BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 04034

SUBJECT: Contour Spectrograms for POGO Analysis - Case 320

DATE: April 10, 1970

FROM: A. T. Ackerman
L. A. Ferrara
J. J. O'Connor

ABSTRACT

In our work on Saturn V POGO problems, we discovered a commerically available spectrum analyzer which can preserve signal amplitude by creating contour lines of constant signal level on a two dimensional plot with frequency and time axes. A brief discription of this equipment concentrates on the inherent flexibility in displaying the resulting spectrograms. Some 24 contour spectrograms are presented for six S-II flight measurements (three for SA-504 and three for SA-507) and two S-IVB-507 flight measurements. The previously published intensity spectrograms of these eight measurements are again presented for comparison; the intensity spectrograms forego amplitude preservation to allow an Automatic Gain Control action to search into the noise for the presence of a signal.

The trade-off between the contour and intensity spectrograms is not straight forward and depends on the particular characteristics of the signal to be detected. This study shows the obvious advantage of having both types of spectrograms.

The contour spectrograms indicate that the S-II POGO phenomenon is probably not caused by the intersection of two modes, as the intensity spectrograms would indicate. It is probably associated with one mode with an unknown mechanism causing the signal to suddenly drop down in frequency with an adrupt increase in amplitude, followed by a gradual return to the mode frequency.

The contour spectrograms compliment the intensity spectrograms for the S-IVB measurements. There is nothing new added to the rather simple POGO signal, but some additional information is gained about the very complicated time-frequency history of a signal that has been associated with the S-IVB LOX line resonance.

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MEMORANDUM FOR FILE

I. INTRODUCTION

In our previous activity on the Saturn V POGO problems, particularly those associated with the S-II stage, we found spectrogram analysis of flight measurements to be a useful tool. The spectrogram is a graphical presentation of signal level on the two-dimensional space of time versus frequency. Spectrograms (herein identified as intensity spectrograms) were derived from the telemetered flight data on specialized (but not optimized) equipment at the Ocean Systems Laboratory of the Bell Telephone Laboratories (BTL). While the spectrograms had been given wide distribution, the analyzing equipment was not generally available. Functionally equivalent analysis systems can, however, be derived from commercially available components.

II. INTENSITY SPECTROGRAMS

Figure 1a is a sample of the intensity spectrogram. Since the BTL equipment is set up to do real-time low-frequency analysis, it has the advantage of being able to process the input directly, that is, without external time compression of the measurement. Further, it can conveniently process signals of various durations.

One advantage of this implementation is that time and frequency are directly related. Figure 1a has a convenient frequency scale but a shortened time scale; if the time scale were doubled, the frequency scale would be halved.

A problematic feature of this equipment is its AGC -- Automatic Gain Control -- which tends to make each linear inch along the frequency axis a constant level of gray. The purpose of this AGC is to search into the noise for the presence of a signal; the background noise gives a speckled effect without pattern showing the lack of a signal. There are two disadvantages of this AGC action. First, a weak signal will be suppressed by a strong signal if their frequencies are close together. Second, the intensity of the display cannot be used to derive relative amplitudes of signals which are removed from each other in time and/or frequency. This lack of amplitude information has been the most serious criticism of this technique.

It should be mentioned that the intensity spectrograms have been extremely useful in uncovering the presence of signals by (a) the time-frequency patterns visible in the speckled noise, (b) the harmonic realtionships which are detected by the multiple frequency (and slope) relationships, and (c) the similarity of certain features in the intensity spectrograms of different measurements.

III. CONTOUR SPECTROGRAMS

Recently we learned about a commercially available spectrum analyzer which preserves amplitude and generates spectrograms with contour lines of constant signal level. These are identified herein as contourgrams. This equipment is made by Signatection, Inc. of Waltham, Mass. We also learned that we could purchase processing time on a model ST-701 of this equipment at Hydrospace Research Corp. of Rockville, Md. Since we had SA-504 and SA-507 telemetry tapes, we decided to process several flight measurements on an experimental basis for two reasons: first, to derive any additional insight into the data for use in our S-II POGO analysis, and second to disseminate samples of the contourgrams to interested people.

A. Analysis Technique

The ST-701 can analyze one, two or four seconds of an input signal in the 0-20 KHz range* with a resolution (filter bandwidth) of 40, 100 or 300 Hz. The sample of input signal, stored on a magnetic drum, is used to amplitude modulate a carrier frequency. By decreasing the carrier frequency, the lower sideband moves past a fixed filter at 455 KHz. The filter is one of three crystal or magnetostrictive filters. The output of the filter is peak-detected and fed as a voltage to a stylus which moves along the (horizontal) time axis with each revolution of the magnetic drum, that is, for a complete pass of input sample, and along the (vertical) frequency axis as a function of the carrier frequency. (Cf. Figure 1b.) Whenever the filter output is equal to a specific fraction of the maximum output (for all time and frequency of the stored sample) a gate circuit generates a spike of voltage on the writing

*Actually the lowest input signal is 50 Hz, but since this converts to 0.1 Hz for our use, the distinction is dropped.

stylus. This spike generates a black dot which forms the contour lines during the writing scans.

B. Physical Output

The contourgram is an 11"x17" sheet of electrosensitive paper. The writing stylus develops on the paper a grayness proportional to the applied voltage. Starting with the maximum level, each line is down 6 dB from the previous one. Since seven contour lines are available, the output is capable of displaying up to 42 dB of dynamic range. The time scale is set by the duration of the stored data sample, and this is somewhat of a disadvantage in that sample duration has to be predetermined. There is great flexibility, however, in the frequency scale since it is only necessary to set the initial and final values of the carrier frequency. Another parameter to adjust the display is the filter bandwidth. Here we are governed by the usual trade-off between frequency resolution and transient response, but the choice of three filters does allow us to examine the data under difference conditions.

C. Frequency Range

An obvious disadvantage of this equipment is the wide-band (0-20 KHz) input range. We are interested in low frequencies (0-40 Hz). In order to use the full input range, an overall time compression (frequency expansion) of 500:1 is necessary. This was done, in part, by tape dubbing with slow-recording and fast-playbacks. The trade-off here is that each tape speed transition introduces noise as wow or flutter on one hand and on the other hand the full-scale accuracies of the spectrum analyzer are decreased by using less than full scale inputs. Incidentally a factor of 512 gives an unusual frequency scale; an adjustment of the analyzer magnetic drum speed corrected this to a factor of 500. With this time compression, the three available filters have equivalent bandwidths of 0.08, 0.2 and 0.6 Hz for our 0-40 Hz input.

D. Frequency Scale

The equipment has internal frequency markers which generate a horizontal grid. We found that these markers did not have consistently uniform spacing and therefore we generate a "best fit" frequency scale. This is why the horizontal grid does not align exactly with the frequency scale on the attached contourgrams.

E. Time Scale

The equipment does not have any internal means to generate a time scale. However, we were able to establish an absolute time scale by identifying certain features of the signal, e.g. an inflight calibration, on the spectrogram. We were able to identify the same feature on an oscillogram (O-gram) which is a signal amplitude versus time recording. The O-grams are correlated to range time.

F. Contourgram Labels

There are several features of the contour spectrograms which will be discussed with reference to Fig. 1b. As mentioned previously, the frequency scale was fitted to the internal frequency markers. A check on this is the agreement seen at the 38.3 Hz tone we added. This is labelled "Calibration Tone" and the blossoming at each initiation and termination of this tone is typical of a narrow-band filter response to a sine wave step function.

The two or more "Inflight Cal" labels identify the distinctive signature of these one-second stair-case signals, which are automatically added by the flight telemetry system at prescribed intervals. As mentioned previously, these Inflight Cal indications give the best measure of the spectrogram time scale.

The labels "RF Dropout" and "Noise" were added only where they were identified on the O-grams; incidentally this shows how well the O-grams and the spectrograms agree. On the S-IVB measurements the engine mixture ratio shift is labelled "EMR Shift."

The label "ECO" on the S-II 504 measurements stands for engine cutoff; "CECO" and "OECO" on the S-II 507 measurements stand for center engine cutoff and outboard engine cutoff, respectively; on the S-IVB 507 measurements labels are "First Ignition," "First ECO," "Second Ignition" and "Second ECO" to identify the two burns of that stage. These ignition-cutoff labels were checked against post-flight event times and found to be consistent with the spectrogram time scales.

Each label was inserted only if the spectrogram showed some evidence of the event.

G. Time Scale Gaps

Two other items should be clarified. The contourgrams of Figs. 4-6 show scale break at 550 seconds. Near the end of its burn, the S-II was over the horizon and the KSC signal was lost. However, the Bermuda tape has an eight second overlap. Our study of the spectrograms to identify common signal characteristics indicated the (time) spacing of the spliced tape. This is shown by the size of the time scale gap; the arbitrary positioning of this gap at 550 seconds was to aid the reader to interrelate the observed events.

A somewhat similar problem occurred on S-IVB-507 when the ARIA (Apollo Range Instrumentation Aircraft) was running out of magnetic tape on one recording instrument and a second one was started up. This is seen on Fig. 7d.

IV FLIGHT DATA

Of the 100 contour spectrograms processed, the most informative ones are the 24 included herein, as listed in Table I. Of the eight measurements included, six are for the S-II stage (three for SA-504 and three for SA-507) and two are for the S-IVB stage (SA-507). It should be mentioned that the improvement of the instrumentation on SA-507 (compared to SA-504) was obvious in the resulting spectrograms. To examine S-II POGO under its more severe conditions (late in the burn), we include the SA-504 spectrograms, although they are poorer in quality.

In our study of the contourgrams we found the intensity spectrograms very useful and have included a copy for each of the eight figure sets, although they had been distributed previously. The SA-504 intensity spectrograms (Figs. 1a, 2a, 3a) are copies of copies and contain medium-level gray patches which are not related to the data.

As indicated in Table I we present contourgrams of 0-40 Hz for all measurements. Other selected frequency ranges are also presented to bring out special features. Where a frequency range is shown with two figure numbers, this range is shown in (two) expanded time scales.

A. SA-504 S-II Measurements

SA-504 was the Saturn V launch vehicle used on the Apollo 9 mission in March 1969. The presence of POGO during the last part of the S-II burn was suspected on the previous launch but this vehicle confirmed the problem.

The LOX sump prevalve longitudinal vibration intensity spectrogram, Fig. 1a, shows signal content in the 15-17 Hz region throughout the flight, but it also shows many modes which increase in frequency as time increases, that is, as the propellant is depleted. The existence of POGO is seen near 500 seconds Range Time by the strong signal between 17 and 19 Hz. It is interpreted as "strong" because it suppresses (via AGC action) the intensity at other frequencies in this time period. Also a second harmonic is seen in the 34-36 Hz region.

Examination of Fig. 1a at 500 seconds and 17 Hz suggests the intersection of two modes: an early mode with a small slope of increasing frequency is interrupted by a mode with sharply increasing frequency. Perhaps this second mode exists earlier, but its lower amplitude is suppressed by the strength of the first mode. This theory was imposed on our structrual modeling activity without complete success. It is one of the main points to examine on the contourgrams.

Figure 1b shows many of the same features as Fig. 1a but the amplitude preservation of the contourgrams does several things: its makes the high amplitude POGO indication near 520 seconds and 18 Hz immediately obvious; it makes the other modes more difficult to trace. In fact it requires some imagination to identify several of the modes. Once identified, however, it does show the existence of two modes at close frequencies with significant time overlap. (The effect of Fig. 1a is that one mode abruptly stops when it is replaced by a lower frequency mode.)

To examine these features in more detail, Fig. 1c enlarges the 10-20 Hz region of Fig. 1b. This figure makes the theory of the intersection of two modes less plausible. It shows, rather, a single mode from 250 seconds and 12 Hz, passing through 450 seconds and 16 Hz and continuing to 535 seconds and 19 Hz. The POGO signal starts on this mode, falls abruptly in frequency, then gradually returns to this mode. One is hard pressed to extrapolate a second mode back to earlier times. This rationale would admit a more reasonable structures model but requires some other mechanism to cause a rapid growth of amplitude when the oscillation is departing from an apparent structural resonance. Hard cavitation of the LOX pump inlet has been suggested as a possibility, but to our knowledge this mysterious feature of the flight data has not been reproduced in any analytical model.

Figure 1d enlarges the 18-28 Hz region of Fig. 1b to examine the higher frequency tank modes for confirmation of structures models. With the possible exception of the indication at 400 seconds and 25 Hz, not much new has been gained.

Figure 2a shows that the center engine longitudinal vibration intensity spectrogram has many of the same features as Fig. 1a in the 15-19 Hz region, but the higher frequency (tank) modes are missing. This is even more dramatically seen in the contourgram of Fig. 2b. (Note, however, the time overlap of engine truss modes on Fig. 2b.) The 10-20 Hz expanded range of Fig. 2c is very similar to Fig. 1c in the 15-19 Hz region; again the POGO signal appears to be a departure from and a return to a single mode.

Figure 3a, the engine 1 vibration intensity spectrogram, is very similar to Fig. 2a with somewhat less activity. The contourgram, Fig. 3b, has many of the same features as Fig. 2c.

B. SA-507 S-II Measurements

SA-507 was the launch vehicle used on the Apollo 12 mission in November 1969. It did not experience POGO during the last portion of the burn because early center engine cutoff had been activated on all vehicles after SA-504. However, there were indications of POGO during earlier parts of the burn, as had been suspected on SA-506 (Apollo 11). It was for this reason that intensity spectrograms had been generated, and therefore, the flight tapes were available for the contourgram experiment. Incidentally the S-II (and S-IVB) intensity spectrograms contain data for times other than the operation of the S-II (and S-IVB) stage. The stage operation times are shown on the right-hand border of the SA-507 intensity spectrograms; the dot within the S-IC and S-II sections indicates center engine cutoff.

The LOX sump prevalve longitudinal vibration intensity spectrogram, Fig. 4a, shows four distinct periods of POGO-like activity between 160 and 460 seconds Range Time in the 15 to 17 Hz region; harmonics are also seen in the 30-34 Hz and 45-50 Hz regions. Incidentally a signal is seen at 520-560 seconds and 10-12 Hz; this may be related to the fact that our stability model shows decreasing stability with the third body mode for the same times and frequencies.

The contourgram, Fig. 4b, shows the four periods of POGO activity at, say, 180, 250, 300 and 430 seconds. Figs. 4c and 4d are the same measurement with expanded time scales. All of these figures indicate the activity at 250 and 300 seconds are associated with the same mode; at 430 seconds it is definitely a separate mode; and at 180 seconds it could be still another mode but there is too little evidence to identify the mode. This is also confirmed by the expanded (10-20 Hz) frequency scale of Fig. 4e, except one could argue that the second and third events are from separate modes of close frequency.

The contourgrams, Figs. 4b-4e, show signals in the 10-15 Hz region which were washed out in the intensity spectrogram, Fig. 4a, due to the AGC action of the high intensity signals in the 15-17 Hz region. Also the contourgrams show more modal data in 22-34 Hz region than the intensity spectrogram. For these reasons the contourgrams would be more useful to verify structures models.

Note on Figs. 4b, 4d and 4e the 11 Hz signal at burnout (third body mode instability?). Also the break in the time scale at 550 seconds is due to the overlap between KSC and Bermuda data as discussed in section III G.

The amazing agreement between the LOX sump pressure and the prevalve vibration can be seen by comparing Figs. 5a-5e with Figs. 4a-4e. About the only difference is in the detailed pattern. Therefore, all the comments made about Figs. 4 apply to Figs. 5. The similarity of these signals is not surprising since the pressure at the tank bottom and the acceleration of the structure at that point should have a cause and effect relationship, but it is nice to graphically see that the spectrograms preserve this relationship. Incidentally Fig. 5f expands the 2-12 Hz frequency region in an attempt to reduce the clutter in that region of Fig. 5b.

The center engine longitudinal vibration intensity spectrogram, Fig. 6a, appears very similar to those of Figs. 4a and 5a except it contains a stronger second harmonic in the 30-34 Hz region. However, the contourgram, Fig. 6b, is more heavily cluttered in the 14-20 Hz region and has less modal data in the higher and lower frequency regions than do Figs. 4b and 5b. This is closer to SA-504 data which show that the center engine responds only in a limited frequency band.

Figures 6c and 6d have both expanded frequency (10-20 Hz) and expanded time scales, and while this complicates graphical comparison to Figs. 4 and 5, it does show the POGO activity of the engine truss is very similar to that of the tank bottom. That's what makes it POGO-like; it appears to be a closed-loop driven oscillation rather than an open-loop response to noise excitation.

One should note on Figs. 6b and 6d the 11 Hz signal just prior to outboard engine cutoff (OECO) which spans the gap in the time scale (third body mode instability?).

C. <u>SA-507 S-IVB Measurements</u>

An astronaut's comment at the end of the second S-IVB burn on Apollo 10 (SA-505) led to the generation of intensity spectrograms for that flight. They showed in that time region a 45 Hz signal which has been attributed to an acoustic effect due to the chattering of (primary and backup) vent valves of the S-IVB fuel tank. However, they also showed an unexcepted 18-20 Hz signal during the early part of the S-IVB first burn which had many POGO characteristics. Intensity spectrograms for the SA-507 S-IVB confirmed the presence of this POGO-like signal, and for this reason, two of these measurements were included in the contourgram experiment.

