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15/16 ips Operation of the Precision Instrument Company Model P15100 Tape Recorder to Record the Standard (30 Hz) NCER Seismic Data Multiplex System

by

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature

15/16 ips OPERATION OF THE PRECISION INSTRUMENT COMPANY MODEL PI 5100 TAPE RECORDER TO RECORD THE STANDARD (30 hz) NCER SEISMIC DATA MULTIPLEX SYSTEM

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I. Introduction

In recent months the need has arisen to record special seismic networks consisting of a dozen or more standard NCER seismic systems telemetered to a central collection point on a reliable, portable, low power tape recorder. Because of its simplicity and the ease with which it can be adapted for the purpose, the PI 5100 field recorder should be considered for such use. In the tests described here, a PI 5100 was speeded up to run at 15/16 ips and signals from the standard multiplex system test modulator bank[1] were recorded on one tape track by means of a simple, improvised AM record amplifier. The results of these tests are extremely encouraging: the dynamic range of the system when played back on the Bell and Howel Model 3700 B reproduce machine, with subtractive compensation, is nearly as high as for the system employing the B & H 3700 B for recording.

These notes indicate the principle employed to speed up the recorder, outline the circuit required to drive the tape heads in the AM record mode, and describe the tests carried out to evaluate the system's performance.

II. Tape recorder modifications and AM record electronics

1. Increasing the tape speed from 15/160 ips to 15/16 ips

A block diagram of the PI 5100 motor drive servo system is shown in Figure 1. The principal change required to speed up the recorder was the

1. "Notes on some experiments on the application of subtractive compensation to USGS seismic magnetic tape recording and playback systems", USGS Open File Report, August 1975 - J. P. Eaton

substitution of a 2700 hz square wave reference signal for the 270 hz frequency standard signal provided in the original design. It was also necessary to modify the motor drive amplifier card and to increase the supply voltage to it to provide the small increase in power required to drive the motor faster.

2. Test signals and AM record electronics

The channel layout of the standard NCER seismic multiplex system is shown in Figure 2: the 8 data channels have center frequencies of 340 (1 + N) hz, where N is the channel number, and deviations of $\pm$ 125 hz; the timing channel has a center frequency of 3700 hz and a deviation of $\pm$ 100 hz; the unmodulated compensation reference frequency is 4688 hz. The test VCO bank used to generate signals for these tests was described in detail in reference (1).

The summing amplifier output stage of the test VCO bank is shown on the left of Figure 3. The subcarriers (modulated when appropriate) of the 8 data channels, timing channel, and compensation channel are multiplexed in summing amplifier #1, which has an adjustable output level. A 30 K hz sine wave bias signal is combined with the multiplexed signal from the test VCO bank in summing amplifier 2, which also has an adjustable output level and served as the head driver amplifier for AM recording during these tests.

3. Bias and modulation head current levels for optimum performance

In AM recording the data signal is superposed on a large amplitude high frequency bias signal prior to introduction to the recording head to overcome hysteresis effects in the magnetic tape. The bias signal and data signal levels must be chosen carefully for optimum (low noise) performance of the recorder. For this purpose, tests were carried out for a wide range of data and bias signal levels. The head current levels corresponding to the data signal and the bias signal were measured as peak to peak voltage drops across the 10 ohm resistor in series with the head (Figure 3). Tests were run for data signal "levels" from 1.5 mv to 10 mv and for bias signal levels from 30 mv to 70 mv. The results of these tests are summarized in Figure 4, where a 1 hz square wave at the - 40 db (1%) modulation level was recorded on all 8 data channels to provide a basis for estimating noise levels. The test tapes were played back on a Bell and Howell Model 3700 B reproducing maching and the recorded signals were detected by Develco Model 6203 discriminators employing subtractive compensation. From Figure 4, it appears that the best results were obtained for a data signal level of 5.0 mb, a bias signal level of 45 mv (the corresponding head currents were 0.5 ma and 4.5 ma, of course).

III. System performance tests

1. Compensation frequency response

A 1 hz to 100 hz swept frequency sine wave modulation in the proportional deviation mode at the - 10 db (32%) modulation level was imposed on the 8 data channels and the compensation channel, and the resulting multiplexed signal was recorded on the PI 5100 AM test track. The recorded signal was then played back on the Bell and Howel 3700 B through the standard NCER multiplex system discriminators [1], with subtractive compensation, and recorded on the Slemens Oscillomink (recording oscillosgraph) at a paper speed of 25 mm/sec (Figure 5). Playout sensitivities were 12.5 mv/mm for the compensated data tracks, 125/mm for the (uncompensated) compensation track, and 500 mv/mm for the heavily modulated, uncompensated timing track. The minimum levels of rejection of the simulated tape speed variation signal, and the corresponding frequencies, for the 8 data channels were: Ch 1, 20 db at 20 to 30 hz; Ch 2, 27 db at 20 to 30 hz; Ch 3, 29 db at 20 to 30 hz; Ch 4, 25 db at 20 to 30 hz; Ch 5, 25 db at 20 to 30 hz; Ch 6, 25 db at 20 to 30 hz; Ch 7, 26 db at 20 to 30 hz; Ch 8, 26 db at 20 to 30 hz.

The tape speed variation simulated by this test was about ± 2%.

2. Compensation effectiveness tests

To test the effectiveness of compensation in reducing tape speed variation noise, the 8 data channels were modulated at the - 60 db level by a 1 hz square wave and the multiplexed signal was recorded on the PI 5100 AM test tract. During playback on the B & H 3700 B through the standard discriminator bank, records were made both with compensation and without compensation (i.e., the compensation discriminator was unplugged). This test is illustrated in Figure 6. The data track sensitivities remained the same (12.5 mv/mm) throughout the test, but the paper speed was increased from 10 mm/sec to 25 mm/sec during the uncompensated part of the record to obtain a clearer picture of the frequency characteristics of the noise.

For the uncompensated case, noise levels increased from about 40 mv p-p on Channel 1 to 240 mv p-p on Channel 8. The noise levels relative to 100% modulation (4000 mv pp) on the 8 data channels were : Ch 1, - 40 db; Ch 2 - 37 db; Ch 3, - 34 db; Ch 4, - 32 db, Ch 5, - 30 db; Ch 6, - 27 db; Ch 7, - 26 db; Ch 8, - 24 db. With compensation the corresponding noise levels were in the range of - 42 db to - 46 db for all channels.

3. Noise (dynamic range) tests

All 8 channels were modulated by a 1 hz square wave at levels of 0 db (100%); - 10 db, (32%); - 60 db (0.1%); and the resulting multiplexed signal was recorded on the PI 5100 AM test track. The tape was played back on the B & H 3700 B and the multiplexed signal recovered from tape was discriminated by the standard NCER discriminator bank, with subtractive compensation, and played out on the Oscillomink at a paper speed of 10 mm/sec. The Oscillomink sensitivities were adjusted to produce clear records (Figure 7), i.e., sensitivities were reduced for large signal levels to avoid clipping. Examination of Figure 7 shows that the noise levels on all data channels were nearly equal and averaged about - 46 db with respect to 100% modulation.

4. System response tests

All 8 data channels were modulated by a 1 hz to 100 hz swept frequency since wave at modulation levels of 100%, 10%, and 1%, the timing channel was modulated at a level of about 20% by an IRIG- code from the time code generator, and the compensation channel was left unmodulated. The resulting multiplexed signal was recorded on the PI 5100 AM test track. The tape was played back on the B & H 3700 B, and the recovered multiplexed signal was discriminated by the standard NCER discriminator system, with subtractive compensation applied to the 8 data channels. The discriminated signals were played out on the Oscillomink at a paper speed of 10 mm/sec (Figure 8). Measured from Channel 3 for the case of 100% modulation, the system response relative to 1 hz was approximately: 1 hz, 1.0; 10 hz, 0.95; 20 hz, 0.80; 30 hz, 0.60; 50 hz, 0.25; 100 hz, $\sim$ (Figure 8a).

The degradation of the appearance of tests for lower modulation levels (10%, Figure 8b and 1%, Figure 8c) is consistent with the system noise levels measured in the previous test.

5. Cross talk tests

To examine intermodulation effects between channels each data channel and the timing channel was in turn subjected to 100% modulation by a 1 hz square wave and a 1 hz to 100 hz swept sine wave while the other data channels were left unmodulated. The multiplexed signal was recorded on the PI 5100, played back on the B & H 3700 B through the standard NCER discriminators (with compensation on the data channels) and recorded on the Oscillomink (Figure 9). At the Oscillomink sensitivity used to record the unmodulated data channels, 12.5 mv/mm, no intermodulation effects are visible on the records. This result is compatible with the modulator/discriminator cross talk tests of the standard NCER seismic data multiplex system described in reference (1).

Figure Captions

Figure 1. Modification of the P.I. 5100 tape speed control servo system to change speed from 15/160 ips to 15/16 ips.

Figure 2. Channel layout of the Standard (30 hz) NCER Multiplex System and of the Broad-band (150 hz) NCER Multiplex System.

Figure 3. Circuit diagram showing: 1) combination of "signal subcarriers to produce a multiplex signal for recording on one tape track, 2) combination of the multiplex signal with a bias signal (required for direct recording), and 3) the head driver circuit employed in the tests described in these notes.

Figure 4. Tests of noise level versus head signal current and head bias current. Each test is characterized by the peak to peak mf's (in millivolts) across the 10 ohm head current monitor resistor produced by the signal current and by the bias current (V_{sig}/V_{bias}). In all tests the 8 data subcarriers were modulated at the 1% level by a 1 hz square wave, the timing subcarrier was modulated about 20% by the output (IRIG-C) of the time code generator, and the compensation subcarrier was unmodulated. Oscillomink settings of 10, 2.5, and 0.25 correspond to sensitivities of 500 mv/mm, 125 mv/mm, and 12.5 mv/mm, respectively.

a. V_{sig} = 7.0 mv; V_{bias} = 40, 45, 50, 55, 60, and 70 mv
b. V_{sig} = 5.0 mv; V_{bias} = 40, 45, 50, 55, 60, and 70 mv
c. V_{sig} = 3.0 mv; V_{bias} = 40, 45, 50, 55, and 60 mv
d. V_{sig} = 2.5 mv; V_{bias} = 30, 35, 40, 45, and 50 mv

Figure 5. Compensation versus frequency test

The 8 data channels and the compensation channel were modulated at the - 10 db level in the "proportional" mode

($\delta FC_i = \pm 0.316 \times 125 \times \frac{FCi}{3125}$) by a 1 hz to 100 hz swept frequency sine wave. The timing channel was modulated at about the 20% level by IRIG-C code from the time code generator. On the playback, compensation was applied to the eight data channels, but not to the timing channel nor the compensation channel, of course. Oscillomink settings of 10, 2.5, 1.0, and 0.25 correspond to sensitivities of 500 mv/mm, 125 mv/mm, 50 mv/mm, and 12.5 mv/mm, respectively.

Figure 6. Compensation effectiveness tests

The 8 data channels were modulated at the - 60 db level (0.1%) by a 1 hz square wave. The timing channel was modulated at about the 20% level by IRIG-C code from the time code generator. The compensation subcarrier was unmodulated. On playback compensation was applied to the 8 data channels on the left quarter of the figure (with a playback paper speed of 10 mm/sec). Compensation was removed (compensation discriminator unplugged) for the rest of the figure. The second quarter of the figure shows the uncompensated playback at a paper speed of 10 mm/sec; and the right-hand half of the figure shows the uncompensated playback at a paper speed of 25 mm/sec. Oscillomink settings of 10, 2.5 and 0.25 correspond to sensitivities of 500 mv/mm, 125 mv/mm, and 12.5 mv/mm, respectively.

Figure 7. Noise (dynamic range) tests

The 8 data channels were modulated at levels of 0 db (100%), - 10 db (32%), ..., - 60 db (0.1%) by a 1 hz square wave. The timing channel was modulated at about the 20% level by IRIG-C code from the Time Code Generator. The compensation subcarrier was unmodulated. On playback, subtractive compensation was applied to the 8 data channels, but not to the timing channel. Oscillomink settings of 10, 2.5, 1.0, and 0.25 correspond to sensitivities of 500 mv/mm, 125 mv/mm, 50 mv/mm and 12.5 mv/millimeters, respectively.

