The EOB Tape of June 20, 1972

Report on a Technical Investigation

Conducted for the U.S. District Court for the District of Columbia

by the Advisory Panel on White House Tapes

May 31, 1974

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Technical Note 4

PHASE CONTINUITY AS A TEST OF RECORDER STOPS AND STARTS

Listening to the Evidence Tape, the Panel was able to detect occasional clicking sounds within the buzz section. We examined these clicks visually by means of magnetic development (explained in Technical Note 1), and found magnetic marks corresponding to the erase and record heads of the Uher 5000 recorder. Such marks strongly suggested that the recording of the buzz was not done as one continuous event, but rather in several sections involving stops and starts of the recorder.

If the 18.5 minute buzz section were in fact recorded as a single continuous piece, the 60-Hz signal that originated in the AC power supply should be recorded as a signal that is continuous in phase over the entire 18.5 minute section. We conducted two kinds of tests to find out whether the phase was continuous. The first kind of test provides a comparison of the signal waveforms immediately before and after an event such as a mark made by a record head. The second kind of test offers a more sensitive means of detecting phase discontinuities and provides a direct measure of the amount of phase shift. However, it obscures changes of very short duration because the instrument used takes some time to recover from a sudden change in the input signal.

The first kind of test consists of direct observation of the 60-Hz waveform on an oscilloscope screen. We used a Tektronix Model 545 oscilloscope for the display and photographed the screen to obtain pictures of the waveforms in the vicinity of transient events on the tape.

As the accompanying illustrations show, we obtained pictures of the waveform just before, during, and just after the occurrence of the transients that correspond to the magnetic marks.

In making each picture, we carefully positioned the waveform to put the peaks or valleys of the wave preceding the transient directly over the vertical graticule lines on the face of the oscilloscope. If the phase is continuous, then the peaks or valleys, whichever were used as the reference points, should still lie directly over graticule lines following the transient event.

The second kind of test involves the use of a phasemeter, an instrument specially designed to make measurements of this kind. The test setup is shown in this drawing:

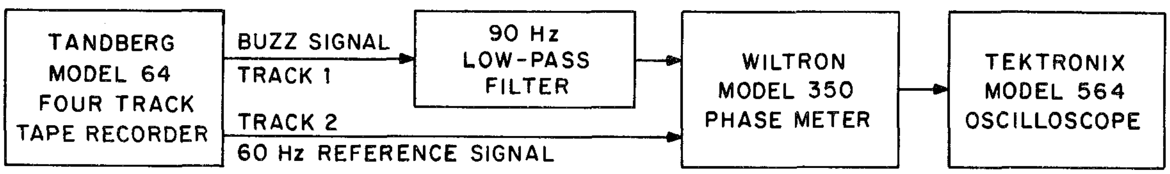


Diagram of Equipment Arrangement for
Phase Measurement Test

Using a Tandberg Model 64 four track recorder/reproducer, we recorded the buzz section of the Evidence Tape onto Track 1 of a blank tape to be used later in the phase measurement test. We simultaneously recorded onto Track 2 of the same tape a reference signal, which was obtained from a Krohn-Hite Model 4100 signal generator, and adjusted its frequency to be precisely the same as the frequency of the "60-Hz" tone on the Evidence Tape just before the event to be examined. In general the frequency of this tone would not be exactly 60 Hz, because the machine that recorded the tone onto the Evidence Tape was not running at exactly its standard speed, nor was its speed constant.

We played the test tape back on the Tandberg recorder/reproducer. The buzz signal on Track 1 was fed through a low pass filter that extracted the 60-Hz component, which was then fed into a phasemeter (Wiltron Model 350). The signal on Track 2 was fed directly into the phasemeter. The phasemeter output, which is the phase difference between the two input signals, was displayed on a Tektronix Model 564 oscilloscope and photographed. The amplitude of the display was calibrated at 90 degrees per division for measuring large phase changes, and 36 degrees per division for measuring smaller phase changes.

Figure 1 illustrates the results obtained by these types of measurements at Event Time 612 seconds. Figure 2 shows similar data at Event Times 1061 seconds and 1065 seconds. The phase discontinuities at each of these events is immediately apparent. To estimate the magnitude of a phase discontinuity, straight lines were fitted to the waveform of the phasemeter output in the regions just before and after a transient of interest. The phase discontinuity was determined as the phase difference between these lines at the start of the transient.

The table that follows presents the estimated phase discontinuity at six of the events associated with magnetic marks on the Evidence Tape. The table does not include data for Event Times 46, 275, 1041, and 1042 sec. At these events the observed phase changes coincide with a sizeable change in buzz level, so phase discontinuity cannot be taken as an unambiguous indication of recorder stops and starts at these points. However, the event at 49 sec. is included even though the level changes here, because the phase discontinuity coincides with an abrupt change in phase slope. This means that both the phase of the buzz and the speed of the recording are discontinuous at this event, which can occur only if the recorder was stopped and restarted.

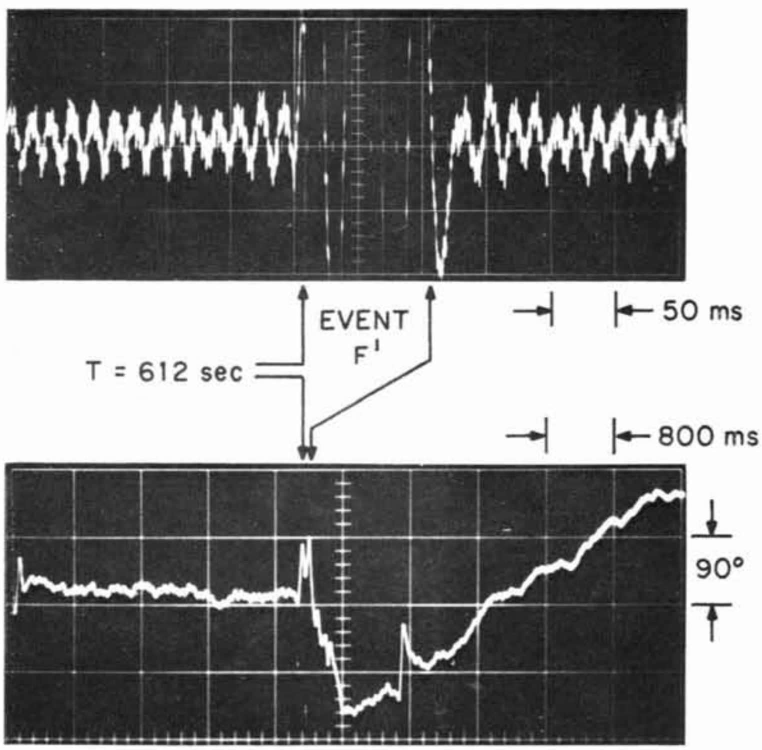


Figure 1. Results of Phase Continuity Tests on Event at 612 seconds in Buzz Section

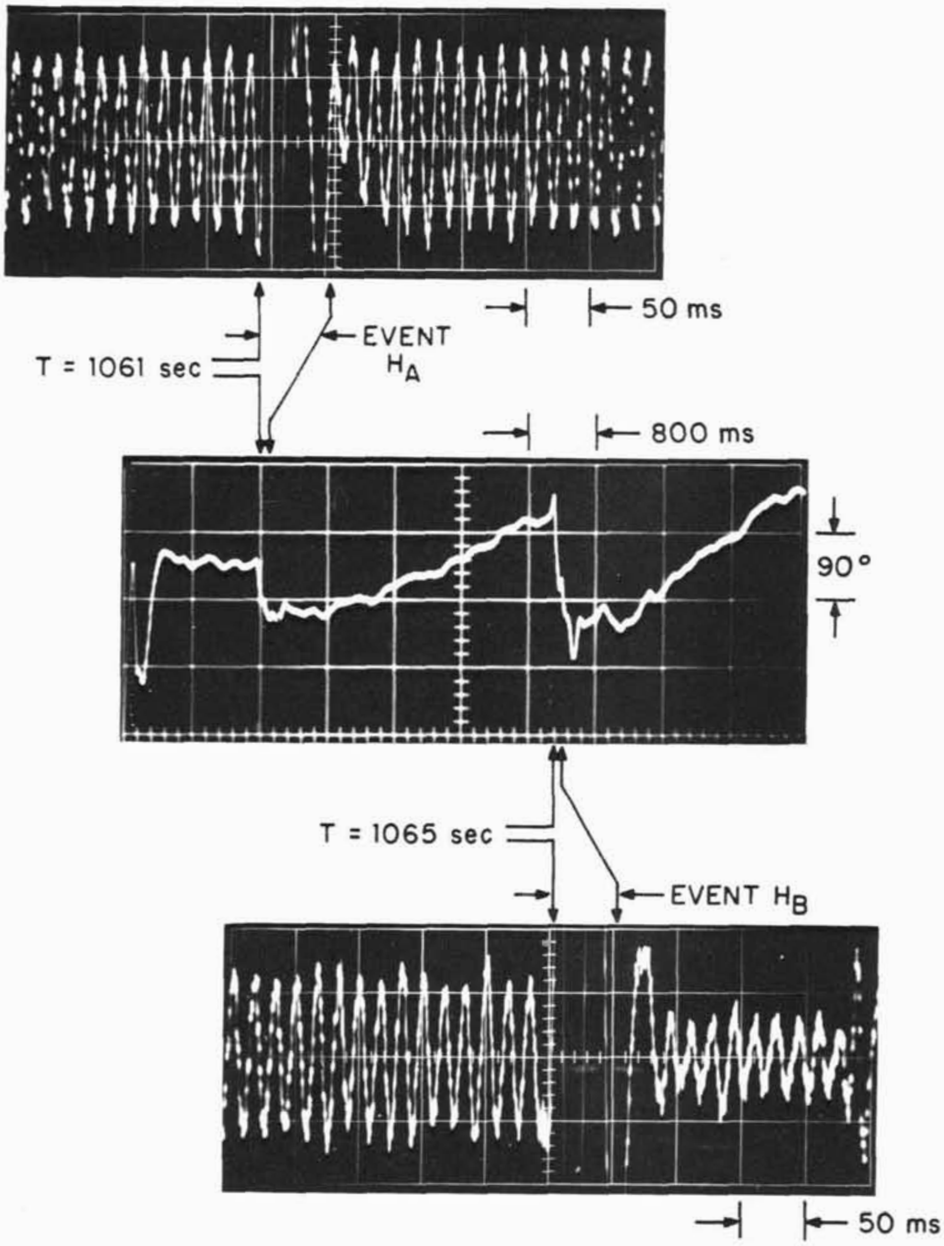


Figure 2. Results of Phase Continuity Tests on Events at 1061 and 1065 seconds in Buzz Section

Event No.	Event Code	Event Time (seconds)	Event Occurrence	Estimated Phase Change (degrees)	Comments
4	B2	49	Record-Head off	Undeterminable	No signal immediately followed the event.
			Record-Head on	160	Phase after 48.6 seconds was compared with the phase of the signal just before 48.3 seconds.
			Erase-Head off	Undeterminable	Below the resolution of the phasemeter.
5	D	155	Record-Head on	30	
7	F'	612	Record-Head off Record-Head on	150	The phase discontinuity was measured across the pair of record-head marks.
			Erase-Head off	Undeterminable	The underhum region is too brief to allow the phasemeter to settle.
8	G	684	Record-Head off Record-Head on	50	The phase discontinuity was measured across the pair of record-head marks.
			Erase-Head off	35	The underhum following the quartet was sufficiently long, 55 msec, to permit measurement of phase.
11	H_A	1061	Record-Head on	50	
12	H_B	1065	Record-Head on	180	

Table 1. Phase Changes At Six Events on the Evidence Tape

Conclusion

Since phase shifts are associated with the stop/start events listed in the table above, we conclude that the recorder was stopped and restarted at each of these points in the buzz section of the recording. The lack of phase continuity shows that the marks left by the Record/Erase head at these points could not have occurred as a result of electrical transients in the recording system while the tape was in continuous motion.

Technical Note 5

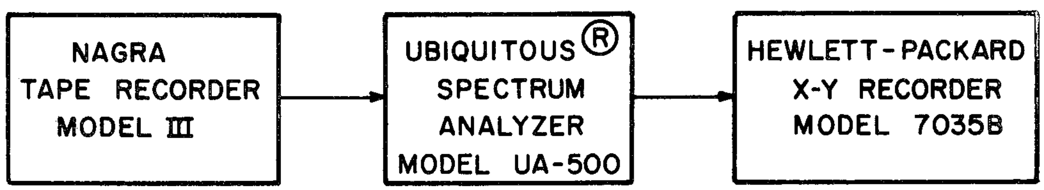
AVERAGE SPECTRA OF THE BUZZ

A person listening to the buzz section of the Evidence Tape hears a sound of harsh quality, and notices that its loudness changes at several points in the recording. However, a person simply by listening cannot determine what component sounds made up the buzz or whether the components change significantly at segment boundaries in the recording. This Technical Note describes the methods we used to determine these characteristics, presents the results we obtained, and discusses the conclusions that can be derived from these results.

To determine the composition of the buzz we used a spectrum analyzer. This device measures the frequency and amplitude of each sound that contributes to the overall sound being analyzed. The output of the analyzer is called the spectrum of the input signal. It usually is portrayed in the form of a graph in which the frequencies of signal components are indicated on the horizontal axis and their amplitudes by the height of peaks above this axis. For example, the spectrum of a pure tone, such as a whistle, will contain a single peak at a point that indicates the frequency of the whistle and will have a height that is proportional to the strength of the sound. A more complex sound, such as a note struck on a piano, will exhibit a spectrum with peaks at the frequency of the note and at the harmonics or overtones of the note. As will be seen, the buzz is a highly complex sound, consisting of more than seventy significant components.

Although the buzz seems to sound much the same throughout each section of the recording where its level is constant, the buzz actually varies somewhat from moment to moment. These variations are caused primarily by flutter in the tape motion at the time the buzz was recorded. To avoid uncertainties that these variations might introduce in the spectrum analyses, we averaged the sequence of spectra obtained over a short interval of time.

The setup that we used to obtain the average spectrum of the buzz at various points on the Evidence Tape is shown below.



We reproduced the Evidence Tape on a Nagra Model III tape recorder. Spectra of the buzz were obtained by a Federal Scientific Corporation Model UA 500 Ubiquitous Spectrum Analyzer, set to cover a 5 kHz range with a frequency resolution of 10 Hz. The individual analyses determined the frequency composition of successive 0.1-second segments of the buzz, and 128 successive spectra were averaged in the analyzer to obtain the final output, which then was plotted by the X-Y recorder.

The technique described above was used to obtain average spectra at nine points in the buzz: the start of the buzz, the end of buzz, and just before and after Events B, D, E, F', G, C, and H. For the spectra obtained after Event E and before Event C the sensitivity of the spectrum analyzer was increased by 10 dB to compensate for the approximately 10 dB decrease in the buzz level in these regions of the tape. The results of the analyses are presented in Figures 1 through 16.

The first conclusion we draw from these spectra is that the buzz is made up exclusively of harmonics of the power line frequency, 60 Hz, and that almost all of the energy is contained in odd harmonics. The harsh quality of the buzz sound probably is due to the presence of significantly strong odd harmonics up to about 2500 Hz.

The large number of harmonics present in the buzz spectrum indicates that the waveform of the buzz signal is pulselike in character. This is borne out by photographs of the waveform, such as the one shown in Figure 17. As can be seen, the buzz signal consists of a distorted 60-Hz sinewave combined with a complex pattern of narrow pulses. The spectrum components up to 300 Hz are related primarily to the sinewave. The components above 300 Hz correspond mainly to the pulses.