The LOX sump longitudinal acceleration spectrogram, Fig. 7a, contains a wealth of information, only part of which relates to the S-IVB. For instance the uncoupled first body mode during S-IC burn is seen in the 5 Hz region from 0 to 160 seconds The four periods of S-II POGO are seen in the 15-17 Hz region from 160 to 440 seconds; even the third harmonic is seen in the 45-50 Hz region. Also the 10-12 Hz signal is seen at S-II burnout. The main S-IVB POGO indication is the 18-20 Hz signal early in the first burn. The second burn shows many tank modes of smoothly increasing frequency. A peculiar signal starts at one third of the second S-IVB burn at 24 Hz, step-wise reduces to 22 Hz and then returns to 23 Hz at cutoff. This unique indication was observed on all S-IVB-507 intensity spectrograms, including Fig. 8a. Further study revealed another peculiar signal in the 22-24 Hz region of first burn, seen on both Figs. 7a and 8a. It is our understanding that this signal has been correlated with LOX tank ullage pressure and that it represents the first resonance of the S-IVB LOX line. If so, this is true serendipity as it gives the most realistic confirmation of experimental results derived on an MSFC LOX line test facility.

The contourgram for the first S-IVB burn, Fig. 7b, shows the POGO signal at 18 Hz and 620 seconds. (Incidentally these S-IVB contourgrams had the 256:1 time speed-up so the internally generated frequency markers are not integer values of frequency; the frequency scale at either side should be used to read frequency numbers.) The amplitude preservation nature of these contourgrams allows some additional insight into the POGO signals: it builds up at 605 seconds and 17.5 Hz, reaches a peak at 618 seconds and 18 Hz and dies down at 638 seconds and 19 Hz. This is more information than available from Fig. 7a. The several decreasing-frequency signals in the 21-24 Hz region at, say, 580-590, 605-625 and 635-660 second time intervals are related to the LOX line frequency and show much better on Fig. 8b.

The second burn, shown on Figs. 7c and 7d, does not have POGO-like signals. The increasing frequency modes are interpreted as tank modes and would be useful to verify structures models. The signal wandering within the 21-24 Hz band for the latter two thirds of the second burn is related to the LOX line frequency.

There is an overlap near the end of the burn on Fig. 7d due to the use of two ARIA tapes as mentioned in section IIIG. The time scale is simply repeated with the proper gap so that the data can be interrelated.

The LOX pump pressure spectrogram, Fig. 8a, is not as close to Fig. 7a as Fig. 5a was to Fig. 4a because the pressure is being measured at the bottom of the LOX line. With the line effectively filtering the signal, we do not really see the S-IC first body mode; we do see some indication of the S-II POGO events but almost no harmonics are visible. Also the S-IVB tank modes are missing. However, the 18-20 Hz POGO signal is clearly visible during the first burn and the 21-24 Hz LOX line resonance is actually enhanced. A further refinement of this resonance is seen in the first part of the second burn. The resonance appears to start at 30 Hz, it moves up to 33 Hz, and at 10,152 seconds Range Time, it suddenly falls to 24 Hz. This is the time of programmed engine mixture ratio shift. The remaining history of the resonance is similar to that discussed previously for Fig. 7a.

The contourgram of the first burn, Fig. 8b, again shows the POGO signal at 18 Hz and 620 seconds, but the time duration over which this mode can be seen is far less than on Fig. 7b. However, Fig. 8b gives a much clearer indication of the line resonance. In fact it can be seen that the line resonance starts near 26 Hz and then falls into the 21-24 Hz band. The same pattern can be detected in Fig. 8a, but in this particular case, the contourgram gives a much better pattern than the intensity spectrogram.

The main signal of interest on the second burn, Figs. 8c and 8d, is the line resonance since neither POGO nor structural mode data exist on these contourgrams. The line resonance in the 21-24 Hz band is clearly visible, but it requires close observation to discern the initial 30-33 Hz excursion of line resoannce. Also the sudden shift to the lower band is not obvious. In this particular case intensity spectrogram gives a better pattern. Conceivably the choice between spectrogram types can be reversed by adjustment of the time and frequency scales used.

V CONCLUSIONS

A. Spectrograms

The main conclusion is that spectrograms are useful in the study of system-level problems, such as POGO, and their usefulness increases with increasing number and types of spectrograms available. This is not true of all kinds of data formats where the sheer bulk of paper -- rolls of graphs or sheets of computer print-out -- can deter even a serious investigator. Of course, spectrograms do not eliminate the requirement for other forms of the data. The signal phase, its absolute amplitude and precise timing is best done by the usual formats of amplitude-time oscillograms, PSD's (Power Spectral Densities), etc.

While the contourgrams are capable of defining signal amplitude, we did not use them this way. One reason for this is that other investigators have already determined and published the significant amplitudes. Another reason is that it would require the determination of an end-to-end scale factor starting with the transducer, the telemetry system, etc. but should also include the exact filter characteristic of the spectrum analyzer. Rather we used the contours to examine the buildup and decay characteristic of prominent signals and to trace obscure signals through the clutter.

Therefore, the main advantages of this model ST-701 contour spectrum analyzer include the following. The spectrograms are large size -- 11"x17". The amplitude information is very graphically displayed as contour lines and only partially depends on the signal level/gray scale relationship of the spectrogram paper. There is a range of flexibility of the parameters of the spectrogram: frequency range and scale are great, filter bandwidth choice is good and time scale is fair. The analyzer is a self-contained unit which gives adequate front panel control and has a good mechanical scanning arrangement to generate the spectrograms. (The paper is mounted on a drum which moves longitudinally through a ring which had the rotating stylus.)

There are also several disadvantages. The main one is the high frequency range of the input; this requires time compression (tape dubbing) to use a significant fraction of the input range. A fixed duration of input signal must be (manually) transferred to the drum, and changing or adjusting this sample is one of the least flexible features of the equipment. There does not appear to be a convenient way to derive a time scale on the contourgram other than using known features of the signal itself. Finally the spectrogram paper is pressure sensitive and requires delicate handling.

B. Flight Data

The contourgrams of the eight measurements contain a great deal of information, but most of the observations had been made previously on the basis of the intensity spectrograms. It is indeed encouraging that the different types of spectrograms lead to the same conclusions.

The one exception to this agreement is the most subtle feature of S-II POGO. The intensity spectrogram would indicate the abrupt intersection of two modes, which is a very difficult feature to derive from a structures model. The contourgram indicates that this is probably a wrong interpretation of the intensity spectrogram because the "second" mode cannot be extrapolated to earlier time. Instead the contourgram would indicate a single mode of rising frequency with the POGO signal as a sudden departure from this mode while it is rapidly increasing in amplitude. This is an equally difficult feature to derive from a reasonable model of the entire POGO loop.

In the case of the S-IVB measurements the intensity and the contour spectrograms compliment each other and indicate a very intricate time-frequency characteristic of the LOX line resonance.

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<table>
<tr><th rowspan="3">S-II MEASUREMENTS</th><th colspan="2">INTENSITY SPECTROGRAM</th><th colspan="6">CONTOURGRAM</th></tr>
<tr><th>SA-504</th><th>SA-507</th><th colspan="2">0-40 Hz</th><th colspan="2">10-20 Hz</th><th>2-12 Hz</th><th>18-28 Hz</th></tr>
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<tr><td>CENTER ENG. VIBRATION</td><td>2a</td><td></td><td colspan="2">2b</td><td colspan="2">2c</td><td></td><td></td></tr>
<tr><td>ENG. NO. 1 VIBRATION</td><td>3a</td><td></td><td colspan="2"></td><td colspan="2">3b</td><td></td><td></td></tr>
<tr><td rowspan="2">LOX SUMP VIBRATION</td><td rowspan="2"></td><td rowspan="2">4a</td><td colspan="2">4b</td><td colspan="2" rowspan="2">4e</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>4c</td><td>4d</td></tr>
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<tr><td>5c</td><td>5d</td></tr>
<tr><td>CENTER ENG. VIBRATION</td><td></td><td>6a</td><td colspan="2">6b</td><td>6c</td><td>6d</td><td></td><td></td></tr>
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<table>
<tr><th rowspan="3">S-IVB MEASUREMENTS</th><th colspan="2">INTENSITY SPECTROGRAM</th><th colspan="3">CONTOURGRAM</th></tr>
<tr><th rowspan="2">SA-504</th><th rowspan="2">SA-507</th><th colspan="3">0-40 Hz</th></tr>
<tr><th>FIRST BURN</th><th colspan="2">SECOND BURN</th></tr>
<tr><td>LOX SUMP ACCELERATION</td><td></td><td>7a</td><td>7b</td><td>7c</td><td>7d</td></tr>
<tr><td>LOX SUMP PRESSURE</td><td></td><td>8a</td><td>8b</td><td>8c</td><td>8d</td></tr>
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TABLE 1
SPECTROGRAM LISTING