In this and subsequent tests the peak to peak signal and bias head currents were .25 ma and 4.5 ma, respectively (2.5 mv/45 mv voltage drops across the 10 ohm head current monitoring resistor).

Figure 8. System response tests

All 8 data channels were modulated by a 1 hz to 100 hz swept frequency sine wave at modulation levels of 100% (0 db), 10% (- 20 db), and 1% (- 40 db). The timing channel was modulated at about the 20% level by IRIG-ode from the time code generator. The compensation subcarrier was unmodulated. On playback, subtractive compensation was applied to the 8 data channels, but not to the timing channel. Oscillomink settings of 10, 2.5, 1.0, and .25 correspond to sensitivities of 500 mv/mm, 125 mv/mm, 50 mv/mm, and 12.5 mv/mm, respectively.

a. 100% modulation of data channels

b. 10% modulation of data channels

c. 1% modulation of data channels

Figure 9. Cross talk tests

In each test one channel was modulated at the 0 db (100%) level by a 1 hz square wave and a 1 hz to 100 hz swept frequency sine wave while the other data channels and the compensation channel were left unmodulated. In all the test but the last (Fig. 9i), the timing channel was modulated at about the 20% level by IRIC-C code from the Time Code Generator. On playback, the modulated (data) channel and the compensation channel were reproduced at Oscillomink settings of 2.5 (125 mv/mm), while the unmodulated data tracks were reproduced at settings of 0.25 (12.5 mv/mm). The timing trace was reproduced at a setting of 10 (500 mv/mm) in all cases. Playback compensation was employed on all data channels.

a) 100% mod. of data Ch 1, b) 100% mod. of data Ch 2,

c) 100% mod. of data Ch 3, d) 100% mod. of data Ch 4,

e) 100% mod. of data Ch 5, f) 100% mod. of data Ch 6,

g) 100% mod. of data Ch 7, h) 100% mod. of data Ch 8,

i) 100% mod. of timing channel.

15/160 to 15/16 Speed Conversion of the PI 5100 Recorder

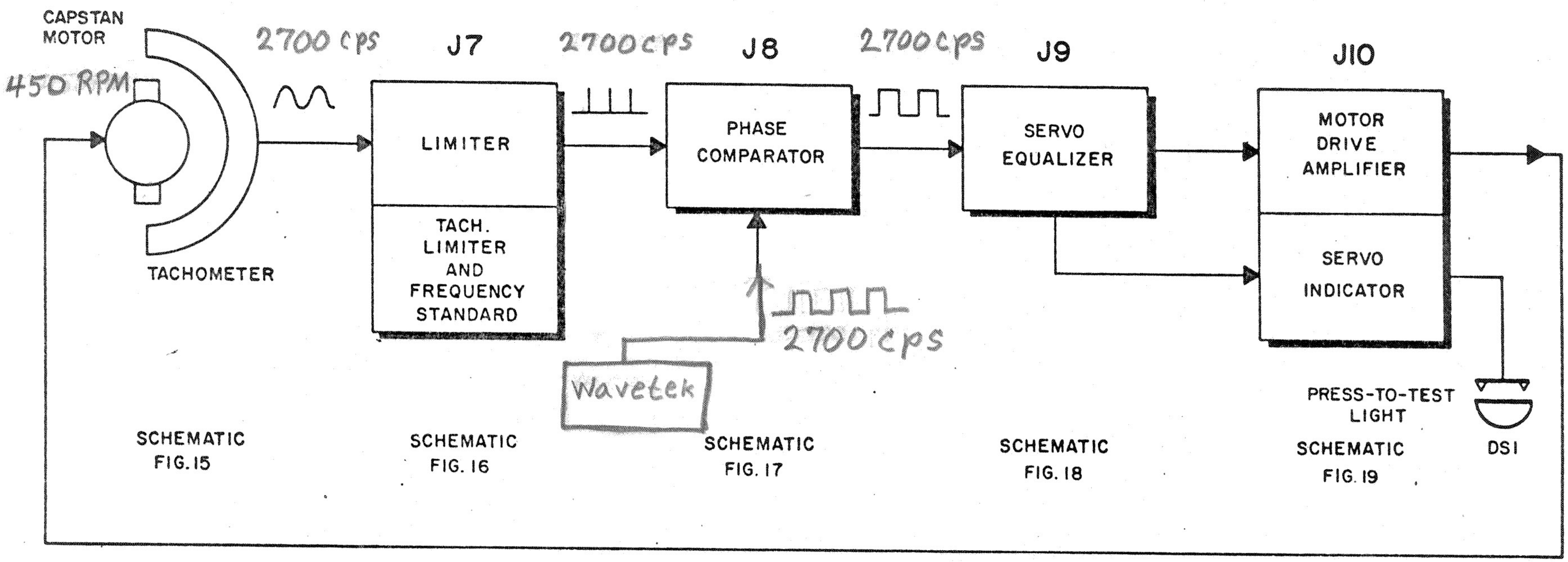
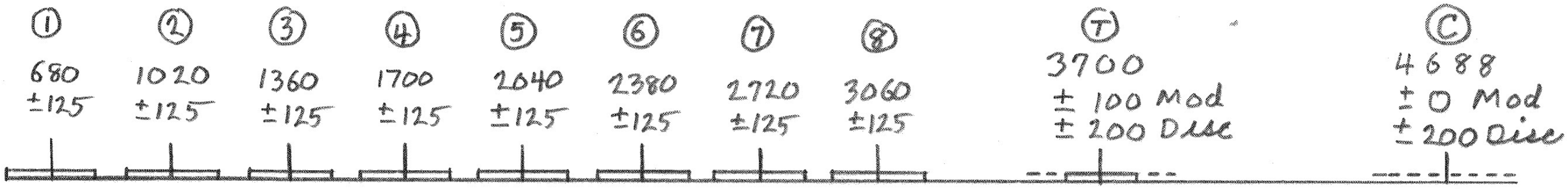


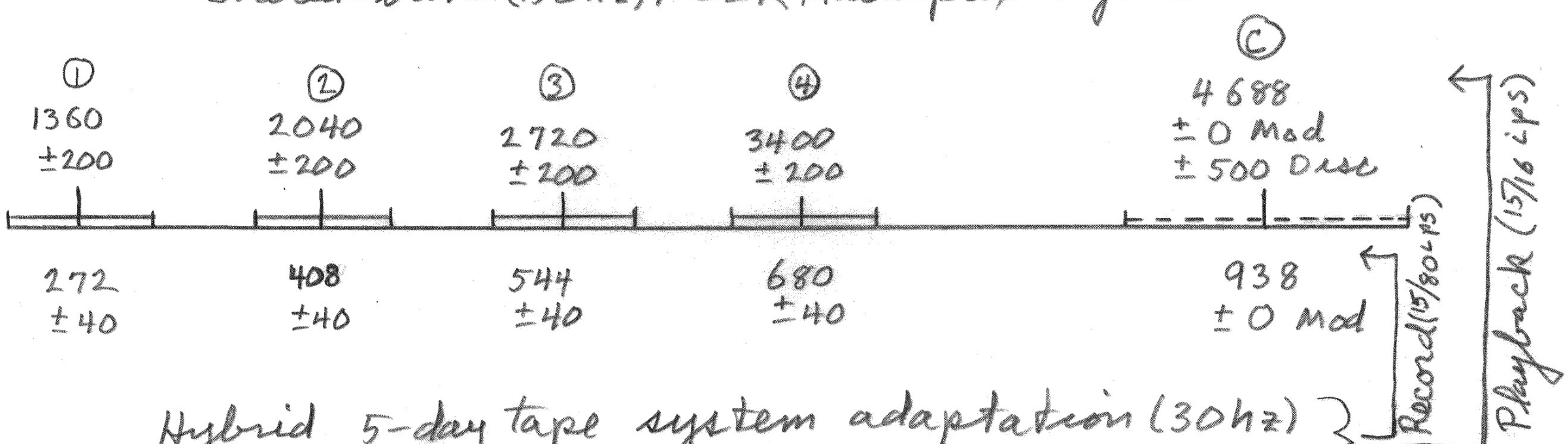
Fig 1

Standard (30hz) NCER Multiplex System (1)



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

Broad-band (150hz) NCER Multiplex System (2)



Hybrid 5-day tape system adaptation (30hz) of the broad-band multiplex system

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

Fig 2

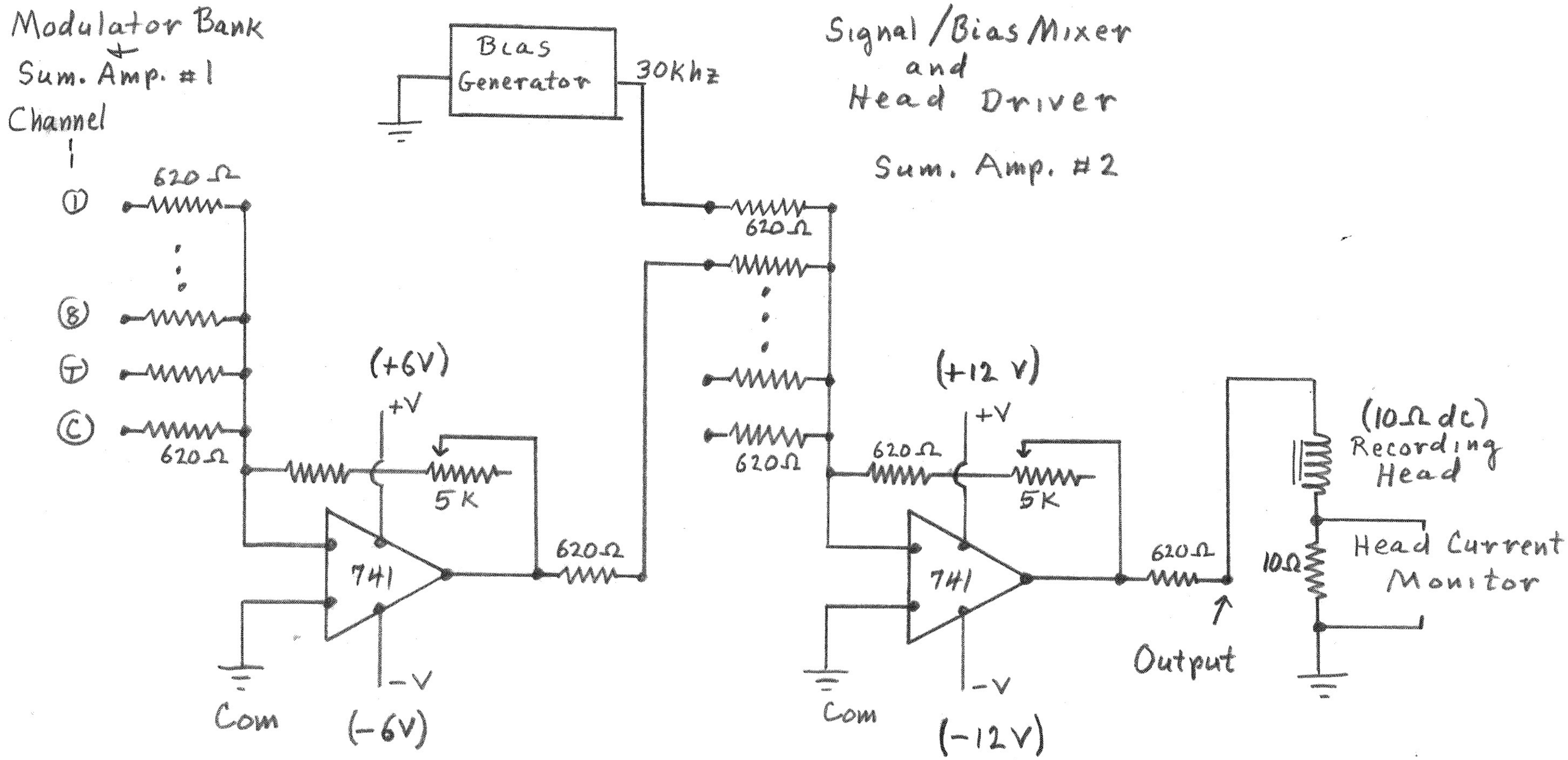

Modulator Bank
Sum. Amp. #1
Channel
①
⑧
Ⓣ
Ⓒ
620Ω
620Ω
Bias Generator
30Khz
(+6V)
+V
5K
741
620Ω
-V
(-6V)
Com
Signal/Bias Mixer
and
Head Driver
Sum. Amp. #2
620Ω
620Ω
620Ω
(+12 V)
+V
5K
741
-V
(-12V)
Com
620Ω
Output
(10Ω dc)
Recording Head
10Ω
Head Current Monitor

