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Dolby Introduces New S-type System for Audio Cassettes

TOKYO – Dolby Laboratories of San Francisco introduced its new Dolby S-type recording system at the Hotel Okura in Tokyo on October 30 and 31. Representatives of the press and Dolby licensees from throughout Southeast Asia were invited to attend the first demonstrations and detailed explanations of Dolby S-type, which has been developed to improve the quality of the analog audio cassette. According to Dolby Vice President Ed Schummer, "When incorporated in a high-quality machine using today's best tape formulations, Dolby S-type provides analog cassette performance subjectively equivalent to digital media under home listening conditions."

Dolby S-type, like the other Dolby systems, is a circuit for building into cassette machines to encode tapes as they are recorded and decode them on playback. The new system effects 10 dB of noise reduction at low frequencies, and 24 dB at the higher frequencies where most cassette noise lies. The new system also reduces distortion and improves headroom, and has been designed to be particularly resistant to decode errors. Moreover, cassette recordings encoded with Dolby S-type, but played back with Dolby B-type or no decoding, are essentially free of such dynamic artifacts as "pumping".

Based on principles of Dolby SR

Dolby S-type is based upon operating principles developed for Dolby SR, the professional Spectral Recording system Dolby Laboratories introduced in 1986. More than 30,000 channels of Dolby SR are now in use worldwide by the music recording, broadcasting, and cinema industries. Among the techniques of

Dolby SR utilized by Dolby S-type is the combination of both fixed and sliding bands. Being optimized specifically for cassette recording, as opposed to professional analog media, Dolby S-type is a simpler and thus less costly design.

Dedicated Dolby S-type ICs

The demonstrations in Tokyo were conducted using cassette decks modified by Pioneer to incorporate a dedicated Dolby S-type three-IC set developed by Sony in co-operation with Dolby Laboratories. The three-chip set is an intermediate iteration of Dolby S-type and will be incorporated in the first consumer products next year. Schummer said that several manufacturers licensed by Dolby Laboratories have announced their intentions to exhibit prototypes of products with Dolby S-type at next January's Consumer Electronics Show in Las Vegas. Single-chip Dolby S-type circuits with identical performance are expected to become available from Sony later next year, and other IC manufacturers have expressed interest in also developing S-type ICs.

New standards for licensed products

Simultaneously with Dolby S-type, Dolby Laboratories is introducing to its licensees new, higher standards for cassette recorders incorporating the system. Among the new standards are wider frequency range, more headroom in the electronics, lower wow and flutter, and for the first time in the cassette industry, a standard for head azimuth. While some manufacturers may have to design new models to meet these standards, Schummer stressed that many top-of-the-line models currently available will have little trouble meeting them. He said that cassette recorders with Dolby S-type are likely to be up-market models initially, as a result of both the higher standards and Dolby S-type's complexity (3-4 times that of the current Dolby noise reduction systems). He added that all machines with Dolby S-type will include Dolby B-type NR for compatibility with pre-recorded cassettes and older cassette machines.

Interest from software industry

Schummer reported that considerable interest in Dolby S-type has been expressed by the software industry, and that demonstrations have already been conducted for major cassette duplicators. He said that the software companies are particularly interested in the sound of cassettes encoded with Dolby S-type when played with Dolby B-type decoding or no decoding at all, adding that over the years Dolby B-type encoding has become virtually standard worldwide for pre-recorded cassettes. "The software industry is reluctant to release titles in more than one format, so they are concerned by the so-called 'compatibility' of S-type cassettes," Schummer stated. He said that the industry, not Dolby Laboratories, will be making that judgment, but added, "S-type's freedom from dynamic artifacts should figure favorably in making that call."

Assuring cassette's future

Schummer pointed out that more than 270 million cassette machines with Dolby noise reduction have been manufactured so far, which he estimates puts the total number of cassette machines built at well over one billion. He also stressed that pre-recorded cassettes outsell LPs and CDs combined by a substantial margin. Yet the introduction of completely new media such as the CD indicates substantial interest in better sound. Thus he concluded, "The high level of performance Dolby S-type extracts from the convenient, standard audio cassette bodes well for the future of the most popular recorded music medium ever."

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The Dolby S-type Recording System

Operating principles

In 1986 Dolby Laboratories introduced its Spectral Recording system, Dolby SR, to the professional recording, broadcast, and cinema industries. More than 30,000 channels of Dolby SR are now in use worldwide, attesting to the effectiveness of the system and its principles of operation. Now Dolby Laboratories is introducing the Dolby S-type recording system, based on several of the same principles in a simpler, lower-cost format optimized specifically for consumer cassette recording.

