UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

PHYSICS 397

MECHANICAL EXCITATION OF ELECTRIC GUITAR PICKUPS

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Electric guitar pickups are simple devices composed of a magnet and a coil, whose behavior however has not been modeled completely yet. Its understanding involves the basic principles of electromagnetic theory, though the difficulty comes from the complexity of the motion of vibrating strings over the pickup and the effects caused by this motion.

As it now, the behavior of a guitar pickup has been tried to be explained by using a theoretical model, basically a simple CRL circuit. Nevertheless, in order to prove its efficacy, it is necessary to study the response of a pickup to a real input signal or excitation. For this pursuit, pickups have been excited by *electronic signal injection*, though the results have been far from the theoretical model.

In this experiment a new method of excitation will be implemented. A guitar pickup will be excited by the circular movement of a string using a high-speed air drill. As in the electronic method, a lock in amplifier will be used to detect the output signal of the pickup, and on-line graphs will be plotted and compared with graphs obtained by the electronic method.

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I ACKNOWLEDGEMENTS

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I would like to thank also Jack Boparai for all the technical help given in the realization of the experiment.

II INTRODUCTION

How a guitar pickup works

An electric guitar pickup consists of an assembly of permanent magnets that has been coiled with metallic wire. Guitar strings are made of metallic, magnetically permeable material. So, when a string is played on a guitar, it oscillates over the pickups and is magnetized by their permanent magnetic field. The field lines from the permanent magnet concentrate in the permeable magnetic material of the string. Thus, when the string vibrates, it acts as a *vibrating* source of magnetic field. Furthermore, the permanent magnet stretches and channels the magnetic flux from the magnetized string through the permanent magnet, and thus through the entire coil. If there is additionally a flat piece of magnetically permeable metal at the base of the pickup, this further channels or stretches the magnetic field lines/magnetic flux from the magnetized string[1].

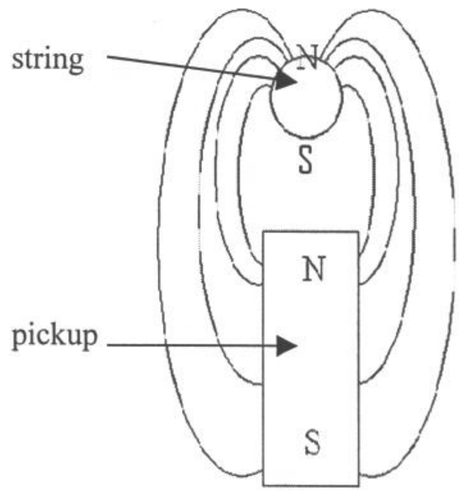


Fig. 1

The EMF induced in the coil due to a time varying field is

$$\varepsilon = -\frac{d\Phi}{dt} \tag{1}$$

where Φ is the magnetic flux:

$$\Phi = \int_S \vec{B}.d\vec{A} = BA \tag{2}$$

here A is the effective cross-section of the coil. B, the magnetic field induced in the string by the permanent magnet is more or less constant. However, Φ must be a time-dependent function, otherwise no sound would be emitted. Therefore, the effective cross-sectional area of the coil, lined by the magnetic flux is what changes with time:

$$\text{e.g.} \qquad A = A_o[1 - \in \sin \omega t] \tag{3}$$

where $\in$ is a small fraction of the total cross sectional area of the pickup coil. Then, going back to equation (1):

$$\varepsilon = -\frac{d\Phi}{dt} = BA_o \in \omega \cos \omega t \tag{4}$$

so the induced EMF is 90° out of phase with the original permanent magnetic field.

In the following sections I briefly summarize the antecedents and previous work done in this field.

The theoretical model

The first theoretical model for a guitar pickup (Prof. Errede) was a simple CRL circuit:

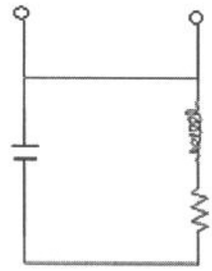


Fig. 2

Where the conventional symbols for *capacitor, inductor,* and *resistor* correspond respectively to stray capacitance, lumped inductance, and resistance associated with the guitar pickup. They were also assumed to have constant values, independent of frequency. However, the results of this model did not agree very well with the experimental results, so a second model was implemented with an additional resistance of the order of R in fig.2, and in series with the capacitance C:

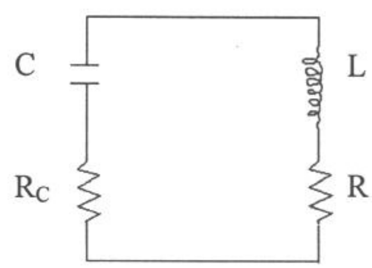


Fig. 3

The theory of circuits by which the values of voltage, current, and impedance are obtained from these circuits are not detailed in this report; these models are mentioned only to illustrate the motivation for implementing experimental methods that allow us to study the response of guitar pickups comparing the results between both parts, theoretical and experimental.

The first experimental model: ***electronic signal injection***

In order to have a frame of reference with which we can compare theoretical results, a first experimental method was implemented (Prof. Errede). This method consisted in a function generator from which different input signals were sent to a pickup, and the output signal was detected with a lock in amplifier and then passed to a computer by means of a National Instruments Lab PC and DAQ card. Then, graphs of pickup response vs. frequency were obtained (see graphs 15, 16, 17, and 18).

The results of this experimental method differed a lot with the results of the theoretical model (see reference 1).

A new experimental model: ***mechanical excitation using an air drill***

Since there was not an agreement between theory and experiments performed with an electronic signal injected in the pickups, and since we did not have complete certainty that the electronic method be as close as reality as we expected, we implemented a different method (which is the main point of this experiment), where we could actually emulate the movement of a string over a pickup, just like in a real guitar.

In this model we will use a high-speed air drill, capable of rotating up to 900 Hz or 54000 rpm. We will attach a piece of a 0.009" guitar string to a plastic rod and spin it at different frequencies with the air drill over a Fender-1979-Mustang pickup, at a distance approximately equal to the separation between the strings and the pickups on a real guitar. With the aid of a simple circuit, a laser pen and a photodetector, the frequency of the drill will be measured and sent to an oscilloscope and a lock in amplifier. Finally, the output signal from the pickup will be sent and detected by the lock in and the real and imaginary parts will be sent to a computer, as in the electronic method.

III EXPERIMENTAL SET UP

The set up used to track the frequency of the rotating drill is illustrated in figure 5.

The laser pen works with a DC voltage source of 3.00 V. As it is observed in fig. 5, when a beam of light from the laser pen goes through the hole of the drill (intended for removing and adjusting the chunk), the photodetector gathers it and sends the signal to the TTL *SN7414N Schmith inverter*, which inverts it and emits an output of *4.5 V* for logic "1." If the photodetector does not receive any beam, the TTL will emit *0.76 V* approximately, for logic "0." The inverter circuit is shown in fig. 6.

For this part of the setup to work correctly, it is necessary to have a good alignment between the laser pen, the drill's hole, and the photodetector; several clamps were used for this purpose.

Table 1 lists the model of each piece in the set up and the main dimensions or lengths.

As mentioned earlier, the output signal from the op amp will go to three meters: an oscilloscope with which we can track the frequency and see what the signal looks like; a frequency counter; and a lock in amplifier, which will receive also the pickup response.

The complete set up is illustrated in figure 7.

IV EXPERIMENTAL PROCEDURE

Measuring the drill's stability

The first step is to measure how stable is our air drill. To accomplish this, we took frequency measurements from 250 Hz until 1800 Hz (the maximum speed of the drill). The range of frequencies is twice as long since the photodetector gathers a beam of light "twice" every time the chunk spins once.

The measurements were done first with the oscilloscope, recording a period and its variation as we increase the speed of the drill (table 2).

The second measurements were done with the lock in amplifier, from which five values of frequency were recorded for each increment of speed of the drill (table 3).

Recording the response of the pickup

Once we have measured the stability of the drill we can start recording the pickup response. In order to ensure drill stability two equally long pieces of string were attached to the plastic rod, separated approximately 180 degrees from each other. We used a program written in Lab Windows, which reads the frequency and the real and imaginary parts of the voltage from the lock in amplifier. The program also calculates the magnitude of the signal and the phase in degrees (table 4).

Although using two strings on the plastic chunk might take care of stability issues, it is not a very accurate emulation of reality. In a real electric guitar, when a string is played it bounces around over the pickups in an elliptical path which at the same time may rotate or vibrate. The use of two strings attached to the plastic rod is rather equivalent to playing two strings over a pickup (if we look carefully to this type of motion we can see for instance that when one of the strings is at the top of the trajectory, the other one is at the bottom, which wouldn't occur with only one string; so the excitation could be actually close to doubled, with one string at the top of the rod and another one at the bottom of it).

Consequently, one of the strings was removed. At the end of the experiment we realized that stability does not depend much on this factor since the weight of the string is so small that becomes negligible. So, we recorded the same values (table 5). In this case, the values of frequency had to be divided by two manually, since we have only one piece of string exciting the pickup. This final measurement was done in order to compare both sets of data: with a single string and with two strings, to see if superposition applies.

For all the measurements running the air drill to its highest frequency rough carton and metallic covers were used for questions of safety.

V CHANGES AND IMPROVEMENTS

Divide by two flip-flop circuit

So far we have worked with only one TTL circuit, which inverts the signal and sends it to the scope and lock-in, as a function of frequency. However, the frequency that we have been counting is really twice the real frequency of rotation of the drill since the beam hits the photodetector twice every time the chunk spins once. In order to account for this fact we manually divided the values of frequency by two and input them in the computer program, nevertheless, this was a possible not so small source of error. So we added a *divide by two flip-flop circuit,* using a *7474 D – type flip-flop* electronic component (figure 8).

Alignment and vibration control

One of the main problems encountered along the realization of the experiment was the vibration produced by the pickup when rotating at high frequencies (say from 600 to 800 aprox. – see graph 19). To solve this inconvenient we had to redesign the setup so the pickup were attached to the same block where the drill, circuit, and laser were located (the idea was to reduce the difference in vibration between the pickup and the drill). Using long stainless steel screws and springs we installed a pair of doglegs on our wooden block, so we were able to hold the pickup to the base and avoid vibration. The height of the doglegs could be adjusted in order to hold any pickup within a reasonable range of heights. We used thin rubber layers between the doglegs and the pickup since this is very delicate and an exaggerated amount of pressure could easily break it.

It is important that the material of the screws and other pieces that form the doglegs be some non-magnetically permeable material (such as stainless steel), so the response of the pickup will not be influenced.

After all these adjustments we still found some jumps in the response of the pickup at critical frequencies. So we tried to reduce the vibration on the drill itself by holding it with long pieces of solid plastic and even with pieces of foam in order to absorb the vibration. Although some improvement was observed (graph 20), a breakpoint of the linearity was still present between 680 and 730 Hz approximately. The final try to avoid this was to have someone to hold the sides of the drill while we ran the experiment. The results are presented in graph 21, and they show that this was the best pattern obtained.

VI ANALYZING DATA – PLOTTING RESULTS

Stability plots

From table 2, the fraction $\Delta f / f$ was computed. Graph 1 shows the drill's stability in percentage. Table 3 lists the average and standard deviation for the values of frequency read from the lock in amplifier. Graph 2 then, reflects the drill's stability, also in percentage, according to this table.

In both graphs we can clearly see that our drill's instability is below 1%, which means this factor *apparently* will not affect significantly the results of our further experiments. In fact, the accuracy of the measurements, namely the mean of the percentage values of instability is **0.28%** for the first set of measurements and **0.25%** for the second set of measurements.

Pickup response plots

Graphs 3, 4, 5, and 6 are plots of voltage vs. frequency for excitation with two strings. The range of frequencies for these graphs goes from 250 to 1800 Hz. From the plots corresponding to the real and imaginary parts of the signal (graphs 3 and 4) it can be observed a big difference in the phase of the two components with respect to frequency. This difference accounts for the fact that the attached string was not aligned with the drill's hole, so we will not worry about it.

Graphs 7, 8, 9, and 10 are plots of voltage vs. frequency for excitation with a single string. The range of frequencies in this case goes from 80 to 820 Hz.

Graphs 11, 12, 13, and 14 show a comparison between the two methods. Obviously, the comparison can only be made in a range until about 900 Hz.

In graph 13 we can observe the difference between the magnitudes of both signals. This difference can be calculated by comparing the differences between the final and initial values of |V| for both methods:

	Frequency [Hz]		*|V| [mV]*		
	final pt.	*initial pt.*	*final pt.*	*initial pt.*	*difference*
Single string:	*820*	*240*	*21.79*	*6.49*	*15.3*
Two strings:	*820*	*240*	*33.90*	*9.90*	*24.0*

Now, comparing both differences

$$\frac{24.0 - 15.3}{24.0} = 0.3625$$

so the magnitude of the signal of the two measurements, single string and two strings, vary by 36.25 percent. From this fact we conclude that the pickup response **does not follow superposition** as we increment the number of strings that excite the pickup. Several factors might play an important roll in this conclusion: as we mentioned before, the fact that in a real guitar there is only one string vibrating and not two in a given position; and also, when we use two strings, the induced magnetic field of each one affects the other one and in turn this modifies the excitation of the pickup and its response.

In graph 14 the phases of both signals can be compared. For the two-string measurements the total variation in phase is approximately *4.23 ± 0.06 degrees*. For the single string measurements the total variation in phase is approximately *4.09 ± 0.01 degrees*. So both variations are almost equal, which agrees with the expected results since the variation in the phase of the signal must be independent of the number of strings used to excite the pickup.

Graphs 15, 16, 17, and 18 show a comparison of the curves of voltage vs. frequency for excitation by mechanical means with one and two strings, and by electronic signal injection over the same pickup. The slope of the magnitude of V reflects the amplitude of each signal. For example, for the electronic excitation, the function generator was set to 1 volt; if we would increase this value by the appropriate factor we could get the same slope as in the response to the excitation using the drill; this last one, in turn, depends on the distance from the pickup to the spinning chunk.

Graph 14 shows the phase of V, from which we conclude that so far there is not a clear relationship between both methods. The phase of the signal of the electronic method changes a lot, which suggests that probably there are some other factors –such as induced currents- within the mechanical excitation, which have a different effect in the phase of the signal. These effects constitute a wide field for further study.

Graphs 17 through 36 show results with the flip-flop divide by-two circuit added. Although we had expected these results to show a more symmetrical pattern (namely, a perfect linear relation), they show a big jump in the range 600 – 800 Hz. We blamed this on vibration, based on the sound the drill emitted while running the experiment. After some corrections made in order to reduce such vibration (described in section V), the range of critical frequencies was shortened to 670 –730 Hz approximately. Graphs 29 through 32 show results when we used a solid plastic piece and foam to hold the drill and avoid excessive vibration, but we can still observe another small incoherence in the range 480 – 510 Hz. This was solved by using a "human holder" in addition to the plastic and foam holder of the drill (i.e. someone hold the sides of the drill while we ran the experiment). Graph 33 through 36 show the results. If we compare the plots of | V | vs frequency, we can see that the "human holder" technique eliminates virtually any jig in the straight line, except for main one, located at approximately 700 Hz. This final result gives rise to the conclusion that we would need to hold our air drill with more than a clamp and a piece of plastic and foam. Since it is capable of rotating at very high frequencies, a very well designed, heavy metallic holder is needed to avoid vibration completely.

The main breakdown of linearity that we have been mentioned lately comes out with the presence of the flip-flop divide by two circuit; not meaning that there was not jumps at all in the first tries, but since we added this last circuit to obtain the real values of frequencies, we have observed the same breakdown at the same point in our graphs of magnitude of V vs frequency. Therefore, we can conclude that there might be some estrange effects caused

VI SUGGESTIONS FOR FURTHER WORK

The results of this experiment have opened the doors for a big number of possibilities and variations to be tested in the future.

With the implementation of a new testing model, closer to reality, several changes can be tested in order to improve the theoretical model and the experimental models themselves.

There are a lot of things to investigate, which were not done in this experiment for questions of time. How the radius of the rod affects the response of the pickup; the fact that the speed of the drill must be changed manually, up to now, might intervene as well; etc.

Once a testing model is sufficiently improved, namely it provides the best possible results, other things can be studied such as magnetic properties of different strings and magnetically permeable materials, properties of pickups and permanent magnets, etc.

FIGURE 5

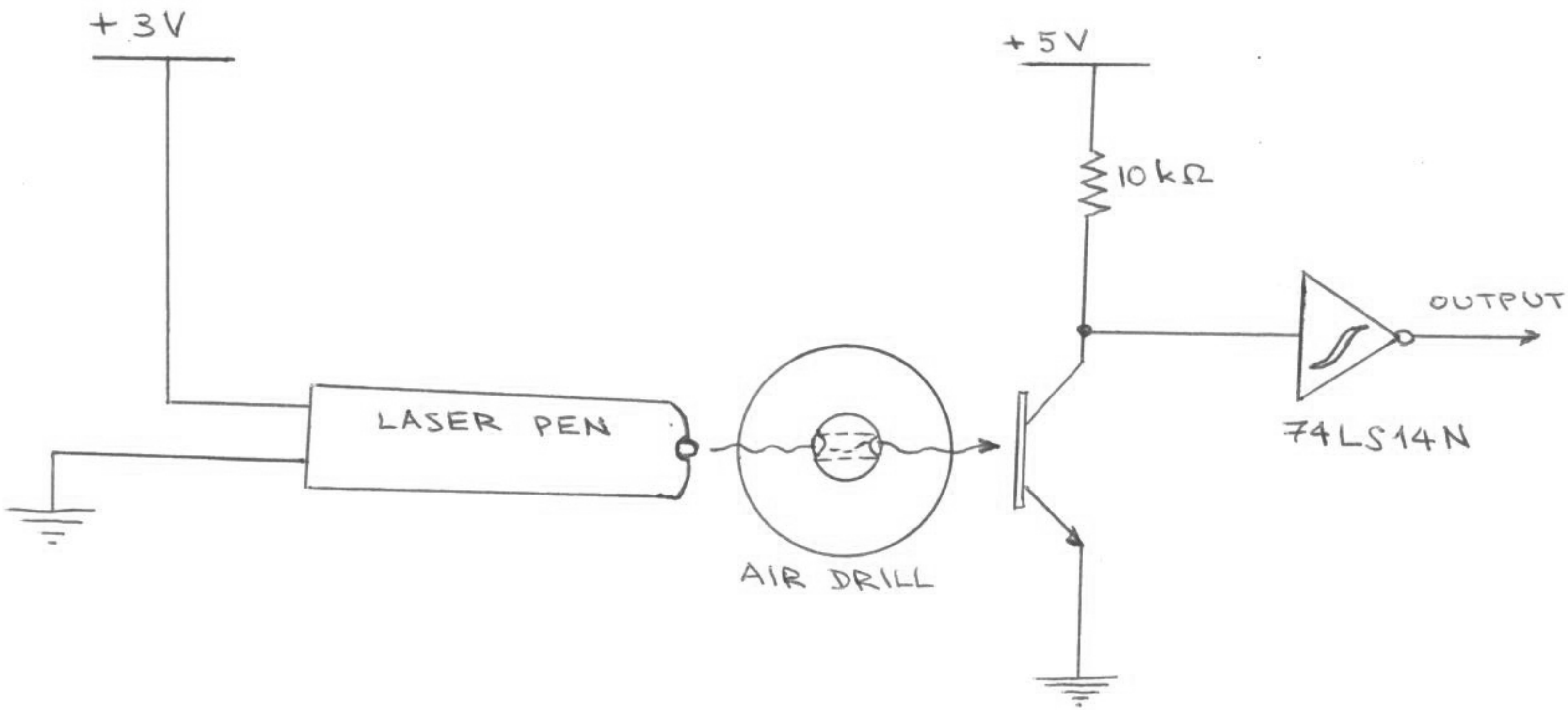


FIGURE 6

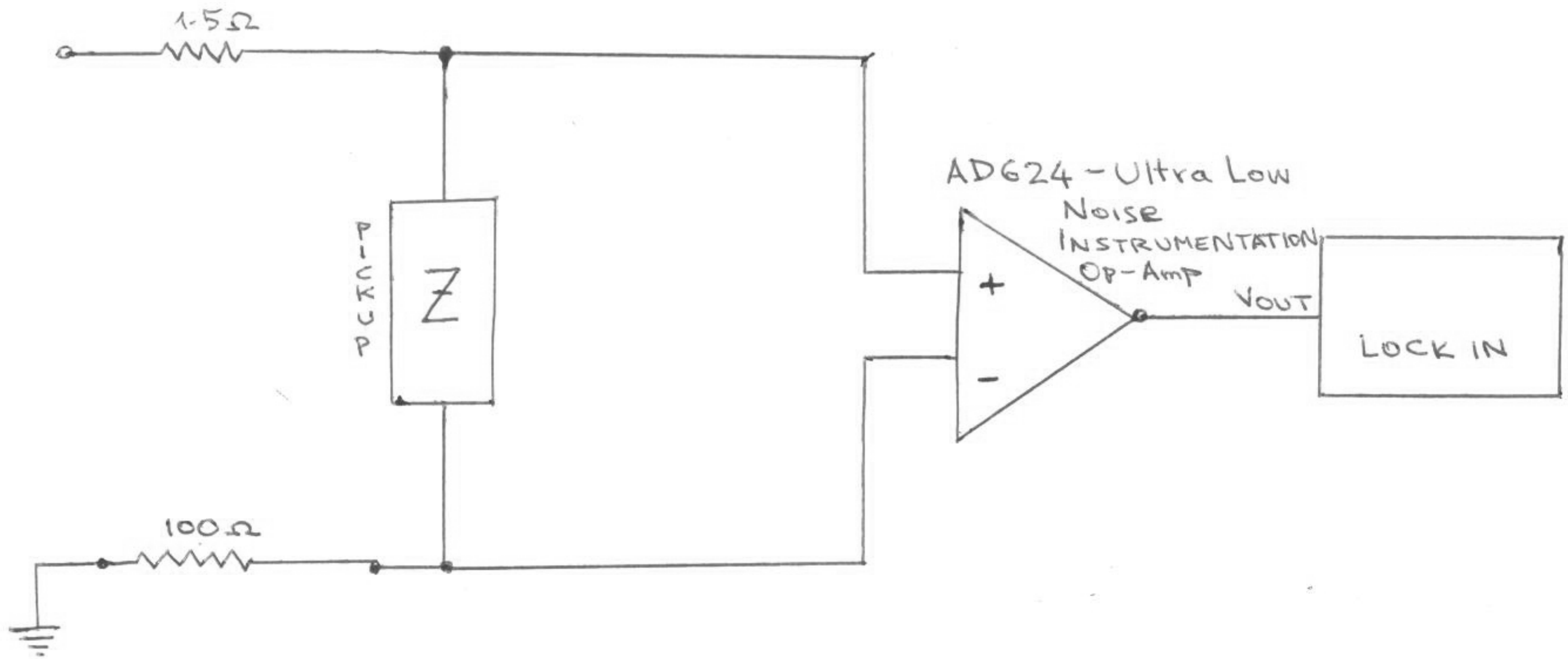
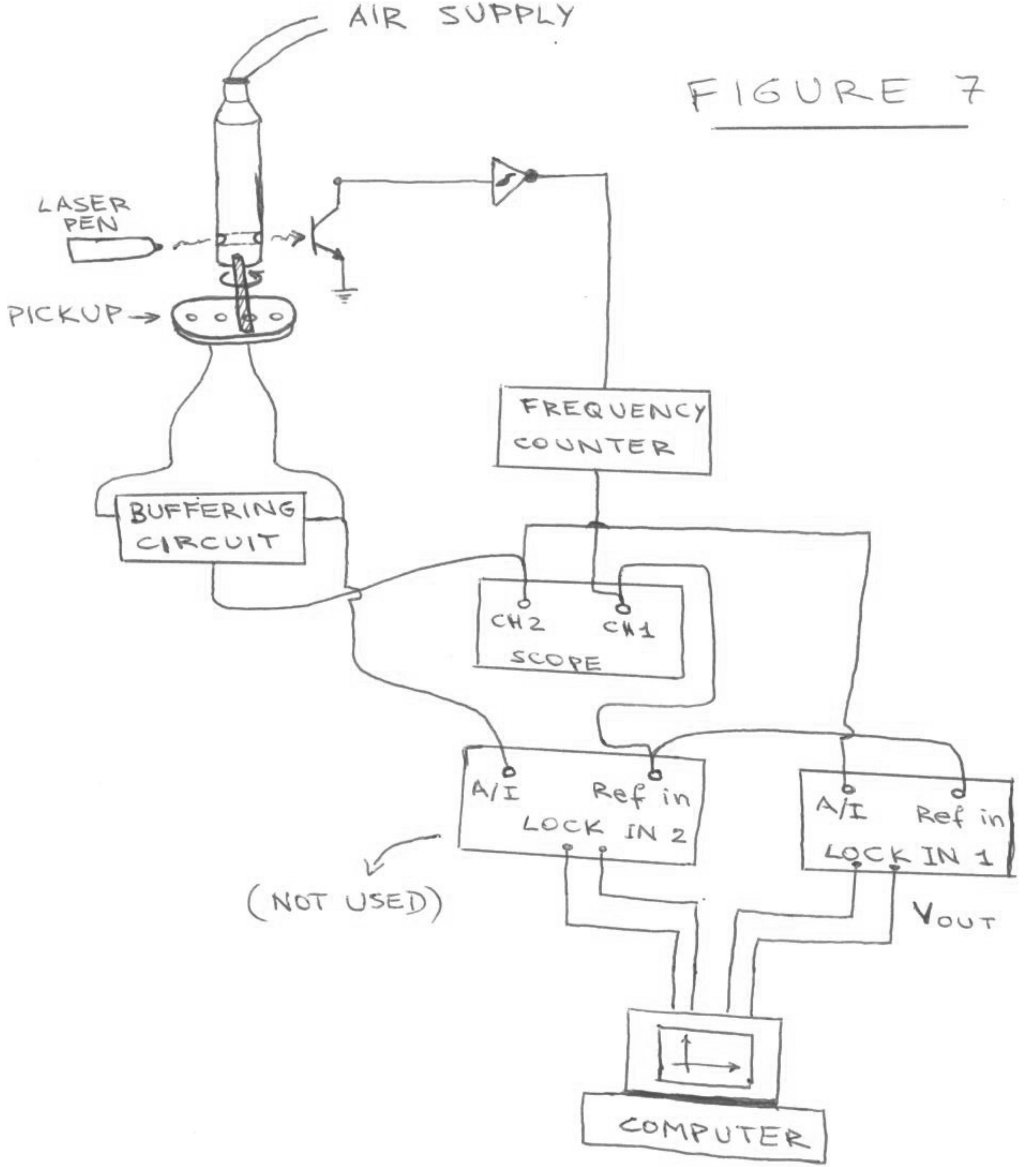

1.5Ω
PICKUP
Z
100Ω
+
−
AD624 - Ultra Low
Noise
INSTRUMENTATION
Op-Amp
VOUT
LOCK IN

FIGURE 7


AIR SUPPLY
LASER PEN
PICKUP
BUFFERING CIRCUIT
FREQUENCY COUNTER
CH2
CH1
SCOPE
A/I
Ref in
LOCK IN 2
A/I
Ref in
LOCK IN 1
(NOT USED)
V_{OUT}
COMPUTER

