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345 Middlefield Road
Menlo Park, California 94025

TESTS OF THE STANDARD (30 hz) NCER FM MULTIPLEX TELEMETRY SYSTEM, AUGMENTED BY TWO TIMING CHANNELS AND A COMPENSATION REFERENCE SIGNAL, USED TO RECORD MULTIPLEXED SEISMIC NETWORK DATA ON MAGNETIC TAPE

by

Jerry P. Eaton

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J. P. Eaton March 1976

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I Introduction

The application of subtractive compensation to USGS seismic magnetic tape recording and playback systems was examined in a recent USGS Open-file report (1). It was found, for the standard (30 hz) NCER multiplex system, that subtractive compensation utilizing a 4688 hz reference signal multiplexed onto each data track was more effective than that utilizing a 3125 hz reference signal recorded separately on a different track. Moreover, it was found that the portion of the spectrum between the uppermost data channel (3060 hz $\pm$125 hz) and the compensation reference signal (4688 hz) could be used to record an additional timing signal, with a center frequency of 3700 hz and a broader playback bandwidth (ca 0 to 100 hz) than that of the standard data channels. Accordingly, for the tests described in that report, the standard 8-data-channel multiplex system was augmented by one additional timing channel with a center frequency of 3700 hz. The 3700 hz discriminator used in those tests was not successfully set up to utilize subtractive compensation; so its output from a tape playback was quite noisy.

Subsequently, further tests have been carried out on the application of subtractive compensation to a 4-channel broad-band multiplex system and to the standard multiplex system, both recorded on field tape recorders with relatively poor tape speed control (2), (3). In the course of these experiments, it was discovered that two separate timing channels, not just one, can be inserted between the uppermost data channel and the compensation reference signal. Furthermore, it was possible to adjust the discriminators used to playback these timing channels so that they profited significantly from subtractive compensation even though the playback bandwidth was 0 to 100 hz (for short rise times of square wave timing signals). The advantages of recording two timing signals on each data track include:

1) one standard time signal to be used for critical timing, e.g. IRIG E, can be recorded with the data on each track, eliminating any problem that might arise from tape head misalignment if the timing base were recorded on a separate track from the data signals being timed,

2) other essential timing signals e.g. WWVB and IRIG C, can each be recorded on several tracks, to insure more reliable recording through redundancy, without displacing data from standard data channels,

3) the broader playback bandwidth of the special timing channels reproduces the sharp-edged timing codes with much less distortion than is obtained from the standard data channels.

In order to implement subtractive compensation with the 4688 hz multiplexed signal and to record timing signals on the proposed special timing channels, it was necessary to design and build a signal generator/multiplexer unit. The functions of this unit are:

1) generate a stable (x-tal controlled) compensation reference frequency (4688 hz),

2) generate two timing channel subcarriers (3500 hz and 3950 hz) and provide for their modulation by appropriate timing signals,

3) separately, for each of the 14 tape tracks, adjust the relative levels of the timing and compensation subcarriers and multiplex them, at the appropriate

level, with the incoming multiplexed data signals for introduction to the tape system direct record amplifiers. These units will be described in detail by Gray Jensen, who designed and built them, as well as being shown diagramatically in this report.

This report continues the work described in reference (1), and it should be read as a supplement to that report rather than as an independent effort. It introduces changes in the multiplex system and test circuits employed in the tests and then repeats the tests from the earlier report that are required to illustrate the characteristics of the modified system.

II Multiplex system format and equipment modifications

The channel layout of the fm multiplex system studied in these tests is shown in figure 1. The 8 data channel subcarriers have center frequencies given by $CF_i=(1+i)340$ hz; i=1, 8. The maximum deviation imposed on the subcarriers is ± 125 hz. The two timing channel subcarriers have center frequencies of 3500 hz and 3950 hz, and the maximum deviation imposed on the timing subcarriers is ± 25 hz. The compensation reference frequency, 4687.5(=3x1562.5 hz), was selected because it is an integer multiple of the reference frequency needed for capstan speed control in the Bell and Howell model 3700 B tape playback machine, it is near the upper limit of the recording range (in direct record mode at a 15/16 ips tape speed) of the B&H 3700 B, and it is well outside the range of frequencies (ca. 300 hz to 3200 hz) that can be transmitted over voice grade phone circuits and can be used for data transmission.

The data channel discriminators used with this system on playback have input (subcarrier) bnadwidths of ± 125 hz and output (data) bandwidths of 0 to 30 hz. The timing channel discriminators also have an input bandwidth of ± 125 hz, but the output (timing signal) bandwidth is 0 to 100 hz. The input bandwidth of the compensation reference discriminator is ± 200 hz, and its output (compensation signal) bandwidth is about 0 to 350 hz. The characteristics of the compensation discriminator filters are extremely critical: for effective compensation of the data and timing channels, the phase of the compensating signal (which has passed through both filters) must match the phase of the compensated signal at the point it emerges from its input bandpass filter, before it actually undergoes discrimination.

The test VCO bank to generate the multiplexed signals required for adjusting the compensation signal input levels to the data and timing discriminators and to evaluate various aspects of the performance of the overall system was modified to include the two timing channels (figure 2). As in the earlier version, each modulator can be included in or excluded from the multiplexed signal and modulated or left unmodulated independently of the others. Also, either of two modes of modulation can be selected: the equal deviation mode in which each subcarrier is shifted ± 125 hz for a ± 3.0 v modulating signal (or proportionaly less for smaller signals), and the proportional deviation mode in which each subcarrier is deviated an amount proportional to its center frequency ($\pm 188 \times \frac{CFi}{4688}$ hz for a ± 3.0 v modulating signal). The proportional deviation mode simulates the signals, as viewed on playback, that result from tape speed variations on record and/or playback.

In actual use, the multiplexed data signals will arrive at the recording point via phone line and will be mixed with locally generated time signals and compensation reference signal. The modulation of the timing channels will also be independent of that of the data channels - a condition that cannot be met by the test modulator bank by itself. To provide more realistic tests of the system that will actually be used to record telemetered seismic network data and to play it back with compensation, a hybrid test modulator bank was constructed by combining the test modulator bank described above with one of the standard "compensation and timing multiplexer" units that will be used with all of the network tape recorders (figure 3). In the hybrid test modulator bank, the compensation reference signal remained unmodulated and the timing channels were modulated (with square waves to simulate timing codes) independently of the data channels. The timing and compensation channels of the "normal" test modulator bank were, of course, switched off when it was used in the hybrid configuration.

III Tests with the test modulator bank

As a partial test of the discriminators that were modified (from standard data channel units) to play back the two timing channels, three experiments were carried out with the test modulator bank driving the discriminator bank directly.

a. Noise/dynamic range test

All data and timing modulators were deviated in the equal deviation mode by a 1 hz square wave at modulation levels ranging from 0 db (100 %) to -60 db (0.1 %). The resulting multiplexed signal was fed directly into the discriminator bank; and the output signals from the discriminators, which were subjected to subtractive compensation, were recorded on the Oscillomink direct writing oscillograph (figure 4). The Oscillomink sensitivity was increased as modulation level was decreased to produce legible records. Background noise on the data channels was a little greater than -60 db (i.e., 0.1 % of maximum output for full deviation). Background noise on the timing channels was at about the -50 db level. The effect of out-of-adjustment subtractive compensation can be seen on the -20 db test strip, where the compensation channel was also modulated for part of the experiment.

b. Compensation adjustment test

To permit critical adjustment of the potentiometers that set the level of compensation signal input to the data and timing discriminators, all channels of the test modulator bank, including the conpensation reference signal, were modulated in the proportional deviation mode by a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave at a modulation level of -10 db (31.6 %) for the 4688 hz reference channel. This level of modulation produces signals equivalent to a 1.26 % variation in tape speed. The multiplexed signals were fed directly to the discriminator bank, and the discriminator output signals were recorded on the Oscillomink (figure 5). Subtractive compensation was applied to all data and timing signals. With the 1 hz square wave modulation in progress, the compensation input level potentiometers on the individual discriminators were adjusted to minimize the steps produced by the square wave. The playout sensitivity of the compensation channel is 20 db lower than that of the other channels. On figure 5, the expected level of the uncompensated (raw) signal and the level of the compensation error signal, both in mv p-p, are shown for each data and timing channel. Compensation was more effective for the data channels than the timing channels, as was expected because of the broader bandwidth of the timing channel discriminator output filters. For the data channels, the peak error signals range from 12.5 mv p-p (channel 4) to 29.0 mv p-p (channel 7) for a simulated tape speed variation of 1.26%. Scaling these figures to ±1.0% tape speed variation and noting that the maximum discriminator output level is 4.0 v p-p, we find that the noise resulting from ±1 % tape speed variation should be down 45 db to 52 db below the maximum output level. The amount of compensation achieved in this test is near 30 db for channels 3 through 8, 24 db for channel 2, and 17 db for channel. For the timing channels, the amount of compensation realized depends strongly on frequency: at 25 hz, it is about 12 db for (T1) and 19 db for (T2); and at 50 hz it is about 8 db for (T1) and 15 db for (T2).

c. System frequency response test

To illustrate the frequency response of the timing channels and to compare it with that of the data channels, the timing and data channels were modulated in the equal deviation mode at the -10 db (31.6%) level by a 4 hz to 100 hz swept frequency sine wave (figure 6). The amplitude of the timing channel signals is down to 50% of the low frequency maximum at about 100 hz, whereas the response of the data channels falls off to that level at about 30 hz.

IV Tests with the hybrid test modulator bank: test modulator combined with the compensation and timing multiplexer unit

Prior to its use in evaluating the effectiveness of tape speed compensation, the hybrid test modulator bank was connected directly to the discriminator bank for the following tests to choose a modulation level for the timing channels, compare the response of the timing and data channels to time code signals, and to investigate noise levels, frequency response, and cross-talk levels of the system used without tape recording.

a. Noise/dynamic range test

The timing channels were modulated by a 0.5 hz square wave at a level of $\pm$1.5 v ($\pm$25 hz), the compensation channel was not modulated (x-tal controlled), and the data channels were modulated in the equal deviation mode by a 1 hz square wave at levels ranging from 0 db (100%) to -60 db (0.1%) in 10 db steps. The resulting multiplexed signal was fed to the input of the discriminator bank, and the ouput signals from the discriminators, which were subjected to subtractive compensation (with 1 exception noted below), were played out on the Oscillomink at a paper speed of 10 mm/sec and at the sensitivity settings indicated on the individual traces (figure 7).

The timing channel modulation appears to have no effect on data channel noise levels, although it does affect the level of high frequency noise on the compensation channel output. Heavy modulation of channel 8, however, produces noise on the output of timing channel T1. Although the level on T1 for 100% modulation of 8 is about 40% of that produced by $\pm$25 hz modulation of T1, it does not seriously impair the legibility of time code recorded on T1. An increase in the time-code-induced modulation level of T1 would lead to a proportional increase in the time code signal relative to the noise from heavy modulation of channel 8. Timing channel T2 is unaffected by strong modulation of other channels.

Inspection of the tests for low data channel modulation levels (-50 db and -60 db) shows that the hybrid test modulator/discriminator/Oscillomink system noise level is about 60 db below the maximum discriminator output level. The character and level of the noise is altered only slightly (decreased) when the compensation discriminator is removed.

b. System response

The timing channels were modulated by a square wave at a level of $\pm$1.5 v ($\pm$25 hz), the compensation channel was unmodulated, and the data channels were modulated by a 5 hz to 100 hz swept frequency sine wave at various levels. The multiplexed signals were fed to the discriminator bank, operating with subtractive compensation; and the discriminator output signals were played out on the Oscillomink at a paper speed of 100 mm/sec and at the sensitivity settings indicated on the individual traces (figure 8). The noise on channel T1 induced by strong modulation of channel 8 is evident on figure 8a (100% modulation). The imposed data signals are clearly recoverable to frequencies as high as 50 hz, even for the 1% modulation level (figure 8c).

c. Timing channel modulation test

All 8 data channels were modulated in the equal deviation mode at a level of -60 db (0.1%), the compensation channel was unmodulated, and the timing channels were modulated by a 0.5 hz square wave at modulation levels of $\pm$2.0 v ($\pm$33 hz), $\pm$1.5 v ($\pm$25 hz), $\pm$1.0 v($\pm$17 hz), and $\pm$0.5 v ($\pm$8 hz). The multiplexed signals were fed directly to the discriminator bank; and the outputs of the discriminators, which were operated with subtractive compensation, were played out on the Oscillomink at a paper speed of 10 mm/sec and at the sensitivity settings indicated on the individual traces (figure 9). The background noise level on all data traces was near -60 db, relative to the maximum discrimitor ouput, and was independent of the timing channel modulation level. High frequency noise on the compensation channel increased in amplitude with increasing timing channel modulation, but no adverse effect on the data or timing traces is discernable.

d. Comparison of timing channel and data channel response to square waves.

A 10 hz square wave modulating signal was applied to both timing channels and all data channels except 2 and 7. The Oscillomink traces normally used for the latter were used to record the square wave modulating signal directly. The Oscillomink paper speed was 500 mm/sec, and the sensitivity settings were selected to provide comparable amplitudes for the data, timing, and modulation "channel" signals (figure 10). Delay times, relative to the sharp changes in modulating voltage levels, in the response of average timing and data channels are:

% Shift	T1 and T2	3 and 6
10%	3.2 ms	10.6 ms
50%	5.4 ms	17.6 ms
90%	7.4 ms	25.8 ms

For critical timing applications where a timing precision of a few milliseconds is required, the broad-band timing channels are clearly superior to the data channels for recording time codes.

e. Cross-talk tests

Timing channels T1 and T2 were modulated at the ± 1.5 v(± 25 hz) level by a

0.5 hz square wave, the compensation channel was unmodulated, and the data channels were modulated, but only one at a time, at the 0 db (100%) level by a 2 hz square wave and a 2 hz to 100 hz swept frequency sine wave. The multiplexed output of the modulator bank was fed directly to the discriminator bank, and the output signals from the discriminators, which were subjected to subtractive compensation, were recorded on the Oscillomink at a paper speed of 25 mm/sec and at the sensitivity settings indicated on the individual traces (figure 11).

During the 100% square wave modulation of a given data channel,cross-talk appears on other data channels, particularly the next lower frequency channel where the induced noise can be as high as 45 db below maximum output. During the 100% sine wave modulation of a given data track cross-talk to other data channels is generally minimal (approaching -60 db). The one important exception is channel 1, which shows cross-talk from channel 2 at the -52 db level and from channel 3 at the -56 db level. Full modulation of data channel 8, however, induces a 250 mv p-p (out of 800 mv p-p for the $\pm$25 hz time channel modulation) cross-talk signal on time channel T1. Because the induced signal is very high frequency, it does not impair the legibility of the time code, but it still might degrade the performance of a time code decoder. Thus, T1 should be used for WWVB or IRIG-C, which are primarily for visual use or (WWVB) for occasional calibration of the time code generator.

V Tests on playbacks from the Sony model TC-126 cassette tape recorder

To illustrate the efficacy of subtractive compensation applied to the NCER fm multiplex system when the multiplexed signal is recorded and played back on an inexpensive consumer grade tape recorder, the following tests were carried out with a Sony model TC-126 cassette tape recorder. Speed variations in this machine are about $\pm 1\%$, and the audio response is reasonably flat between 500 hz and 1 khz and falls off to about 40% at 100 hz and 6 khz (using standard iron oxide tape).

a. Compensation test

The compensation adjustment test described under section IIIb was repeated with the following modification: the multiplexed signal from the test modulator bank (modulated in the proportional deviation mode) was recorded on the Sony, then played back on the Sony to recover the multiplexed signal which was fed into the discriminator bank. The discriminators were subjected to subtractive compensation, and their output signals were recorded on the Oscillomink at a paper speed of 10 mm/sec (figure 12). The modulating signal consisted of a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave at a level of -10 db (31.6%) on the 4688 hz channel. The Oscillomink settings on figure 12 are the same as those on the earlier test, figure 5, in which the multiplexed signal was fed directly from the test modulator bank to the discriminaotr bank. Allowing for the difference in recording speed (10 mm/sec vs. 50 mm/sec), the records of the two tests are quite comparable except for the higher level of high frequency noise on the Sony test (figure 12). In this test, subtractive compensation was operating to suppress real tape-speed induced noise as well as the simulated tape-speed-induced noise generated by the test modulator bank.

b. System response test (hybrid test modulator bank)

The timing channels were modulated by a 2 hz square wave at a level of $\pm$ 1.5V ($\pm$ 25 hz), the compensation reference channel was not modulated, and the data channels were modulated by a 1 hz to 100 hz swept frequency sine wave at modulation levels of 0 db (figure 13a), - 20 db (figure 13b), and - 40 db (figure 13c). The multiplexed signals from the modulator bank were first recorded on the Sony, then played back on the Sony and fed into the discriminator bank. The output signals from the discriminators, which were operating with subtractive compensation, were played out on the Oscillomink at a paper speed of 25 mm/sec and at the sensitivity settings indicated on the individual traces.

On figure 13a, the "drop outs" on positive going wave crests on channels (1), (6), and (7) are not understood. A comparable test, at the same modulation level (100%), in which the modulator bank output was fed directly to the discriminator bank produced similar "dropouts" on channel 1 only. The Oscillomink electronics may be responsible for this problem.

On figure 13c (1% modulation level) the data signal can be separated from the noise at frequencies below 30 hz, but above 30 hz the data signal level drops into the noise.

c. Compensation effectiveness tests (hybrid test modulator bank)

The timing channels were modulated by a 2 hz square wave at a level of $\pm$1.5 v ($\pm$25 hz), the compensation channel was unmodulated, and the data channels were modulated by a 1 hz square wave at levels of -30 db (3.2%), -40 db (1.0%), and -50 db (0.32%). The multiplexed signal from the modulator bank was first recorded on the Sony, then played back on the Sony and fed to the discriminator bank. The output from the discriminators was recorded on the Oscillomink at paper speeds and sensitivity settings indicated on figure 14. For the first part of each record, the subtractive compensation circuit was in operation; but for the second half, the compensation discriminator was removed to permit easy, direct comparison of the compensated and uncompensated playbacks.

figure	Modulation	Paper Speed	Data Channel Sensitivity
14a	-40 db (1.0%)	25 mm/sec	1.0 (50 mv/mm)
14b	-50 db (.32%)	25 mm/sec	0.25 (12.5 mv/mm)
14c	-40 db (1.0%)	25 mm/sec	0.25 (12.5 mv/mm)
14d	-30 db (3.2%)	100 mm/sec	0.25 (12.5 mv/mm)

Examination of the compensated portion of these records shows that the noise level is about -46 db (referred to maximum discriminator output) and that it varies little from trace to trace. During the uncompensated portion of the tests, the noise level increases steadily from channel 1 (about 150 mv p-p) to channel 8 (about 750 mv p-p). The predominant frequency in the noise, both for the compensated and the uncompensated case, is about 30 hz. The compensated noise level on channel T1 is about 150 mv p-p; and on channel T2, about 100 mv p-p. For both timing channels, the signal level (for ±25 hz deviation) is 400 mv p-p, and the uncompensated noise level is about 500 mv p-p.

The uncompensated noise level varies considerably in amplitude and character from place to place on the tape.

VI Tests on playbacks from the Bell and Howell model 3700 B tape recorder

Although extensive tests on the application of subtractive compensation to this tape recorder were reported in reference (1), the introduction of two timing channels, instead of one, between data channel (8) and the compensation reference signal and the modification of the compensation discriminator to enhance compensation of the timing channels constitute important changes in the system. Hence, minimal tests were carried out with the 3700 B to ascertain that the changes have not led to degradation of the performance of the compensation system.

a. Compensation adjustment test (test modulator bank)

The test carried out under section III b (test modulator bank driving the discriminator bank directly), and section V a (test modulator bank recorded on the Sony/Sony played back to drive the discriminator bank) was repeated with the 3700 B.