When incorporated in a high-quality cassette recorder[1] with today's best tape formulations, Dolby S-type provides audio cassette performance which surpasses that of any other analog consumer medium, and subjectively equals that of digital consumer media under home listening conditions.

The principle of least treatment

Complementary noise reduction systems work by boosting low-level signals during recording, then reducing them – along with added tape noise – during playback. High-level signals are not boosted to prevent tape overload. To prevent such audible side effects as noise modulation, during recording the ideal NR system would apply constant gain wherever there are no high-level signals, even in the presence of such signals elsewhere in the spectrum. This is called *the principle of least treatment*. Dolby S-type adheres more closely to this principle than previous consumer systems.

As a result, high-level signals have little effect on low-level signals. This contributes to freedom from audible side effects, and also reduces susceptibility to decoding errors, such as those introduced by using a tape formulation for which the recorder has not been optimized. In addition, S-type recordings heard with Dolby B-type or no decoding will be free of such obvious dynamic flaws as "pumping".

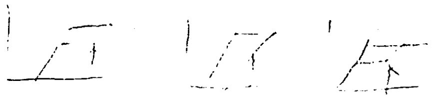
Action substitution

At the higher frequencies where cassette noise predominates, Dolby S-type combines both fixed and sliding bands (at low frequencies, where noise is far less

1 Higher performance standards for licensed cassette machines incorporating Dolby S-type are being introduced simultaneously with the new system.

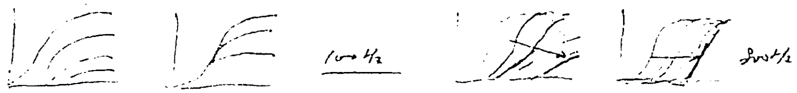
significant, a fixed band alone is used). This combination results in *action substitution*, whereby the advantages of each type of action are realized while minimizing their disadvantages.

Action substitution applies the principle of least treatment to the noise reduction band itself. It minimizes the reduction in record compression which occurs at frequencies above higher-level signals when a fixed band alone is used, and at frequencies below higher-level signals when a sliding band alone is used. The effect of higher-level signals on low-level signals is therefore minimized within the noise reduction band.



Modulation control

Where action substitution minimizes the effects of moderately high-level signals within a noise reduction band, *modulation control* minimizes the effects of very high-level signals outside the NR bands on the bands themselves. For example, without modulation control, the stronger a signal in the midrange, the further away from that signal a sliding high-frequency band wants to move, thereby reducing the audible NR effect. Modulation control prevents high-level signals above a certain threshold from causing the sliding band to move any further than necessary. Therefore, in keeping with the principle of least treatment, modulation control helps to keep low-level signals more consistently compressed.



Staggered-action compression

Dolby S-type provides more than 20 dB of noise reduction at higher frequencies. Providing that much NR using conventional techniques would subject low-level signals to an unduly high compression ratio. Therefore, with Dolby S-type *compression is provided by two staggered stages* operating at different signal levels with comparatively gentle compression ratios. This technique was pioneered in Dolby C-type NR and further refined in Dolby SR.

Spectral skewing and anti-saturation

These techniques were also introduced with Dolby C-type NR and refined in Dolby SR. Both are frequency-shaping networks which in the case of *spectral skewing* desensitize the system to frequency response errors, and in the case of *anti-saturation* "load" the tape more effectively. Anti-saturation provides increased headroom and lower distortion; unlike Dolby C-type, in Dolby S-type anti-saturation is applied at low frequencies as well as high. This helps to reduce the low-frequency distortion often resulting from the substantial low-frequency boost imparted by cassette record equalization.

Differences between Dolby S-type and Dolby SR

The cassette medium differs substantially from such professional media as 15 or 30 ips open-reel tape recording. The spectral content of the noise is different, the lower cassette operating speed minimizes print-through, and home listening levels are typically lower than studio monitoring levels. Optimizing Dolby S-type for these criteria has resulted in a simpler and less costly system than Dolby SR.

Because cassette tape noise is concentrated at higher frequencies, and because of comparatively low print-through, with Dolby S-type only a single-stage, fixed NR band at low frequencies is necessary. By contrast, Dolby SR provides two staggered stages of both fixed and sliding band low-frequency NR. At higher frequencies, where Dolby S-type provides two staggered stages of both fixed and sliding band NR, Dolby SR has three. This virtually eliminates the possibility of audible noise modulation at very high professional listening levels. Therefore, although there are others, a major difference between Dolby SR and Dolby S-type is that the former requires ten active NR elements while the latter needs only five.

