Sound Talk®

Scotch Magnetic Tape

Volume I
No. 1
1968

DESIGN CONSIDERATIONS TO INSURE INTERCHANGEABILITY OF RECORDING TAPE

As the variety of magnetic recording tapes increases, questions are being asked about tape similarities and differences. What are the basic differences between the popular types of tape? Is it possible to interchange the different types of tape without sacrificing performance? How can I achieve maximum performance from my recording system using a specific tape?

Because of the large variety of professional and home recording systems, each of them built to individual manufacturing specifications with different settings and adjustments, it would be impossible to list all the specific differences for each system. Quality magnetic recording tape is manufactured to established specifications and its performance is predictable and easily measured. Reviewing some of the individual properties and characteristics of recording tape will show us what the tape is capable of reproducing with specific inputs. Observing some of the similarities and differences in performance will show some of the requirements for optimization of the recording system to take advantage of the individual characteristics of each tape.

For convenience this paper will cover the three most popular types of magnetic recording tape.

We will consider "standard" recording tape as a reference and will use it as a basis of comparison for the other tapes.

Classification	*Example of Commercial Number*
Standard	#111, 102
Extra-play	#150, 190 & 200
Low Noise	#201, 202, 203

TAPE PROPERTIES

Magnetic recording tape receives and retains magnetic signals from the recorder head. The thin layer of ferric oxide, coated on a polyester or acetate backing is the substance that reacts to magnetic signals. The magnetic properties of an oxide coating are the basic factors which determine the differences between tapes. Certainly, the thickness of the oxide coating, the application and purity of the oxide, particle size and orientation, and the type and thickness of the backing are all variables, but for this discussion we will be concerned with the magnetic properties. Future *SOUND TALK* Papers will explore the types of backing and the physical parameters of tape more completely as separate subjects.

The parameters which identify the fundamental magnetic differences between tapes are the intrinsic magnetic properties of Coercivity, Retentivity, and Remanence. The intrinsic magnetic properties are the measurements of magnetic flux interaction with the tape's coating; and the coatings ability to receive and retain the magnetic signal.

COERCIVITY

As a strict definition, coercivity is a measure of the magnetic flux intensity required to return a magnetic material from saturation back to zero. Practically speaking, it represents the flux intensity or magnetic field strength required to record a magnetic signal onto the tape. A high coercivity tape requires a greater flux intensity (a higher signal and bias level from the recorder head) to record on the tape. An example is low noise tape which has a coercivity measurement of 315 oersteds (a unit of measure of magnetic field strength). In comparison, standard tape has a coercivity measurement of 270 oersteds which indicates a lower flux density is required to record on this tape. The extra-play tape has an even lower coercivity of 260 oersteds which shows that this tape will respond to an even lower flux density level. The coercivity of a tape is a function of the basic oxide particles used to form the dispersion that will ultimately become the coating. Coercivity, therefore, is a measure of the magnetic field strength required to establish magnetism in the coating.

RETENTIVITY

Now that we have magnetized a section of tape with a signal from the recorder head, the next tape parameter is concerned with how much of the signal, in terms of magnetic strength, is retained in the tape coating the instant it leaves the influencing field of the recorder head. This is known as Retentivity; which is the measurement of the number of flux lines (or gauss) per square centimeter of the coating cross section (width of tape and the coating thickness).

Although some tapes respond to a magnetizing signal output more readily than others, they all will retain the resultant magnetic impulse indefinitely. Retentivity is primarily a magnetic property of the coating dispersion (particle size, density, and composition) without reference to the tape size, and it varies with the particular coatings used for recording tapes. A typical retentivity measurement for standard tape is 920 gauss (a unit measure of magnetic induction or quantity value of magnetic flux). The dispersion used for a low noise tape has a retentivity of 790 gauss which is lower than standard tape. The extra-play tape has an extremely high retentivity of 1120 gauss. Each dispersion used in the manufacture of the three basic tapes has a different value of retentivity. This value however, defines one of the properties of the dispersion before being coated onto a backing. A more meaningful measurement to the user would take into account the result of applying the dispersion in a given thickness to a particular width of backing. Since the majority of recorders use a ¼" wide tape, the industry developed a parameter with the ¼" as a constant. This is known as remanence. Since the tape width is a constant, the two immediate variables are coating thickness and dispersion type.