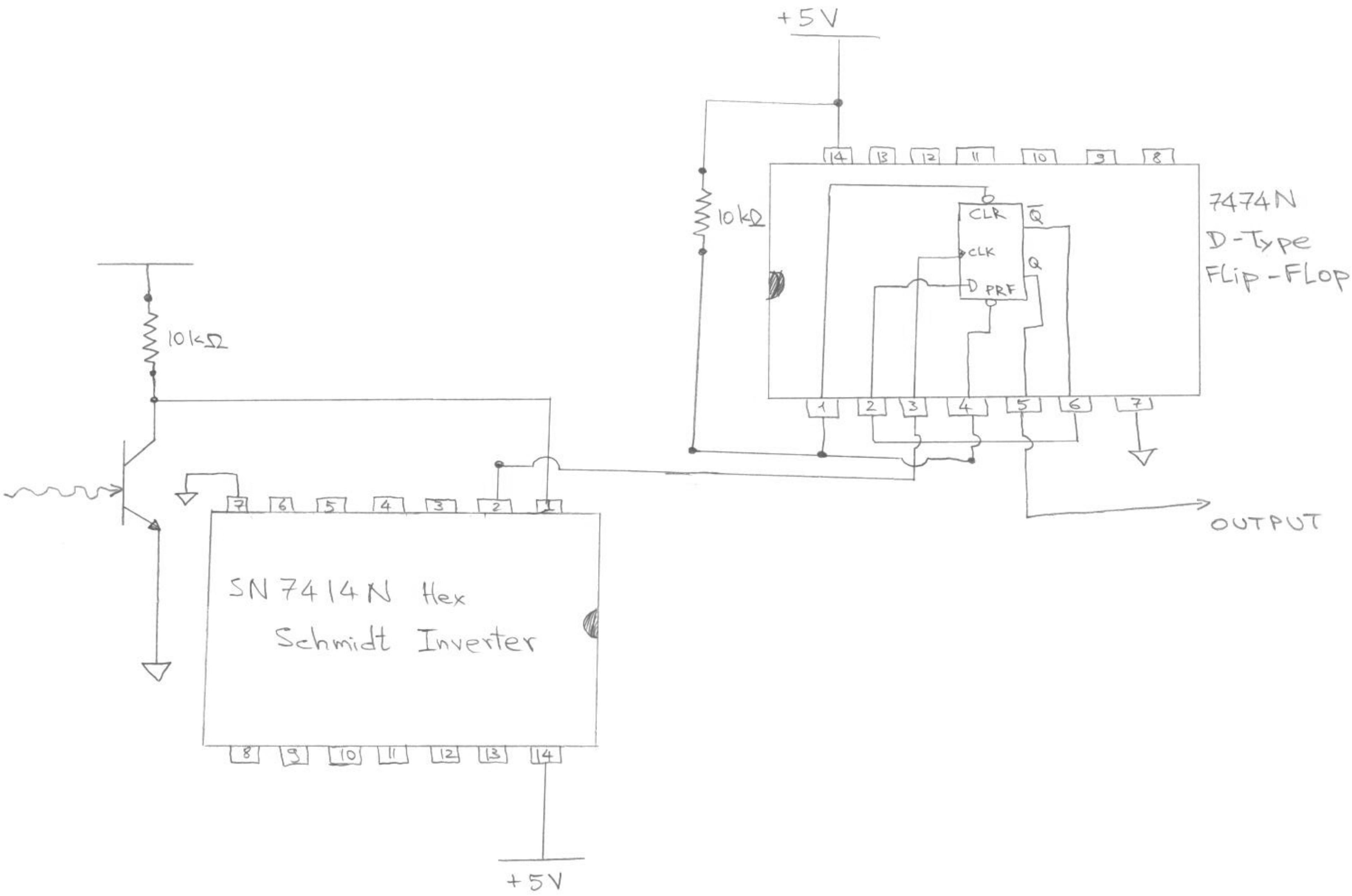

+5V
10kΩ
7474N
D-Type
Flip-Flop
CLR
CLK
D
PRF
Q
10kΩ
OUTPUT
SN7414N Hex
Schmidt Inverter
+5V

FIGURE 8

TABLE 1

SET UP MATERIALS

Pickup:	Fender-1979-Mustang
String:	D'Addario EXL120, 0.009"
Drill:	NSK Air Line Kit AL-807
TTL Schmidth Inverter:	Texas Inst. 87AFFXK, SN7414N
Photodetector:	Motorola MRD300, K9042
TTL flip-flop:	Texas Instruments 511CS - SN7474N D-Type flip-flop
PC card:	National Instruments Lab PC+ DAQ Card
Lock-in Amplifier:	Stanford Research SR830 Lock-In
Radius of plastic rod:	1.90 mm

SETTINGS FOR THE LOCK-IN FOR VOLTAGE MEASUREMENTS:

Time constant:	1
Slope	6 dB / active
Channel	A
DC couple	
Ground	float
Sensitivity	500 mV
Normal Reserve	
Line Filter	off
Channel 1 output x	display
Channel 2 output y	display
First harmonic	
Reference in	positive edge

TABLE 2

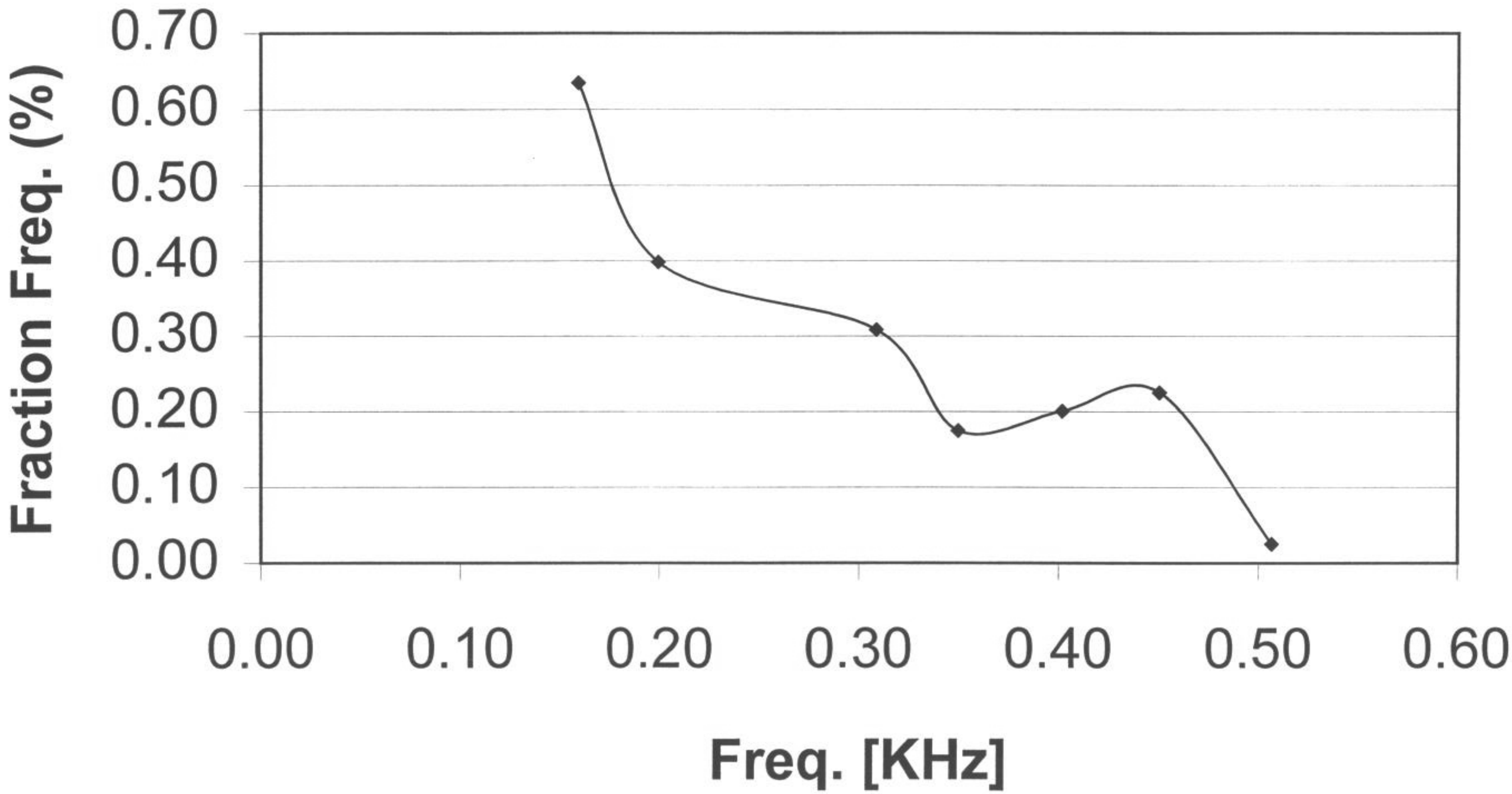
Frequency [Hz]	Uncertainty [Hz]	T [ms]	T1 [ms]	T2 [ms]	F [KHz]	F1 [KHz]	F2 [KHz]	deltaF [KHz]	Frac_F(%)	Raw Data T/2 [ms]
320	± 6	6.300	6.280	6.320	0.1587	0.1592	0.1582	0.0010	0.63	3.150
400	± 6	5.020	5.010	5.030	0.1992	0.1996	0.1988	0.0008	0.40	2.510
600	± 6	3.240	3.235	3.245	0.3086	0.3091	0.3082	0.0010	0.31	1.620
700	± 6	2.860	2.858	2.863	0.3497	0.3500	0.3493	0.0006	0.17	1.430
800	± 6	2.490	2.488	2.493	0.4016	0.4020	0.4012	0.0008	0.20	1.245
900	± 6	2.220	2.218	2.223	0.4505	0.4510	0.4499	0.0010	0.23	1.110
1000	± 6	1.974	1.974	1.974	0.5066	0.5066	0.5065	0.0001	0.03	0.987

deltaT [ms]
0.040
0.020
0.010
0.005
0.005
0.005
0.001

TABLE 3

LOCK IN FREQUENCIES: [Hz]	180.5	214.7	303.1	402.6	515.4	607.1	704.3	801.7	913.2	1009.8	1115.4	1221.3	1306.6	1401.0	1512.6	1603.2	1712.0	1804.2
	181.7	215.2	303.1	401.2	513.6	606.1	702.0	802.3	908.3	1006.2	1116.8	1222.6	1303.2	1404.8	1509.2	1604.4	1710.5	1805.6
	181.3	214.7	301.2	400.6	512.6	605.3	702.5	805.6	904.0	1002.7	1115.6	1224.4	1301.0	1398.2	1506.3	1602.6	1716.8	1806.8
	182.0	215.3	302.3	400.0	512.1	604.3	701.0	805.3	901.3	1004.6	1113.5	1223.9	1299.8	1401.2	1503.5	1605.6	1712.9	1802.7
	180.3	215.1	301.4	400.2	510.2	602.8	701.1	806.4	897.7	1005.8	1114.8	1220.7	1295.1	1394.5	1510.2	1604.7	1710.6	1810.8
Uncertainty [Hz]:	± 3.0	± 3.0	± 2.5	± 2.5	± 2.0	± 2.0	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.5	± 1.0	± 1.0	± 1.0	± 1.0	± 1.0
Average Freq [Hz]	181.16	215.00	302.22	400.92	512.78	605.12	702.18	804.26	904.90	1005.82	1115.22	1222.58	1301.14	1399.94	1508.36	1604.10	1712.56	1806.02
Standard Deviation [Hz]	0.74	0.28	0.90	1.04	1.92	1.66	1.34	2.11	6.04	2.61	1.20	1.60	4.25	3.84	3.53	1.20	2.57	3.08
Fraction Frequency %	0.41	0.13	0.30	0.26	0.37	0.27	0.19	0.26	0.67	0.26	0.11	0.13	0.33	0.27	0.23	0.07	0.15	0.17

Graph 1: DRILL STABILITY



Graph 2: DRILL STABILITY

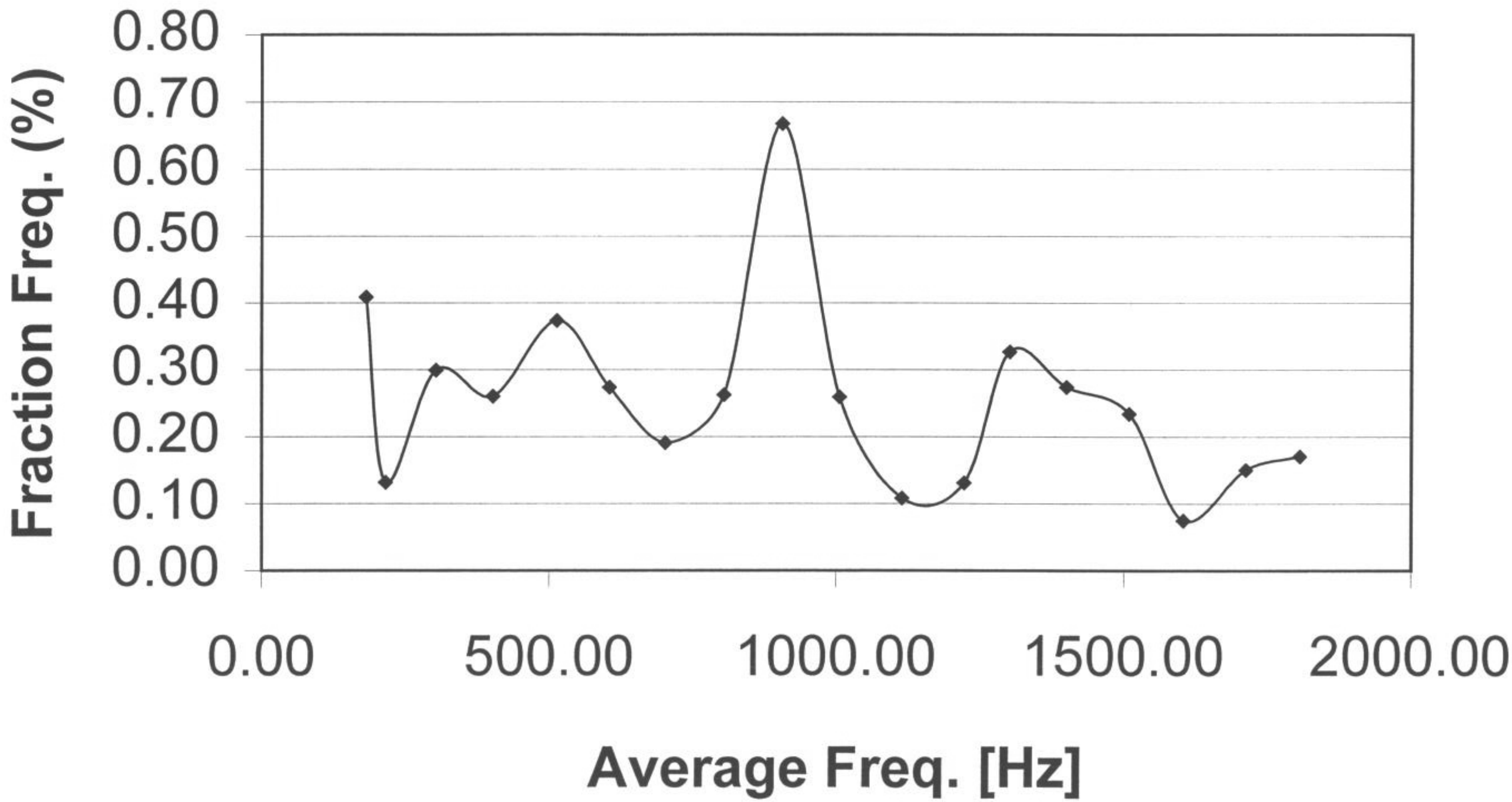


TABLE 4

c:\cvi\P398EMI\Data\drill1_79mustang.dat

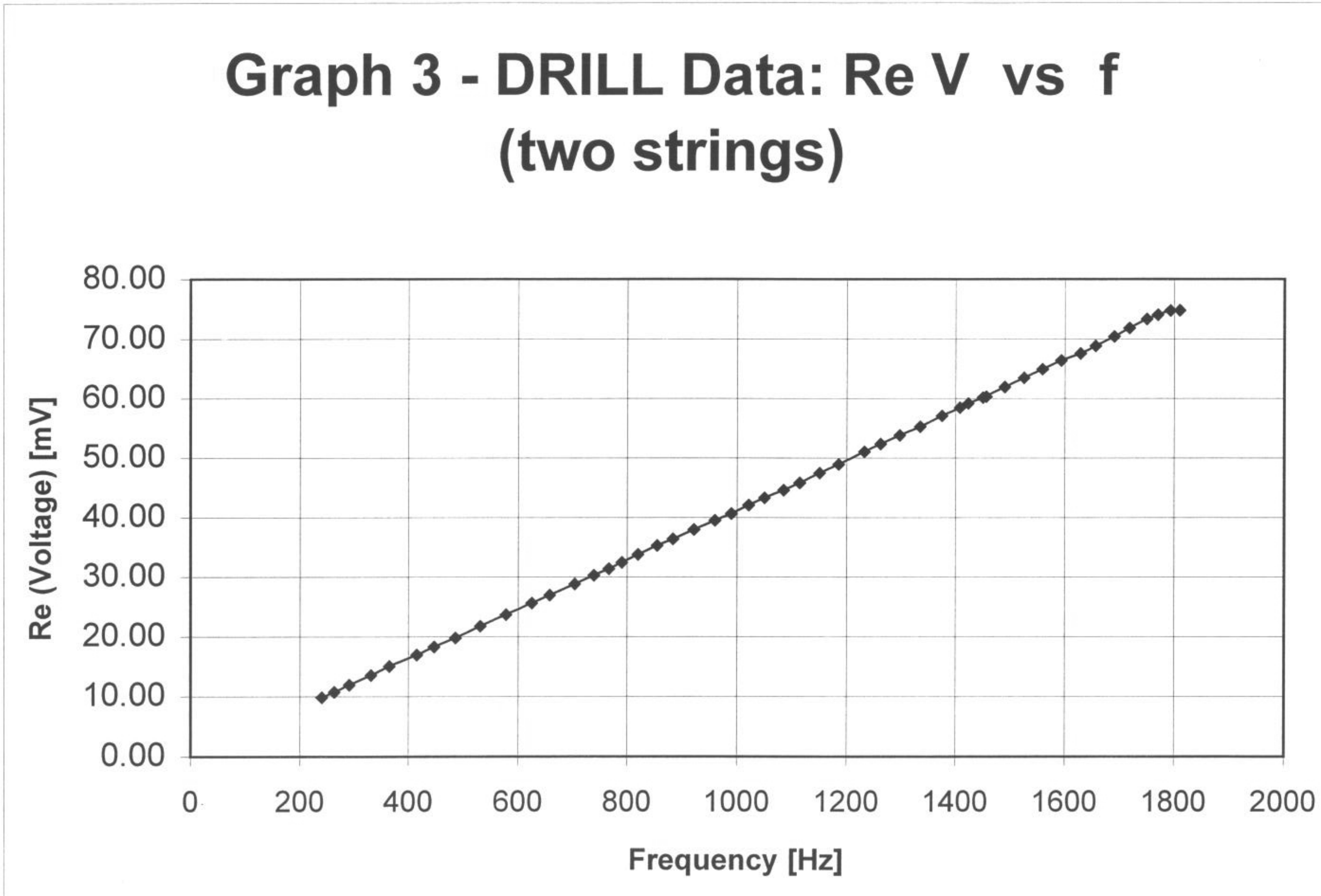
DAQ PROGRAM: DRILL1.prj

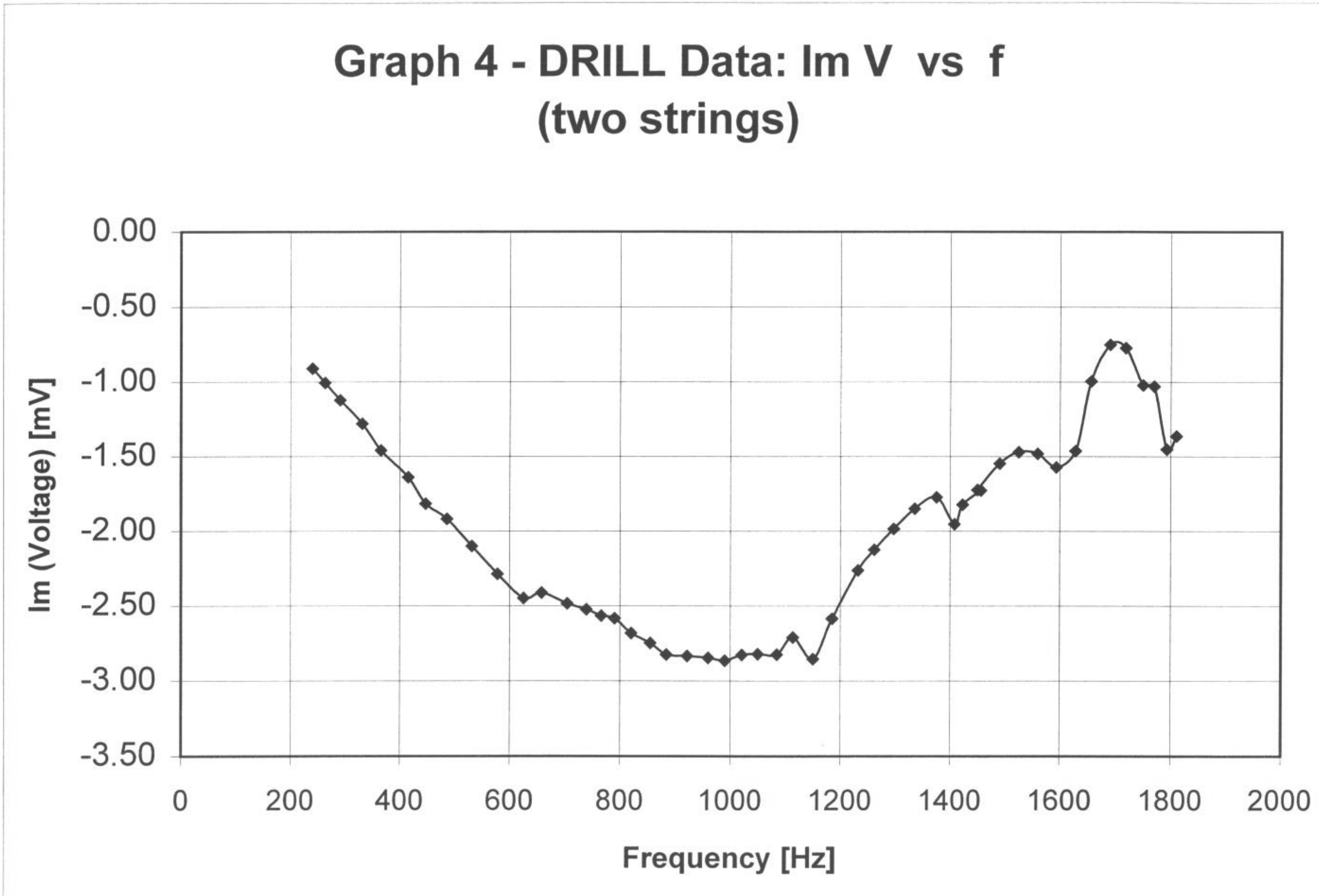
Date:
11/30/01
Time:
15:36:45
Number of Freq Measurements:
49
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
499.892
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
500
CURR LockIn Sensitivity (mV):
500

DRILL-1 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
240	9.86	-0.91	9.90	-5.28	~ 0.5
263	10.78	-1.01	10.83	-5.33	~ 0.5
291	11.96	-1.12	12.01	-5.36	~ 0.5
331	13.55	-1.28	13.61	-5.40	~ 0.5
365	15.08	-1.46	15.15	-5.53	~ 0.5
415	16.95	-1.64	17.03	-5.52	~ 0.5
447	18.29	-1.82	18.38	-5.67	~ 0.5
486	19.78	-1.92	19.87	-5.54	~ 0.5
531	21.78	-2.10	21.88	-5.51	~ 0.5
578	23.71	-2.29	23.82	-5.51	~ 0.5
625	25.64	-2.45	25.75	-5.45	~ 0.5
658	26.98	-2.41	27.09	-5.11	~ 0.5
704	28.80	-2.48	28.91	-4.93	~ 0.5
739	30.26	-2.52	30.37	-4.77	~ 0.5
766	31.37	-2.57	31.48	-4.67	~ 0.5
790	32.47	-2.58	32.57	-4.55	~ 0.5
820	33.79	-2.68	33.90	-4.54	~ 0.5
855	35.30	-2.75	35.41	-4.45	~ 0.5
884	36.39	-2.82	36.49	-4.44	~ 0.5
922	37.97	-2.83	38.08	-4.27	~ 0.5
960	39.51	-2.85	39.61	-4.12	~ 0.5

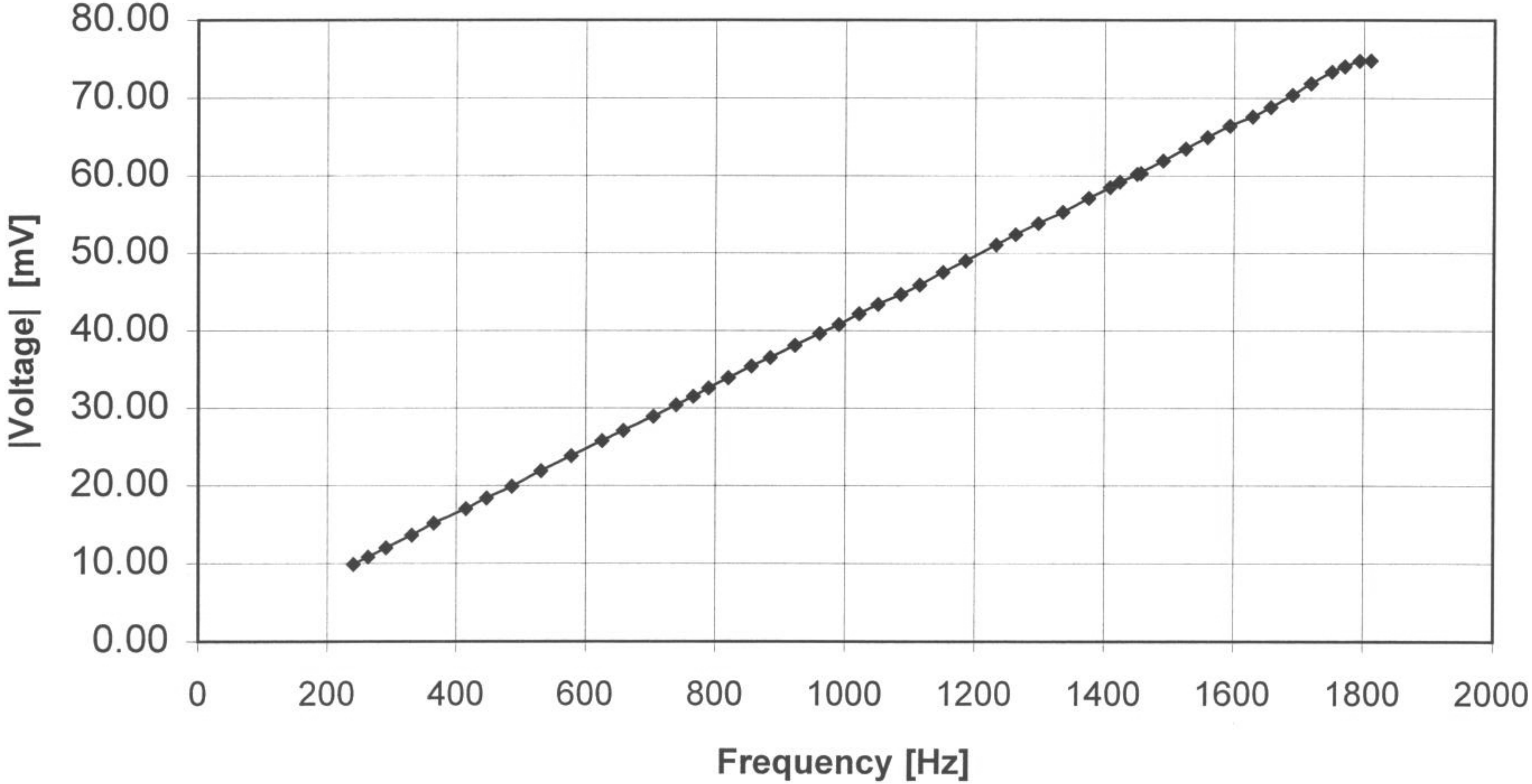
990	40.66	-2.86	40.76	-4.03	~ 0.5
1021	42.05	-2.83	42.15	-3.84	~ 0.5
1050	43.29	-2.82	43.38	-3.73	~ 0.5
1085	44.58	-2.82	44.67	-3.63	~ 0.5
1114	45.80	-2.71	45.88	-3.39	~ 0.5
1150	47.46	-2.85	47.55	-3.44	~ 0.5
1185	48.95	-2.58	49.02	-3.02	~ 0.5
1232	51.05	-2.26	51.10	-2.54	~ 0.5
1262	52.36	-2.12	52.40	-2.32	~ 0.5
1297	53.82	-1.98	53.86	-2.11	~ 0.5
1335	55.30	-1.85	55.33	-1.92	~ 0.5
1375	57.08	-1.77	57.11	-1.78	~ 0.5
1408	58.47	-1.95	58.50	-1.91	~ 0.5
1423	59.19	-1.82	59.22	-1.76	~ 0.5
1456	60.32	-1.73	60.34	-1.64	~ 0.5
1450	60.18	-1.72	60.21	-1.64	~ 0.5
1490	61.93	-1.55	61.95	-1.43	~ 0.5
1525	63.48	-1.47	63.50	-1.33	~ 0.5
1559	64.94	-1.48	64.96	-1.31	~ 0.5
1593	66.40	-1.57	66.42	-1.36	~ 0.5
1628	67.59	-1.46	67.61	-1.24	~ 0.5
1656	68.82	-0.99	68.83	-0.83	~ 0.5
1690	70.41	-0.75	70.41	-0.61	~ 0.5
1718	71.85	-0.77	71.85	-0.62	~ 0.5
1750	73.35	-1.02	73.36	-0.80	~ 0.5
1770	74.04	-1.03	74.04	-0.80	~ 0.5
1793	74.74	-1.45	74.75	-1.11	~ 0.5
1810	74.78	-1.36	74.80	-1.04	~ 0.5