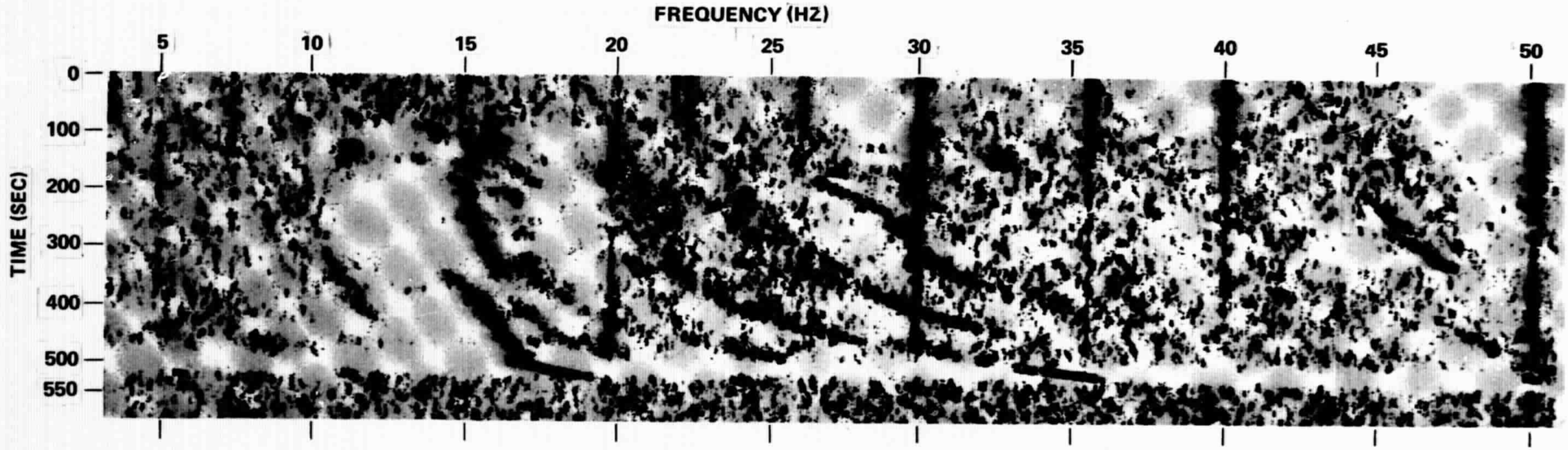

FIGURE 1a - SA-504 S-II E362-206 LOX SUMP PREVALUE LONGITUDINAL VIBRATION

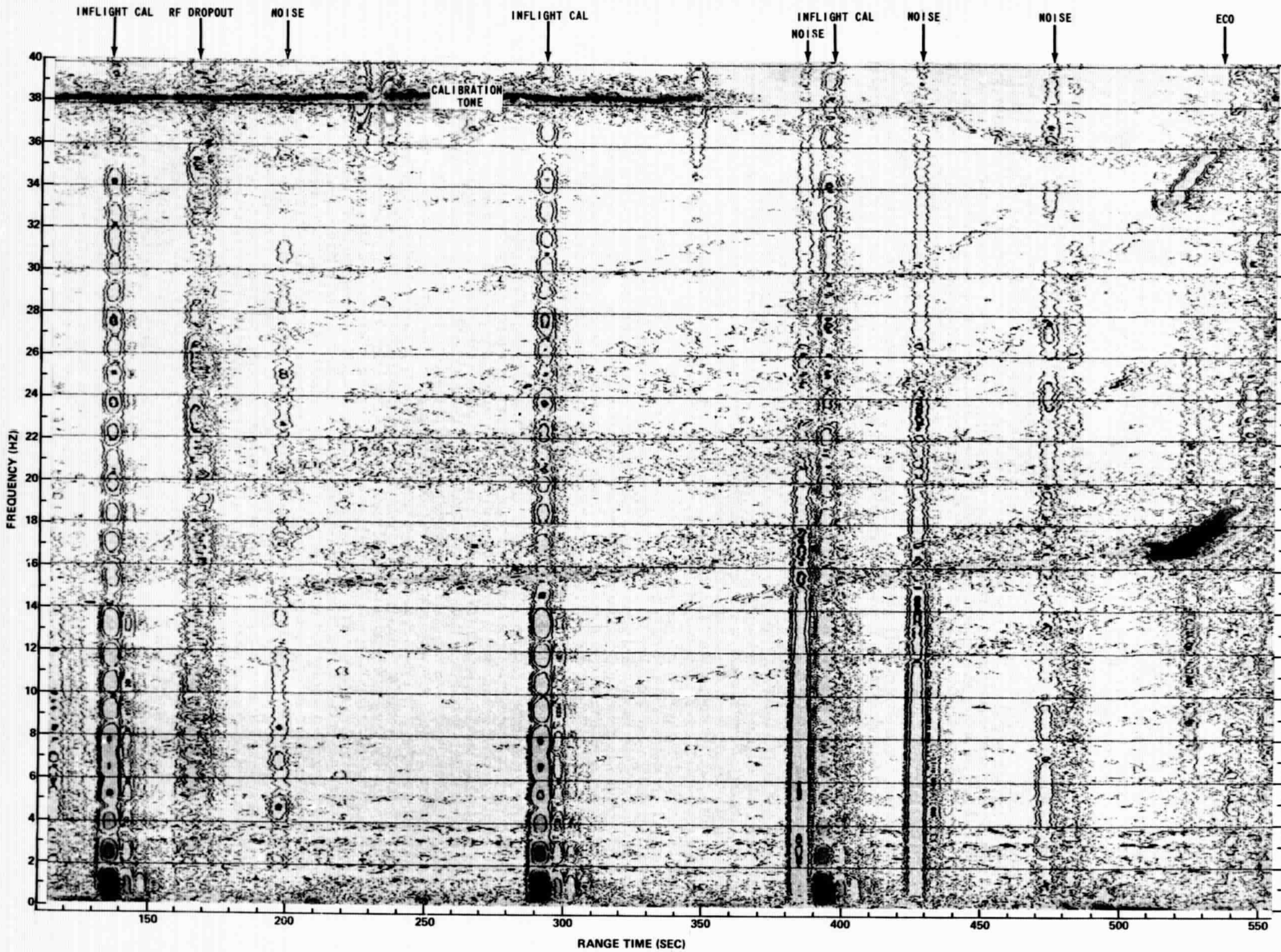

FIGURE 1b - SA-504 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

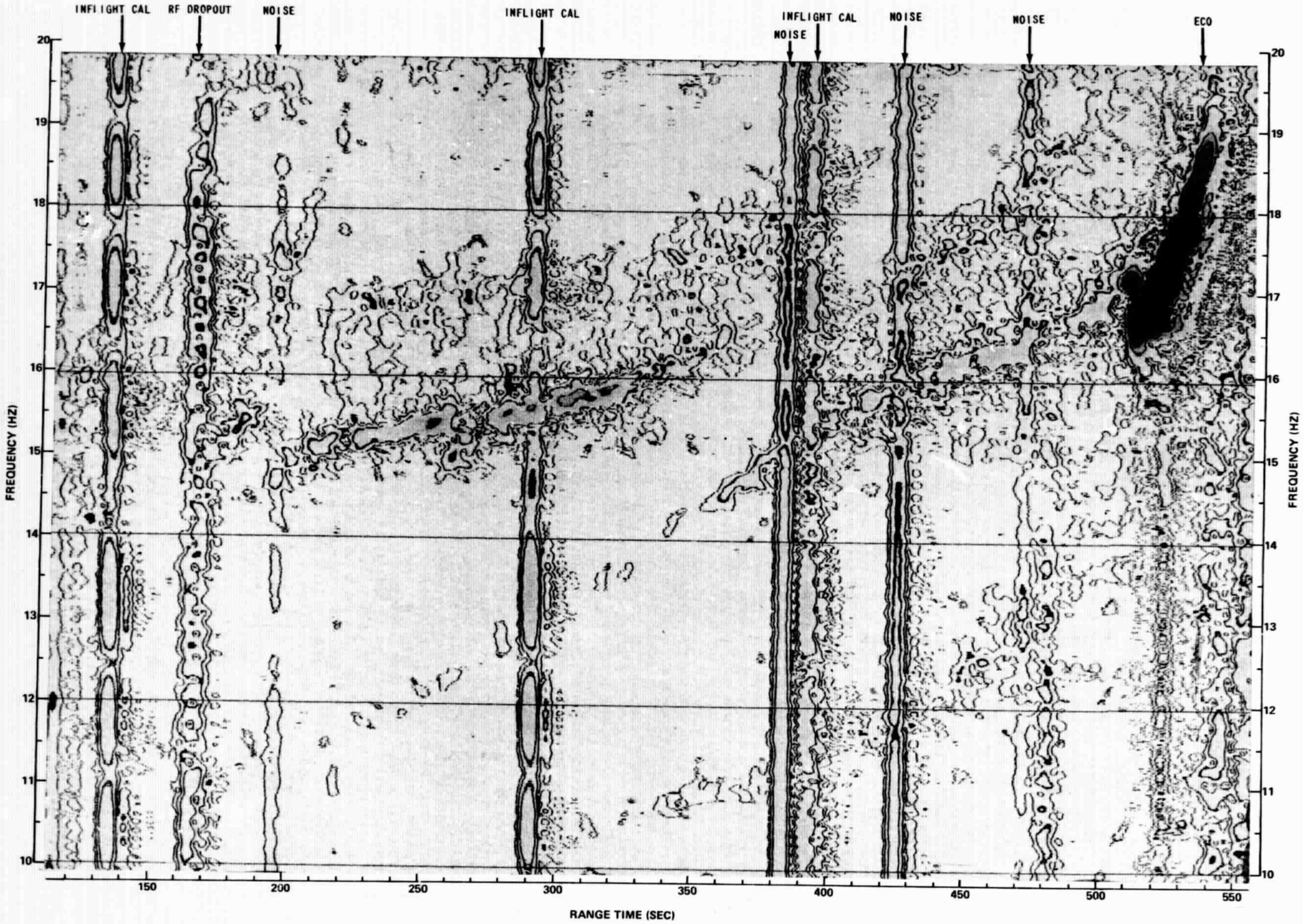

FIGURE 1c - SA-504 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

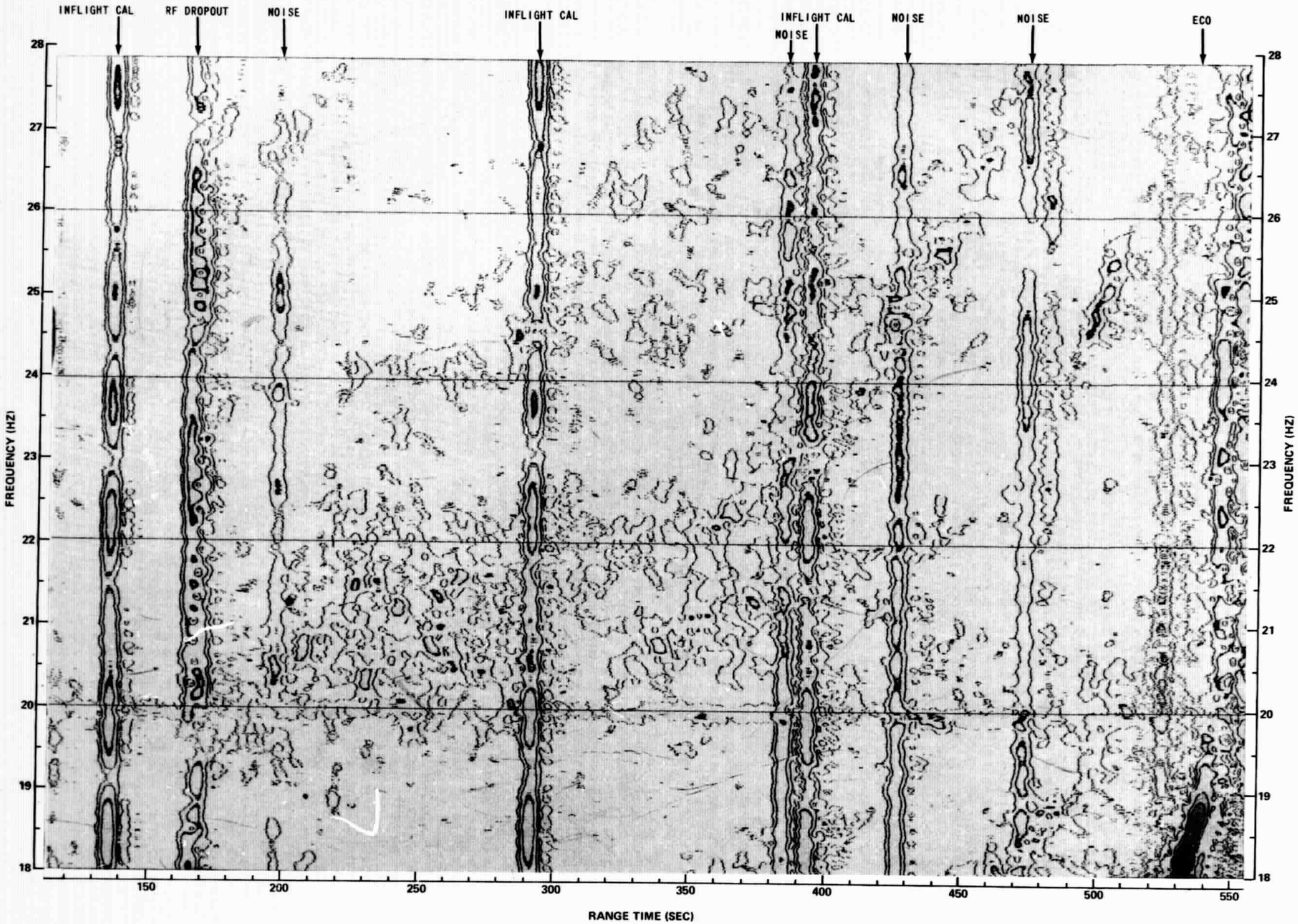

FIGURE 1d - SA-504 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

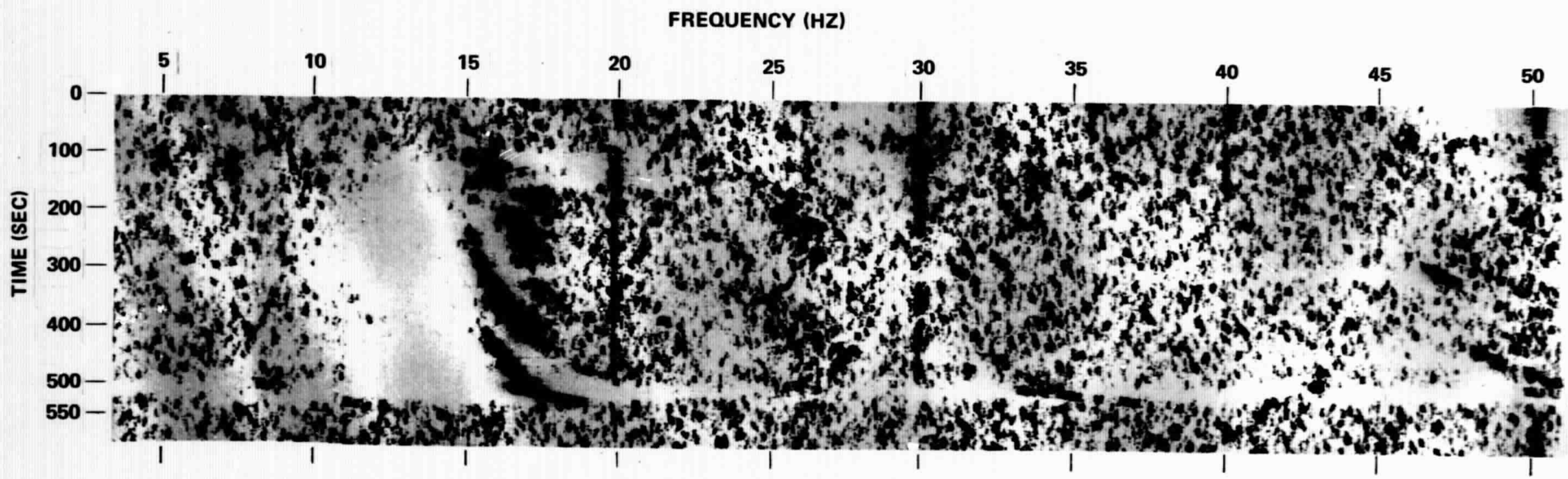

FIGURE 2a - SA-504 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

