Fermilab

TS-SSC 91-120
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**To:** J. Butteris, S. Delchamps, W. Kinney, M. Lamm, J. Strait, C. Hess

**From:** K. Coulter

**Subj:** Notes on Tangential Probes: Calculations for Probe 14 at Lab 2.

Probe 14 is the new 25cm probe under construction in Lab 2. There are a tangential, a belly band, and 2 dipole windings, D1 and D2, as well as an auxiliary tangential winding.

The pertinent probe geometry parameters are listed on page 1. The calculations follow from references [1], [2] and [3]. Page 2 shows the bucking factor when using only the belly band. Page 3 shows the bucking factors when using only D1 and D2 (no belly band). Pages 4.0 - 4.2 show the equations and bucking factors when using D1 and D2 to make corrections to bucking with the belly band. Since this correction is required only in the event of probe imperfections, these factors will have to be determined from measurements using the probe.

Page 5 reiterates the definitions of $C_n$ $S_n$ $F_n$ and $\gamma_n$ from reference [3]. Page 6 is a table of $F_n$'s for no bucking, belly band bucking, and D1 and D2 bucking, for multipole number n, where D=0 is the dipole. These results are from the FORTRAN program TANGENTIAL.

Figure 1 shows the probe sensitivity factor, $F_n$, for probe 14 as a function of multipole number n, where n=0 is the dipole. The results for both the unbucked and bucked tangential winding (using the belly band) are similar to the example calculation in reference [3]. The magnitude is lower by approximately a factor of 5 since the length of probe 14 is about 1/5 the probe length used in the example calculation. Figure 2 shows $F_n$ vs multipole for the unbucked tangential winding and for the bucked tangential winding using D1 and D2 for bucking instead of the belly band.

Tables 1, 2 and 3 list the output from the program TANGENTIAL that was used to make the figures. I have also written in the bucking factors computed in program TANGENTIAL for comparison with the values calculated on pages 2 and 3.

References

[1] J. Strait, Notes on Tangential Probes: Basic Equations, TS-SSC 90-082, 11/9/90.

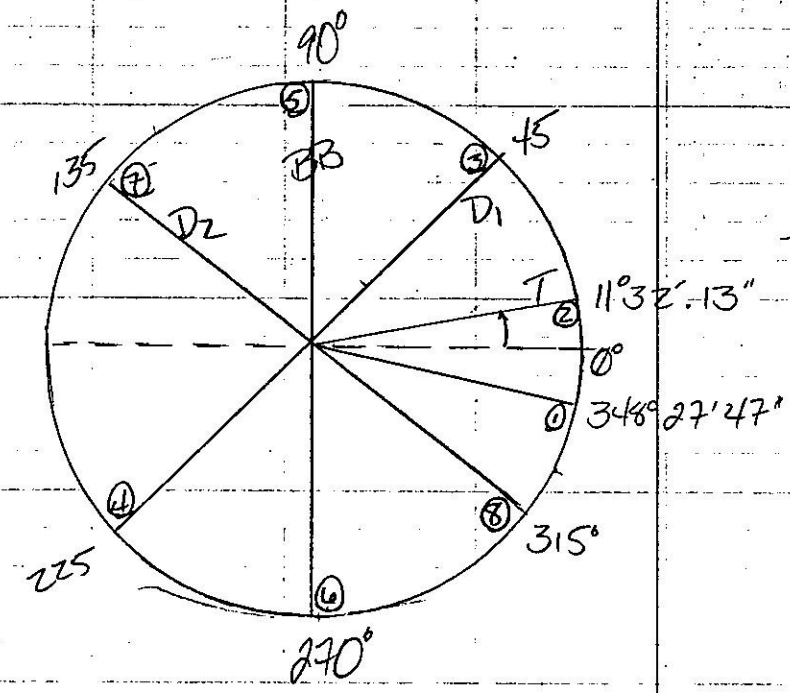
[2] J. Strait, Notes on Tangential Probes: Basic Equations II, TS-SSC 90-092, 11/27/90.

