THE TAPE HEAD RELATIONSHIP IN MULTI-TRACK RECORDING

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Presented at the
11th Annual Meeting
Oct. 5-9, 1959

Preprint No. 117

Member Price - - - - - - - - $0.50
Non member Price - - - - - $0.85

AN AUDIO ENGINEERING SOCIETY PREPRINT

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This paper evaluates the basic tape-to-head relationship that applies in multi-track recording in comparison to that relationship in monaural operation. It studies such factors as frequency response, crosstalk, signal-to-noise ratio, distortion, and tape drop-outs, and shows that the only significant difference that occurs in multi-track recording is a small deterioration in the signal-to-noise specifications. The mechanical considerations of azimuth alignment and gap-to-gap spacing are also discussed.

The basic tape-to-head relationships in multi-track recording are much the same as in monaural full track recording, so this paper will deal mainly with the differences that occur in multi-track or narrow track systems.

Magnetic tape consists of a thin layer of finely divided iron oxide particles coated on a layer of plastic tape. The oxide is usually between .0003 and .0005 inch thick and is composed of a multitude of tiny magnets whose directions can be oriented by the field of a recording head. Thus, the record head leaves a magnetic pattern on the tape, and is an excellent means of storing electrical signals.

As the tape passes by the playback head, the flux field surrounding the tape threads through the coils of this head and reproduces the electrical signals. The magnetic pattern can be removed by an erase head which is energized with a high frequency bias current.

The head is constructed by winding a coil of fine wire on a high permeability magnetic core shaped in the form of a ring. The core is divided in two halves with a gap formed by inserting a very thin non-magnetic spacer between the halves. The tape is then made to contact the head at this gap, both for recording and reproducing.

In multi-track recording the width of each head is always smaller than the overall width of the magnetic tape. This introduces some differences, since there is magnetic tape on one or both sides of the head. This material may or may not be magnetized with signals. (Of course, if there are no signals, there are no problems.) Let us first consider the effects produced on overall system frequency response if a signal is present. A practical situation occurs when a full track standard frequency response tape is reproduced on a multi-track head. It is observed that the low frequency response is increased by an amount depending on such factors as tape speed and whether the narrow track playback head is at one edge of the tape or nearer the center of the tape. This effect is not present when reproducing recorded tracks that are the same width as the reproduce head and which are centered directly on the reproduce head. It is caused by the fringing magnetic field from the area of the tape that is adjacent to the playback head. As the recorded wavelength becomes longer, the fringing field increases and induces more voltage in the playback head, causing the recorder to seem "hot" as the frequency decreases below about 500 cycles. This effect can amount to approximately 2 to 5 db at 50 cycles, again depending on the type of recorder. Therefore, caution should be exercised when using full width standard tapes on narrow track recorders. Narrow track standard tapes would eliminate the effect, but it is not feasible for a manufacturer to supply standard tapes for all the various types of multi-track recorders manufactured, so that only full track tapes of this type are available.

This is not a practical problem in magnetic tape recording because of the standard practice of adjusting the playback amplifier equalization to a standard curve. The recorder will then be flat at the lower frequencies, since there are no practical difficulties with tape and heads at the low frequency end of the spectrum. The overall system response can then be checked at the low frequencies by making a response run on the recorder being tested, since its record head will record the same width track as the playback head. The playback amplifier equalization should not be adjusted at the low frequencies on a full width standard tape. The fringing effects are not noticeable at the higher frequencies, so a full track standard tape can be used to test these frequencies on a multi-track machine.

The next most important factor is crosstalk. First, consider the fringing effect which was mentioned before. If a recorded track adjacent to the playback head carries a second signal, there would apparently be the possibility that the fringing flux from this second track would induce a voltage in the playback head and thereby produce crosstalk. It would also seem logical to assume that as the wavelength increased (that is, as the frequency decreased) this type of crosstalk would become worse. This line of reasoning is correct; however, the fringing field decreases so rapidly as the interfering track is spaced away from the playback head, that in the practical case where there is a small spacing between the adjacent track and the head, this type of crosstalk has completely disappeared and is not a practical problem.

