GEM TN-92-74
PDT-BU-92-3

Wire Positioning Accuracy Based on Knowledge of Wire Tension

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Abstract:

The wire tension test setup is presented. The sagita-tension relation is presented both calculated and measured, with and without the presence of the electric field.

GEM MEMO

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The PDT technique requires that wire sags of the order of 250 microns be corrected for accurately to enable an overall single wire resolution of 100 microns to be achieved. We have carried out tests on an exposed wire to determine the accuracy with which a wire's position can be determined based on knowledge of the wire's tension.

Fig. 1 shows the experimental set-up and relevant formulae. The wire used was gold plated tungsten (6% gold by weight), with a nominal radius of 25 microns, and a length of 3.7 m. Its measured resistance of 99.5 ohms at 70 degrees F implied an actual diameter of 49.6 microns. Tension was established by hanging weights on the wire after it had passed over a low friction bearing (establishing tension T_3 in that part of the wire; see Fig. 1). The other end of the wire was attached to a weight on a digital scale, also having passed over a bearing. The scale determined the tension in that part of the wire (T_2). The tension in the main length of the wire, T_1, was determined from the fundamental resonant frequency, f. This was determined by passing a sinusoidal current through the wire in the presence of a magnetic field. The ILB force induced oscillations, and resonance was determined electronically by viewing the phase shift in the circuit established by $d\phi/dt$ (see the Figure for details). Note that although the oscillations of the wire were readily visible at resonance, its frequency was determined only by viewing the Lisajous figure on the oscilloscope (as would have to be done for a wire in a tube). With the measured frequency, a wire tension could be determined by the formula given in Fig. 1, and the sag could be calculated (also given in Fig. 1). This sag was then compared with the actual sag determined by viewing the wire through the microscope.

Note from Fig. 1 that the sag of the wire can be determined solely from a measurement of the resonant frequency (it is not necessary to separately determine the wire radius and tension).

Fig. 2 shows a comparison of the actual position of the wire with that determined through the frequency measurement for 7 different wire tensions. Fig. 3 shows

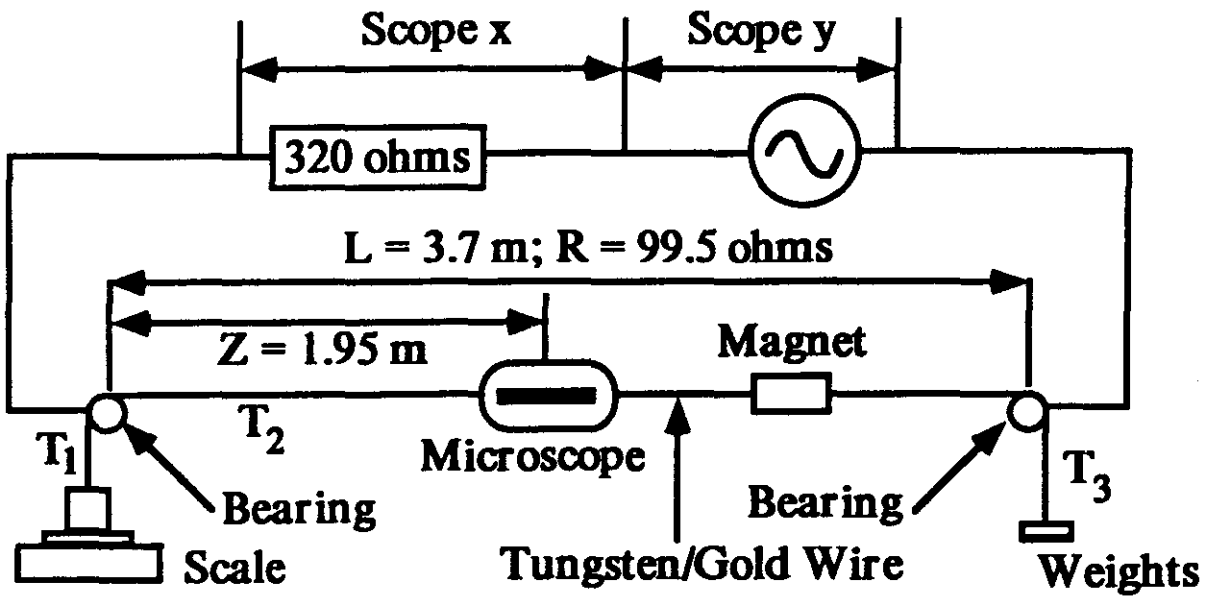
the difference of these numbers. Note that a precision of the order of 5 microns is achievable.