The average spectrum of the buzz before Event B, shown in Figure 2, is essentially identical to the average spectrum after the event, as seen in Figure 3. The same is true at Events D, F', G, and H. Even at Events E and C, where the buzz level changed by 10 dB, only minor differences are observed in the overall shape and in most of the fine details of the average spectra before and after these Events.

At a few points in the average spectra before and after Event E, shown in Figures 6 and 7, noticeable differences show up in the fine details of the spectra. However, since the speed of the tape and the phase of the signal were continuous at this event, the buzz immediately before and after the event must have been recorded by the same machine with continuous tape motion. Consequently, the differences observed in the spectra before and after Event E are not significant. Differences of the same sort are observed in the spectra before and after Event C, in Figures 12 and 13. It is worth noting that the spectra of the loud buzz after Event C, Figures 13 through 16, are almost identical to those before Event E, Figures 1 through 6, pointing toward a common source of these recorded sections of the tape.

These observations support the second conclusion, that the entire buzz section was recorded on the same machine, since recordings made on different machines would almost certainly have resulted in significant differences in both the fine details and overall shape of the spectra before and after one or more of the segment boundaries.

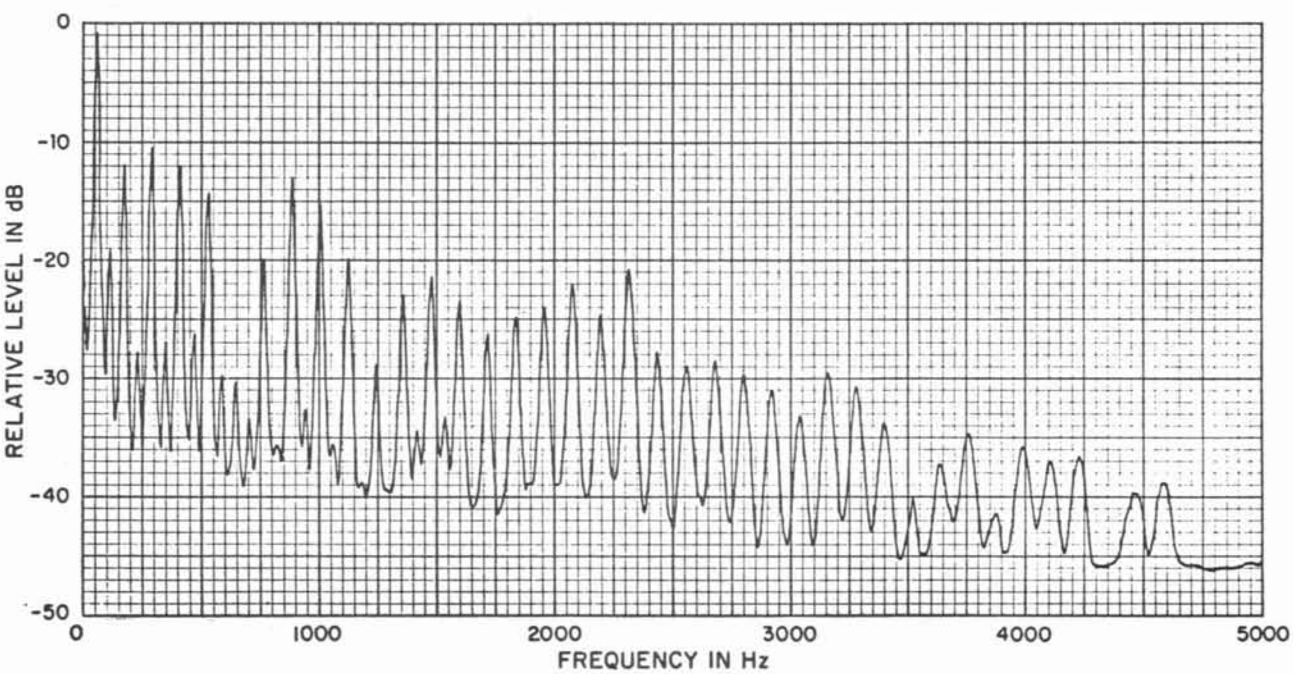


Figure 1. Average spectrum of the buzz at the start of buzz.

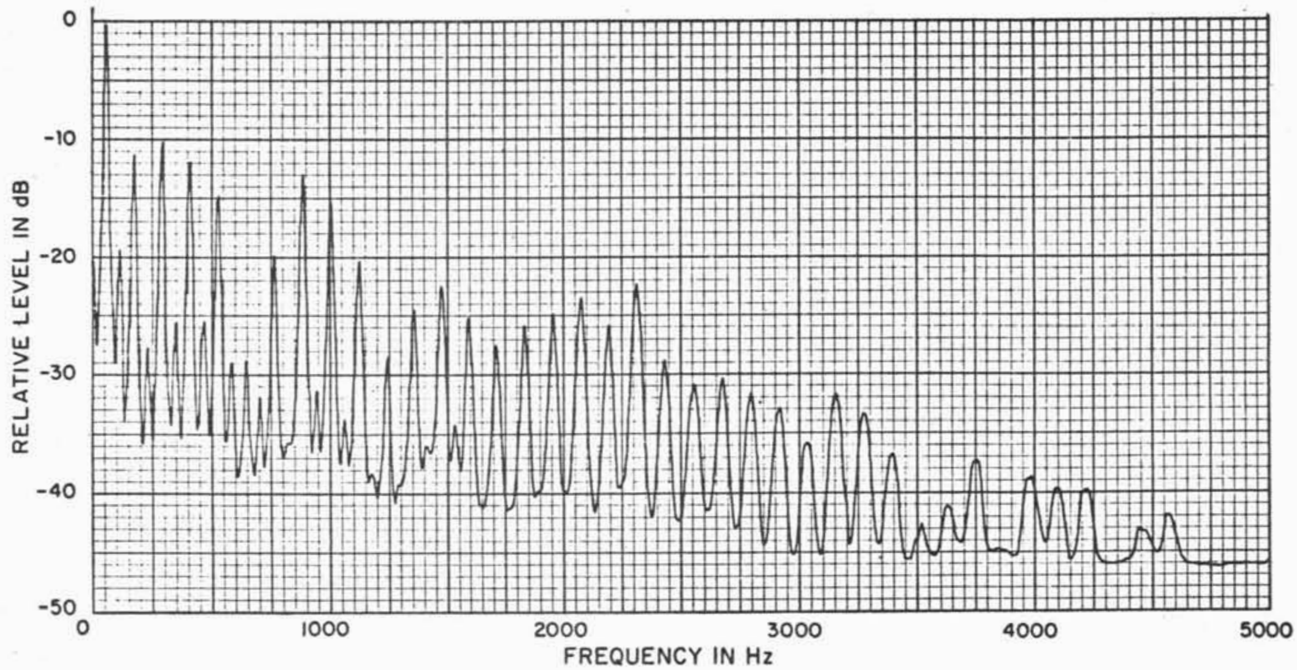


Figure 2. Average spectrum of the buzz just before Event B.

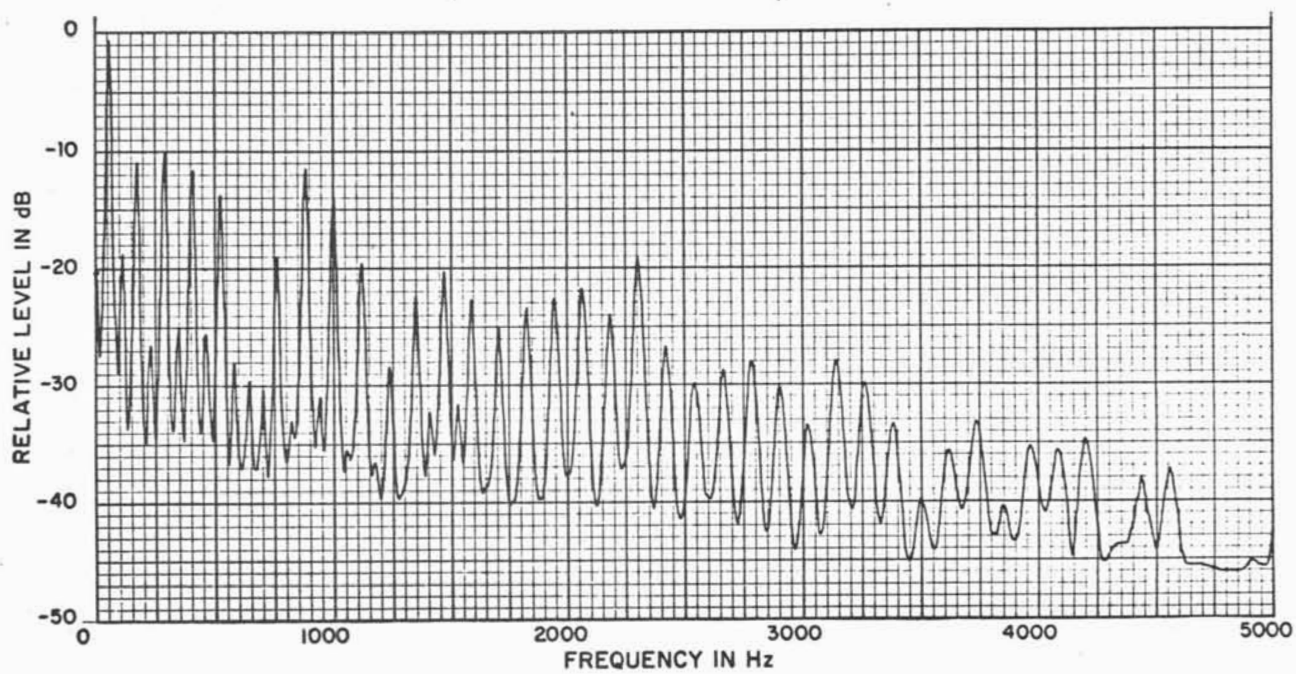


Figure 3. Average spectrum of the buzz just after Event B.

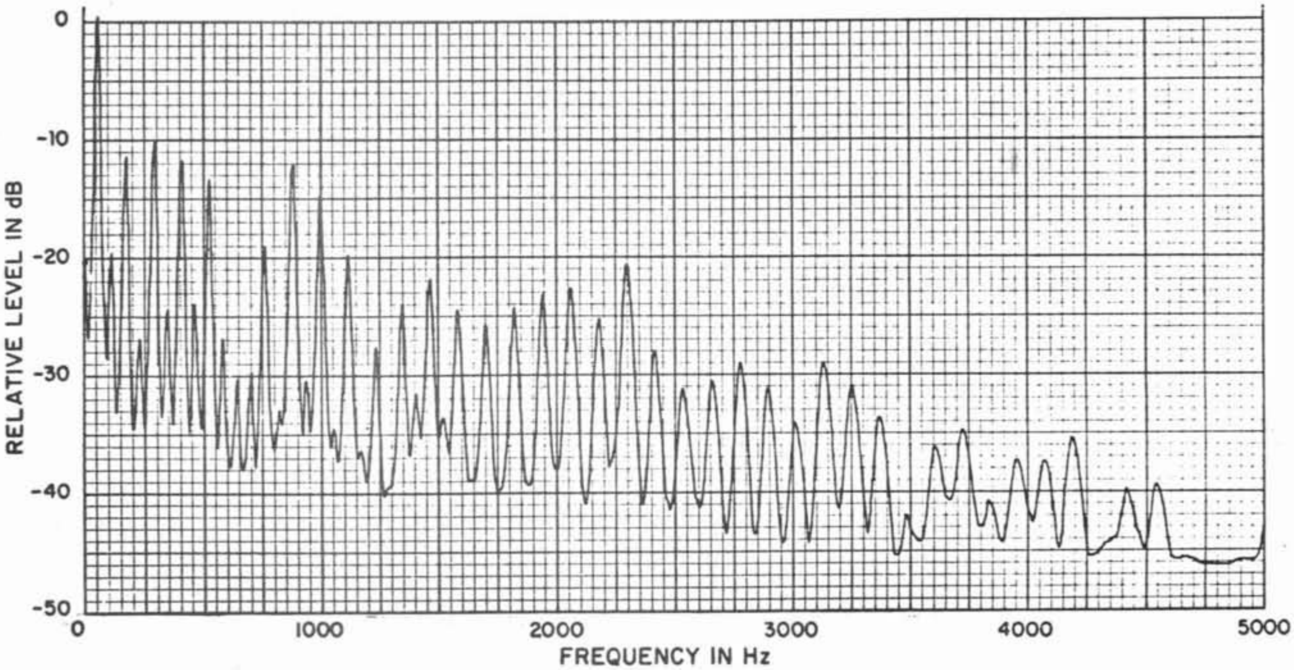


Figure 4. Average spectrum of the buzz just before Event D.

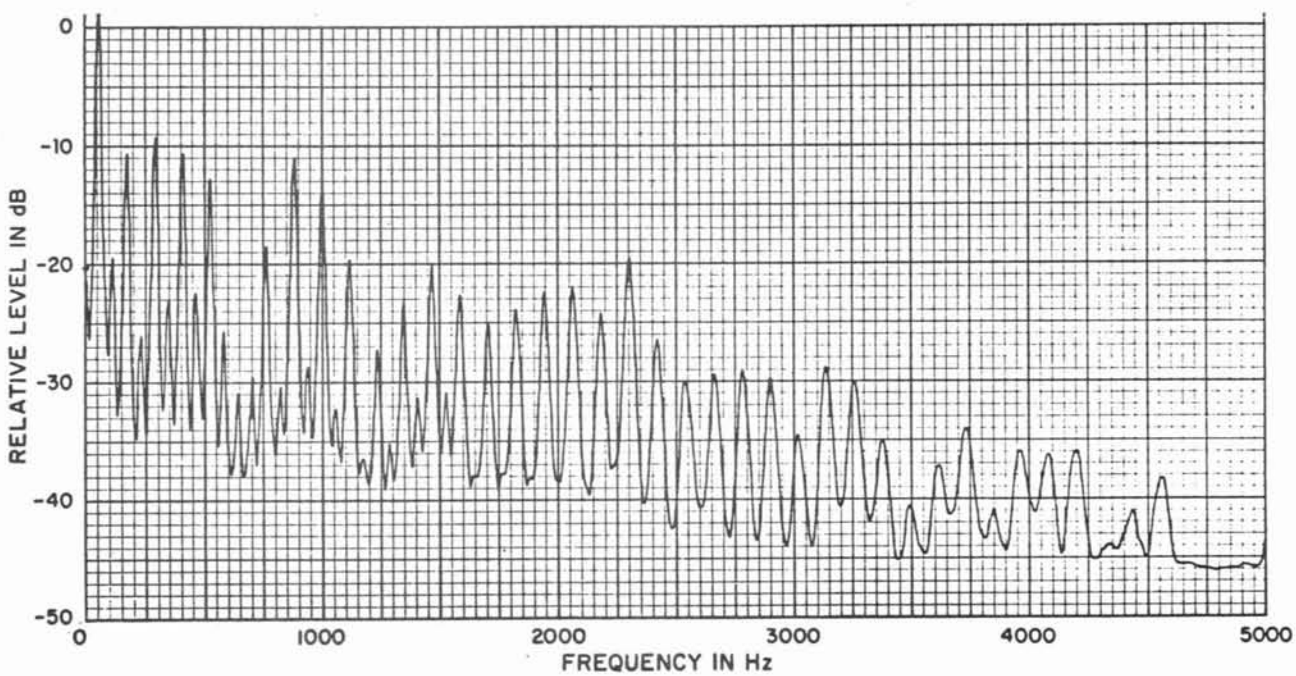


Figure 5. Average spectrum of the buzz just after Event D.