Dolby S-type Noise Reduction
Technical Description

S-Type Circuit Operation

Like all other Dolby noise reduction systems, S-type is complementary, that is, signals are encoded before being recorded, then decoded in a complementary manner during playback. The following discussion will describe the operation of an encoder, but it should be noted that an encoder can be switched to the decode mode in the same manner as an A-type, B- type, C-type, or SR processor.

As with C-type NR, an S-type encoder has two staggered-action compressors, each having a passive main path which is summed with an active side chain, and each of which operates over a different signal level range. The **high level stage** has three compressors in its sidechain, which are known as the **high frequency fixed band** (HF/FB), the **high frequency sliding band** (HF/SB), and the **low frequency fixed band** (LF/FB). The **low level stage** has a **high frequency fixed band** and a **high frequency sliding band**. Fixed bands are band limited to provide more compression at frequencies below dominant signals above 6 kHz, which gives less signal modulation in the encoder and less overall noise modulation. The fixed and sliding bands operate together in a technique known as **action substitution**.

The encoder output is filtered and then fed back to the control paths of each compressor to control compressor action using a technique known as **modulation control**.

Spectral skewing is provided to reduce sensitivity to very low and high frequency signals. The low frequency spectral skewing network is located at the encoder input, while high frequency attenuation is provided by two high frequency spectral skewing circuits which are distributed between the low and high level stages to reduce compression ratios at high frequencies. Two stages of **antisaturation** provide high frequency attenuation at high levels to reduce tape overload.

An S-type encoder adapts its characteristics to the input signal in such a way as to provide the maximum amount of boost at all times, especially at frequencies which are lower or higher than the dominant signal. The **overshoot suppression (O/S)** circuits used are also designed to allow maximum boost from the compressor. Thus, the **least treatment** is given to the signal at all times, resulting in a very stable output with little dynamic action. When the signal is decoded, the maximum amount of noise reduction is obtained in the presence of signals, ensuring low noise modulation and a high degree of tolerance to errors in the transmission chain. Up to 24 dB of noise reduction at high frequencies and 10 dB at low frequencies is provided.

High Level Stage

The high level stage is active for signal levels in the range from -25 dB to Dolby level, and provides up to 12 dB of boost at frequencies above 400 Hz and 10 dB of boost at frequencies below 200 Hz.

The LF/FB is basically a passive low pass filter followed by a variable attenuator, with the amount of attenuation increasing with signal level. The HF/FB is similar, although the variable attenuator follows a high pass filter. The HF/SB is a variable frequency high pass filter whose corner frequency rises with increasing signal level or frequency (as in B and C-type processors). The input of the sliding band is connected in such a way as to provide an output which is the sum of the fixed band output and a signal which is the difference of the HF/FB output and the input signal (action substitution).

