SOUND TALK

FROM THE MAKERS OF "SCOTCH" BRAND MAGNETIC TAPE

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VARIOUS ASPECTS OF "TAPE NOISE"

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If the tape motion is halted while listening to the reproduction of a magnetic recording, all sound ceases except the residual noises in the reproducing system. This "machine" noise level may be noticeably lower than when the tape is in motion, even during the quietest passages in the program. The increase in noise level experienced when the tape is restored to motion is ordinarily attributed to "tape noise" and is looked on as inherent in the particular tape used.

However, the above analysis is an over simplification of the tape noise problem. Even excepting the possibility that the noise originated in the program material previous to recording, there are a number of other factors involving both the machine and the tape, which affect the tape noise level.

It is well known that the noise present during strongly recorded portions (modulation noise) is much greater than that occuring during periods when there is no recorded signal (background noise). Since this modulation noise varies with signal intensity, it is usually masked by the signal and therefore goes unnoticed.

However, if the modulation noise is sufficiently intense, it may be heard in the background of the recorded program. This is particularly true in the case of sustained tones or sine wave test signals. While modulation noise is perhaps not the most serious problem in magnetic recording, it most certainly deserves attention in any study of tape noise.

Surprisingly enough, two of the most troublesome forms of modulation noise are not magnetic in origin at all, but arise from mechanical considerations. They are frequency modulation noise and drop-out noise.

FREQUENCY MODULATION NOISE

The tape is usually driven past the recording heads by a mechanical drive system similar to that illustrated in Figure 1. The free span of

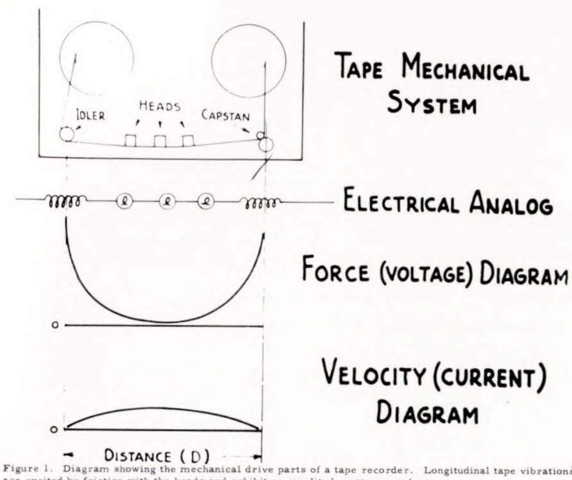

Figure 1. Diagram showing the mechanical drive parts of a tape recorder. Longitudinal tape vibrations are excited by friction with the heads and exhibit an amplitude pattern as shown.

tape between the capstan drive and the idler roller represents a highly resonant mechanical body which is easily excited into longitudinal vibration by friction as it slides over the heads. The resultant fluctuations in tape motion cause frequency modulation of the recorded signal which may be audible as noise.

This type of noise is quite easy to demonstrate by recording a sine wave tone of about 3 to 5 KC and listening for the background noise. It can be verified that the origin of the noise is motion flutter by placing a small roller in contact with the tape near the point of contact with the recording or reproducing head. In most cases a sharp drop in background noise results, and the signal is noticeably clearer.

While the small amount of FM noise present in most recording systems is not usually a problem on program material, an abnormal condition such as a sticking idler, or the tape binding in the guides may greatly increase this effect and cause it to become objectionable.

DROP-OUT NOISE

It is well known that anything which momentarily interrupts the intimate contact between the recording heads and the tape usually causes a corresponding momentary reduction in signal intensity. This interruption may be caused by an irregularity in the tape coating itself, but it is more often caused by dust and other contaminants. In some cases, a small dent in the tape can cause a drop-out. Almost without exception, a defect of this sort will cause a click or pop to appear in the recording due to the sharp drop in signal.

There is an important distinction between these noises and background noise in that, if a non-magnetic drop-out happens to occur in the erased tape, there will be no resultant noise pulse.

MODULATION NOISE CAUSES

The conventional modulation noise is caused by rapid fluctuations in signal amplitude. These are believed to result from local disturbances of the recorded magnetization in the tape due to (1) the fact that the coating is composed of small, discrete particles rather than a continuous phase; (2) small structural defects in the coating, such as agglomeration and the like, and (3) gross variations due to the coating process.

The noise contribution of the latter effect is usually quite negligible because of the long wavelengths involved which represent sub-audible frequencies in most systems.

The particle size effect seems to be rather inherent in the nature of magnetic materials for even if a "continuous" magnetic medium such as a metallic plating were employed, the inevitable magnetic domain structure would result in some considerable degree of "graininess"

This fact has been borne out by experiences with metallic wire, the noise problems of which are well known.

It is in the microstructure of the magnetic coatings that the greatest strides have been made in the reduction of noise in magnetic tapes. This is illustrated in the DC noise spectra of Figure 2.