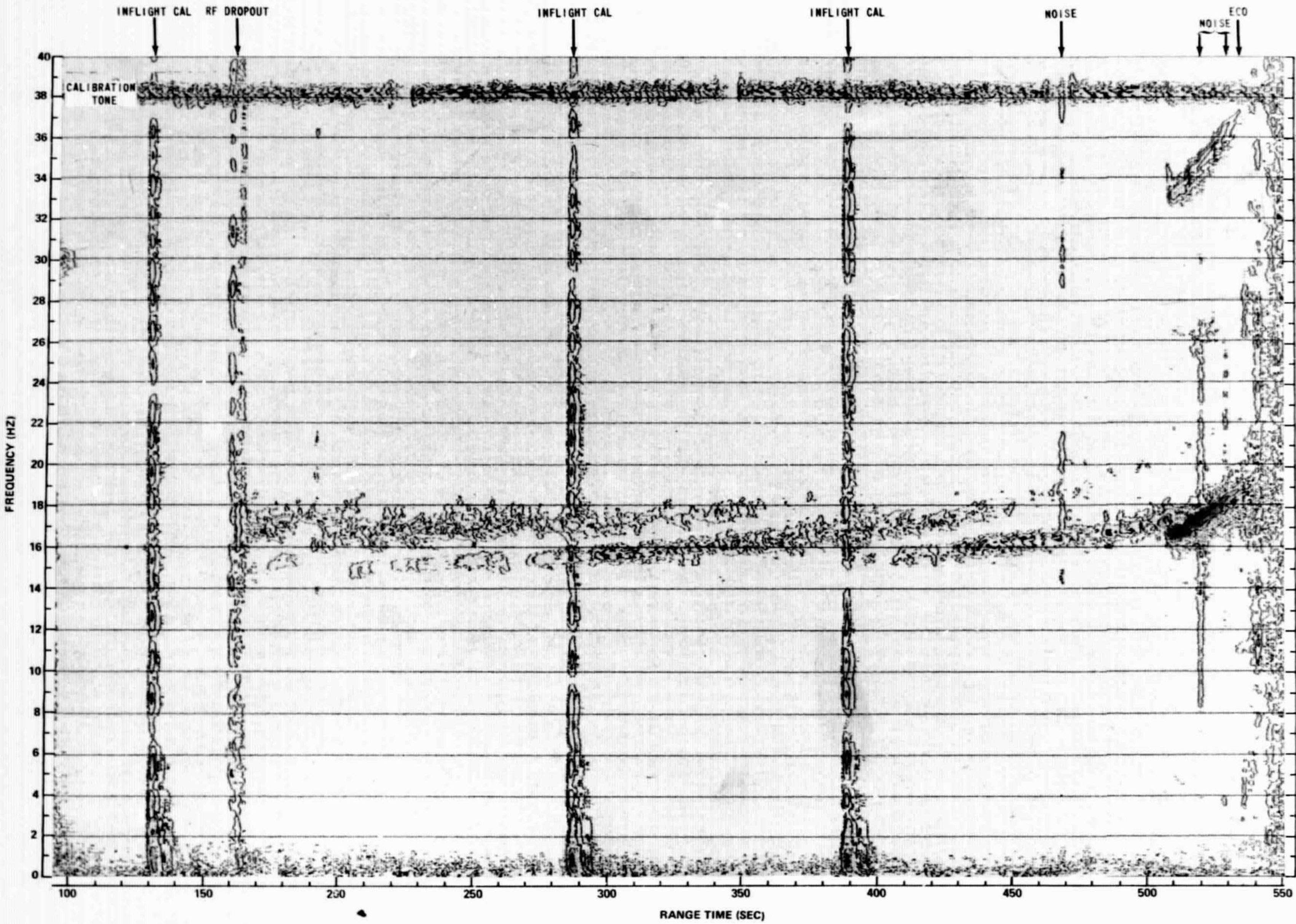

FIGURE 2b - SA-504 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

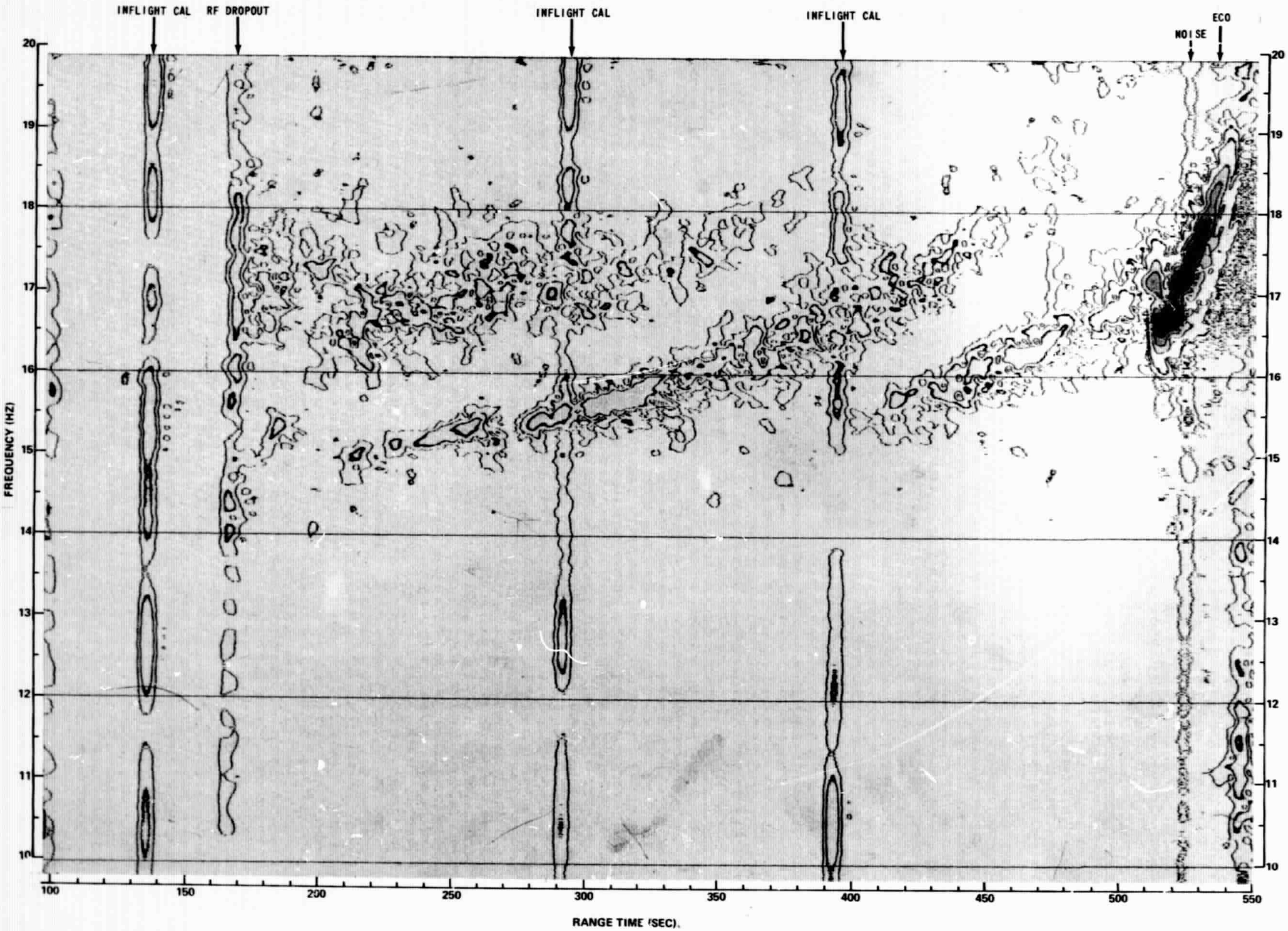

FIGURE 2c - SA-504 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

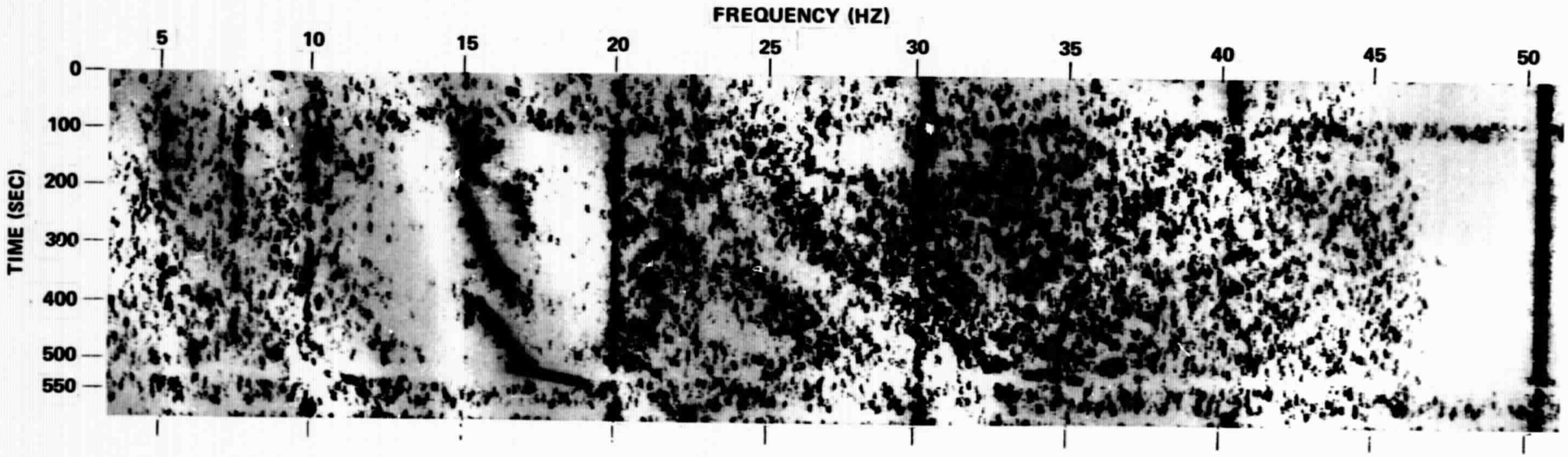

FIGURE 3a - SA-504 S-II E361-206 ENGINE 1 LONGITUDINAL VIBRATION

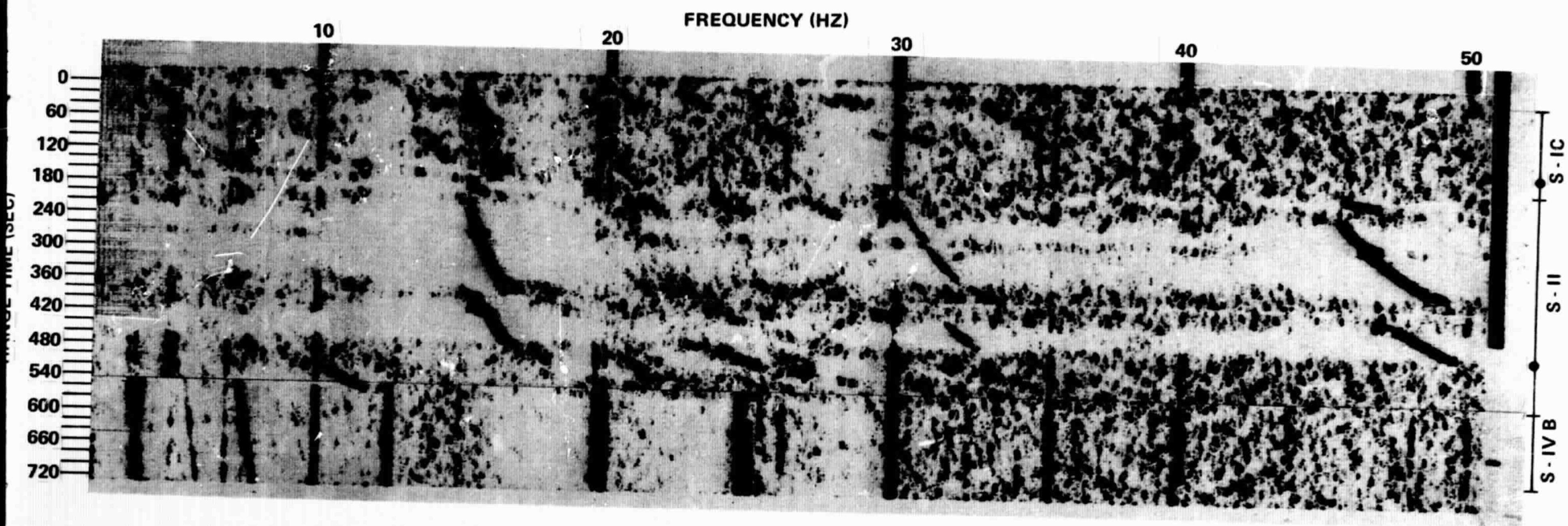

FIGURE 4a - SA-507 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

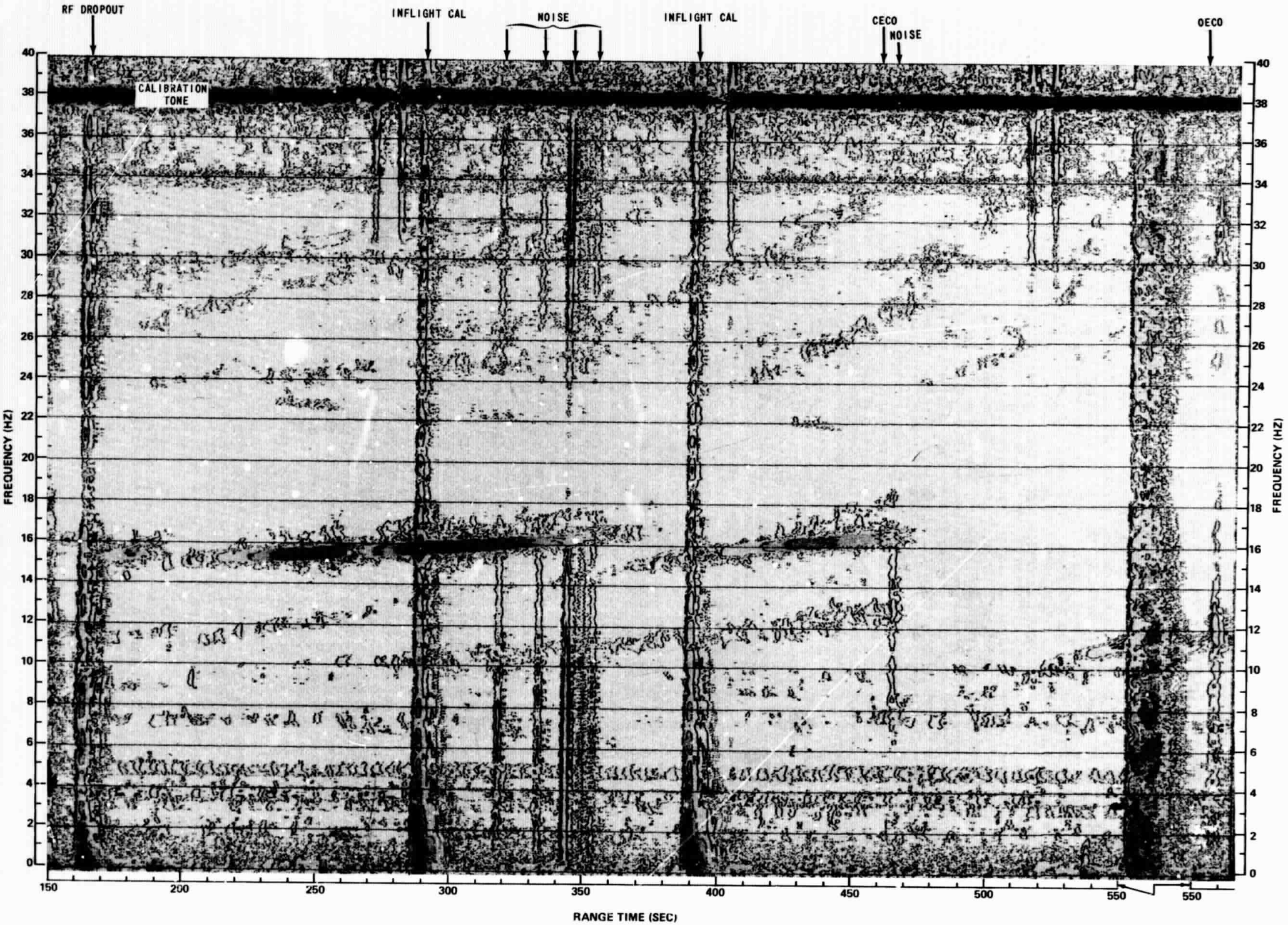

FIGURE 4b - SA-507 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