Effects do arise, though, if two heads are stacked one above the other. The two coils of the heads become equivalent to a very poor transformer, and a transformer action exists whereby the current flowing in one coil can induce a voltage in the adjacent coil and produce crosstalk. On a magnetic coupling basis, this crosstalk increases as the frequency decreases.

Another source of crosstalk is through the capacitive coupling between the two heads and any associated wiring. This produces crosstalk at the higher frequencies.

Proper head construction and shielding reduce these effects to the point where crosstalk is not a practical problem in multi-track recording. Of course adequate precautions must be taken in the design of the electronic circuits, since it is possible to produce crosstalk in the electronics themselves.

The next effect to be considered is that of signal-to-noise ratio; since multi-track recording implies a track narrower than the full width of the tape, the effect of reducing track width will be discussed on the basis of signal-to-noise ratio. If all other factors remain equal, reducing the track width by one-half will produce one-half the voltage in the playback head, a reduction of 6 db. Because of the random nature of the noise produced from the tape, the noise will be reduced only 3 db. Therefore, the overall signal-to-noise ratio is reduced 3 db for a 50% reduction in track width. (The assumption was made here that the tape noise was the predominant noise present. If the system is limited by amplifier noise, then the signal-to-noise ratio would be decreased 6 db, but this is usually not the case.) The overall effect of a 50% reduction in track width is to degrade the signal-to-noise ratio by a factor somewhere between 3 and 6 db, usually a little over 3 db.

There is no change in distortion as the track width is reduced.

In magnetic tape recording, an effect known as drop-outs occur when the oxide of the tape is not in intimate contact with the head. This can be caused by a speck of dirt on the tape or by a hole in the oxide layer. In either case, the signal drops out as this defect passes the head. The bigger the particle or hole, the greater is the reduction in signal level. These effects are usually of very short duration and primarily affect the high frequencies. They are not especially noticeable in audio recorders. Reduction of track width increases this effect since a given size particle will remove a larger percentage of the narrower track from contact with the head. Modern day tapes have fewer such defects than in the early days of magnetic tape recording.

The azimuth alignment of narrow recording tracks is not as critical as in full track recording; as the track width is reduced, the azimuth alignment error can be proportionately larger. This azimuth alignment error can be caused both by misadjustment of the head and by variations in the way the tape passes over the heads. Azimuth alignment affects the high frequency response of the recorder, and so narrow track recording is quite steady at the high frequencies in regard to azimuth alignment and tape weaving across the heads.

Flutter is the same in a multi-track recorder as in a full track recorder, especially if all the heads are located vertically in one stack. It is conceivable that if the heads are in two or more stacks, there might be some flutter effect in the phase of the signals in the various head stacks. This is not a practical problem in audio recorders.

Care must be taken in the construction and wiring of a multi-track head assembly to make sure that all channels are in phase, since the reversal of connections to one head would make that channel 180 degrees out of phase with all other channels. More than one head stack is often used in multi-track recorders where more than two or three tracks are involved. This is done to produce low crosstalk head structures with very close track spacing on the tape. In this case the gap-to-gap distance between the record head stacks must be identical to that spacing in the playback head stacks in order to prevent phase shift of the signals on adjacent tracks. This can be accomplished with great accuracy.

To summarize, the head-to-tape relationship in multi-track recorders is quite similar to that of full track monaural recorders. The greatest difference is a slight loss in signal-to-noise ratio as the track width is decreased. Azimuth alignment is less critical, but care must be taken in the design and construction of the head assembly to prevent crosstalk. In using standard frequency response tapes on multi-track recorders, it must be recognized that the frequency response measured from such a tape will be a little "hot" on the low frequency end of the spectrum.