The test modulator bank was modulated in the proportional deviation mode by a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave at a level of -10 db (31.6%) for the 4688 hz channel. The multiplexed signal was first recorded on the 3700 B. then played back on the 3700 B and fed to the discriminator bank. The outputs of the discriminators, which were subjected to subtractive compensation, were played out on the Oscillomink at a paper speed of 25 mm/sec, and at the sensitivity settings indicated on the traces (figure 15). Compensation acted to suppress real tape-speed-variation induced noise as well as the simulated tape-speed-variation induced noise generated by the modulator bank. Allowing for the differences in paper speed and sensitivity of the timing and compensation tracks, the results illustrated in figure 15 for the 3700 B are very similar to those (figure 12) for the Sony. The residual high frequency background noise level is less for the 3700 B than for the Sony.

b. Compensation effectiveness test (hybrid test modulator bank)

This test was nearly the same as that described under section V c for the Sony. The timing channels were modulated by a 1 hz square wave at a level of ±1.5 v (±25 hz), the compensation channel was unmodulated, and the data channels were modulated by a 1.5 hz square wave at levels of -40 db (10%), -50 db (0.32%), and -60 db (0.1%). The multiplexed signal from the modulator bank was first recorded on the 3700 B (on tape track 5) and then played back on the 3700 B and fed to the discriminator bank. The outputs of the discriminators were recorded on the Oscillomink at a paper speed of 25 mm/sec. During the first portion of each test, the compensation circuit was in operation; but during the second portion of each test, the compensation discriminator was removed to facilitate easy comparison of the compensated and uncompensated playbacks.

Figure	Modulation	Paper Speed	Data Channel Sensitivity
16a	-40 db (11.0%)	25 mm/sec	0.1 (5 mv/mm)
16b	-50 db (0.32%)	25 mm/sec	0.1 (5 mv/mm)
16c	-60 db (0.1%)	25 mm/sec	0.1 (5 mv/mm)

Examination of the compensated portion of these tests shows that the noise level on the data channels is about -50 db relative to maximum discriminator output (full modulation). Channels 3,4,5, and 6 are somewhat quieter than channels 1,2,7, and 8. The noise peaks on the latter channels approach 20 mv p-p. During the uncompensated portion of the tests, the noise level increases steadily from channel 1 (about 25 mv p-p) to channel 8 (about 90 mv p-p).

The predominant frequency in the noise is about 8 hz. Previous experience indicates that it is related to the operation of the capstan servo system in the 3700 B.

The noise level on both timing channels is about 100 mv p-p with compensation and about 150 mv p-p without (compared to a signal of about 450 mv p-p from the $\pm$25 hz time code modulation).

The foregoing results substantiate the more extensive tests carried out previously on the 3700 B.

References

(1) Notes on some experiments on the application of subtractive compensation to USGS seismic tape recording and playback systems - by J.P. Eaton, USGS Open-file report # 75-663, 1975

(2) Notes on a broad-band variant of the NCER seismic data multiplex system for use with field tape recorders - by J.P. Eaton, USGS Open-file report # 76-87, 1976

(3) 15/16 ips operation of the PI 5100 tape recorder to record the standard (30 hz) NCER seismic data multiplex system - by J.P. Eaton, USGS Open-file report # 76-252, 1976

Figure Captions

Figure 1

Channel layout of the standard (30 hz) NCER 8-data-channel fm multiplex system augmented by 2 timing channels and a compensation reference signal for magnetic tape recording and playback.

Figure 2

Test VCO bank to generate multiplexed signals from the 8 data channels, 1 through 8, 2 timing channels, T1 and T2, and the compensation reference signal, C. Any subcarrier can be switched on or off independently; and the modulation of the data and timing channels can be in the "equal" mode ($\pm$125 hz for $\pm$3.0 v) or the "proportional" mode ($\pm\delta Fi = \pm 188 \times \frac{Fi}{4688}$ hz for $\pm$3.0 v input).

Figure 3

Schematic circuit diagram of the multiplex signal augmentation circuit. It generates the compensation reference signal and the two time-signal-modulated subcarriers and multiplexes all three with each of the 14 multiplexed data signals to be recorded on a 14 track tape recorder. Only one data channel with its multiplexing summing amplifier is shown. In practice, there are two T1 channels: one is modulated by WWVB and the other by the IRIG-C code from the chronometer. These signals are recorded on alternate tracks on both recording heads. Channel T2 is modulated by the IRIG-E code from the chronometer and is recorded on all tracks.

Figure 4

Noise/dynamic range test of the test modulator bank and playback discriminator bank. The 8 data channels and the 2 timing channels of the test modulator bank were modulated in the equal deviation mode at levels of 0 db (100 %), -10 db,...., -60 db (0.1%) by a 1 hz square wave, and the resulting myltiplexed signal was introduced directly to the discriminator bank input. Playout was on the Oscillomink direct writing oscillograph at the paper speeds and sensitivity settings indicated on the figure. Sensitivities corresponding to the various settings (underlined numbers at the top of the figure) are: 10 → 500 mv/mm; 2.5 → 125 mv/mm; 1.0 → 50 mv/mm; 0.25 → 12.5 mv/mm; 0.10 → 5 mv/mm. The compensation discriminator was functioning, and its reference signal was unmodulated except for the second half of the -20 db modulation test.

Figure 5

Compensation evaluation test for the test modulator bank. All channels, including the reference, were modulated in the proportional deviation mode (at the -10 db or 31.6% level for the 4688 hz channel) by a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave. The multiplexed output of the test modulator bank was introduced directly to the input of the discriminator bank. All channels (except the reference channel) were subjected to subtractive compensation. The discriminator output signals were played out on the Oscillomink at a paper speed of 50 mm/sec and the sensitivity settings indicated on the individual traces: 2.5 → 125 mv/mm; 0.1 → 5 mv/mm.

Figure 6

System frequency response test for the test modulator bank. All channels except the compensation reference channel were modulated in the equal deviation mode at the -10 db (31.6%) level by a 4 hz to 100 hz swept frequency sine wave, and the multiplexed output was introduced directly to the input of the discriminator bank. The subtractive compensation system was in operation. Playout of the discriminated signals was on the Oscillomink at a speed of 100 mm/sec and the sensitivity settings indicated on the individual traces: 1.0 → 50 mv/mm; 0.1 → 5 mv/mm.

Figure 7

Noise/dynamic range test for the hybrid test modulator (8 data channels from the test modulator bank plus 2 timing channels and a x-tal controlled reference signal from the compensation and timing multiplexer unit). The multiplexed signal from the hybrid test modulator was introduced directly to the input of the discriminator bank, and the discriminated signals were recorded on the Oscillomink at a paper speed of 10 mm/sec and the sensitivity settings indicated on the individual traces: 10 → 500 mv/mm; 2.5 → 125 mv/mm; 1.0 → 50 mv/mm; 0.25 → 12.5 mv/mm; 0.1 → 5 mv/mm. The timing channels were modulated by a 0.5 hz square wave at the ±1.5 v level (±25 hz) throughout, and the reference signal was not modulated. The data channels were modulated by a 1 hz square wave at levels of 0 db (100%) to -60 db (0.1%). Compensation was applied to all phases of the test but the last (far right), where the compensation discriminator was removed.

Figure 8

System response test for the hybrid test modulator. The data channels were modulated by a 5 hz to 100 hz swept frequency sine wave; and the timing channels were modulated by a 10 hz square wave (0.5 hz on test c) at a level of $\pm$1.5 v ($\pm$25 hz). The reference signal was not modulated. The multiplexed signal from the hybrid test modulator was introduced directly into the input of the discriminator bank, and the discriminated signals were played out on the Oscillomink at a paper speed of 100 mm/sec and at the sensitivity settings indicated on the individual traces: 10 → 500 mv/mm; 1.0 → 50 mv/mm; 0.1 → 5 mv/mm.

a. Data channel modulation level = 0 db (100%)

b. Data channel modulation level = -20 db (10%)

c. Data channel modulation level = -40 db (1%)

Figure 9

Timing channel modulation level test for the hybrid test modulator bank. The timing channels, T1 and T2, were modulated by a 0.5 hz square wave at levels of $\pm$2.0 v ($\pm$33 hz), $\pm$1.5 v ($\pm$25 hz), $\pm$1.0 v ($\pm$17 hz), and $\pm$0.5 v ($\pm$8 hz); the compensation reference signal was unmodulated, and the data channels were modulated by a 1 hz square wave at a level of -60 db (0.1%). The multiplexed signal from the modulator bank was introduced directly to the input of the discriminator bank, and the discriminator ouput signals were recorded on the Oscillomink at a paper speed of 10 mm/sec and at the sensitivity settings indicated on the individual traces: 1.0 → 50 mv/mm; 0.1 → 5 mv/mm. Compensation was applied to the timing channels and the data channels.

Figure 10

Square wave response-time test of the timing and data channels. A 10 hz square wave modulating signal was applied to data channels 1, 3, 4, 5, 6, and 8. at the -10 db (31.6%) level, to the inputs of timing channels T1 and T2 at the $\pm$1.5 v ($\pm$25 hz) level, and was recorded directly on traces 3 and 9 of the Oscillomink, which was running at a paper speed of 500 mm/sec. Compensation was applied to the timing and data channels. Playout sensitivities of the Oscillomink were adjusted to produce comparable signal levels on all traces (except the compensation channel, which was unmodulated).

Figure 11

Cross-talk tests: hybrid test modulator bank-discriminator bank. Timing channels T1 and T2 were modulated at the $\pm$1.5 v ($\pm$25 hz level) by a 0.5 hz square wave, and the data tracks were modulated, one at a time, at the 0 db (100%) level by a 2 hz square wave and a 2 hz to 100 hz swept frequency sine wave. The multiplexed output of the modulator bank was fed directly to the input of the discriminator bank, and the output signals from the discriminators were recorded on the Oscillomink at a paper speed of 25 mm/sec. Oscillomink sensitivity settings are indicated on the individual traces: 2.5 $\rightarrow$ 125 mv/mm; 1.0 $\rightarrow$ 50 mv/mm; 0.1 $\rightarrow$ 5 mv/mm.

a. ch 1 modulated at the 0 db level
b. ch 2 modulated at the 0 db level
c. ch 3 modulated at the 0 db level
d. ch 4 modulated at the 0 db level
e. ch 5 modulated at the 0 db level
f. ch 6 modulated at the 0 db level
g. ch 7 modulated at the 0 db level
h. ch 8 modulated at the 0 db level

Figure 12

Compensation adjustment test.

All channels of the test modulator bank - data channels, timing channels, and compensation reference - were modulated in the proportional deviation mode (at the -10 db or 31.6% level for the 4688 hz channel) by a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave. The multiplexed output was recorded on a Sony model TC-126 cassette tape recorder at a level (across the Sony input) of 250 mv p-p. The recorded tape was played back on the Sony and fed into the input of the discriminator bank. The outputs from the individual discriminators (to which subtractive compensation had been applied) were recorded on the Oscillomink at a paper speed of 10 mm/sec and at the sensitivity settings indicated on the traces: 2.5 → 125 mv/mm; 0.1 → 5 mv/mm.

Figure 13

System response tests: hybrid test modulator bank/Sony TC 126 cassette recorder/compensated discriminator bank.

The timing channels were modulated by a 2 hz square wave at the ±1.5 v (±25 hz) level, the compensation reference signal was not modulated, and the data channels were modulated at various levels by a 1 hz to 100 hz swept frequency sine wave. The multiplexed signal was recorded on the Sony (at a level of 250 mv p-p across the Sony input) and then played back on the Sony into the discriminator bank input. Subtractive compensation was applied to the timing and data discriminators, and their output signals were recorded on the Oscillomink at a paper speed of 25 mm/sec and at the sensitivity settings indicated on the traces: 2.5 → 125 mv/mm; 1.0 → 50 mv/mm;

0.25 12.5 mv/mm; 0.1 5 mv/mm.

a. 0 db (100%) modulation of data channels

b. -20 db (10%) modulation of data channels

c. -40 db (1%) modulation of data channels

Figure 14

Compensation effectiveness tests with the Sony TC-126 cassette tape recorder.

The timing channels of the hybrid test modulator bank were modulated by a 0.5 hz square wave at a level of $\pm$1.5 v ($\pm$25 hz), the data channels were modulated by a 1 hz square wave at various levels, and the x-tal controlled reference signal was not modulated. The multiplexed output signal was recorded on the Sony TC-126 cassette tape recorder at a level of 250 mv p-p across the Sony input. The tape was then played back on the Sony and the reproduced multiplexed signal was fed to the discriminator bank input. Subtractive compensation was applied to all timing and data discriminators for the first parts of the test intervals illustrated; but it was turned off (discriminator removed) during the remainder of each test. The discriminator output signals were played out on the Oscillomink at the paper speeds (25 mm/sec) and sensitivity settings (1.0 50 mv/mm; 0.1 5 mv/mm) indicated.

a. Modulation level -40 db (1%), Paper speed 25 mm/sec

b. " " -50 db (0.32%), " " " " "

c. " " -40 db (1%), " " " " "

d. " " -30 db (3.2%), " " 100 mm/sec

Figure 15

Compensation adjustment test

All channels of the test modulator bank - data channels, timing channels, and compensation reference - were modulated in the proportional deviation mode (at the -10 db or 31.6% level for the 4688 hz channel) by a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave. The multiplexed output signal was recorded on a Bell and Howell model 3700 B tape recorder; then it was played back through the same machine and fed to the input of the discriminator bank. Subtractive compensation was applied to all timing and data discriminators, and their outputs were recorded on the Oscillomink at a paper speed of 25 mm/sec and at the sensitivity settings indicated on the traces: 1.0 → 50 mv/mm; 0.25 → 12.5 mv/mm; 0.1 → 5 mv/mm.

Figure 16

Compensation effectiveness tests with the Bell and Howell model 3700 B recorder.

The timing channels of the hybrid test modulator bank were modulated by a 0.5 hz square wave at a level of $\pm$1.5 v ($\pm$25 hz), the data channels were modulated by a 3/2 hz square wave at various levels, and the x-tal controlled compensation reference signal was not modulated. The multiplexed signal from the modulator bank was first recorded, then played back, on the Bell and Howell model 3700 B recorder. The reproduced multiplexed signal was fed to the input of the discriminator bank. Subtractive compensation was applied to the discriminators during the first parts of the test interval and then cut off (compensation discriminator removed) during the rest of the interval. The discriminator output signals were recorded on the Oscillomink at a paper speed of 25 mm/sec and the sensitivity settings indicated: 1.0 → mv/mm; 0.1 → 5 mv/mm.

a. Data channel modulation = -40 db (1%)

b. Data channel modulation = -50 db (.32%)

c. Data channel modulation = -60 db (0.1%)

Standard (30hz) NCER Multiplex System

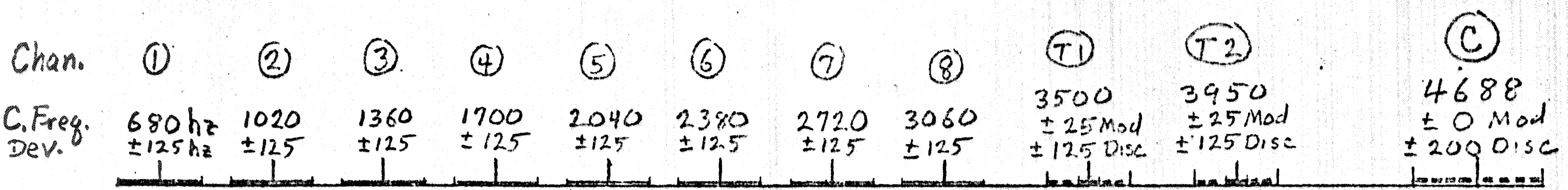


Fig 1

Test VCO bank for Standard NCER Mx System

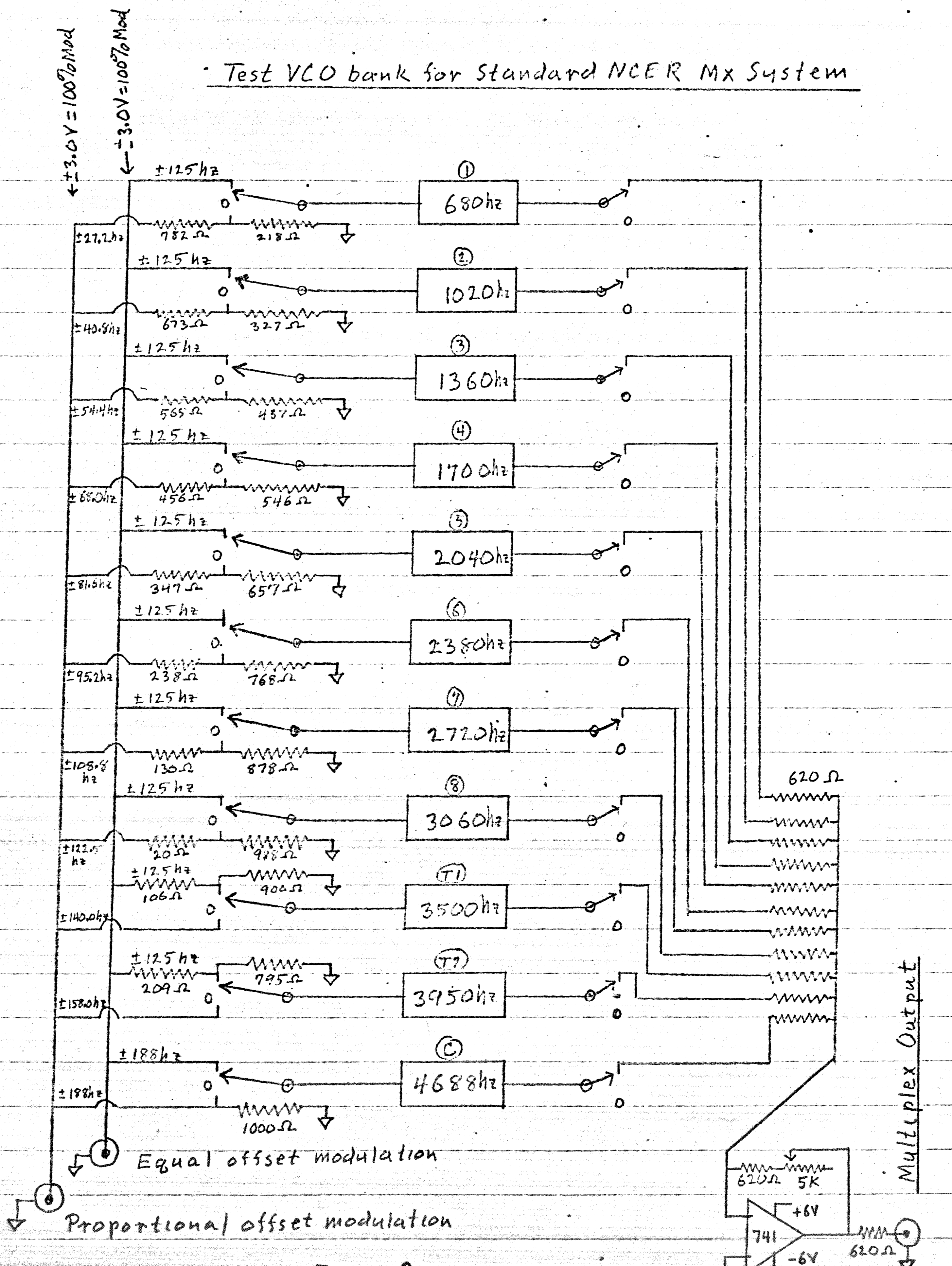
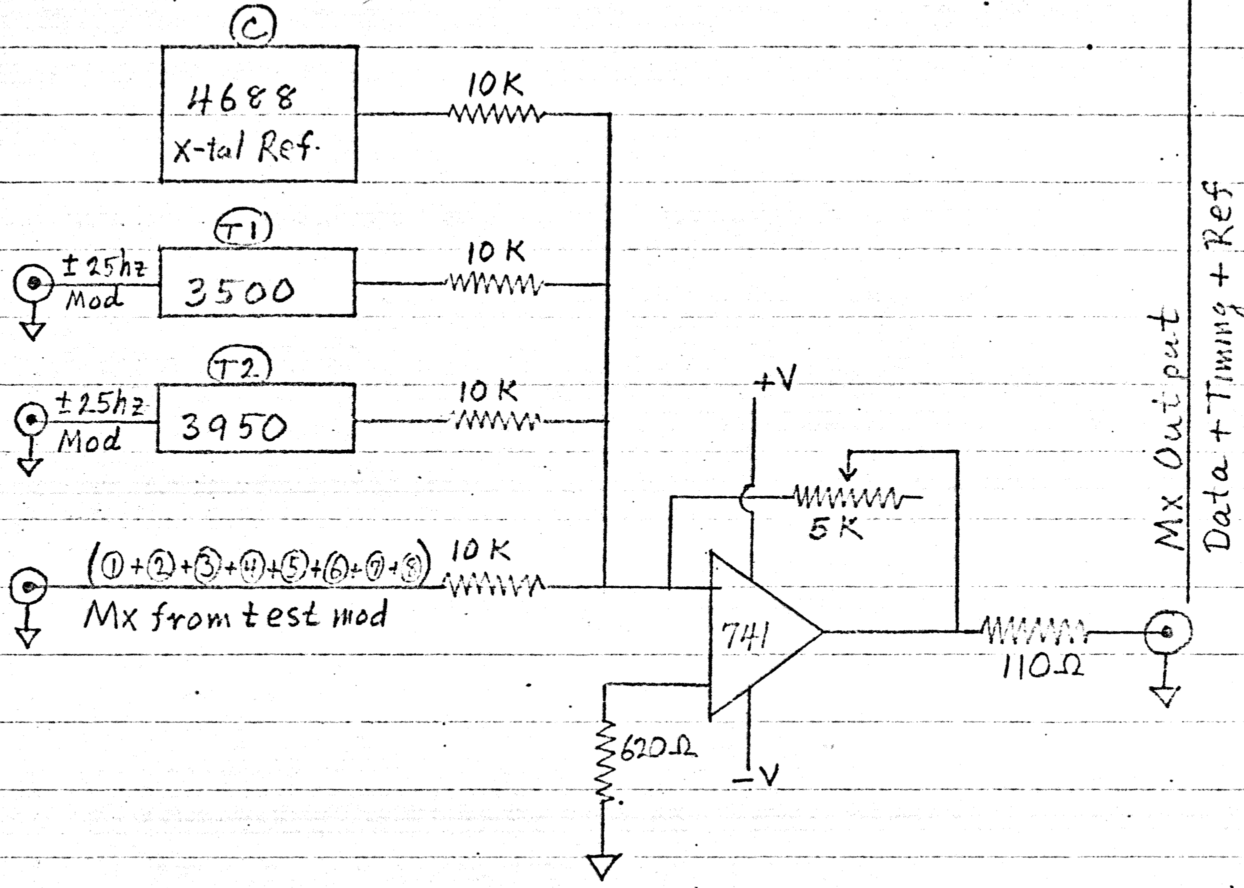