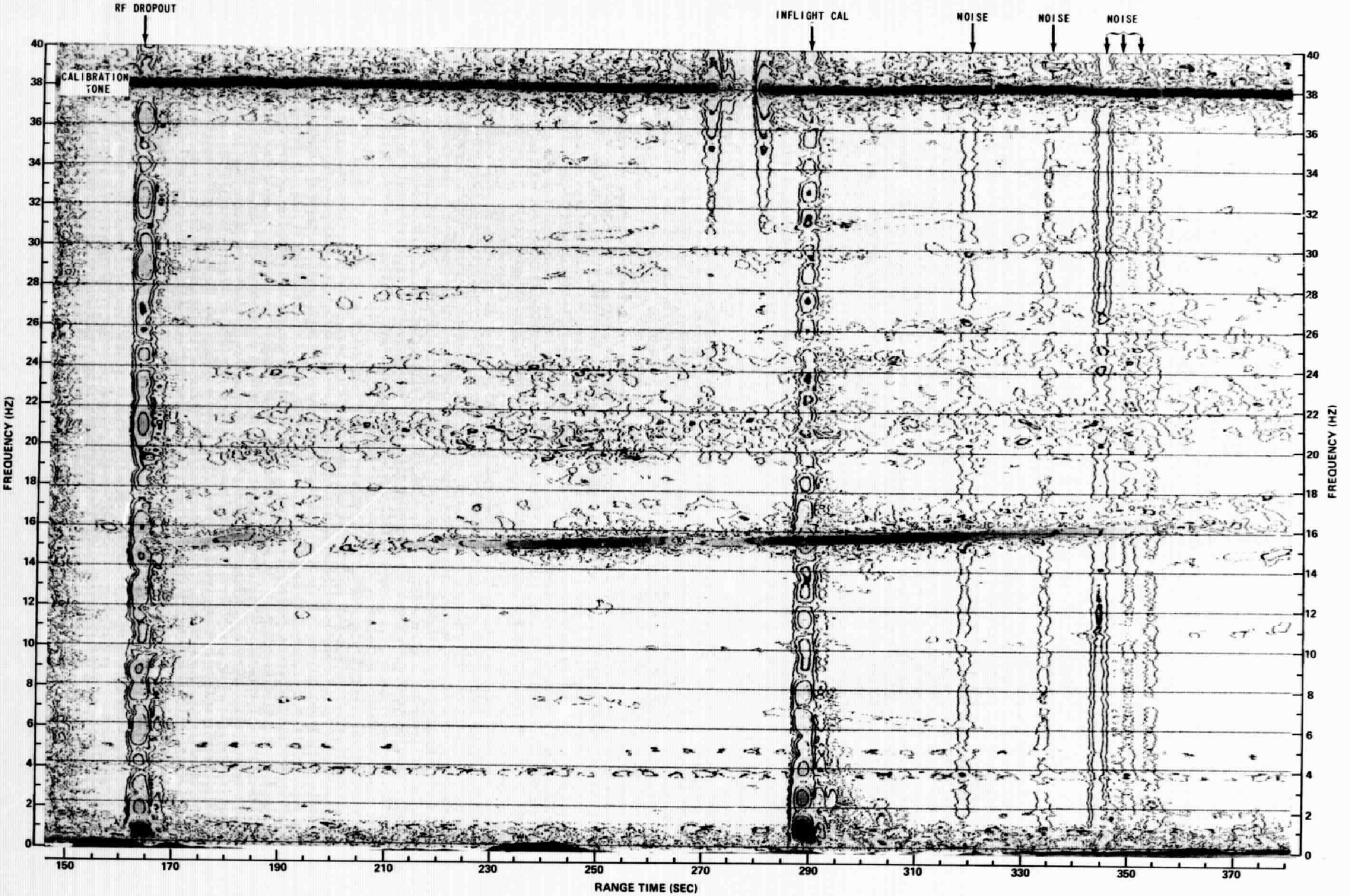

FIGURE 4c - SA-507 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

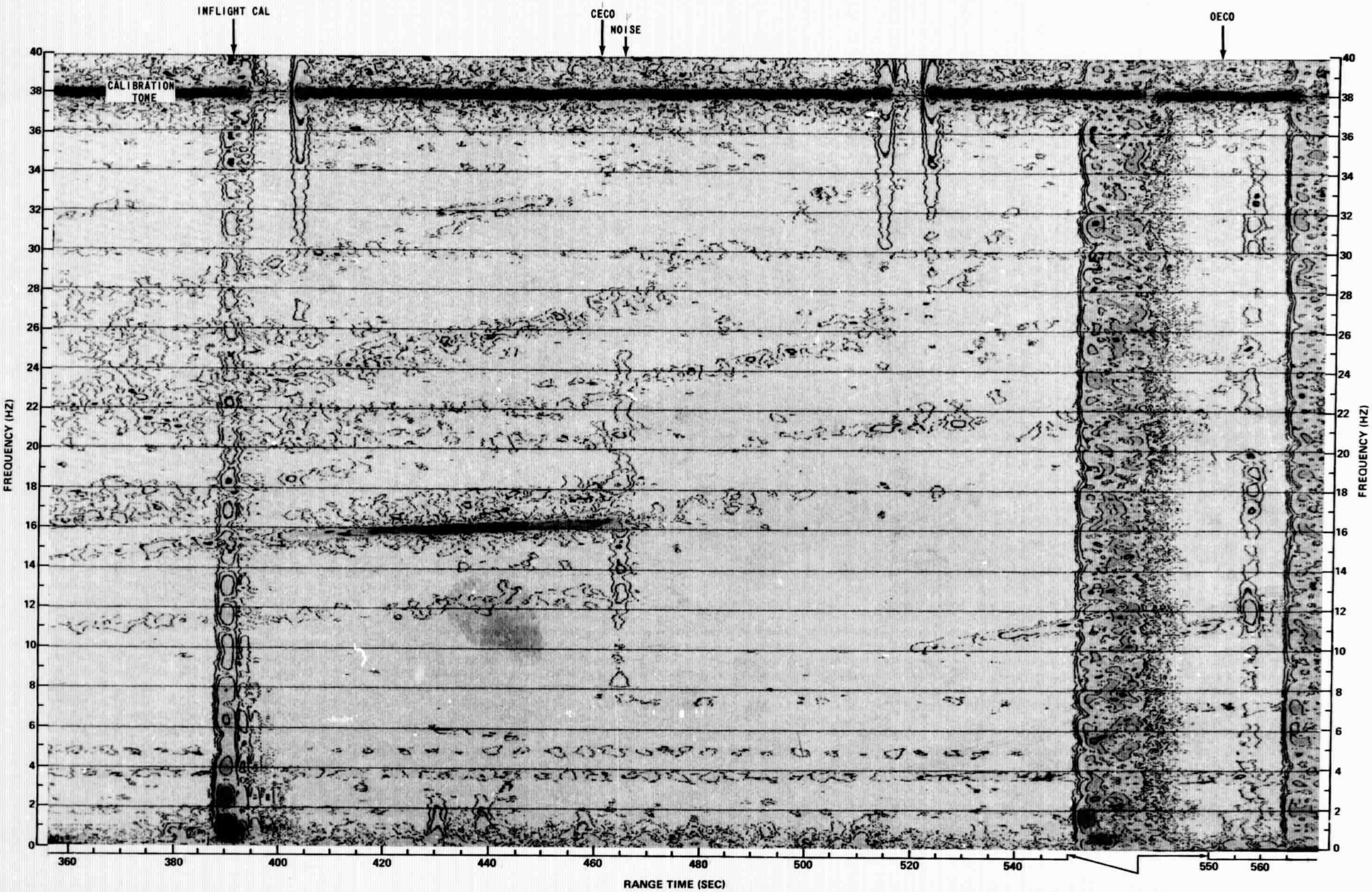

FIGURE 4d - SA-507 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

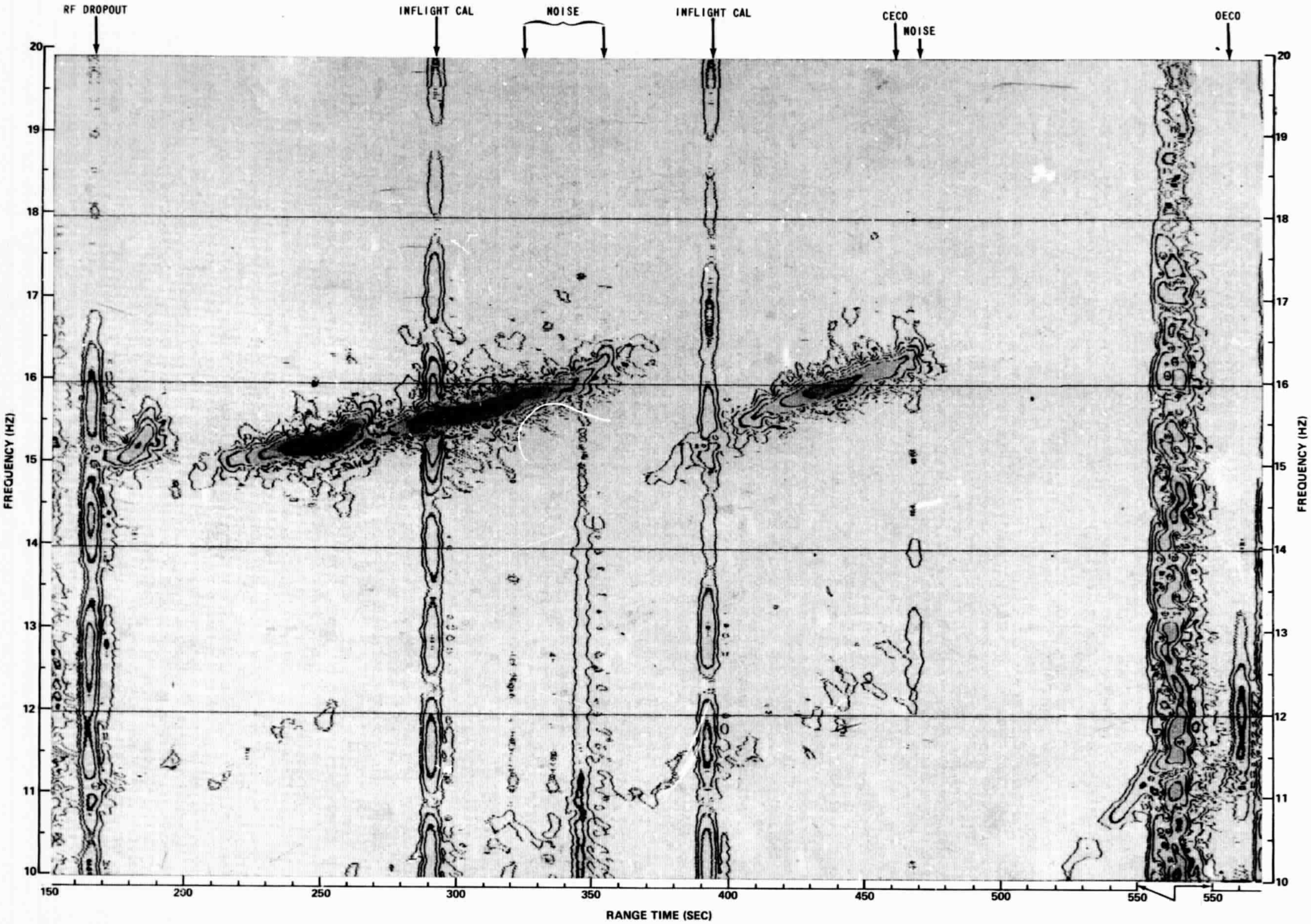

FIGURE 4e - SA-507 S-II E362-206 LOX SUMP PREVALVE LONGITUDINAL VIBRATION

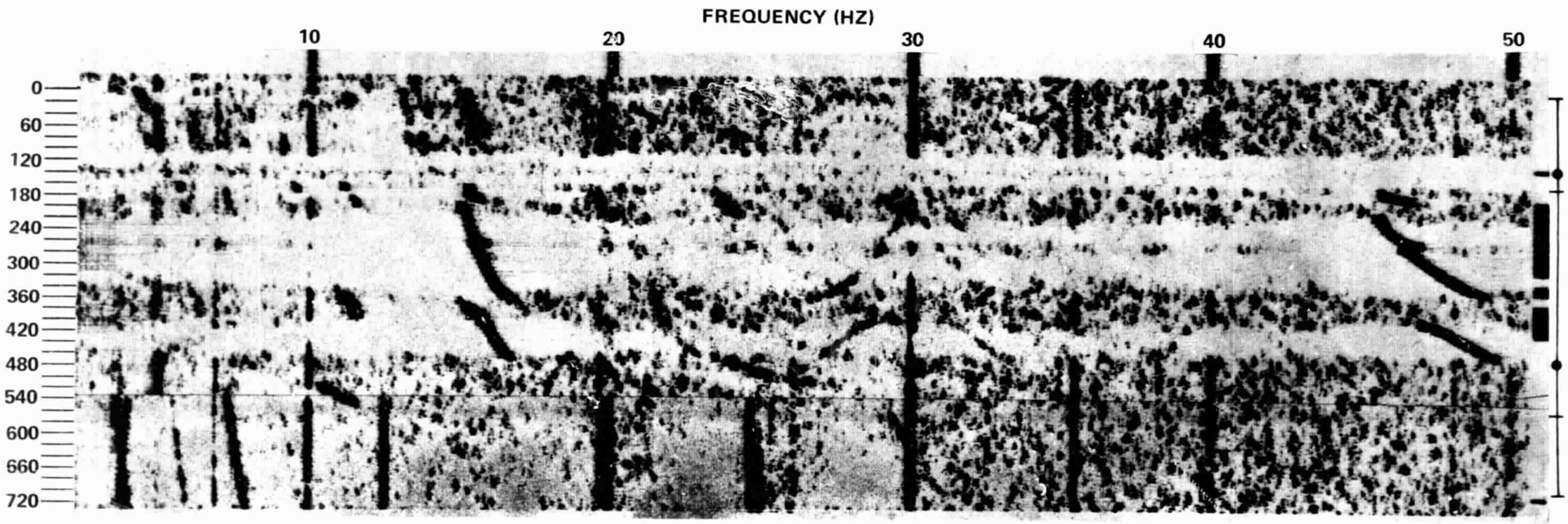

FIGURE 5a - SA-507 S-II D266-206 LOX SUMP PRESSURE

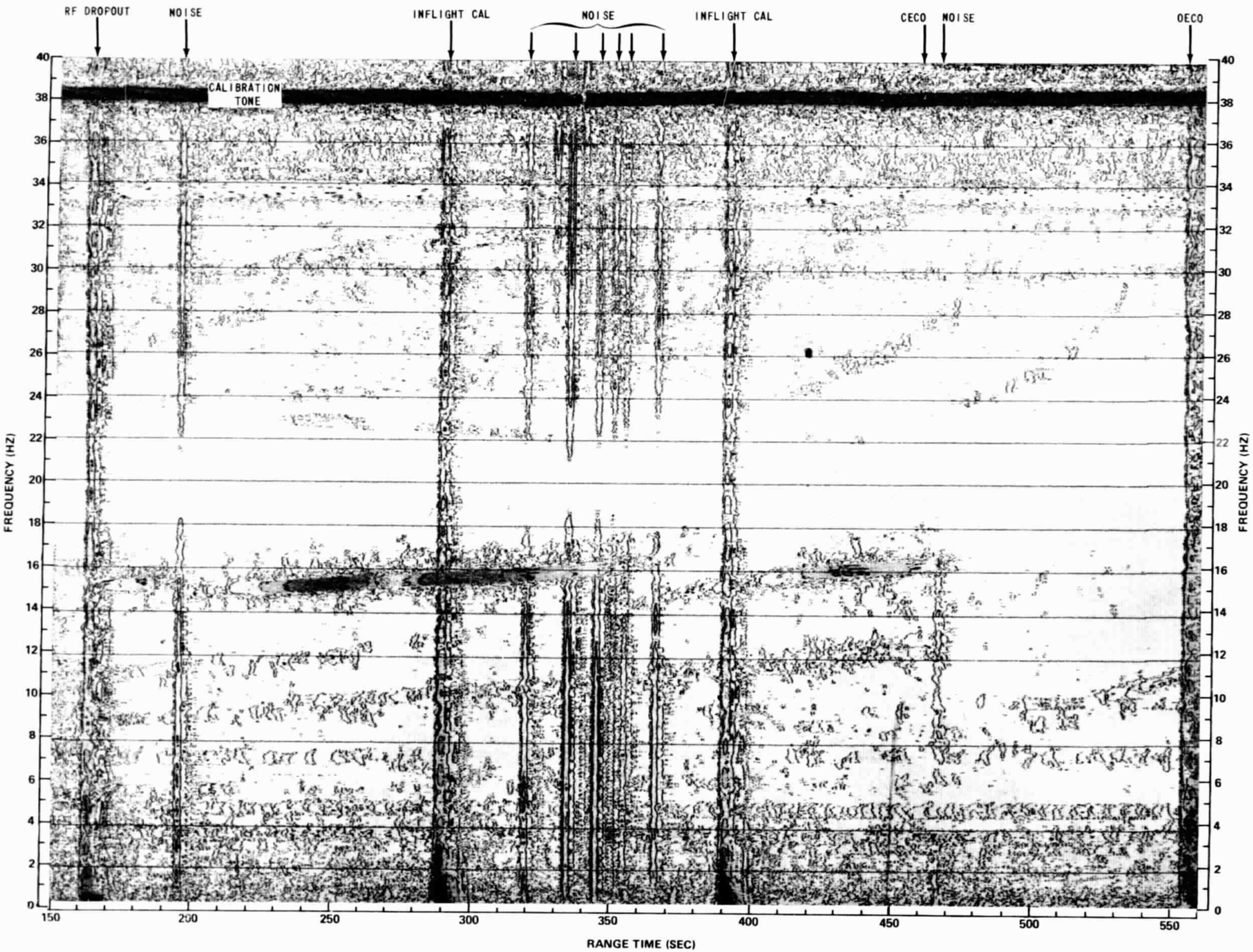

FIGURE 5b - SA-507 S-II D266-206 LOX SUMP PRESSURE