Graph 3 - DRILL Data: Re V vs f
(two strings)
Re (Voltage) [mV]
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]



Graph 4 - DRILL Data: Im V vs f
(two strings)
Im (Voltage) [mV]
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
-3.50
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]

Graph 5 - DRILL Data: |V| vs f
(two strings)



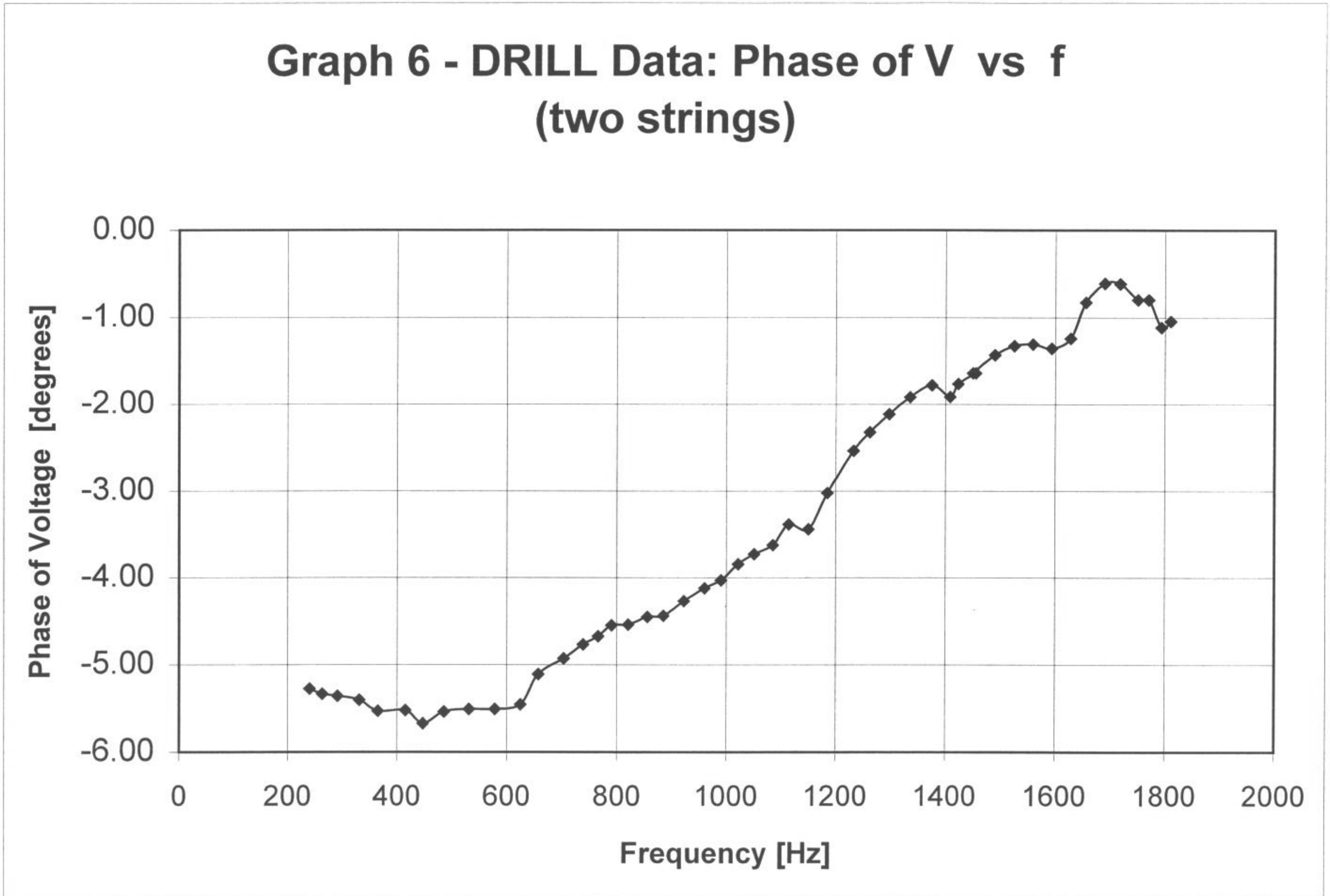

Graph 6 - DRILL Data: Phase of V vs f
(two strings)
Phase of Voltage [degrees]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]

TABLE 5

c:\cvi\P398EMI\Data\Pickup_Data\drill3_79mustang.dat

DAQ PROGRAM: DRILL1.prj

Date:
12/4/01
Time:
16:09:41
Number of Freq Measurements:
75
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
566.846
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
500
CURR LockIn Sensitivity (mV):
500

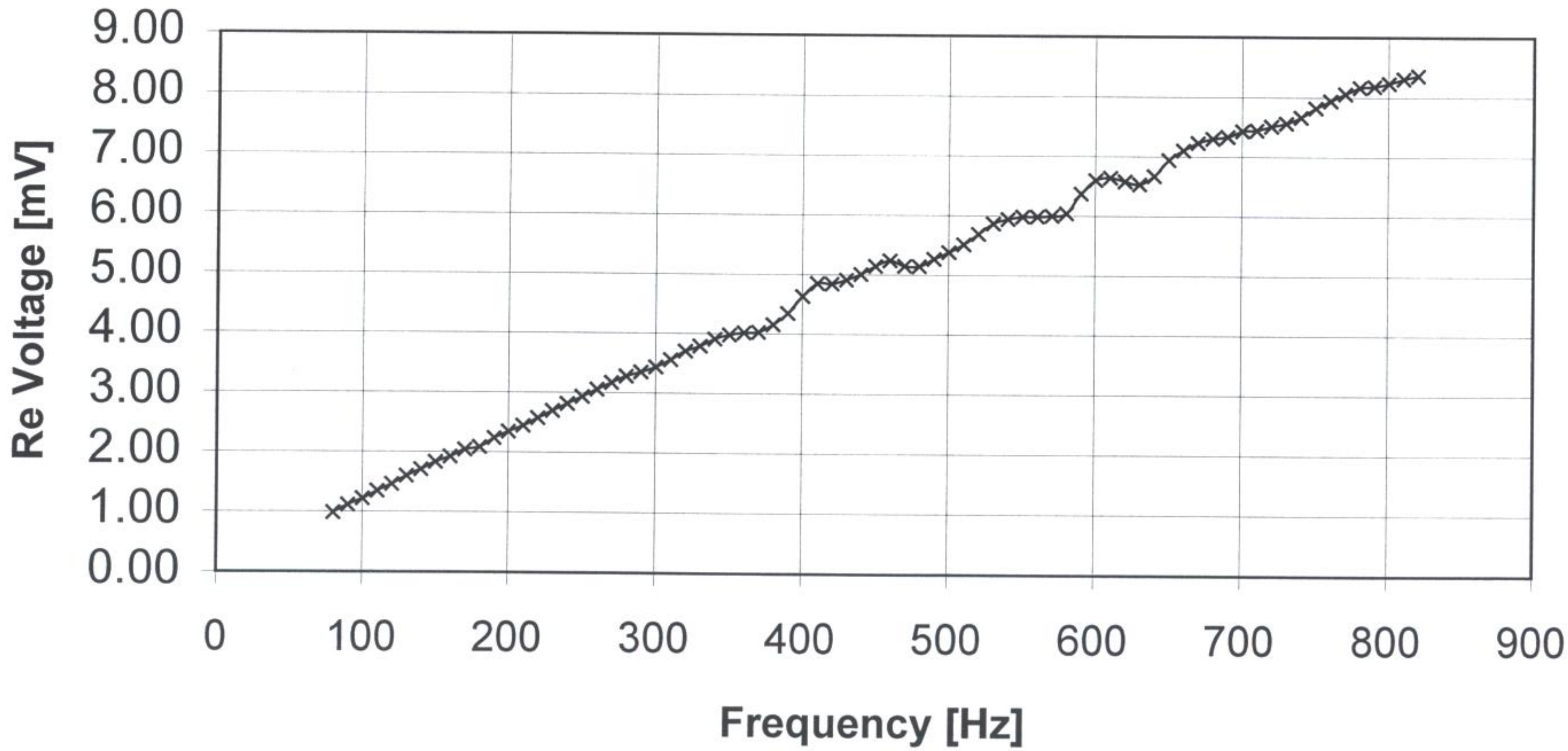
DRILL-1 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
80	0.98	1.94	2.18	63.14	~ 0.5
90	1.11	2.21	2.48	63.35	~ 0.5
100	1.22	2.42	2.71	63.33	~ 0.5
110	1.34	2.67	2.99	63.29	~ 0.5
120	1.46	2.92	3.26	63.43	~ 0.5
130	1.59	3.23	3.60	63.74	~ 0.5
140	1.70	3.40	3.80	63.41	~ 0.5
150	1.83	3.65	4.09	63.40	~ 0.5
160	1.92	3.89	4.34	63.75	~ 0.5
170	2.04	4.13	4.60	63.75	~ 0.5
180	2.08	4.30	4.78	64.17	~ 0.5
190	2.23	4.62	5.13	64.22	~ 0.5
200	2.34	4.87	5.40	64.32	~ 0.5
210	2.44	5.11	5.66	64.48	~ 0.5
220	2.57	5.36	5.95	64.40	~ 0.5
230	2.69	5.59	6.21	64.31	~ 0.5
240	2.81	5.84	6.49	64.30	~ 0.5
250	2.93	6.07	6.74	64.26	~ 0.5
260	3.05	6.32	7.02	64.22	~ 0.5
270	3.16	6.57	7.29	64.29	~ 0.5
280	3.28	6.81	7.56	64.32	~ 0.5

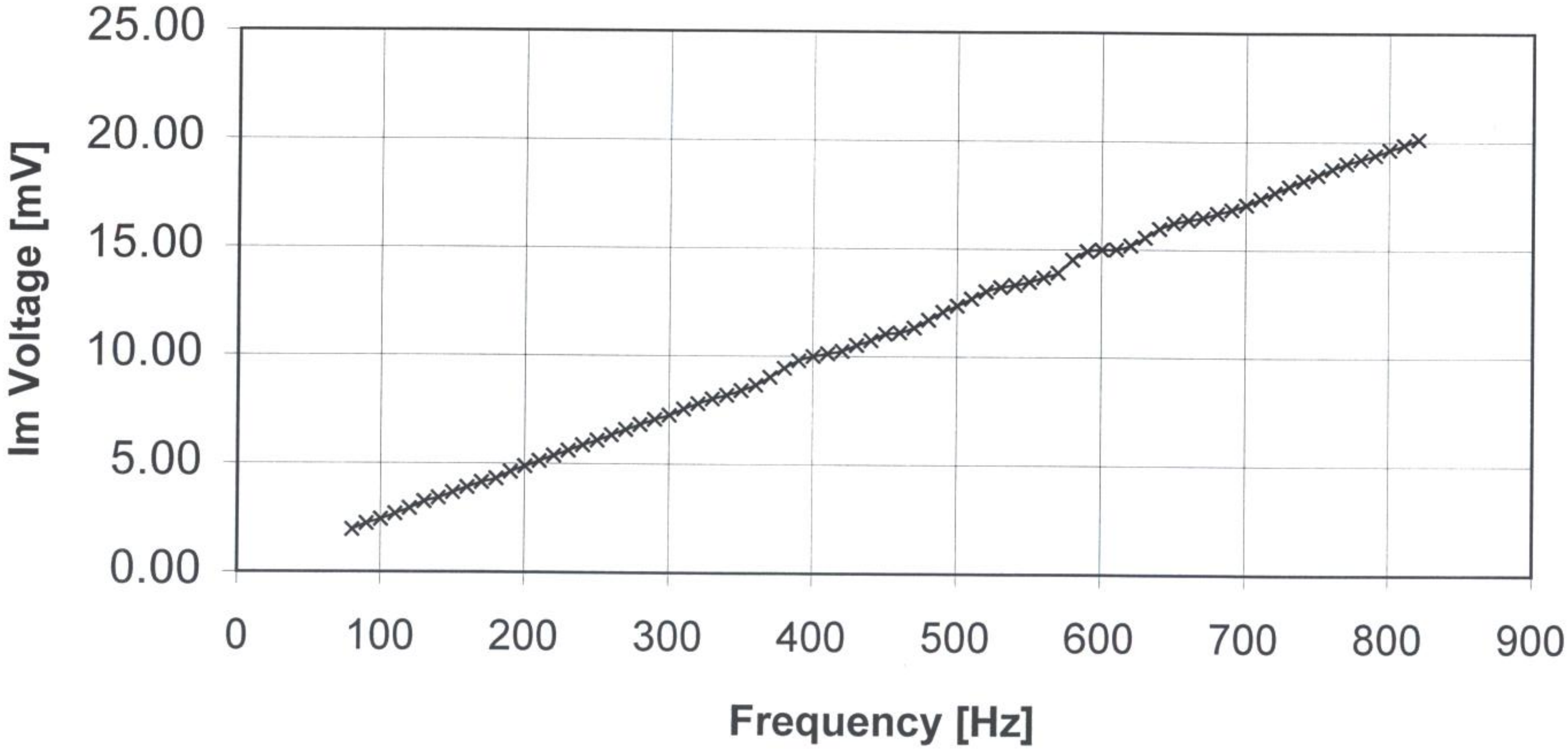
290	3.35	7.04	7.79	64.58	~ 0.5
300	3.43	7.24	8.01	64.64	~ 0.5
310	3.56	7.53	8.32	64.70	~ 0.5
320	3.70	7.78	8.62	64.55	~ 0.5
330	3.79	8.00	8.85	64.65	~ 0.5
340	3.91	8.17	9.06	64.46	~ 0.5
350	3.98	8.40	9.30	64.67	~ 0.5
360	4.01	8.65	9.53	65.10	~ 0.5
370	4.02	9.02	9.87	65.96	~ 0.5
380	4.15	9.43	10.31	66.23	~ 0.5
390	4.34	9.80	10.72	66.10	~ 0.5
400	4.63	10.00	11.01	65.17	~ 0.5
410	4.85	10.12	11.22	64.40	~ 0.5
420	4.84	10.24	11.33	64.70	~ 0.5
430	4.91	10.51	11.60	64.97	~ 0.5
440	5.00	10.75	11.85	65.03	~ 0.5
450	5.14	11.04	12.18	65.04	~ 0.5
460	5.23	11.10	12.27	64.75	~ 0.5
470	5.14	11.33	12.44	65.59	~ 0.5
480	5.14	11.70	12.78	66.28	~ 0.5
490	5.26	12.07	13.17	66.43	~ 0.5
500	5.38	12.35	13.47	66.47	~ 0.5
510	5.51	12.68	13.83	66.52	~ 0.5
520	5.69	13.03	14.22	66.42	~ 0.5
530	5.86	13.22	14.46	66.09	~ 0.5
540	5.94	13.32	14.59	65.98	~ 0.5
550	5.98	13.47	14.74	66.06	~ 0.5
560	5.98	13.68	14.93	66.38	~ 0.5
570	5.99	13.90	15.14	66.68	~ 0.5
580	6.04	14.51	15.72	67.42	~ 0.5
590	6.37	14.90	16.20	66.86	~ 0.5
600	6.60	14.98	16.37	66.24	~ 0.5
610	6.64	15.00	16.40	66.11	~ 0.5
620	6.58	15.18	16.54	66.57	~ 0.5
630	6.53	15.55	16.86	67.21	~ 0.5
640	6.67	15.95	17.29	67.31	~ 0.5
650	6.94	16.22	17.65	66.84	~ 0.5
660	7.10	16.37	17.84	66.55	~ 0.5
670	7.23	16.48	17.99	66.31	~ 0.5
680	7.30	16.68	18.20	66.36	~ 0.5
690	7.33	16.85	18.37	66.48	~ 0.5
700	7.43	17.08	18.62	66.48	~ 0.5
710	7.44	17.37	18.90	66.80	~ 0.5
720	7.51	17.65	19.18	66.96	~ 0.5
730	7.56	17.93	19.46	67.14	~ 0.5
740	7.66	18.21	19.75	67.18	~ 0.5
750	7.82	18.46	20.04	67.05	~ 0.5
760	7.93	18.74	20.35	67.06	~ 0.5
770	8.06	18.99	20.63	67.01	~ 0.5

780	8.16	19.19	20.85	66.96	~ 0.5
790	8.18	19.39	21.04	67.13	~ 0.5
800	8.23	19.64	21.29	67.26	~ 0.5
810	8.31	19.86	21.53	67.31	~ 0.5
820	8.36	20.12	21.79	67.44	~ 0.5

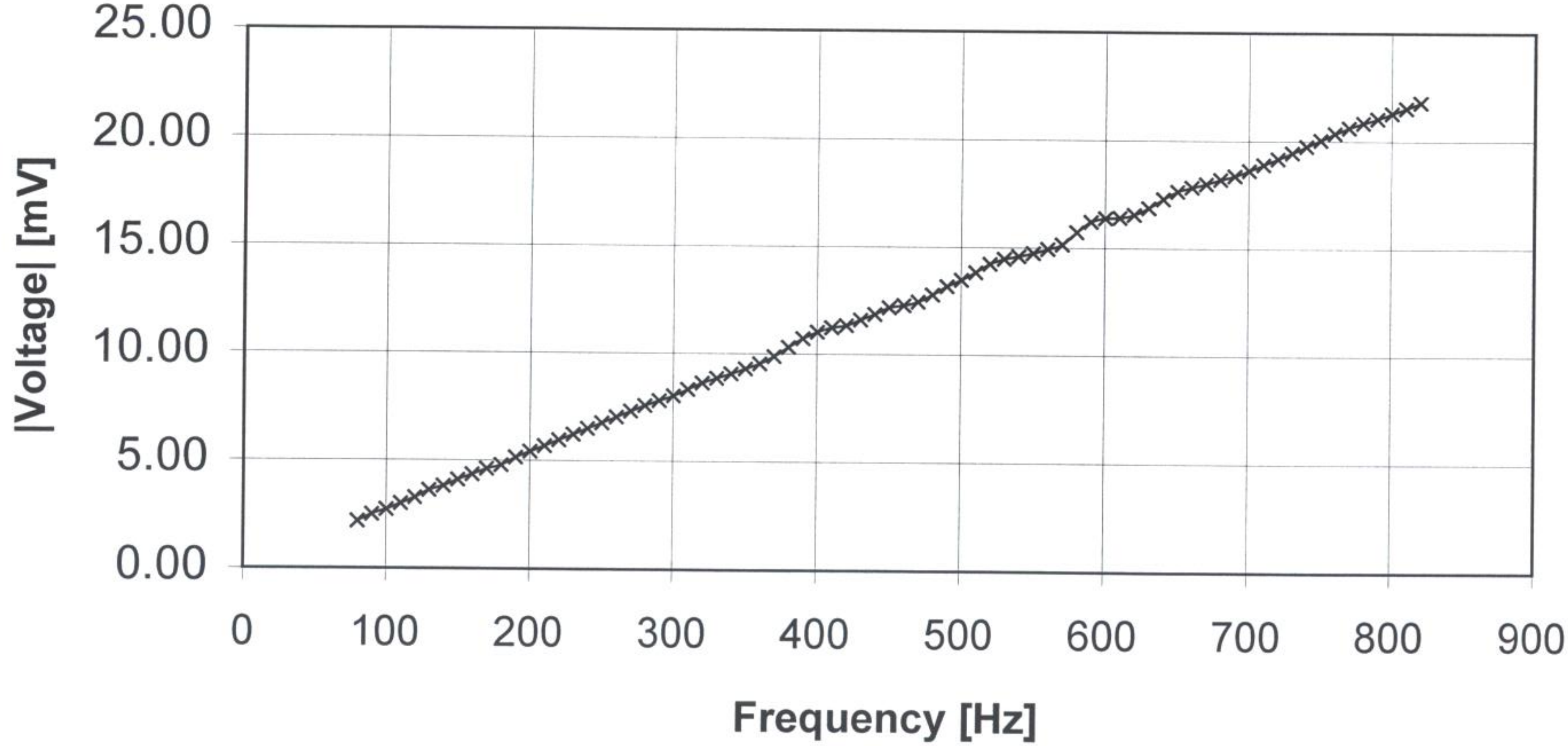
Graph 7 - DRILL Data: Re V vs f (single string)



Graph 8 - DRILL Data: Im V vs f (single string)



Graph 9 - DRILL Data: |V| vs f (single string)



Graph 10-DRILL Data: Phase of V vs f (single string)

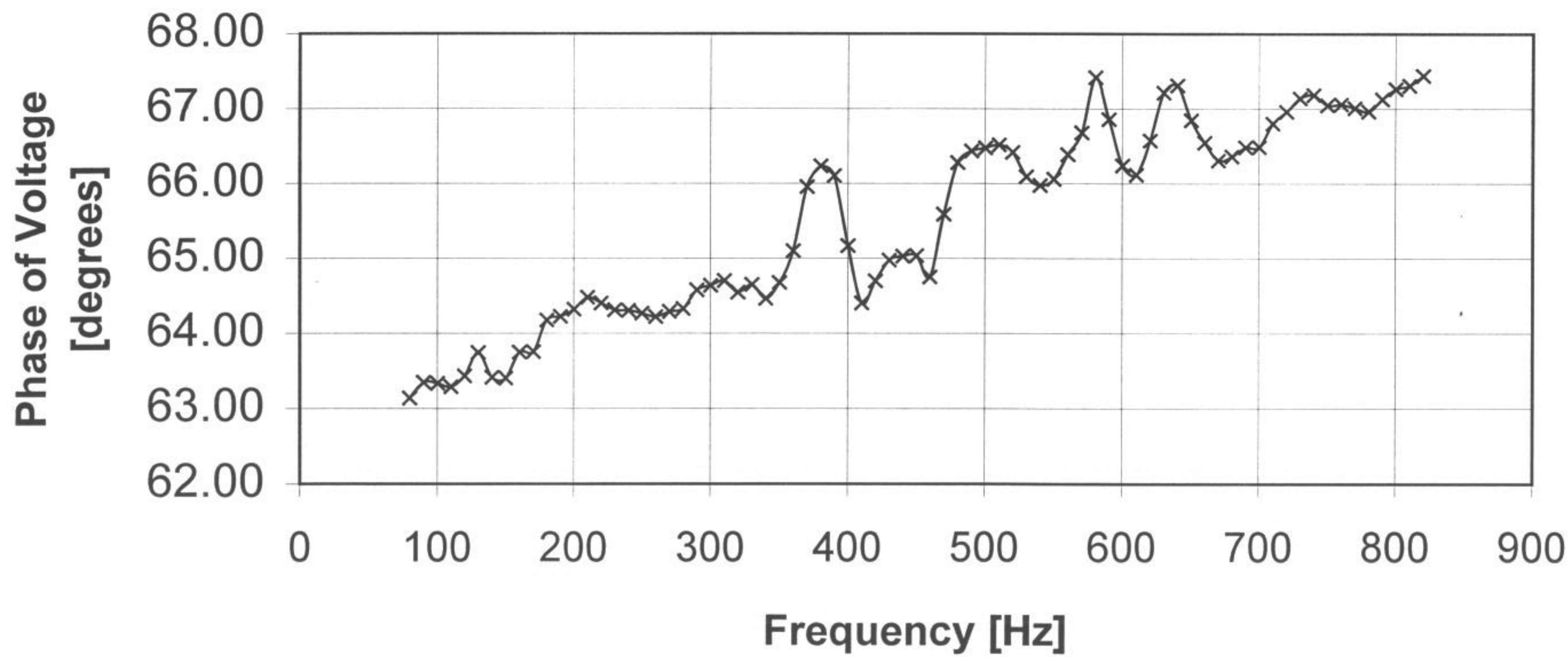


TABLE 6

c:\cvi\P398EMI\Data\Pickup_Data\Fender_1979_Mustang_PU.dat

DAQ PROGRAM: PICKUP2.prj

Date:
10/8/01
Time:
14:38:30
Number of Freq Measurements:
1995
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
11213.05
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
Nominal Freq Step Size (Hz):
10
Signal Gen Amplitude (Volts):
1
VOLT LockIn Sensitivity (mV):
1000
CURR LockIn Sensitivity (mV):
500

PICKUP-2 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**
10	2.532358	-0.031567	2.532555	-0.71419
20	2.520151	0.057544	2.520808	1.308037
30	2.499399	0.134082	2.502993	3.070729
40	2.481821	0.198169	2.48972	4.565279
50	2.482676	0.205249	2.491146	4.726038
60	2.442271	0.070605	2.443291	1.655946
70	2.490977	0.241626	2.502668	5.540386
80	2.486216	0.399585	2.518122	9.130504
90	2.502207	0.44585	2.541618	10.10308
100	2.585947	0.457568	2.626117	10.03429
110	2.581064	0.50188	2.629406	11.00367
120	2.597422	0.627979	2.672257	13.59158
130	2.597056	0.692798	2.687874	14.93656
140	2.588511	0.698413	2.681076	15.09957
150	2.581187	0.804858	2.703761	17.31838
160	2.494761	0.888599	2.64829	19.60518
170	2.591074	0.928271	2.752336	19.71044