Fig 3

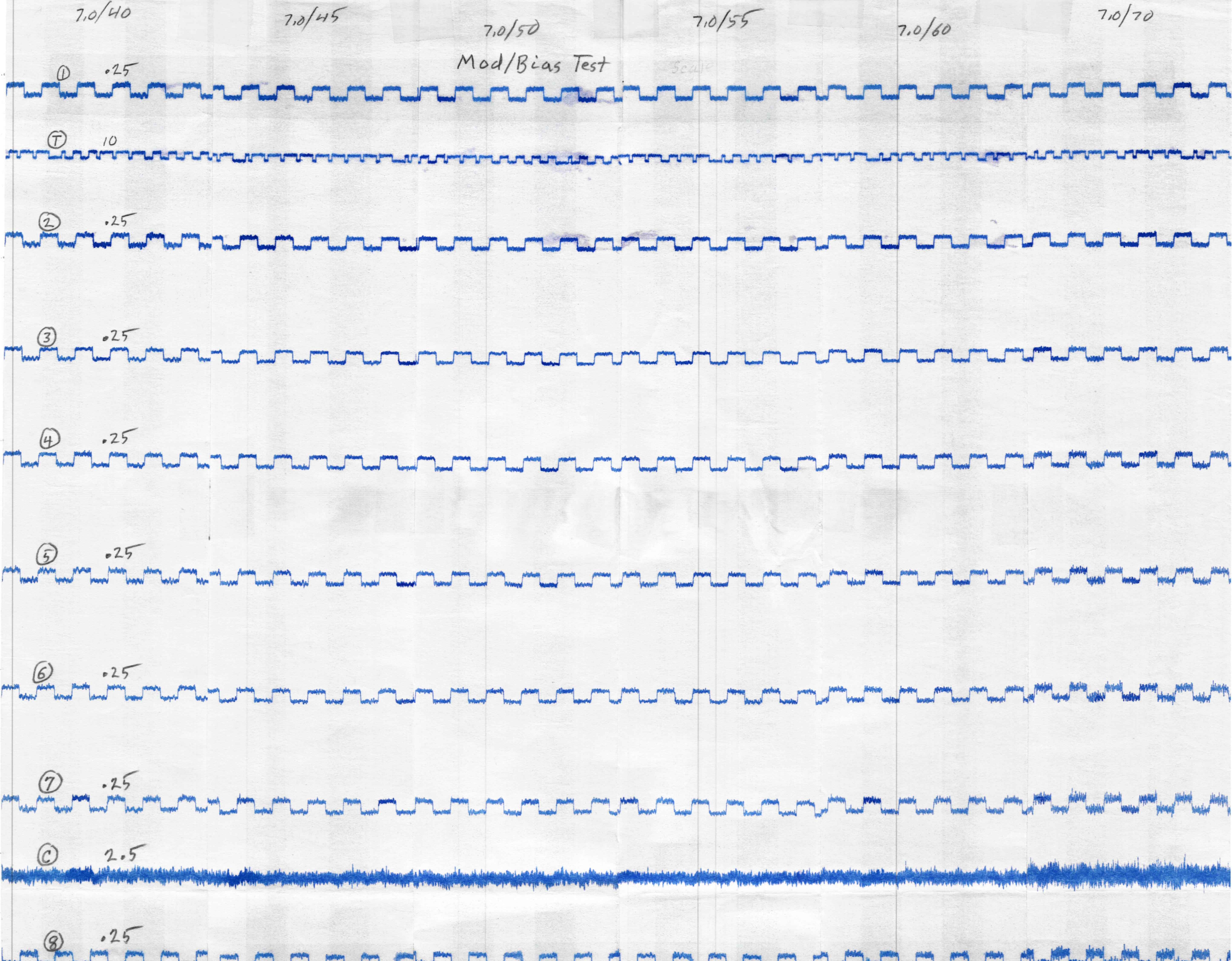

7.0/40
7.0/45
7.0/50
7.0/55
7.0/60
7.0/70
Mod/Bias Test
① .25
Ⓣ 10
② .25
③ .25
④ .25
⑤ .25
⑥ .25
⑦ .25
Ⓒ 2.5
⑧ .25

Fig 4a

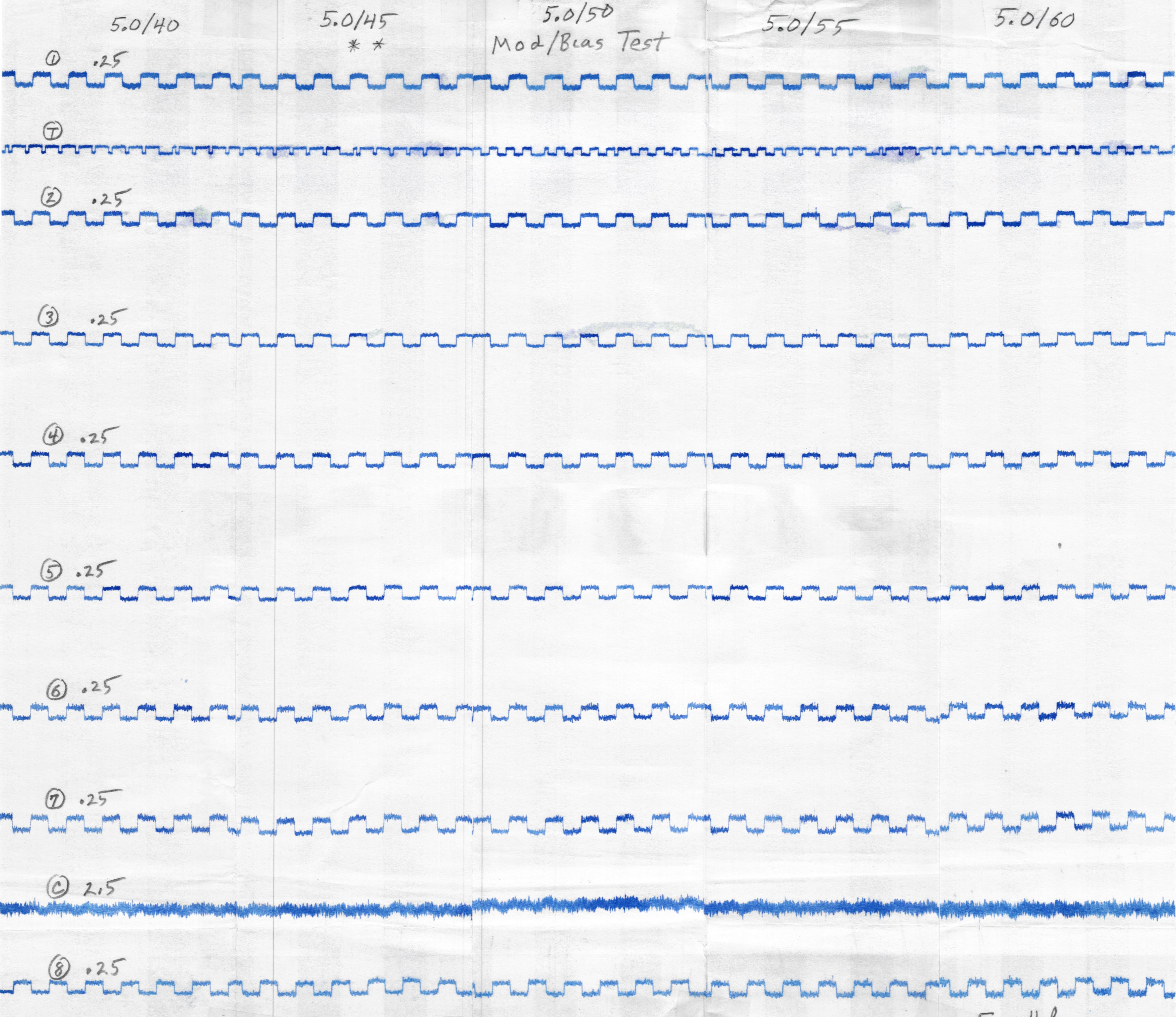

5.0/40
5.0/45
* *
5.0/50
Mod/Bias Test
5.0/55
5.0/60
① .25
Ⓣ
② .25
③ .25
④ .25
⑤ .25
⑥ .25
⑦ .25
Ⓒ 2.5
⑧ .25

Fig 4b

① .25
Mod/Bias test
T 10
② .25
③ .25
3.0/45
3.0/50
3.0/55
3.0/60
④ .25
3.0/45
3.0/50
3.0/55
3.0/60
⑤ .25
⑥ .25
⑦ .25
C 2.5
-40 db mod
10 mm/sec
⑧ .25