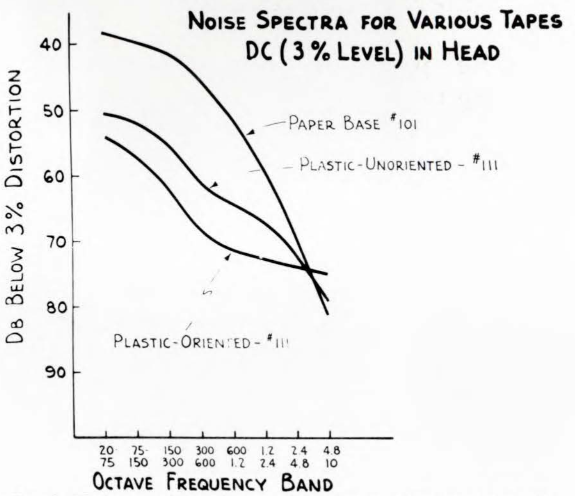

Figure 2. DC noise spectra for paper base tape and plastic base tapes with and without particle orientation. Tape speed 7.5 ips. NARTB playback equalization.

These curves were made on a standard audio recorder at 7.5 ips speed using normal recording bias. A DC current corresponding in amplitude to the RMS value of a 3% distorted signal was also introduced in the head winding to simulate the effect of a recorded signal.

The resulting playback signal was passed through an amplifier equalized to the NARTB curve and measured on an octave band filter. The readings for the various octaves (indicated on the abscissa) were plotted as a "spectrum". The octave band filter method obviates many of the difficulties normally encountered in measuring tape noise with a sharply tuned wave analizer.

Early tapes manufactured in this country employed a paper base which, owing to the porous and fibrous surface, were a rather poor support for a magnetic coating. The coarse microstructure of coatings on paper gives rise to the high modulation noise level noted in Figure 2.

The next significant advance came with the introduction of plastic film base. It can be seen that early acetate base tapes with unoriented coatings were some 10 db improved over the paper tape. It is interesting to note that noise in the highest frequency bands actually increased in going from paper to plastic base, presumably because of the improved head contact and playback resolution.

Since about 1950, particle orientation has been employed to reduce the modulation noise level and increase the sensitivity of magnetic tape. The decrease in modulation noise averages about 5 db for oriented tapes as shown in Figure 2.

Thus far we have dealt only with modulation noise which appears when signals are recorded on the tape. The problem of background noise is perhaps of much greater concern in magnetic recording. In the absence of any recording on the tape, noise in the system is, of course, much more noticeable.

The best of current theories on tape background noise indicates that it is due principally to the random orientation of the spontaneously magnetized domains in the tape. In the usual case, these domains are actually the particles of magnetic oxide in the coating. There is much experimental evidence to corroborate this theory.

The erased noise spectra of Figure 3 apply to the same three

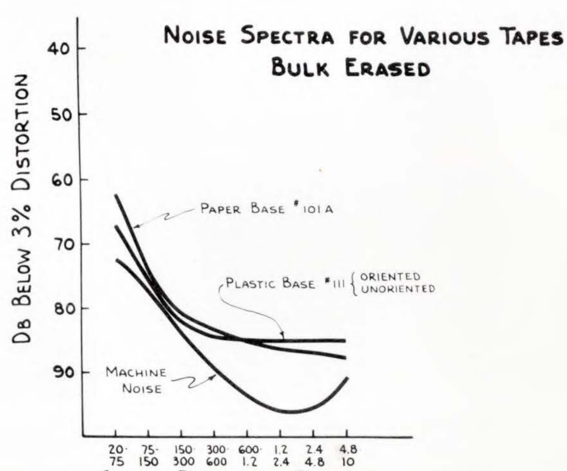

Figure 3. Bulk erased noise spectra for the same tapes as in Figure 2. The machine noise (tape motion stopped) is also shown.

tapes of Figure 2, and it will be seen that, although the paper base tape, the unoriented plastic base tape and the oriented plastic base tape all have widely different modulation noise spectra, the erased noise levels are remarkably similar. This strongly suggests that irregularities on a size scale larger than that of the particles do not influence the background noise. Incidentally, the identical type of oxide material was used in each of these examples.

ERASURE PROBLEMS

The above experiments were conducted with bulk erased tape, and although we have no concrete evidence to indicate whether or not the tapes were really neutralized, this process yielded the lowest noise level of any method tried. Unfortunately, the degree of erasure attained in these samples is very seldom achieved in actual use of tape on practical devices. Even the use of a bulk eraser does not assure that tapes will be properly erased. Only after several trials with the noise eraser (during which it was determined that the maximum permissible speed of the tape through the erasing field is only about 1 inch per second) were consistently low noise levels achieved.

The matter of preventing the tape from subsequently becoming magnetized requires some considerable care. The most frequently encountered troubles involve residual magnetization in the heads and guides. These are well known offenders, and the practice of periodic demagnetization of heads and other machine parts is well established in the industry. However, for the highest quality work, it would be well to check these very carefully.

One quick test for a magnetized playback head is to turn up the playback gain to maximum and tap the head gently with the fingernail, or the wooden part of a pencil. If a click is heard in the play channel, the head is magnetized and is responding to magneto strictive modulation of its own field.