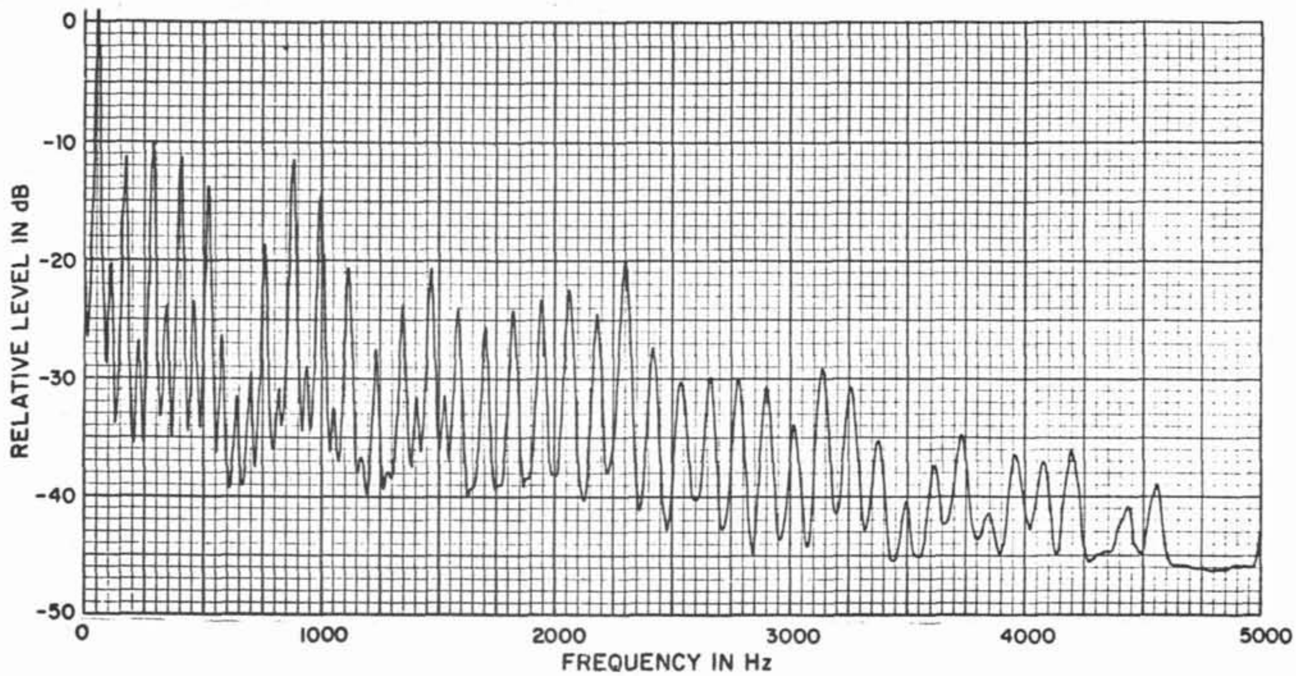


Figure 6. Average spectrum of the buzz just before Event E.

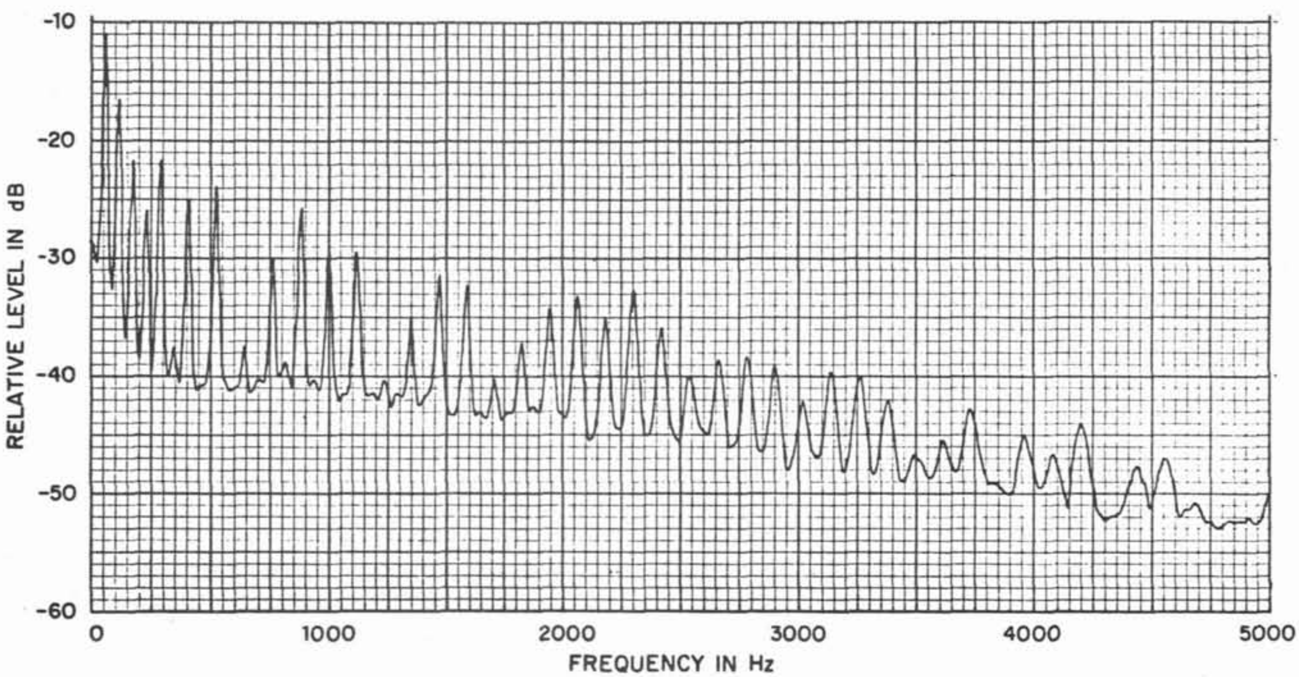


Figure 7. Average spectrum of the buzz just after Event E.

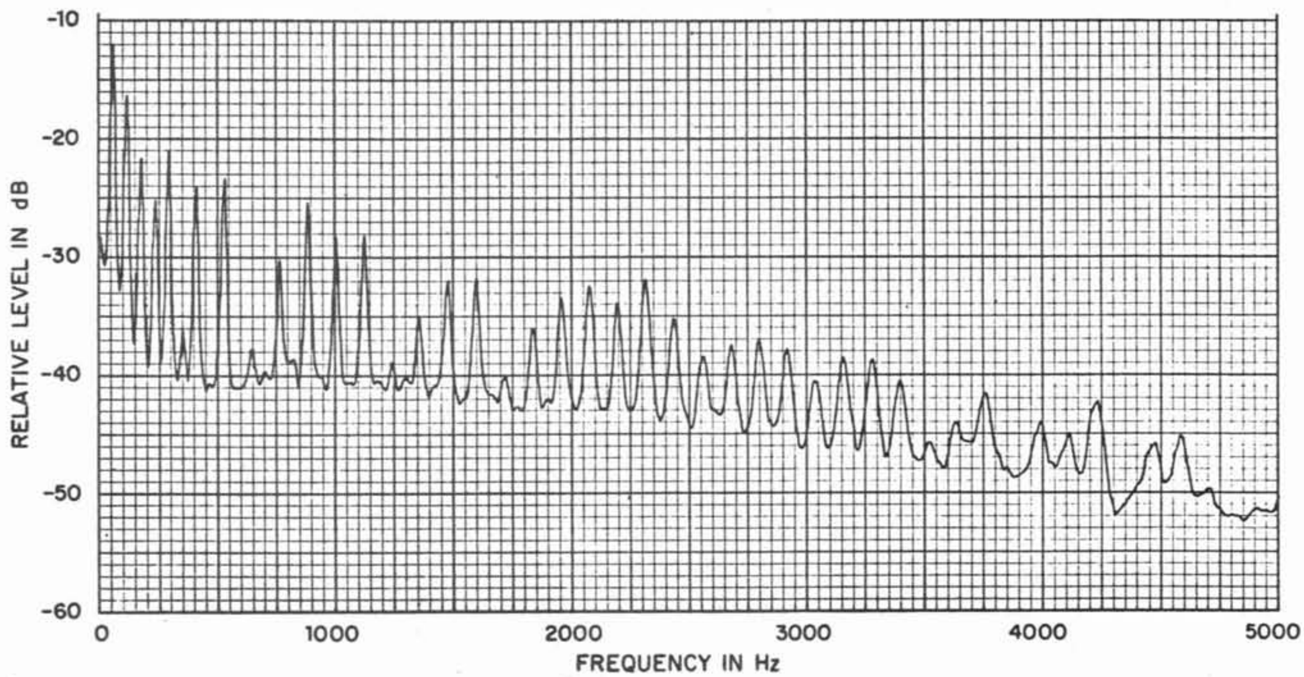


Figure 8. Average spectrum of the buzz just before Event F'.

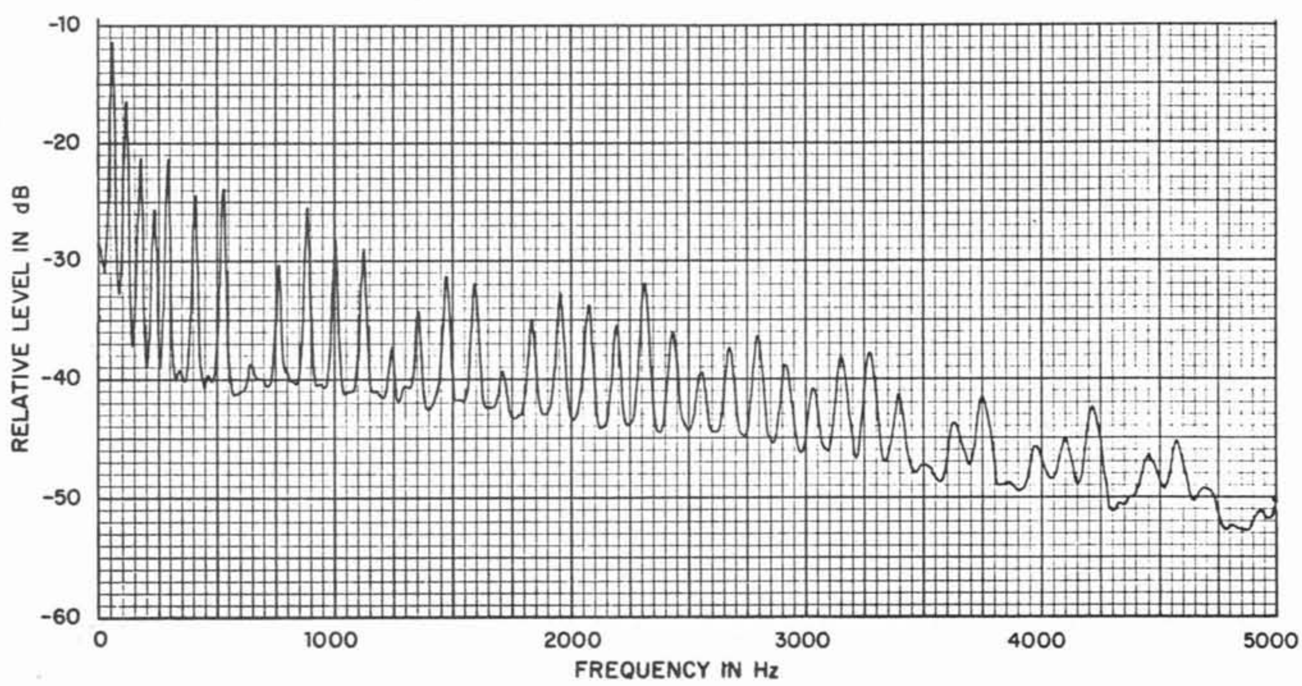


Figure 9. Average spectrum of the buzz just after Event F'.

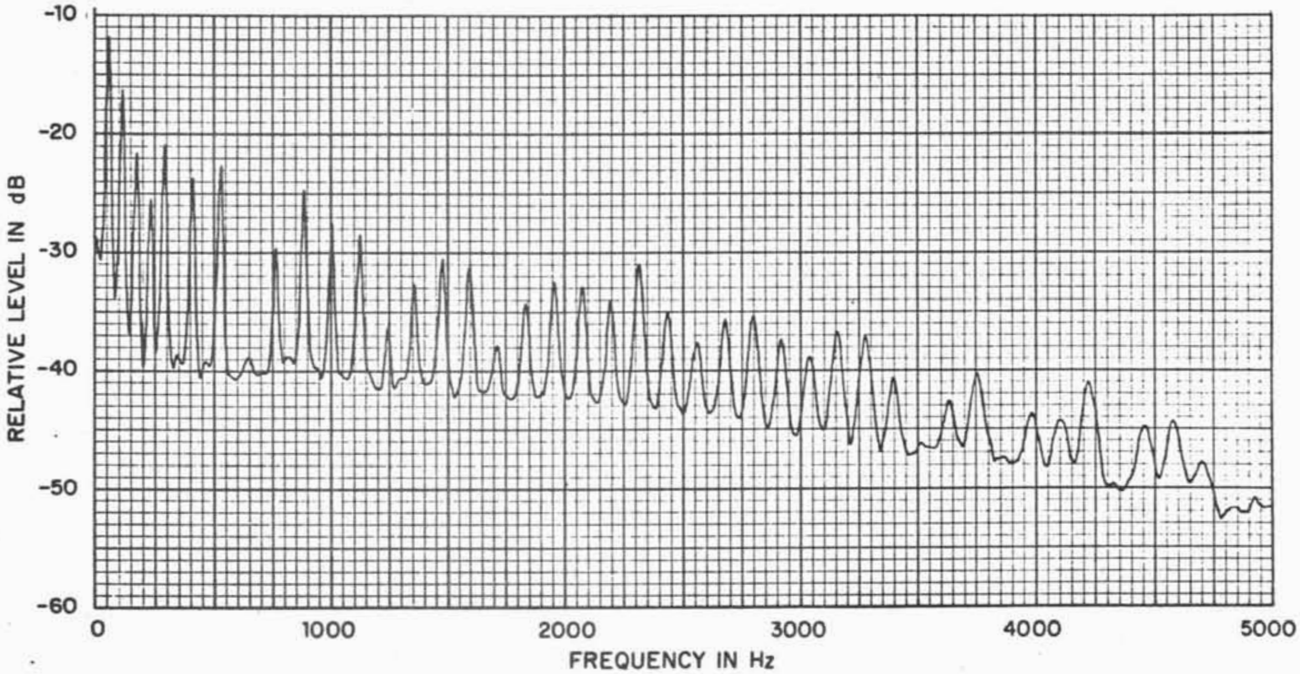


Figure 10. Average spectrum of the buzz just before Event G.