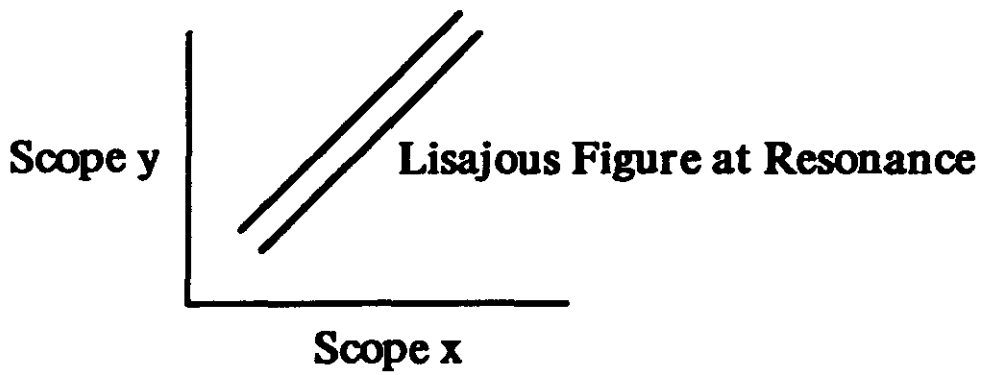
Fig. 4 shows the differences between the tensions T_1, T_2, and T_3. Note that the actual wire tension is typically about 10% lower than the weight, due to friction forces.

Fig. 5 shows the resonant frequency for the 7 different wire tensions. An interesting point is that it was noted by viewing the wire through the microscope that the characteristic building frequency was about 10 Hz (corresponding to the resonant frequency for 25 grams tension). It is important to make sure that vibration frequency spectra in the GEM experimental area are not such as to induce oscillations in the PDT wires.

Finally, Fig. 6 shows the additional wire sag induced on a wire in a tubes due to electrostatic forces. For the voltage required on a PDT (about 4 kV probably), such sag is only of the order of 10 microns.

Wire Tests





R = 99.5 ohms implies diameter = 2r = 49.6 microns (70 F)

S = wire sag
ρ = mass density = 19.3 g/cc (gold and tungsten)
g = gravitational acceleration
f = fundamental resonant frequency
T = tension in wire