[3] J. Strait, Notes on Tangential Probes: Example Calculations, TS-SSC 90-093, 11/29/90.

cc: S. Gourlay
T. Jaffery
W. Koska

1. calculate d's
2. calculate $F_n$'s $(\div \rho^{n+1})$

Probe 14




| | $i$ | $\phi_i$ | $N_i$ | $f_i$ | $l_i$ (cm) | $r_i$ (cm) |
|---|---|---|---|---|---|---|
| T | 1 | 348.463 | 20 | +1 | 24.30 | 1.242 |
| T | 2 | 11.537 | 20 | −1 | 24.30 | 1.242 |
| $D_1$ | 3 | 45° | 1 | $-d_3$ | 25.0 (8.442) | 1.242 (.499) |
| $D_1$ | 4 | 225° | 1 | $+d_3$ | 25.0 | 1.242 |
| BB | 5 | 90° | 4 | $-d_5$ | 24.32 | 1.242 |
| BB | 6 | 270° | 4 | $+d_5$ | 24.32 | 1.242 |
| $D_2$ | 7 | 135° | 1 | $-d_7$ | 24.68 | 1.242 |
| $D_2$ | 8 | 315° | 1 | $+d_7$ | 24.68 | 1.242 |

Belly Band buckling only (no $D_1$ & $D_2$)

$$C_0 = N_1 l_1 r_1 [\cos\varphi_1 - \cos\varphi_2] + N_5 l_5 r_5 d_5 [\cos\varphi_5 - \cos\varphi_6] \equiv \emptyset$$

$$A + B d_5 = \emptyset$$

$$S_0 = N_1 l_1 r_1 [\sin\varphi_1 - \sin\varphi_2] + N_5 l_5 r_5 d_5 [\sin\varphi_5 - \sin\varphi_6]$$

$$C + D d_5 = \emptyset$$

$$d_5 = \frac{A - C}{D - B}$$

$$= \frac{N_1 l_1 r_1 [C_{12} - S_{12}]}{N_5 l_5 r_5 [S_{56} - C_{56}]}$$

$$\frac{20(24.30)[\emptyset - -0.4]}{4(24.32)[2 - \emptyset]}$$

$$d_5 = .99918$$

for bucking with belly band alone

$D_1$ & $D_2$ bucking (no belly band)

from Jim's paper 11/9/90

$$d_3 = \frac{N_1 l_1 r_1 (C_{12} S_{78} - S_{12} C_{78})}{N_3 l_3 r_3 (C_{78} S_{34} - S_{78} C_{34})}$$

$$\frac{20(24.30)\left[\emptyset - (-0.4)(-1.414)\right]}{1(25.0)\left[\underbrace{(-1.414)(1.414)}_{-2} - \underbrace{(1.414)(1.414)}_{2}\right]}$$

$$\boxed{d_3 = -2.7488}$$

$$d_7 = \frac{N_1 l_1 r_1 (C_{12} S_{34} - S_{12} C_{34})}{N_7 l_7 r_7 (C_{78} S_{34} - S_{78} C_{34})}$$

$$\frac{20(24.30)\left[\emptyset - (-0.4)(1.414)\right]}{1(24.68)\left[-2 - 2\right]}$$

$$\boxed{d_7 = -2.7845}$$

for bucking using $D_1$ & $D_2$ only (no belly band)

Belly Band Bucking w/ $D_1$ & $D_2$ for correction

$$C_0 = N_1 l_1 r_1 [\cos\varphi_1 - \cos\varphi_2] + N_3 l_3 r_3 [\cos\varphi_3 - \cos\varphi_4] d_3 + N_5 l_5 r_5 [\cos\varphi_5 - \cos\varphi_6] d_5 + N_7 l_7 r_7 [\cos\varphi_7 - \cos\varphi_8] d_7$$

$$= A + Bd_3 + Cd_5 + Dd_7$$

$$S_0 = N_1 l_1 r_1 [\sin\varphi_1 - \sin\varphi_2] + N_3 l_3 r_3 [\sin\varphi_3 - \sin\varphi_4] d_3 + N_5 l_5 r_5 [\sin\varphi_5 - \sin\varphi_6] d_5 + N_7 l_7 r_7 [\sin\varphi_7 - \sin\varphi_8] d_7$$

$$= E + Fd_3 + Gd_5 + Hd_7$$

Choose $d_5 = 1.0$ (belly band) from pg 2 since $D_1$ & $D_2$ are used only to correct for geometric imperfections in probe