Fig 2



C
4688
X-tal Ref.
10K
T1
±25hz
Mod
3500
10 K
T2
±25hz
Mod
3950
10 K
(①+②+③+④+⑤+⑥+⑦+⑧)
Mx from test mod
10 K
+V
5 K
741
620Ω
−V
110Ω
Mx Output
Data + Timing + Ref

Fig 3

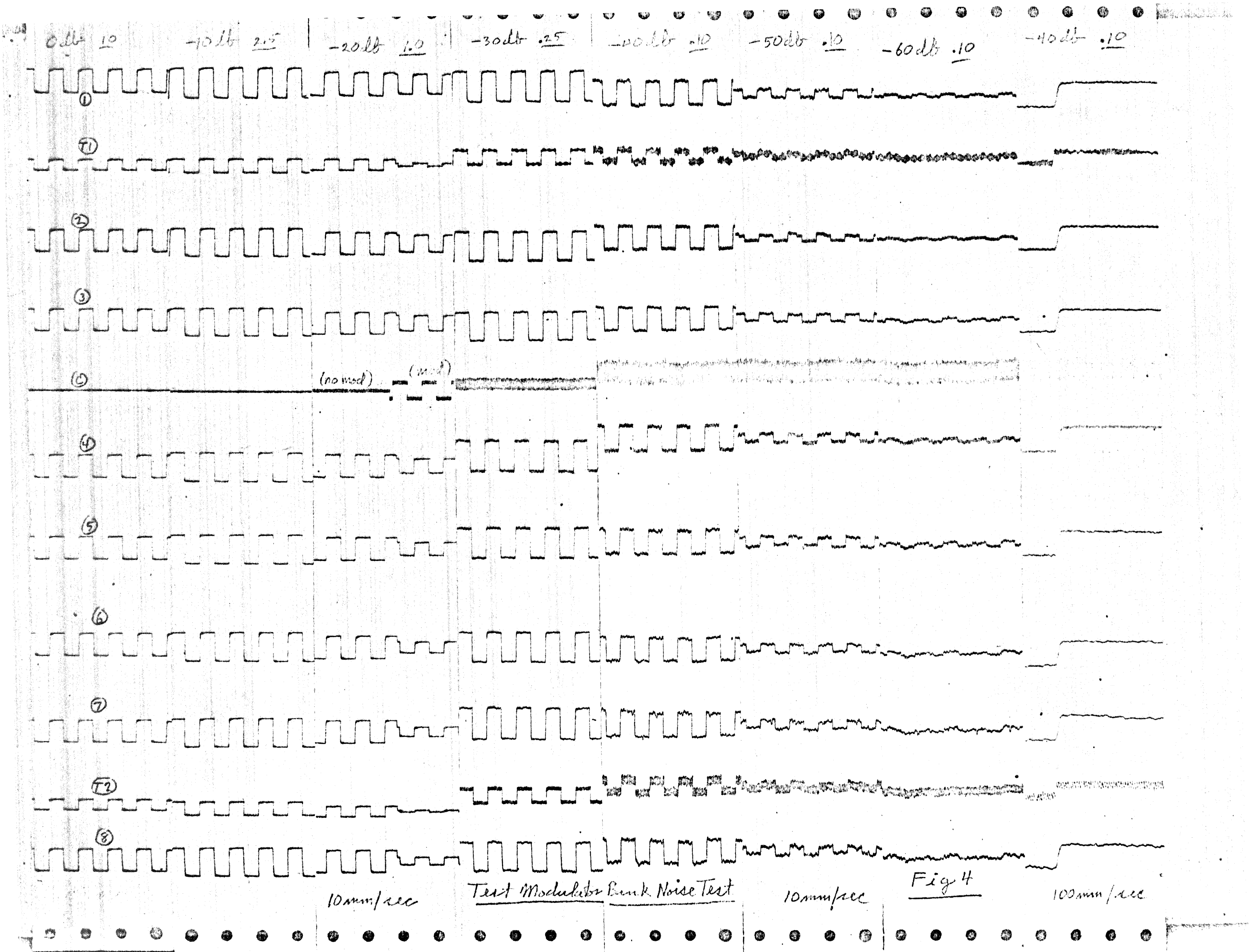

0db 1.0
-10db 2.5
-20db 1.0
-30db .25
-40db .10
-50db .10
-60db .10
-40db .10
(no mod)
(mod)
10mm/sec
Test Modulator
Bench Noise Test
10mm/sec
100mm/sec

Fig 4

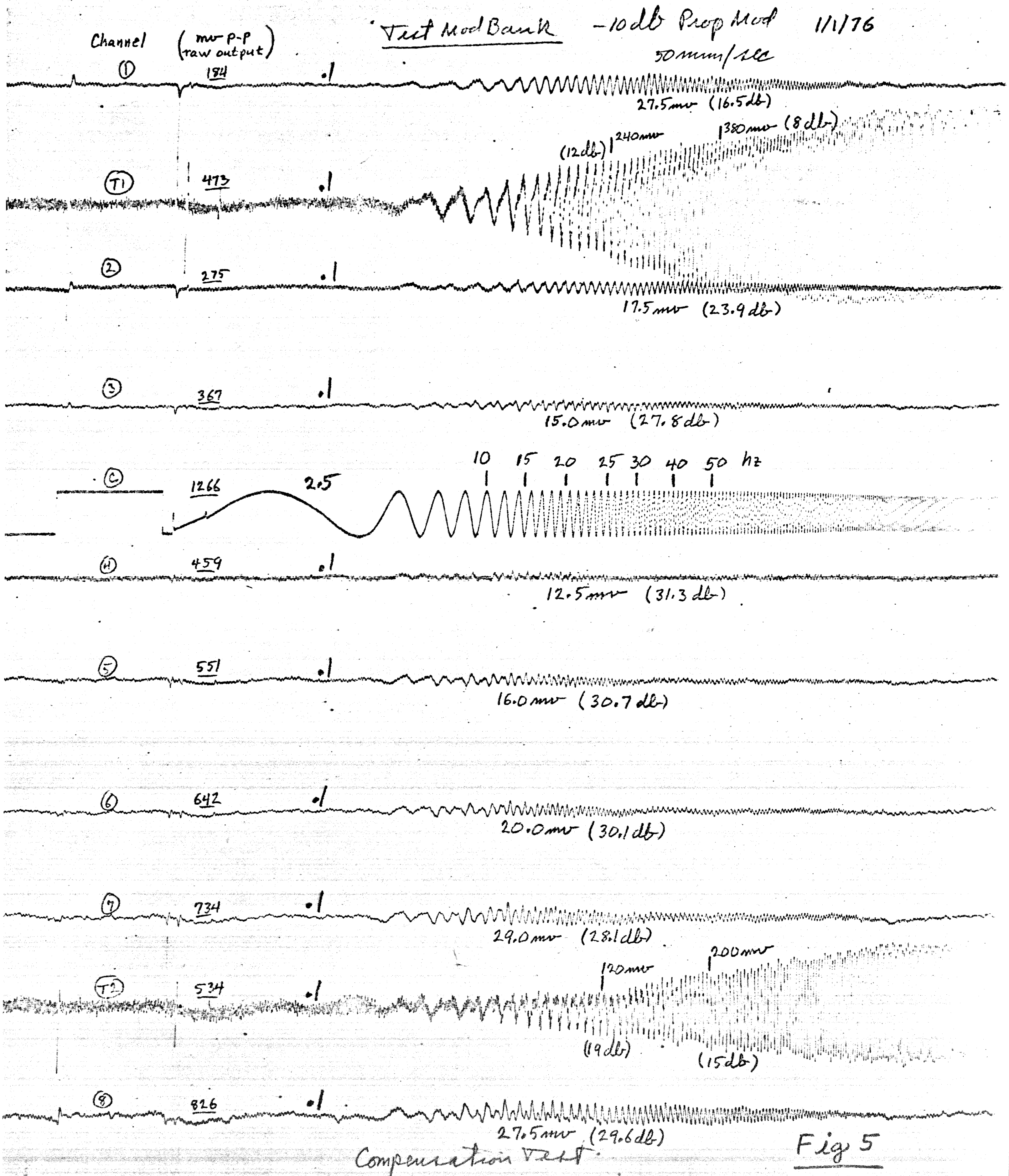

Vest Mod Bank -10db Prop Mod 1/1/76
50 mm/sec
Channel
(mv p-p raw output)
① 184
27.5mv (16.5db)
(12db) 240mv
380mv (8db)
T1 473
② 275
17.5mv (23.9db)
③ 367
15.0mv (27.8db)
10 15 20 25 30 40 50 hz
C 1266
2.5
④ 459
12.5mv (31.3db)
⑤ 551
16.0mv (30.7db)
⑥ 642
20.0mv (30.1db)
⑦ 734
29.0mv (28.1db)
120mv
200mv
T2 534
(19db)
(15db)
⑧ 826
27.5mv (29.6db)
Compensation Test

Fig 5

Test Mod Bank 12/29

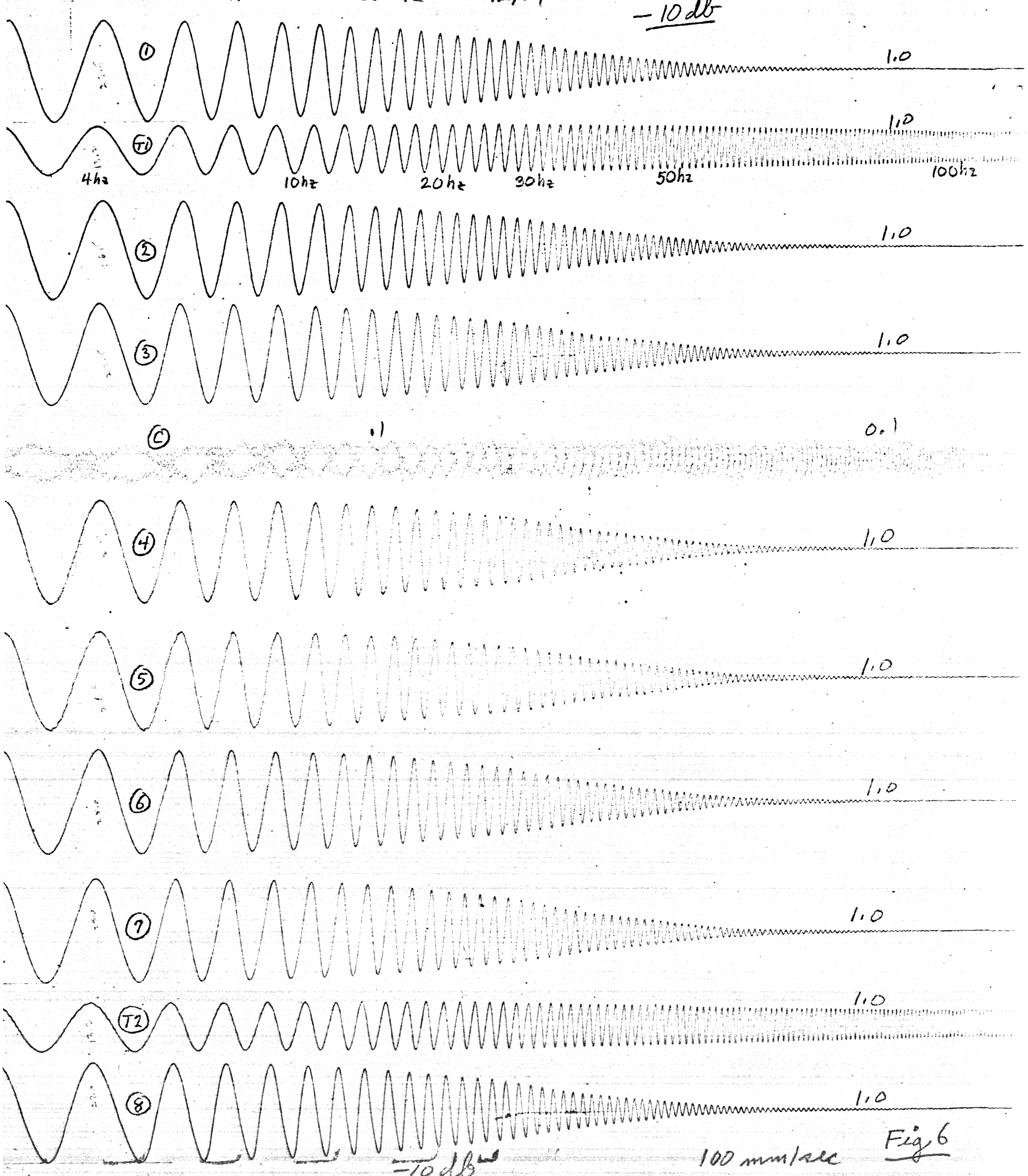
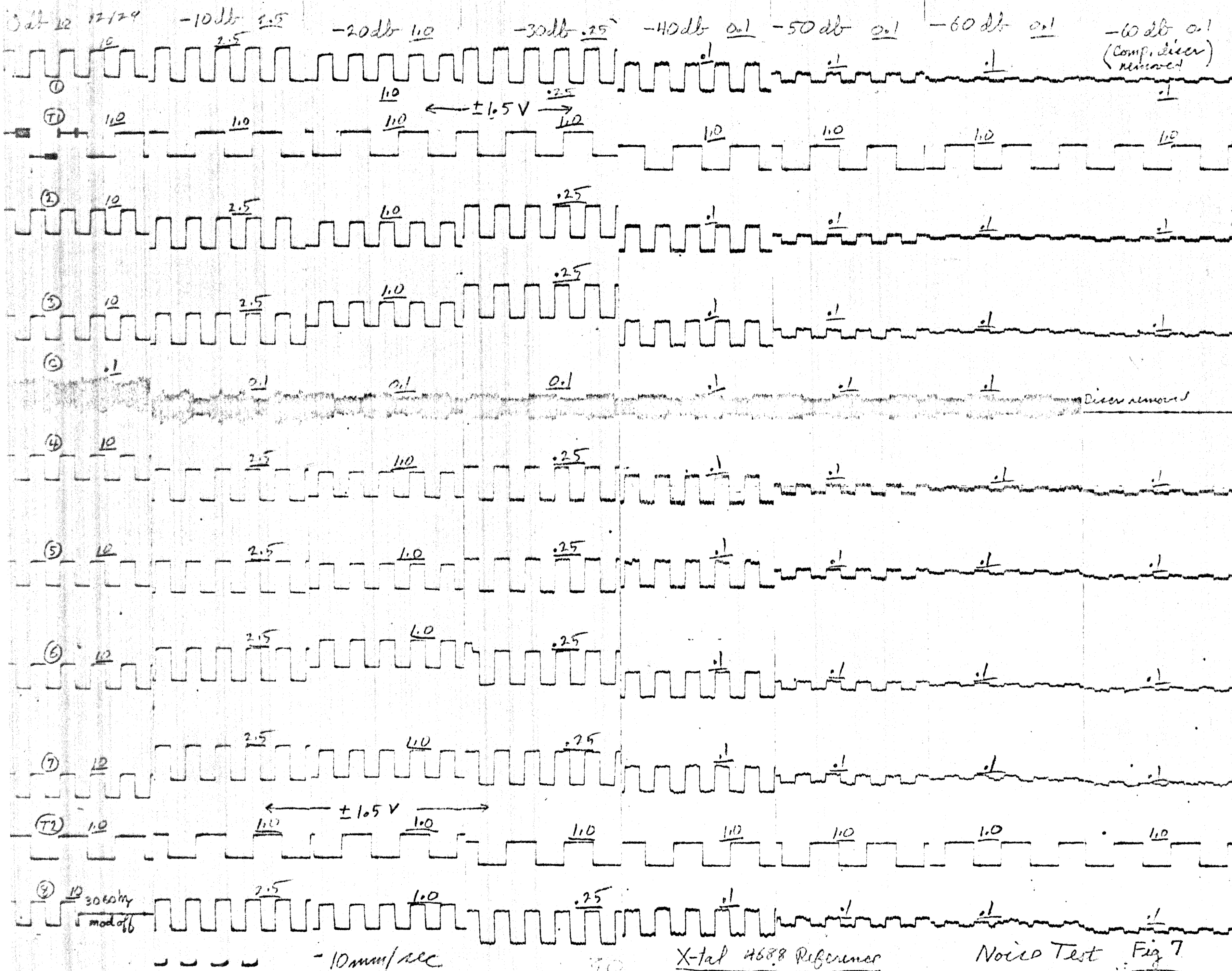


