covered by the receiver mask. However, on most receivers of American manufacture, having a long time-constant, the horizontal circuits may not recover from the abrupt change in timing of sync until a third or more down from the top of the picture. In this case, the resultant skewing is very disturbing and must be corrected if viewer satisfaction is to be achieved.

The time-base error can result from differences in radius of the video heads' travel because manufacturing tolerances and wear of the pole pieces. However, the largest errors usually are the result of tape tension adjustments and environmental effects of humidity and temperature; the latter will be covered in detail under magnetic tape factors.

The recording writing speed and playback time-base errors are adjusted by control of tape tension, the latter in part or completely depending on the type of control used. Goldmark Communications has developed an automatic braking system for tension control and accompanying skew correction which reduces the error to under a micorscond.

Other systems for timing error correction are available from Television Microtime and Consolidated Video Systems which reduce the time-base error by introducing an automatically-controlled variable delay in the playback video signal.

Tape Guiding: Improper tape guiding around the head drum can cause partial or total loss of the video signal. It also can result in improper wind of tape on the feed and take-up reels and possible jamming of tape in the player.

MAGNETIC TAPE
Magnetic Properties: In order to obtain a maximum signal-to-noise ratio, helical scan equipment normally is designed to operate with high energy magnetic tape. Two types of coatings provide this character-

istic; they are chromium dioxide and cobalt oxide. Both of these materials provide substantially higher playback signal levels than ferric oxide tape. However, in order to achieve this performance, higher record current is required. In summary, with proper record current levels, and with the more efficient ferrite video heads, an improvement of 3 or 4dB is achieved.

Humidity and Temperature Effects: Environmental effects from variations in humidity and temperature can be major factors in restricting interchangeability. Because of the long track traced by each head, a dimensional change in the tape, or in diameter of the head drum, can cause a large variation in resultant tape-to-head writing speed. The primary control of this parameter is through an adjustment of tape tension as it passes over the head drum so as to introduce a controlled amount of tape stretch. Thus, a head-to-tape reading speed can be maintained during playback which is equal to the writing speed during recording.

The range of timing difference resulting from humidity and temperature changes can be calculated, for example, for the 3/4-in. U-Matic format using the following constants:

Humidity coefficient of tape
11×10^{-6} in/in/%RH

Temperature coefficient of tape
15×10^{-6} in/in/°C

Temperature coefficient of aluminum
11.7×10^{-6} in/in/°C

Head-writing speed
404 in/sec.

Track length
6.7 in/field

The calculations of change in microseconds for each percent of relative humidity and degree fahrenheit are tabulated below:

$$\frac{11 \times 10^{-6} \times 6.7}{404 \times 10^{-6}} = 0.182 \text{ u sec/field/\%RH}$$

$$\frac{(15 - 11.7)\ 10^{-6} \times 6.7}{404 \times 10^{-6}} \times \frac{5}{9} = -0.2 \text{ u sec/field/\%RH}$$

It is interesting to note that temperature changes cause a timing error opposite to that from humidity. This results from the fact that the effect of a temperature change on the head drum is greater than on tape and, in addition as related to timing errors, is in the opposite direction.

The importance of environmental control is highlighted by a calculation of the timing error resulting if a recording made under conditions of 50% RH and 70° RH is played back with an ambient of 90% RH and 90°F. The humidity increase will cause an increase in recorded track length of 7.28 microseconds, whereas the increase in temperature will cause an increase in head speed which is equivalent to a reduction in track length of 4.0 microseconds. The net effect is a timing error of 3.28 microseconds. This will be apparent on the television picture as a shift of video information to the left after the switch between heads.

VIDEO SIGNAL

One of the major problems in any phase of television program transmission is the consistent maintenance of uniform video signal levels. In video-tape recording and playback these parameters are dependent not only upon the gain of the various video amplifiers, but also upon the deviation employed for the frequency modulation of the carrier signal applied to the recording heads. Second in importance to level control is the choice of pre- and post-emphasis for optimum compromise between video bandwidth and signal-to-noise ration.

Carrier Deviation: The choice of deviation frequencies is dependent upon two opposing factors: (a) The bandpass limitation of the tape and head combination, and (b) the need for a maximum signal-to-noise ratio. The signal-to-noise ratio will vary directly with the peak-to-peak magnitude of the deviation. Therefore, it is desirable to modulate the carrier over as wide a band as the system elements will permit. However, if the high-frequency cutoff of the head and tape is exceeded, a distortion of peak white signals is produced. In some types of playback circuitry this results in a failure of limiting action prior to demodulation and permits the random noise from the tape and preamplifier during playback to be amplified to full signal level by the high-gain amplifiers. The resultant noise and streaking in peak white are very objectionable in appearance. In other circuits the effect merely is a loss in peak whites similar to that produced by a peak limiter. It is apparent that the maximum frequency deviation must be limited to that which can be accommodated by any or all playback equipment.

Pre- and Post-Emphasis: Current practice in most systems is to provide a rising amplitude frequency characteristic wherein the 3 MHz response is 10 to 12 dB above the low-frequency response. In order to avoid overload distortion from the higher frequency components, the rising response characteristic is restricted normally to frequencies under 3 MHz. Appropriate post-emphasis is employed to provide a flat overall system response over the desired luminance bandwidth.

CONTROL TRACK

The control track synchronized the rotation of the heads with the tape travel. Most equipments have means to automatically phase the head rotation with the control track. However, this will not correct for errors in recorded phase of the control track relative to video tracks. Correct phase is essential for maximum signal output and signal-to-noise ratio.

CONCLUSION

If the maximum potential quality and operational flexibility in the use of helical tape equipment on an interchangeable basis are to be realized, it is essential that a vigorous control of recording and playback parameters, as well as environmental conditions, be maintained. However, these disciplines in control require that agreement be reached on recommended practices and standards among manufacturers and users. Realizing the importance of the problem, the Joint Committee on Intersociety Coordination (JCIC)* has assigned the task to the Society of Motion Picture and Television Engineers (SMPTE). The SMPTE, in turn, has instructed the Helical Recording Subcommittee of the Video Tape Committee to proceed expeditiously to develop recommendations for industry adoption.

* Representing EIA, IEEE, NAB, NCTA, and SMPTE.