$$A + Bd_3 + C + Dd_7 \equiv \emptyset$$

$$E + Fd_3 + G + Hd_7 \equiv \emptyset$$

$$(A+C) + Bd_3 + Dd_7 = \emptyset$$

$$(E+G) + Fd_3 + Hd_7 = \emptyset$$

$$\left((A+C)H - (E+G)D\right) + (BH - DF)d_3 = \emptyset$$

$$d_3 = \frac{(A+C)H - (E+G)D}{DF - BH}$$

$$\left((A+C)F - (E+G)B\right) + (DF - BH) = \emptyset$$

$$d_7 = \frac{(A+C)F - (E+G)B}{DF - BH}$$

$$d_3 = \frac{(N_1 l_1 r_1 C_{12} + N_5 l_5 r_5 C_{56})\cancel{N_7 l_7 r_7} S_{78} - (N_1 l_1 r_1 S_{12} + N_5 l_5 r_5 S_{56})\cancel{N_7 l_7 r_7} C_{78}}{\cancel{N_7 l_7 r_7} C_{78} N_3 l_3 r_3 S_{34} - N_3 l_3 r_3 C_{34} \cancel{N_7 l_7 r_7} S_{78}}$$

$$d_3 = \frac{N_1 l_1 r_1 (C_{12} S_{78} - S_{12} C_{78}) + N_5 l_5 r_5 (C_{56} S_{78} - S_{56} C_{78})}{N_3 l_3 r_3 (C_{78} S_{34} - S_{78} C_{34})}$$

$$d_7 = \frac{(N_1 l_1 r_1 C_{12} + N_5 l_5 r_5 C_{56})\cancel{N_3 l_3 r_3} S_{34} - (N_1 l_1 r_1 S_{12} + N_5 l_5 r_5 S_{56})\cancel{N_3 l_3 r_3} C_{34}}{N_7 l_7 r_7 C_{78} \cancel{N_3 l_3 r_3} S_{34} - \cancel{N_3 l_3 r_3} C_{34} N_7 l_7 r_7 S_{78}}$$

$$d_7 = \frac{N_1 l_1 r_1 (C_{12} S_{34} - S_{12} C_{34}) + N_5 l_5 r_5 (C_{56} S_{34} - S_{56} C_{34})}{N_7 l_7 r_7 (C_{78} S_{34} - C_{34} S_{78})}$$

.22624

$$d_3 = \frac{20(24.30)\left[\emptyset - (-0.4)(-1.414)\right] + 4(24.32)\left[\emptyset - (2)(-1.414)\right]}{(1)(25.\emptyset)\left[\underbrace{(-1.414)(1.414)}_{-2} - \underbrace{(1.414)(1.414)}_{2}\right]}$$

$$d_3 = -.00226$$

$$d_7 = \frac{20(24.30)\left[\emptyset - (-0.4)(1.414)\right] + 4(24.32)\left[\emptyset - (2)(1.414)\right]}{(1)(24.68)\left[\underset{(-2)}{(-1.414)(1.414)} - \underset{(2)}{(1.414)(1.414)}\right]}$$

$$d_7 = .00229$$

$$C_n = \sum_{j=1}^{8} f_j N_j l_j \frac{r_j^{\bar{n}}}{\rho^{\pi}} \cos \bar{n} \varphi_j$$

$$S_n = \sum_{j=1}^{8} f_j N_j l_j \frac{r_j^{\bar{n}}}{\rho^{\pi}} \sin \bar{n} \varphi_j$$

$$F_n = \sqrt{C_n^2 + S_n^2} \qquad \gamma_n = \tan^{-1}\left(\frac{S_n}{C_n}\right)$$

given Fourier amplit $A_n$ and phase $\delta_n$,

$$h_n = \frac{\bar{n} A_n}{B_0 \rho F_n} \qquad \alpha_n = \delta_n - \gamma_n - \bar{n}\varphi + \pi$$