Fig 6



Noise Test Fig 7

0 db 100mm/sec 12/29 X-tal 4688 ref

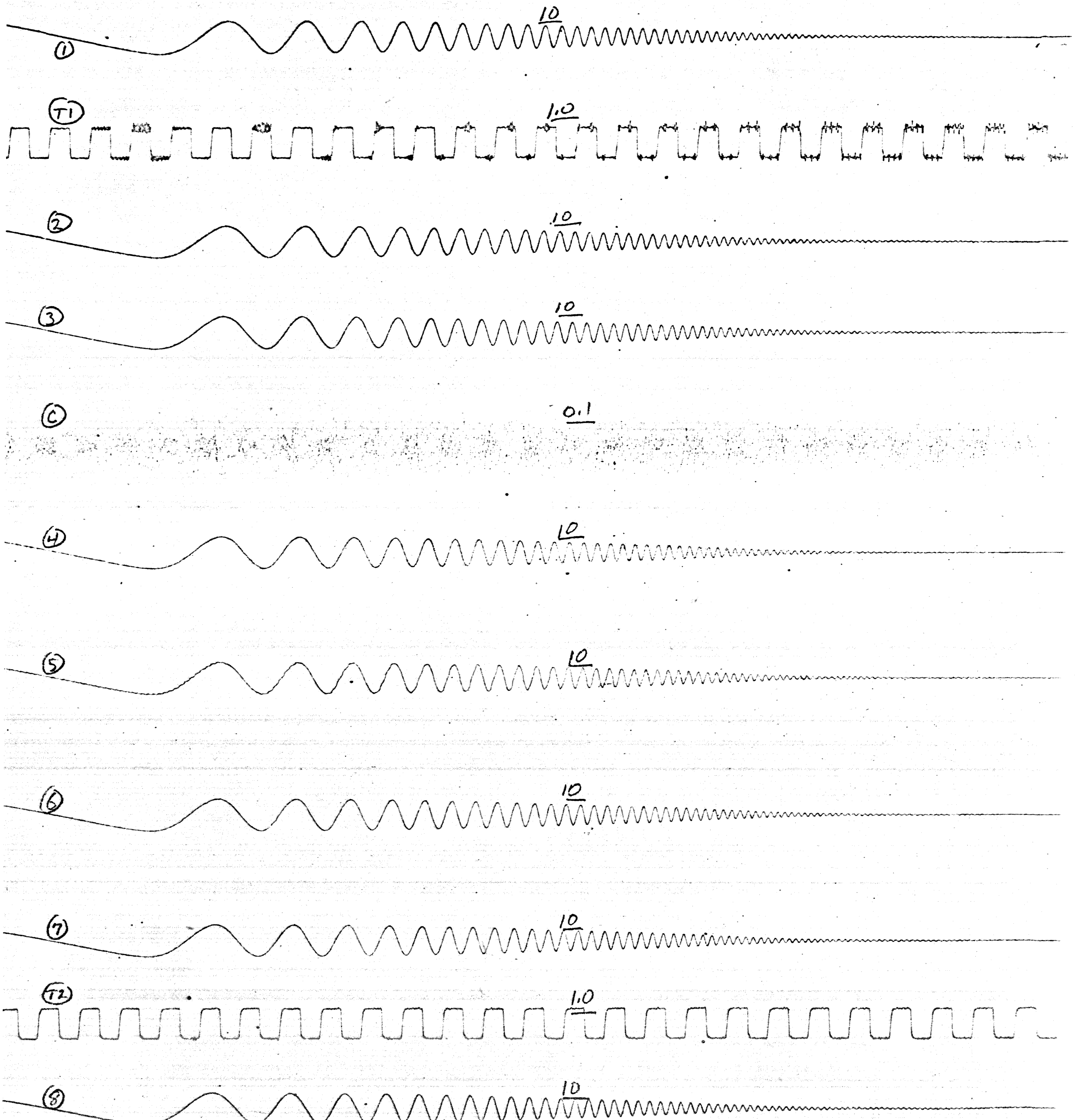


Fig 8a

B2

X-tal 4688 ref   -20 db   100 mm/sec   12/29

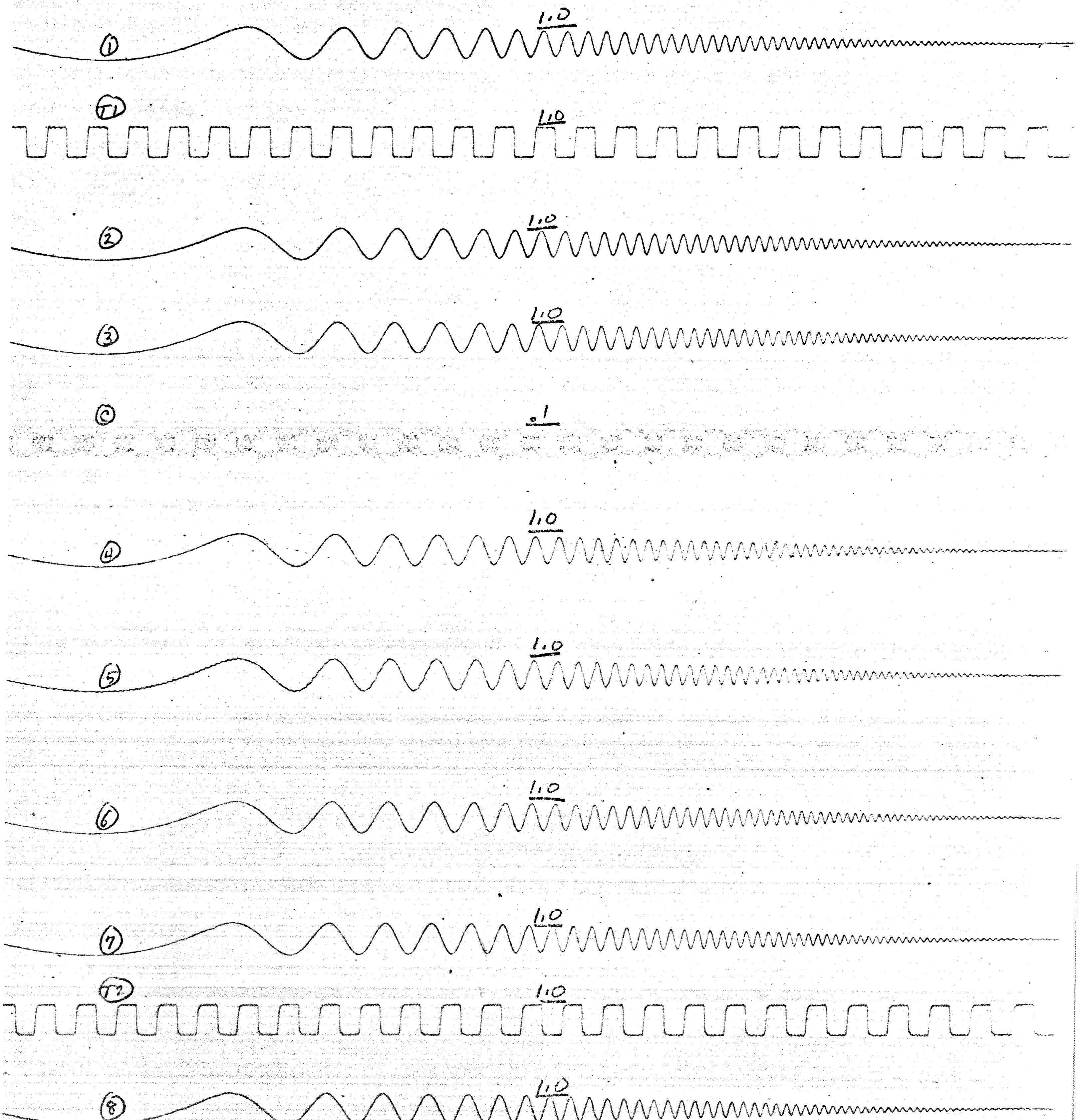


Fig 8b

X-Tal 4688 uf —40 db 100 mm/sec 12/29

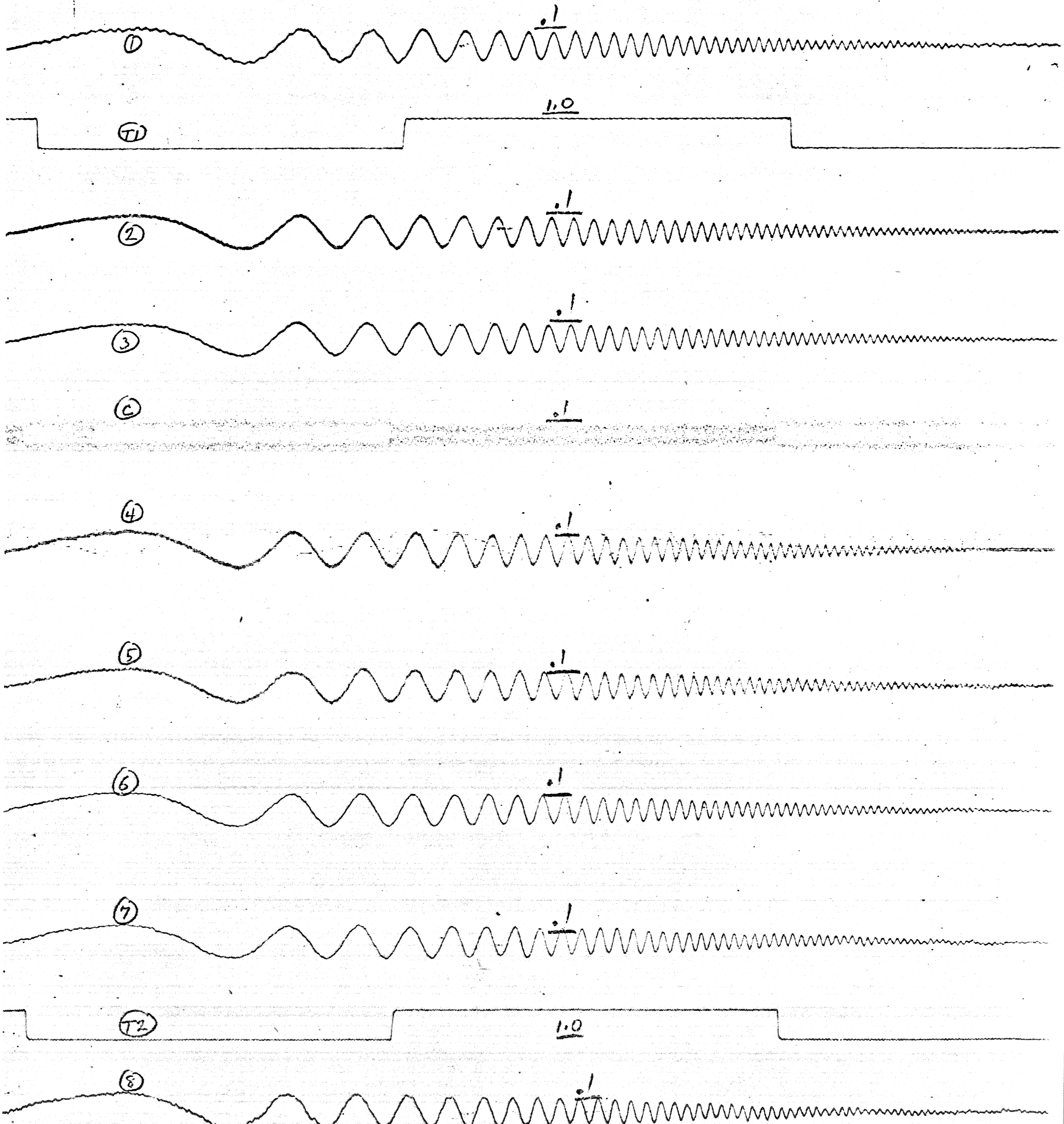
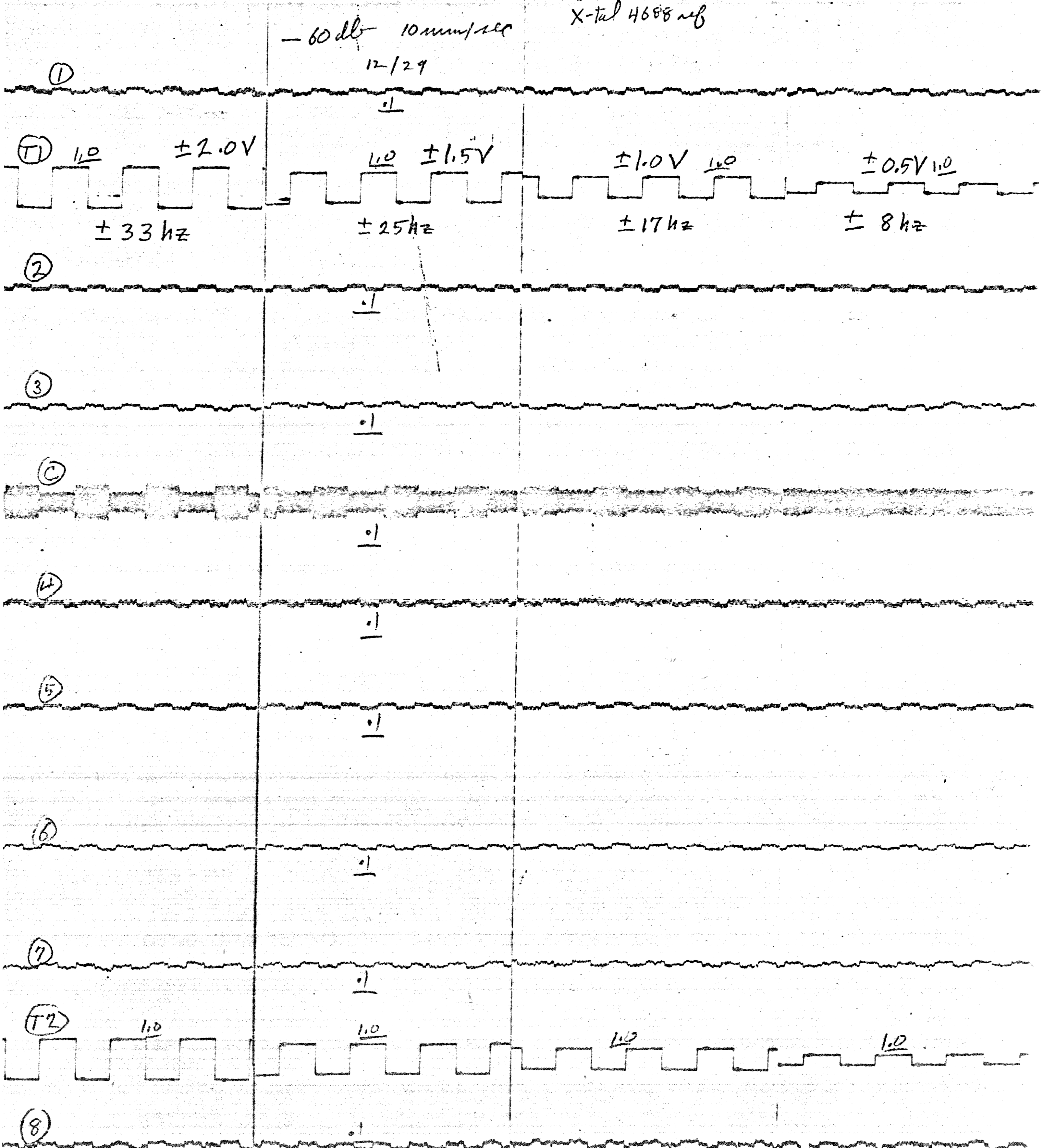
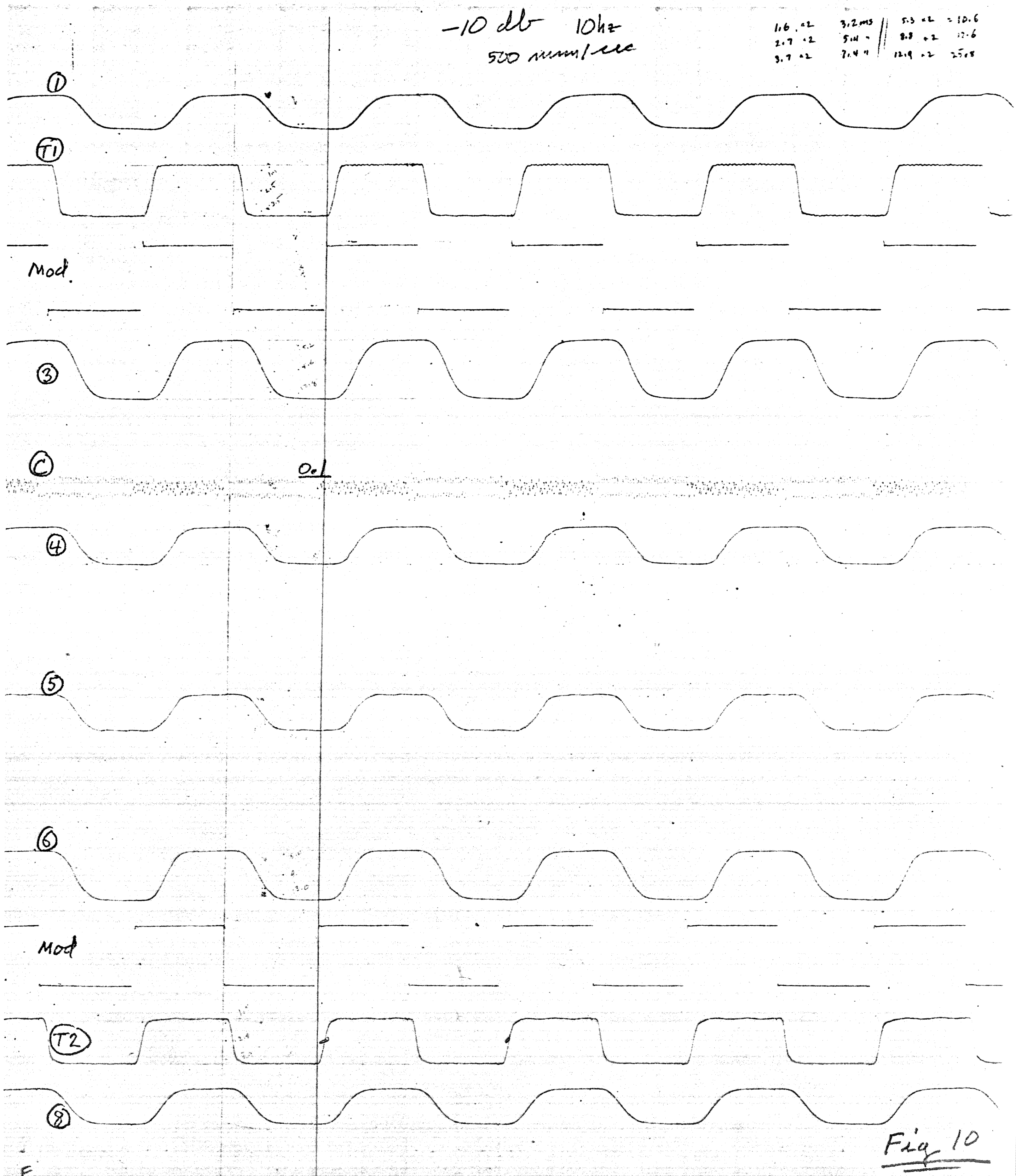


Fig 8C



Timing Channel Modulation Level Tests Fig 9



-10 db 10hz
500 mm/sec
1.6 ×2 3.2ms
2.7 ×2 5.4 "
3.7 ×2 7.4 "
5.3 ×2 = 10.6
8.8 ×2 17.6
12.9 ×2 25.8
①
T1
Mod.
③
C
0.1
④
⑤
⑥
Mod
T2
⑧
E