Another quick test for playback head magnetization is to "play" a paper leader tape across the head and listen for magneto strictive noise as described above. Other parts of the machine can be tested by passing a few inches of bulk erased tape over the part and comparing the relative noise levels. By application of these tests, it is often discovered that the method being used to demagnetize heads and guides is not accomplishing its purpose, and other techniques can be tried.

The problem of adequately erasing tape and preserving the zero signal portions in a neutral state during recording are not easily solved. This is illustrated in the noise spectra of Figure 4. The same

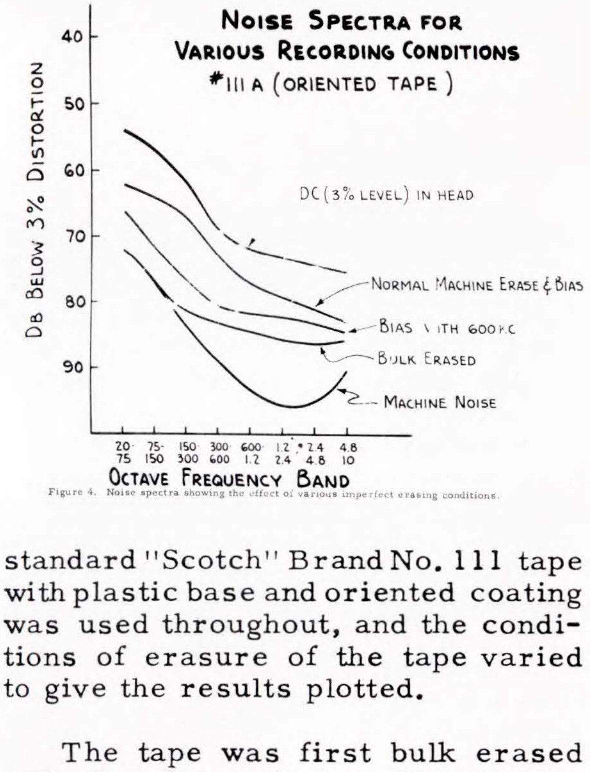

Figure 4. Noise spectra showing the effect of various imperfect erasing conditions.

standard "Scotch" Brand No. 111 tape with plastic base and oriented coating was used throughout, and the conditions of erasure of the tape varied to give the results plotted.

The tape was first bulk erased and played on the machine to determine the "lowest" background noise level. The tape was then erased and biased on a properly adjusted commercial recording machine (with no input signal and the gain turned back to zero) and the noise level was seen to rise about 10 db.

Upon further investigation of this phenomenon, it was determined that both 60 cycle and 100 KC bias frequency were recorded on the tape.

The 60 cycle recording was audible and could be easily verified by speeding up the tape. Incidentally, the application of only the erasing function (recording head disconnected) also resulted in the recording of some 60 cycle signal. It was suspected that the 60 cycle signal was coming through as a modulation on the bias-erase signal.

Recent advances in the art of video recording indicate that much shorter wave lengths can be recorded than formerly supposed. Moreover, short wavelength magnetization may actually be recorded in the tape without necessarily being detected because of limitations in the reproduce head.

In order to verify the fact that the 100 KC bias was being recorded, an external bias source of 600 KC was also tried. This lowered the noise level by some 4 db, indicating that some improvement could be gained by going to a higher bias frequency. Some 60 cycle signal was recorded, however, in spite of precautions taken in the selection of a push-pull oscillator and amplifier for the 600 KC source.

It is interesting to note that in the course of these experiments, a simple test was devised to detect the presence of DC (or long wavelength) magnetization in the tape. If the tape is torn through (to eliminate the possibility of inadvertently magnetizing it from a razor blade or scissors), and the end drawn past the reproduce head, an audible "thump" will be heard in the speaker if there is any DC or long wavelength magnetization in the tape.

This is due to the concentrated magnetic pole which appears at the end of the torn tape. The tape must be held against the head with the finger or a pressure pad to maintain contact to the very end. The indication from long wavelength magnetization (i.e. 60 cycles having a wavelength of 1/4" at 7.5 ips speed) varies, of course, depending upon the exact location of break with respect to a recorded cycle.

The upper curve of Figure 4 shows the effect of a considerable amount of DC magnetization in the tape such as might be caused by a leaky coupling, condenser or a very bad bias wave form. It is interesting to note that the noise output of the tape may vary by as much as 20 db depending upon the conditions under which it is recorded. It is also apparent that extra precaution in setting up the recording equipment may be well rewarded in terms of consistently low noise level recordings.

In summary, it seems apparent that at the present state of the art, the tape quality factors which bear on the noise question are primarily those affecting modulation noise. It would also seem that owing to the difficulty of obtaining ideal erasing and recording conditions, the lowest possible noise levels are seldom achieved in practical equipment.

Therefore, progress in achieving lower tape noise can come only through the concerted efforts of machine manufacturers, tape manufacturers, and tape users.