are the multipole amplitude & phase

$F_n$

| N | Unbucked tangential | Bellyband Bucking | D1 & D2 bucking |
|---|---|---|---|
| 0 | 1.944 | 4.E-17 | 6.E-17 |
| 1 | 3.809 | 3.809 | 3.809 |
| 2 | 5.521 | 7.465 | 3.577 |
| 3 | 7.009 | 7.009 | 7.009 |
| 4 | 8.215 | 6.271 | 10.16 |
| 5 | 9.088 | 9.088 | 9.088 |
| 6 | 9.594 | 11.54 | 11.54 |
| 7 | 9.712 | 9.712 | 9.712 |
| 8 | 9.438 | 7.494 | 7.494 |
| 9 | 8.783 | 8.783 | 8.783 |
| 10 | 7.772 | 9.716 | 5.828 |
| 11 | 6.448 | 6.448 | 6.448 |
| 12 | 4.863 | 2.919 | 6.807 |
| 13 | 3.081 | 3.081 | 3.081 |
| 14 | 1.175 | 3.119 | 3.119 |
| 15 | .7782 | .7782 | .7782 |
| 16 | 2.700 | 4.644 | 4.644 |
| 17 | 4.513 | 4.513 | 4.513 |
| 18 | 6.144 | 4.200 | 8.088 |
| 19 | 7.526 | 7.526 | 7.526 |
| 20 | 8.604 | 10.55 | 6.660 |