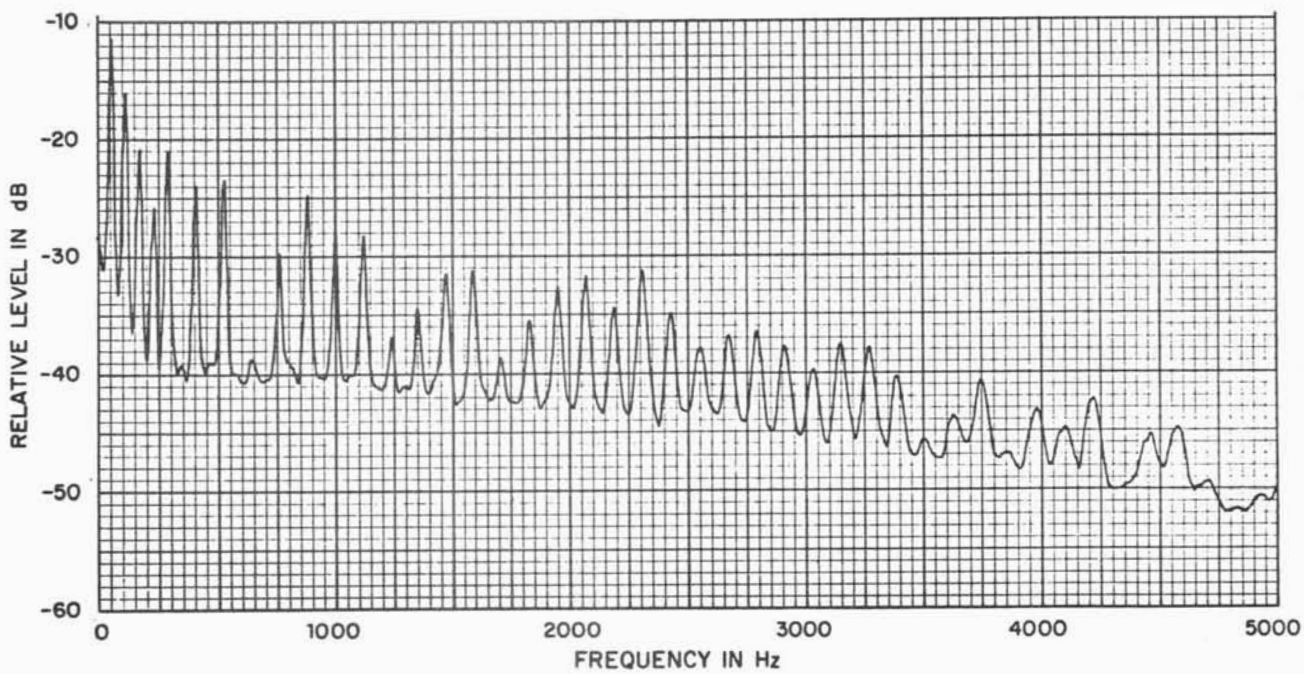


Figure 11. Average spectrum of the buzz just after Event G.

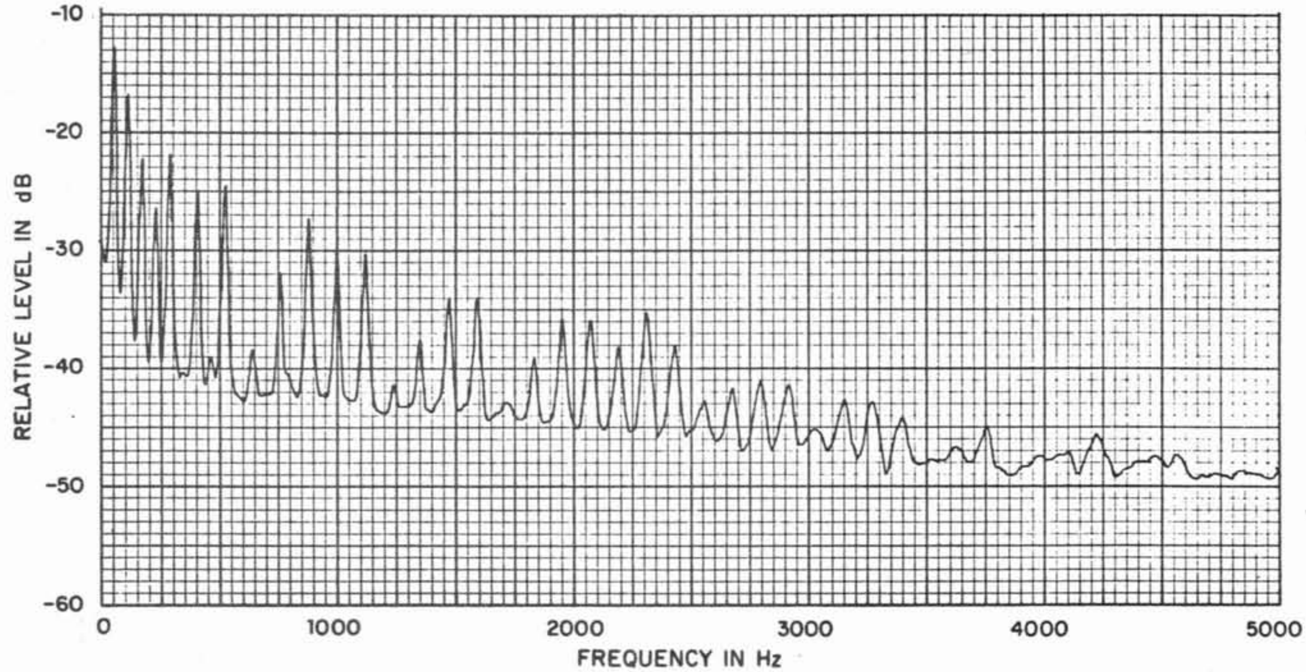


Figure 12. Average spectrum of the buzz just before Event C.

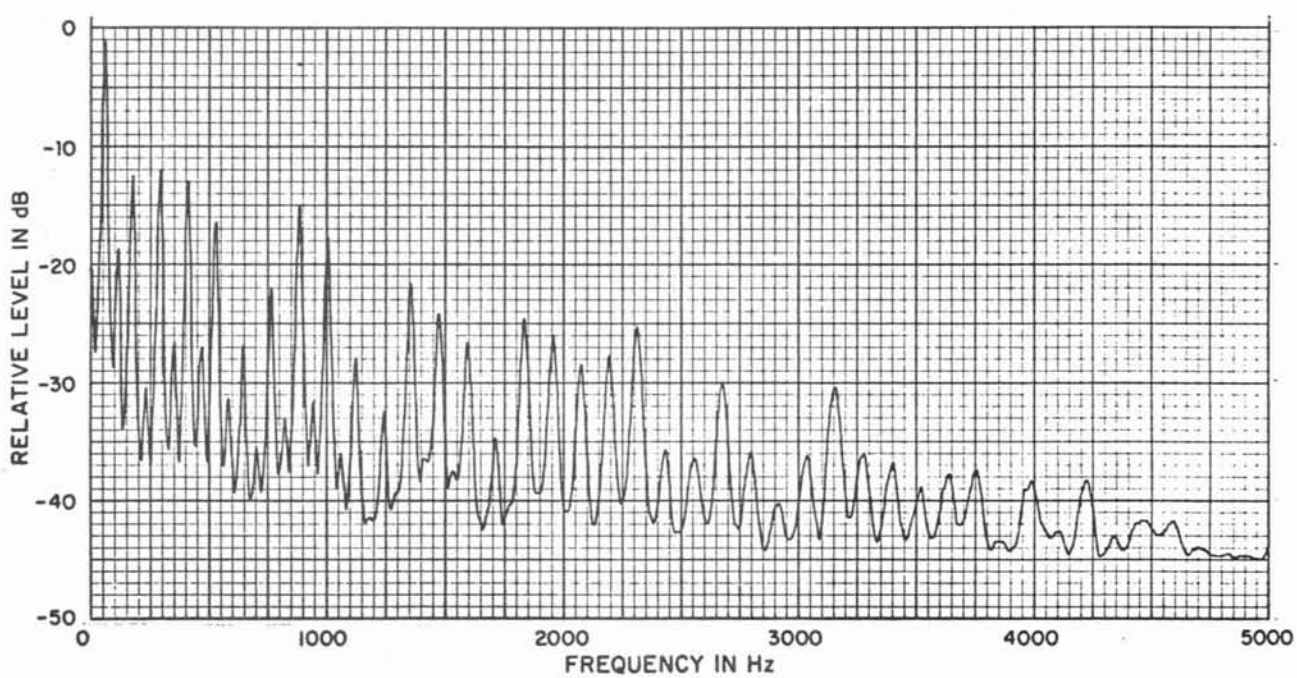


Figure 13. Average spectrum of the buzz just after Event C.

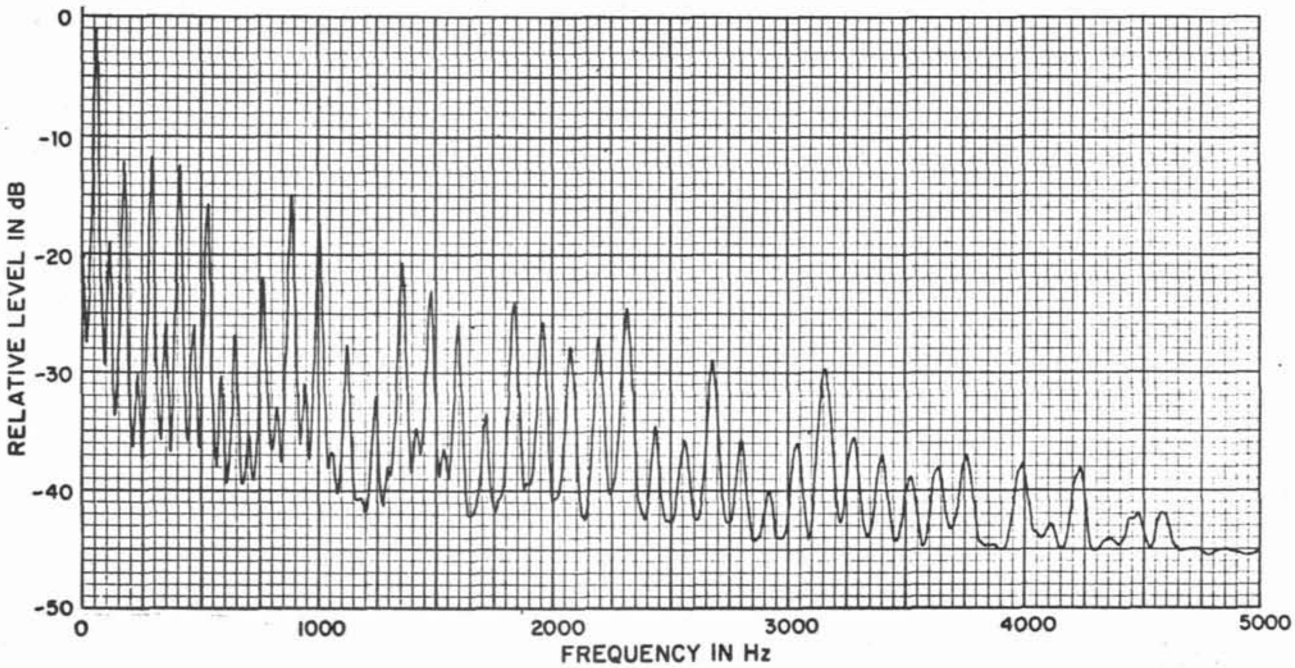


Figure 14. Average spectrum of the buzz just before Event H_A.

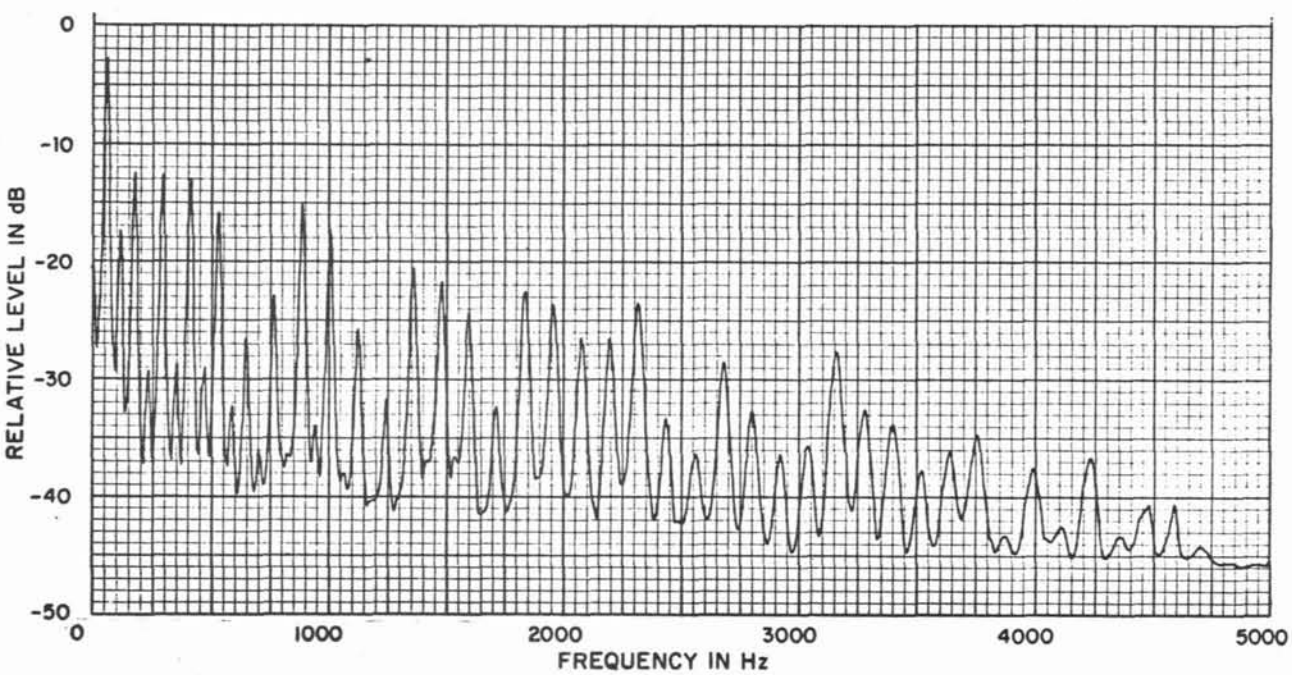


Figure 15. Average spectrum of the buzz just after Event H_B.