REMANENCE

Remanence is the actual magnetic signal retention as applied to a specific tape cross section. For our purposes, we will regard remanence as the induced magnetic flux remaining in a ¼" wide tape after a longitudinally applied field is reduced in intensity from 1000 oersteds to zero. This is explained simply by saying that a ¼" wide tape will have retained the recorded magnetic signal and will exhibit a magnetic field of its own. The remanence property therefore, is what the playback head is magnetically exposed to.

As previously shown, the retentivity of the three basic oxide dispersions are all quite different. From this, one might expect different results in terms of playback. But, by carefully controlling the application of the coating, the remanence value can be established at a desired point. To assure proper interchangeability of the three tape types, the coating variables are structured so that the remanence value is the same for all three tapes. EACH OF THE THREE TAPES HAVE A REMANENCE MEASUREMENT OF 0.64 FLUX LINES PER ¼ INCH WHICH ASSURES A MAGNETIC COMPATIBILITY AND PLAYBACK INTERCHANGEABILITY BETWEEN ALL OF THE THREE TAPES. While the control of the remanence value allows the tapes to be interchanged, the differences in coercivity and oxide retentivity require slightly different magnetic signal input levels during recording to fully exploit the abilities of the different tapes. Some of the differences that the tapes exhibit and the corresponding machine adjustments for maximum performance will be shown in the following paragraphs.

TAPE CHARACTERISTICS

The differences in the magnetic properties are reflected in the particular characteristics which each tape exhibits. Assuming a tape speed of 7.5 ips, some of the characteristic differences can be easily shown in the frequency response curve for each tape (Figure 1). These curves were generated on a good quality professional machine and show the difference in both the low and the high frequency response. To establish these response curves, the recorder was adjusted for maximum performance using the standard type of tape. The record level, bias, and record equalization were set to achieve the best response possible from this machine with standard tape. The individual magnetic properties of each different tape became apparent in the differing output and response when each is run without readjusting the machine.

RESPONSE

The ideal response curve would assume a straight line from the low to the high frequencies, but is limited by the recorder electronics. Note that the standard tape (which had the optimum settings) is nearly level until

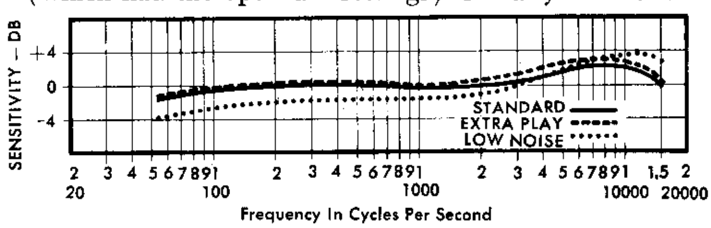

FIGURE 1. FREQUENCY RESPONSE — TAPE AND RECORDER

the high frequency roll off. The extra-play tape, with slightly lower coercivity, shows a slight increase in high frequency response but has a sharper roll off. The high coercivity, low noise tape shows a slight decrease in sensitivity at low frequencies but has a prominent increase at the high frequencies with less roll off. Figure 1 shows only a comparison of typical response for the three tapes, but from our discussion of coercivity, one will remember that each tape required differences in the input signal level. The desired frequency response for either high or low frequencies, *for each particular tape,* can be achieved by changing the bias and record equalization levels. Variations in the bias and equalization settings and the corresponding changes in output will be shown in later paragraphs.

It is possible to design a recording tape for maximum output at either high frequencies (short wavelength) or low frequencies (long wavelength) by formulating different coating dispersions. Variables would be coating thickness, coercivity, and retentivity. In the design of Audible Range Magnetic Tape the challenge lies in the ability to produce a tape that is capable of uniform output over the broad range of wavelengths from less than ½ mil to more than 30 mils. A factor which can affect response is the smoothness of the surface coating. A very smooth coating surface insures maximum contact with the recorder head therefore allowing a maximum of magnetic signal changes to interact on the tape. Minute variations in the coating surface, as found occasionally in low quality recording tapes, will create variations in the head-to-tape contact which will change the magnetic flux level and will affect the playback signal from the tape to playback head.

While discussing tape response, it would be well to mention that recording tape sees the recording in terms of wavelength and not frequency. This is understandable when one considers that there are two variables that affect the recording process. One is the frequency that is being recorded, the other is the relative speed of the tape passing the recording head. Suppose that a tape is travelling at 7½ ips, and that a 7.5 kHz signal is being recorded. This means that 1000 cycles of information are packed on each inch of tape. The distance encompassed by each complete cycle is 1/1000 inch. The wavelength of this recording is 1 mil.