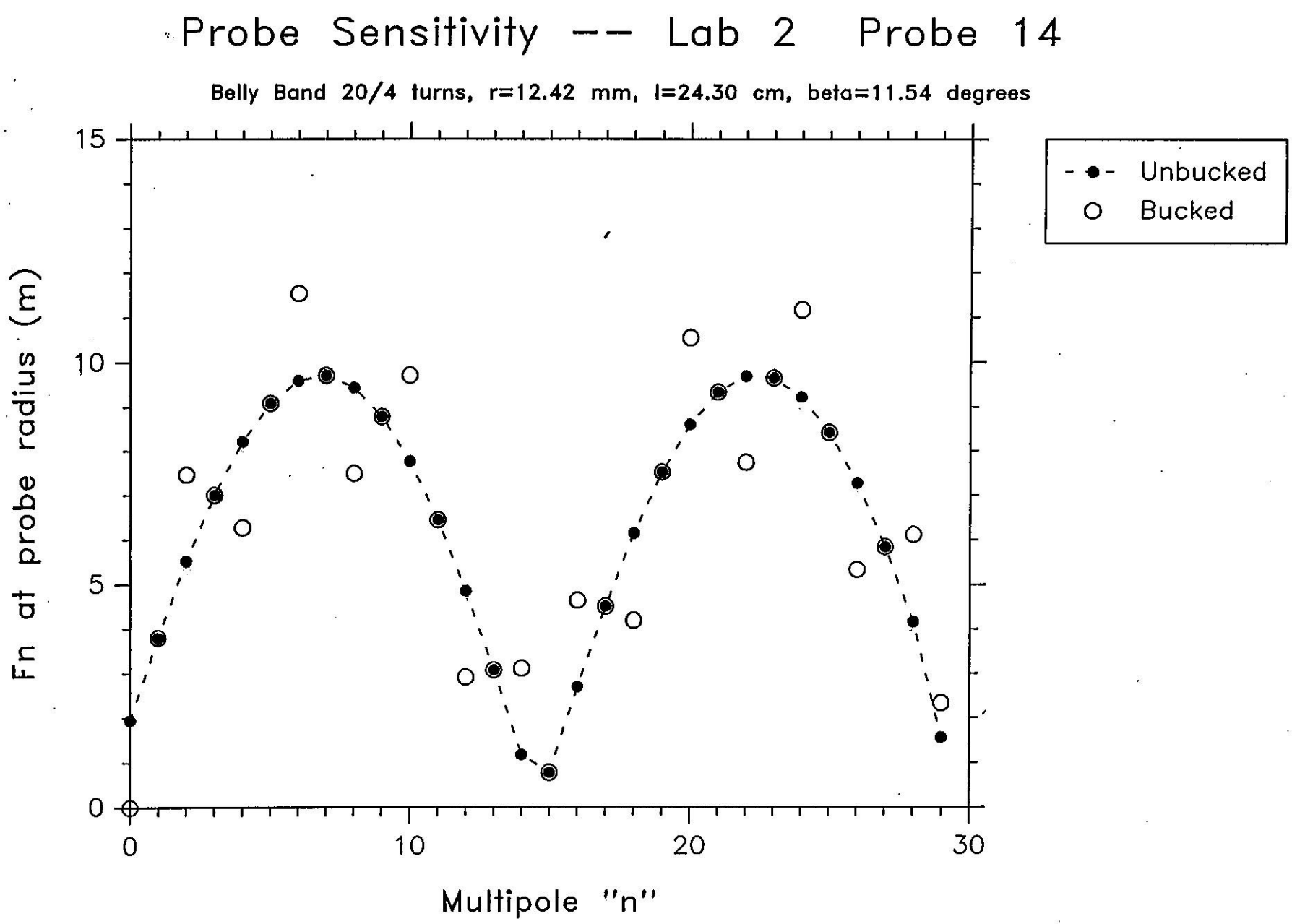

Probe Sensitivity -- Lab 2 Probe 14
Belly Band 20/4 turns, r=12.42 mm, l=24.30 cm, beta=11.54 degrees
Fn at probe radius (m)
Multipole "n"
Unbucked
Bucked
0
5
10
15
0
10
20
30