Fig 10

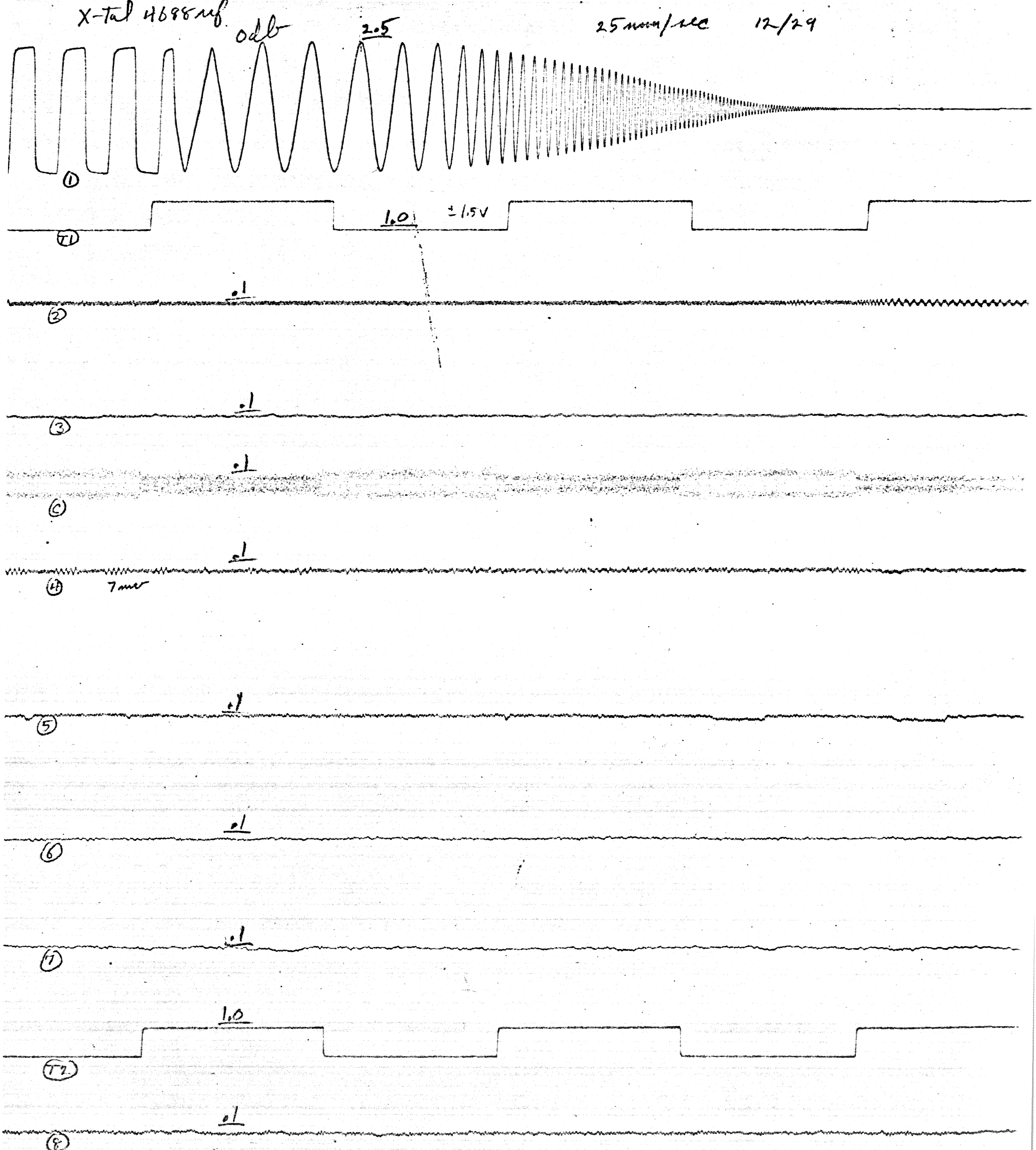

X-Tal 4688 uf
0db
2.5
25 mm/sec
12/29
1
1.0
±1.5V
T1
.1
2
.1
3
.1
C
.1
4
7 mv
.1
5
.1
6
.1
7
1.0
T2
.1
8

Fig 11a

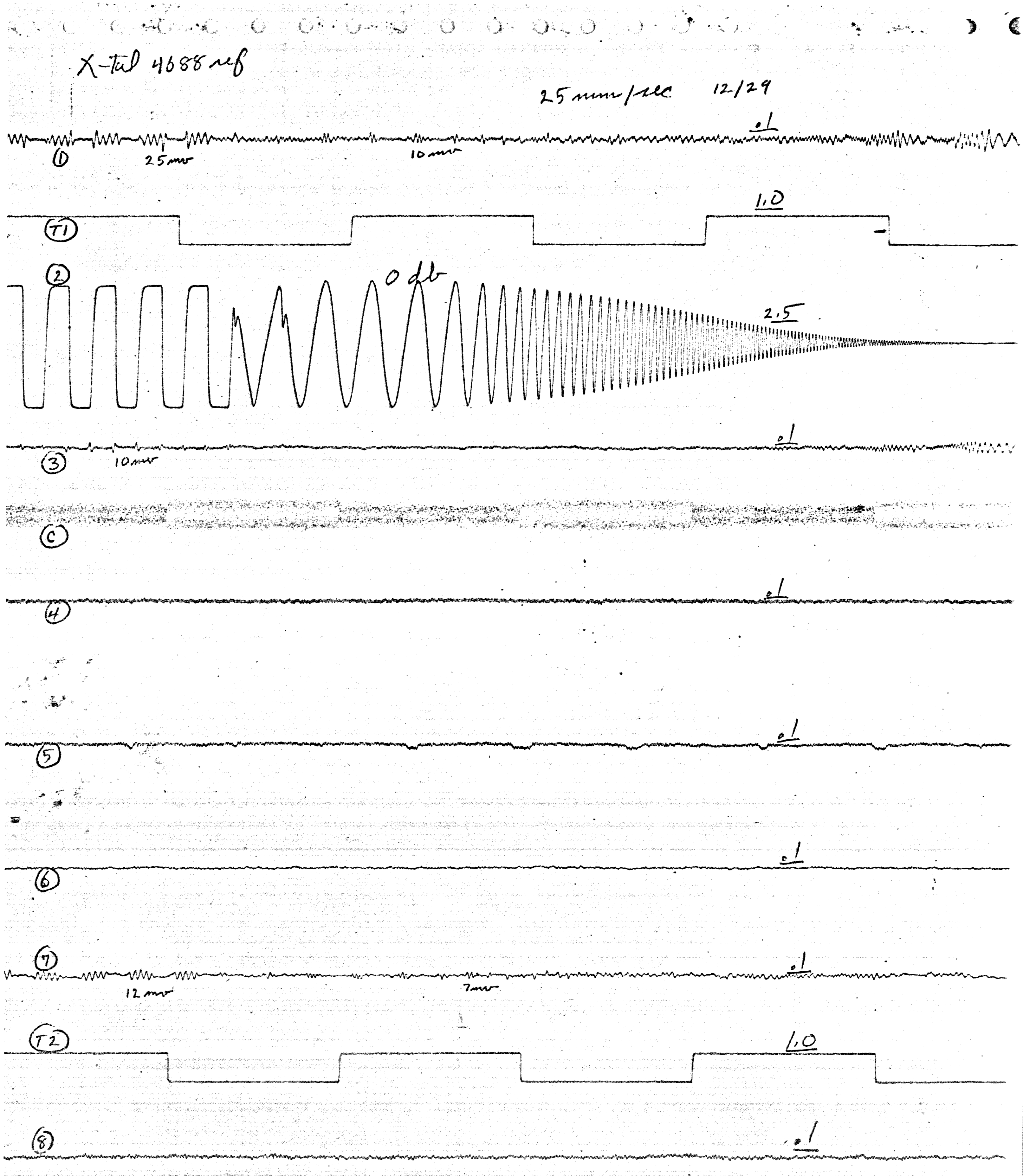

X-tal 4688 uf
25 mm/sec
12/29
.1
(1)
25 mv
10 mv
1.0
(T1)
(2)
0 db
2.5
.1
(3)
10 mv
(C)
.1
(4)
.1
(5)
.1
(6)
(7)
.1
12 mv
7 mv
(T2)
1.0
(8)
.1

Fig 11b

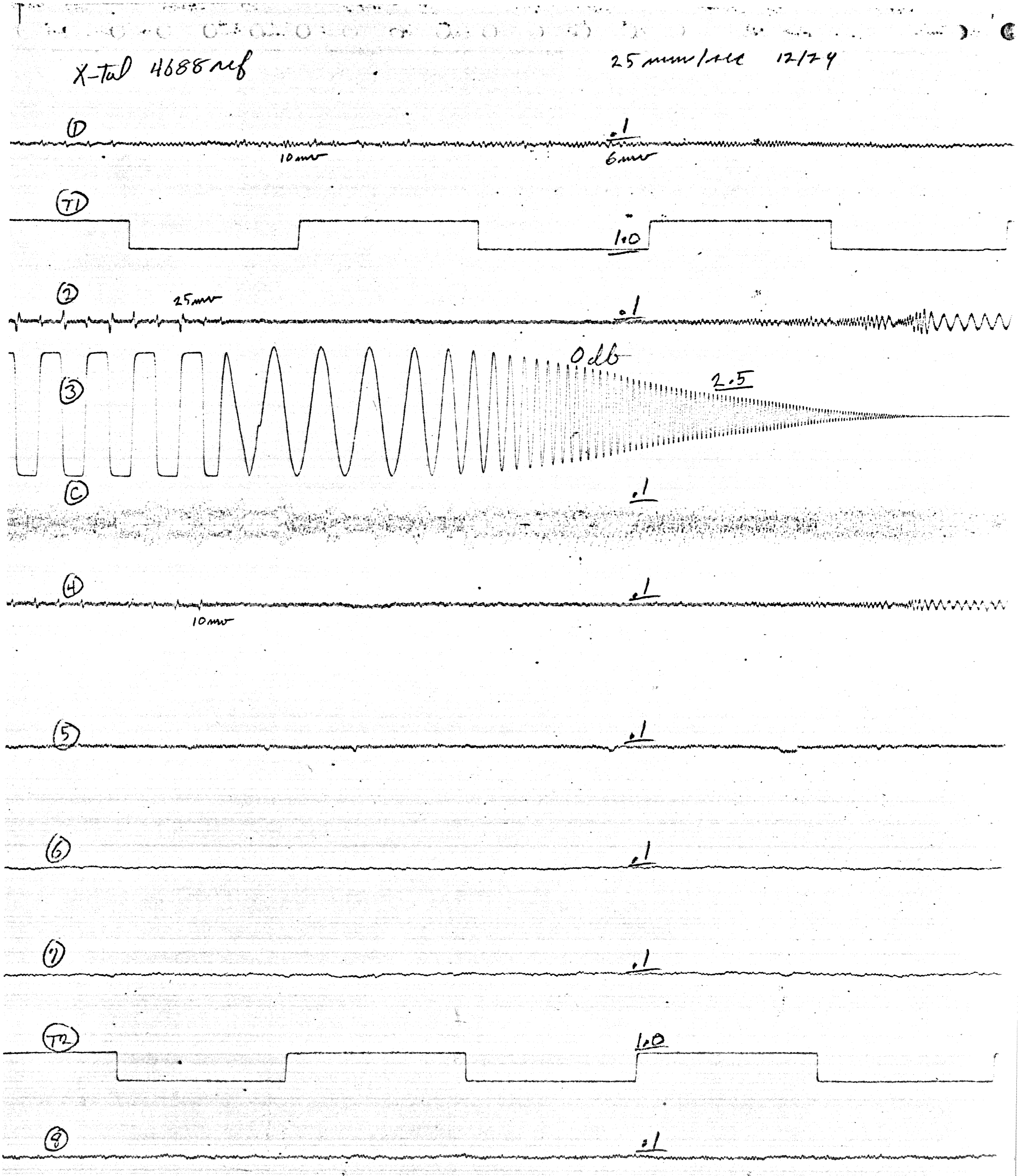

X-tal 4688 ref
25 mm/sec 12/74
①
10 mv
.1
6 mv
(T1)
1.0
②
25 mv
.1
0 db
③
2.5
Ⓒ
.1
④
10 mv
.1
⑤
.1
⑥
.1
⑦
.1
(T2)
1.0
⑧
.1