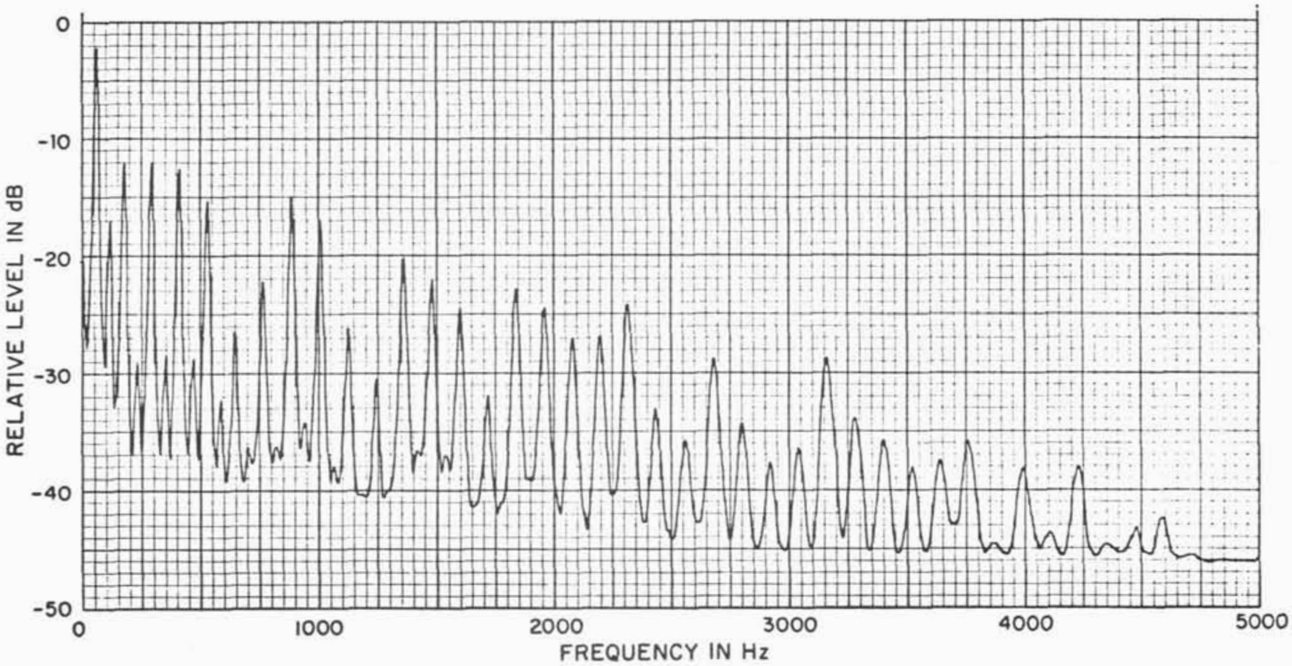


Figure 16. Average spectrum of the buzz at the end of the buzz.

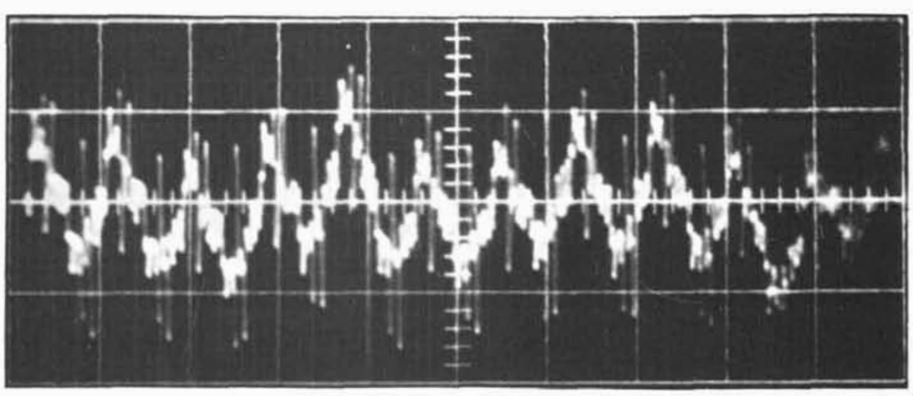


Figure 17. Waveform of the buzz.

Technical Note 6

FLUTTER ANALYSIS FOR IDENTIFYING TAPE RECORDERS

1. Principles

When a magnetic tape is moving at a constant speed, a recorded signal having constant wavelength is reproduced as a constant frequency. In reality the tape drive mechanisms of all tape recorders have mechanical imperfections that cause the tape speed to vary slightly above and below its average value. The constant-wavelength recording is reproduced as a slightly varying frequency because the reproduced frequency is directly proportional to the reproducing speed. In other words, the signal is frequency modulated by the speed variations [1]. This effect is well known in the field of sound recording, and explained in detail in the references to this technical note. Because the frequency variations are directly proportional to the speed variations, and because the audible effect is closely related to the frequency variations, all three processes have come to be known colloquially as "flutter"[2]. The context usually makes the specific meaning clear.

The peak amplitude of flutter is defined as $F = \Delta f/f_o$, where f_o is the average frequency of the signal, and Δf is the frequency deviation (that is, the difference between the maximum or the minimum instantaneous frequency of the signal, and its average frequency) produced by the speed variations. The frequencies at which the speed variations occur are called flutter modulating frequencies, f_m. A plot or table of the flutter amplitudes as a function of the flutter modulating frequency is called a flutter spectrum.

The flutter modulating frequencies are determined by the rotational frequencies of such mechanical elements as the capstan and its driving system, the reels and their driving system, etc. The flutter amplitudes are determined by the magnitudes of the mechanical imperfections of these same elements [3]. Thus it is usually possible to use the flutter spectrum found on a recorded tape to identify both the model of the tape recorder used to make the recording and, with less certainty, the individual recorder itself.

Analysis of the flutter modulating frequencies and amplitudes is usually done directly by frequency demodulation of the modulated signal, and spectrum analysis of this demodulated flutter signal [4]. Commercially-available flutter meters and analyzers are intended for use with a standard test frequency of 3150 Hz; they employ a frequency demodulator which operates over a restricted frequency range. They directly measure the frequency f_m and amplitude F of the flutter.

In using flutter analysis to identify the tape recorder used to record a particular tape, one is very unlikely to have the standard 3150 Hz test tone. It is not uncommon, however, when the recorder is operated from ac powerlines, for a low-level "hum" to be recorded on the tape due to leakage of hum into the recording system. Since the power companies regulate this frequency rather carefully, the 60-Hz hum can be used as the "test tone" for flutter analysis. Since commercial flutter meters do not function with "hum" frequencies (e.g., 60 Hz) a special demodulator would need to be constructed.

An alternate technique of flutter analysis having great flexibility is the use of direct spectrum analysis of the "hum" signal and its sidebands. We call this "flutter sideband spectrum analysis." From traditional frequency-modulation theory [5],

$$e = A \left\{ J_o(m_f) \sin 2\pi f_o t + J_1(m_f) \; [\sin 2\pi(f_o + f_m)t - \sin 2\pi(f_o - f_m)t] + \ldots \right\}$$

where e is the instantaneous value of the waveform (hum signal plus sidebands),

A is an arbitrary constant determining the amplitude of all components,

$J_n(m_f)$ are Bessel functions of the n'th order,

m_f is the "modulation index", $\Delta f/f_m$,

Δ f is the frequency deviation,

f_m is the modulating frequency and

f_o is the frequency of the signal, which is called a "carrier" in frequency-modulation theory.

The first term in the equation represents the "carrier", with frequency f_o and relative amplitude $J_o(m_f)$. The second term represents two "sidebands", with frequencies $f_{s1} = (f_o - f_m)$ and $f_{s2} = (f_o + f_m)$, and relative amplitudes $J_1(m_f)$.

For small values of the modulation index m_f, say $m_f < 0.5$, $J_o(m_f) \geqslant 0.94 \simeq 1$; $J_1(m_f) = m_f/2$; and higher order terms are negligible.

From this, we see that the ratio of sideband amplitude a_s to carrier amplitude a_o for small modulation indices is $a_s/a_o = m_f/2$. But we want flutter $F = \Delta f/f_o$, not modulation index m_f:

$$F = \Delta f/f_o = (\Delta f/f_m)\ (f_m/f_o) = m_f(f_m/f_o)$$

and finally

$$F = 2(a_s/a_o)(f_m/f_o).$$

The above approximation is valid, for instance, when a 60 Hz "carrier" frequency is used to measure flutter whose modulating frequency is greater than 0.5 Hz, and whose amplitude is less than 4 per mill.*

As we have shown above, the "flutter spectrum" and the "flutter sideband spectrum" are not the same, but they do contain the same information, and either can be calculated directly from the other by using the formula given above. In order to compare the flutter on one recording to the flutter on another recording, we may compare the flutter sideband spectra directly. However, when we wish to compare the flutter on a recording to the mechanical elements of the tape recorder that cause the flutter, it is necessary to convert the flutter sideband spectra to flutter spectra.

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* per mill = parts per thousand

2. Measurement of Flutter Sideband Spectra and Calculation of Flutter Spectra on the Evidence Tape

On an ideal tape recording, hum signals would be so small as to be virtually undetectable. However, examination of the speech recording section of the Evidence Tape revealed that the recording contained a large powerline "hum" component that had been picked up in the microphone mixing and feed system. The buzz section also contained a large "hum" picked up from the powerline. Therefore, we could perform flutter spectrum analysis on these hum recordings. The Evidence Tape was played back on a Nagra III recorder-reproducer.* The signal was then fed into a Model UA-500 Ubiquitous® Spectrum Analyzer manufactured by Federal Scientific Corporation. The flutter sideband spectra were plotted on a Hewlett-Packard Model 7035B X-Y graphic recorder.

We measured a typical flutter sideband spectrum from the 60-Hz hum signal on a speech portion of the Evidence Tape. This is shown in Fig. 1. (We have placed all of the figures together at the end of this technical note, pages 6.11 - 6.17. This facilitates comparing one figure with another.) Table 1 tabulates the significant flutter frequencies and amplitudes calculated from this spectrum of the speech section before the buzz.

Similarly, Fig. 2 through 5 show the flutter sideband spectra at various positions within the buzz section of the Evidence Tape. We calculated the major flutter frequencies and amplitudes and these are also given in Table 1.

The flutter sideband spectra, and the table of flutter spectra, show that the flutter spectra for the speech section of the Evidence Tape, and the following buzz section of the Evidence Tape, are quite different.

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* Because of equipment limitations, and in order to save analysis time, the reproduction was performed at 95 mm/s (3.75 in/s), which is four times the original speed of the Evidence Tape, 24 mm/s (15/16 in/s). Thus the frequencies in analysis were all at four times their original values. For clarity of presentation, this report refers only to the original frequencies.

Table 1 Flutter Spectra from the Evidence Tape

Frequency/ [Hz]	Flutter / [per mill]				
		In Buzz Section			
	In Speech Section Before Buzz	Event at Time 1 s	Event at Time 50 s	Event at Time 275 s	Event at Time 1043 s
0.35	-	-	-	-	-
0.7	1.2	0.7	1.0	0.8	0.9
1.25	1.9	0.5	-	-	-
1.4	1.8	-	-	-	-
1.5	-	1.0	1.0	1.3	1.6
1.9	3.2	-	-	-	-
3.0	-	1.4	1.6	1.6	2.0
3.6	-	3.4	3.8	3.4	4.3
3.8	2.3	-	-	-	-
7.2	-	-	-	-	-
8.0	-	3.0	4.3	4.3	4.3

NOTE: "-" indicates amplitude at this frequency is equal to the noise level at this frequency.

3. Mechanical Analysis of the Sony and Uher Recorders, Measurement of their Flutter Sideband Spectra, and Calculation of their Flutter Spectra

3.1 Sony 800B Recorders

Mechanical analysis

The Sony 800B recorder uses a servo-controlled capstan motor whose shaft is itself the capstan that drives the tape. The capstan diameter is 4.0 mm. Thus with a tape speed of 24 mm/s, simple eccentricity produces a flutter frequency of 1.9 Hz, and ellipticity produces a flutter frequency of 3.8 Hz. The tape is driven by friction between the capstan and a freely rotating rubber pulley ("capstan idler") whose diameter is 23.6 mm, producing a frequency of about 0.35 Hz for simple eccentricity.

The reel is driven by a belt-driven clutch whose frequency is 0.7 Hz. As tape winds off the reel, the tape pack radius varies from 54 mm to 23 mm. At the tape speed of 24 mm/s, the rotational speeds vary from 0.07 to 0.16 rev/s, giving flutter frequencies from 0.07 Hz to 0.16 Hz, corresponding to periods of 14.3 s to 6.0 s.

Flutter sideband spectrum measurement and flutter calculations

A 60-Hz tone from a Kron-Hite Model 4100 oscillator was recorded onto blank tape by means of each of six Sony 800B's used in the Executive Office Building and in the Oval Office. The 60-Hz tone was recorded at a level corresponding to the midrange of the recording-level indicator on each machine. Then a flutter sideband spectrum analysis was performed by the means described in Sec. 2 The spectra are shown in Figs. 6 through 11. The flutter frequencies and magnitudes have been calculated for these recorders and are shown in Table 2.

Two points are worth comment: First, that the measured flutter frequencies correspond to the frequencies expected from the mechanical analysis, except for the one small unexplained flutter component at 1.25 Hz. Second, that the flutter amplitude at each frequency is quite variable from one recorder to another.

3.2 Uher 5000 Recorders

Mechanical Analysis

The Uher 5000 uses an induction motor operating from the powerline, driving an intermediate rubber idler, which in turn drives the flywheel that is on the capstan shaft. The motor operates at approximately 1740 rev/s, giving a frequency of 29 Hz. The intermediate idler frequency is 3.6 Hz. The capstan diameter is 5.0 mm. Thus with a tape speed of 24 mm/s, simple eccentricity produces a flutter frequency of 1.5 Hz, and ellipticity produces a flutter frequency of 3.0 Hz. The capstan idler diameter is 21.8 mm, producing a frequency of 0.35 for simple eccentricity. As with the Sony, the reel is driven by belt-driven clutch whose frequency is 0.7 Hz. The reel radii and frequencies are the same as those of the Sony since the same reel sizes are used on both machines in this work.

Table 2 Flutter Spectra from Six Sony 800B Recorders

Frequency/ [Hz]	Mechanical Element	Flutter / [per mill]					
		EOB A SN 12 330	EOB B SN 15 367	EOB C SN 14 384	Oval Office SN 11 561	Oval Office SN 14 396	Oval Office SN 15 102
0.35	Capstan idler	-	0.4	0.4	-	-	-
0.7	Reel-drive clutch	0.5	1.3	0.7	0.9	0.9	0.6
1.25	?	0.3	0.3	0.3	-	-	0.5
1.4	2 X Reel-drive clutch	0.4	0.4	-	-	0.4	0.4
1.5	None	-	-	-	-	-	-
1.9	Capstan	1.0	0.8	4.5	1.0	1.6	1.8
3.0	None	-	-	-	-	-	-
3.6	None	-	-	-	-	-	-
3.8	2 X Capstan	-	-	-	1.9	-	1.2
7.2	None	-	-	-	-	-	-

NOTE: "-" indicates amplitude at this frequency is equal to the noise level at this frequency

Flutter sideband spectrum measurement and flutter calculations

The recording of tones and the sideband spectrum analysis were carried out as before on the Uher 5000's "Exhibit 60" and "Secret Service," and the spectra are shown in Fig. 12 and 13. The flutter frequencies and magnitudes have been calculated for these two recorders, and are shown in Table 3.

As with the Sony recorders, the frequencies correspond to those calculated by mechanical analysis, and the differences between the two individuals are rather large.

4. Determining Which Model Tape Recorder Recorded the Speech and the Buzz Sections of the Evidence Tape

This section is predicated on the assumption discussed elsewhere that only Sony 800B and Uher 5000 recorders might have been used in recording and erasing the Evidence Tape.

4.1 Comparison of Sony and Uher Flutter Spectra

The capstan idlers on both the Sony and the Uher recorders produce 0.35 Hz flutter, and the reel-drive clutches both produce 0.7 Hz flutter. Therefore the amplitudes of these two components mean little in distinguishing Sony recordings from Uher recordings. The components at 1.4 Hz and 1.5 Hz are characteristic of these recorders, but the noise background amplitude in the Evidence Tape makes it very difficult in this particular case to distinguish a 1.4 Hz component from a 1.5 Hz component. Therefore we will not consider the component amplitudes at 1.4 Hz and 1.5 Hz.