Expanding the previous example, we find that doubling the frequency 15 kHz will cause 2000 cycles of information to be placed on each inch of tape. This renders a recorded wavelength of ½ mil, as each individual cycle takes up .0005 inch of tape. If we reduce the tape speed to 3¾ ips, and leave the frequency to be recorded at 7.5 kHz, we once again will be recording a ½ mil signal. If both the frequency and the tape speed are doubled, the tape will see no change in recorded wavelength.

Since the information is recorded on the tape coating magnetically, it could be viewed by applying a fine metallic powder to the tape and viewing it with a magnifying glass (Figure 2). Notice the variations in magnetic pole density, the low frequencies are widely spaced (long wavelength) and the high frequencies are packed very close together (short wavelength). When recording at the short wavelengths, the coating which becomes *magnetized for each cycle* of information; must faithfully establish each set of poles without disturbing the preceding pole. When the magnetic poles are very close together the coating's ability to receive and hold magnetization (coercivity and retentivity), without influence from adjacent magnetic fields is very important. The oxide dispersion must be carefully prepared and applied to assure correct coating caliper, coating density, coating surface smoothness, as any variations will create changes in the magnetic properties and the sensitivity.

FIGURE 2. MAGNETIZED PORTION OF RECORDED TAPE

SIGNAL TO NOISE

Another important tape characteristic is the signal to noise ratio. Tape noise is strongly influenced by the particular type of oxide coating. Specially designed low noise oxide and precise manufacturing control allows the production of tape with a greatly improved signal to noise ratio. A comparison of standard and low noise tape shows a difference of 6 db at 500 cps to the upper limits of the audible spectrum (Figure 3). Low noise tape, as you recall from earlier paragraphs, has a high coercivity coating. This is a basic property difference of the special low noise oxide. Tape noise is a very low level signal and may be masked by the recorded sounds but does become critical during quiet musical passages. This extension of the dynamic range is important for full fidelity enjoyment. For maximum purity of reproduced sound, the use of low noise tape is recommended. In addition to the benefit of noise reduction, the coating properties of this tape give greater fidelity and response in the high frequency region of recording.

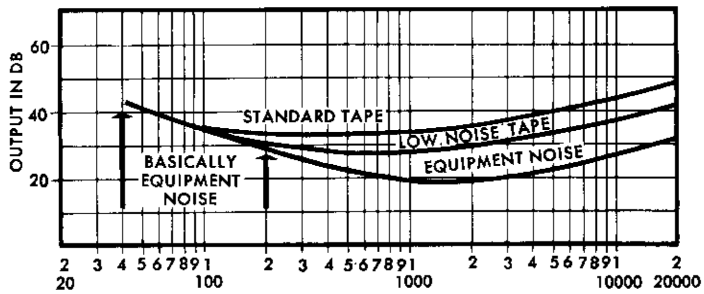

FIGURE 3. NOISE BY ⅓-OCTAVE BANDS

PERFORMANCE

Because of the different coatings available, magnetic tape is manufactured to meet a variety of recording requirements. Although the Audible Range constitutes a challenge because of the frequency bandwidth, an important factor is the production of tapes which are compatible to each other on the large variety of recording systems available. As previously shown, each particular type of tape has its individual magnetic properties which respond, in terms of maximum performance, to specific input levels.

BIAS

Figure 4 shows a typical example of optimized bias settings for each of the three tapes. Some of the recorders now in use have a fixed bias level which cannot be changed, but the majority of them offer some control over bias level. As part of the basic design, each recorder manufacturer establishes a bias level which is adjusted for a particular recording head and a laboratory tape. On any recorder care should be taken in making bias adjustments, and the recommendations of the recorder manufacturer should be followed. Professional recorders have specific adjustments for bias and equalization, and these adjustments can be made with more ease. Because of the large variety of recorders available, each with their own specifications, no attempt has been made to indicate bias level on the graph in Figure 4 in terms of actual bias current.

Bias level is indicated as a percentage of that which is proper for standard tape; the standard tape value being 100%. The percentage value relationship will hold generally true for all recorders. In a comparison of the bias current vs. output curves, note that the output in db is the same for each tape, but notice also the difference in bias level requirements. The high coercivity low noise tape requires additional bias for a given output in comparison to the standard and extra-play tapes which require less bias.