$$T = \rho\pi r^2(2Lf)^2$$

$$\boxed{S = \rho\pi r^2 g(Z^2 - LZ)/(2T) = g((Z/L)^2 - (Z/L))/(8f^2)}$$

NOTE: S depends on f only, and has no additional dependence on T or r

Fig. 1

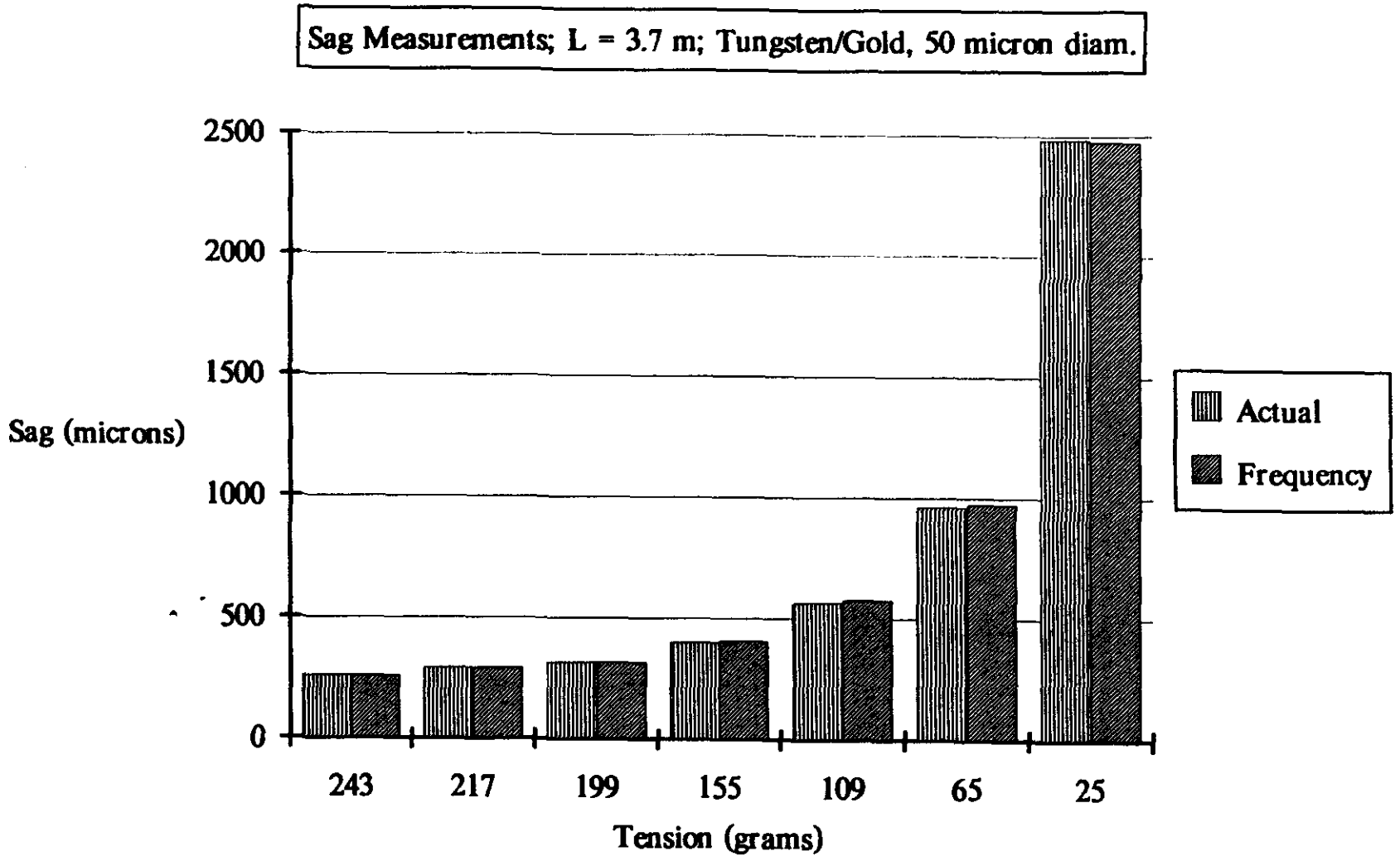
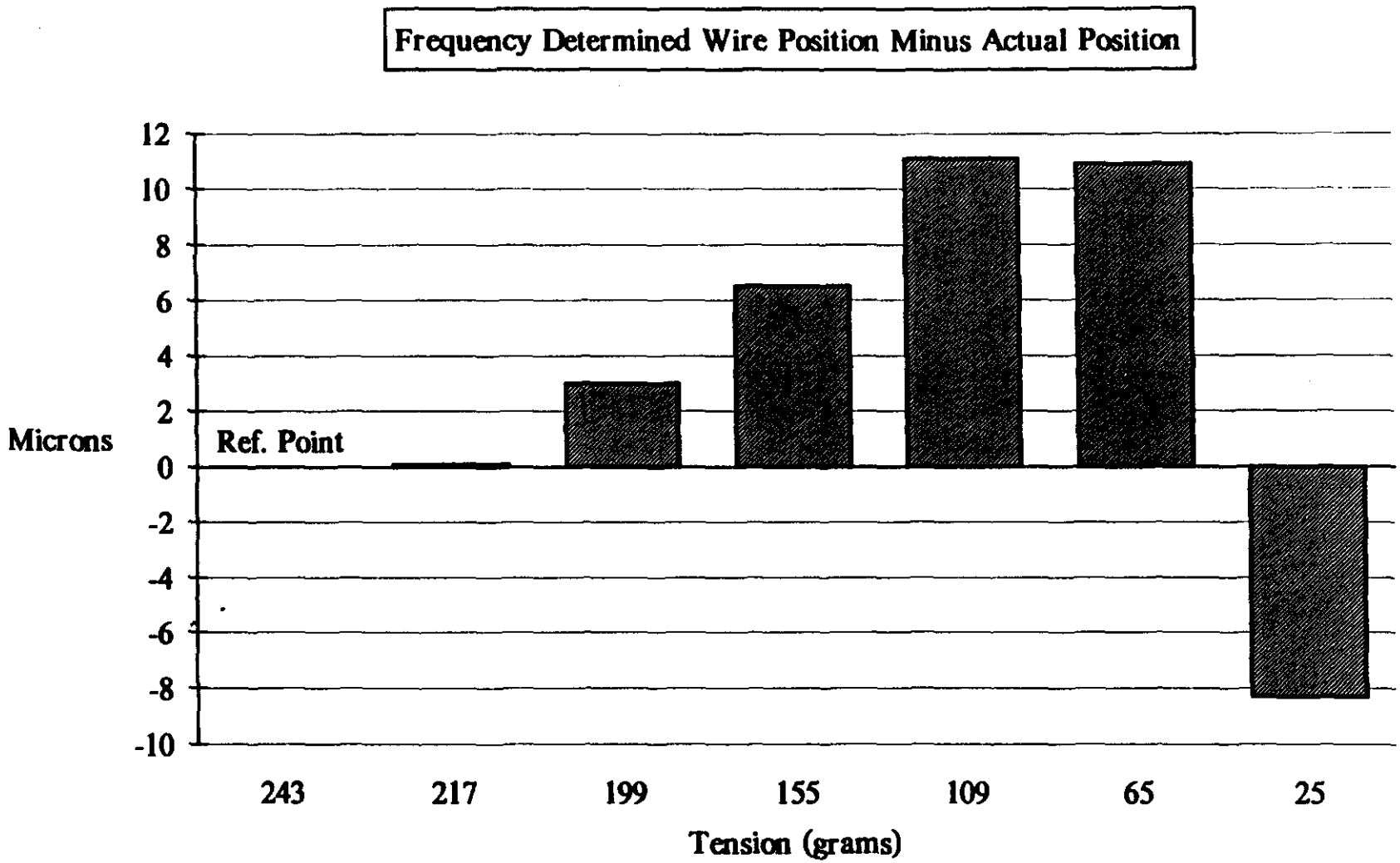