The clearest differences between Sony and Uher flutter spectra are seen at 1.9 Hz (Sony capstan frequency), and at 3.6 Hz (Uher intermediate idler frequency): Table 2 shows that all of the Sonys tested show appreciable flutter at 1.9 Hz, and no flutter at 3.6 Hz. Table 3 shows that both of the Uhers tested show no flutter at 1.9 Hz, and appreciable flutter at 3.6 Hz. Thus the flutter frequencies of 1.9 Hz and 3.6 Hz should be examined in order to differentiate Sony recordings from Uher recordings.

4.2 Comparison of Flutter Spectra of the Speech and Buzz Sections of the Evidence Tape

Table 1 shows that the recording of the speech before the buzz section contains a large flutter component at 1.9 Hz, and no flutter component at 3.6 Hz. These findings point to a Sony 800B. The amplitudes of the other components are consistent with those found in the Sony 800B flutter spectra of Table 2. Thus we conclude that the speech section was certainly recorded on a Sony 800B.

Table 3 Flutter Spectra from Two Uher 5000 Recorders

Frequency/ [Hz]	Mechanical Element	Flutter / [per mill]	
		Secret Service	Exhibit 60
0.35	Capstan idler	0.9	-
0.7	Reel-drive clutch	0.4	0.7
1.25	None	-	-
1.4	2 x Reel-drive clutch	-	-
1.5	Capstan	1.3	1.2
1.9	None	-	-
3.0	2 X Capstan	-	1.4
3.6	Intermediate idler	3.0	4.8
3.8	None	-	-
7.2	2 X Intermediate idler	1.8	1.9

* NOTE: "-" indicates amplitude at this frequency is equal to the noise level at this frequency.

Table 1 also shows that the several recordings of the buzz all contain a large flutter component at 3.6 Hz, and no component at 1.9 Hz. These point to a Uher 5000. The amplitudes of the other components are consistent with those found in the Uher 5000 flutter spectra of Table 3. Thus we conclude that all of the buzz section was certainly recorded on a Uher 5000.

5. Determining Which Sony Recorder Recorded the Speech Section

The flutter spectrum of the speech section of the Evidence Tape (Table 1) may be compared with the flutter spectra of the six Sony 800B recorders in evidence (Table 2). The flutter spectrum on the Evidence Tape contains 3.2 per mill of flutter at 1.9 Hz, and 2.3 per mill at 3.8 Hz. The flutter spectra of the six Sony 800B recorders do not contain these amplitudes at these frequencies. On the basis of this evidence, we must conclude that although the speech section of the Evidence Tape was certainly recorded on some Sony 800B, it was not one of the Sonys that we tested.

6. Determining Which Uher Recorder Recorded the Buzz Section

The flutter spectra of the several parts of the buzz section of the Evidence Tape (Table 1) may be compared with the flutter spectra of the two Uher 5000 recorders in evidence (Table 3). For ease of comparison, the critical frequencies are re-tabulated in Table 4. Inspection of this table shows a good correlation at all of the critical frequencies between the flutter spectrum of the buzz section and that of the Uher "Exhibit 60." The correlation with the Secret Service Uher is not at all good. We therefore conclude that, given these two Uher 5000 recorders, the buzz section was very likely recorded on the Uher 5000 "Exhibit 60."

Table 4 Comparison of Critical Frequencies in the Flutter Spectra of Two Uher Recorders and the Buzz Section

Frequency/ [Hz]	Flutter / [per mill]						
	Tape Recorder		Part of Buzz Section				
	Secret Service	Exhibit 60	Average of 4	Event at Time 1 s	Event at Time 50 s	Event at Time 275 s	Event at Time 1043 s
0.35	0.9	-	-	-	-	-	-
0.7	0.4	0.7	.9	0.7	1.0	0.8	0.9
3.0	-	1.4	1.7	1.4	1.6	1.6	2.0
3.6	3.0	4.8	3.7	3.4	3.8	3.4	4.3

INDEX OF FLUTTER SIDEBAND SPECTRA

1. Speech recording before buzz
2. Buzz at 1 s.
3. Buzz at 50 s.
4. Buzz at 276 s.
5. Buzz at 1043 s.
6. thru 11. Sony recorders
12. Uher "Secret Service"
13. Uher "Exhibit 60"

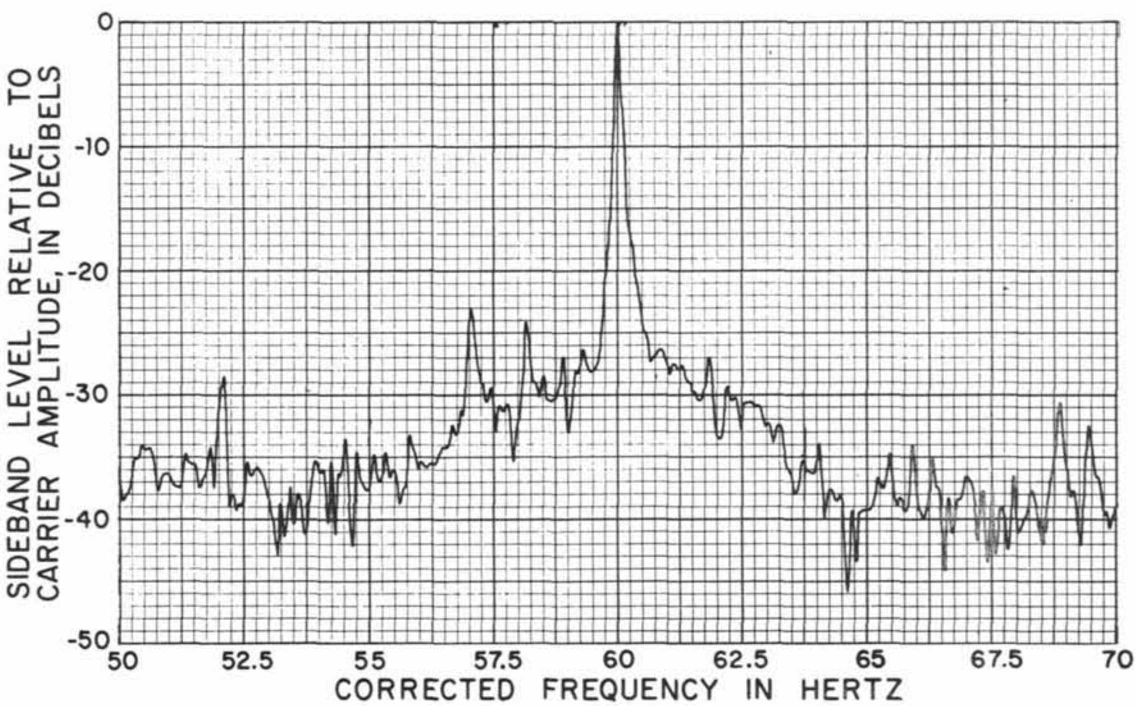

Fig. 1. Flutter sideband spectrum of the hum in the Evidence Tape speech recording before the buzz section. Resolution, 0.05 Hz. Average of 2 spectra, 20 s each. Duration of signal analyzed, 40 s.

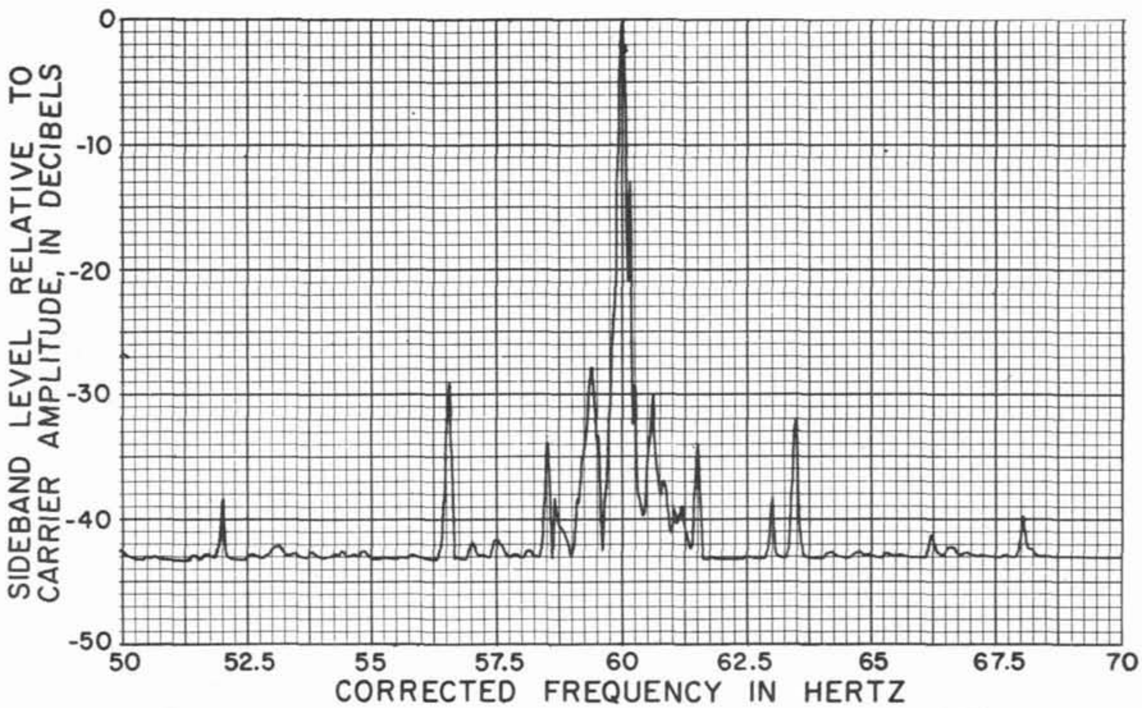

Fig. 2. Flutter sideband spectrum of the buzz in the Evidence Tape buzz section beginning at Event Time 1 s. Resolution, 0.05 Hz. Average of 2 spectra, 20 s each. Duration of signal analyzed, 40 s.

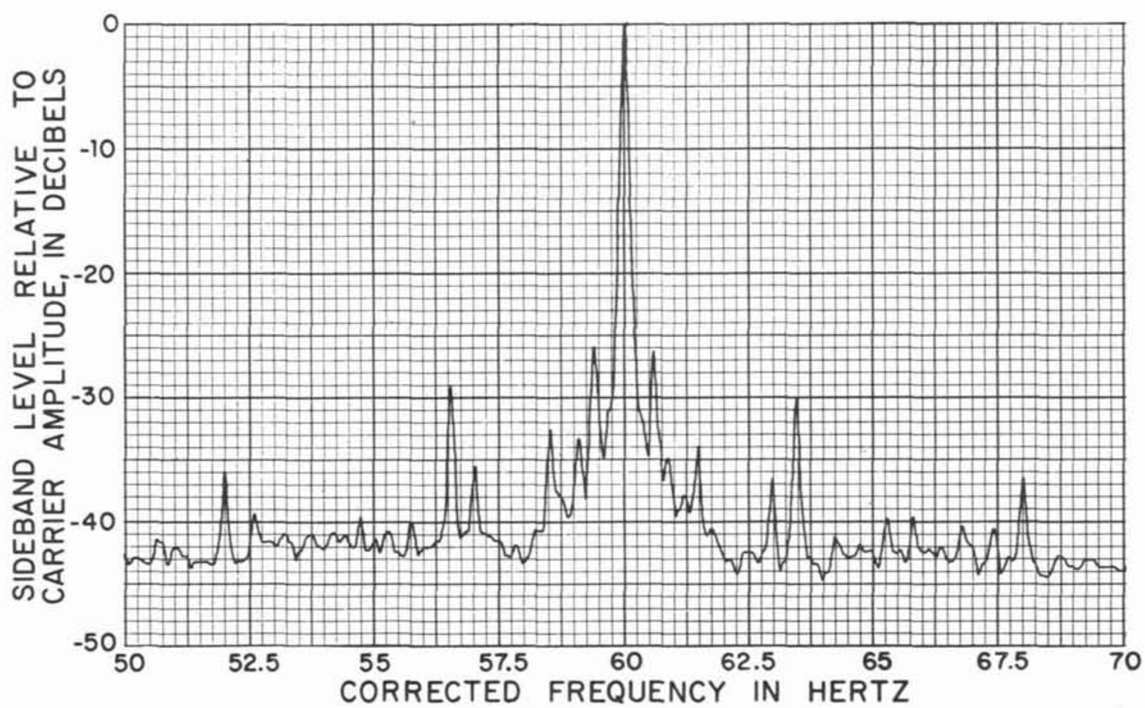

Fig. 3. Flutter sideband spectrum of the buzz in the Evidence Tape buzz section, beginning at Event Time 50 s. Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

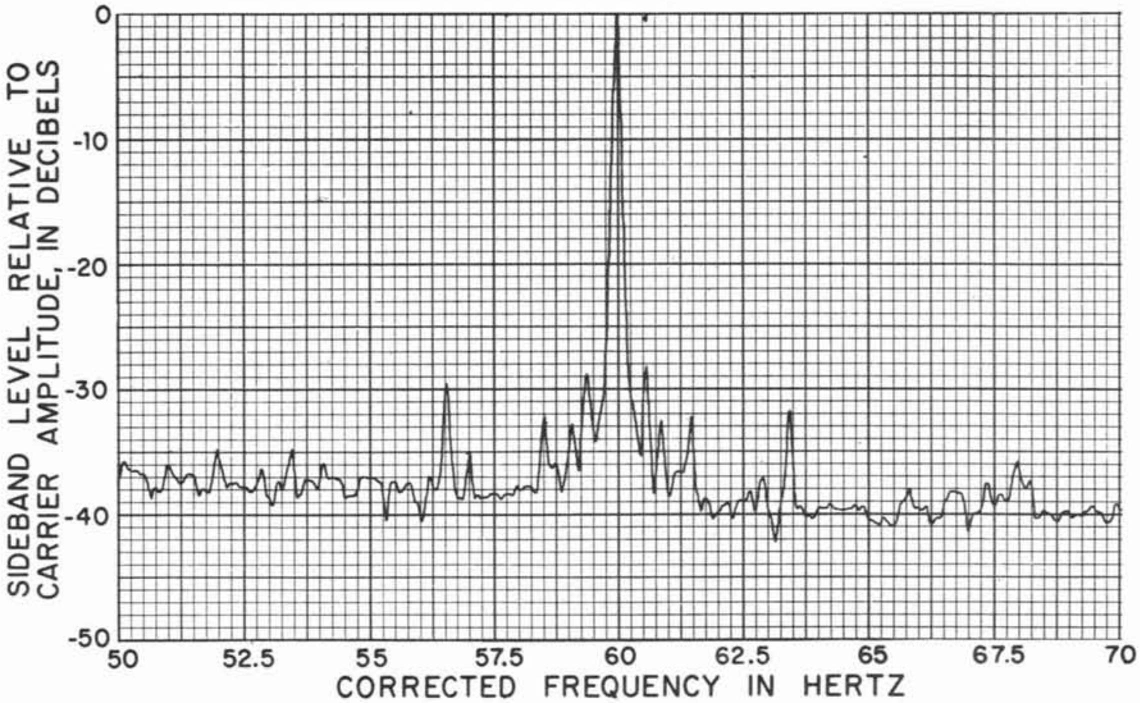

Fig. 4. Flutter sideband spectrum of the buzz in the Evidence Tape buzz section, beginning at Event Time 276 s. Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