BIAS AND FREQUENCY

As can be seen from the graphs in Figure 4, the recommended peak bias for a given tape type is that point where the 2 curves cross. With standard and extra-play tape as bias is decreased below the recommended peak, the short wavelength output will be increased but the long wavelength response will suffer. If the bias is increased, the long wavelength response will be improved at the expense of the short wavelength. It is interesting to note that the high coercivity coating used in the low noise tape has essentially the same bias requirement for both low (15 mil wavelength) and high (1 mil wavelength) frequencies. This tape, although requiring greater input drive, allows a bias setting which compliments both the high and low frequencies.

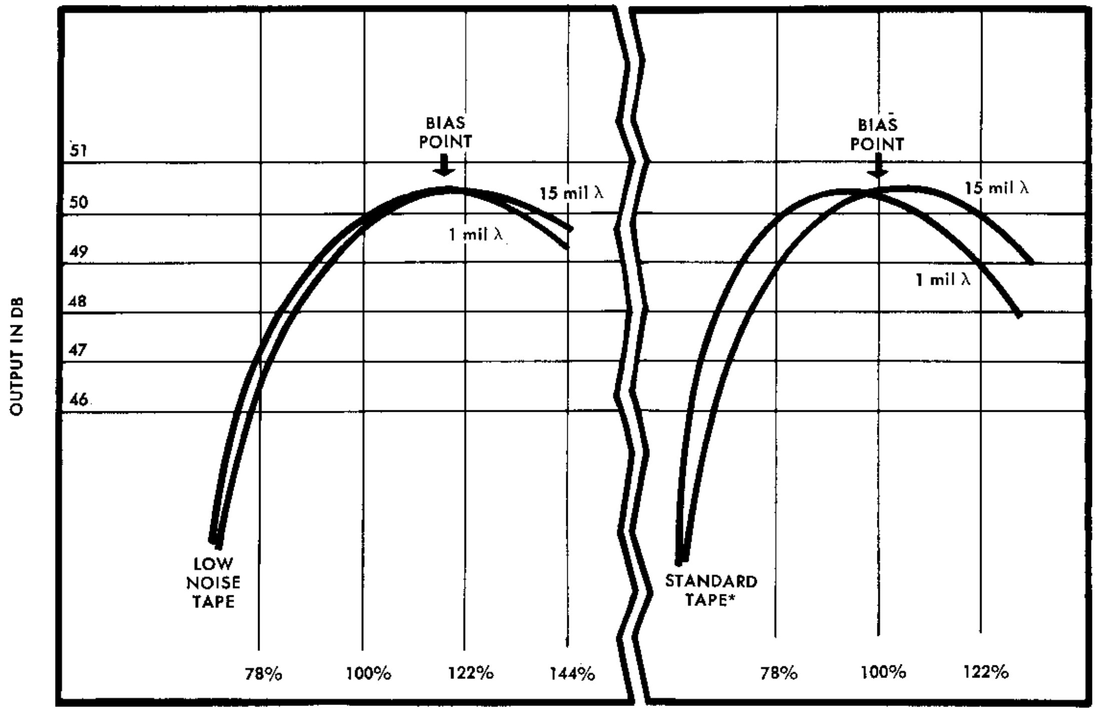

FIGURE 4. BIAS AND WAVELENGTH RESPONSE

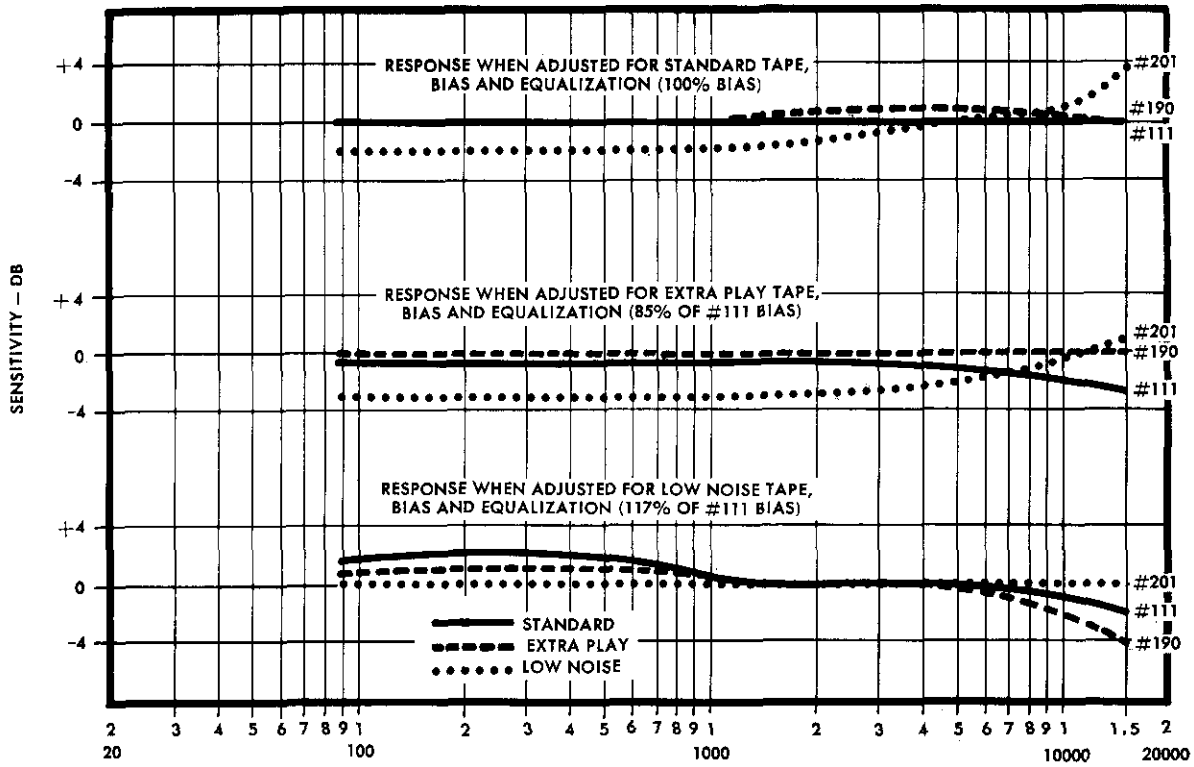

FIGURE 5. NORMALIZED TAPE RESPONSE CURVES

RECORDER OPTIMIZATION

Recalling the discussion of magnetic properties, it was stated that the coercivity measurement represents the flux intensity or magnetic field strength required to record a signal on a section of tape. To maintain a specific output level, a high coercivity tape requires a greater input signal level and, in comparison, the lower coercivity tape requires less drive. Notice, though, that in all cases the bias requirements for a given tape type do not constitute a major change in the recording system. To compensate for the differences in tape sensitivity, the equalization settings of the recorder can be adjusted so the frequency response curve will achieve the desired overall flat response. Figure 5 shows the result of optimizing bias and equalization for each tape type and the effect this has on the other two tapes. To achieve perfect results these can be adjusted, but because the amount of change in record level, bias, and equalization is only minor, the average outputs from the different tapes do not vary widely from each other. The three tapes can be interchanged without any severe decrease in overall performance.