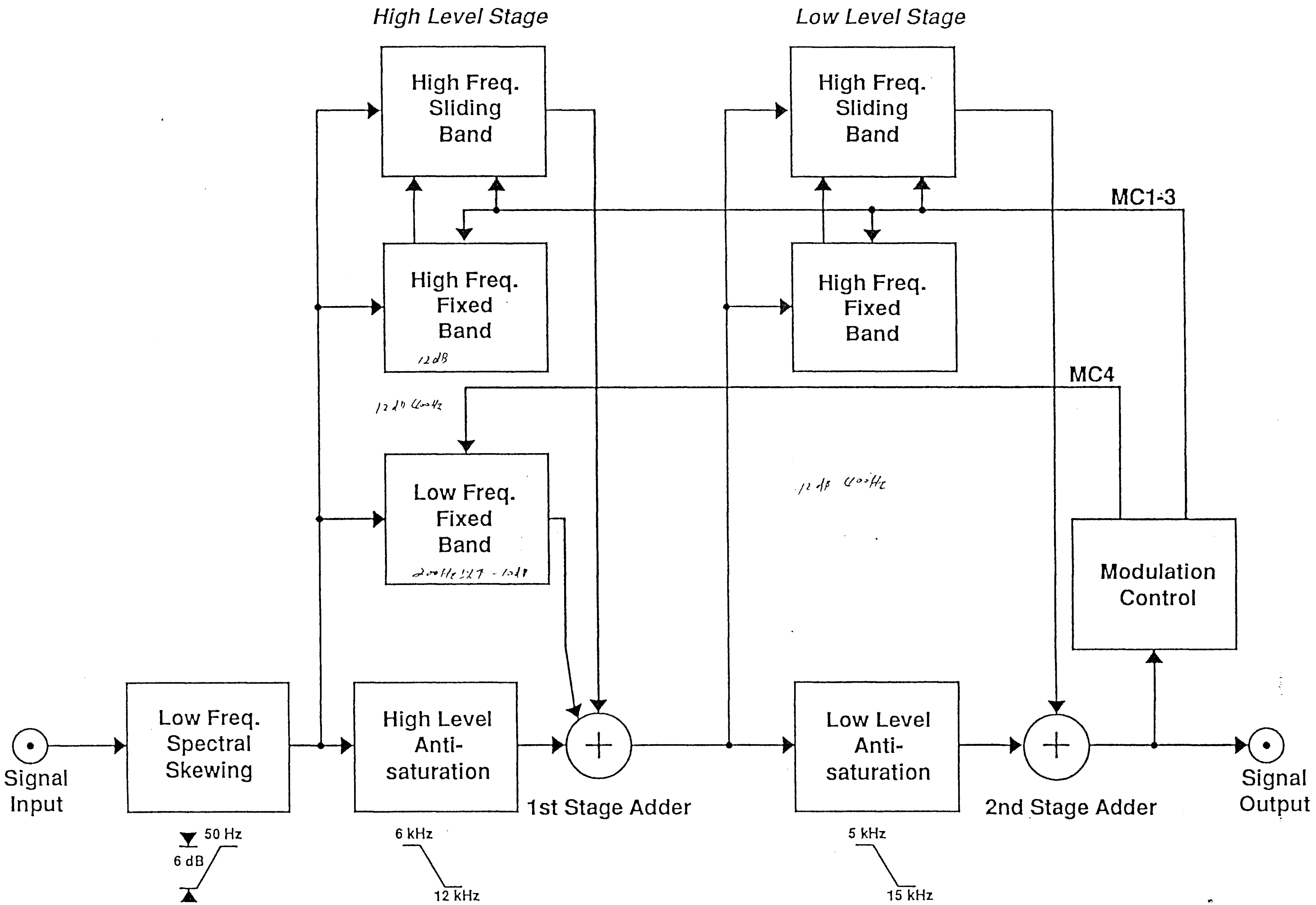
The control signals are derived from the compressor output, which is filtered, rectified, and averaged to produce a smooth control signal. An alternate path is provided to quickly charge the control path under high level transient conditions to suppress overshoots. Modulation controls signals are subtracted from the control path to reduce the control signal and the resultant attenuation under conditions where extra attenuation is not necessary. The final signal is then fed to a nonlinear control law stage which provides the required attenuation versus control voltage characteristics.