Sag Measurements; L = 3.7 m; Tungsten/Gold, 50 micron diam.
Sag (microns)
2500
2000
1500
1000
500
0
243
217
199
155
109
65
25
Tension (grams)
Actual
Frequency

Fig. 2

Fig. 3


Frequency Determined Wire Position Minus Actual Position
Microns
12
10
8
6
4
2
0
-2
-4
-6
-8
-10
Ref. Point
243
217
199
155
109
65
25
Tension (grams)

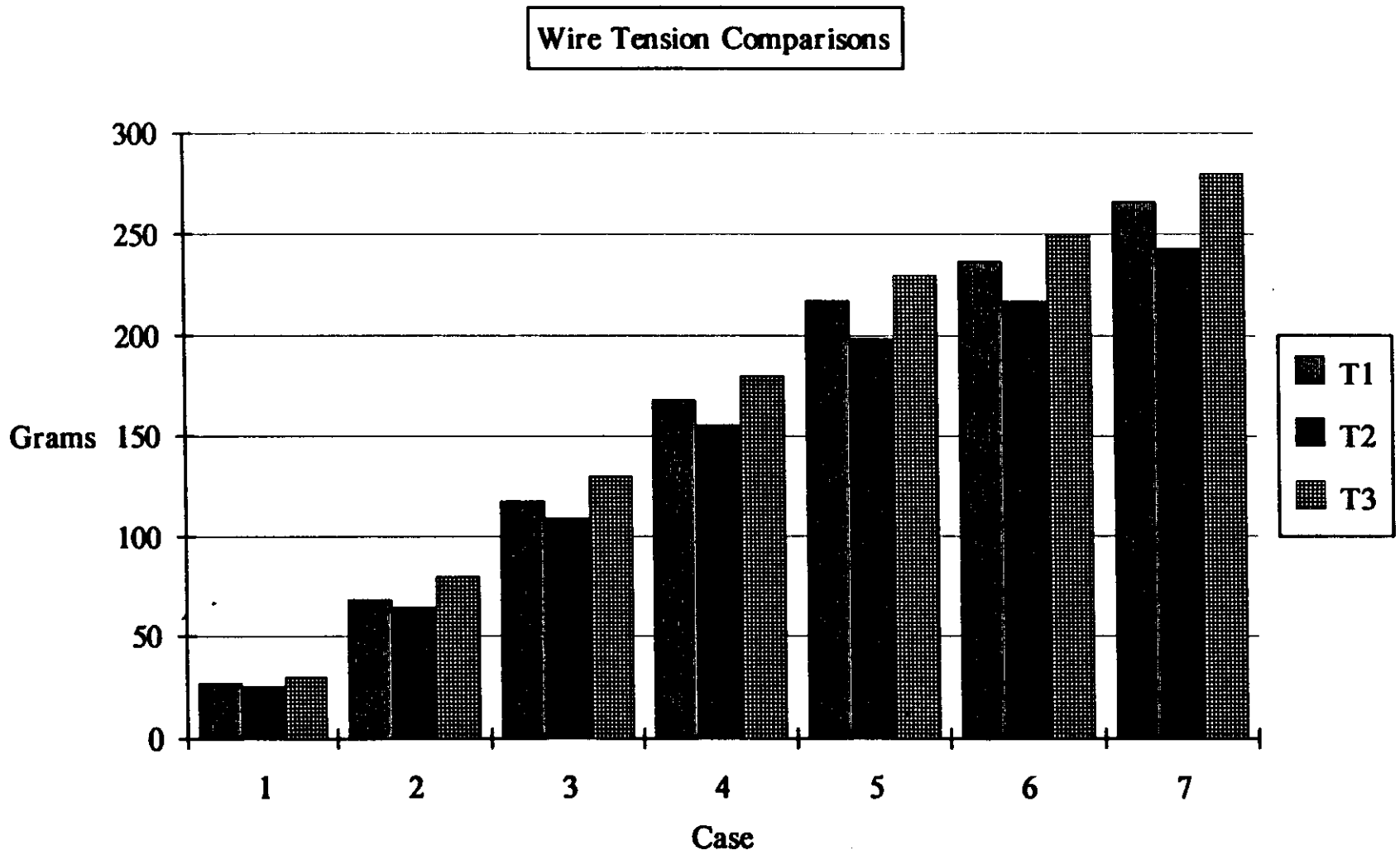

Wire Tension Comparisons
300
250
200
150
100
50
0
Grams
1
2
3
4
5
6
7
Case
T1
T2
T3

