the discussion of the tape transport, so we will treat the first three in this portion and then follow with additional factors encountered in stereophonic recording.

Distortion

Distortion in magnetic recording is a function of both the bias adjustment and the recording level. We have already seen the effect of the bias voltage near the point of zero magnetization on the tape (see Electronic Circuits) so in this we will cover only the effect of the recording level.

To achieve a maximum signal-to-noise ratio, we wish to record at the highest possible signal level. But as we increase our recording level we will eventually reach the point where any further increase has little effect in magnetizing the tape. We have "saturated" the medium, and any additional current in the record head will simply give distortion.

In distortion caused by over-recording, the odd harmonics will stand out, with the third harmonic predominating. Our prevailing standards define the *normal recording level* as the point where there is a 1% third harmonic content of the signal, and the *maximum recording level* as the point where there is a 3% third harmonic content.

Such a standard implies that the professional user will have equipment to adjust his recorder to meet these distortion specifications. It is rare that wave analyzers or distortion meters are available, therefore the calibration is usually made by using a standard tape (see Basic Adjustments).

Signal-To-Noise Ratio

Many factors complicate the signal-to-noise problem, some of them entirely beyond any control of the manufacturer of magnetic tape recorders.

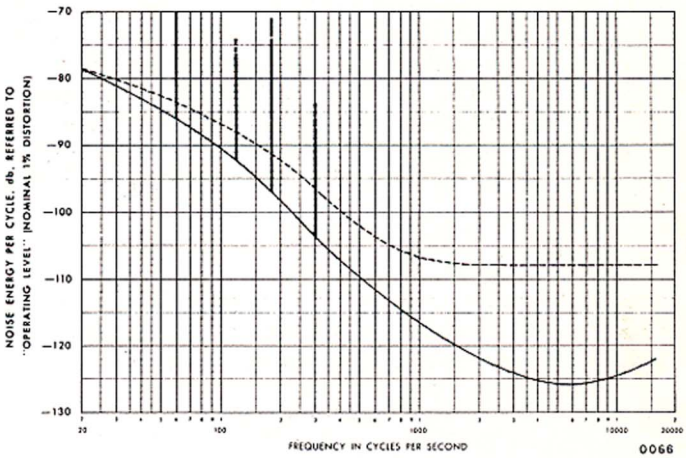
First is the tendency of both studios and "hi-fi" fans to reproduce music at a greater volume than that of the original source. This, of course, also increases the audible noise level.

Then there is the fact that the average loudspeaker is deficient in response, and directional at high frequencies. The deficient response sometimes results in the user increasing the high frequency energy electrically (with an equalizing circuit) during the recording process. This extra high frequency energy increases the problems that exist in high frequency overloading. The directional pattern at high frequencies means that, if the average high frequency energy throughout the room is to equal the energy at lower frequencies, the high frequency energy *on the axis of the speaker* is higher than that of the middle frequencies, and the audible noise level is increased. The noise coming from a small area is also more noticeable than if it emanated from a large source.

But probably the major complication is that the human ear is most sensitive to noise in the 1 to 6 kc area, and the noise below 100 cps must be very great before it is objectionable. The usual meter indication consists largely of the low frequency component of noise, which is inaudible; it is for this reason that a recorder which tests quieter than another on our normal measuring devices sometimes sounds noiser when we actually listen to it. (Significant noise measurements, therefore, can be achieved only by using a weighting network with an inverse response to that of the human ear.)

But these are things we cannot control. What *can* we do to get the best signal-to-noise ratio?

Our major limiting factor today is the magnetic tape. Our "system noise" (which includes the tape) is from 8 to 10 db higher than our "equipment noise". A theoretical study has shown that an improvement in the noise characteristic of the tape should be possible by decreasing the size of the oxide particles, and tape manufacturers are experimenting with this theory.



Typical spectral noise density of the system (dash line) and the equipment (solid line). Readings taken on an Ampex full track Model 351 at 15 ips. Noise spikes occur at 60, 120, 180, and 300 cps on both curves (that at 60 cps rises to —55 db and —57.5 db respectively). System noise taken with tape in motion, equipment noise with tape stopped.

Assuming a given tape noise, we are mainly concerned with track width, track spacing (in multichannel equipment), tape speed, and equalization.

Track Width

Where the maximum signal-to-noise ratio is necessary, wide tracks are desirable, but there are certain limitations. Economically, the amount of tape used, and therefore the cost, increases roughly in propor-