Fig 11C

X-Tal 4688 ref   25 mm/sec   12/29

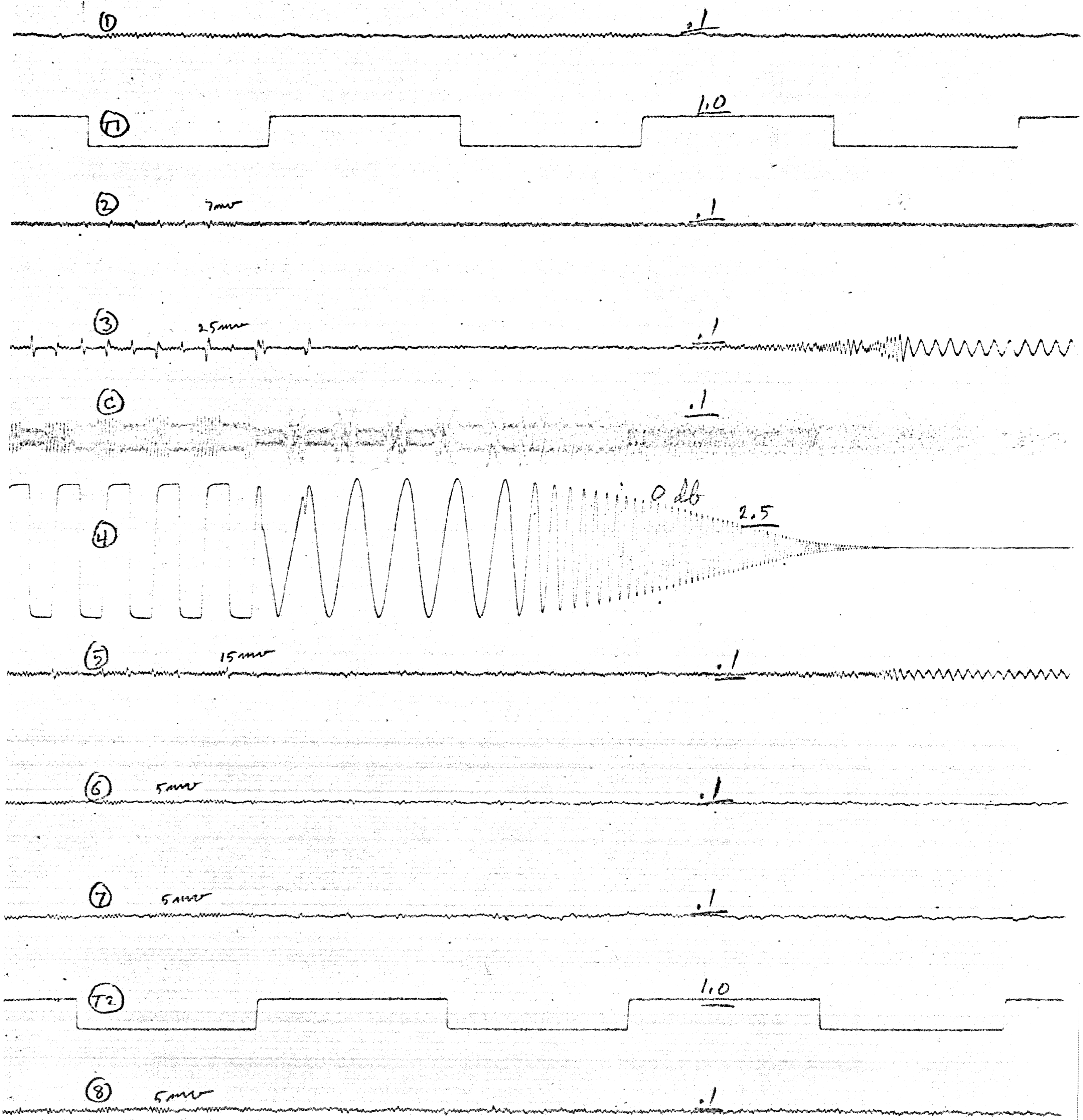


Fig 11d

X-Tal 4688 ref   25 mm/sec 12/29

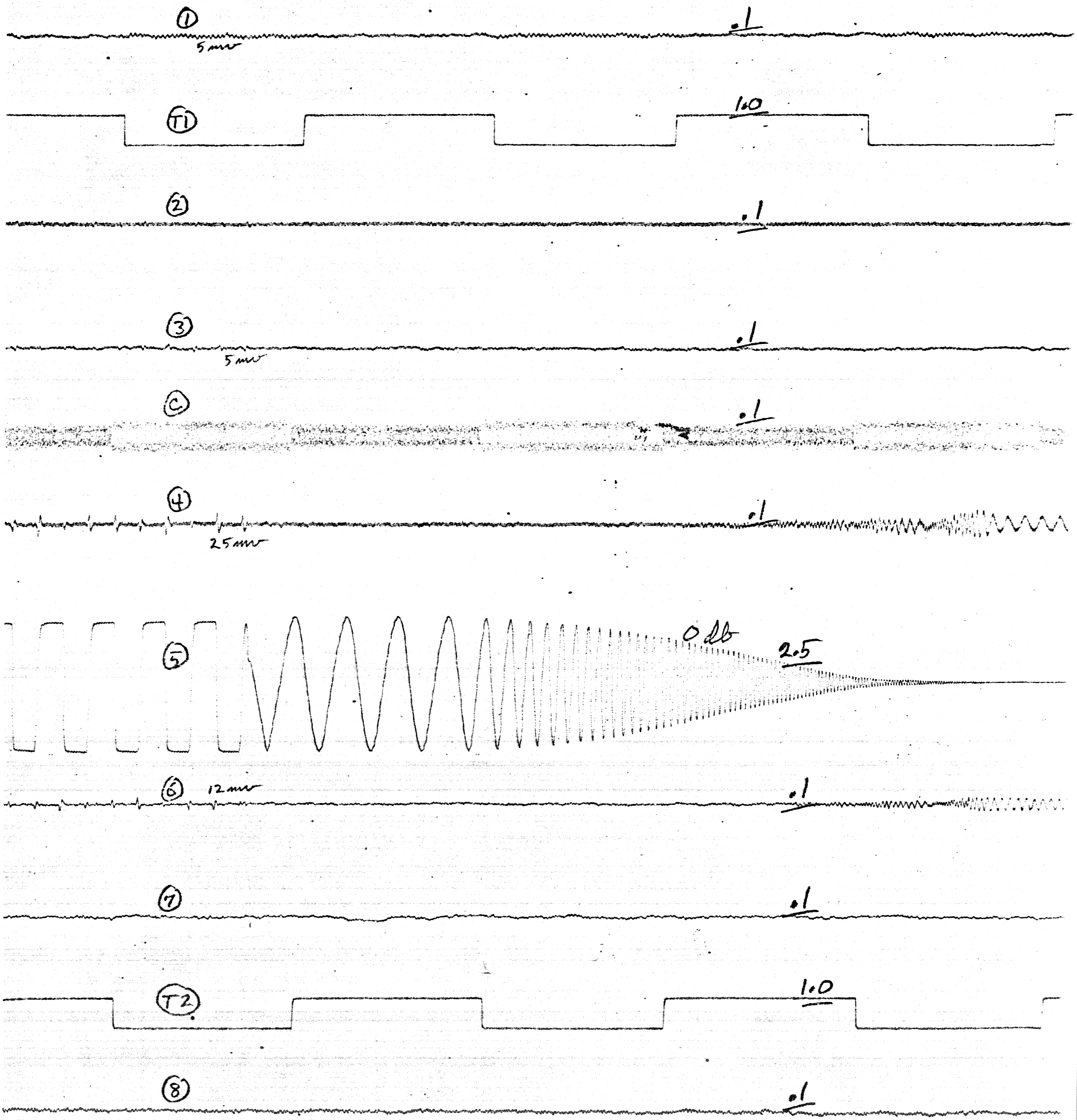


Fig 11e

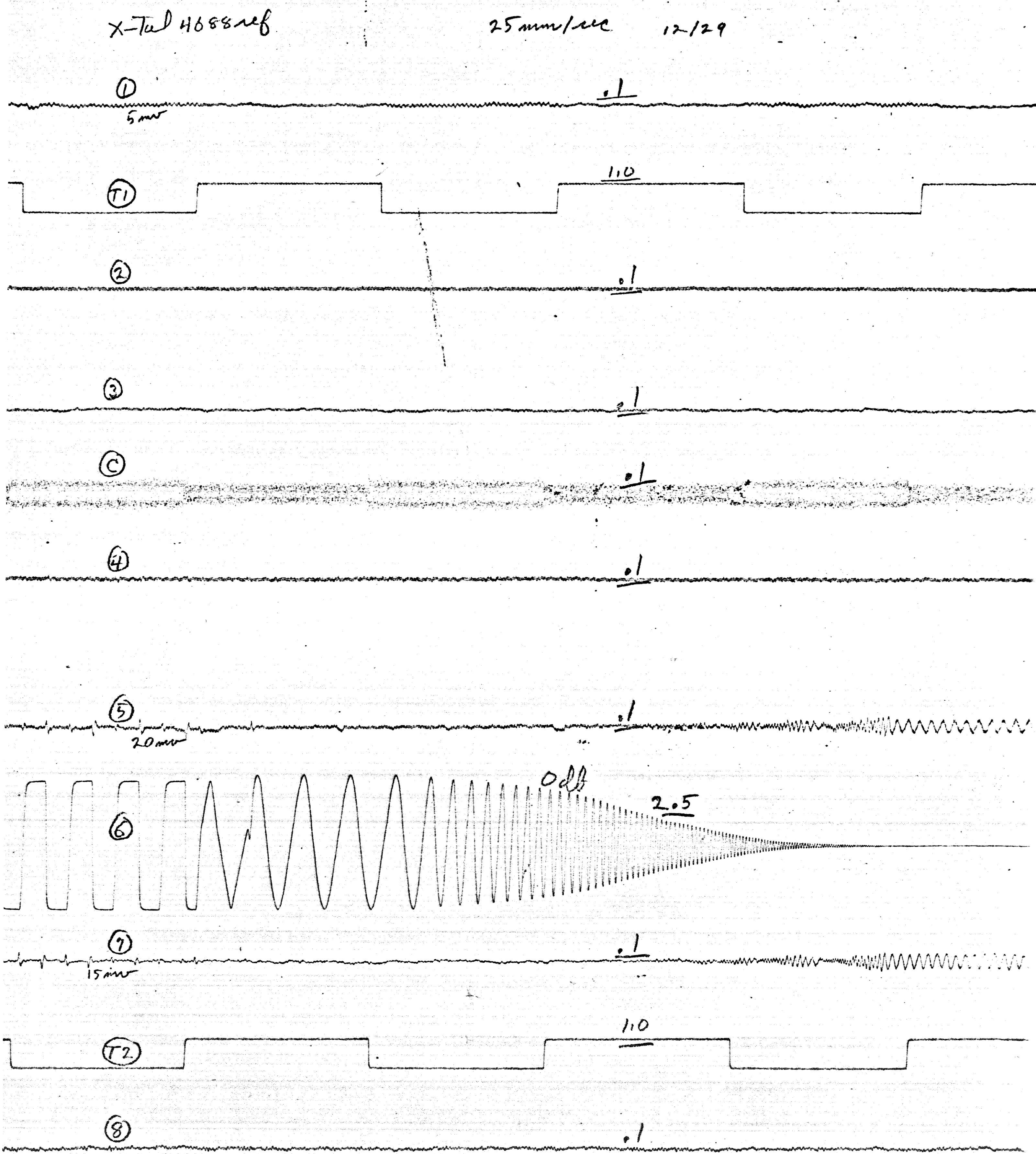
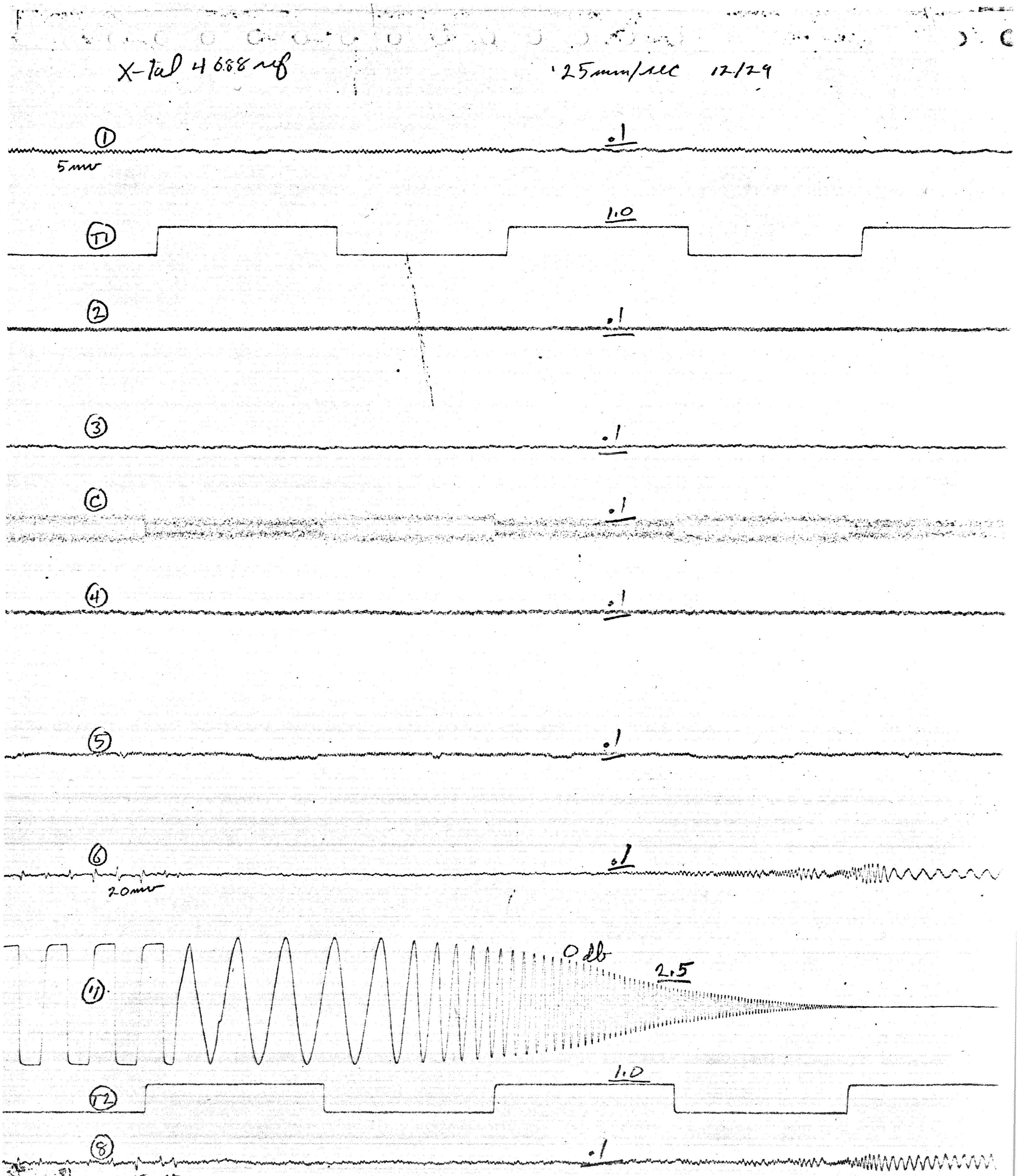

X-Tal 4088 ref
25 mm/sec
12/29
①
.1
5 mv
T1
1.0
②
.1
③
.1
C
.1
④
.1
⑤
.1
20 mv
⑥
0 db
2.5
⑦
.1
15 mv
T2
1.0
⑧
.1

Fig 11f



X-tal 4688 ref
25mm/sec 12/29
①
5mv
.1
T1
1.0
②
.1
③
.1
C
.1
④
.1
⑤
.1
⑥
.1
20mv
⑪
0db
2.5
T2
1.0
⑧
.1
15mv

Fig 11g

X-Tal 4688 ref   25 mm/sec. 12/29.

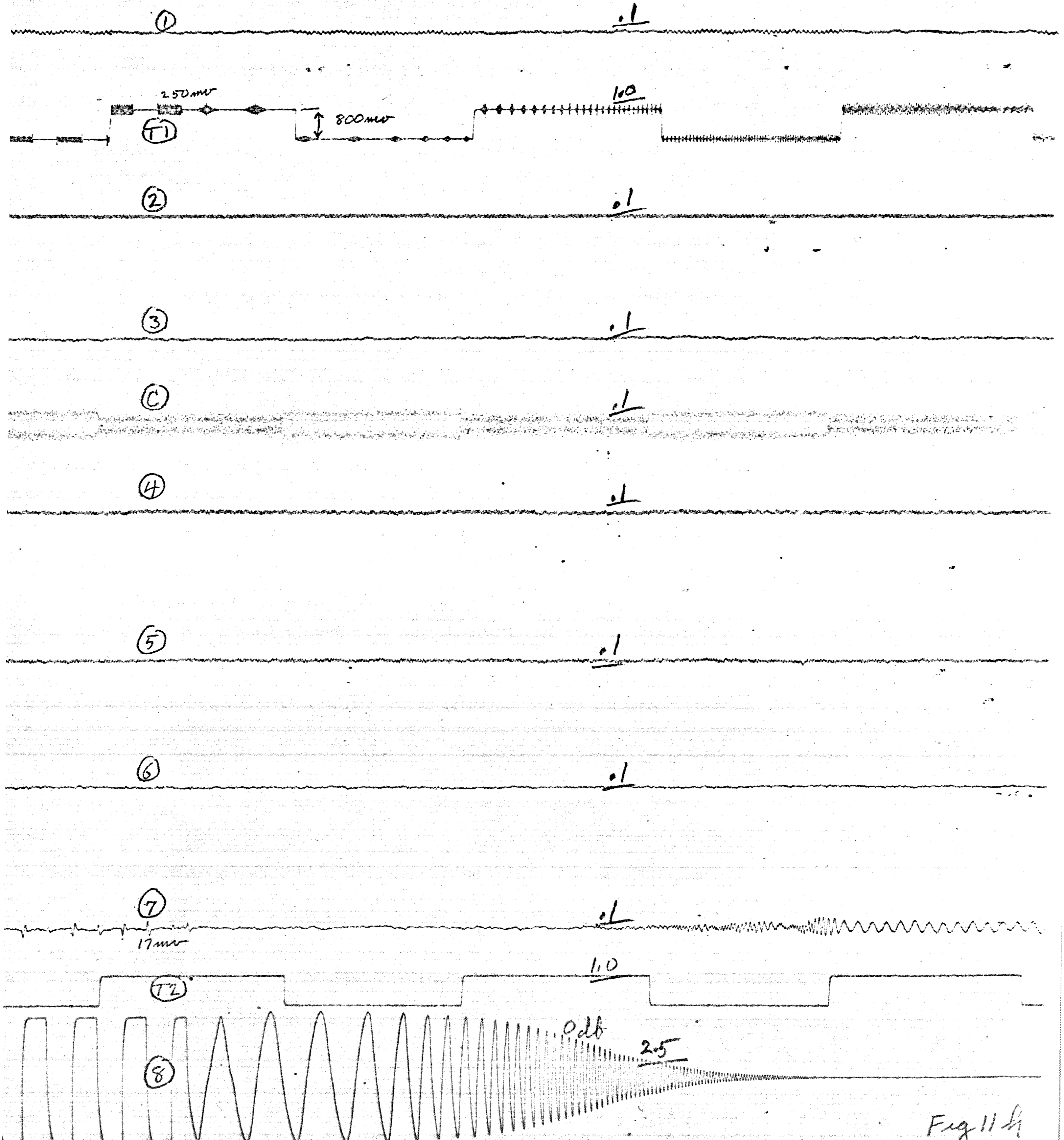
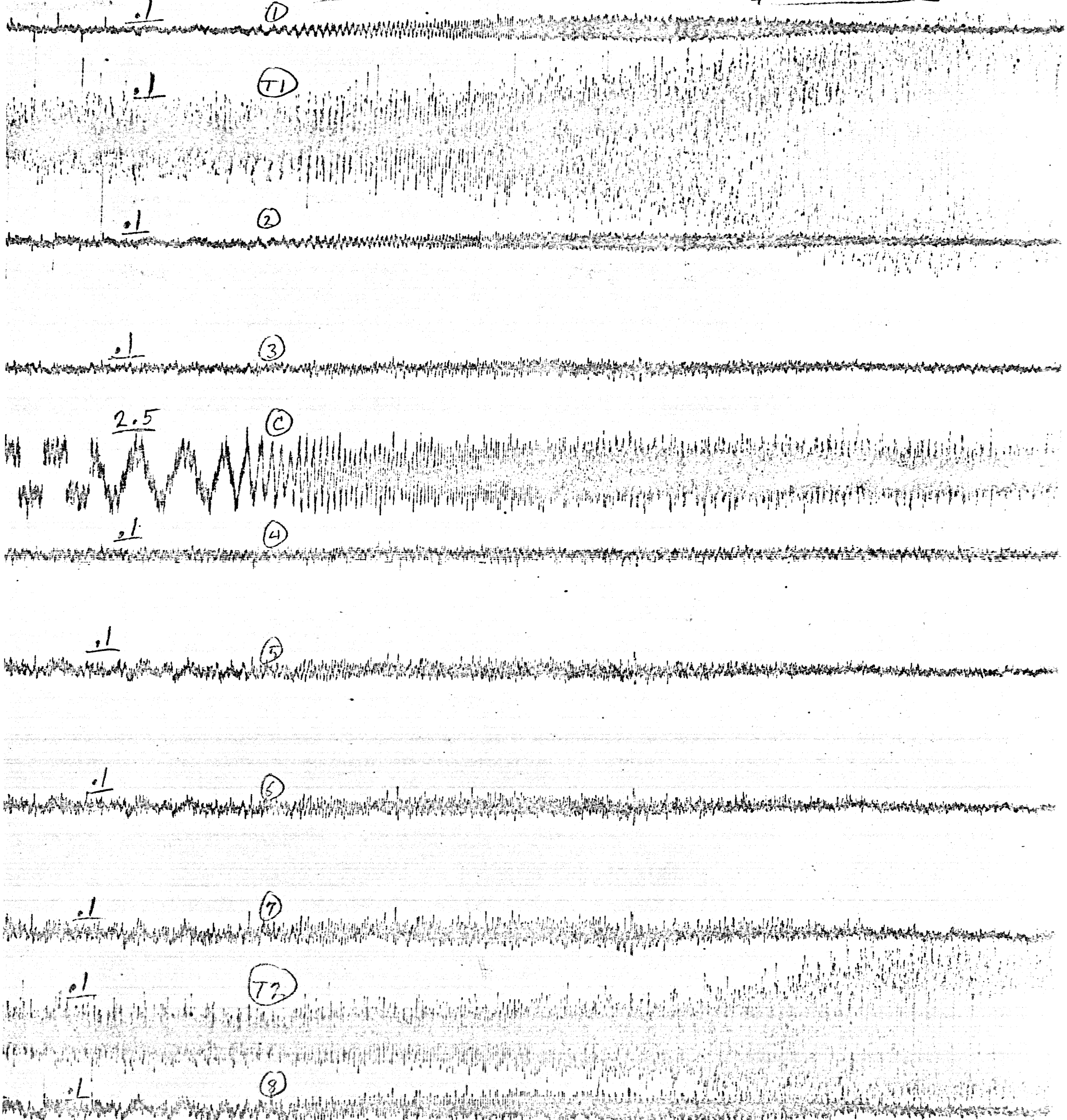


Fig 11 h

Test Mod Bank

Playback from TC-126

Compensation Test



-10db Prop Mod

54'