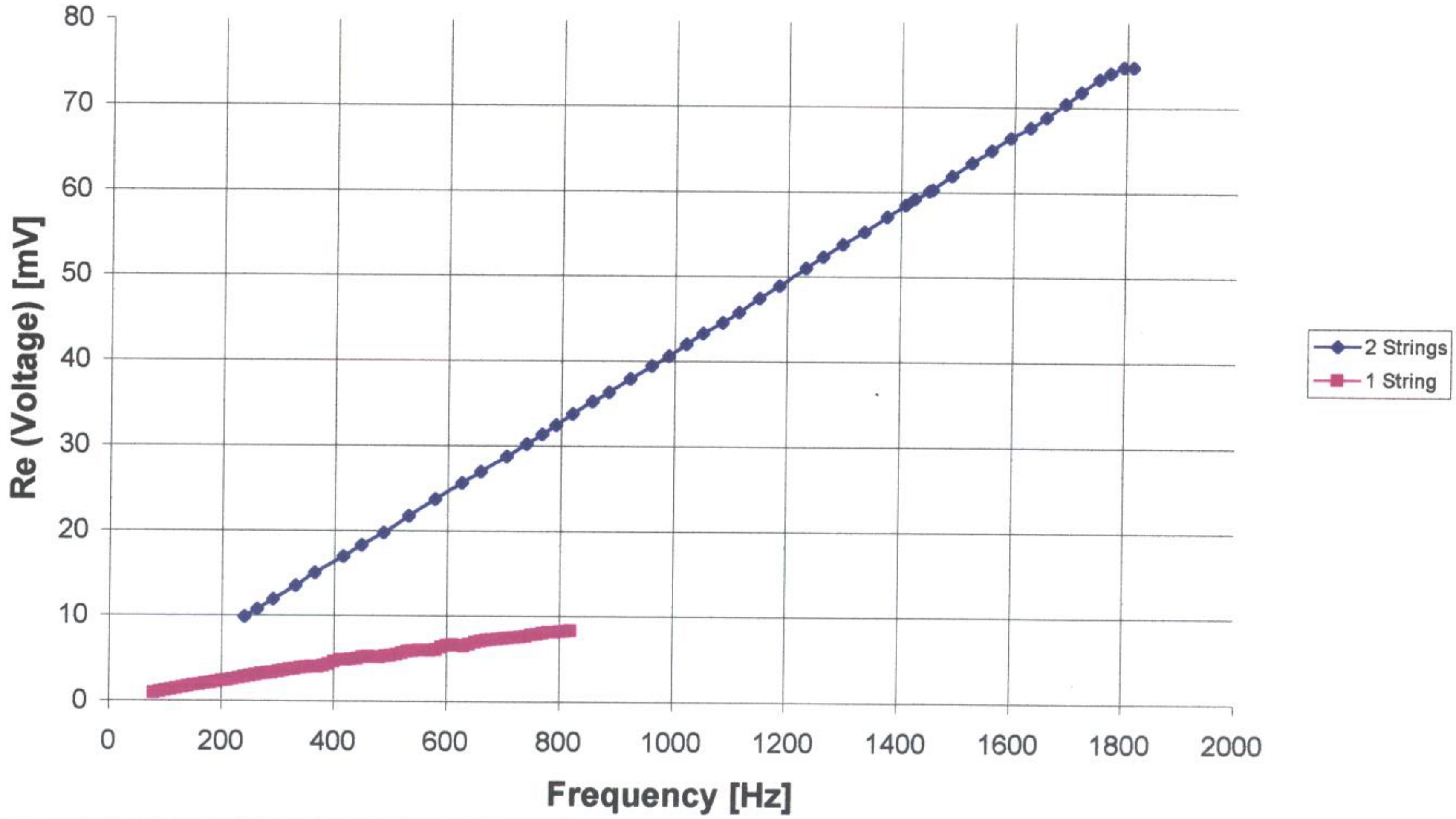
180	2.683481	0.941821	2.843959	19.33954
190	2.596079	1.01897	2.788893	21.43017
200	2.603647	1.152148	2.847179	23.87002
210	2.608774	1.180957	2.863628	24.35562
220	2.606089	1.184985	2.862846	24.45123
230	2.606943	1.288867	2.908149	26.30769
240	2.601694	1.364429	2.937768	27.67425
250	2.606089	1.418628	2.967188	28.56172
260	2.605112	1.434985	2.974188	28.84748
270	2.603037	1.466846	2.987882	29.40183
280	2.583018	1.622607	3.050383	32.13634
290	2.598398	1.666187	3.086722	32.66945
300	2.660044	1.664478	3.137885	32.03558
310	2.592051	1.685229	3.091719	33.03003
320	2.602549	1.84917	3.192599	35.39466
330	2.59144	1.913257	3.221198	36.4384
340	2.589365	1.911914	3.218731	36.44111
350	2.603281	1.975513	3.267985	37.19322
360	2.607188	2.048999	3.315995	38.16395
370	2.594858	2.15105	3.370505	39.65758
380	2.607065	2.16936	3.391595	39.76412
390	2.589609	2.197192	3.396135	40.31343
400	2.581797	2.275195	3.441248	41.38795
410	2.597178	2.3698	3.515862	42.37895
420	2.599497	2.405322	3.541604	42.77818
430	2.655894	2.417651	3.591491	42.3115
440	2.660898	2.486377	3.641765	43.0581
450	2.659434	2.631274	3.741148	44.69505
460	2.658945	2.644214	3.749914	44.84084
470	2.660166	2.681812	3.77738	45.23216
480	2.597178	2.764941	3.793446	46.79202
490	2.654551	2.786182	3.848305	46.38592
500	2.652476	2.886157	3.919889	47.41595
510	2.655283	2.895557	3.928712	47.47856
520	2.66041	3.011646	4.018431	48.54345
530	2.654429	3.074878	4.062126	49.19717
540	2.662241	3.134814	4.112735	49.66042
550	2.663462	3.147998	4.123581	49.76607
560	2.662241	3.18645	4.152227	50.12165
570	2.663828	3.328662	4.263329	51.33076
580	2.68397	3.375659	4.312629	51.51197
590	2.685312	3.381885	4.318339	51.54943
600	2.684946	3.466357	4.384583	52.23961
610	2.684214	3.576709	4.471896	53.11286
620	2.68397	3.623462	4.509232	53.47192
630	2.683604	3.623584	4.509112	53.47658
640	2.684824	3.684009	4.558531	53.91626
650	2.68519	3.837573	4.683718	55.01911
660	2.684946	3.861133	4.702902	55.1861

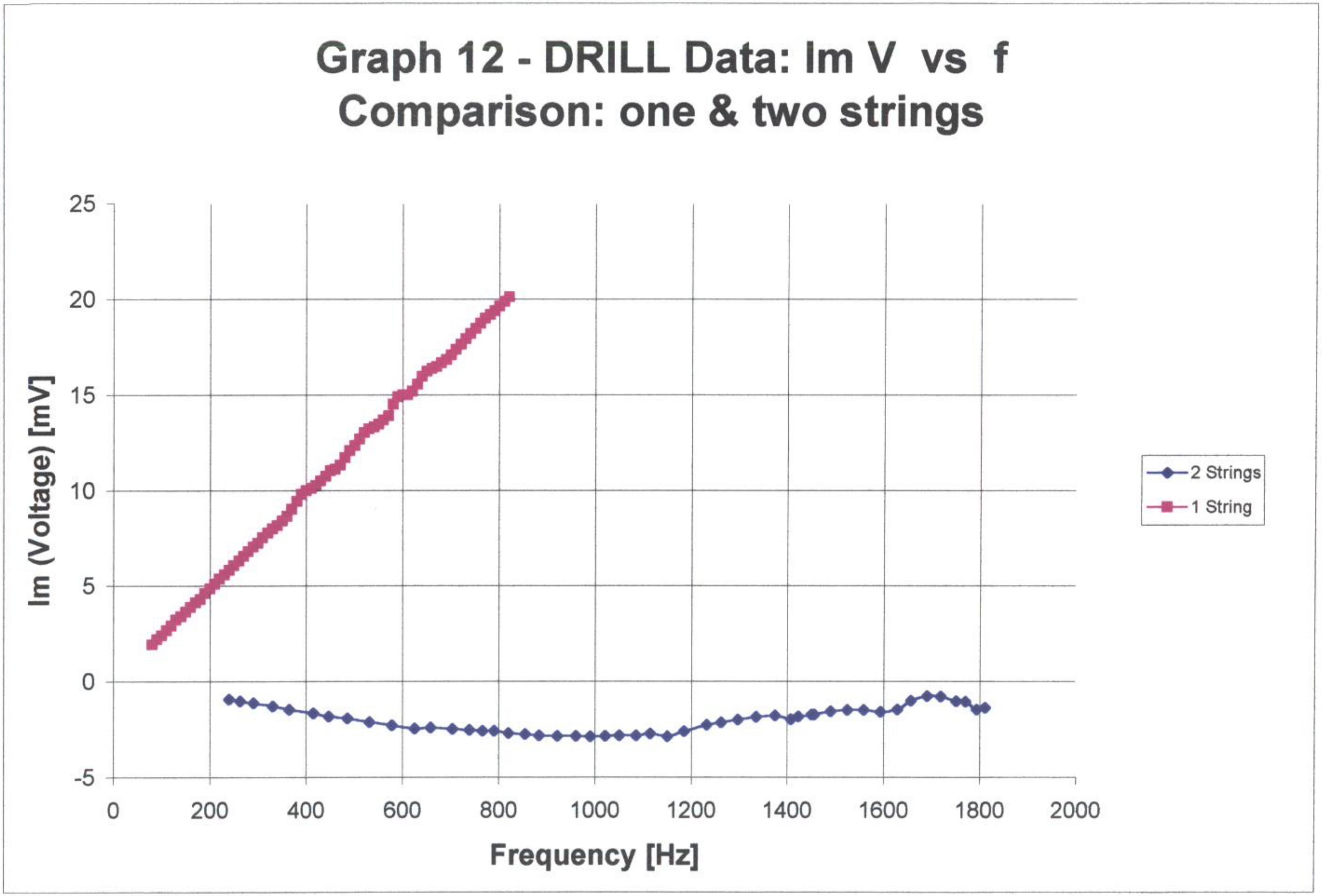
670	2.685679	3.899707	4.735038	55.44531
680	2.685557	3.892627	4.729139	55.39787
690	2.68458	4.033618	4.845312	56.3542
700	2.692148	4.110889	4.913967	56.77992
710	2.690806	4.115405	4.917011	56.82184
720	2.689463	4.128467	4.927215	56.91803
730	2.690317	4.179614	4.970612	57.23159
740	2.69105	4.32854	5.096863	58.13082
750	2.687998	4.353442	5.116424	58.30708
760	2.690562	4.395801	5.153852	58.53023
770	2.691294	4.490527	5.235255	59.06461
780	2.690684	4.558765	5.293592	59.44996
790	2.691538	4.601123	5.330545	59.67347
800	2.690928	4.618091	5.344891	59.77096
810	2.691294	4.781665	5.48702	60.62762
820	2.718394	4.825977	5.538927	60.60815
830	2.720103	4.844775	5.55615	60.68794
840	2.721445	4.906543	5.610742	60.98478
850	2.710825	4.975024	5.665637	61.41462
860	2.707773	5.081958	5.758327	61.95038
870	2.714609	5.08916	5.767899	61.92409
880	2.717417	5.096118	5.775359	61.932
890	2.712534	5.221484	5.884024	62.54836
900	2.725474	5.313647	5.971855	62.84583
910	2.723032	5.337085	5.991609	62.96889
920	2.716196	5.354419	6.003959	63.10217
930	2.722056	5.449268	6.091314	63.45664
940	2.723643	5.568652	6.199042	63.93662
950	2.710947	5.575244	6.199402	64.06879
960	2.713755	5.611499	6.233248	64.19131
970	2.713511	5.678149	6.293212	64.4575
980	2.71229	5.757739	6.364596	64.77635
990	2.712656	5.820728	6.421789	65.01289
1000	2.740732	5.833423	6.445187	64.83433
1010	2.783579	5.981006	6.597025	65.04258
1020	2.78126	6.035938	6.645897	65.26054
1030	2.778574	6.065845	6.671952	65.38896
1040	2.793955	6.091479	6.701665	65.36068
1050	2.79188	6.144214	6.748775	65.56335
1060	2.789561	6.288501	6.879454	66.07807
1070	2.791392	6.309375	6.899281	66.13446
1080	2.789438	6.348926	6.934683	66.28143
1090	2.871104	6.417285	7.030276	65.89618
1100	2.888315	6.520801	7.131845	66.10959
1110	2.887949	6.554736	7.162738	66.22221
1120	2.880503	6.565723	7.169799	66.31206
1130	2.886118	6.715137	7.309086	66.74231
1140	2.890513	6.778003	7.368608	66.90394
1150	2.877329	6.793384	7.377607	67.04498

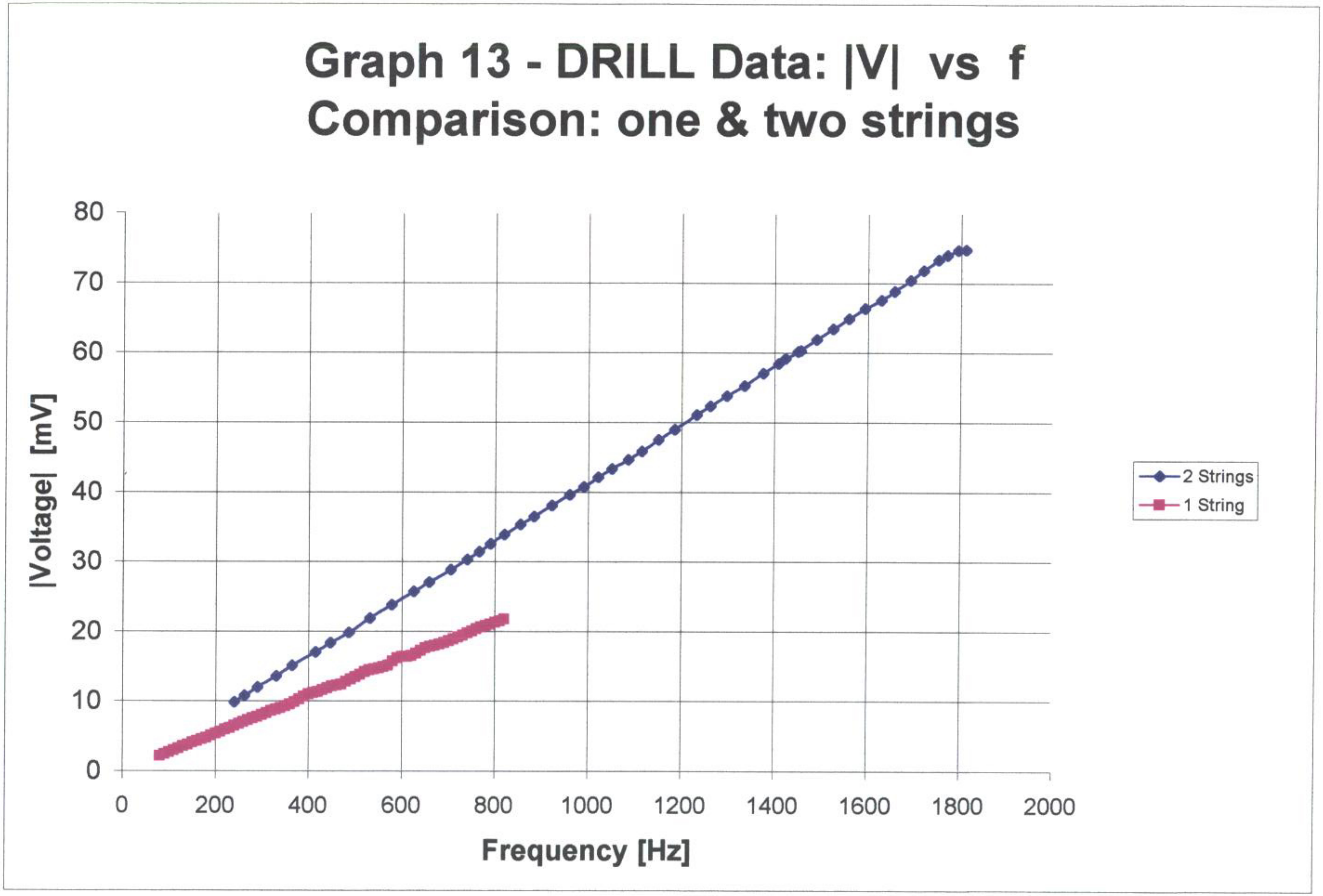
1160	2.882456	6.840747	7.423232	67.15111
1170	2.922983	6.928149	7.519514	67.12514
1180	2.920176	7.033008	7.615158	67.45128
1190	2.917979	7.040576	7.621306	67.48836
1200	2.918589	7.048633	7.628983	67.50729
1210	2.920664	7.169482	7.74156	67.83527
1220	2.919687	7.233569	7.800583	68.01951
1230	2.92042	7.285449	7.848989	68.1563
1240	2.91981	7.303149	7.865194	68.2084
1250	2.920176	7.401294	7.956543	68.46832
1260	2.917734	7.502002	8.049423	68.74758
1270	2.924937	7.52959	8.077746	68.7709
1280	2.921152	7.575854	8.119526	68.914
1290	2.920908	7.655688	8.193978	69.11643
1300	2.922007	7.768848	8.300188	69.38779
1310	2.92103	7.772754	8.303501	69.40359
1320	2.931162	7.790698	8.323863	69.38176
1330	2.932505	7.928027	8.453	69.70103
1340	2.932505	7.997485	8.518178	69.86311
1350	2.932749	8.01897	8.538436	69.9112
1360	2.931772	8.029102	8.547617	69.94067
1370	2.932871	8.150684	8.662296	70.20968
1380	2.949595	8.232959	8.745383	70.28909
1390	2.947275	8.258472	8.768625	70.35958
1400	2.94459	8.270435	8.778992	70.40233
1410	2.946421	8.312793	8.819519	70.48343
1420	2.943857	8.465625	8.962874	70.82527
1430	2.943979	8.499438	8.994858	70.89528
1440	2.948008	8.508472	9.004712	70.88987
1450	3.007944	8.582446	9.09429	70.68564
1460	2.993662	8.657397	9.160379	70.925
1470	3.007334	8.749683	9.252081	71.03176
1480	3.001353	8.760303	9.260185	71.08811
1490	3.005259	8.87334	9.368444	71.28958
1500	3.01356	8.911548	9.407296	71.31634
1510	3.014536	8.990649	9.482574	71.46386
1520	3.015391	9.017383	9.508195	71.51019
1530	3.010264	9.06377	9.550581	71.62762
1540	3.001108	9.209766	9.686405	71.9512
1550	3.015879	9.237598	9.717445	71.91924
1560	3.013682	9.270312	9.74787	71.9912
1570	3.00001	9.336353	9.806505	72.18646
1580	3.102061	9.448413	9.944611	71.82419
1590	3.089487	9.484424	9.97493	71.95733
1600	3.084849	9.494189	9.982781	72
1610	3.090586	9.632739	10.11639	72.21159
1620	3.094126	9.702808	10.18421	72.31305
1630	3.085215	9.731616	10.20896	72.40982
1640	3.14625	9.74541	10.2407	72.10762

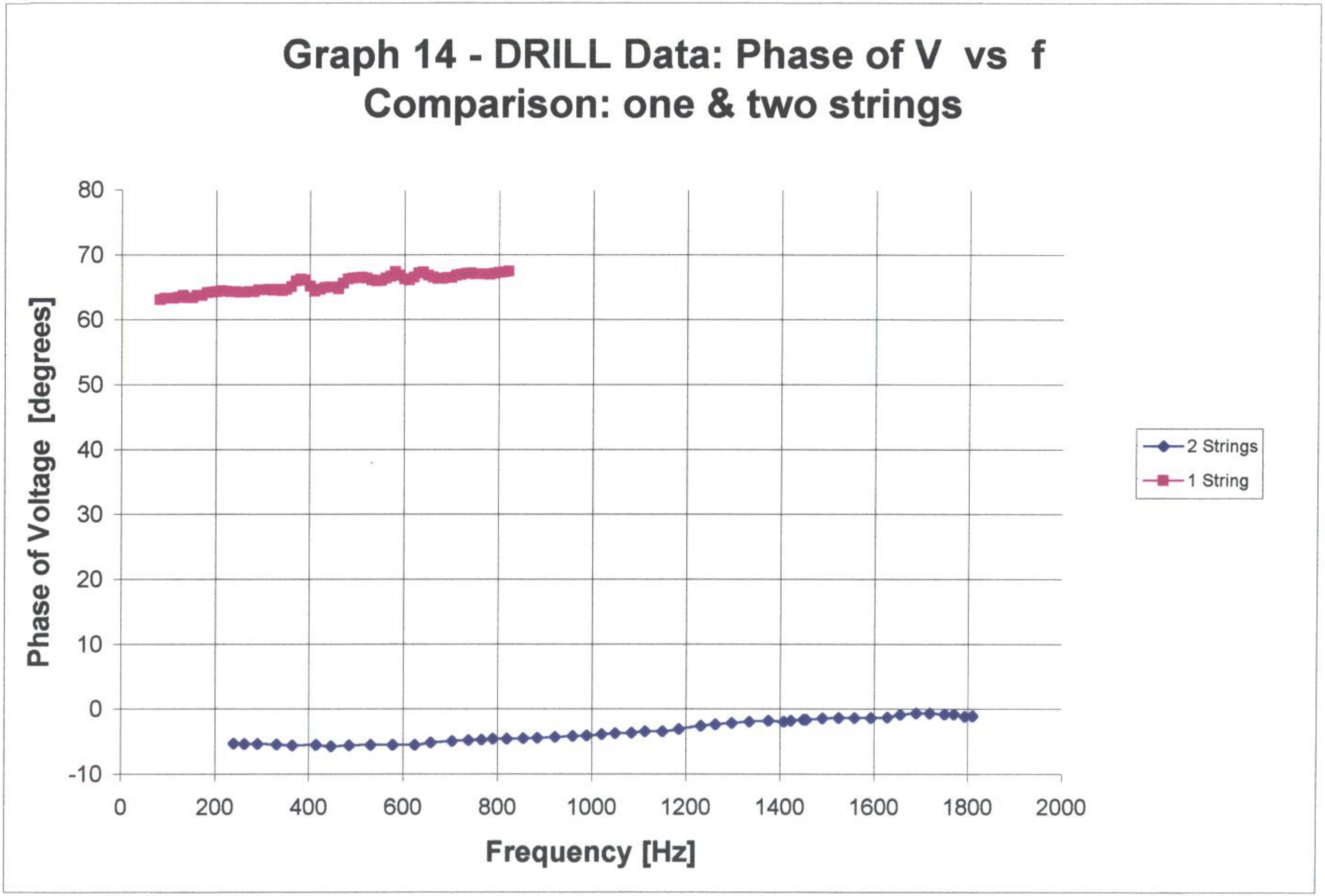
1650	3.147837	9.8073	10.3001	72.20499
1660	3.15687	9.958545	10.44694	72.41133
1670	3.149668	9.970264	10.45593	72.46835
1680	3.151865	9.985645	10.47126	72.48224
1690	3.172617	10.07732	10.56494	72.52457
1700	3.173594	10.19927	10.68161	72.716
1710	3.171274	10.21416	10.69514	72.75157
1720	3.174082	10.27092	10.75019	72.82698
1730	3.174448	10.37432	10.84913	72.98636
1740	3.172007	10.4395	10.91077	73.09878
1750	3.179819	10.46282	10.93535	73.09513
1760	3.179697	10.48723	10.95867	73.13285
1770	3.180674	10.648	11.1129	73.36854
1780	3.179697	10.68999	11.15286	73.43509
1790	3.180063	10.71257	11.17462	73.4663
1800	3.180674	10.85955	11.31576	73.67512
1810	3.181284	10.91985	11.37382	73.75755
1820	3.178477	10.94133	11.39366	73.80133
1830	3.180186	10.94988	11.40234	73.80506
1840	3.179819	11.03276	11.48186	73.92217
1850	3.201548	11.07134	11.52495	73.87148
1860	3.19459	11.18303	11.63038	74.05727
1870	3.193979	11.20098	11.64746	74.0844
1880	3.201792	11.26397	11.71018	74.13215
1890	3.201426	11.41228	11.85282	74.32988
1900	3.264292	11.43291	11.88979	74.06505
1910	3.277598	11.47625	11.93511	74.06074
1920	3.269053	11.54326	11.99723	74.18787
1930	3.260508	11.61492	12.06388	74.31965
1940	3.279429	11.6812	12.13281	74.31823
1950	3.361582	11.69988	12.17322	73.96971
1960	3.359995	11.84966	12.31682	74.16921
1970	3.346934	11.90227	12.3639	74.29395
1980	3.342051	11.92595	12.38538	74.34535
1990	3.362803	11.94854	12.41273	74.28124
2000	3.363657	12.08977	12.54897	74.45219
2010	3.353892	12.14202	12.59671	74.55868
2020	3.364023	12.17595	12.63212	74.55536
2030	3.362314	12.20769	12.66226	74.60106
2040	3.410532	12.38335	12.84442	74.60177
2050	3.409312	12.41362	12.87328	74.64278
2060	3.404062	12.41277	12.87107	74.66431
2070	3.408335	12.46904	12.92648	74.71201
2080	3.418467	12.5418	12.99933	74.75349
2090	3.418345	12.64934	13.10309	74.87766
2100	3.418833	12.67852	13.13138	74.90882
2110	3.418467	12.74553	13.196	74.98611
2120	3.430063	12.88945	13.33804	75.09815
2130	3.427744	12.89995	13.34759	75.11936

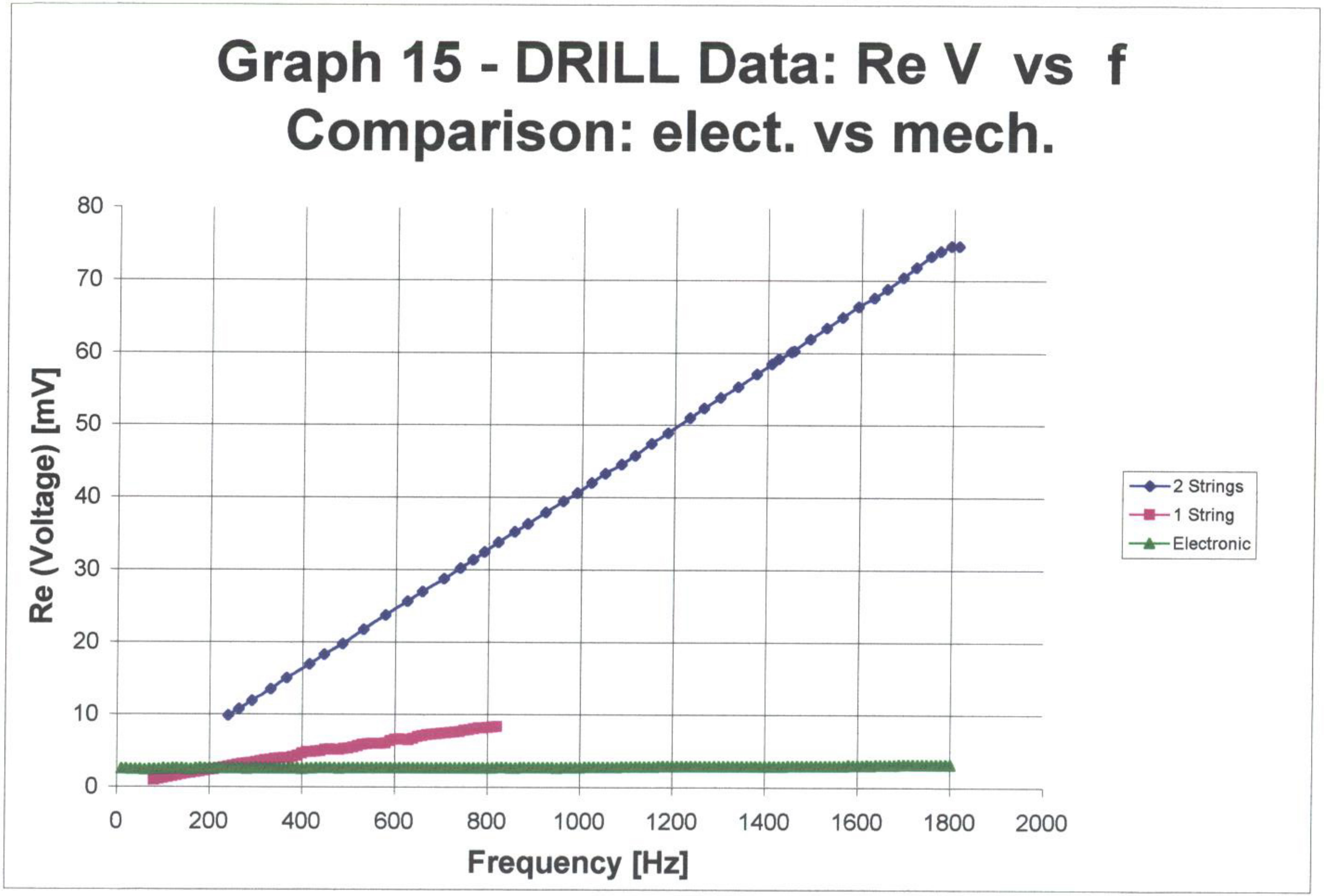
Graph 11 - DRILL Data: Re V vs f
Comparison: one & two strings