Fig 4C

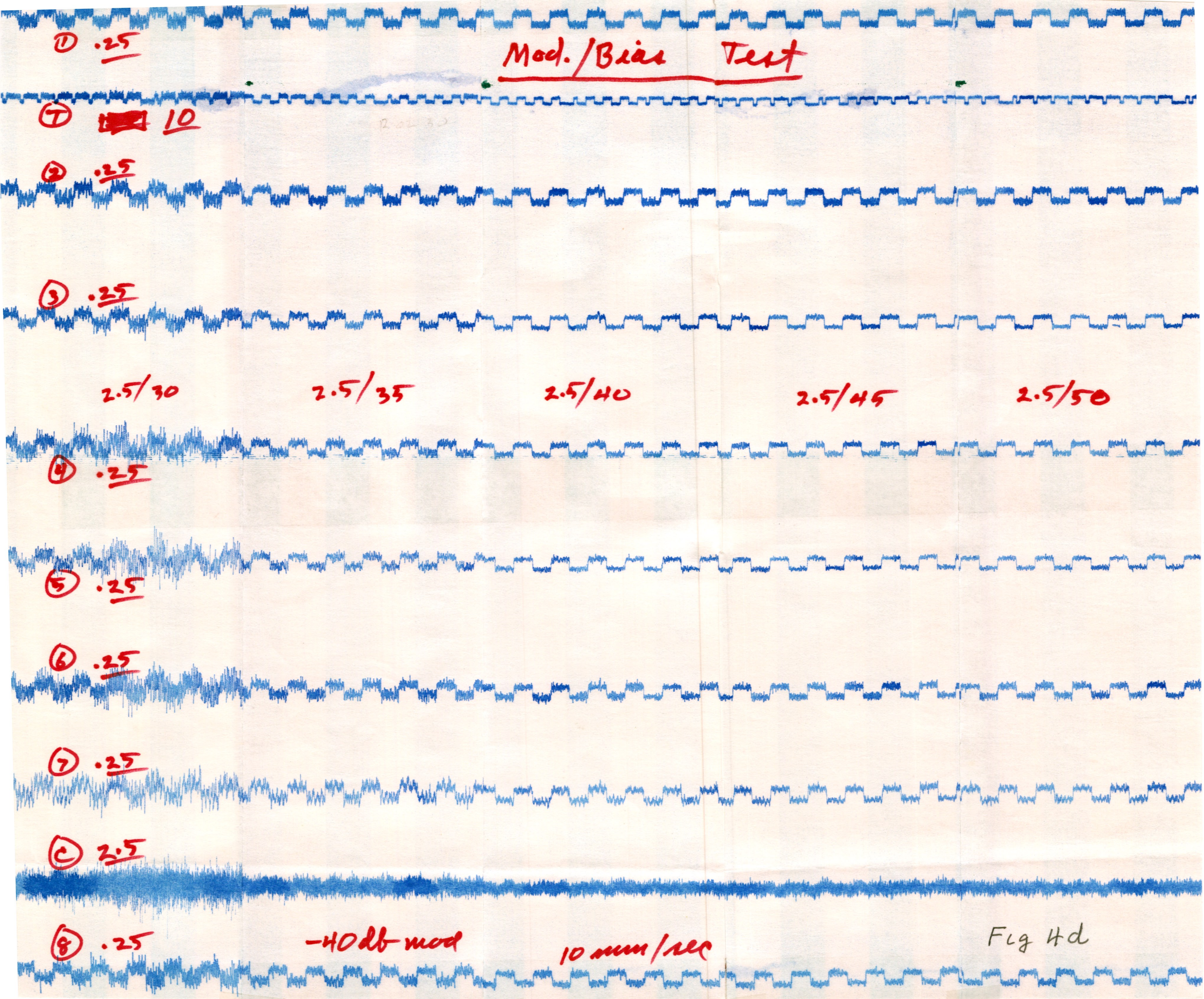
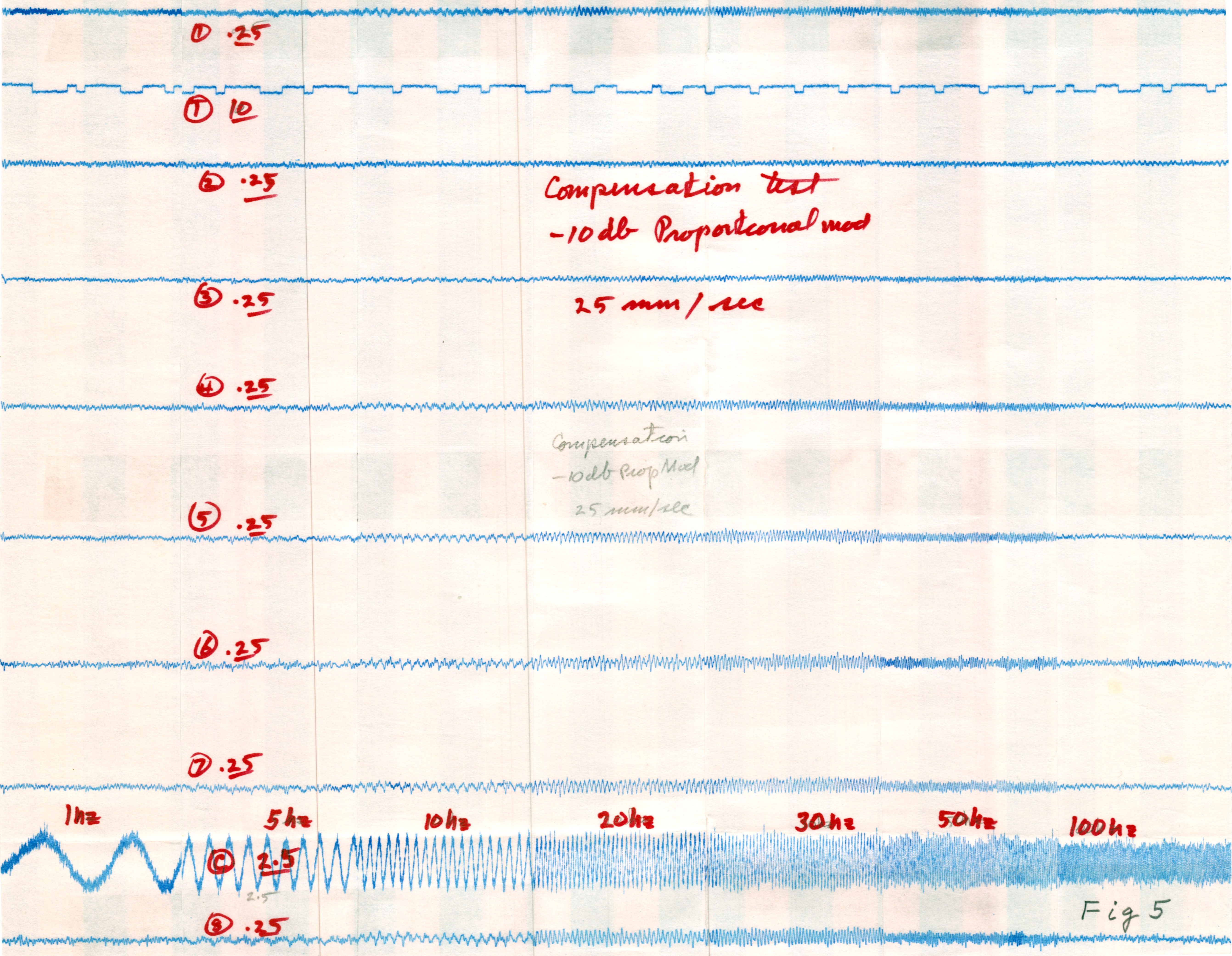
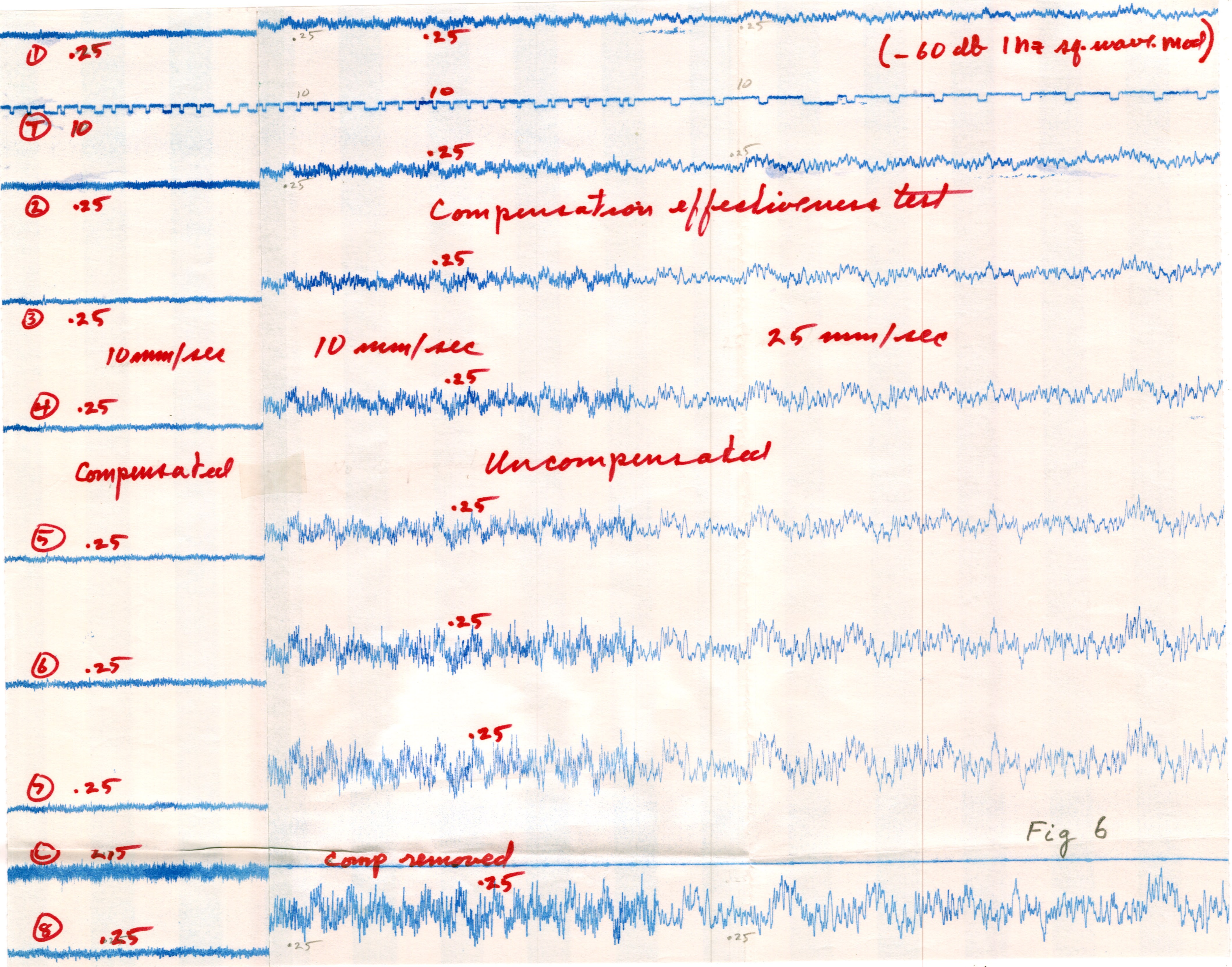

(1) .25
Mod./Bias Test
(T) [redacted] 10
(2) .25
(3) .25
2.5/30
2.5/35
2.5/40
2.5/45
2.5/50
(4) .25
(5) .25
(6) .25
(7) .25
(C) 2.5
(8) .25
-40db mod
10 mm/sec

Fig 4d



(1) .25
(T) 10
(2) .25
Compensation test
-10db Proportional mod
25 mm/sec
(3) .25
(4) .25
Compensation
-10db Prop Mod
25 mm/sec
(5) .25
(6) .25
(7) .25
1hz
5hz
10hz
20hz
30hz
50hz
100hz
(C) 2.5
2.5
(8) .25

Fig 5



(-60 db 1 hz sq. wave mod)
① .25
Ⓣ 10
② .25
Compensation effectiveness test
③ .25
10 mm/sec
10 mm/sec
25 mm/sec
④ .25
Compensated
Uncompensated
⑤ .25
⑥ .25
⑦ .25
Ⓒ .25
comp removed
⑧ .25

Fig 6

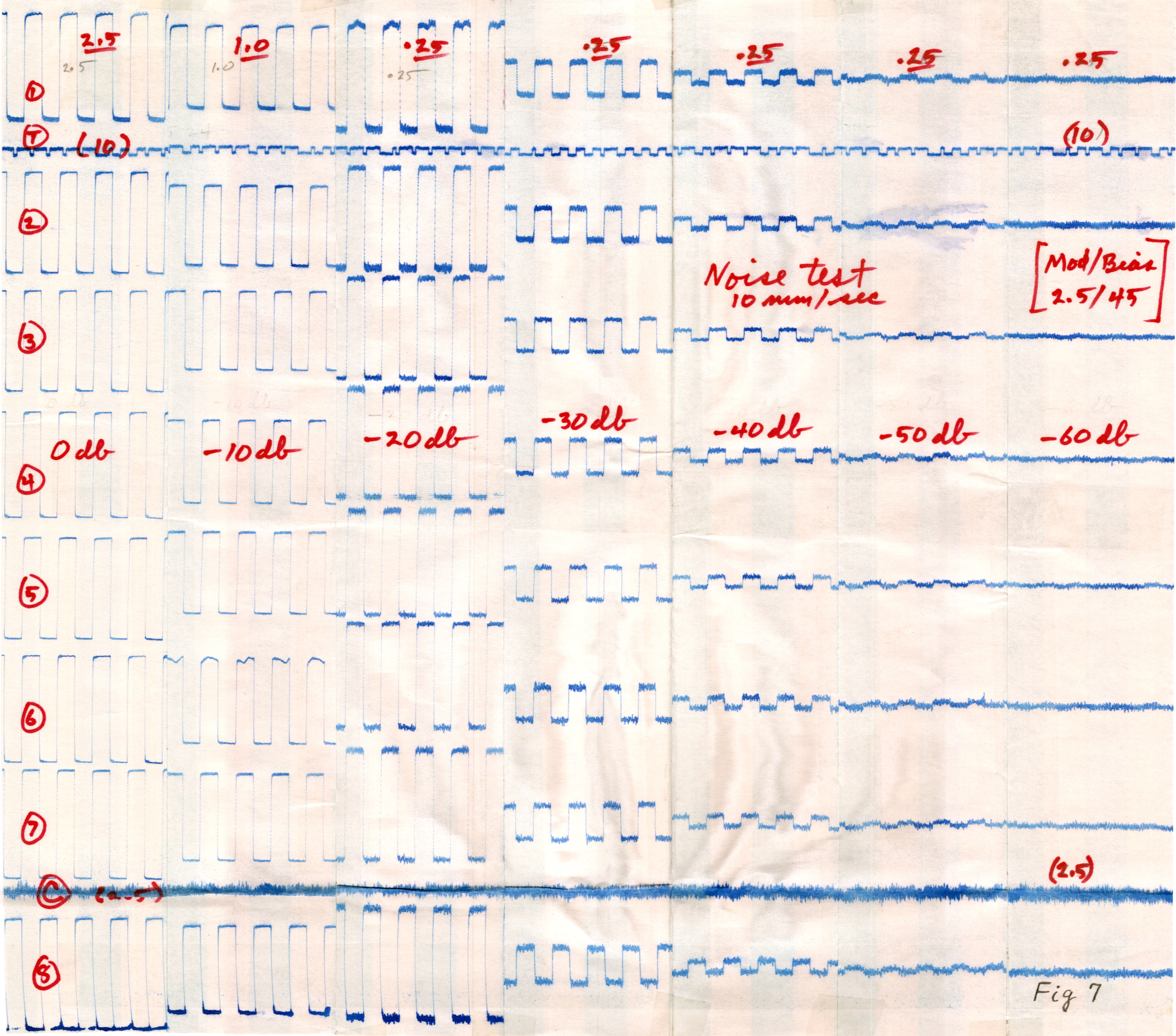

2.5
1.0
.25
.25
.25
.25
.25
1
T
(10)
(10)
2
Noise test
10 mm/sec
[Mod/Bias
2.5/45]
3
0 db
-10 db
-20 db
-30 db
-40 db
-50 db
-60 db
4
5
6
7
C
(2.5)
(2.5)
8