Flat response can be attained, within the limits of the recorder amplifiers, with specific input settings. As shown in Figure 5, the plotted sensitivity range for the different tapes is about 3.5 db. The differences in bias and equalization for flat response for a specific tape will create slight response differences for the other tapes. The response curves exhibited by each tape show that a compromise setting can be used so that all the tapes will produce a similar and relatively flat response curve. The recommended compromise setting for tape interchange is at a bias setting of the standard tape (100%) or just slightly higher. With a bias setting of 105 to 110%, the three tapes will achieve a similar response with less than 1.5 db difference. With this compromise setting, the equalization can remain at a point that was proper for the standard tape.

SUMMARY

The three most popular types of magnetic recording tape do exhibit individual magnetic properties which are a function of the oxide dispersion forming the tape coatings. For maximum performance with a particular tape, the recording system can be adjusted for optimum bias, record level, and equalization. Because the individual differences are not extreme, a compromise setting can be used so the tapes can be interchanged without appreciable loss in performance. By using a recording tape which is properly designed and manufactured, an increase in overall performance can be attained without sacrificing tape-to-tape and tape-to-recording system compatibilities.

If at any time additional information on this topic is desired, it is available by simply writing to:

Technical Service
Magnetic Products Division
3M Company
3M Center
St. Paul, Minnesota 55101

Additional copies of this paper are available from your 3M representative, or by writing to the address above.

Magnetic Products Division 3M COMPANY

LITHO IN U.S.A. WITH 3M OFFSET PLATE.