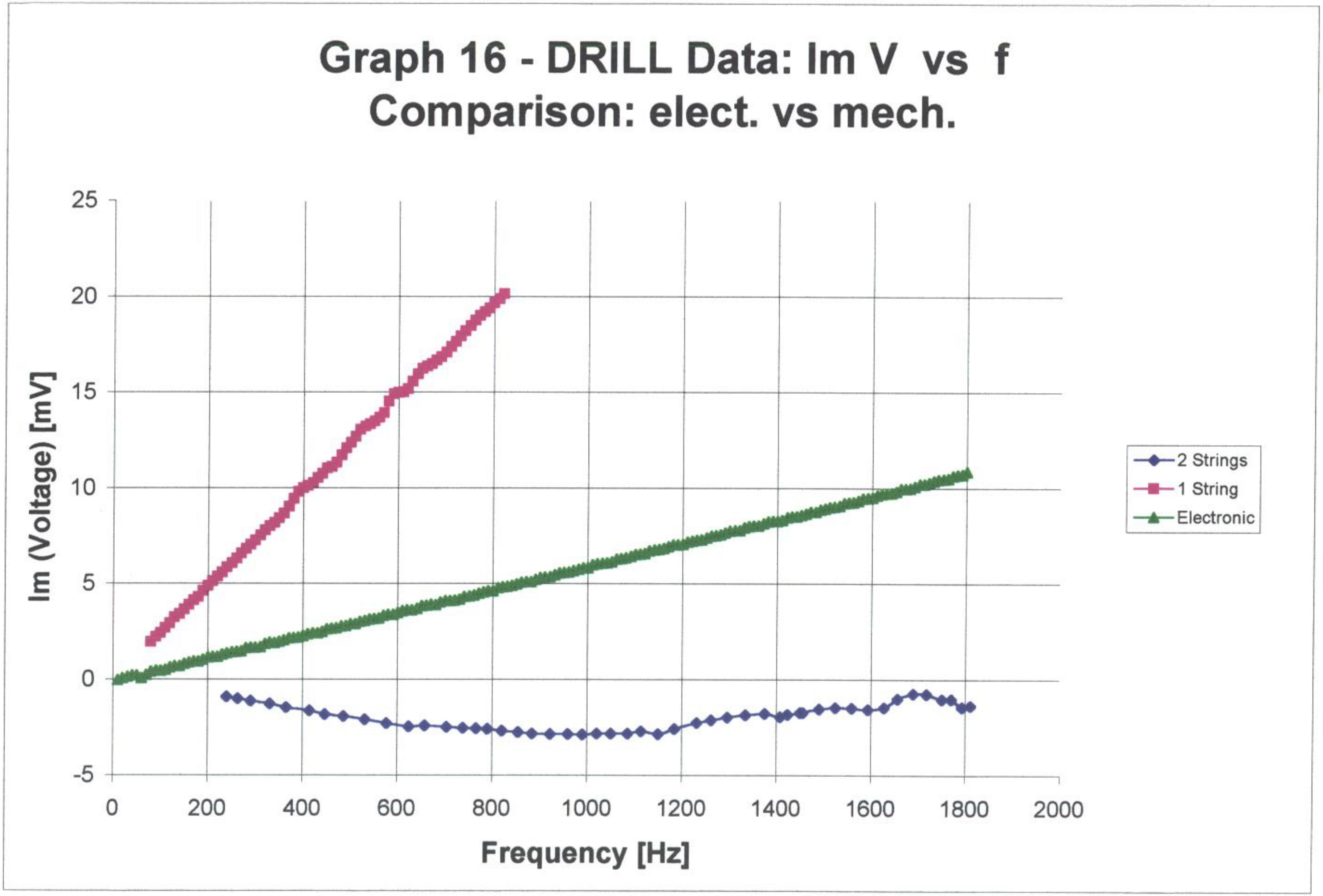


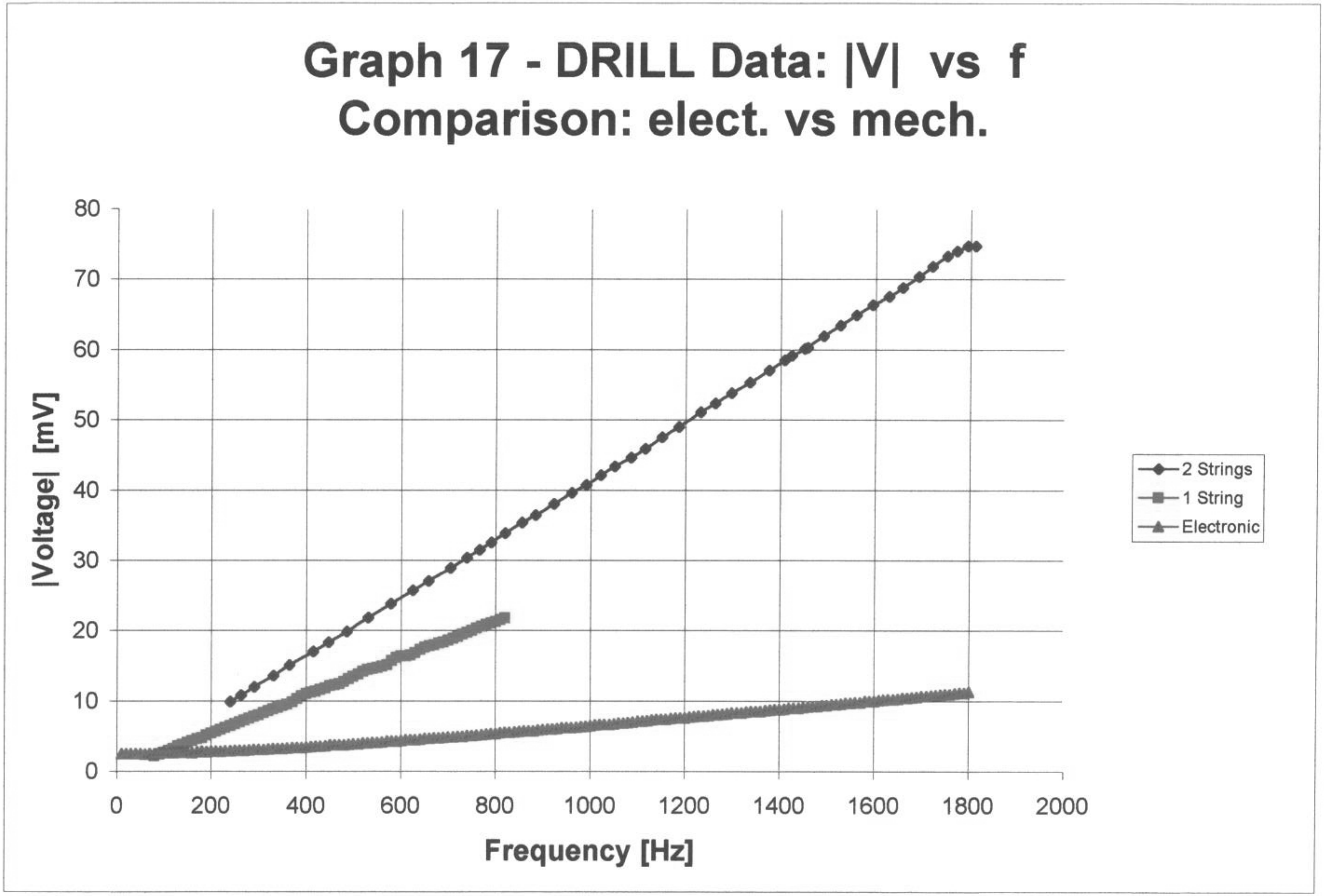

Graph 12 - DRILL Data: Im V vs f
Comparison: one & two strings
Im (Voltage) [mV]
25
20
15
10
5
0
-5
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]
2 Strings
1 String

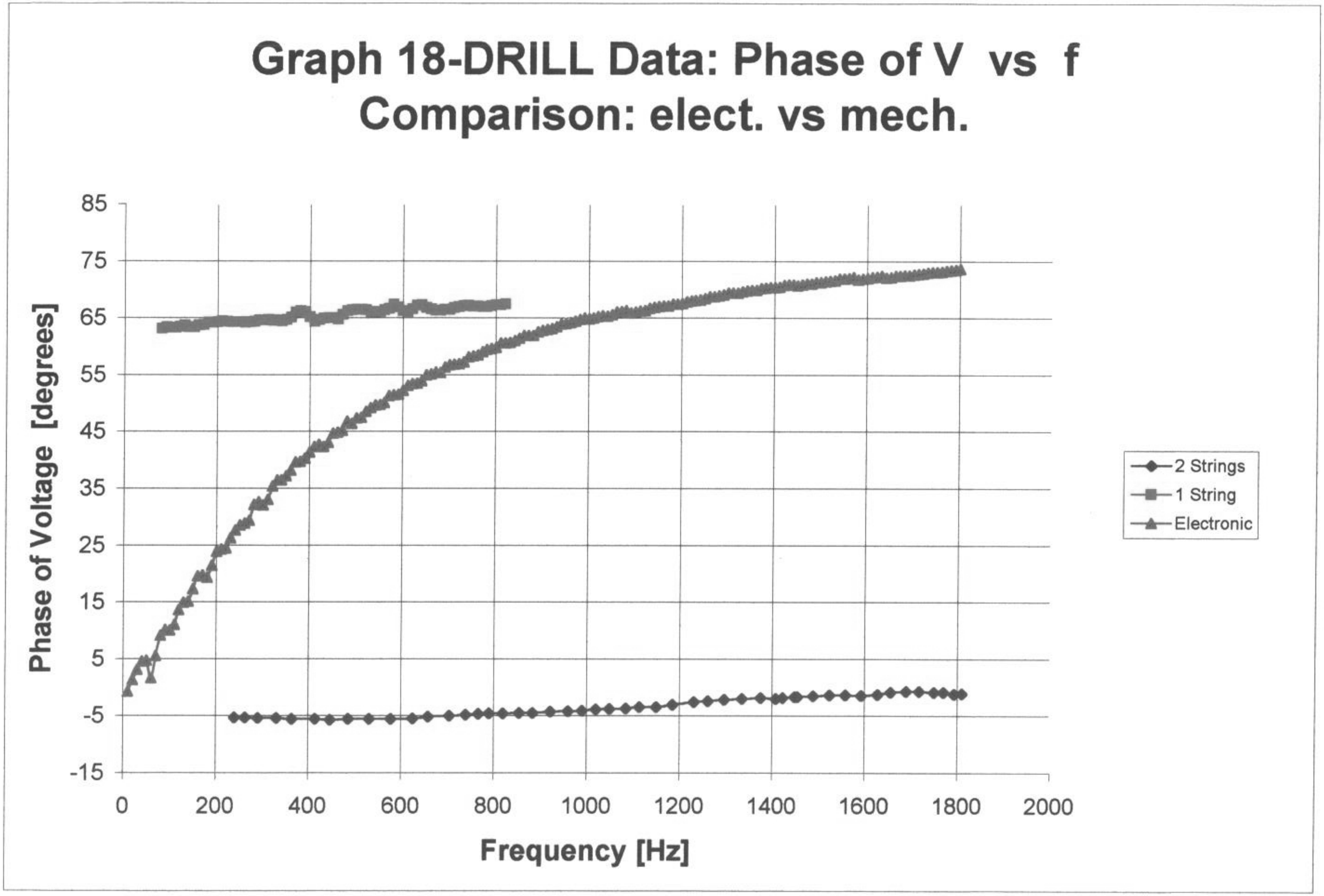

Graph 13 - DRILL Data: |V| vs f
Comparison: one & two strings
|Voltage| [mV]
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]
2 Strings
1 String


Graph 14 - DRILL Data: Phase of V vs f
Comparison: one & two strings
Phase of Voltage [degrees]
80
70
60
50
40
30
20
10
0
-10
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]
2 Strings
1 String


Graph 15 - DRILL Data: Re V vs f
Comparison: elect. vs mech.
Re (Voltage) [mV]
0
10
20
30
40
50
60
70
80
Frequency [Hz]
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2 Strings
1 String
Electronic


Graph 16 - DRILL Data: Im V vs f
Comparison: elect. vs mech.
Im (Voltage) [mV]
25
20
15
10
5
0
-5
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]
2 Strings
1 String
Electronic


Graph 17 - DRILL Data: |V| vs f
Comparison: elect. vs mech.
|Voltage| [mV]
80
70
60
50
40
30
20
10
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]
2 Strings
1 String
Electronic


Graph 18-DRILL Data: Phase of V vs f
Comparison: elect. vs mech.
Phase of Voltage [degrees]
85
75
65
55
45
35
25
15
5
-5
-15
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Frequency [Hz]
2 Strings
1 String
Electronic

c:\cvi\P398EMI\Data\Pickup_Data\drill_03_06_1.dat

DAQ PROGRAM: DRILL1.prj

Date:
37321
Time:
1
Number of Freq Measurements:
75
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
860
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
500
CURR LockIn Sensitivity (mV):
500

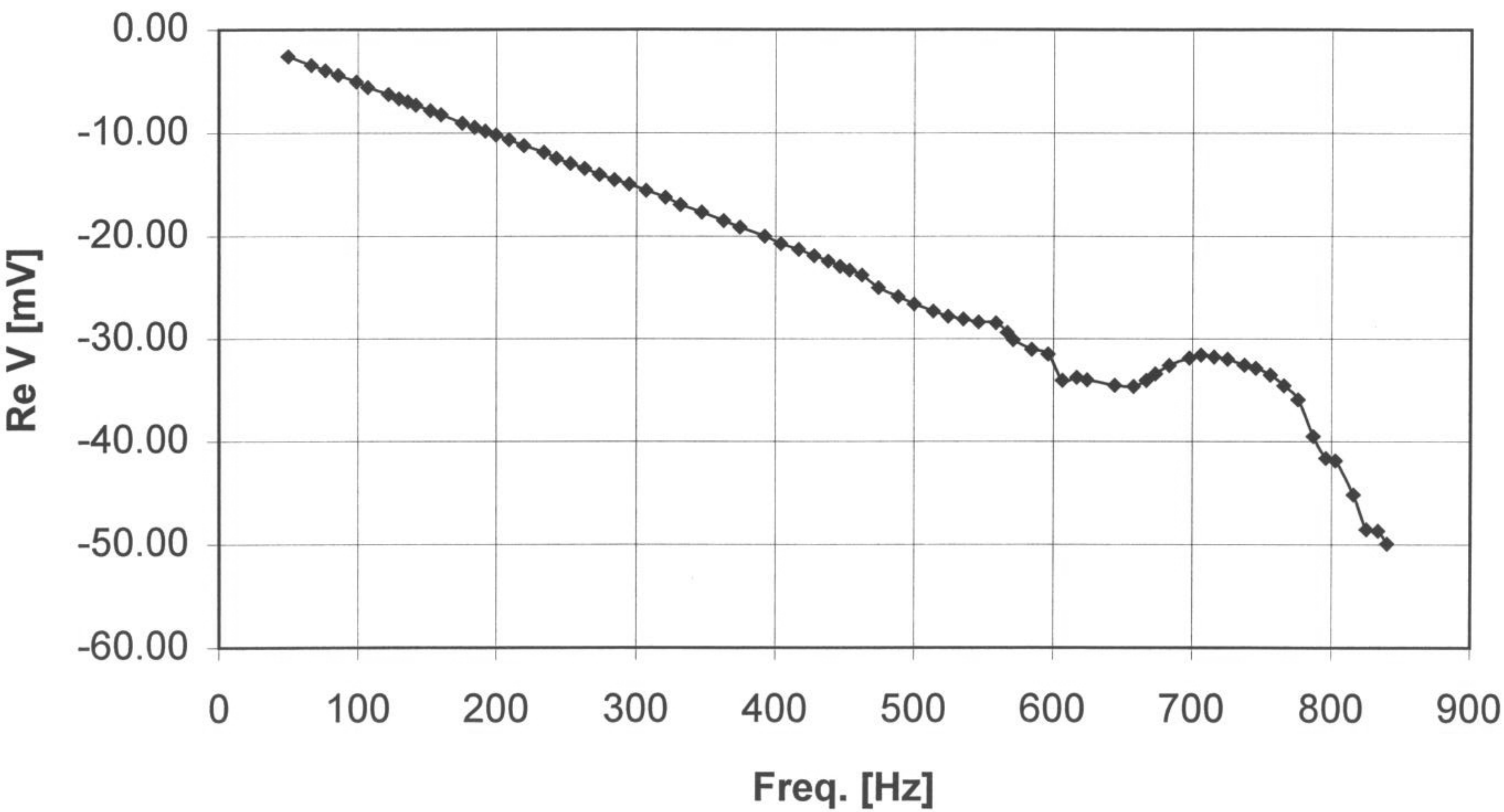
DRILL-1 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
50	-2.59	3.02	3.98	130.63	~ 0.5
66	-3.44	4.01	5.28	130.62	~ 0.5
76	-3.94	4.62	6.07	130.42	~ 0.5
86	-4.40	5.20	6.81	130.20	~ 0.5
99	-5.05	5.96	7.81	130.25	~ 0.5
107	-5.56	6.59	8.62	130.20	~ 0.5
122	-6.24	7.44	9.71	130.01	~ 0.5
129	-6.66	7.94	10.36	129.99	~ 0.5
136	-6.96	8.35	10.87	129.82	~ 0.5
141	-7.27	8.72	11.35	129.81	~ 0.5
152	-7.81	9.38	12.21	129.81	~ 0.5
160	-8.22	9.87	12.84	129.79	~ 0.5
175	-9.02	10.84	14.10	129.78	~ 0.5
184	-9.42	11.33	14.73	129.76	~ 0.5
192	-9.82	11.82	15.36	129.72	~ 0.5
199	-10.19	12.30	15.98	129.64	~ 0.5
209	-10.62	12.82	16.65	129.65	~ 0.5
219	-11.23	13.54	17.59	129.67	~ 0.5
234	-11.86	14.33	18.61	129.61	~ 0.5
243	-12.45	15.02	19.51	129.64	~ 0.5
253	-12.94	15.70	20.34	129.50	~ 0.5
263	-13.44	16.24	21.08	129.60	~ 0.5
273	-14.01	16.95	22.00	129.58	~ 0.5

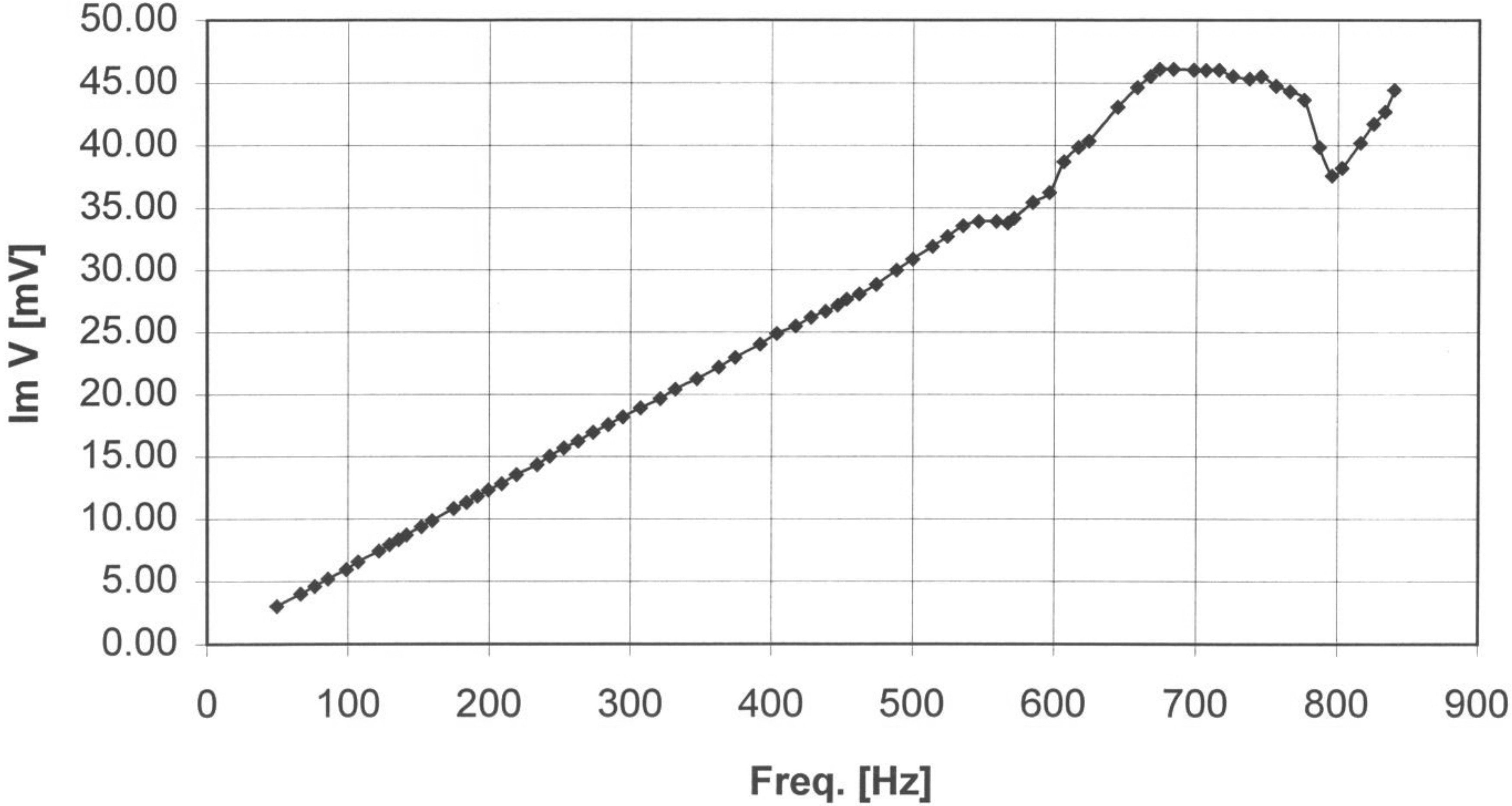
284	-14.52	17.57	22.79	129.56	~ 0.5
295	-14.96	18.18	23.54	129.45	~ 0.5
307	-15.57	18.91	24.49	129.46	~ 0.5
321	-16.23	19.67	25.50	129.54	~ 0.5
331	-16.94	20.40	26.52	129.71	~ 0.5
347	-17.67	21.24	27.63	129.75	~ 0.5
362	-18.49	22.18	28.88	129.81	~ 0.5
374	-19.13	22.96	29.89	129.79	~ 0.5
392	-20.02	24.04	31.28	129.79	~ 0.5
404	-20.74	24.88	32.39	129.81	~ 0.5
417	-21.29	25.49	33.21	129.87	~ 0.5
428	-21.89	26.19	34.13	129.89	~ 0.5
438	-22.42	26.69	34.86	130.04	~ 0.5
447	-22.93	27.17	35.55	130.17	~ 0.5
453	-23.31	27.65	36.17	130.14	~ 0.5
462	-23.79	28.06	36.79	130.30	~ 0.5
474	-25.02	28.83	38.17	130.95	~ 0.5
488	-25.90	29.98	39.62	130.83	~ 0.5
500	-26.61	30.86	40.75	130.77	~ 0.5
514	-27.32	31.92	42.01	130.57	~ 0.5
524	-27.80	32.69	42.92	130.38	~ 0.5
535	-28.09	33.57	43.77	129.91	~ 0.5
546	-28.37	33.92	44.22	129.91	~ 0.5
559	-28.44	33.92	44.26	129.98	~ 0.5
567	-29.38	33.79	44.78	131.00	~ 0.5
571	-30.12	34.15	45.53	131.41	~ 0.5
584	-31.04	35.44	47.11	131.22	~ 0.5
596	-31.49	36.23	48.01	131.00	~ 0.5
606	-34.04	38.71	51.55	131.33	~ 0.5
617	-33.76	39.86	52.24	130.27	~ 0.5
624	-33.99	40.37	52.77	130.09	~ 0.5
644	-34.54	43.07	55.21	128.72	~ 0.5
658	-34.63	44.65	56.50	127.80	~ 0.5
667	-34.05	45.52	56.84	126.79	~ 0.5
674	-33.41	46.09	56.92	125.94	~ 0.5
683	-32.57	46.09	56.44	125.25	~ 0.5
698	-31.87	46.03	55.98	124.70	~ 0.5
706	-31.57	46.00	55.79	124.46	~ 0.5
715	-31.76	46.02	55.91	124.61	~ 0.5
725	-31.97	45.53	55.63	125.08	~ 0.5
737	-32.55	45.33	55.81	125.69	~ 0.5
745	-32.84	45.50	56.11	125.82	~ 0.5
756	-33.53	44.75	55.92	126.84	~ 0.5
765	-34.56	44.32	56.20	127.95	~ 0.5
776	-35.91	43.65	56.52	129.44	~ 0.5
786	-39.49	39.86	56.11	134.74	~ 0.5
796	-41.62	37.58	56.08	137.92	~ 0.5
803	-41.86	38.19	56.66	137.63	~ 0.5
816	-45.16	40.21	60.47	138.32	~ 0.5

825	-48.55	41.72	64.01	139.33	~ 0.5
833	-48.69	42.71	64.76	138.75	~ 0.5
840	-49.92	44.45	66.84	138.32	~ 0.5