Fig 7

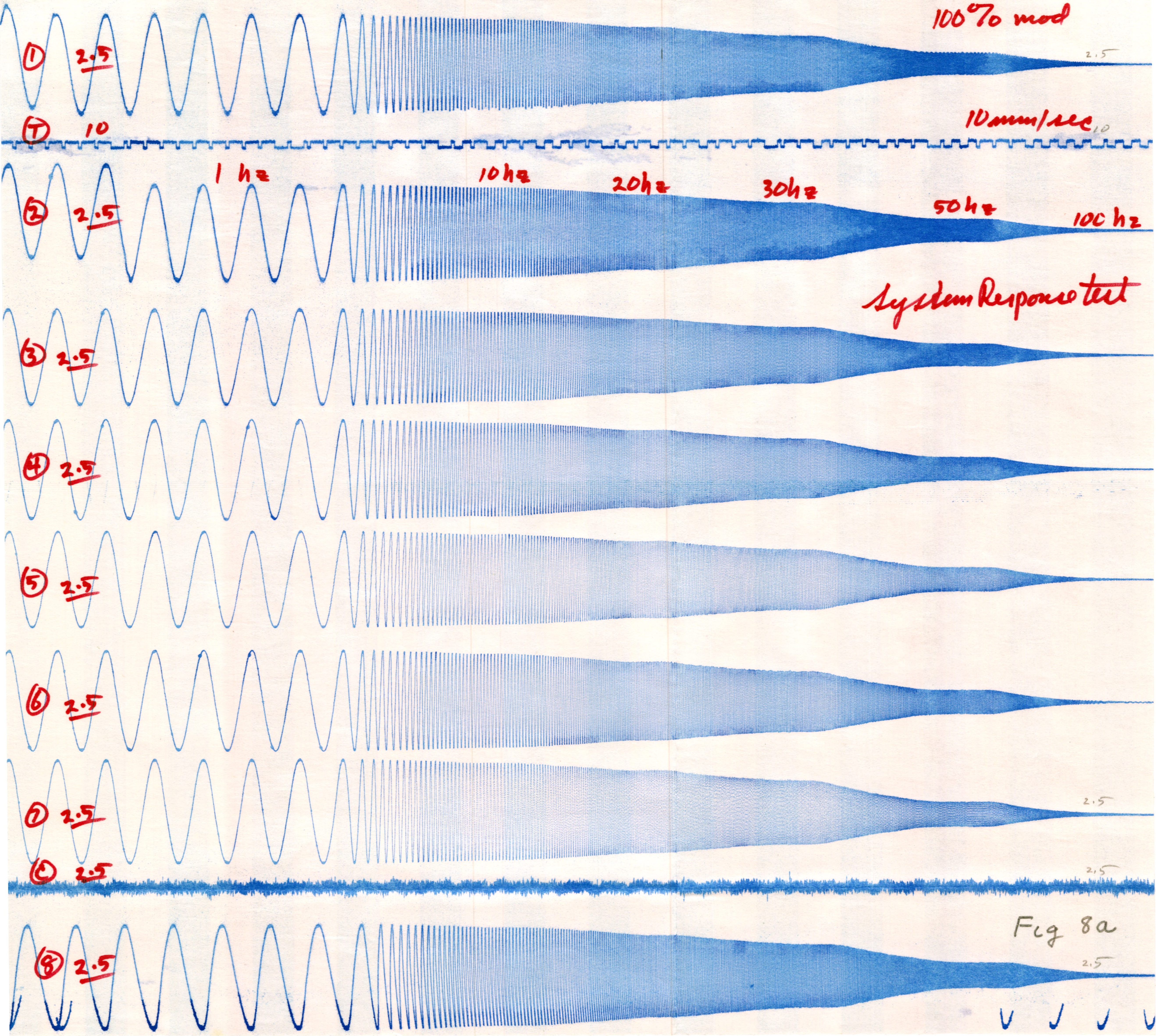
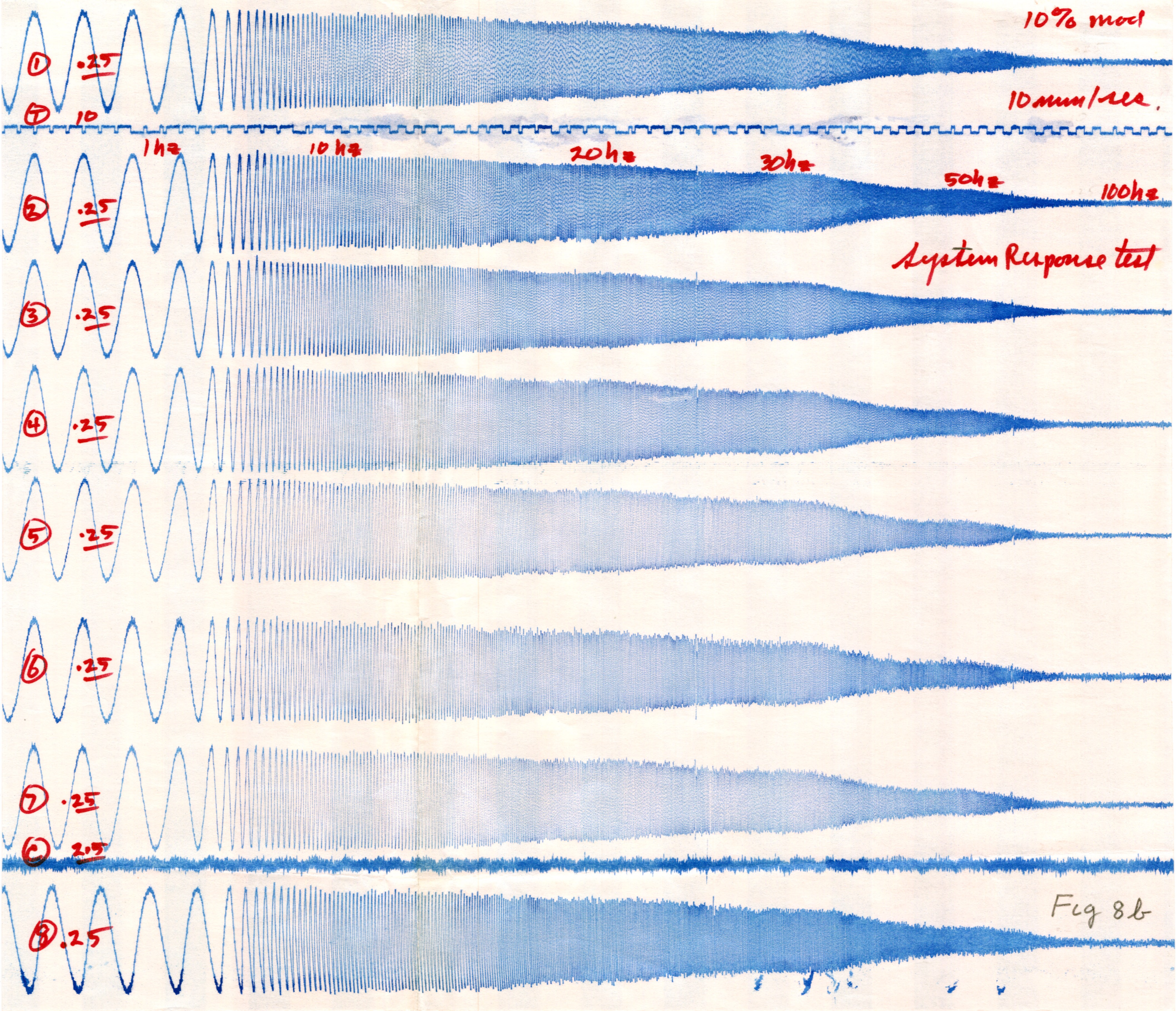

100% mod
1 2.5
T 10
10mm/sec
1 hz
10hz
20hz
30hz
50hz
100 hz
2 2.5
System Responce test
3 2.5
4 2.5
5 2.5
6 2.5
7 2.5
E 2.5
8 2.5

Fig 8a


10% mod
① .25
T 10
10 mm/sec.
1hz
10hz
20hz
30hz
50hz
100hz
② .25
System Response test
③ .25
④ .25
⑤ .25
⑥ .25
⑦ .25
C 2.5
⑧ .25
Fig 8b

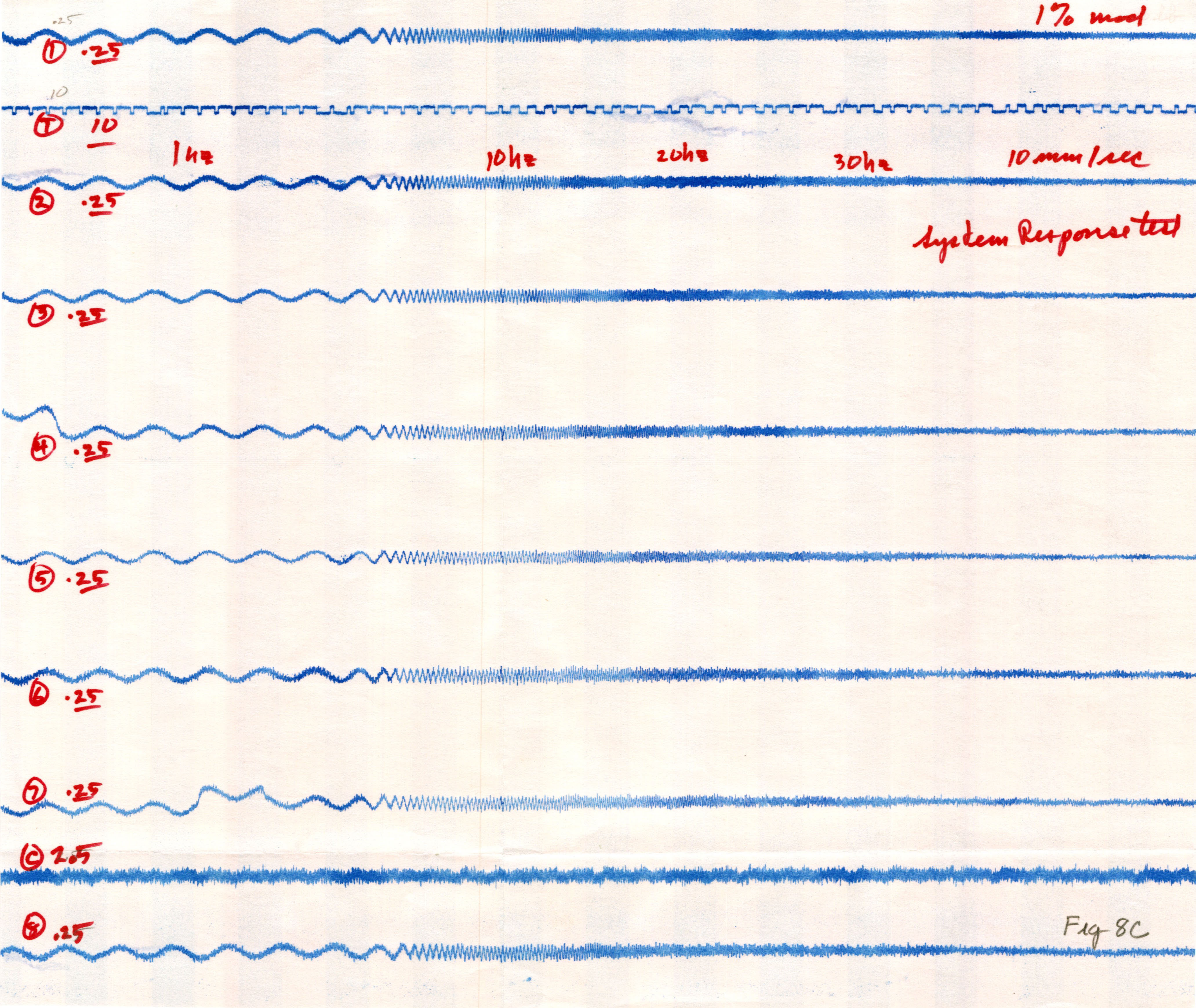

1% mod
① .25
T 10
1hz
10hz
20hz
30hz
10 mm/sec
② .25
System Response test
③ .25
④ .25
⑤ .25
⑥ .25
⑦ .25
C 2.5
⑧ .25