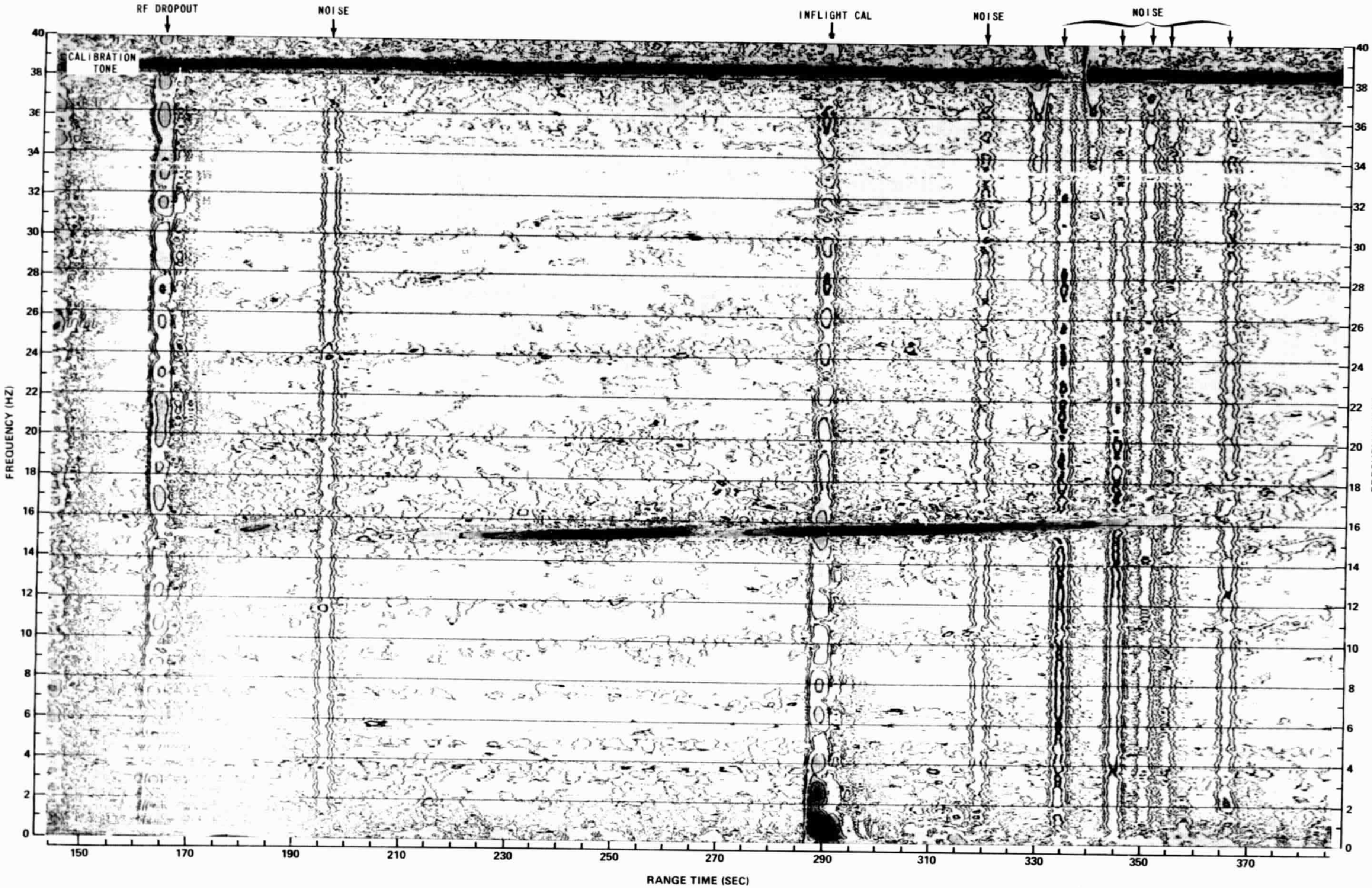

FIGURE 5c - SA-507 S-II D266-206 LOX SUMP PRESSURE

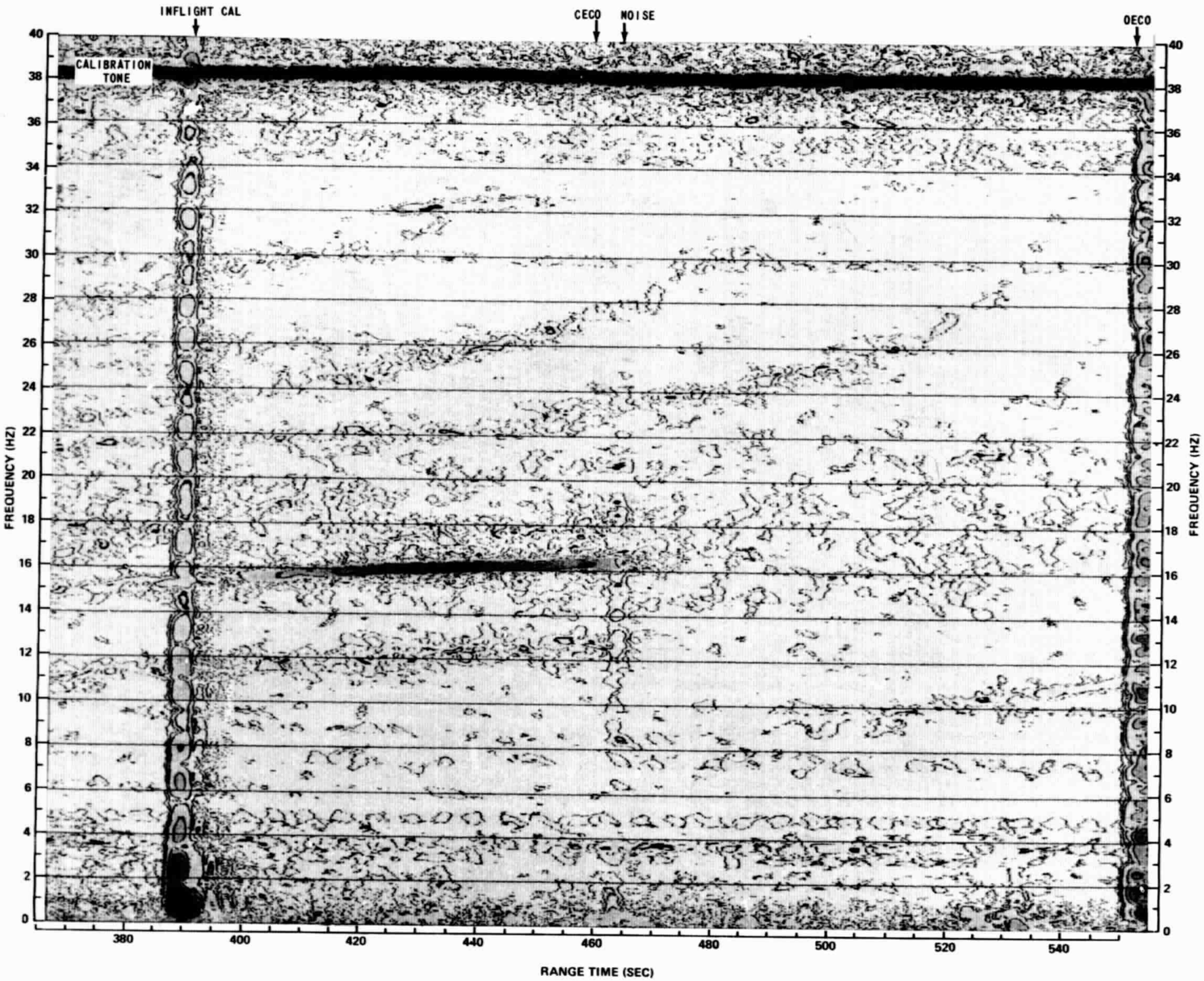

FIGURE 5d - SA-507 S-II D266-206 LOX SUMP PRESSURE

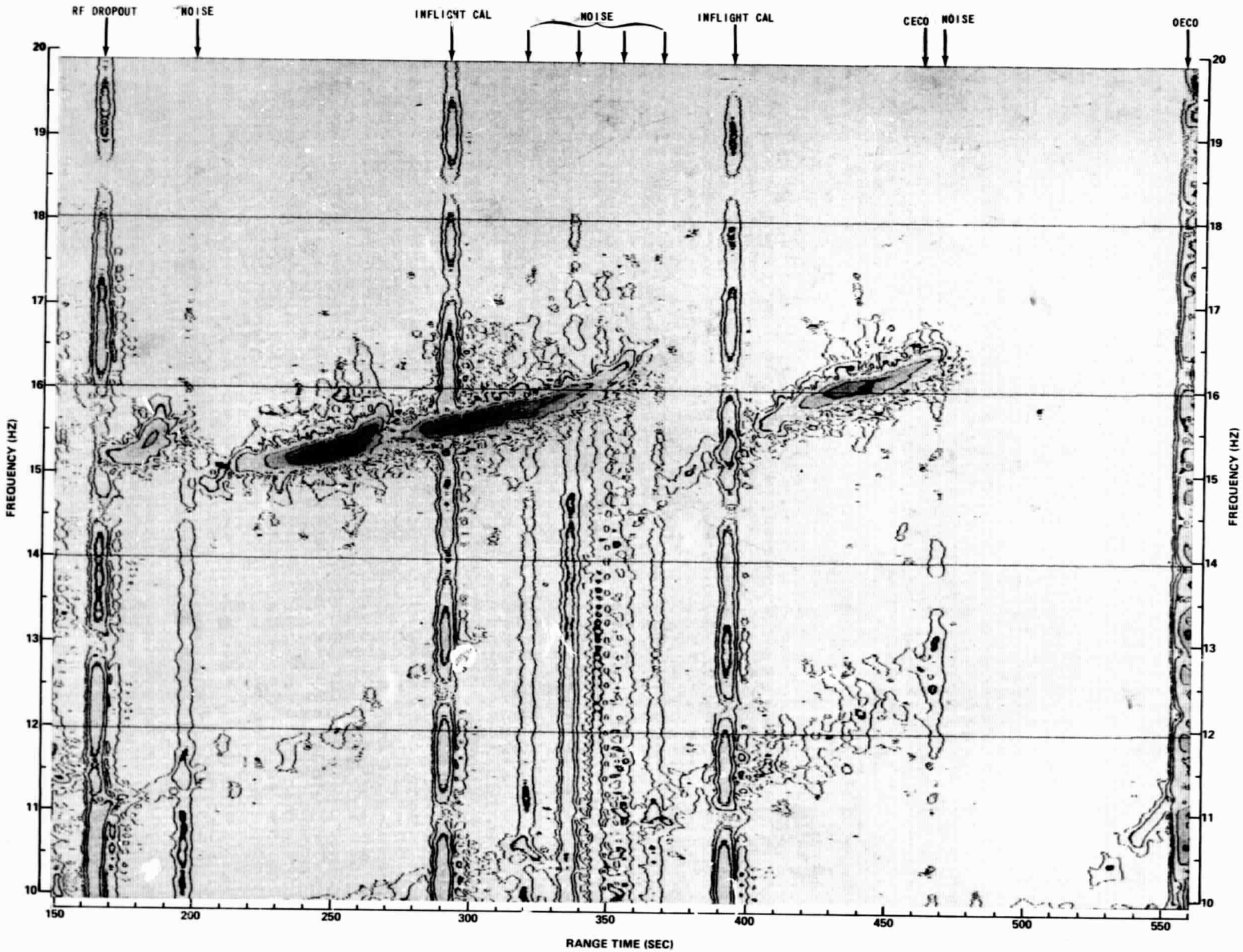

FIGURE 5e - SA-507 S-II D266-206 LOX SUMP PRESSURE

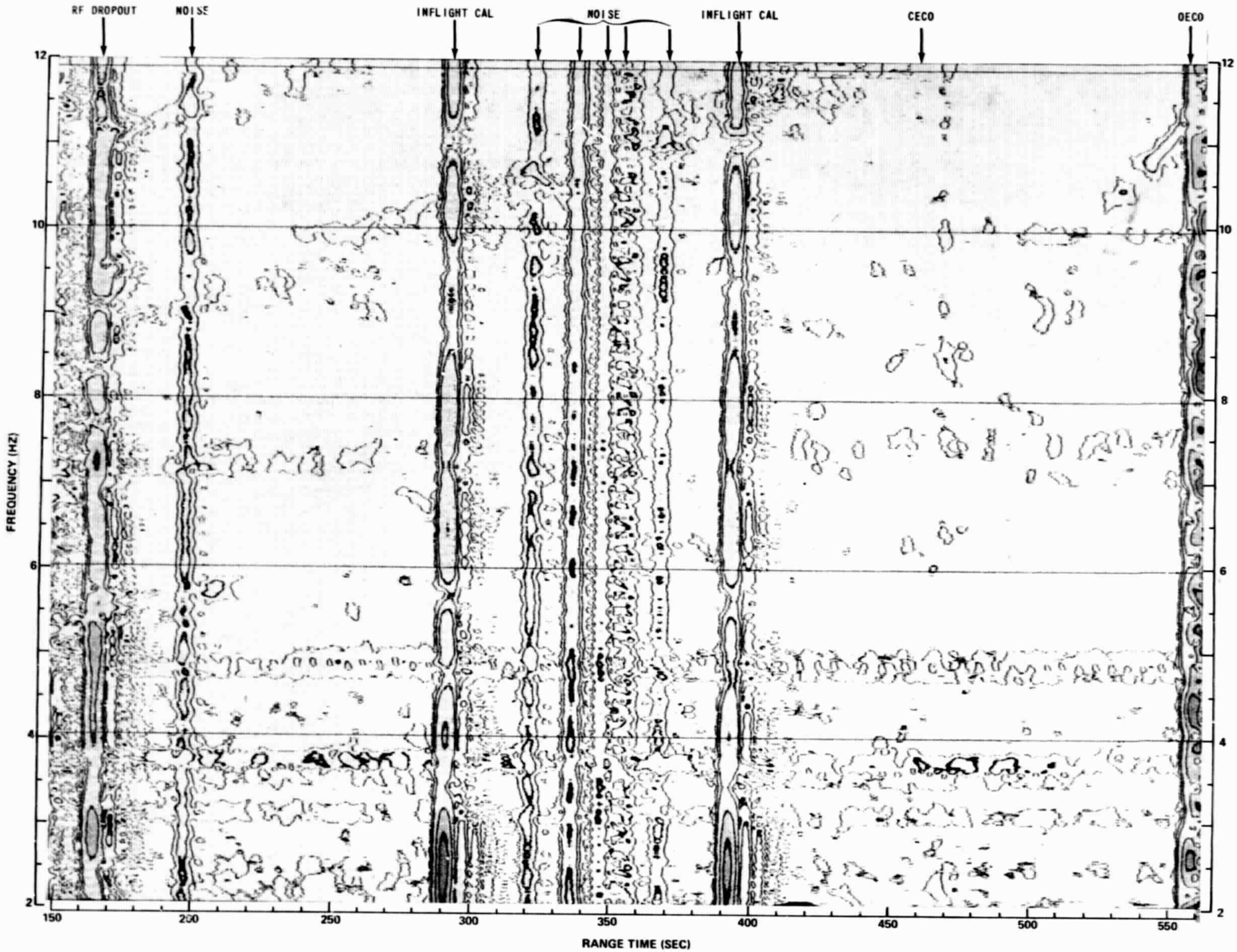

FIGURE 5f - SA-507 S-II D266-206 LOX SUMP PRESSURE

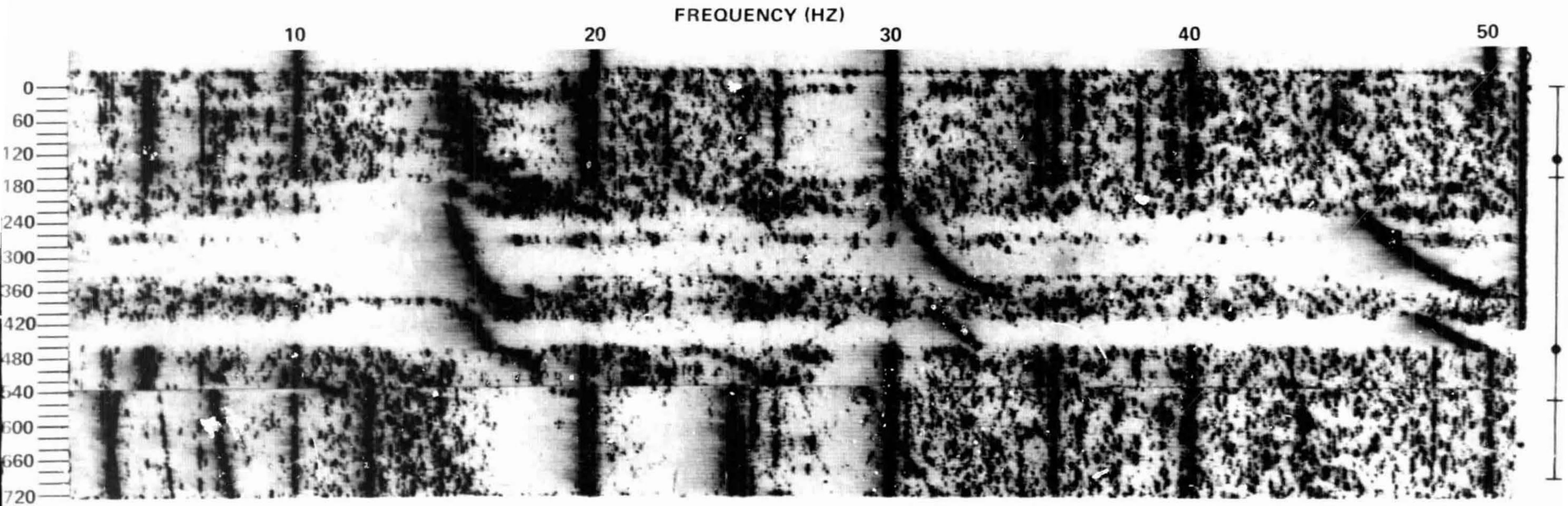

FIGURE 6a - SA-507 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

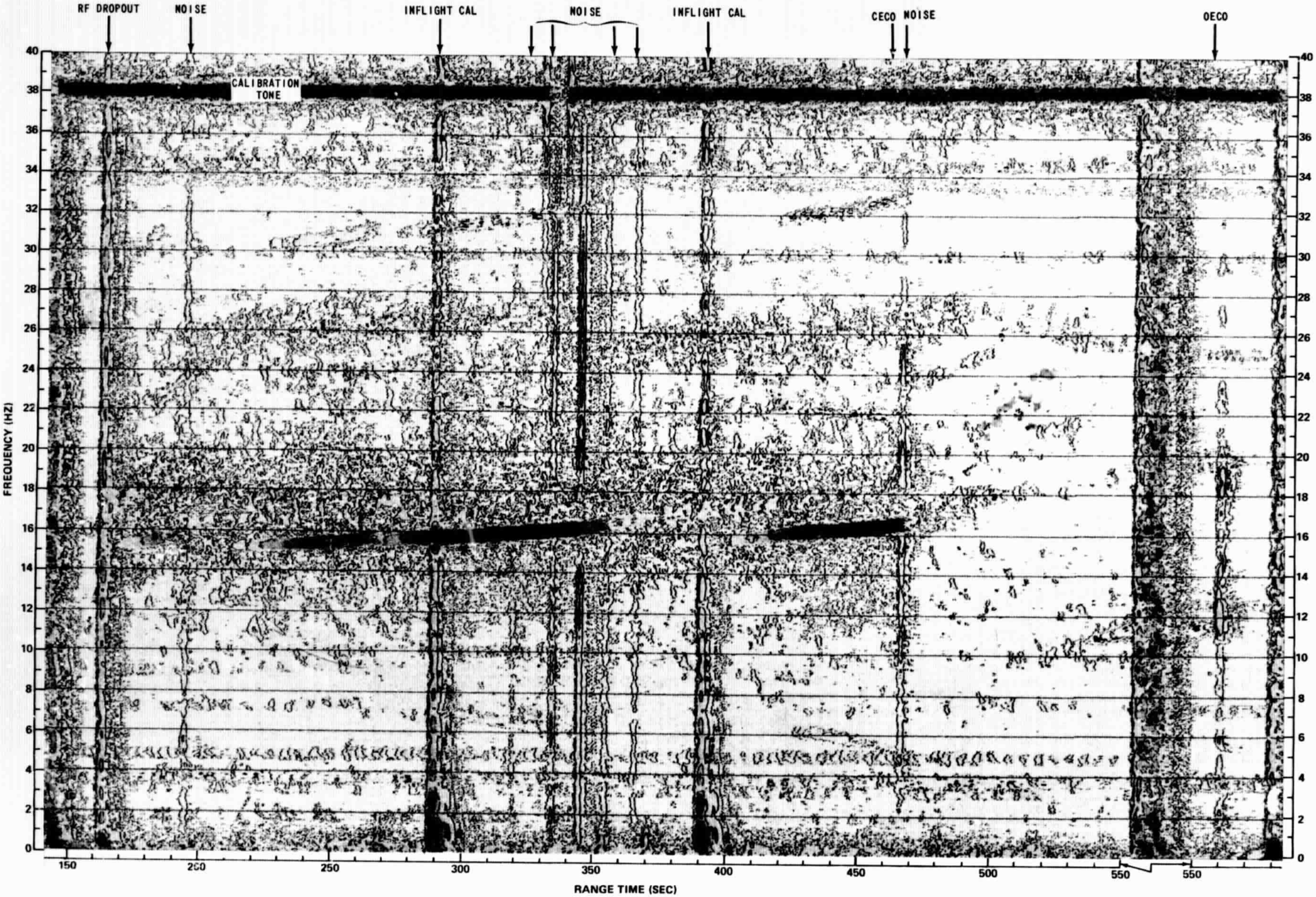