Figure 1

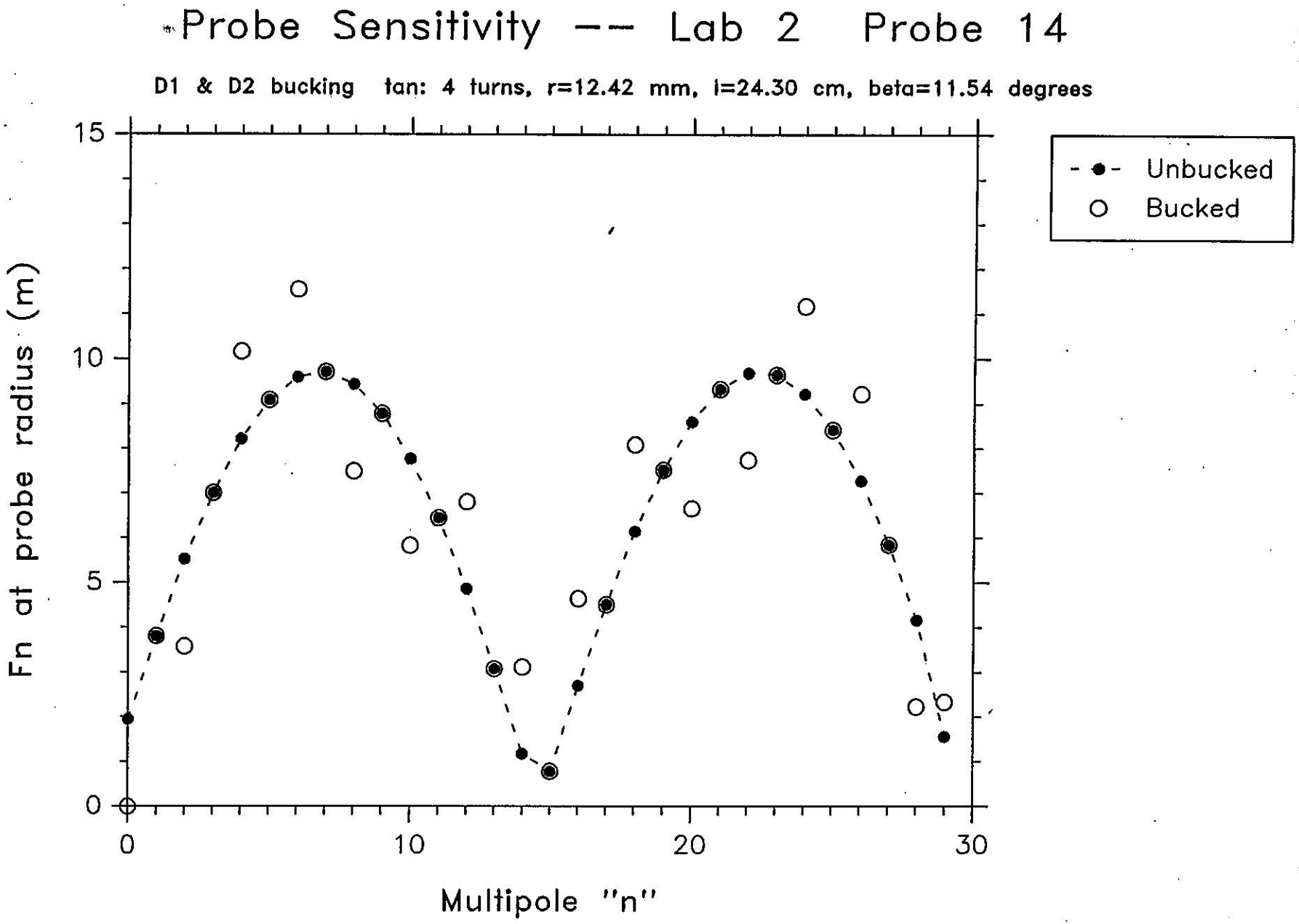

Probe Sensitivity -- Lab 2 Probe 14
D1 & D2 bucking tan: 4 turns, r=12.42 mm, l=24.30 cm, beta=11.54 degrees
Unbucked
Bucked
Fn at probe radius (m)
Multipole "n"
0
5
10
15
0
10
20
30

Figure 2

tangential only — no ducking

| N | NBAR | C | S | F(M**(N+2)) | GAMMA | FORLITZ | FO0.39IN. |
|---|---|---|---|---|---|---|---|
| 0. | 1. | 0.3286E-09 | -.1944E+01 | 0.2415E-01 | -90.00 | 0.1944E+01 | 0.2415E+01 |
| 1. | 2. | 0.1288E-08 | -.3809E+01 | 0.5877E-03 | -90.00 | 0.3809E+01 | 0.5877E+01 |
| 2. | 3. | 0.2799E-08 | -.5521E+01 | 0.1058E-04 | -90.00 | 0.5521E+01 | 0.1058E+02 |
| 3. | 4. | 0.4739E-08 | -.7009E+01 | 0.1668E-06 | -90.00 | 0.7009E+01 | 0.1668E+02 |
| 4. | 5. | 0.6942E-08 | -.8215E+01 | 0.2428E-08 | -90.00 | 0.8215E+01 | 0.2428E+02 |
| 5. | 6. | 0.9216E-08 | -.9088E+01 | 0.3337E-10 | -90.00 | 0.9088E+01 | 0.3337E+02 |
| 6. | 7. | 0.1135E-07 | -.9594E+01 | 0.4375E-12 | -90.00 | 0.9594E+01 | 0.4375E+02 |
| 7. | 8. | 0.1313E-07 | -.9712E+01 | 0.5501E-14 | -90.00 | 0.9712E+01 | 0.5501E+02 |
| 8. | 9. | 0.1436E-07 | -.9438E+01 | 0.6640E-16 | -90.00 | 0.9438E+01 | 0.6640E+02 |
| 9. | 10. | 0.1484E-07 | -.8783E+01 | 0.7675E-18 | -90.00 | 0.8783E+01 | 0.7675E+02 |
| 10. | 11. | 0.1445E-07 | -.7772E+01 | 0.8436E-20 | -90.00 | 0.7772E+01 | 0.8436E+02 |
| 11. | 12. | 0.1308E-07 | -.6448E+01 | 0.8692E-22 | -90.00 | 0.6448E+01 | 0.8692E+02 |
| 12. | 13. | 0.1068E-07 | -.4863E+01 | 0.8142E-24 | -90.00 | 0.4863E+01 | 0.8142E+02 |
| 13. | 14. | 0.7291E-08 | -.3081E+01 | 0.6408E-26 | -90.00 | 0.3081E+01 | 0.6408E+02 |
| 14. | 15. | 0.2980E-08 | -.1175E+01 | 0.3036E-28 | -90.00 | 0.1175E+01 | 0.3036E+02 |
| 15. | 16. | -.2104E-08 | 0.7782E+00 | 0.2497E-30 | 90.00 | 0.7782E+00 | 0.2497E+02 |
| 16. | 17. | -.7758E-08 | 0.2700E+01 | 0.1076E-31 | 90.00 | 0.2700E+01 | 0.1076E+03 |
| 17. | 18. | -.1373E-07 | 0.4513E+01 | 0.2234E-33 | 90.00 | 0.4513E+01 | 0.2234E+03 |
| 18. | 19. | -.1973E-07 | 0.6144E+01 | 0.3777E-35 | 90.00 | 0.6144E+01 | 0.3777E+03 |
| 19. | 20. | -.2544E-07 | 0.7526E+01 | 0.5747E-37 | 90.00 | 0.7526E+01 | 0.5747E+03 |
| 20. | 21. | -.3054E-07 | 0.8604E+01 | 0.0000E+00 | 90.00 | 0.8604E+01 | 0.8161E+03 |
| 21. | 22. | -.3471E-07 | 0.9335E+01 | 0.0000E+00 | 90.00 | 0.9335E+01 | 0.1100E+04 |
| 22. | 23. | -.3766E-07 | 0.9688E+01 | 0.0000E+00 | 90.00 | 0.9688E+01 | 0.1418E+04 |
| 23. | 24. | -.3914E-07 | 0.9650E+01 | 0.0000E+00 | 90.00 | 0.9650E+01 | 0.1754E+04 |
| 24. | 25. | -.3896E-07 | 0.9222E+01 | 0.0000E+00 | 90.00 | 0.9222E+01 | 0.2082E+04 |
| 25. | 26. | -.3700E-07 | 0.8421E+01 | 0.0000E+00 | 90.00 | 0.8421E+01 | 0.2361E+04 |
| 26. | 27. | -.3322E-07 | 0.7280E+01 | 0.0000E+00 | 90.00 | 0.7280E+01 | 0.2535E+04 |
| 27. | 28. | -.2766E-07 | 0.5845E+01 | 0.0000E+00 | 90.00 | 0.5845E+01 | 0.2528E+04 |
| 28. | 29. | -.2045E-07 | 0.4173E+01 | 0.0000E+00 | 90.00 | 0.4173E+01 | 0.2242E+04 |
| 29. | 30. | -.1183E-07 | 0.2333E+01 | 0.0000E+00 | 90.00 | 0.2333E+01 | 0.1557E+04 |