Fig 8C

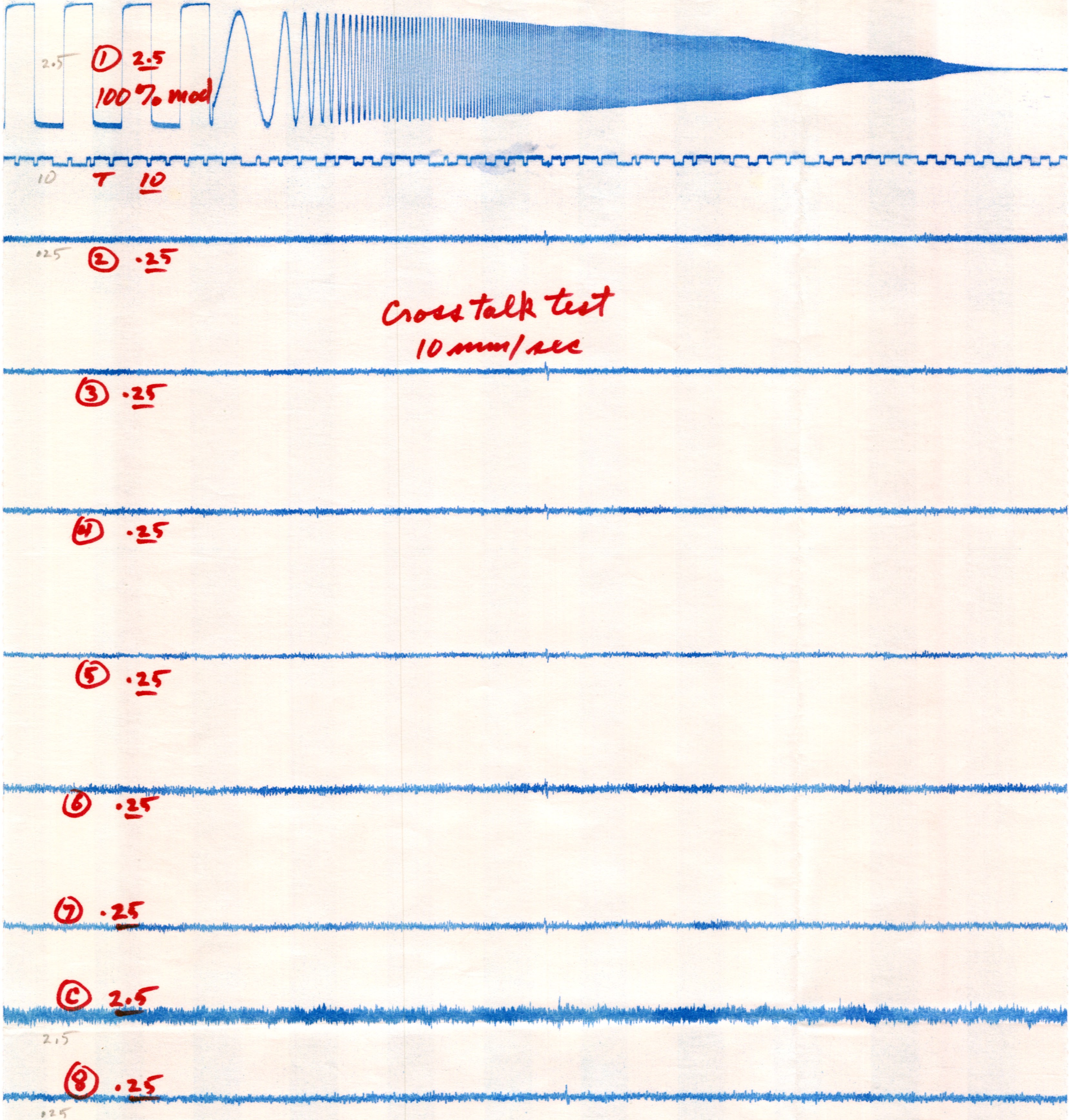

2.5
① 2.5
100% mod
10
T 10
.25
② .25
Cross talk test
10 mm/sec
③ .25
④ .25
⑤ .25
⑥ .25
⑦ .25
Ⓒ 2.5
2.5
⑧ .25
.25

Fig 9a

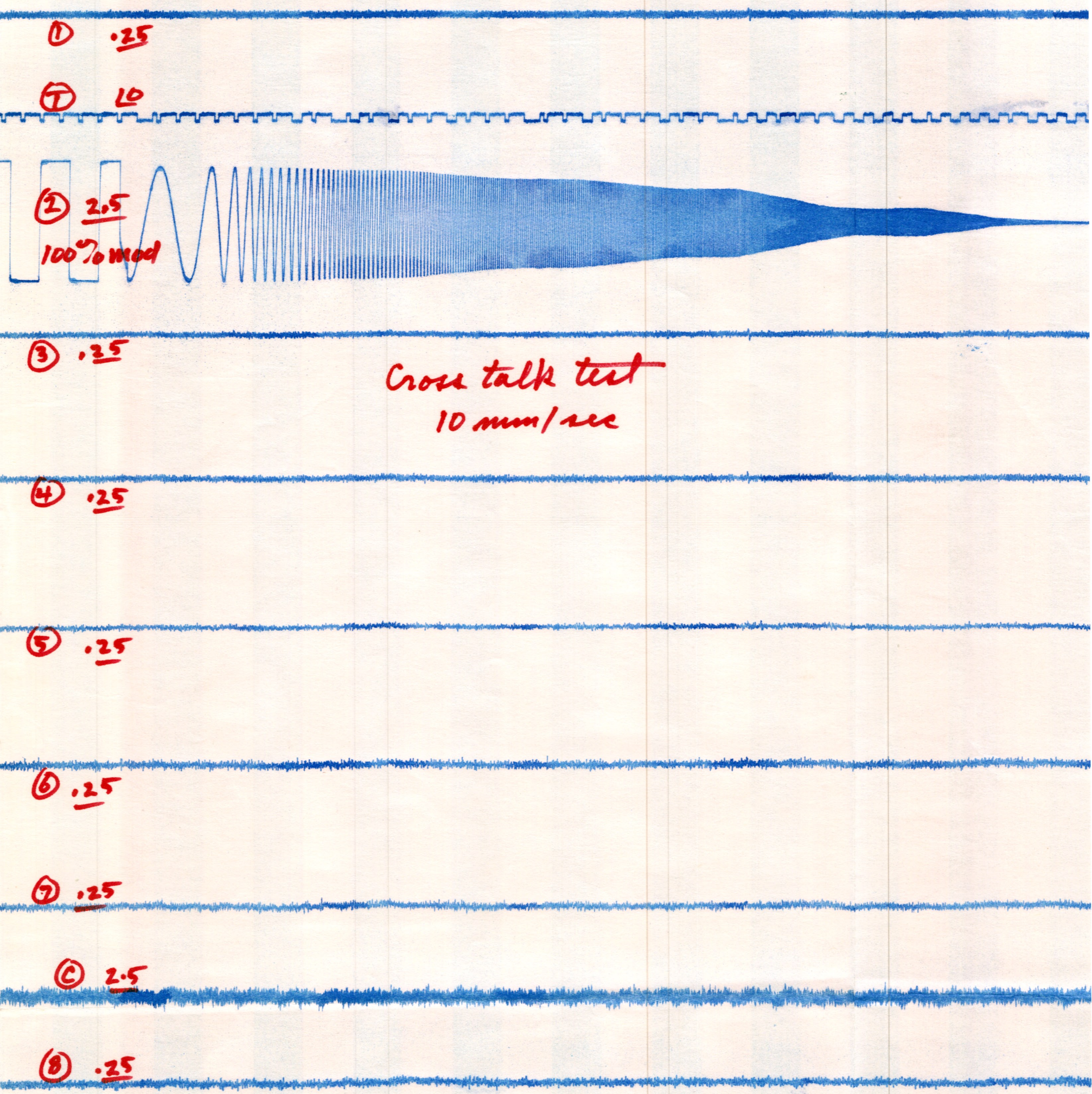

1 .25
T 1.0
2 2.5
100% mod
3 .25
Cross talk test
10 mm/sec
4 .25
5 .25
6 .25
7 .25
C 2.5
8 .25

Fig 9b

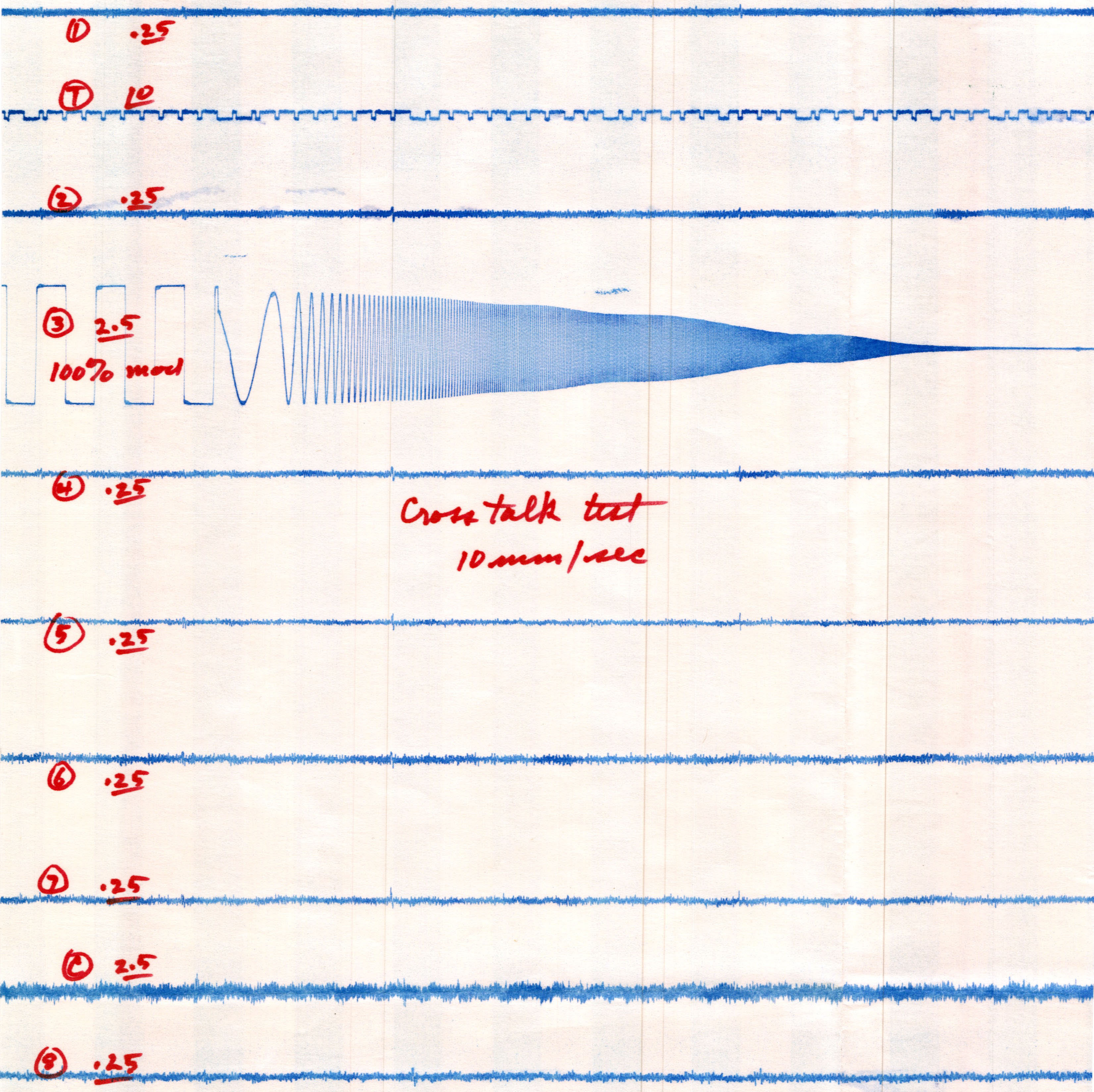

1 .25
T 10
2 .25
3 2.5
100% mod
4 .25
Crosstalk test
10 mm/sec
5 .25
6 .25
7 .25
C 2.5
8 .25