1/1/76

10 mm/sec

Fig 12

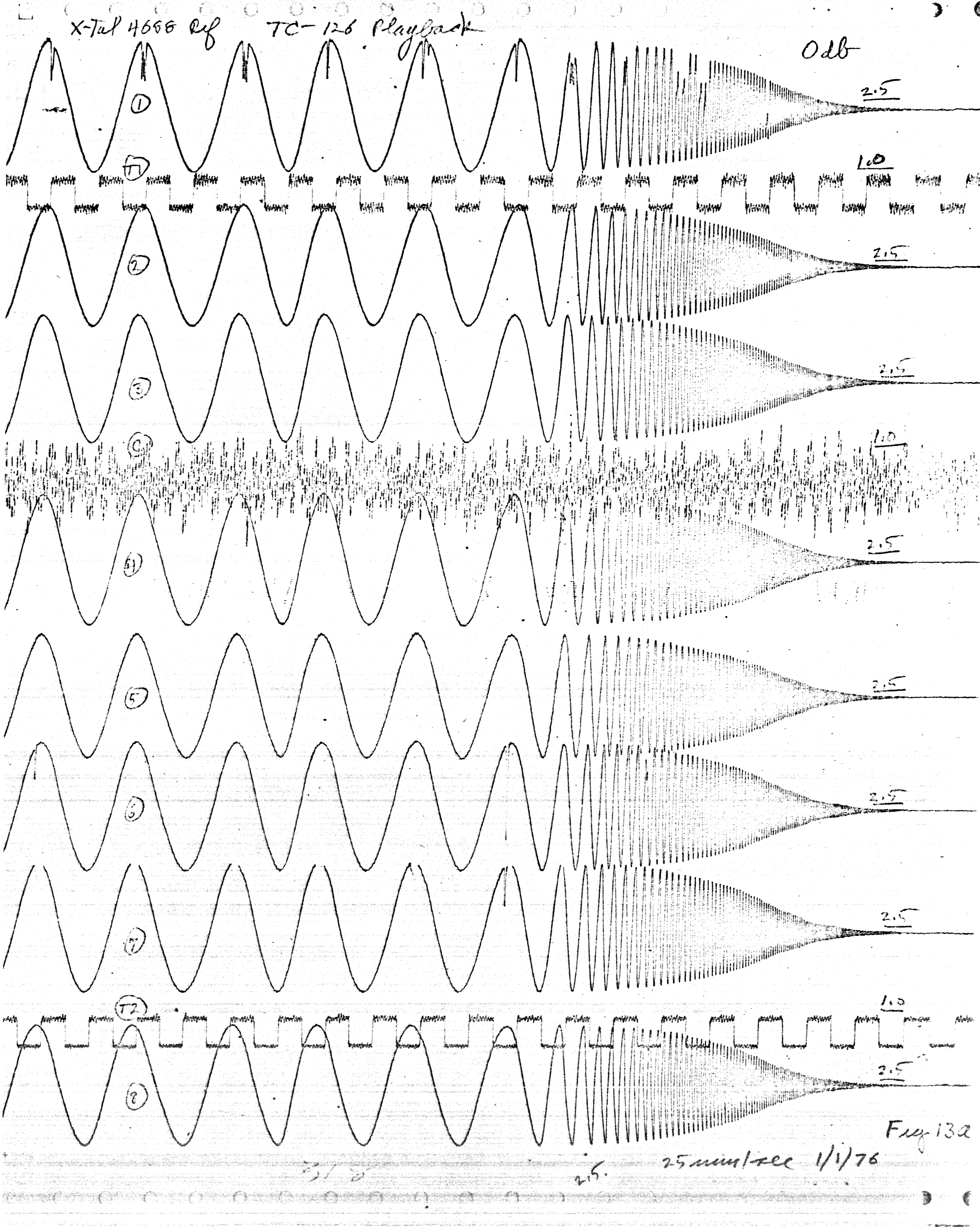


Fig 13a

X-Tal 4688 Rf TC-126 Playback -20db

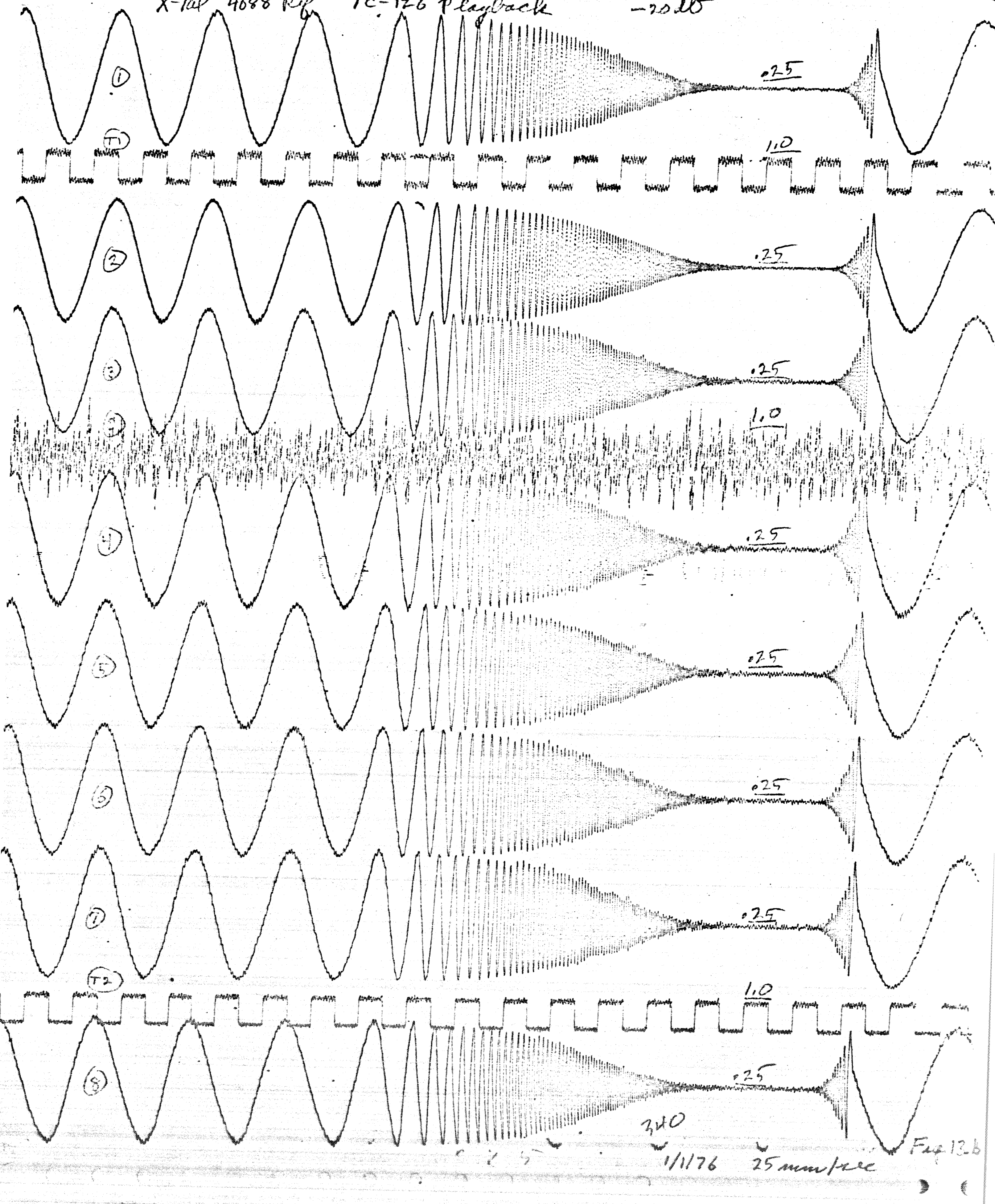
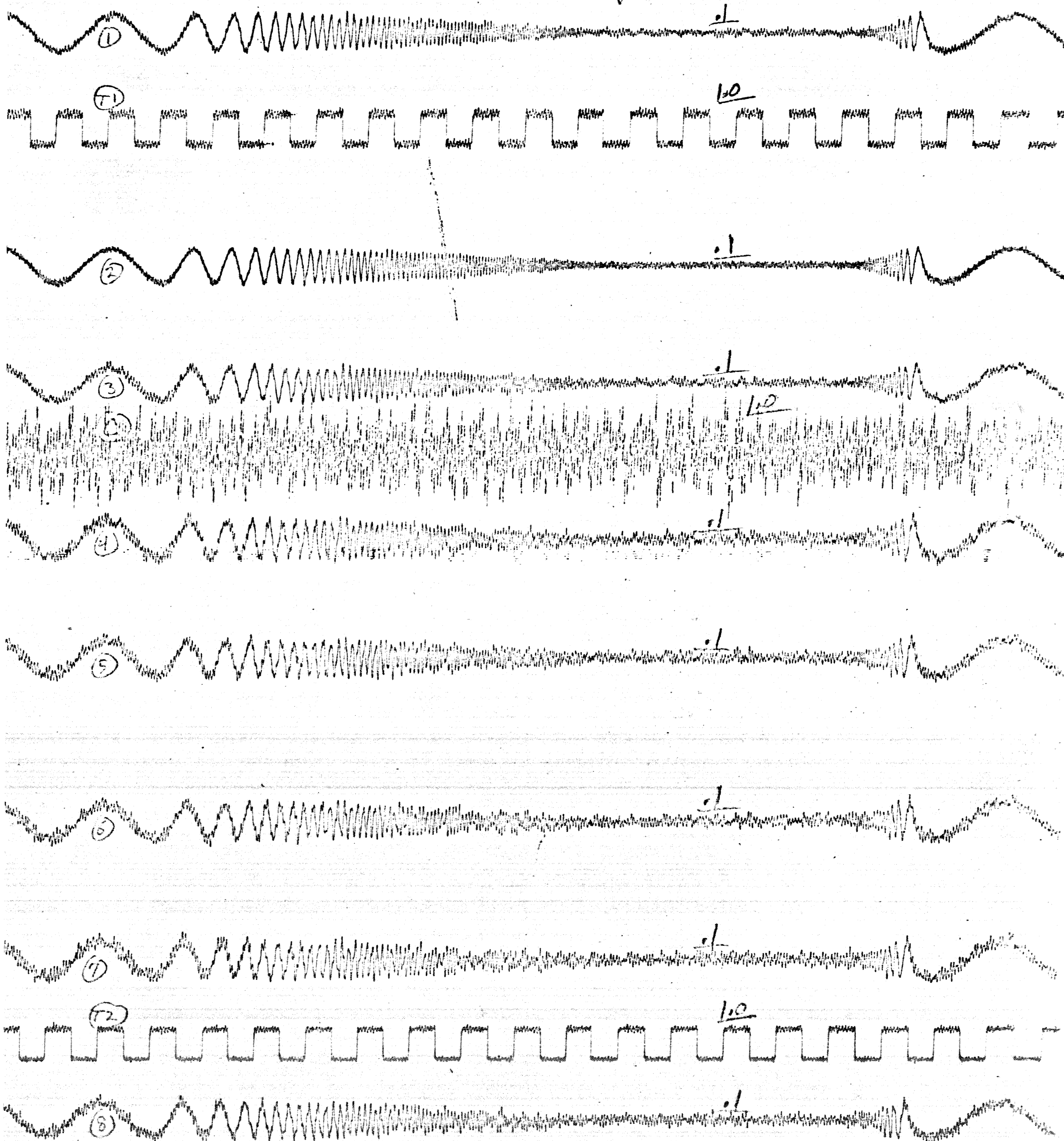


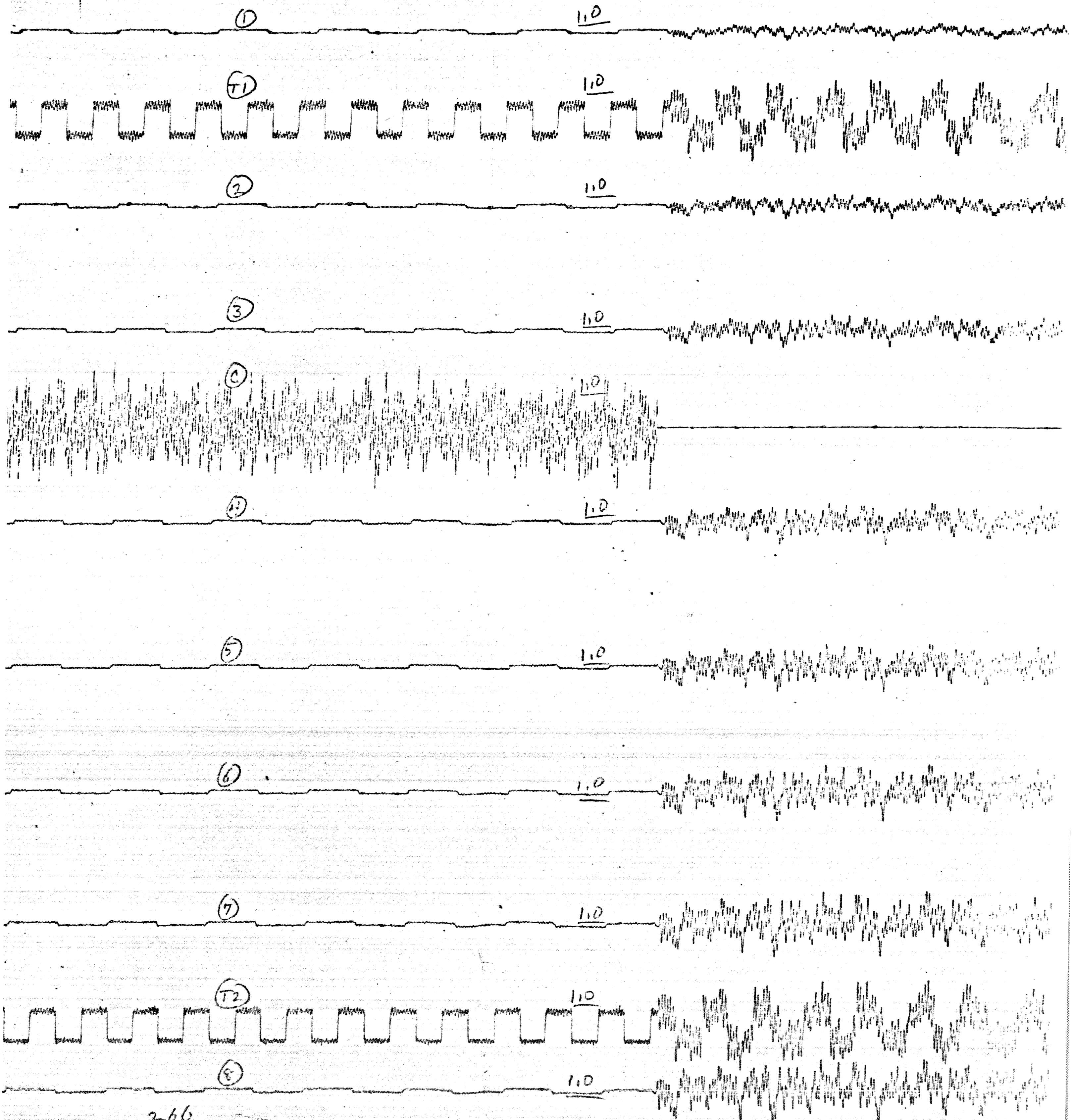
Fig 13.b

X-Tal 4688 Ref TC-126 Playback



300 —40db .1↑ 25 mm/sec 1/1/76 Fig 13C

X-Tal 4658 Ref TC-126 Playback



266

1/1/76 -40 db 25 mm/sec

Fig 14 a

X-Tal 4088 Ref   TC-126 Playback

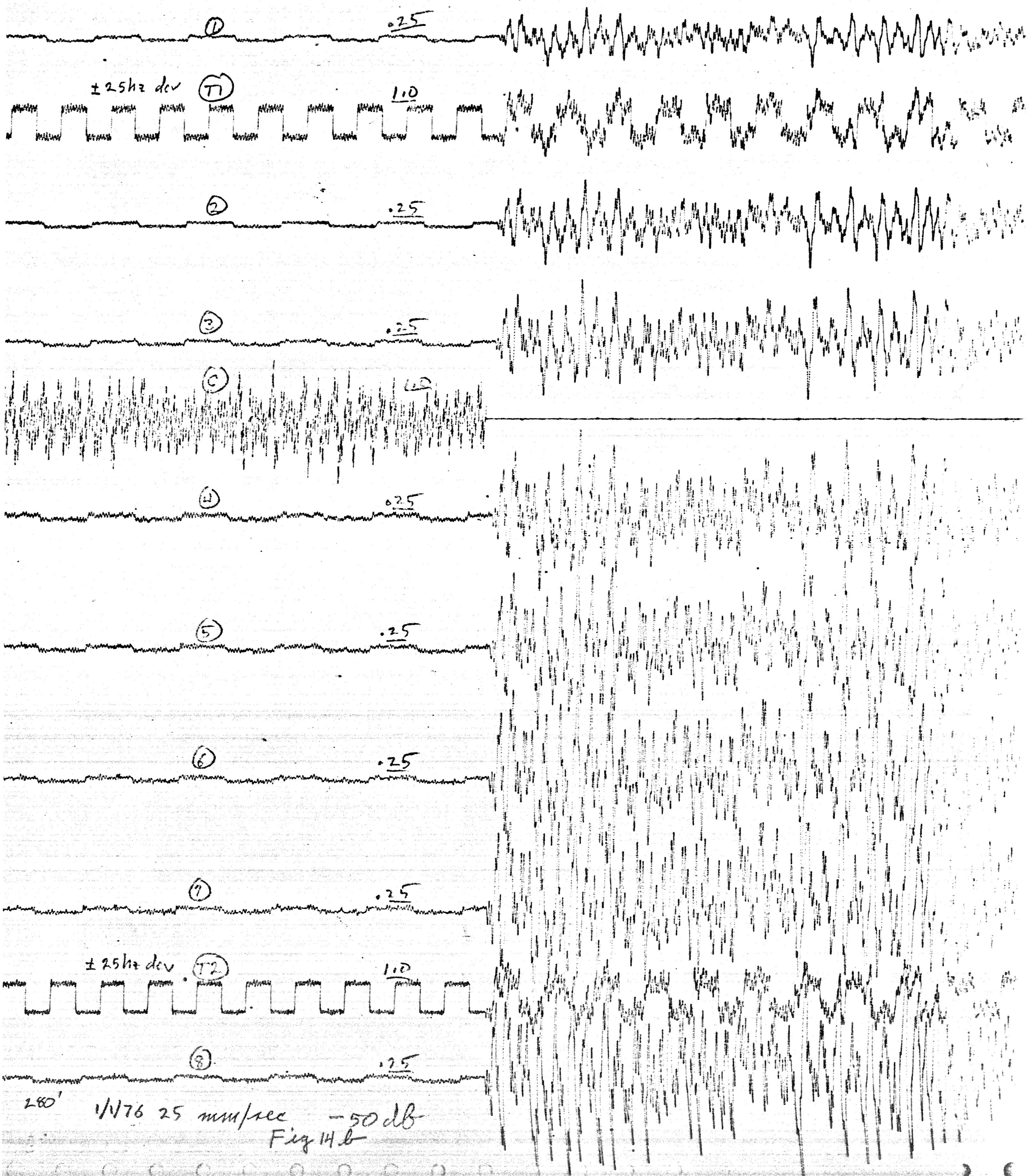


Fig 14 b

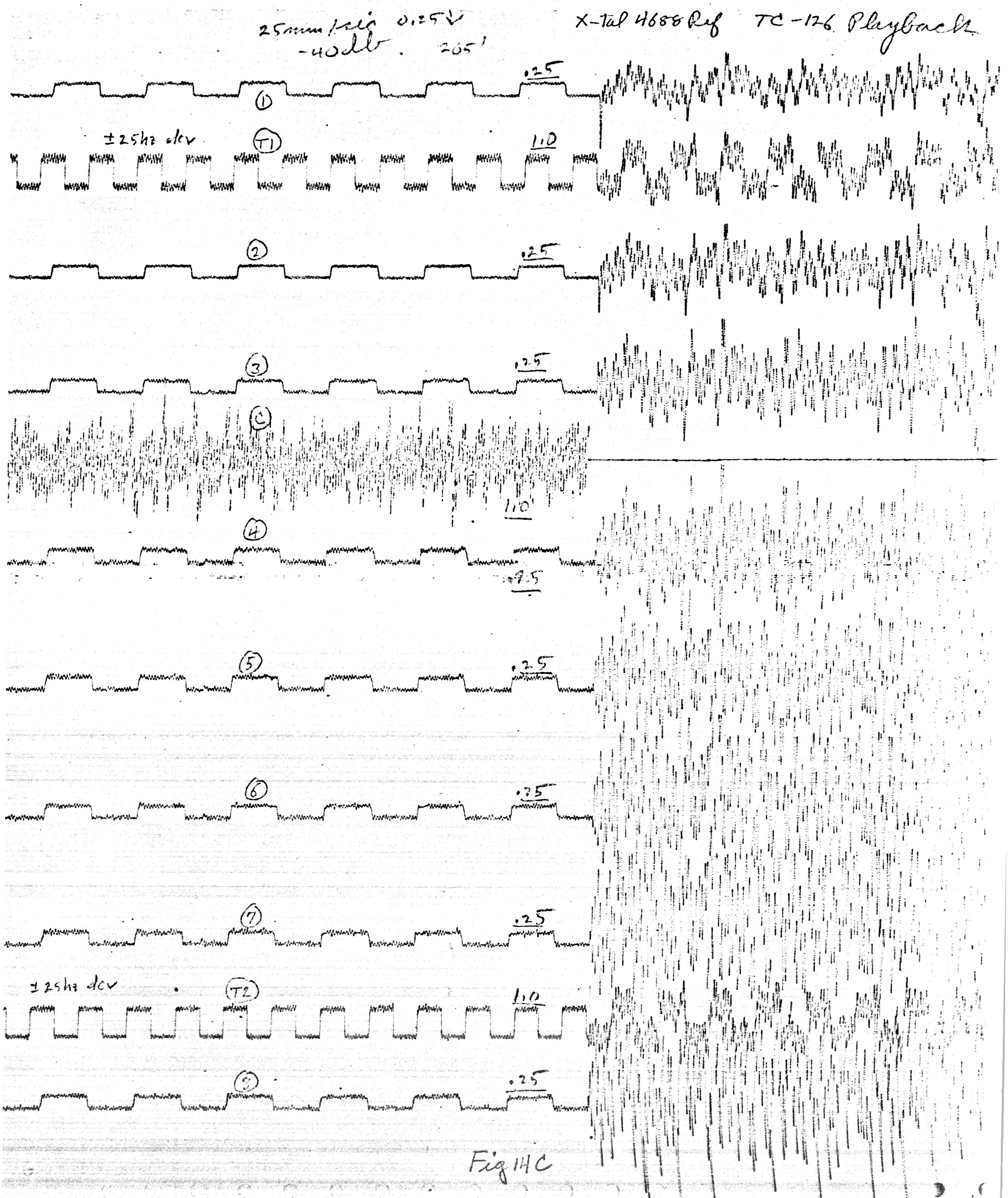

25mm/sec 0.25V
-40db 205'
X-Tal 4688 Ref TC-126 Playback
1 .25
±25hz dev T1 1.0
2 .25
3 .25
C 1.0
4 .25
5 .25
6 .25
7 .25
±25hz dev T2 1.0
8 .25