Low Level Stage

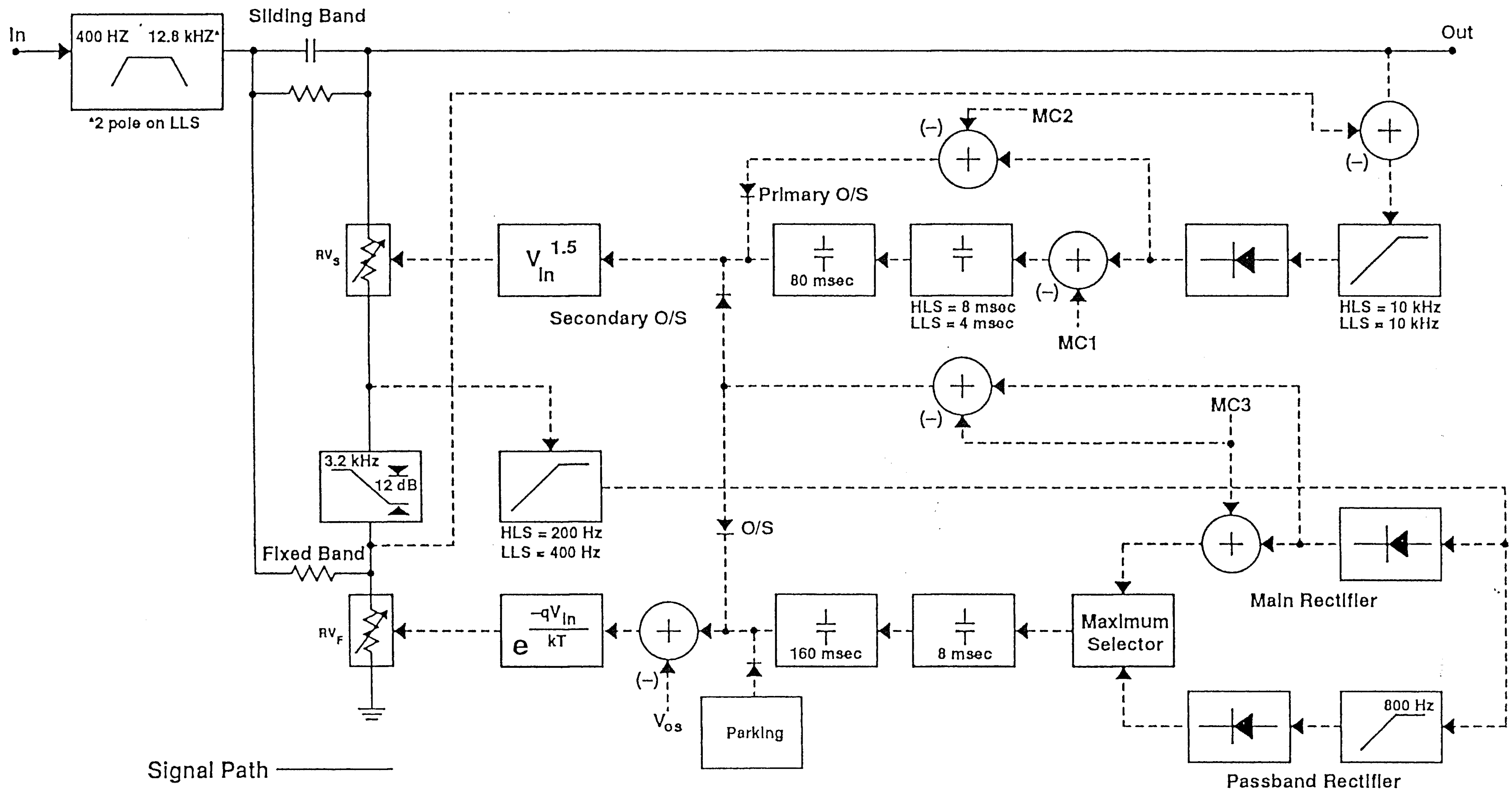
The low level stage is active for signal levels from -50 to -25 dB. No low frequency signal processing is provided, but in all other respects it is quite similar to the high level stage.

Modulation Control

Modulation control is used to prevent unnecessary modulation of the compressors in the presence of high level signals. It is inactive at low levels. The encoder output is fed to the input of the modulation control circuit, where it is split into three frequency bands. The **MC1** signal goes through a 3 kHz high pass filter to a full wave rectifier, and is then fed in opposition to the HF/SB control signals. **MC2** is created by smoothing the MC1 signal using a 2 msec time constant. This signal is then applied in opposition to the HF/SB overshoot suppression signal. **MC3** is low pass filtered at 200 and 400 Hz, full wave rectified, and then fed in opposition to the HF/FB control signals. The LF/FB is controlled by **MC4**, which first passes through 200 and 400 Hz high pass filters and a full wave rectifier.