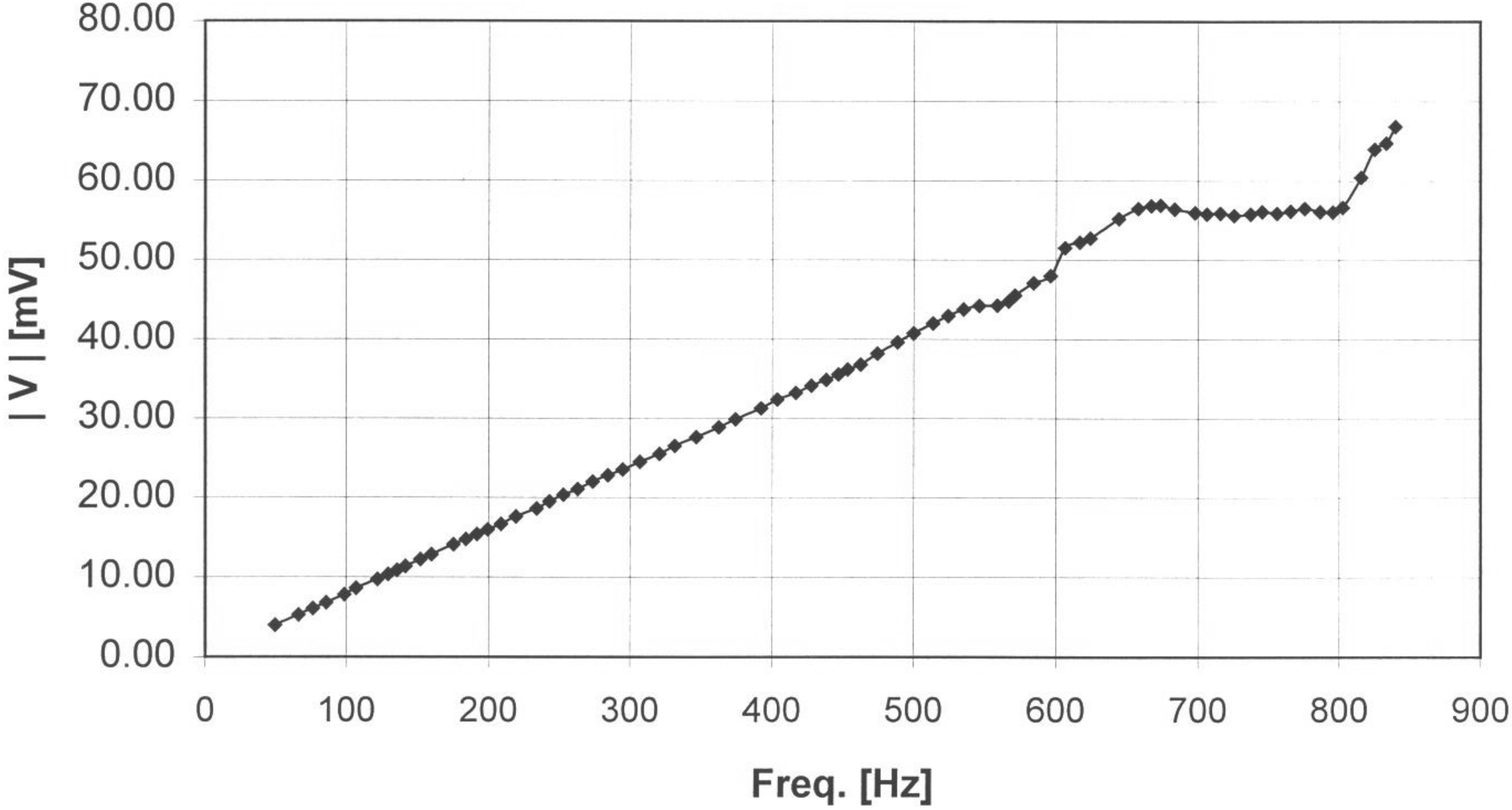
Graph 19: Single String - flip flop/2



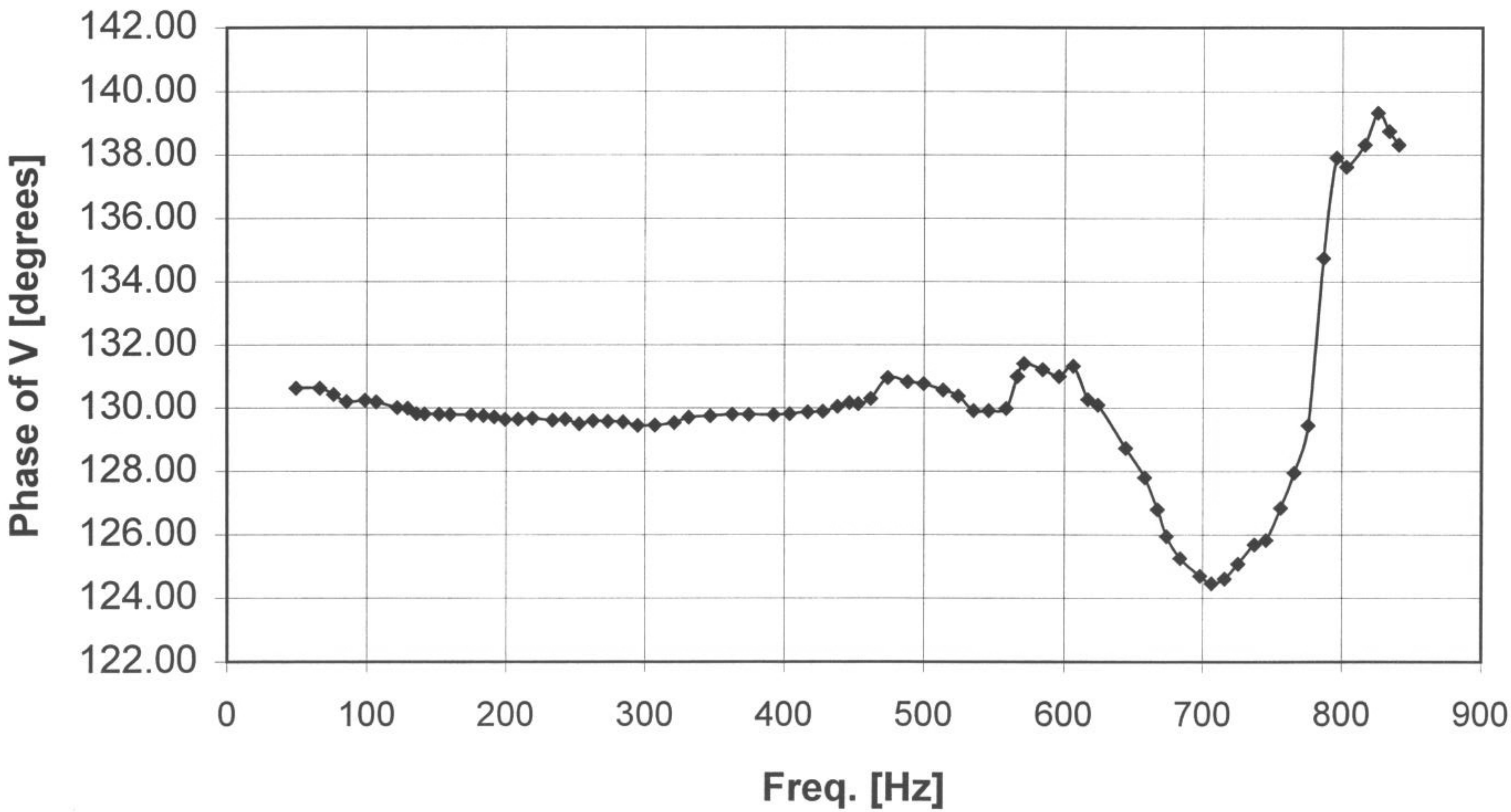
Graph 20: Single String - flip flop/2



Graph 21: Single String - flip flop/2



Graph 22: Single String - flip flop/2



c:\cvi\P398EMI\Data\drill_03_08_1.dat

DAQ PROGRAM: DRILL1.prj

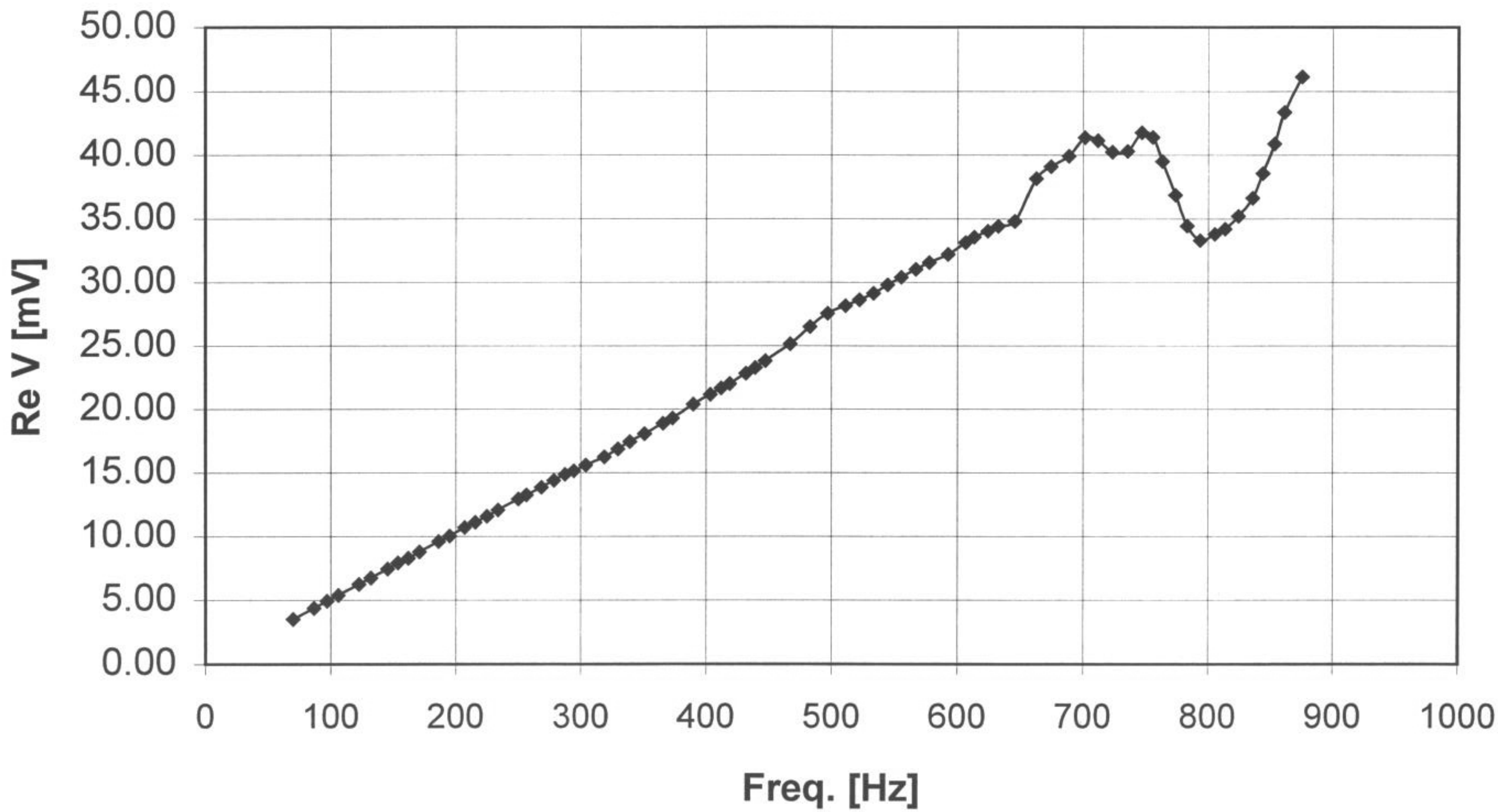
Date:
37323
Time:
1
Number of Freq Measurements:
73
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
1194
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
500
CURR LockIn Sensitivity (mV):
500

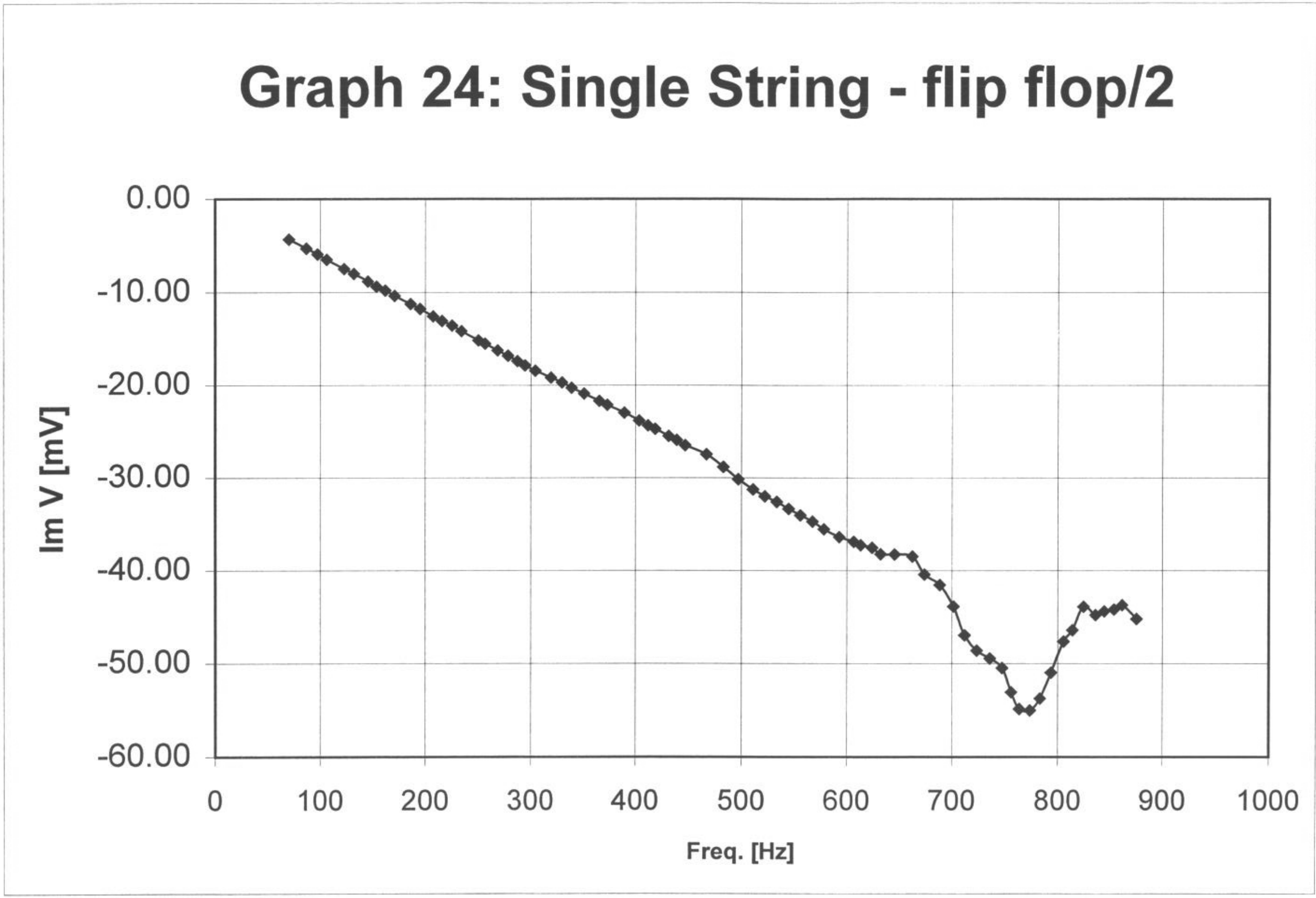
DRILL-1 Data:

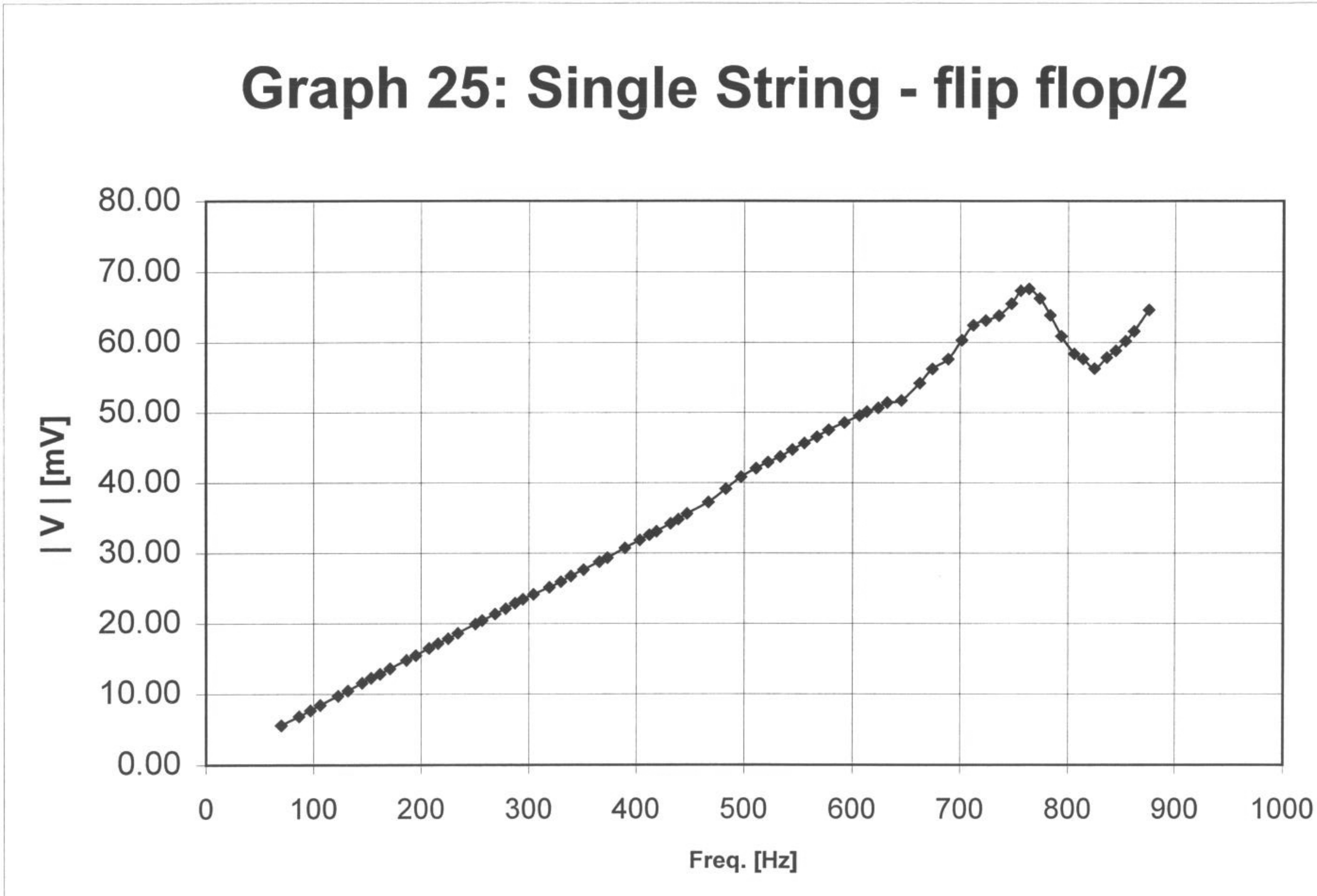
Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
875	46.14	-45.21	64.60	-44.42	~ 0.5
861	43.37	-43.71	61.57	-45.23	~ 0.5
853	40.88	-44.18	60.20	-47.22	~ 0.5
844	38.56	-44.40	58.81	-49.02	~ 0.5
836	36.62	-44.79	57.86	-50.73	~ 0.5
824	35.22	-43.89	56.28	-51.26	~ 0.5
814	34.22	-46.41	57.66	-53.60	~ 0.5
805	33.81	-47.62	58.40	-54.63	~ 0.5
794	33.30	-50.98	60.89	-56.85	~ 0.5
783	34.44	-53.74	63.83	-57.34	~ 0.5
774	36.88	-55.02	66.23	-56.16	~ 0.5
763	39.51	-54.87	67.61	-54.25	~ 0.5
756	41.41	-53.08	67.32	-52.04	~ 0.5
747	41.77	-50.48	65.52	-50.39	~ 0.5
736	40.31	-49.46	63.80	-50.82	~ 0.5
723	40.25	-48.61	63.11	-50.38	~ 0.5
712	41.15	-46.95	62.44	-48.76	~ 0.5
701	41.38	-43.87	60.31	-46.68	~ 0.5
689	39.92	-41.55	57.62	-46.14	~ 0.5
674	39.10	-40.42	56.24	-45.95	~ 0.5
662	38.16	-38.49	54.20	-45.24	~ 0.5
645	34.82	-38.26	51.73	-47.70	~ 0.5
632	34.43	-38.23	51.44	-47.99	~ 0.5
624	34.03	-37.54	50.67	-47.81	~ 0.5

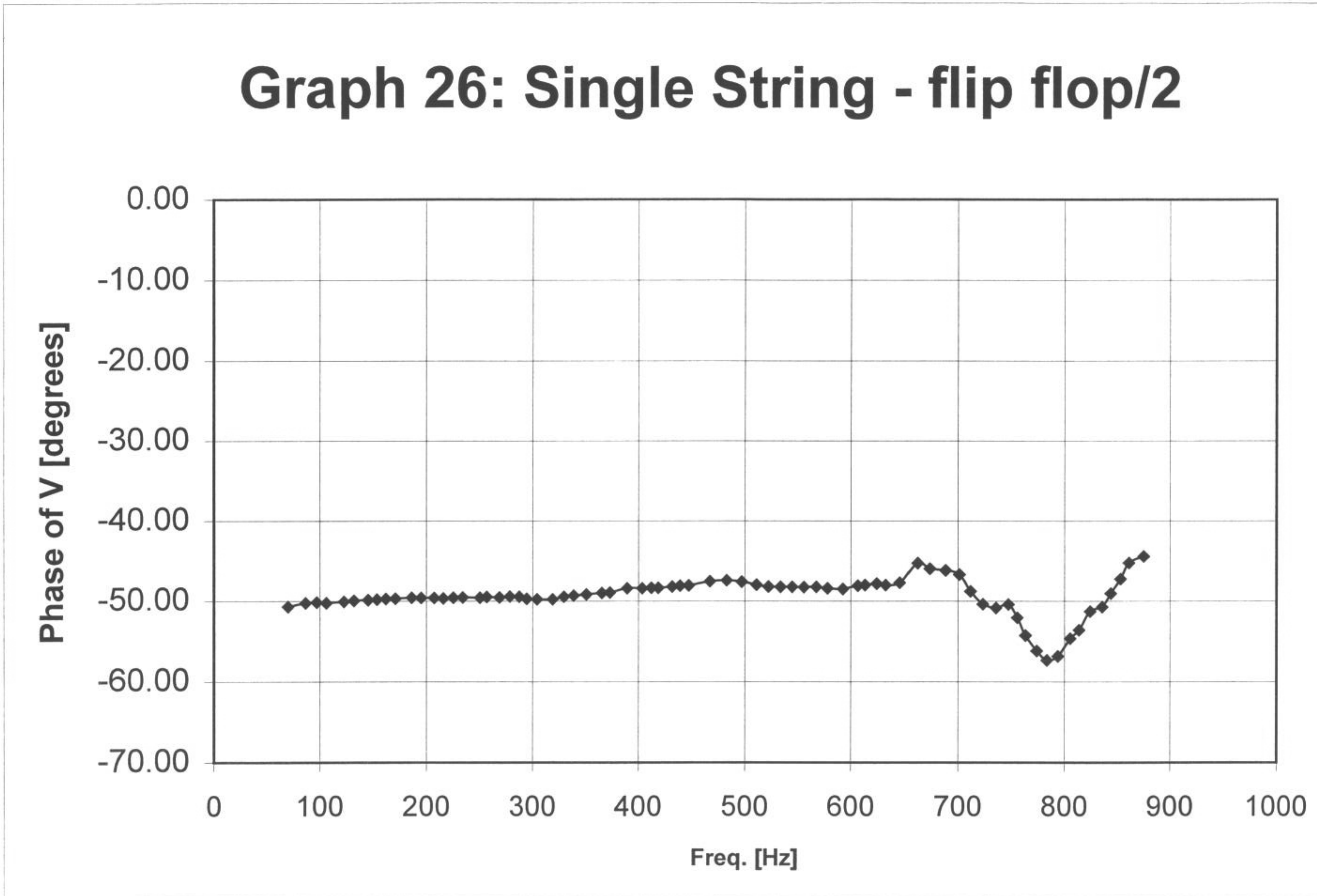
613	33.57	-37.26	50.15	-47.98	~ 0.5
606	33.13	-36.89	49.58	-48.07	~ 0.5
592	32.21	-36.38	48.59	-48.48	~ 0.5
578	31.56	-35.54	47.53	-48.40	~ 0.5
567	31.02	-34.72	46.55	-48.22	~ 0.5
555	30.40	-34.04	45.64	-48.23	~ 0.5
544	29.80	-33.34	44.72	-48.21	~ 0.5
533	29.13	-32.60	43.72	-48.21	~ 0.5
522	28.63	-31.99	42.93	-48.18	~ 0.5
511	28.16	-31.24	42.05	-47.97	~ 0.5
497	27.54	-30.14	40.83	-47.59	~ 0.5
483	26.50	-28.82	39.15	-47.40	~ 0.5
467	25.15	-27.46	37.24	-47.52	~ 0.5
447	23.81	-26.49	35.62	-48.05	~ 0.5
439	23.27	-25.90	34.82	-48.07	~ 0.5
432	22.81	-25.49	34.21	-48.18	~ 0.5
419	22.00	-24.71	33.09	-48.32	~ 0.5
412	21.67	-24.35	32.59	-48.34	~ 0.5
403	21.16	-23.82	31.86	-48.39	~ 0.5
390	20.39	-22.96	30.71	-48.39	~ 0.5
373	19.29	-22.11	29.34	-48.90	~ 0.5
366	18.89	-21.70	28.77	-48.96	~ 0.5
351	18.08	-20.90	27.63	-49.13	~ 0.5
339	17.44	-20.27	26.74	-49.28	~ 0.5
330	16.86	-19.70	25.93	-49.45	~ 0.5
319	16.24	-19.18	25.13	-49.76	~ 0.5
304	15.59	-18.42	24.14	-49.75	~ 0.5
294	15.16	-17.86	23.43	-49.69	~ 0.5
287	14.88	-17.37	22.88	-49.42	~ 0.5
278	14.40	-16.80	22.13	-49.41	~ 0.5
268	13.86	-16.24	21.35	-49.52	~ 0.5
257	13.26	-15.51	20.41	-49.48	~ 0.5
250	12.93	-15.16	19.92	-49.54	~ 0.5
234	12.09	-14.16	18.62	-49.53	~ 0.5
225	11.58	-13.58	17.84	-49.54	~ 0.5
216	11.11	-13.08	17.16	-49.64	~ 0.5
207	10.70	-12.57	16.51	-49.59	~ 0.5
195	10.03	-11.78	15.47	-49.57	~ 0.5
186	9.60	-11.25	14.79	-49.54	~ 0.5
171	8.79	-10.36	13.59	-49.68	~ 0.5
162	8.30	-9.79	12.84	-49.70	~ 0.5
154	7.93	-9.38	12.28	-49.77	~ 0.5
145	7.45	-8.84	11.56	-49.86	~ 0.5
132	6.74	-8.01	10.47	-49.93	~ 0.5
123	6.26	-7.47	9.74	-50.06	~ 0.5
106	5.40	-6.49	8.44	-50.23	~ 0.5
97	4.93	-5.91	7.70	-50.13	~ 0.5
87	4.39	-5.27	6.86	-50.23	~ 0.5
70	3.53	-4.31	5.57	-50.69	~ 0.5

Graph 23: Single String - flip flop/2




Graph 24: Single String - flip flop/2
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
Im V [mV]
0
100
200
300
400
500
600
700
800
900
1000
Freq. [Hz]


Graph 25: Single String - flip flop/2
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
| V | [mV]
0
100
200
300
400
500
600
700
800
900
1000
Freq. [Hz]


Graph 26: Single String - flip flop/2
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
Phase of V [degrees]
0
100
200
300
400
500
600
700
800
900
1000
Freq. [Hz]

c:\cvi\P398EMI\Data\4_2_2(4).dat

DAQ PROGRAM: DRILL1.prj

Date:
37348
Time:
1
Number of Freq Measurements:
95
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
791
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
500
CURR LockIn Sensitivity (mV):
500

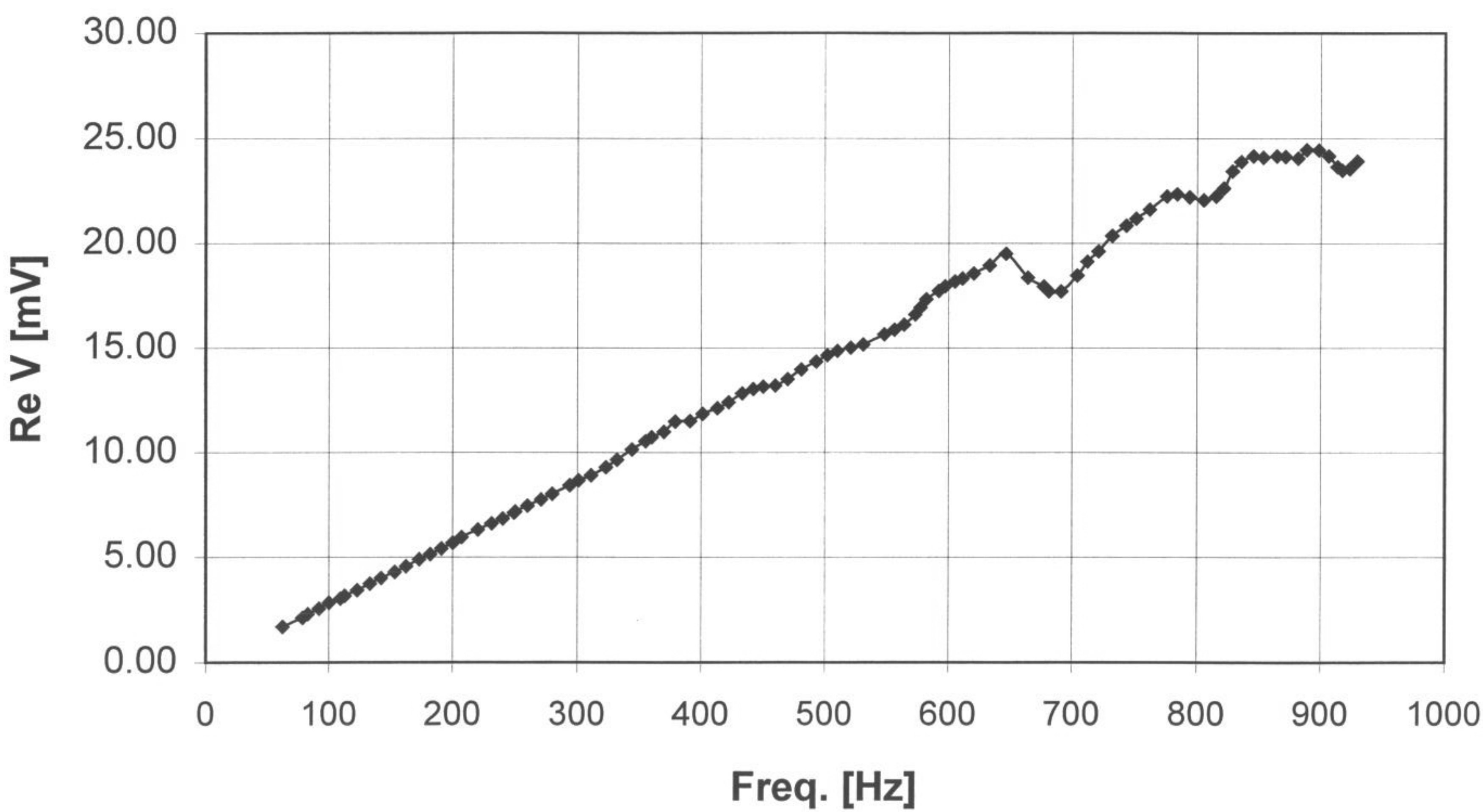
DRILL-1 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
63	1.70	-1.75	2.44	-45.81	~ 0.5
79	2.12	-2.21	3.06	-46.14	~ 0.5
83	2.29	-2.33	3.27	-45.48	~ 0.5
92	2.55	-2.58	3.63	-45.32	~ 0.5
100	2.84	-2.84	4.02	-45.00	~ 0.5
109	3.04	-3.02	4.28	-44.84	~ 0.5
113	3.16	-3.13	4.44	-44.75	~ 0.5
123	3.43	-3.42	4.84	-44.91	~ 0.5
133	3.74	-3.68	5.25	-44.53	~ 0.5
142	4.01	-3.92	5.61	-44.34	~ 0.5
153	4.29	-4.17	5.98	-44.23	~ 0.5
163	4.56	-4.47	6.39	-44.43	~ 0.5
173	4.90	-4.77	6.84	-44.26	~ 0.5
182	5.14	-5.00	7.17	-44.21	~ 0.5
191	5.41	-5.23	7.52	-44.01	~ 0.5
200	5.68	-5.47	7.88	-43.95	~ 0.5
207	5.95	-5.65	8.20	-43.55	~ 0.5
220	6.31	-6.00	8.71	-43.57	~ 0.5
231	6.61	-6.30	9.13	-43.65	~ 0.5
240	6.84	-6.50	9.43	-43.52	~ 0.5
249	7.11	-6.74	9.80	-43.45	~ 0.5
250	7.17	-6.75	9.85	-43.26	~ 0.5
260	7.45	-7.02	10.24	-43.31	~ 0.5