Fig 9C

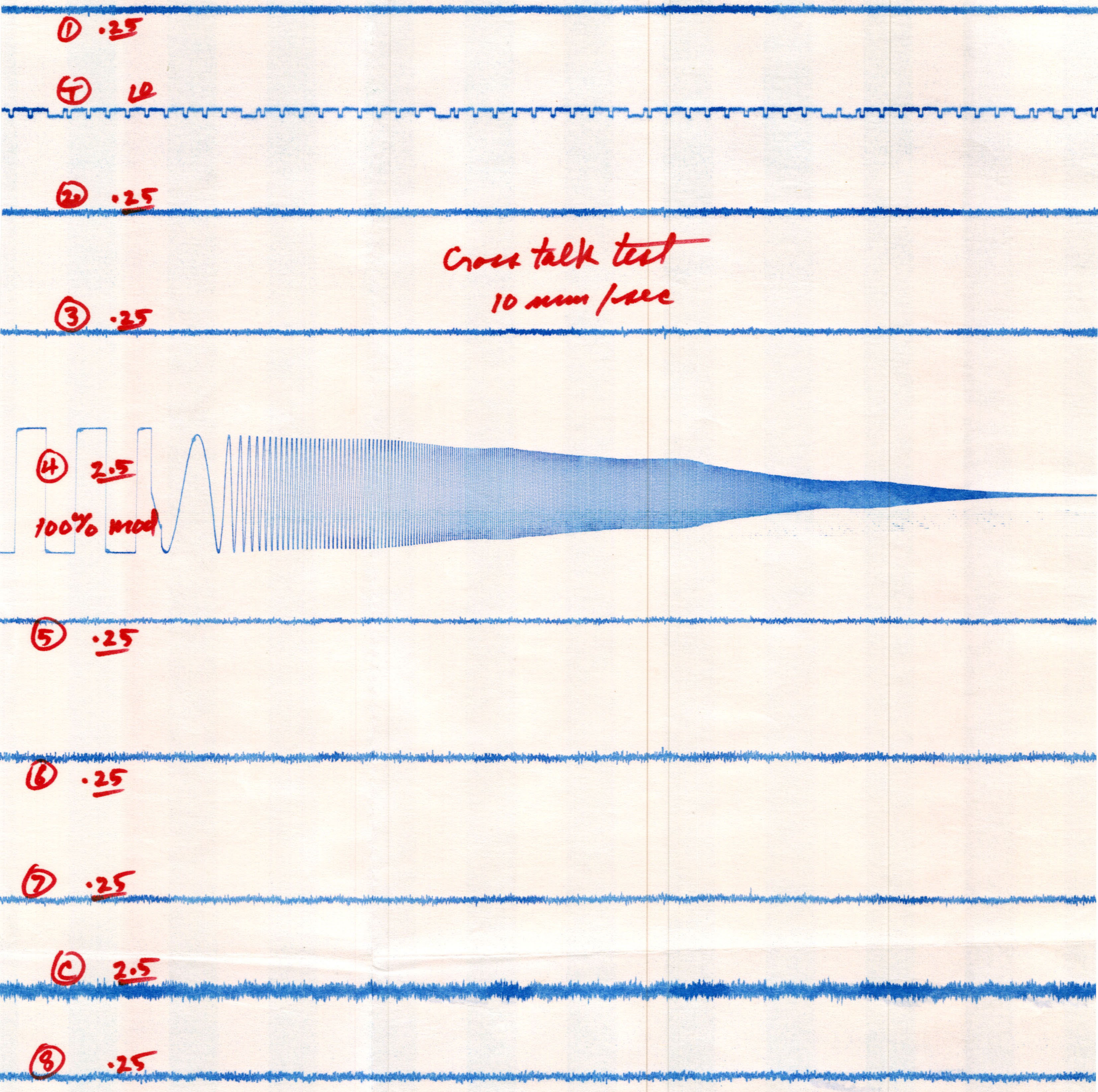

1 .25
.25
Cross talk test
10 mm/sec
3 .25
4 2.5
100% mod
5 .25
6 .25
7 .25
C 2.5
8 .25

Fig 9d

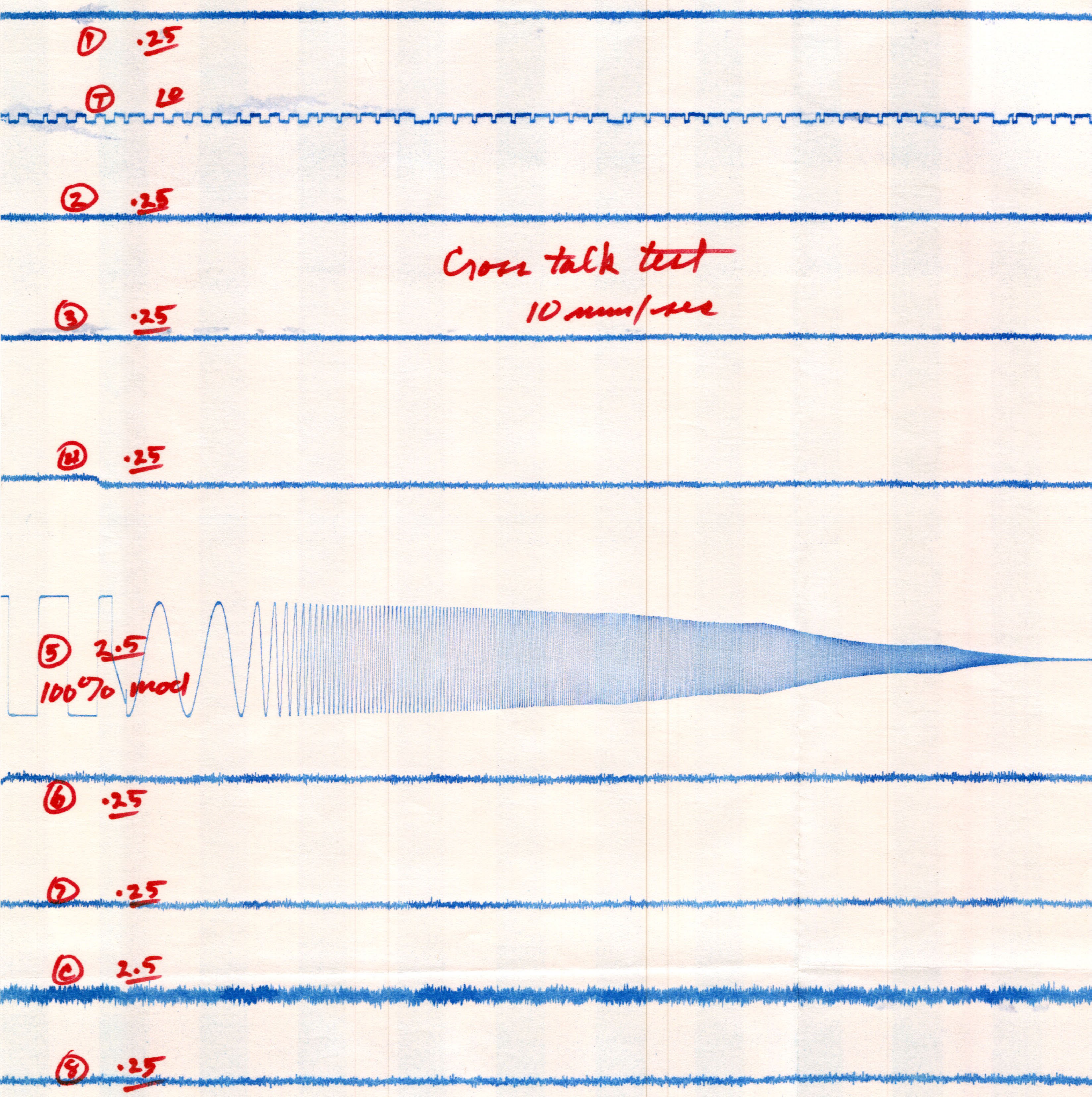

1 .25
T 10
2 .25
Cross talk test
10 mm/sec
3 .25
4 .25
5 2.5
100% mod
6 .25
7 .25
C 2.5
8 .25

Fig 9e

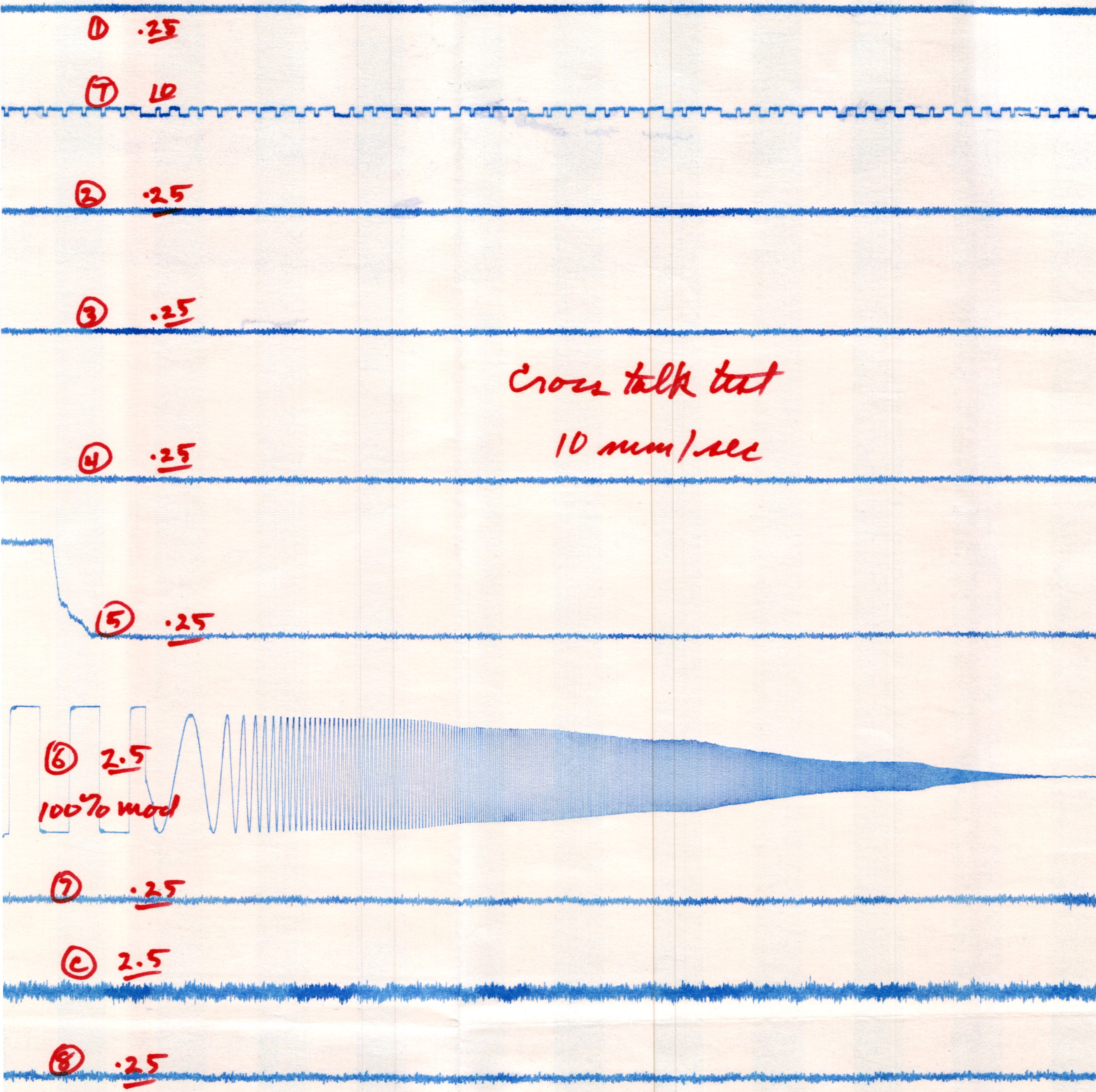

① .25
Ⓣ 10
② .25
③ .25
Cross talk test
10 mm/sec
④ .25
⑤ .25
⑥ 2.5
100% mod
⑦ .25
ⓒ 2.5
⑧ .25