S-TYPE ENCODER BLOCK DIAGRAM

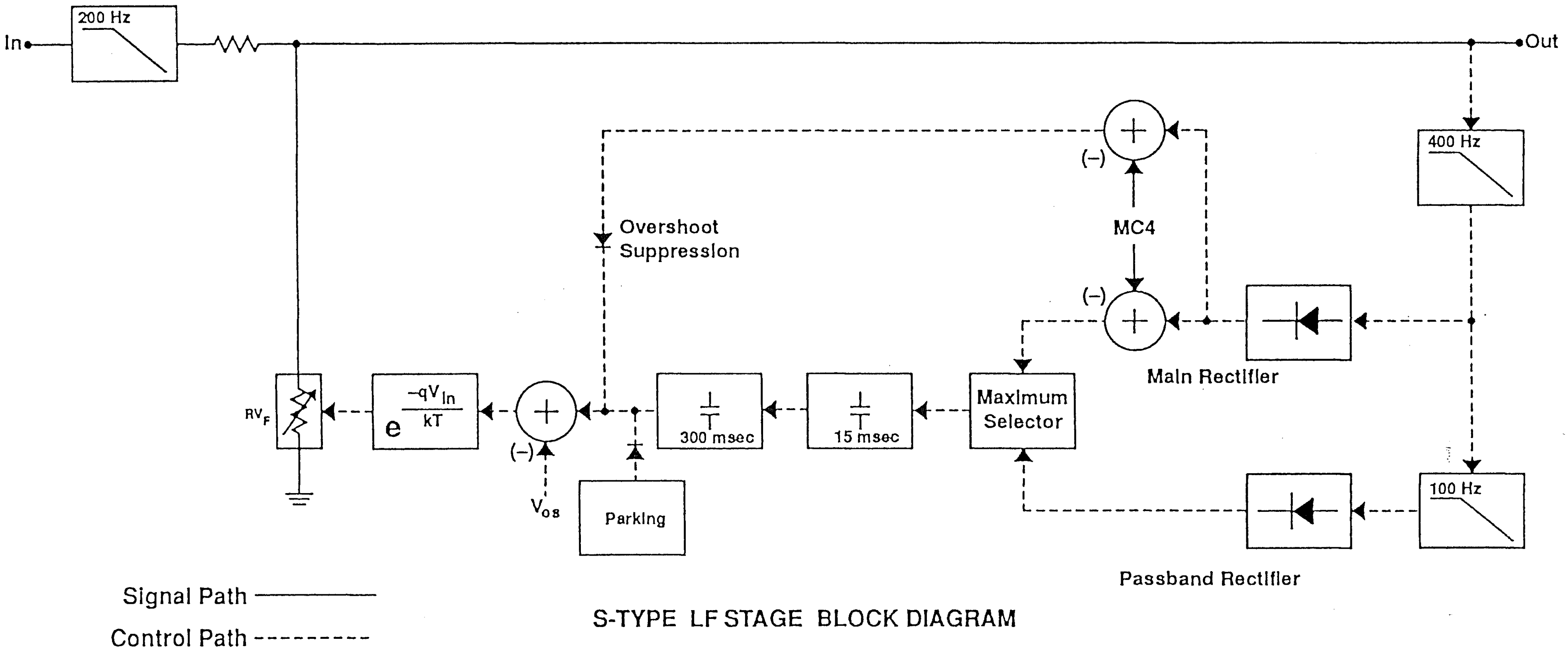


Signal Path ————

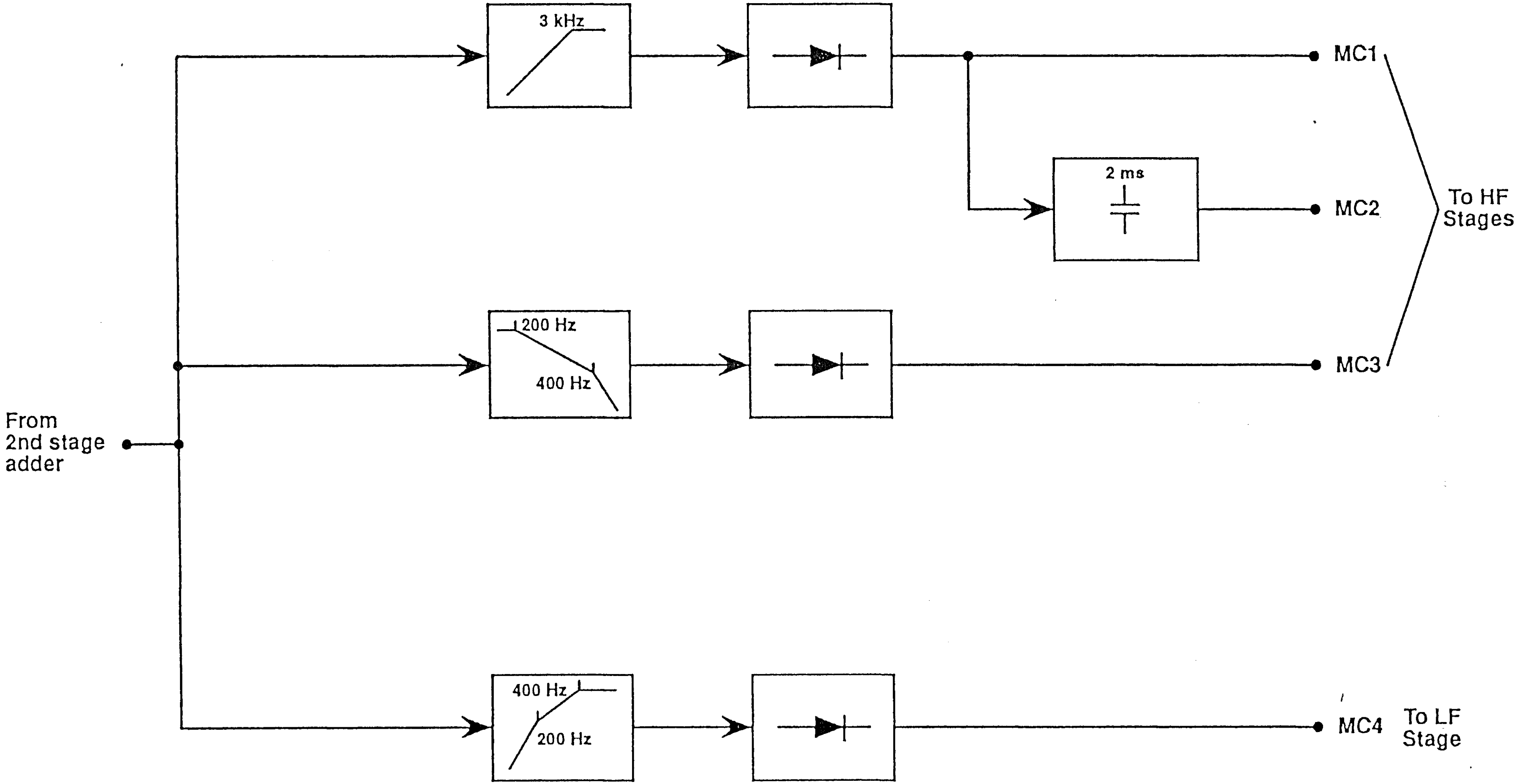
Control Path - - - - - - - -

O/S = Overshoot Suppression

S-TYPE HF STAGE BLOCK DIAGRAM



S-TYPE LF STAGE BLOCK DIAGRAM



S-TYPE MODULATION CONTROL CIRCUITS BLOCK DIAGRAM

Preliminary Specifications for Products Incorporating Dolby S-type Noise Reduction

Introduction

In order to ensure the successful introduction of Dolby S-type noise reduction and to promote eventual widespread use and acceptance of products incorporating S-type in the marketplace, it is necessary to mandate specifications that will not only give outstanding individual product performance but also make S-type machines easy to use and compatible (that is, tapes made on one machine must be able to be played with excellent results on any other machine).

Thus, a whole set of overall performance specifications has been developed that, taken together, will modernize and revitalize the compact cassette medium so that it will be capable of competing effectively in today's and tomorrow's marketplaces. Some of these specifications may require manufacturers and suppliers to redesign and upgrade their design and manufacturing processes, but only by doing so will the long term survival of the cassette be assured.

Azimuth

The single biggest problem with today's compact cassette is poor performance in the top octave (10-20 kHz). Unfortunately, it is in precisely this area that many people judge the overall quality of an audio product. Solving this problem is essential to the success of Dolby S-type, and indeed it could be argued it is essential to the continued success of the compact cassette in general. High frequency performance is usually much worse when tapes are recorded on one machine (or prerecorded) and played on another, yet it is just this compatibility which is most important for the long term success of the compact cassette format.