FIGURE 6b - SA-507 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

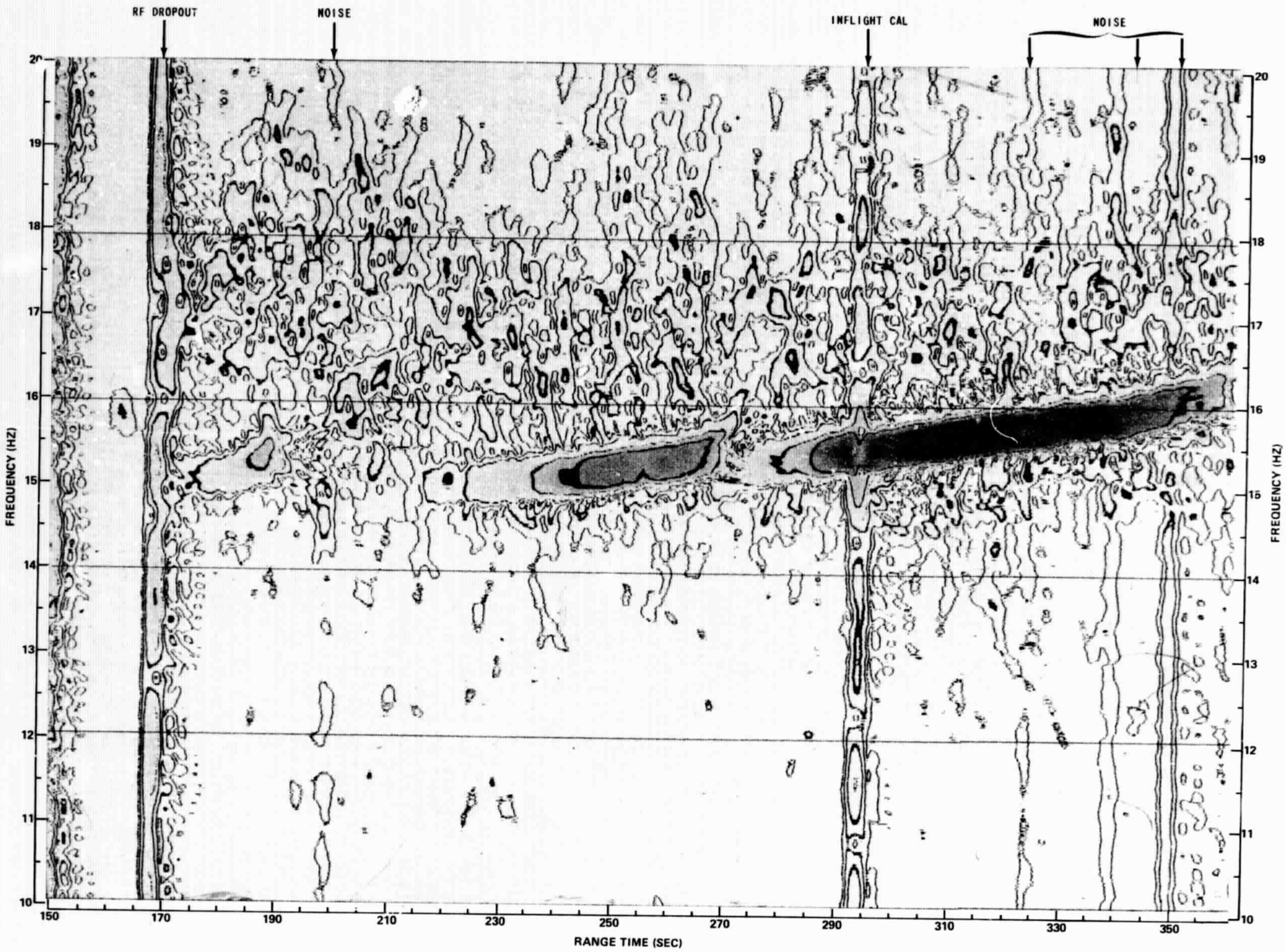

FIGURE 6c - SA-507 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

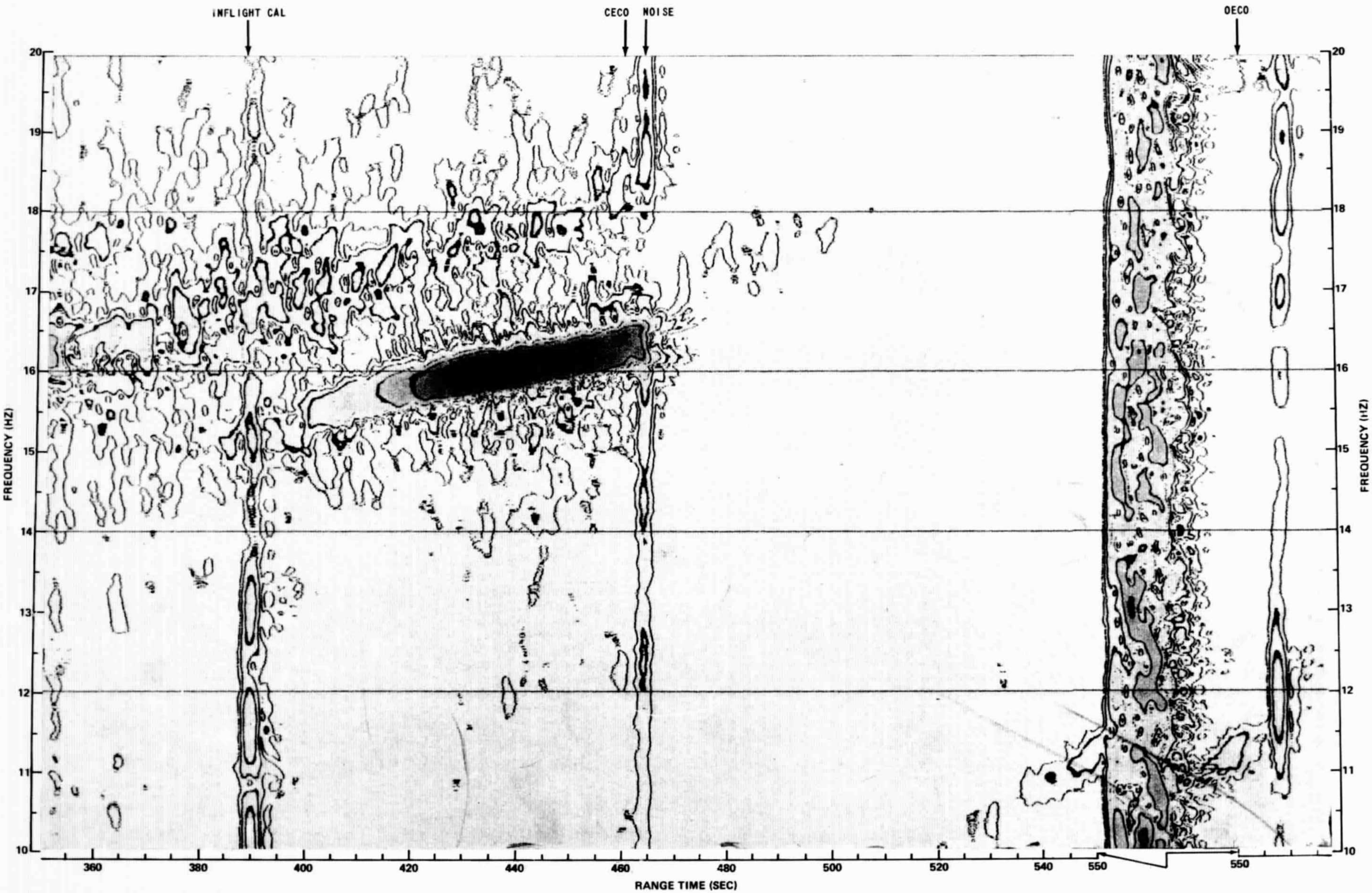

FIGURE 6d - SA-507 S-II E363-206 CENTER ENGINE LONGITUDINAL VIBRATION

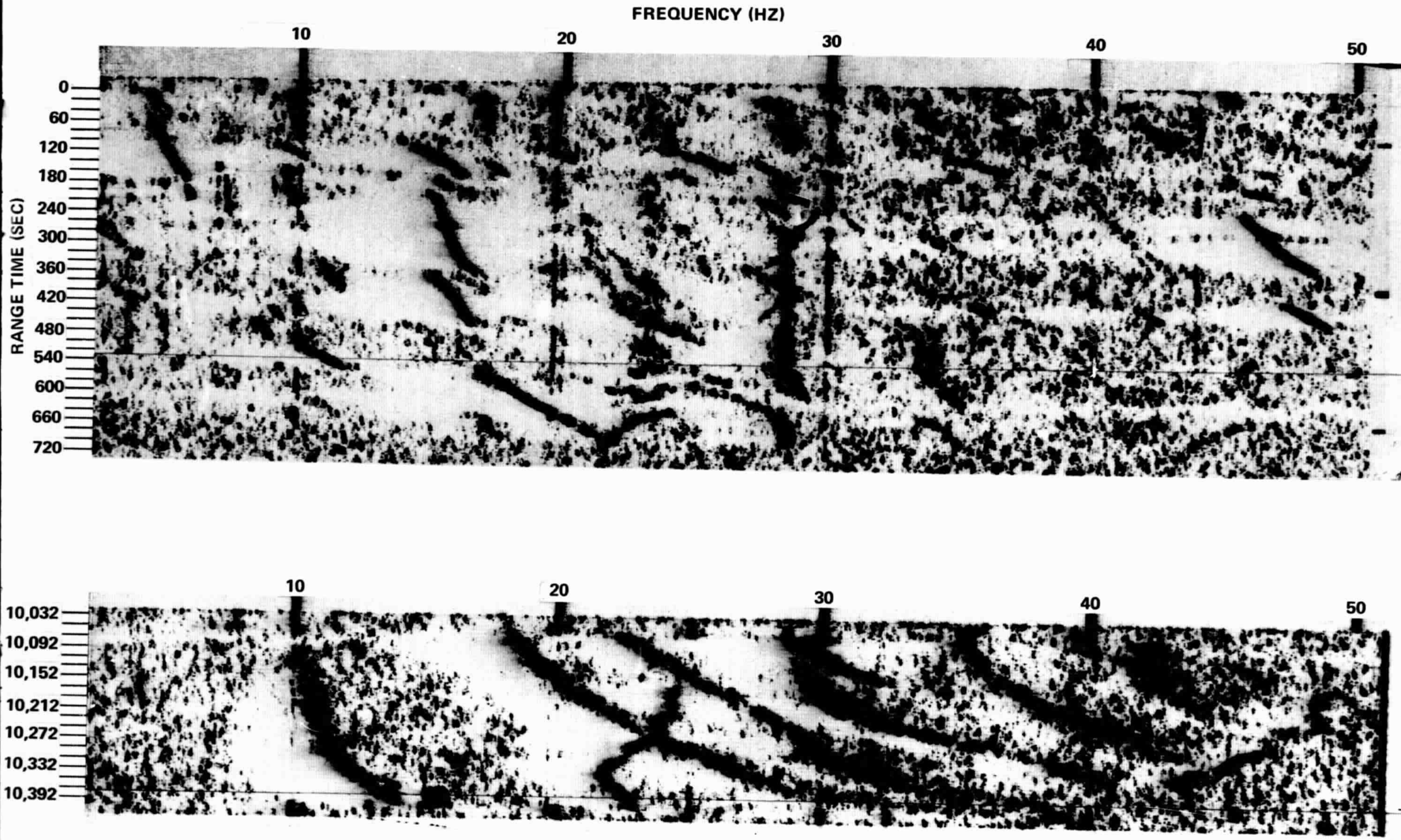

FIGURE 7a - SA-507 S-IVB A15-424 LOX SUMP LONGITUDINAL ACCELERATION

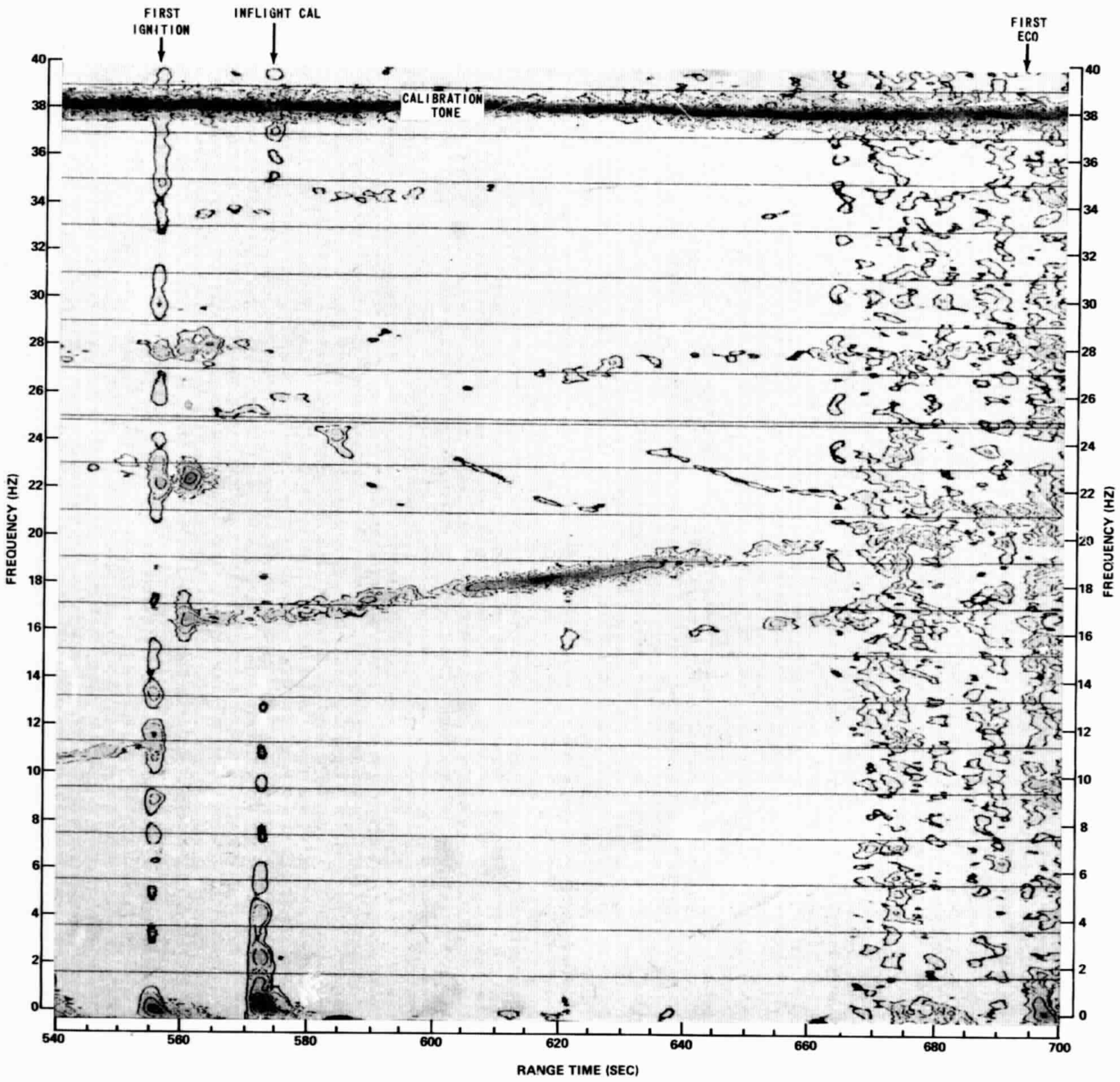

FIGURE 7b - SA-507 S-IVB A15-424 LOX SUMP LONGITUDINAL ACCELERATION

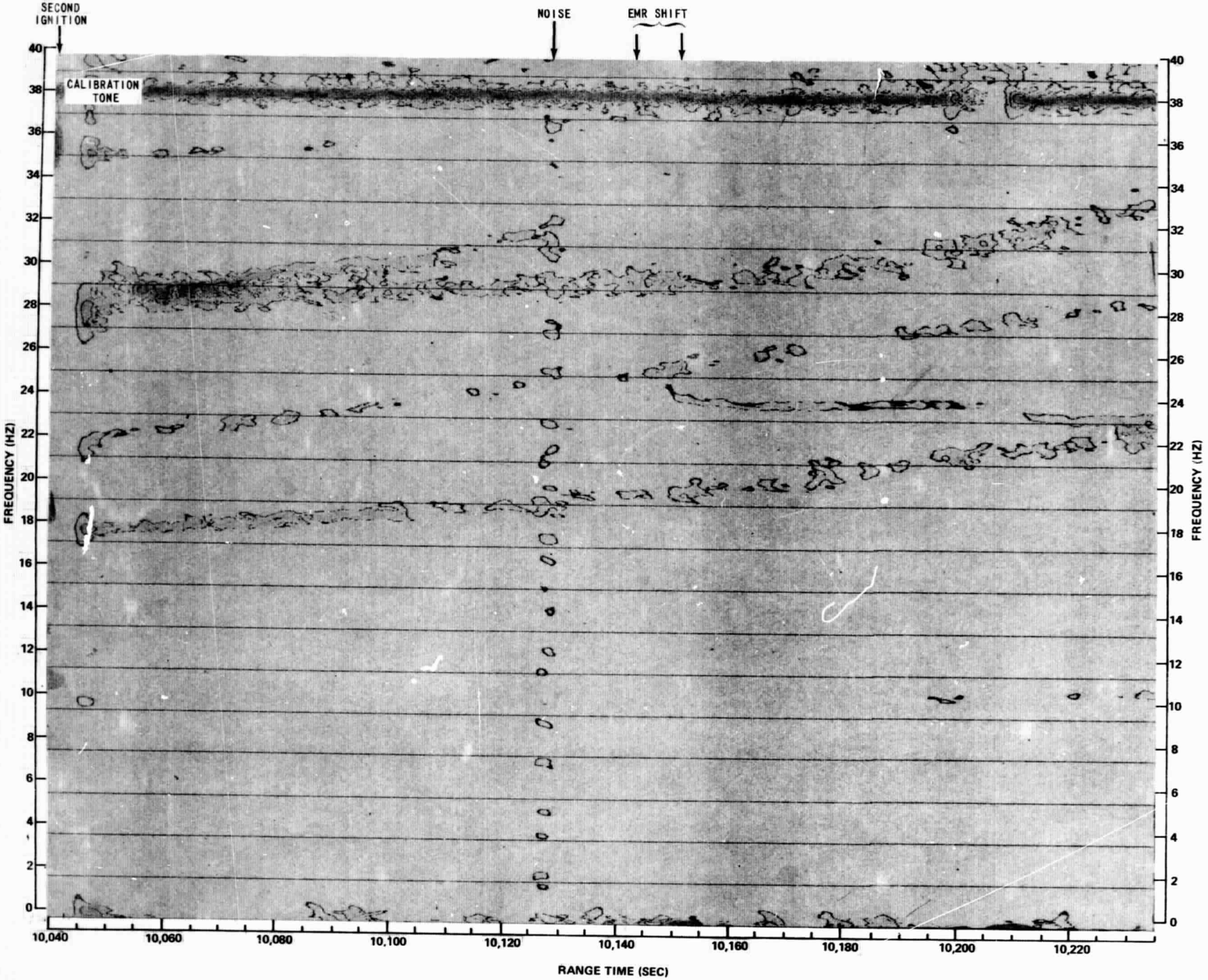