Fig. 4

Fig. 5

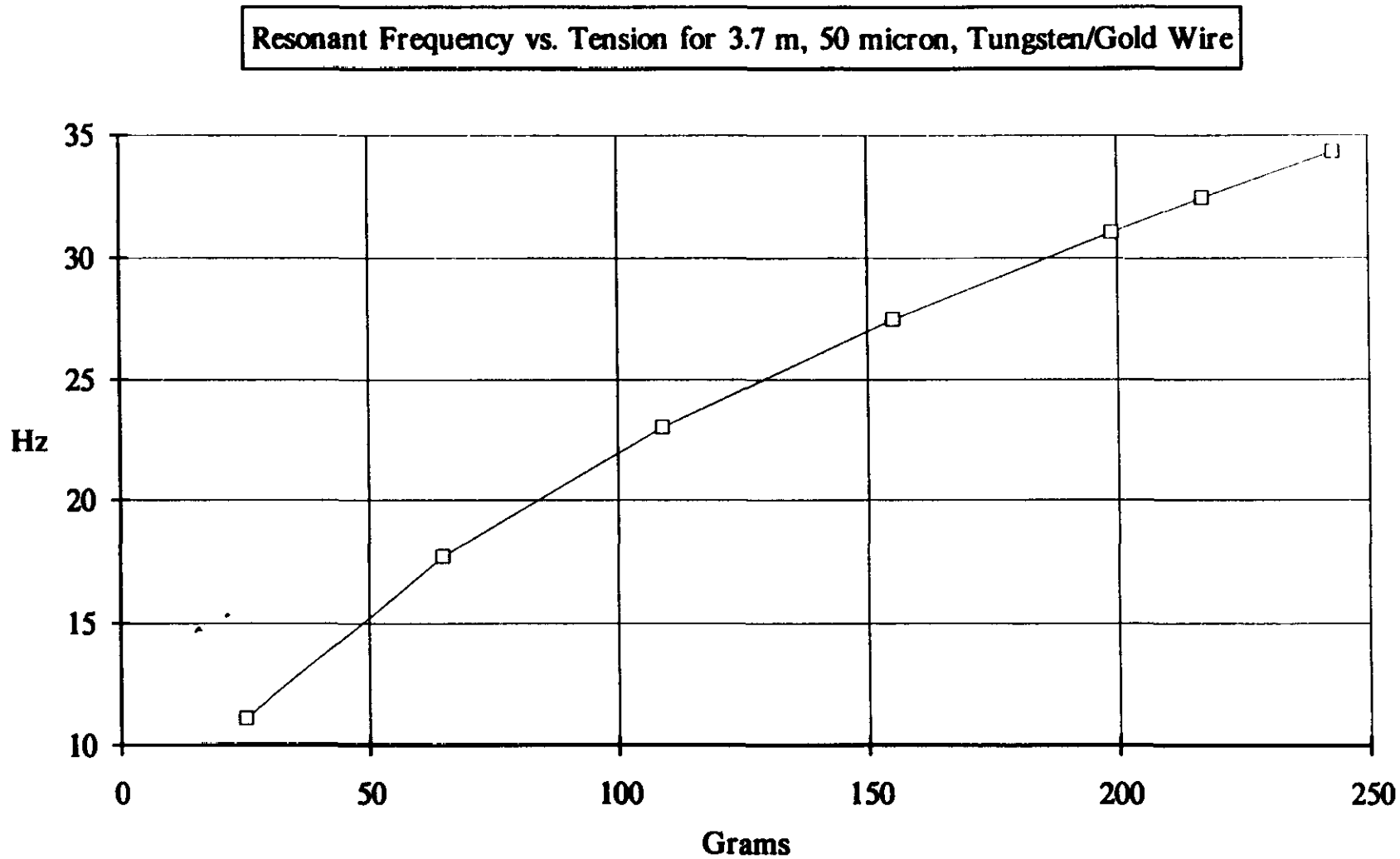
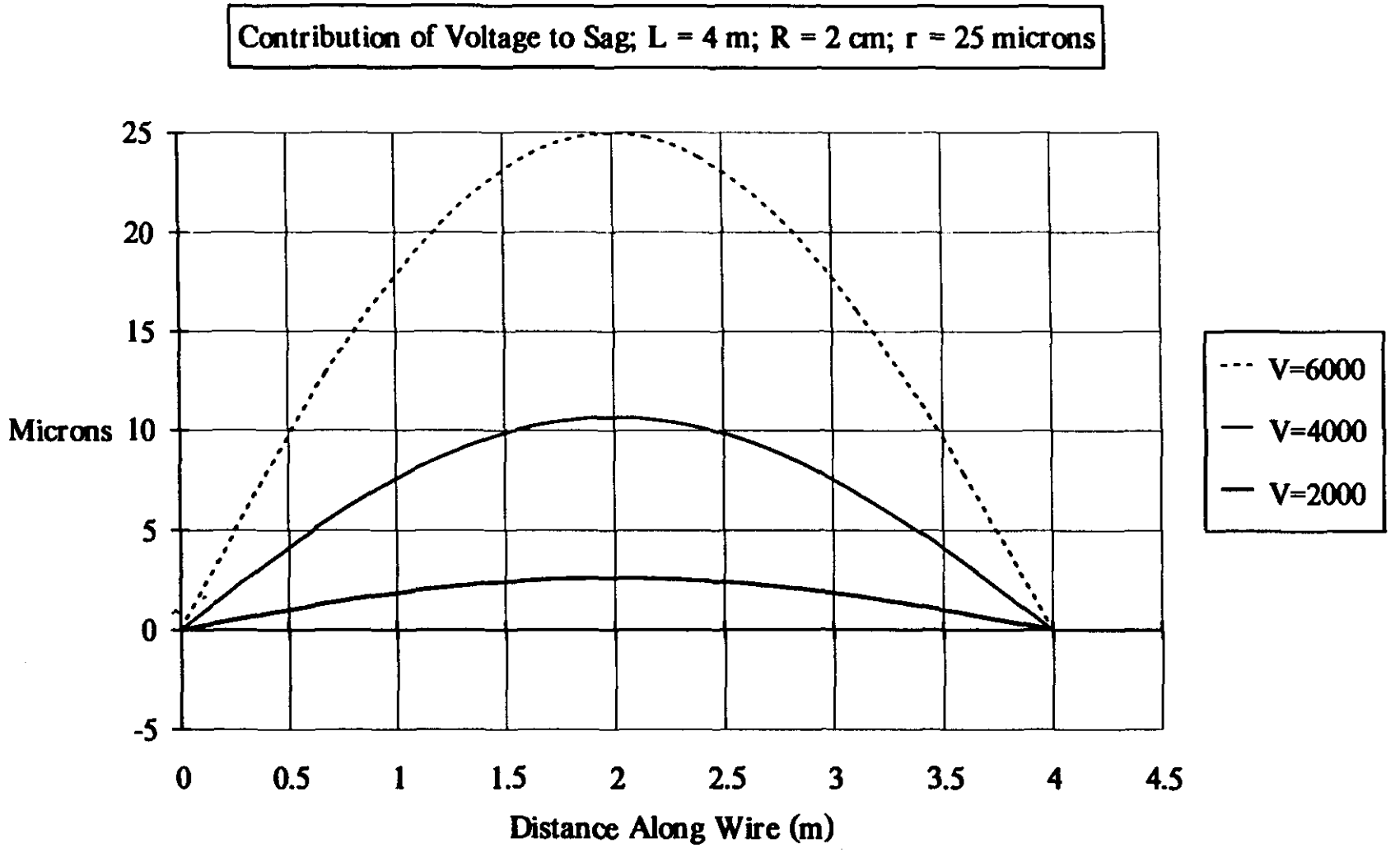

Resonant Frequency vs. Tension for 3.7 m, 50 micron, Tungsten/Gold Wire
35
30
25
20
15
10
Hz
0
50
100
150
200
250
Grams

Fig. 6


Contribution of Voltage to Sag; L = 4 m; R = 2 cm; r = 25 microns
Microns
25
20
15
10
5
0
-5
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
Distance Along Wire (m)
V=6000
V=4000
V=2000