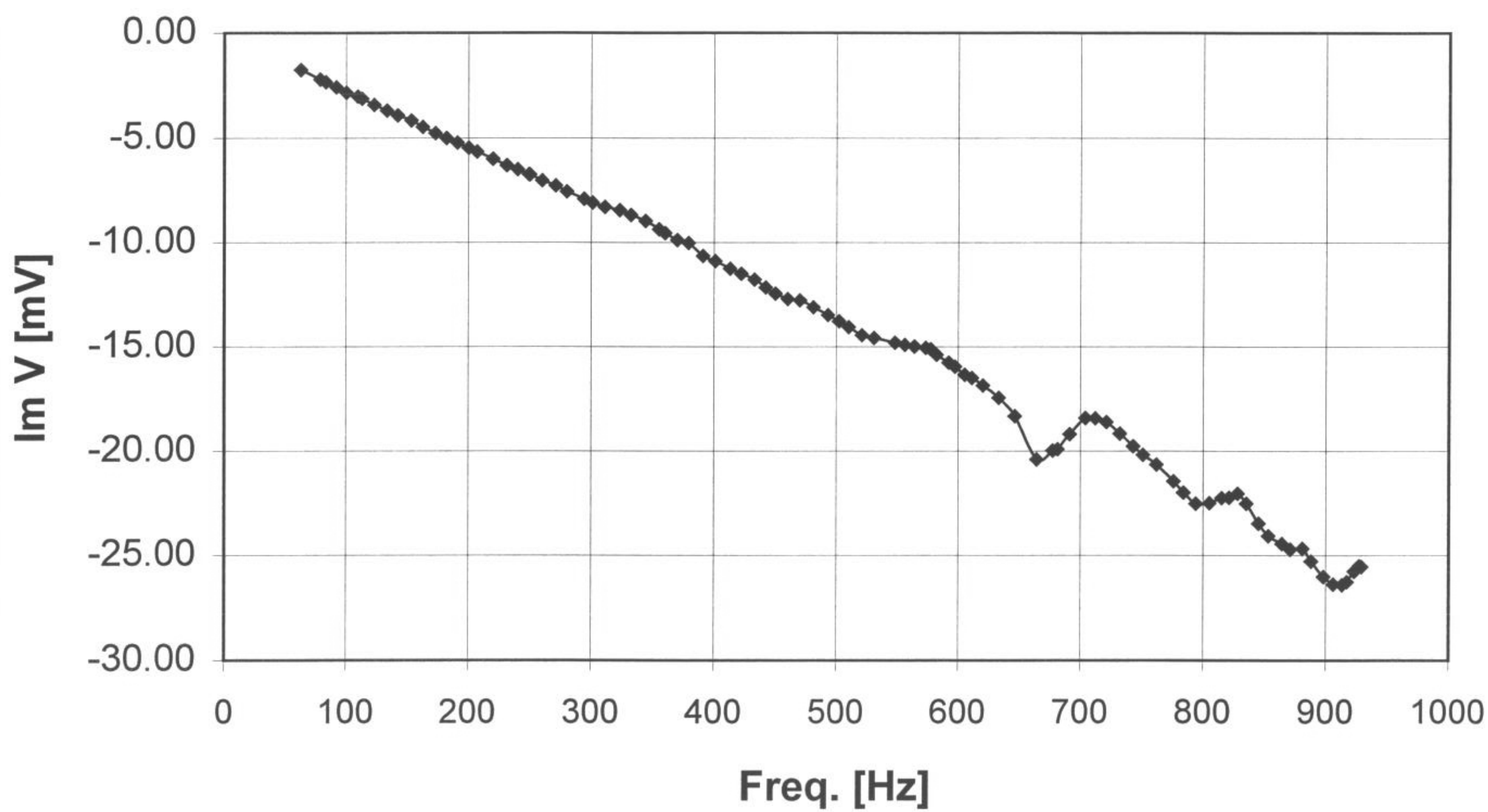
271	7.75	-7.27	10.63	-43.18	~ 0.5
280	8.01	-7.56	11.02	-43.35	~ 0.5
294	8.43	-7.91	11.56	-43.17	~ 0.5
301	8.67	-8.08	11.85	-43.02	~ 0.5
311	8.91	-8.29	12.17	-42.94	~ 0.5
323	9.29	-8.45	12.56	-42.28	~ 0.5
332	9.65	-8.67	12.97	-41.96	~ 0.5
344	10.13	-8.96	13.52	-41.49	~ 0.5
355	10.54	-9.36	14.10	-41.63	~ 0.5
360	10.73	-9.54	14.36	-41.63	~ 0.5
370	10.99	-9.88	14.78	-41.96	~ 0.5
379	11.47	-10.02	15.23	-41.13	~ 0.5
391	11.50	-10.64	15.67	-42.79	~ 0.5
401	11.84	-10.89	16.09	-42.61	~ 0.5
413	12.11	-11.25	16.53	-42.88	~ 0.5
422	12.40	-11.49	16.91	-42.82	~ 0.5
433	12.82	-11.78	17.41	-42.58	~ 0.5
442	13.03	-12.16	17.82	-43.01	~ 0.5
450	13.14	-12.44	18.10	-43.43	~ 0.5
460	13.19	-12.70	18.31	-43.91	~ 0.5
470	13.50	-12.77	18.58	-43.39	~ 0.5
481	13.97	-13.10	19.15	-43.16	~ 0.5
493	14.33	-13.48	19.68	-43.24	~ 0.5
502	14.65	-13.78	20.11	-43.25	~ 0.5
510	14.85	-14.06	20.45	-43.44	~ 0.5
521	15.00	-14.44	20.82	-43.91	~ 0.5
531	15.16	-14.58	21.04	-43.88	~ 0.5
548	15.65	-14.81	21.54	-43.43	~ 0.5
556	15.86	-14.91	21.77	-43.23	~ 0.5
564	16.11	-14.99	22.00	-42.93	~ 0.5
573	16.60	-15.05	22.41	-42.18	~ 0.5
577	16.94	-15.12	22.70	-41.75	~ 0.5
582	17.33	-15.39	23.18	-41.61	~ 0.5
592	17.73	-15.76	23.72	-41.64	~ 0.5
597	17.95	-15.96	24.02	-41.64	~ 0.5
605	18.18	-16.34	24.44	-41.94	~ 0.5
611	18.32	-16.50	24.65	-42.01	~ 0.5
620	18.56	-16.86	25.08	-42.26	~ 0.5
633	18.95	-17.45	25.76	-42.65	~ 0.5
646	19.51	-18.33	26.77	-43.22	~ 0.5
664	18.36	-20.41	27.45	-48.02	~ 0.5
677	17.94	-19.98	26.86	-48.08	~ 0.5
681	17.71	-19.91	26.65	-48.36	~ 0.5
691	17.71	-19.19	26.11	-47.31	~ 0.5
704	18.46	-18.42	26.08	-44.94	~ 0.5
712	19.13	-18.44	26.57	-43.94	~ 0.5
721	19.62	-18.61	27.04	-43.49	~ 0.5
732	20.36	-19.17	27.97	-43.27	~ 0.5
743	20.85	-19.78	28.74	-43.48	~ 0.5

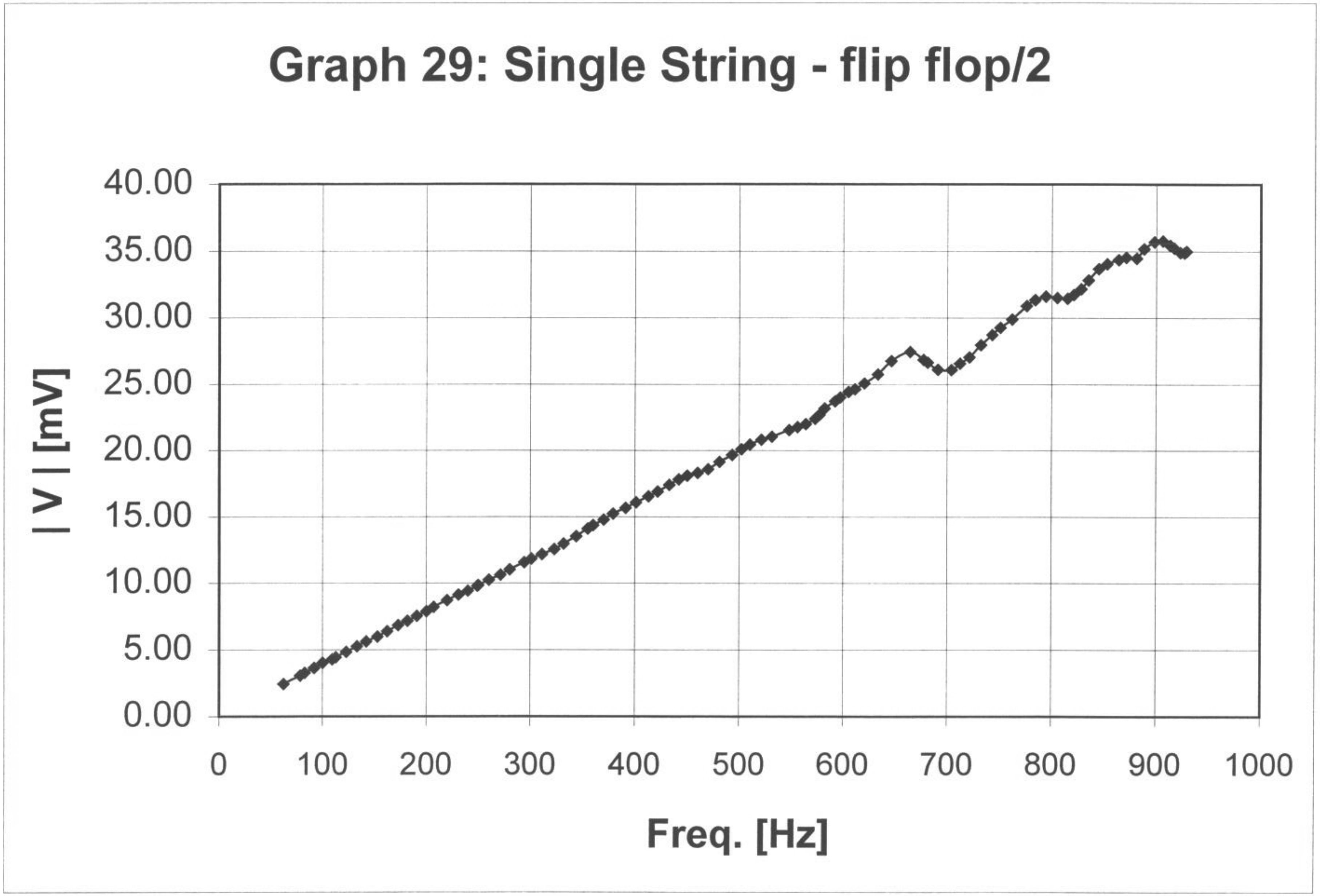
751	21.18	-20.19	29.26	-43.63	~ 0.5
762	21.62	-20.65	29.90	-43.69	~ 0.5
776	22.25	-21.45	30.91	-43.94	~ 0.5
784	22.36	-21.99	31.36	-44.52	~ 0.5
794	22.21	-22.51	31.63	-45.39	~ 0.5
805	22.08	-22.49	31.52	-45.53	~ 0.5
815	22.25	-22.25	31.47	-45.00	~ 0.5
821	22.64	-22.23	31.73	-44.47	~ 0.5
828	23.44	-22.04	32.18	-43.24	~ 0.5
835	23.90	-22.52	32.84	-43.30	~ 0.5
845	24.17	-23.47	33.69	-44.16	~ 0.5
853	24.10	-24.07	34.06	-44.96	~ 0.5
864	24.16	-24.44	34.37	-45.33	~ 0.5
871	24.14	-24.71	34.54	-45.67	~ 0.5
881	24.07	-24.68	34.47	-45.72	~ 0.5
888	24.46	-25.28	35.18	-45.95	~ 0.5
898	24.44	-26.02	35.70	-46.79	~ 0.5
906	24.16	-26.37	35.77	-47.50	~ 0.5
913	23.66	-26.40	35.45	-48.14	~ 0.5
917	23.49	-26.27	35.24	-48.20	~ 0.5
923	23.57	-25.75	34.91	-47.53	~ 0.5
927	23.81	-25.50	34.89	-46.96	~ 0.5
929	23.92	-25.54	34.99	-46.87	~ 0.5

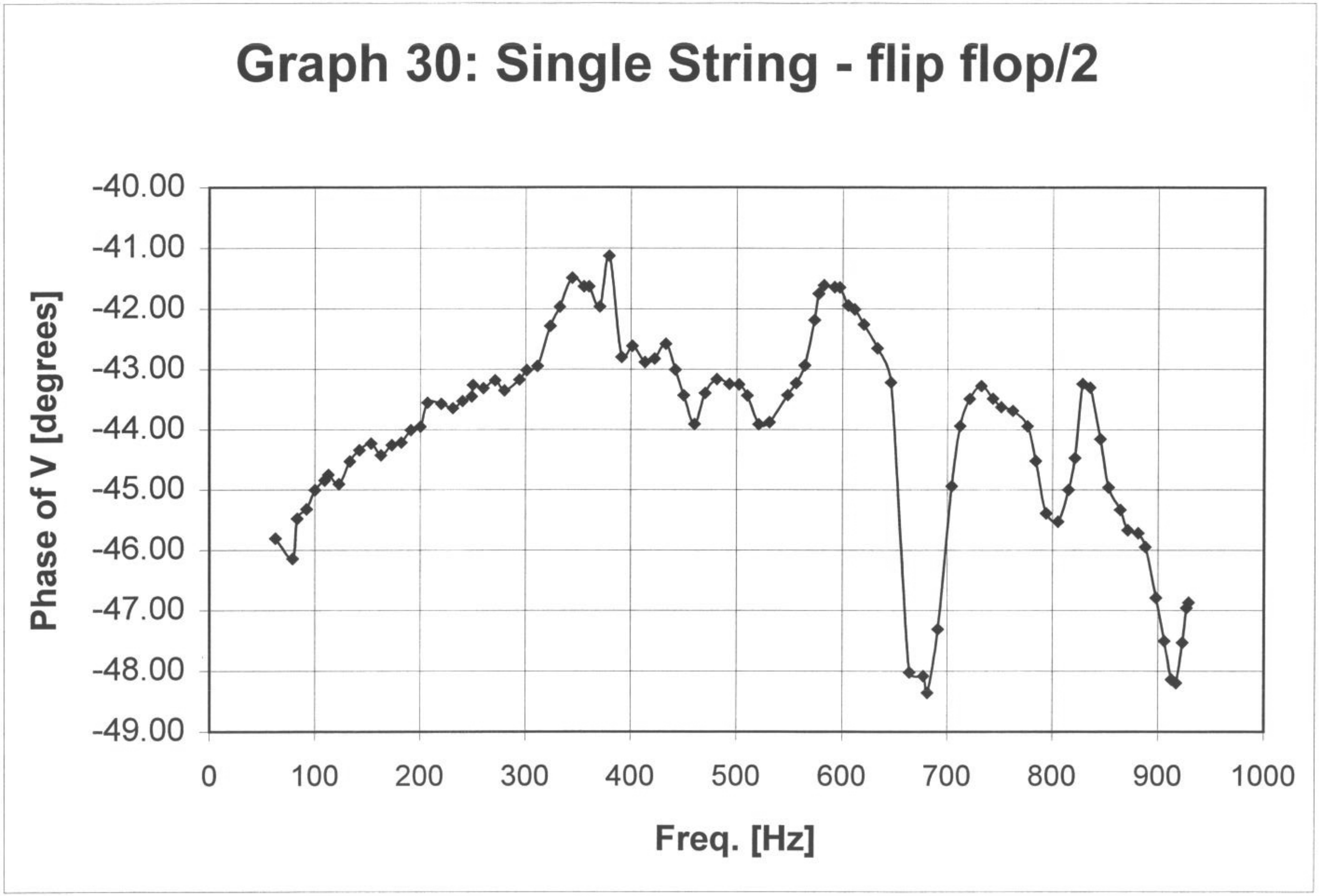
Graph 27: Single String - flip flop/2



Graph 28: Single String - flip flop/2




Graph 29: Single String - flip flop/2
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
| V | [mV]
0
100
200
300
400
500
600
700
800
900
1000
Freq. [Hz]



Graph 30: Single String - flip flop/2
-40.00
-41.00
-42.00
-43.00
-44.00
-45.00
-46.00
-47.00
-48.00
-49.00
Phase of V [degrees]
0
100
200
300
400
500
600
700
800
900
1000
Freq. [Hz]

c:\cvi\P398EMI\Data\drill_04_12_02(1).xls

DAQ PROGRAM: DRILL1.prj

Date:
37358
Time:
1
Number of Freq Measurements:
92
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
601
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
1000
CURR LockIn Sensitivity (mV):
500

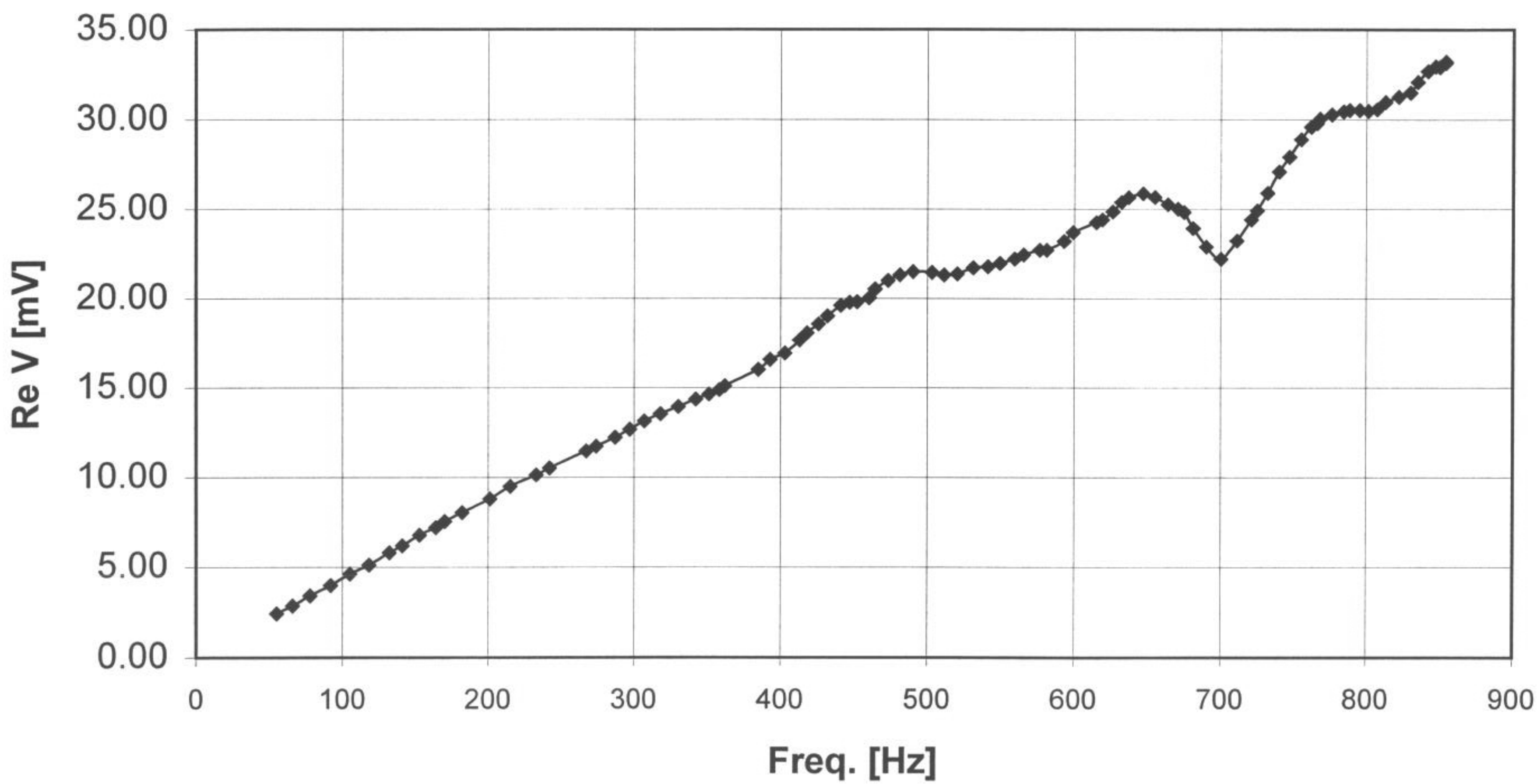
DRILL-1 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
55	2.43	-2.91	3.79	-50.20	~ 0.5
66	2.88	-3.43	4.48	-50.07	~ 0.5
78	3.43	-4.13	5.36	-50.31	~ 0.5
92	4.00	-4.93	6.35	-50.92	~ 0.5
105	4.63	-5.57	7.25	-50.26	~ 0.5
118	5.14	-6.27	8.10	-50.65	~ 0.5
132	5.82	-7.03	9.13	-50.41	~ 0.5
141	6.20	-7.49	9.73	-50.37	~ 0.5
153	6.79	-8.09	10.57	-49.99	~ 0.5
164	7.21	-8.62	11.24	-50.07	~ 0.5
170	7.55	-9.07	11.80	-50.24	~ 0.5
182	8.05	-9.57	12.51	-49.94	~ 0.5
201	8.80	-10.67	13.83	-50.49	~ 0.5
215	9.50	-11.51	14.93	-50.45	~ 0.5
233	10.13	-12.40	16.02	-50.75	~ 0.5
242	10.53	-13.02	16.75	-51.04	~ 0.5
267	11.47	-14.20	18.25	-51.07	~ 0.5
274	11.73	-14.62	18.74	-51.26	~ 0.5
287	12.23	-15.26	19.55	-51.30	~ 0.5
297	12.68	-15.80	20.26	-51.25	~ 0.5
307	13.15	-16.41	21.03	-51.28	~ 0.5
318	13.55	-17.06	21.79	-51.54	~ 0.5
330	13.94	-17.65	22.50	-51.70	~ 0.5
342	14.37	-18.27	23.25	-51.81	~ 0.5
351	14.65	-18.65	23.72	-51.86	~ 0.5

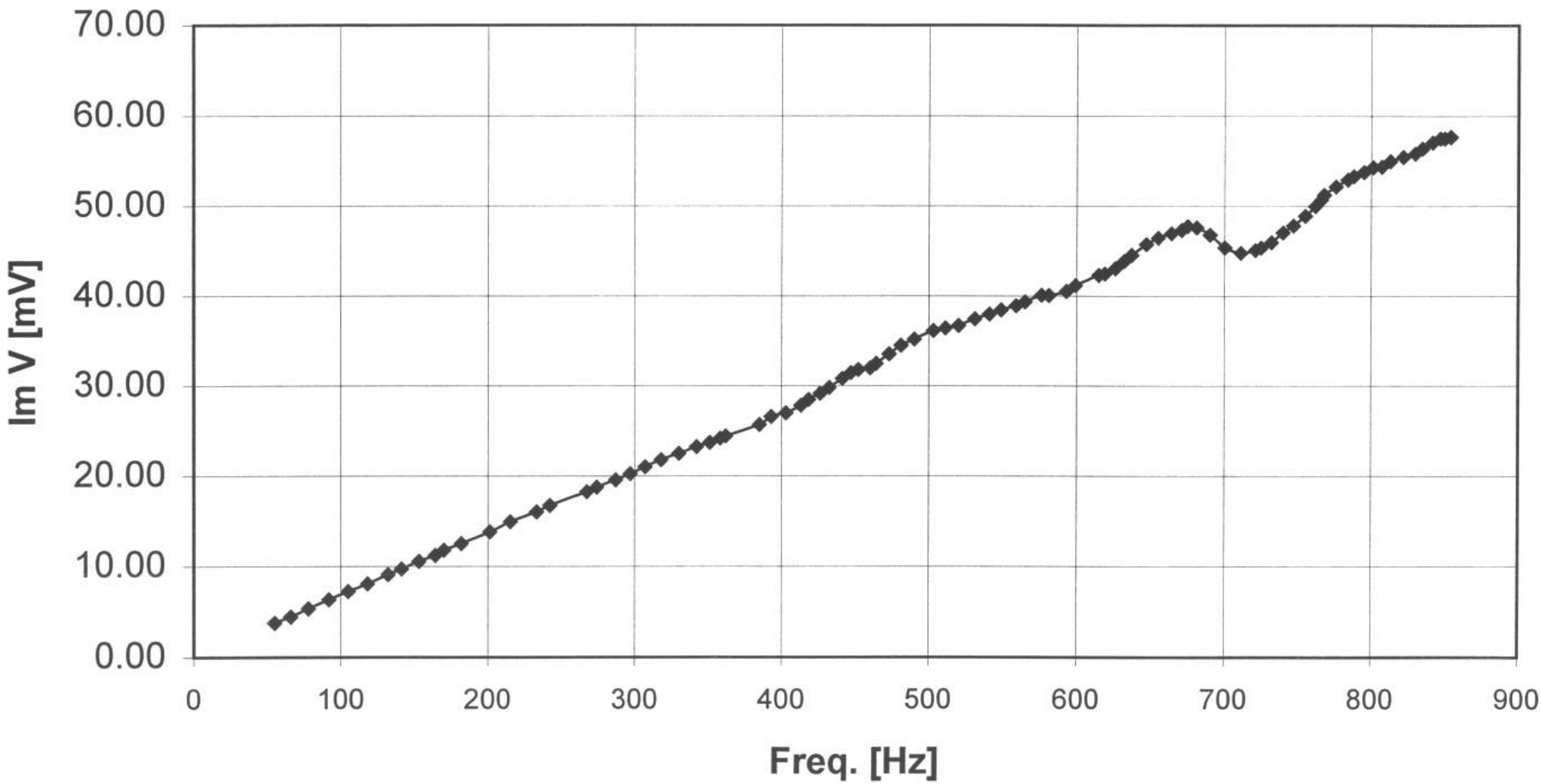
358	14.90	-19.04	24.17	-51.95	~ 0.5
362	15.11	-19.20	24.43	-51.80	~ 0.5
385	16.03	-20.10	25.71	-51.43	~ 0.5
393	16.59	-20.79	26.60	-51.42	~ 0.5
403	16.94	-21.04	27.01	-51.16	~ 0.5
413	17.67	-21.51	27.84	-50.61	~ 0.5
418	18.08	-22.01	28.48	-50.60	~ 0.5
426	18.57	-22.48	29.16	-50.45	~ 0.5
432	19.02	-22.99	29.84	-50.39	~ 0.5
441	19.61	-23.77	30.81	-50.47	~ 0.5
447	19.77	-24.48	31.47	-51.07	~ 0.5
452	19.80	-24.90	31.81	-51.50	~ 0.5
460	20.03	-24.94	31.99	-51.23	~ 0.5
464	20.52	-25.19	32.48	-50.83	~ 0.5
473	21.01	-26.16	33.55	-51.23	~ 0.5
481	21.31	-27.14	34.50	-51.86	~ 0.5
490	21.50	-27.84	35.17	-52.32	~ 0.5
503	21.46	-29.10	36.16	-53.59	~ 0.5
511	21.31	-29.55	36.44	-54.21	~ 0.5
520	21.38	-29.84	36.71	-54.38	~ 0.5
531	21.71	-30.50	37.43	-54.55	~ 0.5
541	21.77	-31.11	37.97	-55.01	~ 0.5
549	21.96	-31.56	38.45	-55.18	~ 0.5
559	22.21	-31.96	38.92	-55.20	~ 0.5
565	22.45	-32.32	39.35	-55.22	~ 0.5
576	22.70	-33.02	40.07	-55.49	~ 0.5
581	22.70	-33.01	40.06	-55.48	~ 0.5
593	23.21	-33.20	40.51	-55.04	~ 0.5
599	23.70	-33.67	41.18	-54.87	~ 0.5
615	24.25	-34.68	42.32	-55.04	~ 0.5
619	24.41	-34.74	42.46	-54.91	~ 0.5
626	24.87	-35.14	43.05	-54.71	~ 0.5
632	25.39	-35.76	43.85	-54.63	~ 0.5
637	25.66	-36.42	44.55	-54.84	~ 0.5
647	25.87	-37.74	45.76	-55.57	~ 0.5
655	25.67	-38.74	46.47	-56.47	~ 0.5
664	25.26	-39.59	46.96	-57.46	~ 0.5
671	25.01	-40.20	47.35	-58.11	~ 0.5
675	24.83	-40.79	47.76	-58.67	~ 0.5
681	23.93	-41.16	47.61	-59.83	~ 0.5
690	22.90	-40.82	46.80	-60.71	~ 0.5
700	22.21	-39.59	45.40	-60.70	~ 0.5
711	23.24	-38.30	44.80	-58.76	~ 0.5
721	24.41	-37.92	45.09	-57.23	~ 0.5
725	24.92	-37.92	45.37	-56.69	~ 0.5
732	25.90	-37.99	45.98	-55.72	~ 0.5
740	27.09	-38.47	47.06	-54.85	~ 0.5
747	27.91	-38.84	47.83	-54.30	~ 0.5
755	28.90	-39.46	48.91	-53.79	~ 0.5
762	29.59	-40.32	50.01	-53.73	~ 0.5
766	29.79	-41.06	50.73	-54.04	~ 0.5