FIGURE 7c - SA-507 S-IVB A15-424 LOX SUMP LONGITUDINAL ACCELERATION

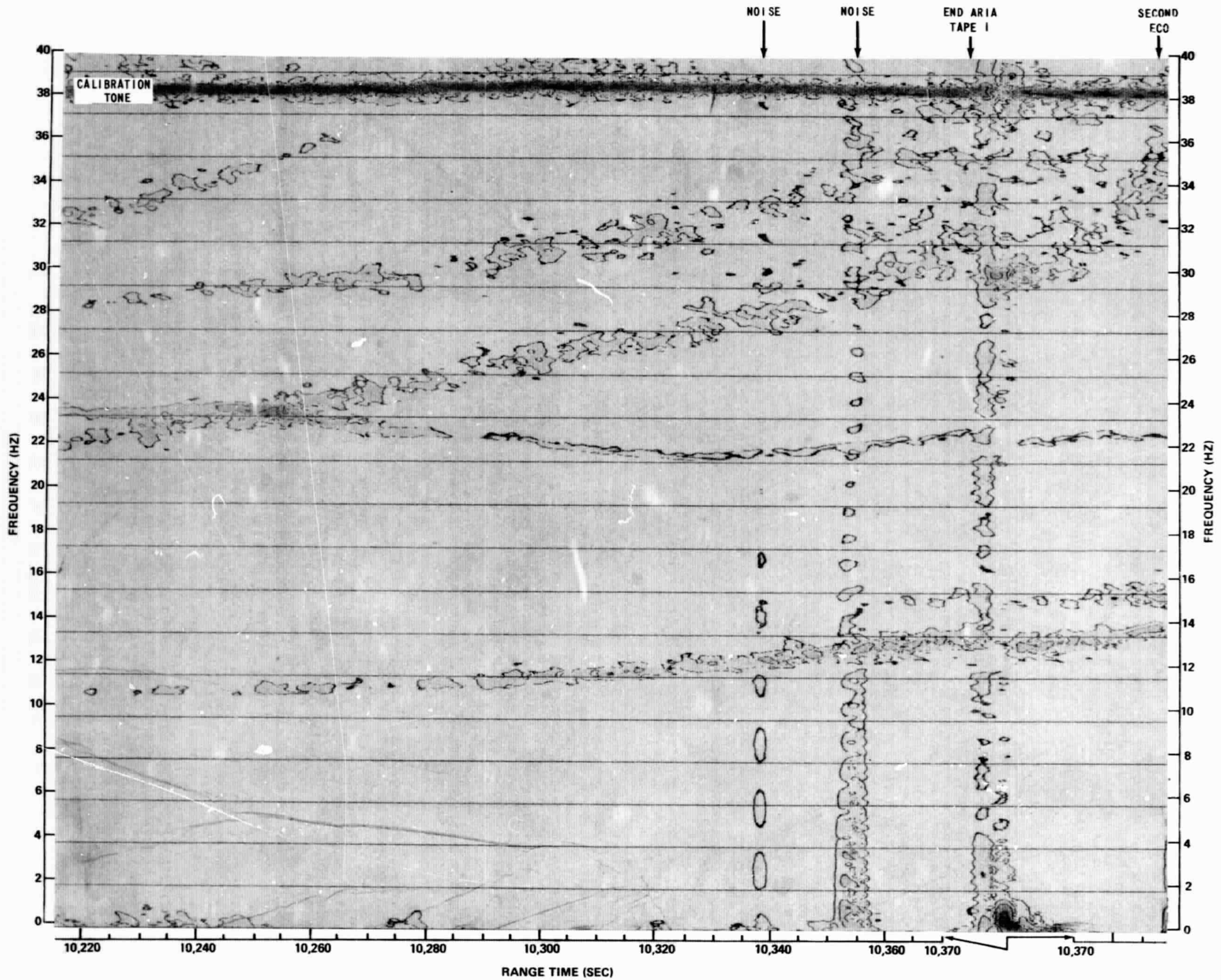

FIGURE 7d - SA-507 S-IVB A15-424 LOX SUMP LONGITUDINAL ACCELERATION

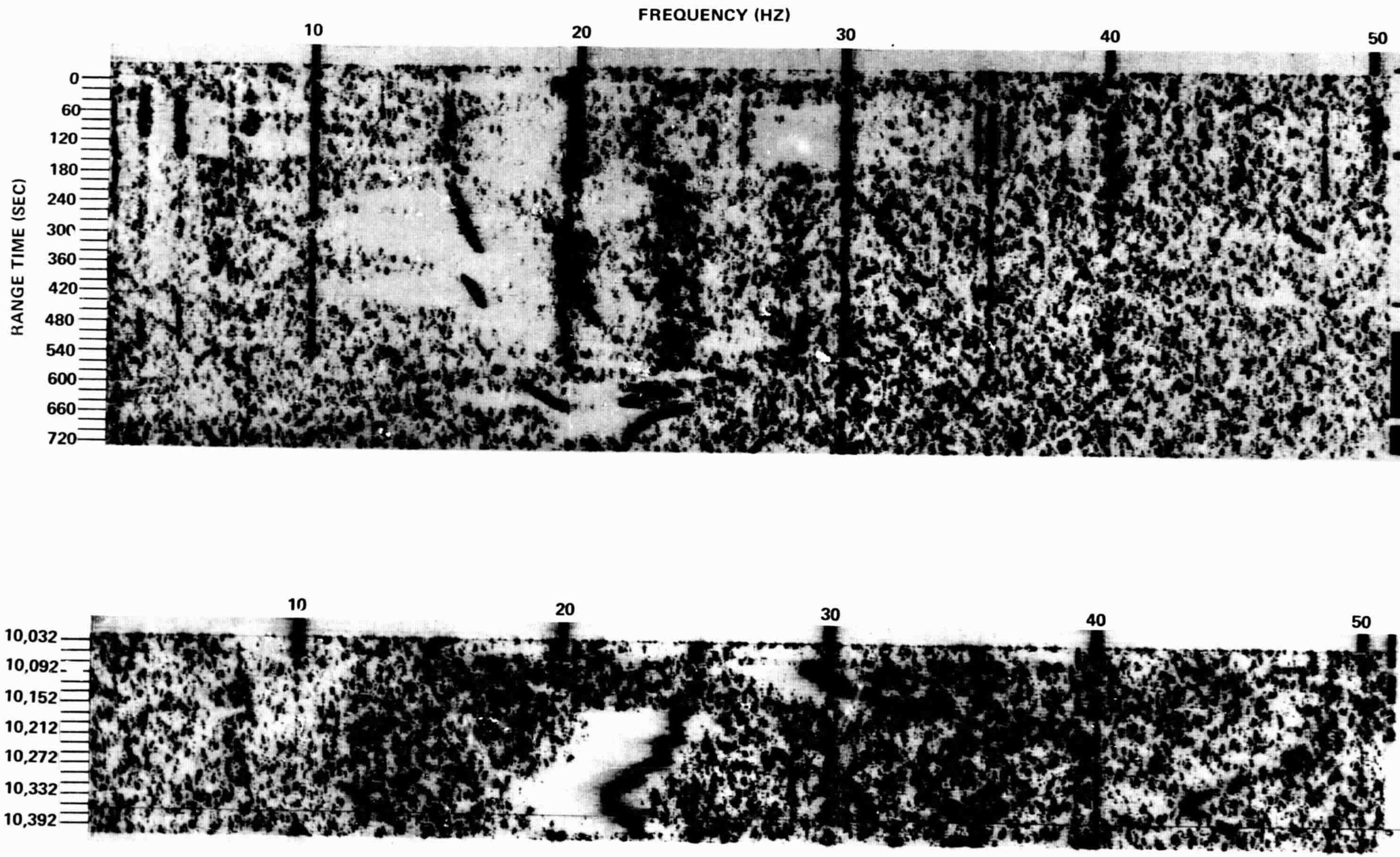

FIGURE 8a - SA-507 S-IVB D3-403 LOX PUMP INLET PRESSURE

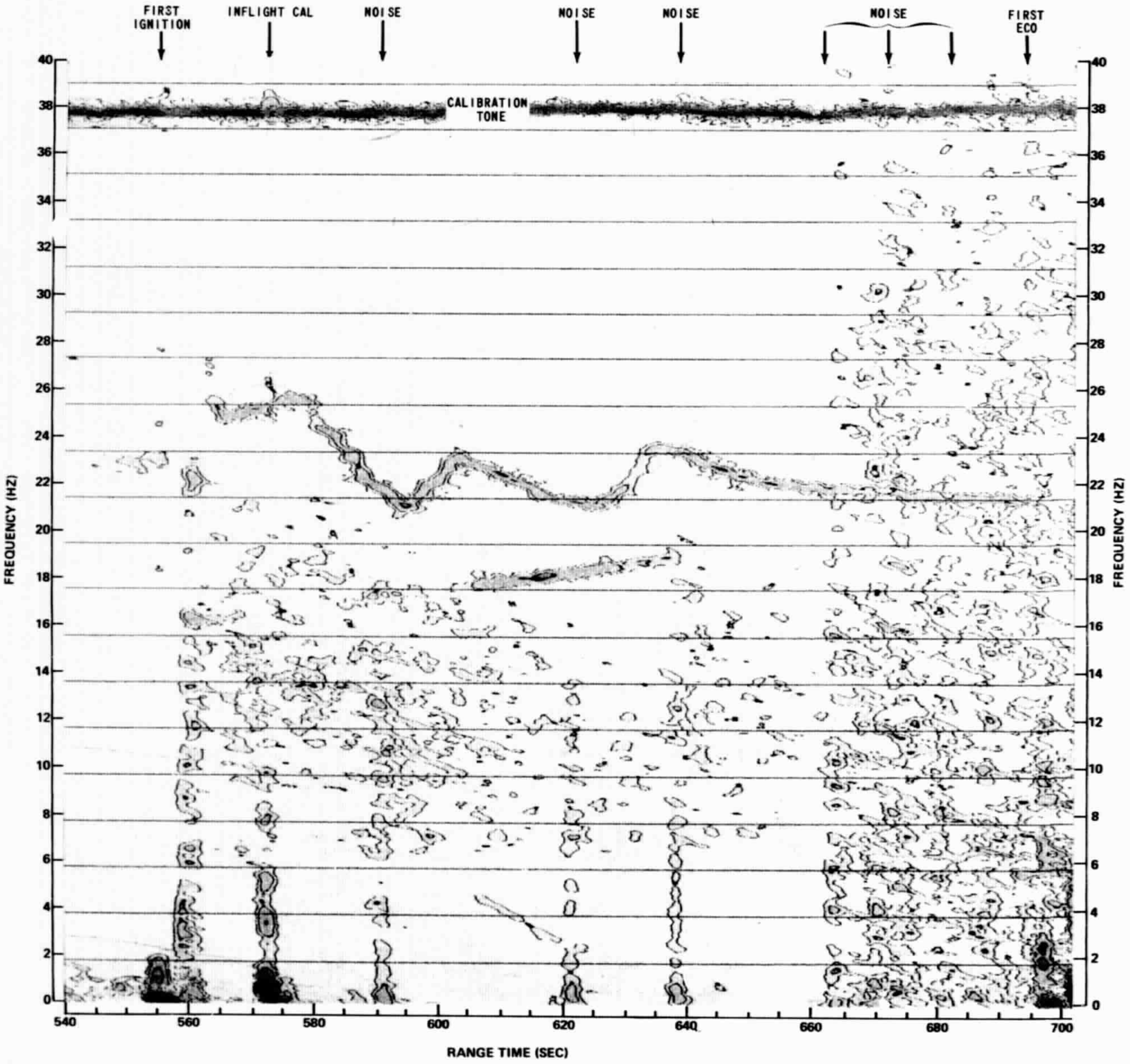

FIGURE 8b - SA-507 S-IVB D3-403 LOX PUMP INLET PRESSURE

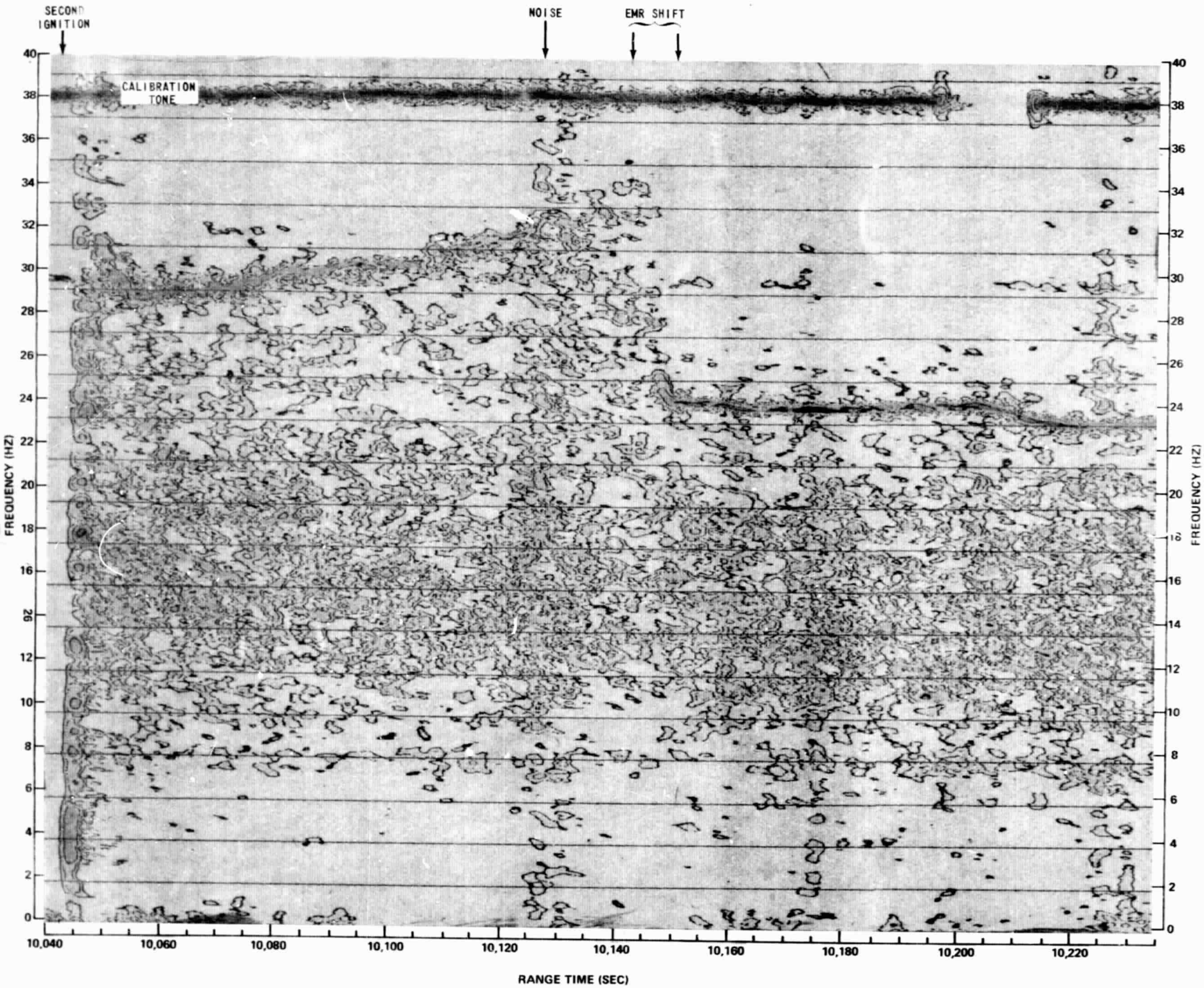

FIGURE 8c - SA-507 S-IVB D3-403 LOX PUMP INLET PRESSURE

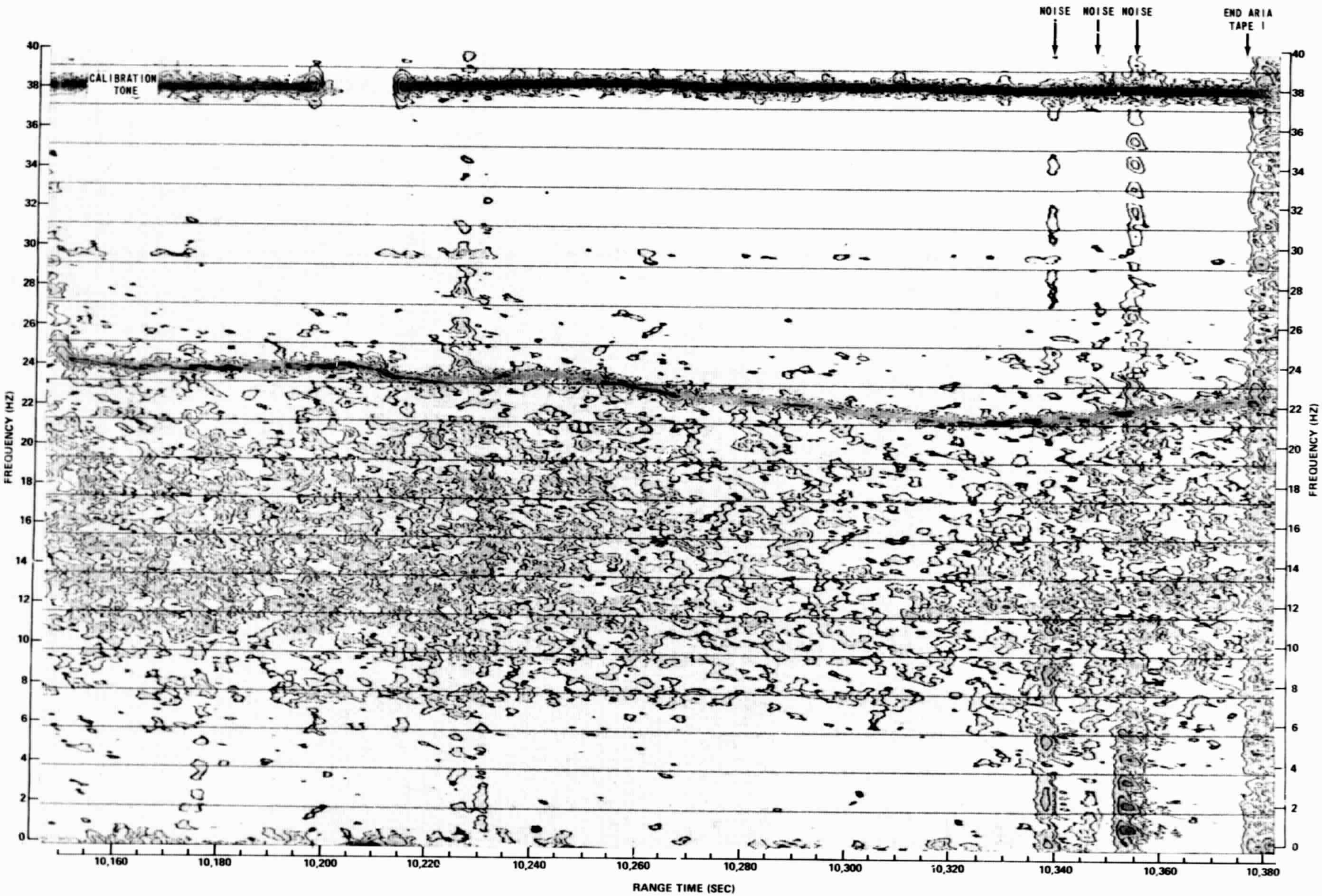

FIGURE 8d - SA-507 S-IVB D3-403 LOX PUMP INLET PRESSURE