Fig 14C

X-Tal 4688 Ref   TC-126 Playback

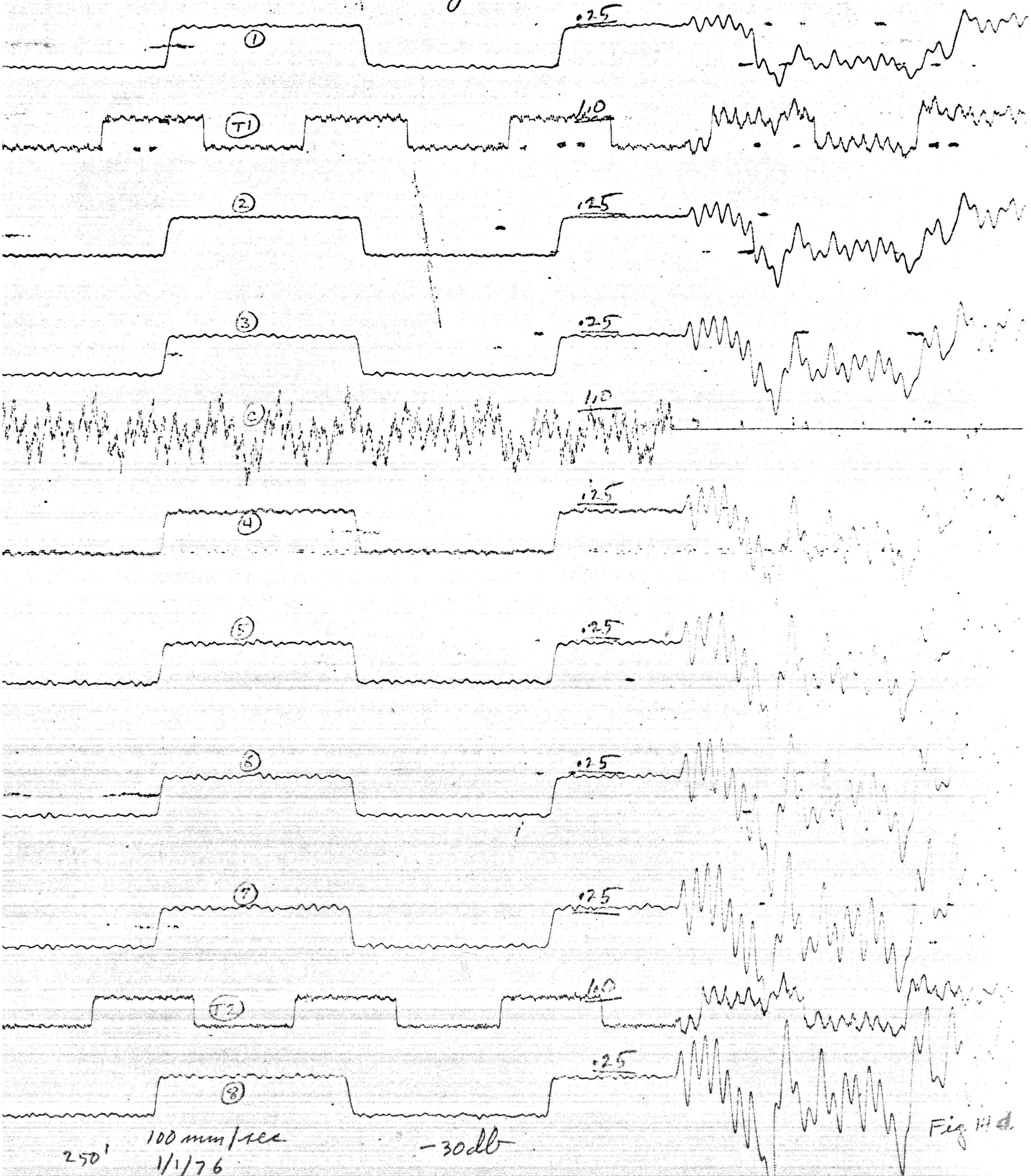
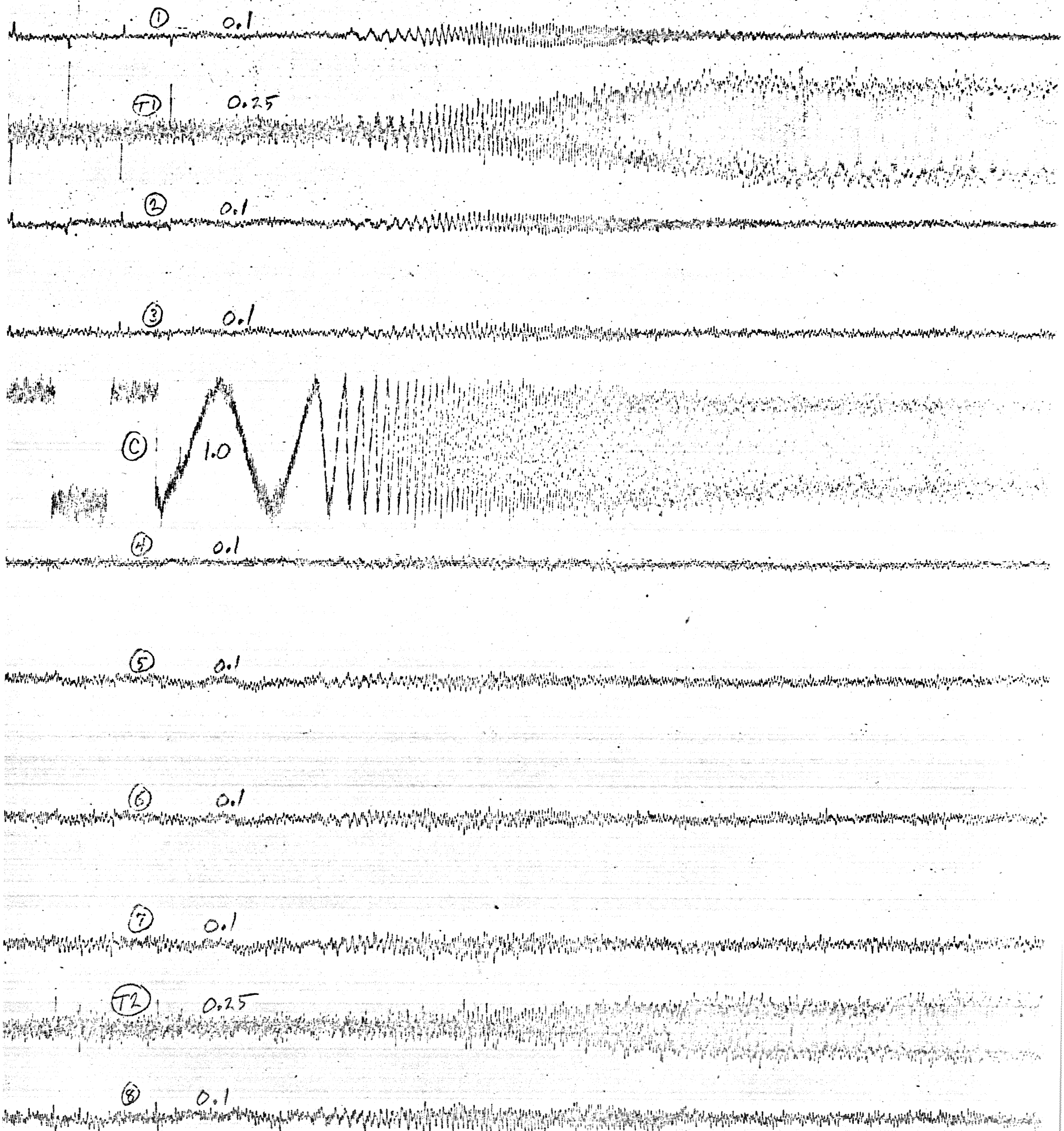


Fig III d.

Test Mod Bank B&H 3700-B Compensation Test



25 mm/sec 1/8/76

Fig 15

Ch5 Noise Test / Compensation Effectiveness Test 1/8/76

XTal Ref -40 db 25 mm/sec

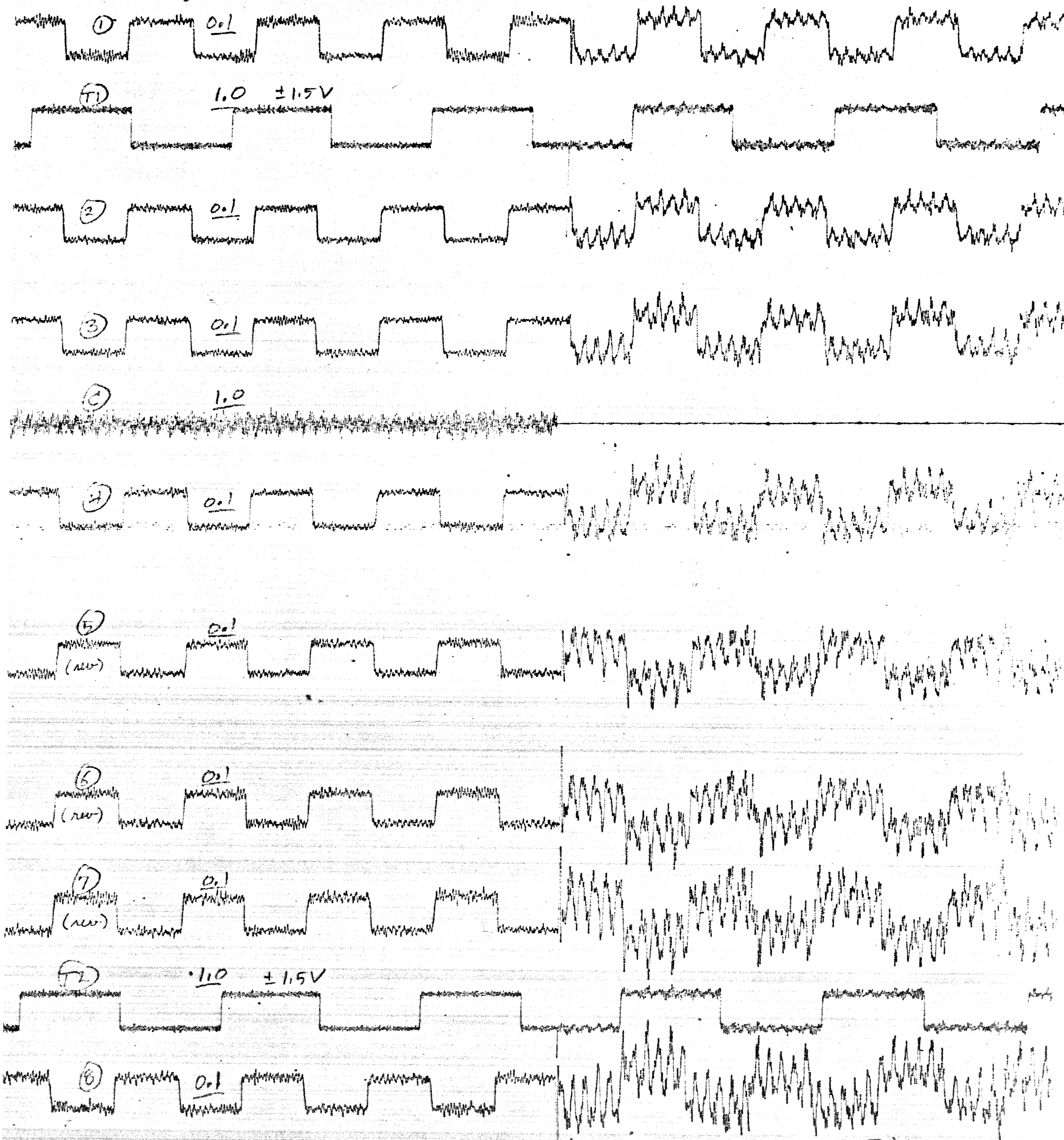


Fig 16a

ch5

Noise Test / Compensation Effectiveness Test

1/8/76

X-tal 4688 Ref

25mm/sec

-50db

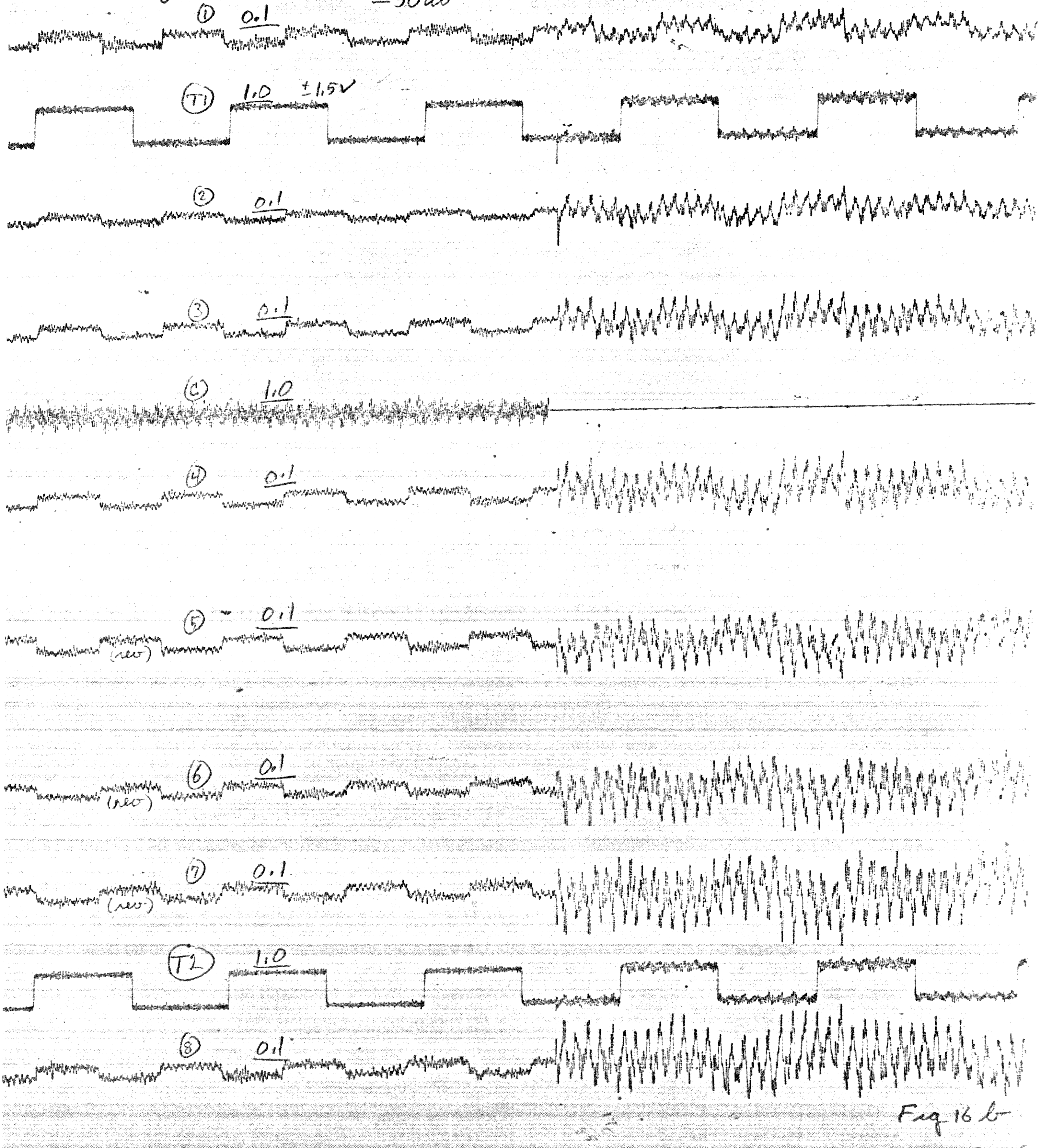


Fig 16 b

Noise Test/Compensation Effectiveness Test — 1/8/76

-60 db — 25 mm/sec

X-tal Ref

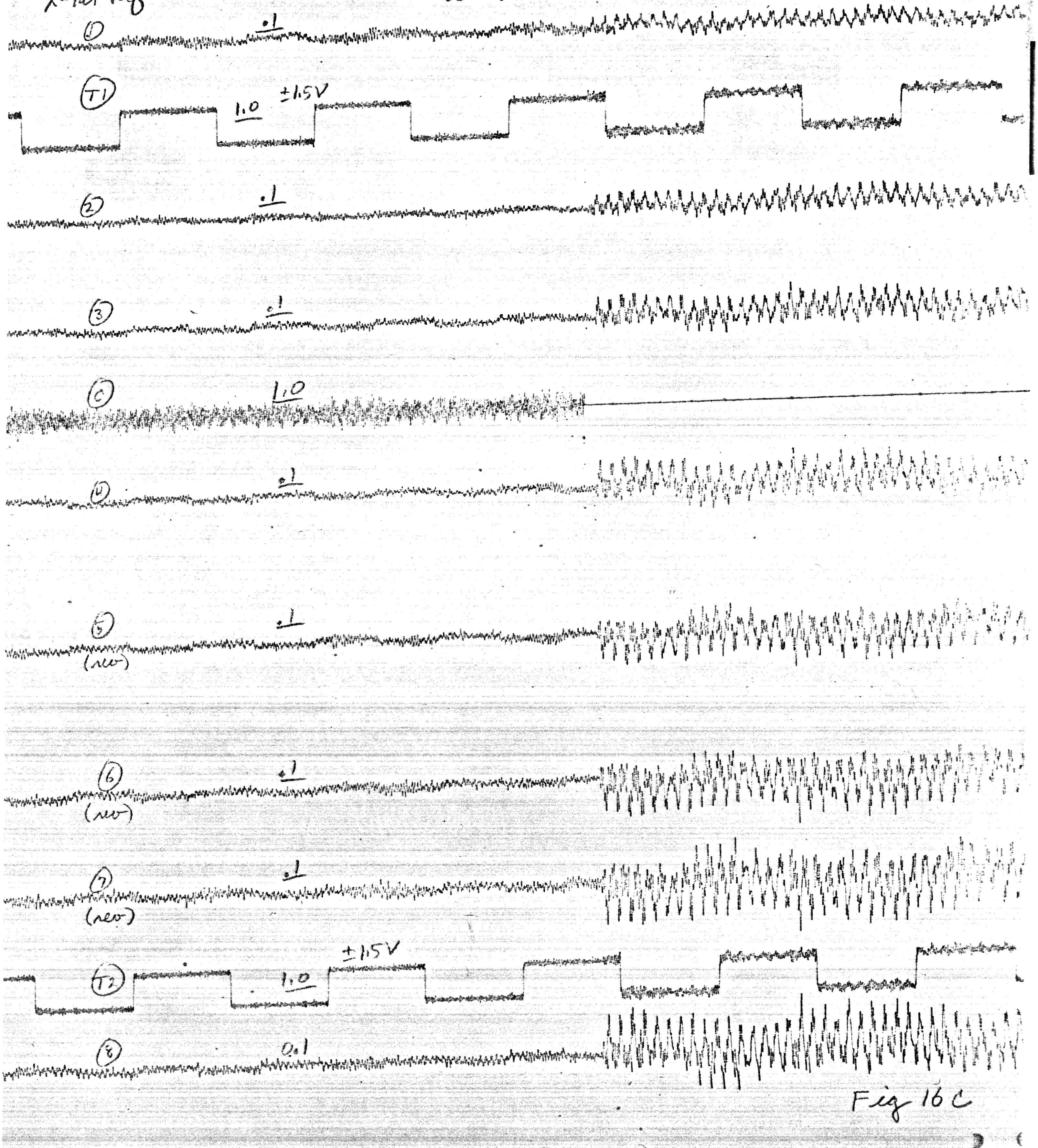


Fig 16C