768	30.03	-41.52	51.25	-54.12	~ 0.5
776	30.27	-42.51	52.18	-54.55	~ 0.5
784	30.44	-43.32	52.94	-54.90	~ 0.5
788	30.52	-43.74	53.34	-55.09	~ 0.5
795	30.52	-44.30	53.80	-55.44	~ 0.5
801	30.47	-44.96	54.31	-55.87	~ 0.5
807	30.57	-44.97	54.38	-55.79	~ 0.5
813	30.98	-45.43	54.99	-55.71	~ 0.5
822	31.26	-45.81	55.46	-55.69	~ 0.5
830	31.50	-46.08	55.82	-55.64	~ 0.5
835	32.09	-46.39	56.40	-55.33	~ 0.5
842	32.69	-46.78	57.07	-55.05	~ 0.5
847	32.96	-47.11	57.50	-55.02	~ 0.5
850	32.92	-47.15	57.51	-55.08	~ 0.5
854	33.15	-47.17	57.65	-54.90	~ 0.5
854	33.21	-47.16	57.68	-54.85	~ 0.5

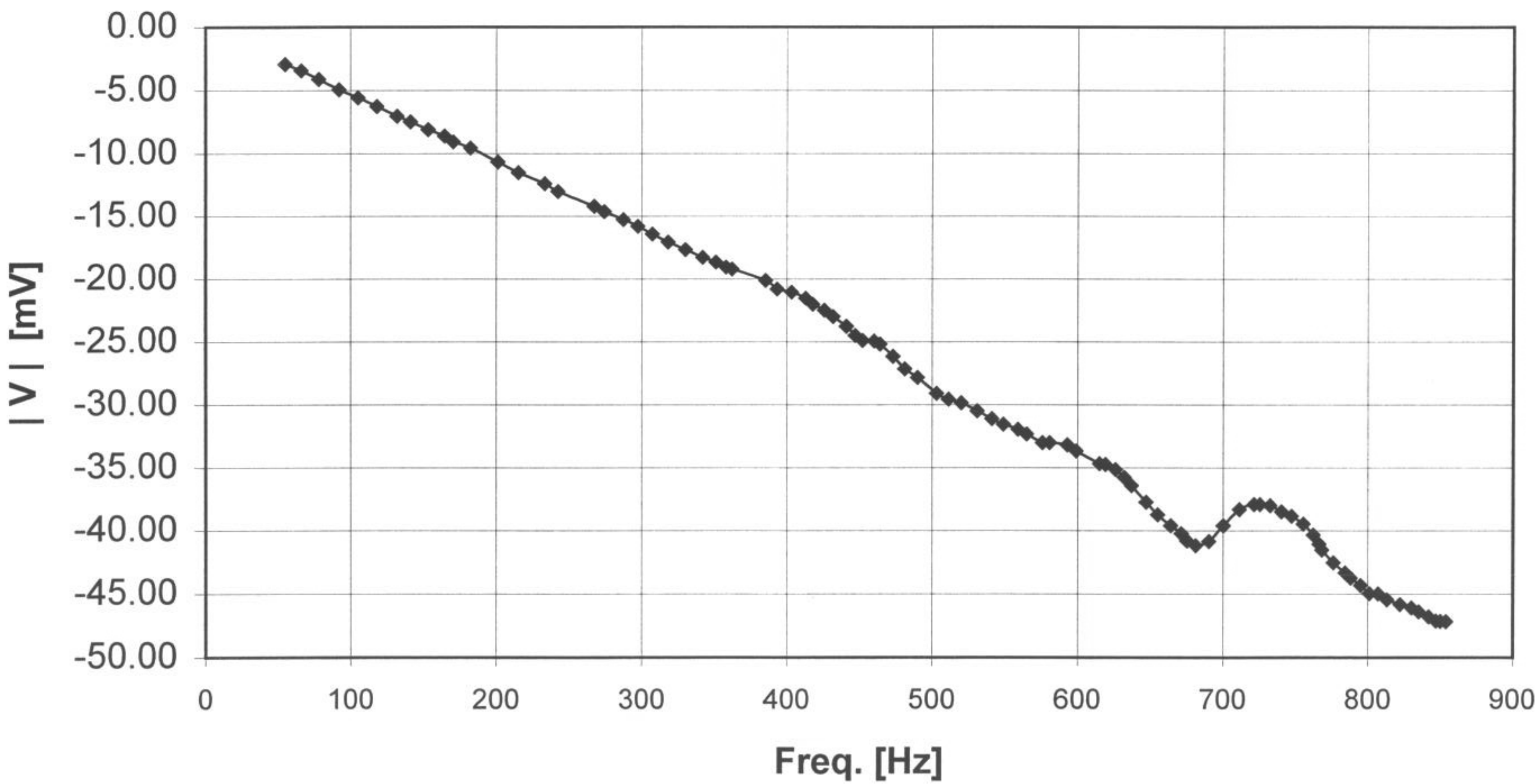
Graph 31: (plastic holder and foam) Single String - flip flop/2



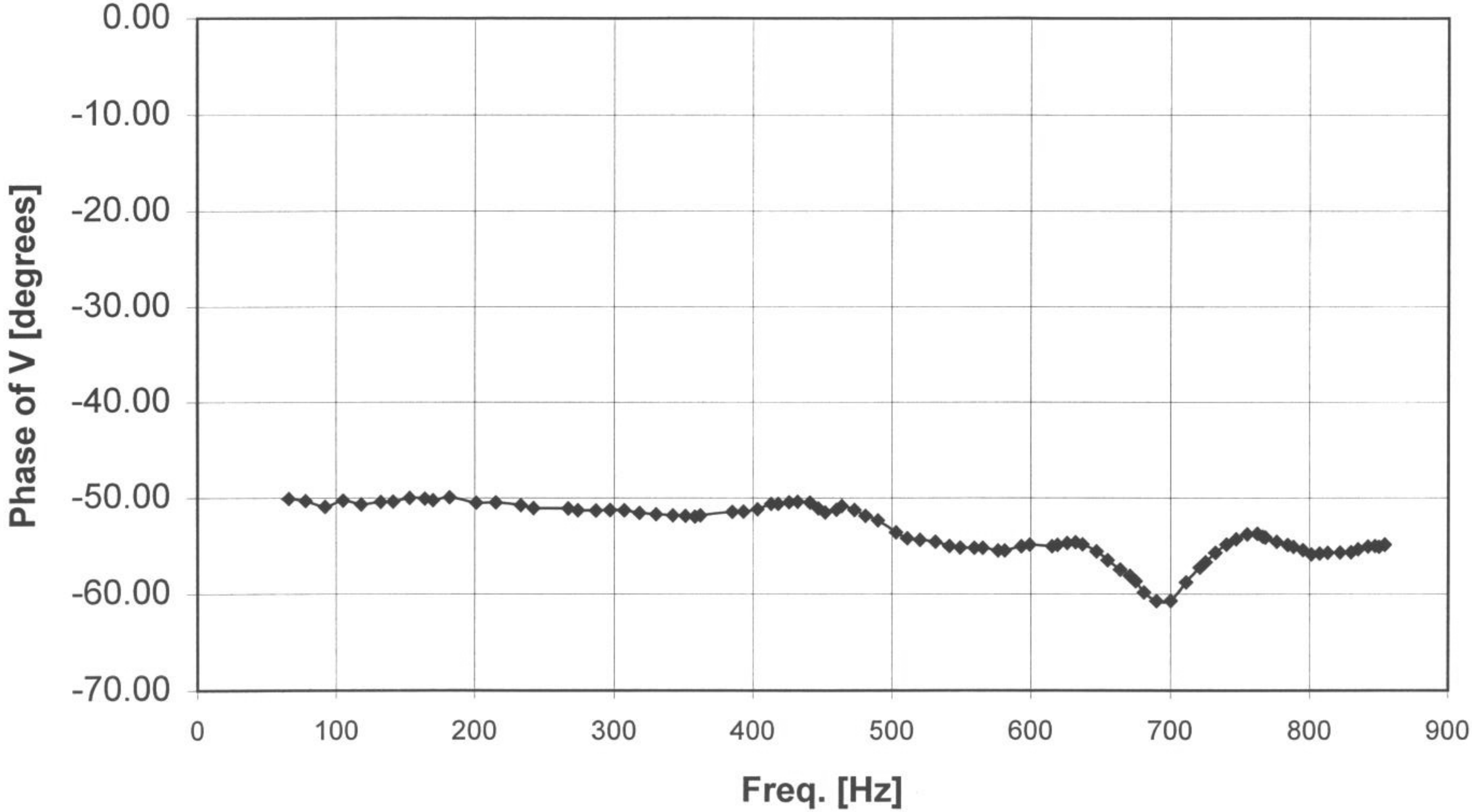
Graph 32: (plastic holder and foam) Single String - flip flop/2



Graph 33: (plastic holder and foam) Single String - flip flop/2



Graph 34: (plastic holder and foam) Single String - flip flop/2



c:\cvi\P398EMI\Data\Pickup_Data\Drill Method\drill_04_16_02.xls

DAQ PROGRAM: DRILL1.prj

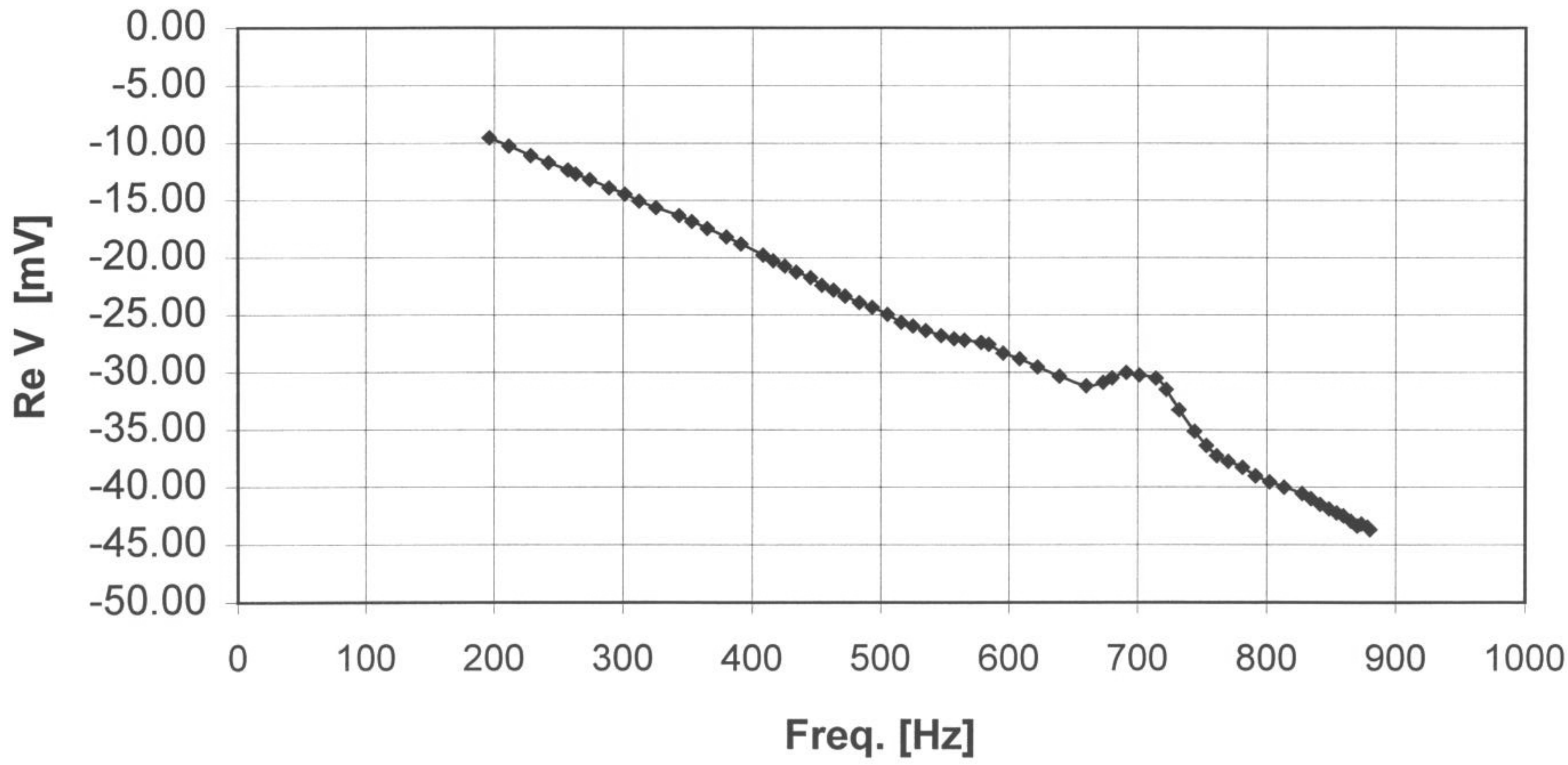
Date:
37362
Time:
1
Number of Freq Measurements:
66
Number of Samples/Freq Point:
2000
Freq Scan Time Duration (sec):
447
Starting Frequency (Hz):
10
Ending Frequency (Hz):
20000
VOLT LockIn Sensitivity (mV):
1000
CURR LockIn Sensitivity (mV):
500

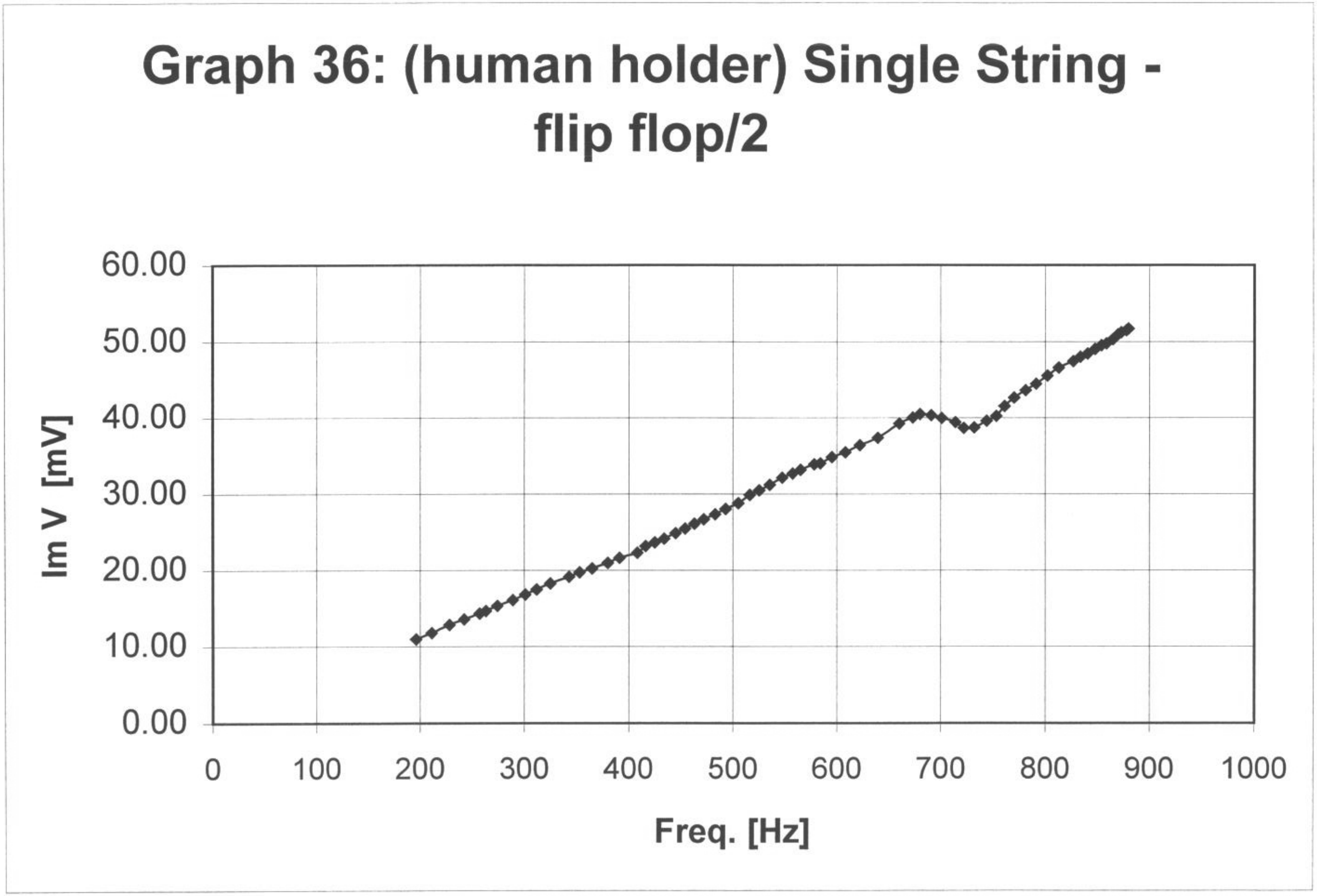
DRILL-1 Data:

Freq	**Vreal**	**Vimag**	**Vtotl**	**VPhase**	**Uncertainty**
196	-9.54	10.97	14.54	130.99	~ 0.5
211	-10.25	11.79	15.62	131.01	~ 0.5
228	-11.09	12.85	16.98	130.80	~ 0.5
242	-11.72	13.59	17.94	130.77	~ 0.5
257	-12.36	14.33	18.92	130.78	~ 0.5
263	-12.70	14.67	19.41	130.88	~ 0.5
274	-13.18	15.33	20.22	130.69	~ 0.5
289	-13.90	16.09	21.26	130.83	~ 0.5
301	-14.45	16.81	22.16	130.68	~ 0.5
312	-15.06	17.47	23.07	130.76	~ 0.5
325	-15.63	18.25	24.03	130.57	~ 0.5
343	-16.33	19.15	25.17	130.46	~ 0.5
353	-16.84	19.71	25.92	130.52	~ 0.5
365	-17.46	20.24	26.74	130.78	~ 0.5
380	-18.20	20.95	27.75	130.98	~ 0.5
391	-18.81	21.62	28.65	131.03	~ 0.5
408	-19.77	22.29	29.80	131.57	~ 0.5
416	-20.26	23.15	30.77	131.18	~ 0.5
425	-20.74	23.64	31.45	131.26	~ 0.5
434	-21.24	24.14	32.15	131.35	~ 0.5
445	-21.75	24.84	33.02	131.20	~ 0.5
454	-22.42	25.45	33.92	131.38	~ 0.5
463	-22.82	26.09	34.66	131.18	~ 0.5
472	-23.35	26.69	35.46	131.19	~ 0.5
483	-23.92	27.33	36.32	131.20	~ 0.5

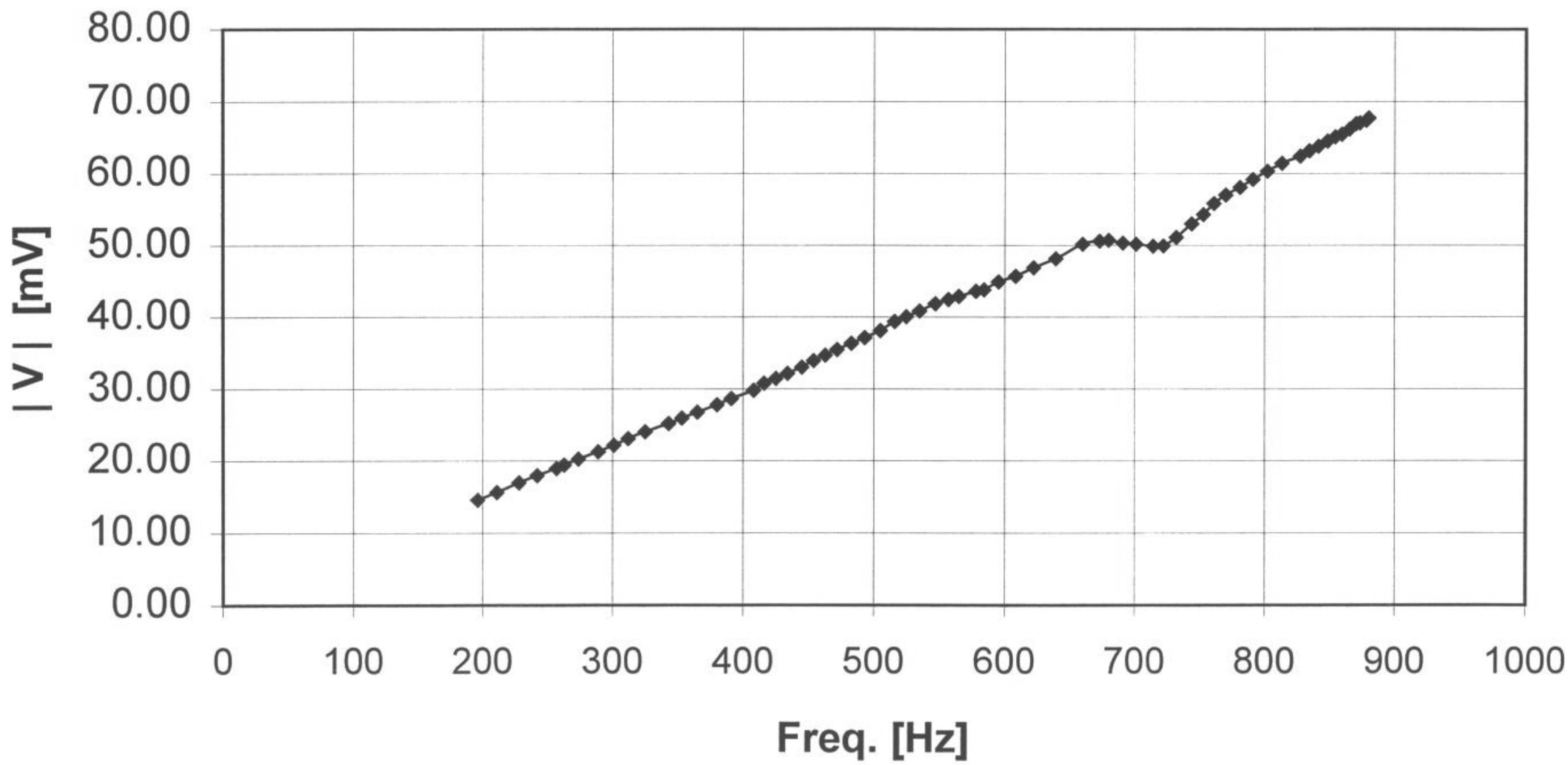
493	-24.33	28.04	37.12	130.95	~ 0.5
505	-24.95	28.78	38.09	130.92	~ 0.5
516	-25.65	29.89	39.39	130.63	~ 0.5
525	-25.95	30.47	40.03	130.42	~ 0.5
535	-26.35	31.21	40.84	130.17	~ 0.5
547	-26.81	32.16	41.87	129.82	~ 0.5
557	-27.07	32.68	42.43	129.64	~ 0.5
565	-27.19	33.16	42.88	129.35	~ 0.5
578	-27.40	33.90	43.59	128.95	~ 0.5
584	-27.57	34.03	43.79	129.01	~ 0.5
595	-28.32	34.82	44.89	129.12	~ 0.5
608	-28.81	35.46	45.69	129.10	~ 0.5
622	-29.53	36.40	46.87	129.06	~ 0.5
639	-30.35	37.37	48.14	129.08	~ 0.5
660	-31.18	39.27	50.14	128.45	~ 0.5
673	-30.88	40.03	50.56	127.65	~ 0.5
680	-30.49	40.49	50.69	126.98	~ 0.5
691	-30.04	40.34	50.30	126.67	~ 0.5
701	-30.25	39.97	50.13	127.13	~ 0.5
714	-30.51	39.42	49.85	127.74	~ 0.5
722	-31.51	38.68	49.89	129.17	~ 0.5
732	-33.29	38.74	51.08	130.67	~ 0.5
744	-35.16	39.60	52.96	131.60	~ 0.5
753	-36.38	40.26	54.26	132.10	~ 0.5
761	-37.28	41.54	55.82	131.91	~ 0.5
770	-37.77	42.69	56.99	131.50	~ 0.5
781	-38.30	43.63	58.06	131.28	~ 0.5
791	-39.02	44.49	59.18	131.25	~ 0.5
802	-39.55	45.55	60.33	130.97	~ 0.5
813	-40.01	46.60	61.42	130.65	~ 0.5
827	-40.55	47.44	62.41	130.53	~ 0.5
834	-40.99	48.03	63.15	130.48	~ 0.5
841	-41.49	48.46	63.80	130.57	~ 0.5
848	-41.90	49.06	64.51	130.50	~ 0.5
854	-42.22	49.52	65.08	130.45	~ 0.5
859	-42.49	49.77	65.44	130.49	~ 0.5
865	-42.95	50.32	66.16	130.48	~ 0.5
870	-43.36	50.97	66.91	130.39	~ 0.5
873	-43.21	51.24	67.02	130.14	~ 0.5
878	-43.47	51.49	67.38	130.17	~ 0.5
880	-43.70	51.72	67.71	130.19	~ 0.5

Graph 35: (human holder) Single String - flip flop/2




Graph 36: (human holder) Single String - flip flop/2
Im V [mV]
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
800
900
1000
Freq. [Hz]

Graph 37: (human holder) Single String - flip flop/2



Graph 38: (human holder) Single String - flip flop/2