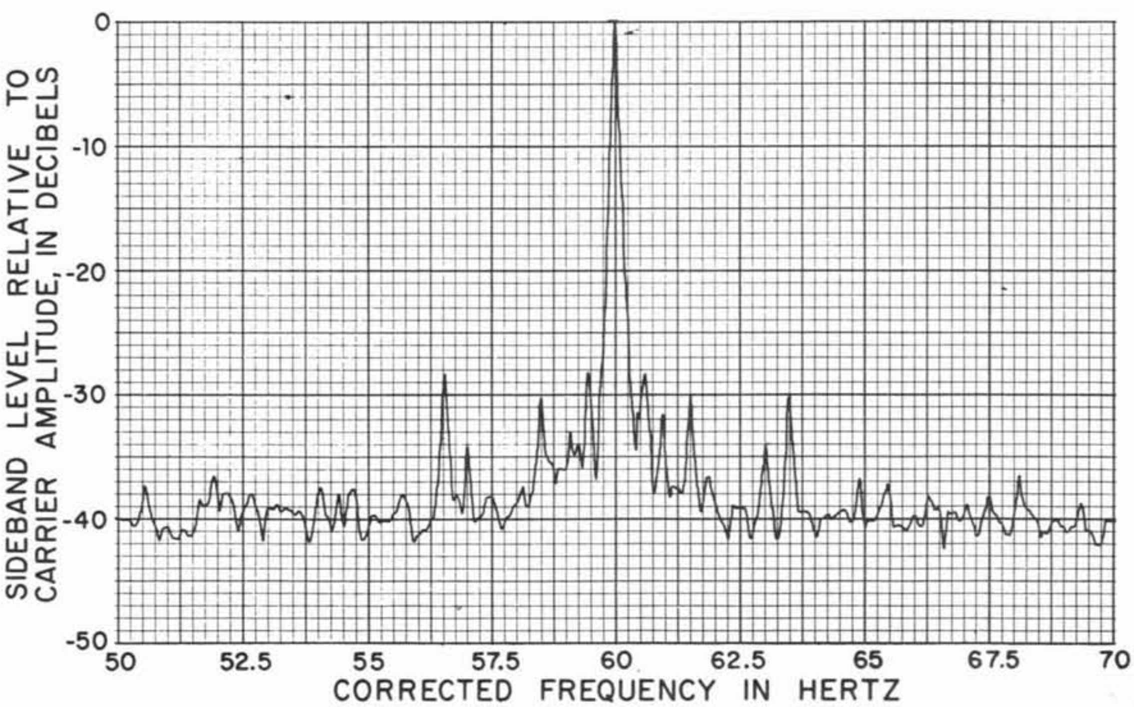

Fig. 5. Flutter sideband spectrum of the buzz in the Evidence Tape buzz section, beginning at Event Time 1043 s. Resolution, 0.05 Hz. Average of 2 spectra, 20 s each. Duration of signal analyzed, 40 s.

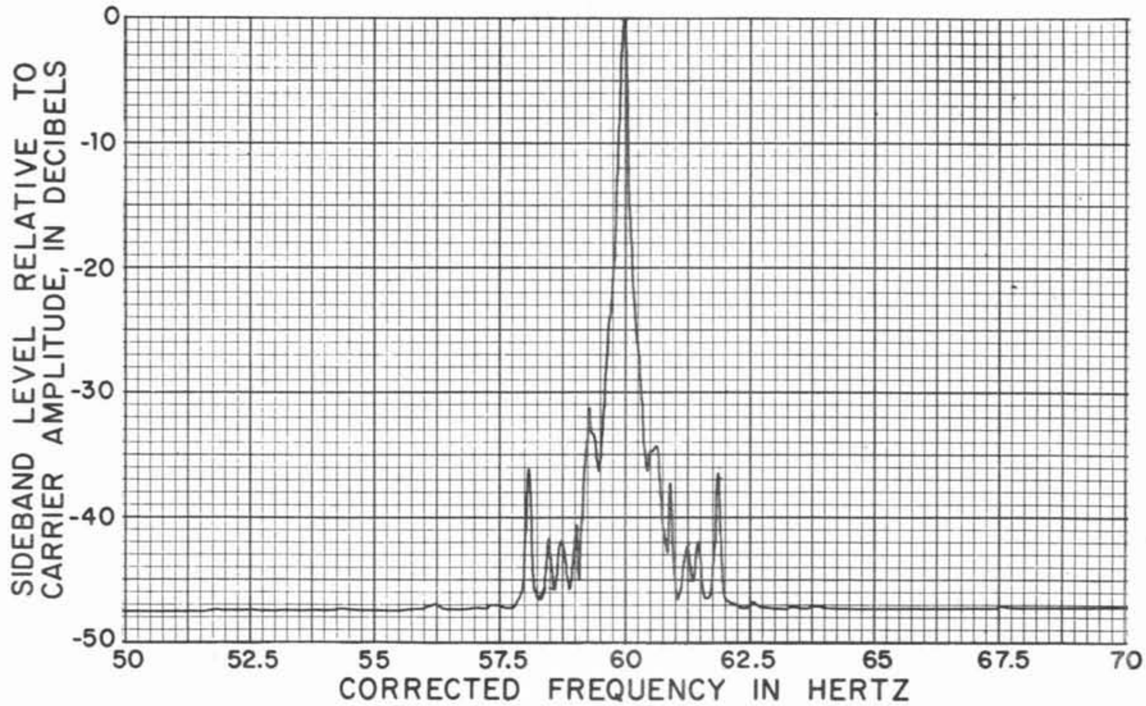

Fig. 6. Flutter sideband spectrum of a 60-Hz test recording from Sony 800B recorder SN 12 330, "EOB A". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

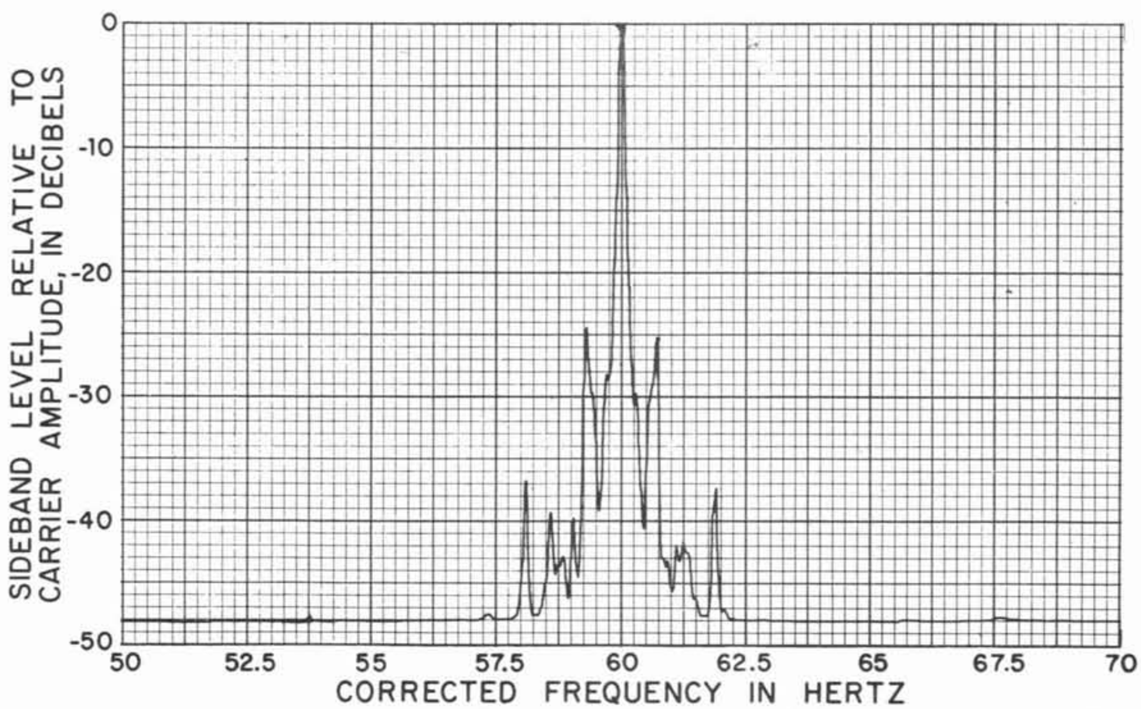

Fig. 7. Flutter sideband spectrum of a 60-Hz test recording from Sony 800B recorder SN 15 367, "EOB B". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

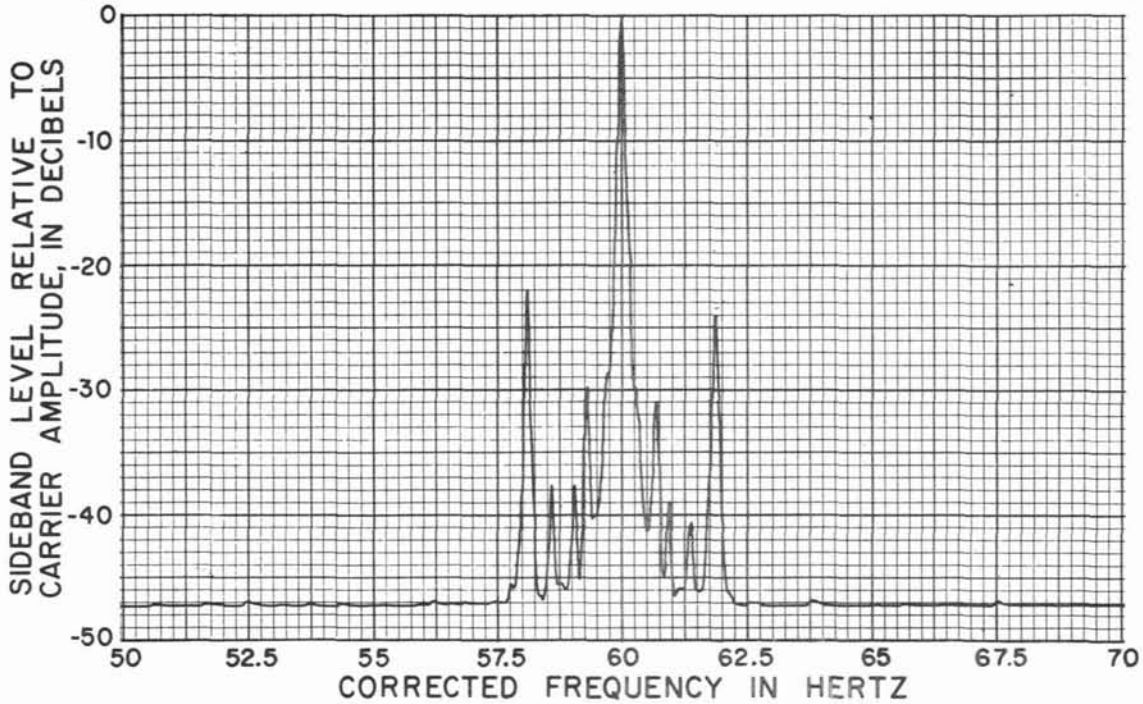

Fig. 8. Flutter sideband spectrum of a 60-Hz test recording from Sony 800B recorder SN 14 384, "EOB C". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

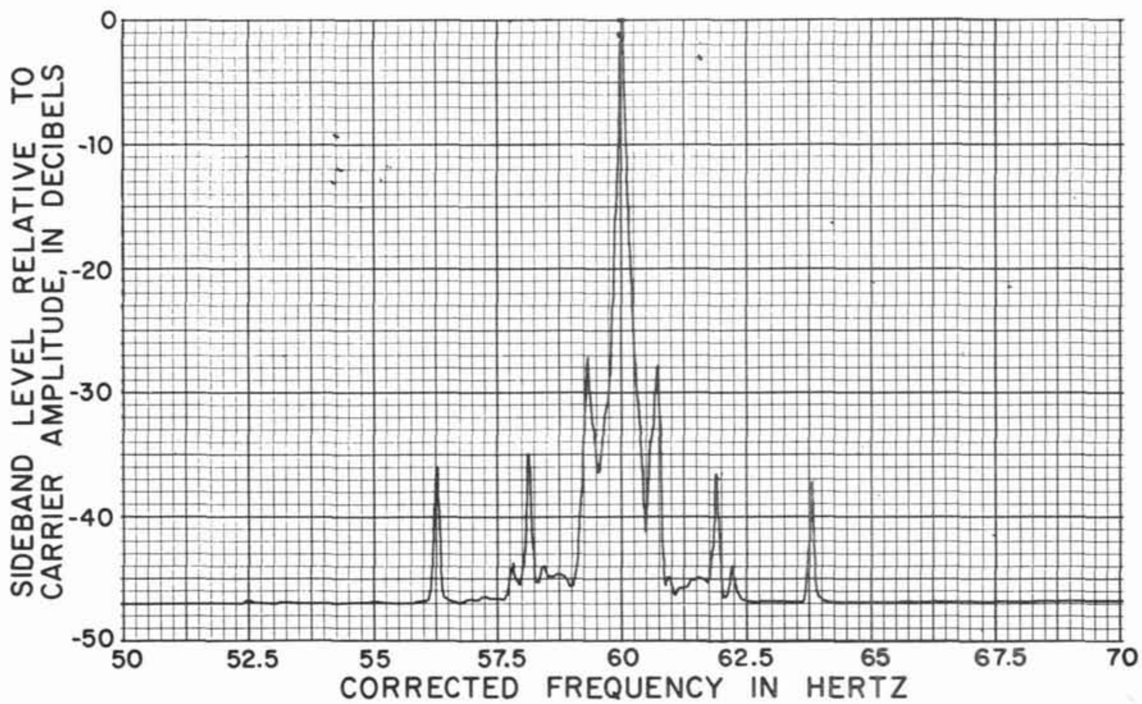

Fig. 9. Flutter sideband spectrum of a 60-Hz test recording from Sony 800B recorder SN 11 561, "Oval Office". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

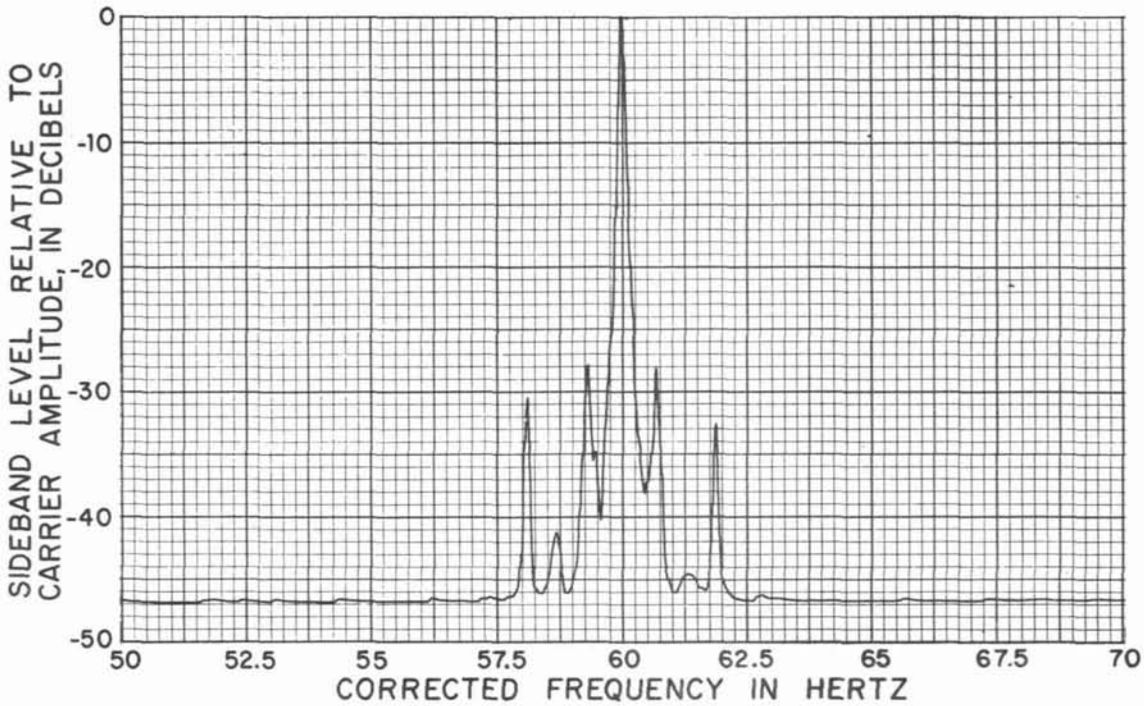

Fig. 10. Flutter sideband spectrum of a 60-Hz test recording from Sony 800B recorder SN 14 396, "Oval Office". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