Fig 9f

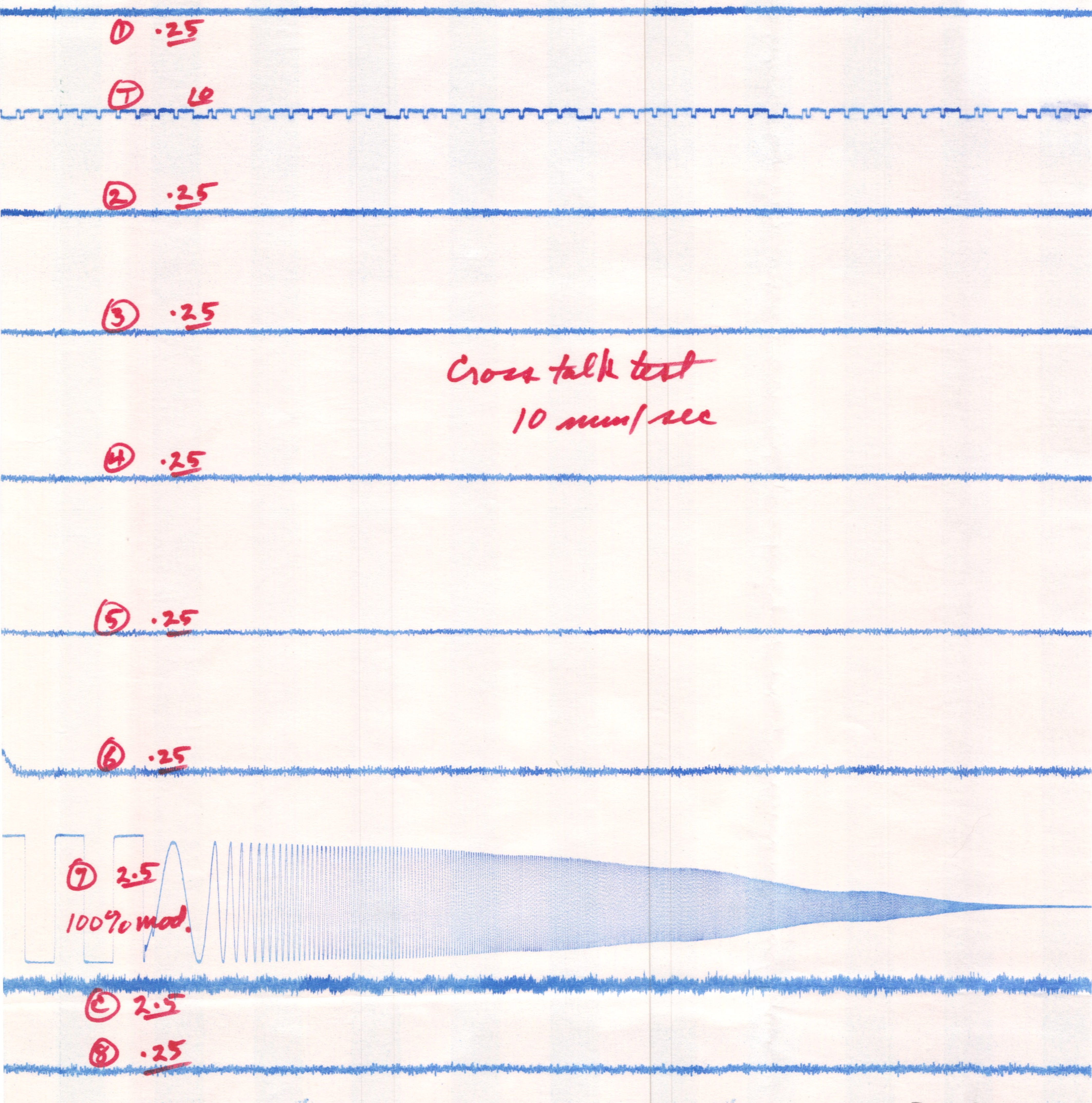

① .25
T
② .25
③ .25
Cross talk test
10 mm/sec
④ .25
⑤ .25
⑥ .25
⑦ 2.5
100% mod.
C 2.5
⑧ .25

Fig 9g

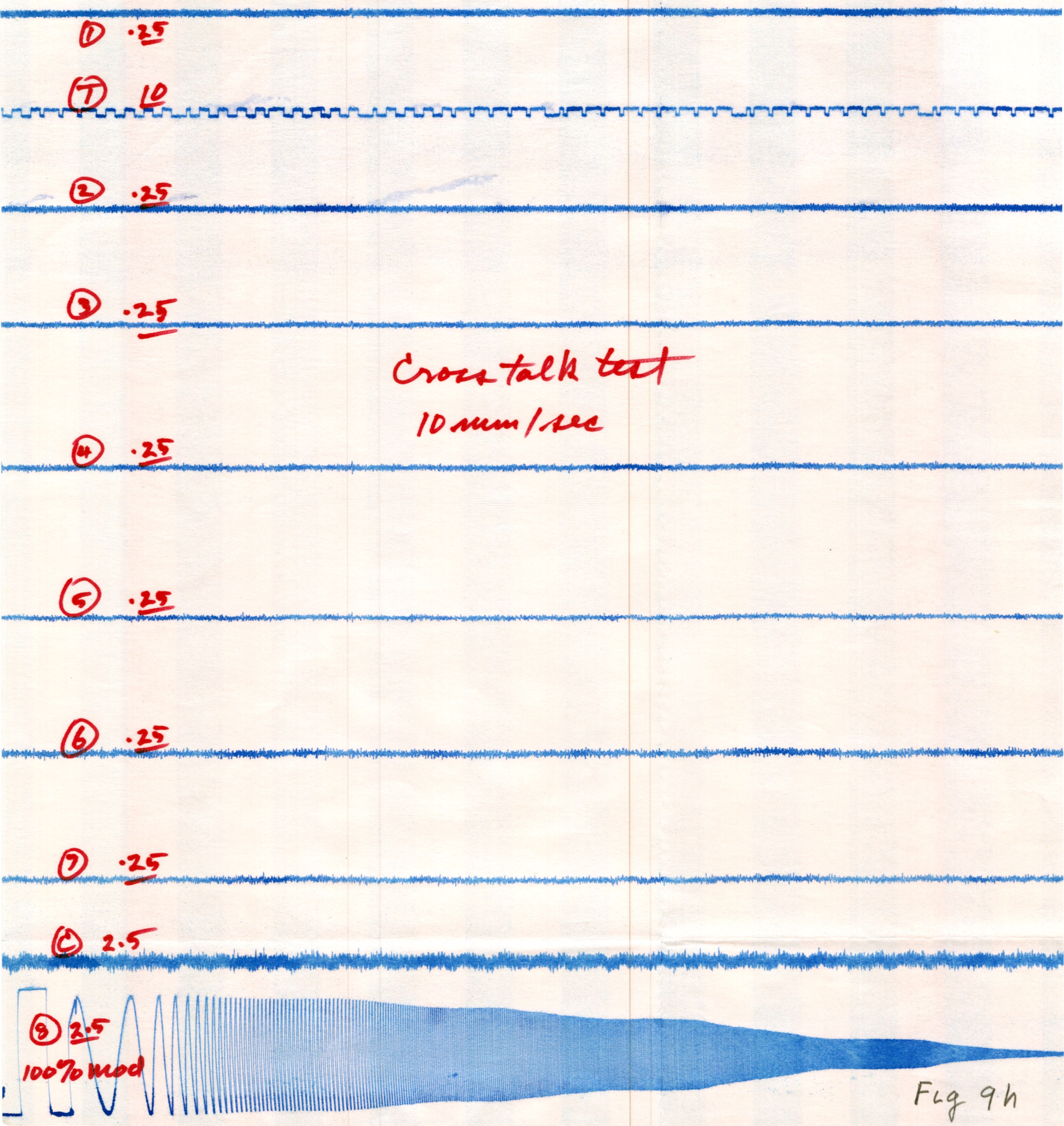

① .25
Ⓣ 10
② .25
③ .25
Cross talk test
10 mm/sec
④ .25
⑤ .25
⑥ .25
⑦ .25
Ⓒ 2.5
⑧ 2.5
100% mod

Fig 9h

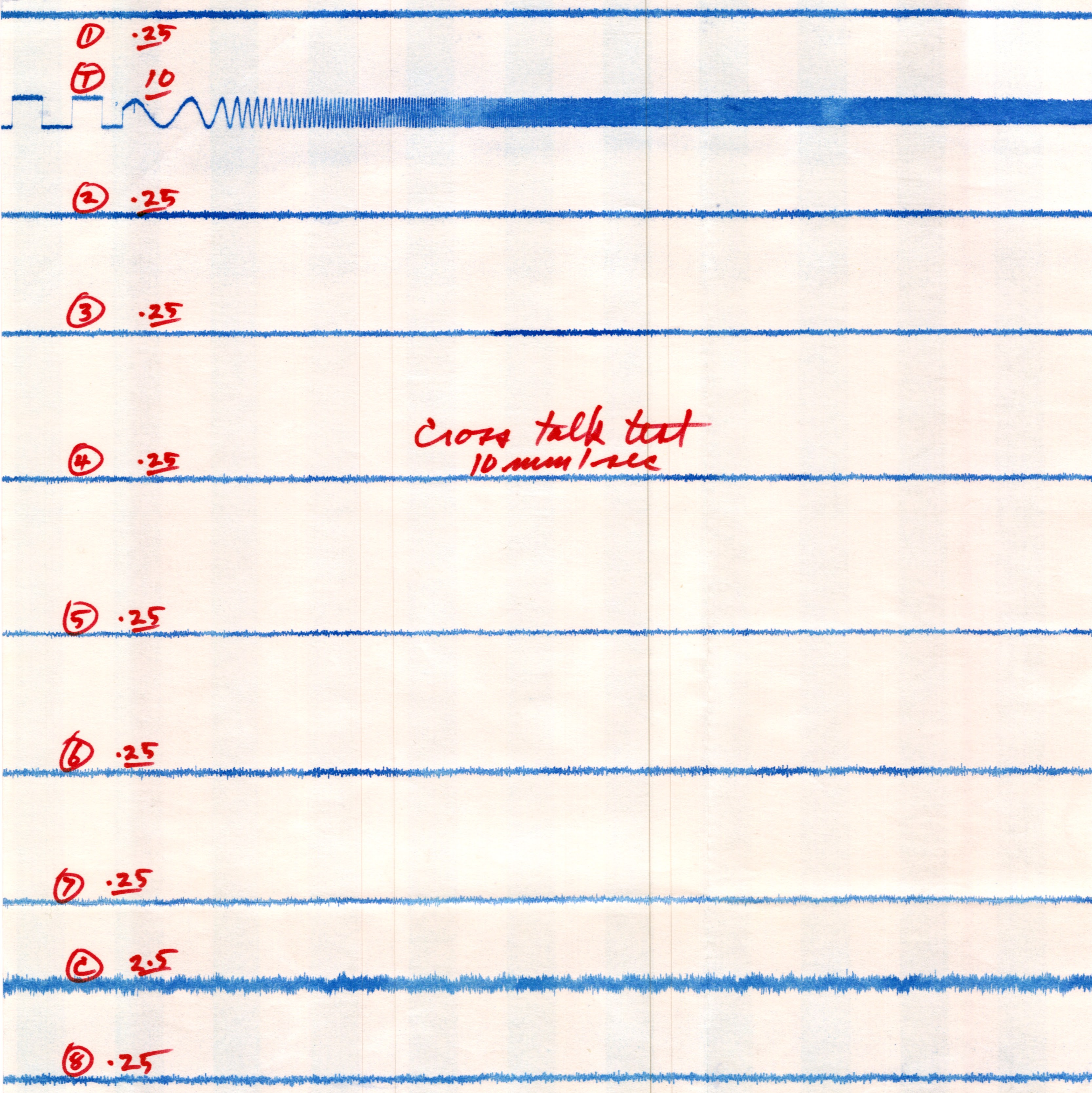


Fig 9i