The introduction of S-type noise reduction and the associated overall system performance requirements has given us the opportunity to improve machine to machine compatibility by introducing an azimuth standard. An azimuth misalignment of just 4 minutes of arc will result in 1 dB of loss at 10 kHz and 4 dB at 20 kHz, while an error of 8 minutes will cause well over 10 dB of loss at 20 kHz.

A tape recorded on any machine must be capable of being played back on any other machine without excessive high frequency loss due to azimuth misalignment. This can be achieved in a number of ways:

1. A conventional fixed-azimuth head mounting arrangement can be used. In this case, azimuth must be adjusted to within ±3 minutes of arc when measured using the ITA standard. Products will be tested by playing the BASF calibration mechanism (or a suitable azimuth tape derived from the BASF tape) and measuring the phase error of the tone. For example, the phase difference between the left and right channels for a 12.5 kHz tone must be less than 75 degrees. The mechanism will be expected to handle plastic shelled azimuth tapes and the calibration mechanism equivalently. For mass production, we intend to be able to specify commercially available azimuth tapes which are derived from, and very close to, the BASF standard.

2. A manual azimuth adjustment can be fitted, with a calibrated zero detent position connected to a record lockout device to prevent recording with improper azimuth.

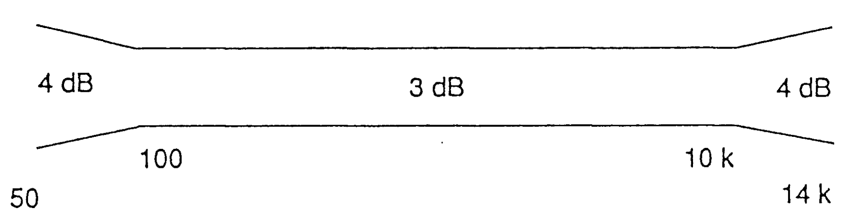
3. An automatic mechanical azimuth adjustment system can be used.