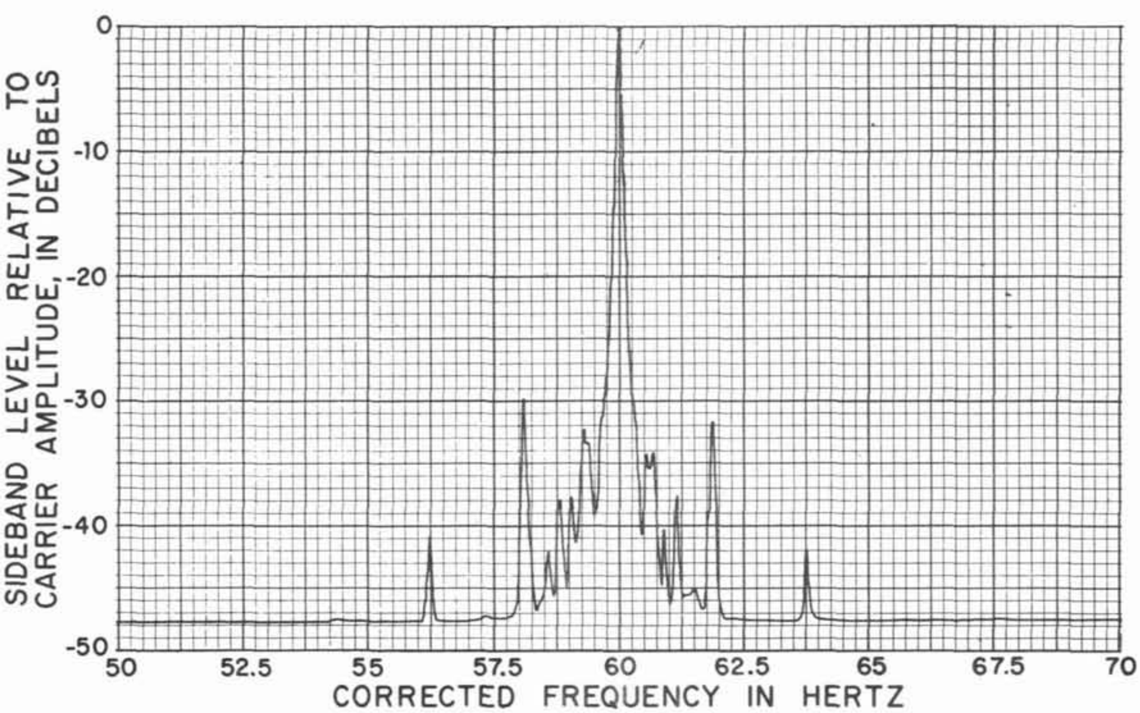

Fig. 11. Flutter sideband spectrum of a 60-Hz test recording from Sony 800B recorder SN 15 102, "Oval Office". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

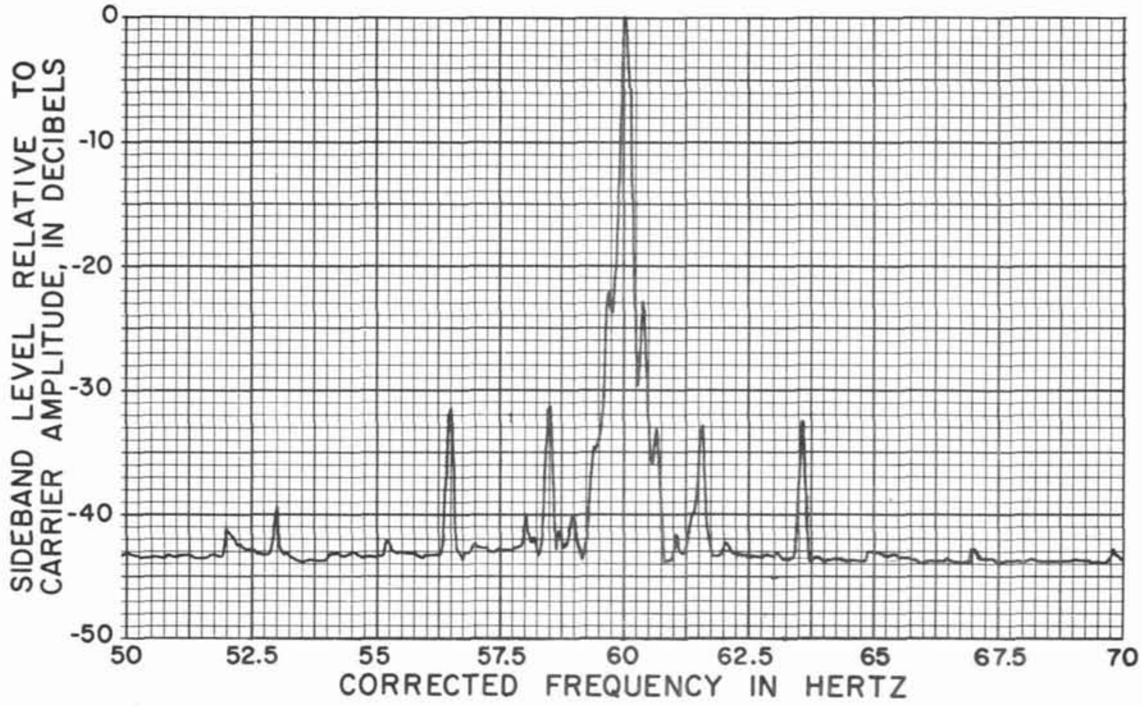

Fig. 12. Flutter sideband spectrum of a 60-Hz test recording from Uher 5000 recorder labeled "Secret Service". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

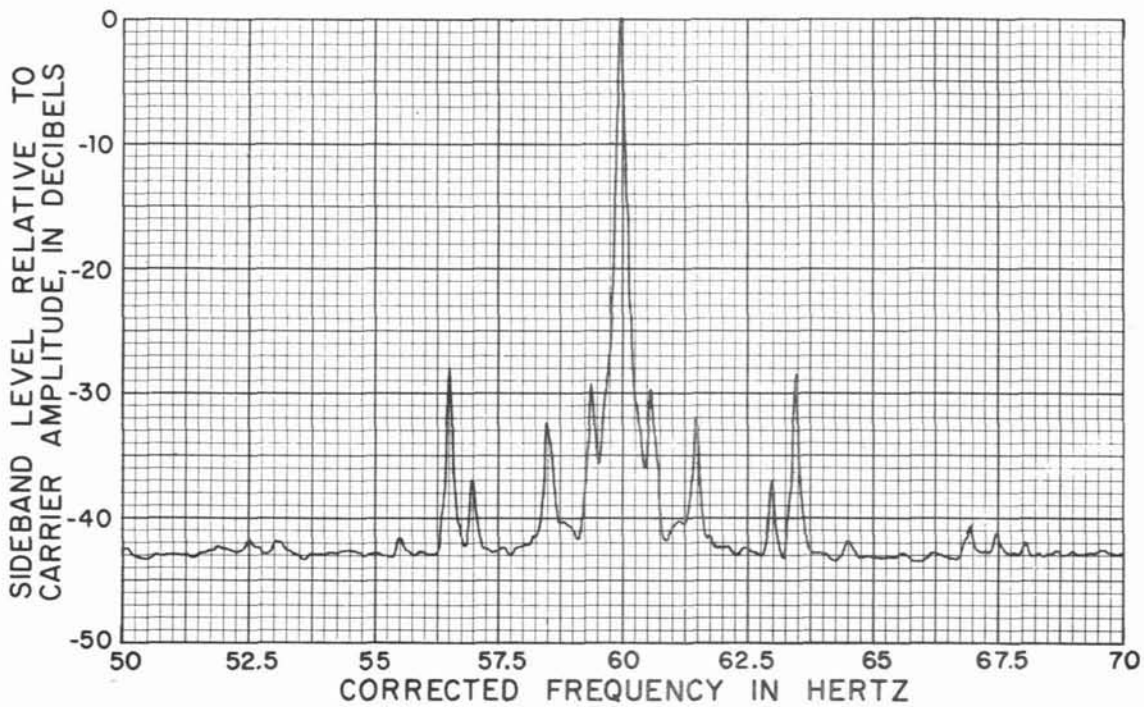

Fig. 13. Flutter sideband spectrum of a 60-Hz test recording from Uher 5000 recorder labeled "Exhibit 60". Resolution, 0.05 Hz. Average of 8 spectra, 20 s each. Duration of signal analyzed, 160 s.

References

[1] Shea, MacNau and Subrizi, "Flutter in Sound Recording," J. Soc. Mot. Pict. Engs. 25, 403-415 (1935 Nov.).

[2] J. G. McKnight, "Time Base Distortion in Continuous Recording Systems," J. Audio Eng. Soc. 10, 44-48 (1962 Jan.).

[3] W. Wolf, "Electromechanical Analogs of the Filter Systems Used in Sound Recording Transports," IEEE Trans. Audio & Electroacoust. AU-14, 66-85 (1966 June).

[4] R. R. Scoville, "A Laboratory Flutter-Measuring Instrument," J. Soc. Mot. Pict. Engs. 29, 209-215 (1937 Aug.).

[5] F. E. Terman, Electronic and Radio Engineering, New York, McGraw Hill, 4th ed., 1955. See Section 17-1, "Frequency-modulated waves," pp. 586-592.

Technical Note 7

TAPE SPEED ANALYSIS OF RECORDERS AND RECORDINGS

Tape recorders do not usually operate at exactly their standard speed. The relative difference between the actual speed and the standard speed of the machine is a specific mechanical characteristic of each individual recorder. The measurement of tape speed is explained in detail in the literature [1].

In Technical Note 6 we described how we measured the flutter sideband spectrum recorded on the Evidence Tape by playing it on a Nagra III recorder-reproducer, feeding the output into a Federal Scientific Corporation analyzer, and plotting the frequency spectrum observed in the vicinity of 60 Hz. The procedure gives the value of the power line hum frequency as actually recorded on the tape. The amount by which the recorded frequency differs from the actual frequency of 60 Hz provides a measure of the speed of the recorder on which the Evidence Tape was recorded.

We used the same procedure to measure the tape speed on the eight recording machines being studied. These were six Sony recorders and two Uher recorders provided to us as evidence equipment. On each of these machines we made a test tape by recording a tone of exactly 60 Hz, and then we measured the recorded frequency in the manner explained above.

The results of the measurements of the Evidence Tape are given in Table 1. The results of the measurements of the eight tape recorders are given in Table 2.

Through these tests we found that all the tape recorders show a drift in speed of about ± 5 parts per thousand (per mill). Therefore, differences between machines must be larger than this amount to provide a significant indication as to which machine was probably involved in making a particular recording. This range in speed is not surprising in view of the tape recorder designs. The Uher recorder uses an induction motor, the speed of which is influenced by temperature and line voltage. In the line voltage range from 105 to 125 volts, the speed of the Uher recorders increased by about 0.5 mill per volt of increase in line voltage. The Sony recorder uses an inexpensive servomechanism system to control the speed, and the resulting control is influenced by temperature and other operating conditions.

Using the data given in Tables 1 and 2, we can compare the speed of the recorder that made the Evidence Tape with the speed of each of the recorders we tested. In both cases we are actually measuring the speed indirectly, by measuring the recorded frequency of a 60 Hz tone. If the recorded frequency is higher than 60 Hz, then the recorder was moving the tape slower than its standard value of 23.8 millimeters per second (15/16 inch per second).

We make the comparisons by using the data given in the last column of the tables. This is the relative speed expressed in parts-per-thousand difference from the standard speed. Table 1 shows a relative speed of +15 for the speech before the buzz section. The machine that recorded the speech was running at 15 parts per thousand faster than 23.8 mm/s, and could have been Sony 800B, Serial Number 14 384 or 11 561.

Data in Table 1 also show that the speed of the machine that recorded the buzz was fairly constant (+23 to +29 per mill) throughout the buzz section. This speed is similar to that of the Exhibit 60 Uher (+28 per mill), but appreciably different from that of the Secret Service Uher (+61).

Therefore the results of recorder speed analysis agree with the results of flutter analysis reported in Technical Note 6. A Sony was used to record the speech on the Evidence Tape and the Exhibit 60 Uher was used to record the buzz section.

REFERENCE

[1] J. G. McKnight, "Speed, Pitch and Timing Errors in Tape Recording and Reproducing," Jour. Audio Eng. Soc. 16, 266-274 (July 1968).

Table 1

Measurement of Speed of the Recorder that Made the Evidence Tape

Recorder	Frequency When Reproduced at 23.8 mm/s [Hz]	Speed of the Recorder Relative to 23.8 mm/s [per mill]
Speech before buzz	59.15	+15
Buzz, Event Time 1 s	58.60	+23
Buzz, Event Time 50 s	58.25	+29
Buzz, Event Time 276 s	58.25	+29
Buzz, Event Time 1043 s	58.65	+24

Table 2

Measurement of the Speed of
Two Uher and Six Sony Recorders

Recorder	Frequency When Reproduced at 23.8 mm/s [Hz]	Speed of the Recorder Relative to 23.8 mm/s [per mill]
Sony Recorders used in Executive Office Bldg.		
SN 12 330 (A)	60.15	-2
SN 15 367 (B)	59.55	+8
SN 14 384 (C)	59.30	+12
Sony Recorders used in Oval Office		
SN 11 561	59.30	+12
SN 14 396	59.48	+9
SN 15 102	59.80	+3
Uher 5000 "Secret Service"	56.53	+61
Uher 5000 "Exhibit 60"	58.30	+28

TECHNICAL NOTE 8

THE K-1 PULSE AS DIRECT EVIDENCE OF KEYBOARD MANIPULATION

The Uher 5000 recorder contains a mechanical switch, labeled K-1 by the manufacturer, which opens and closes only as a result of pushing certain keys on the keyboard of the machine. The K-1 switch cannot be operated by a foot pedal or by the switch on the accessory hand-held microphone. Further, no kind of malfunction in the electronics of the recorder, such as intermittent failure of a diode, transistor, or capacitor, can actuate the K-1 switch.

Operation of the K-1 switch, whether opening it or closing it, generates a transient electrical pulse. If the machine is recording on tape when K-1 is actuated, the pulse will be recorded. We have observed this recorded pulse in three ways: as an audible click, as a magnetic mark, and as a spike in the waveform reproduced from the tape. We call these three kinds of data, individually and collectively, a signature. We have established with certainty that the K-1 signature is generated only when the K-1 switch is actuated. It is not and cannot be generated by any other electro-mechanical component in the recorder.

This Technical Note describes the K-1 switch in detail, shows how it operates, explains its function, and reports on magnetic marks made by operation of the switch. It also gives the results of simulations through which we have demonstrated the role of K-1 data in