4. Other methods may be developed in the future.

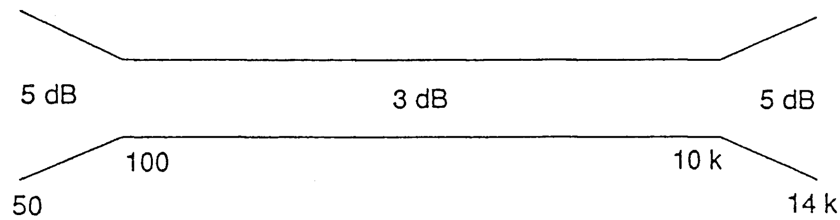
Frequency Response

The spectral balance of a musical program is determined by the ratio of high to low frequencies. If high frequencies predominate the program will sound shrill, and too much low frequency energy will cause the signal to sound tubby and indistinct. To ensure a balanced overall sound and, again, compatibility between products and with prerecorded software, frequency response limits for both overall and playback response have been extended down to 50 Hz, with some accommodation made for contour effect at very low frequencies. High frequency response limits have been extended to 14 kHz, which will encourage the use of higher quality heads and mechanisms in S-type products.

A. Playback response:



B. **Overall response:**



Calibrations

The S-type processor is generally less sensitive to level errors than other noise reduction processors. Therefore, calibration accuracy limits currently specified for products with B and C- type NR will be used in most cases.

However, in order to improve machine to machine compatibility, playback calibration accuracy limits will be tightened to ±0.5 dB.
In addition, a new specification will be added to ensure head height accuracy. A tape will be recorded at 400 Hz on the machine under test so that the level at the test point is the same as the level obtained when playing a Dolby level tape. Then, the tape will be played on a calibrated Studer A80QC machine (outside the shell) and the level again compared to the level obtained when playing the Dolby level cassette. The specification will be +0, -1.0 dB for two head machines and ± 0.5 dB for three head machines (to account for pole piece height differences between the record and play heads). This will ensure that head height errors will be held to less than 2 dB from machine to machine.

Noise

CCIR/ARM weighted noise reduction effect will be specified as 20 dB minimum. The measurement method will be similar to our current procedure, although a 20 Hz - 20 kHz audio bandpass filter with 24 dB/octave rolloff will be added to the signal path.

Hum and low frequency noise limits will remain the same as our current limits for products with C-type NR.

An unweighted noise reduction effect specification will be added. The procedure will be the same as we currently use, and the limit will be 9 dB minimum.

Distortion

The playback overload margin specification now used for products with B and C-type NR will be expanded to cover the entire record/playback chain and a frequency range of 50 Hz to 14 kHz. The limit will be raised to 15 dB to give a comfortable margin over the recording capabilities of current and future high performance tape formulations.

The most difficult circuit to design to the new overload margin specification will be the record amplifier. Due to the considerable peaking used at high frequencies, maintaining a 15 dB overload margin will require special designs and relatively high power supply voltages and/or low inductance heads. However, overload margin will be measured with S-type NR on, so the spectral skewing and anti-saturation circuits will help to offset the amplifier peaking.

A new specification for 333K3 distortion will be added, with a limit of 1% maximum for Type I tapes and 1.5% for Type II and IV tapes. This should present no problem for machines with properly chosen bias operating points.

MPX Filter

A filter similar to those used on current products with B and C-type NR will be required. It is expected that the MPX filter will be switchable to allow a full 20 kHz bandwidth when practical.

Wow and Flutter

In order to ensure that the quality of the mechanism used is consistent with the overall product quality, wow and flutter will be specified as .10% maximum (CCIR weighted) and .20% maximum unweighted. Again, currently available high quality mechanisms can easily meet this specification.

Other Requirements

All products incorporating S-type NR that can record must include the following:

1. Either manual or automatic bias and record calibration adjustment. Due to the wide variety of tape formulations available, the only way to ensure that recordings made on machines with S-type NR will achieve the necessary performance is to provide some means of adjusting bias for flat overall frequency response and record calibrations for differences in tape sensitivity. Ideally, an S-type machine should be able to meet the overall response requirements with any available tape. Samples will be tested with several different typical Type I, II, and IV tapes to check the bias/calibration scheme used (the machine will not be required to meet the overall response limits with unusual formulations).

2. If manual bias and record calibration controls are fitted, the detent position should correspond to the proper settings for the IEC Type I, II, and IV reference tapes.

3. Automatic record equalization and bias sensors. This will ensure that the user will always use the correct bias and equalization for the tape chosen, and will also generally simplify the operation of S-type products. Manual override will be permitted if automatic reset to standard equalization and bias is provided.