Table 1

Buckling w/ Belly band

| N | NBAR | C | S | F(M**(N+2)) | GAMMA | FORLITZ | FOO.39IN. |
|---|---|---|---|---|---|---|---|
| 0. | 1. | -.3866E-16 | 0.2776E-16 | 0.5911E-18 | 144.33 | 0.4759E-16 | 0.5912E-16 |
| 1. | 2. | 0.1288E-08 | -.3809E+01 | 0.5877E-03 | -90.00 | 0.3809E+01 | 0.5877E+01 |
| 2. | 3. | 0.3785E-08 | -.7465E+01 | 0.1430E-04 | -90.00 | 0.7465E+01 | 0.1430E+02 |
| 3. | 4. | 0.4739E-08 | -.7009E+01 | 0.1668E-06 | -90.00 | 0.7009E+01 | 0.1668E+02 |
| 4. | 5. | 0.5299E-08 | -.6271E+01 | 0.1854E-08 | -90.00 | 0.6271E+01 | 0.1854E+02 |
| 5. | 6. | 0.9216E-08 | -.9088E+01 | 0.3337E-10 | -90.00 | 0.9088E+01 | 0.3337E+02 |
| 6. | 7. | 0.1365E-07 | -.1154E+02 | 0.5262E-12 | -90.00 | 0.1154E+02 | 0.5262E+02 |
| 7. | 8. | 0.1313E-07 | -.9712E+01 | 0.5501E-14 | -90.00 | 0.9712E+01 | 0.5501E+02 |
| 8. | 9. | 0.1140E-07 | -.7494E+01 | 0.5272E-16 | -90.00 | 0.7494E+01 | 0.5272E+02 |
| 9. | 10. | 0.1484E-07 | -.8783E+01 | 0.7675E-18 | -90.00 | 0.8783E+01 | 0.7675E+02 |
| 10. | 11. | 0.1806E-07 | -.9716E+01 | 0.1055E-19 | -90.00 | 0.9716E+01 | 0.1055E+03 |
| 11. | 12. | 0.1308E-07 | -.6448E+01 | 0.8692E-22 | -90.00 | 0.6448E+01 | 0.8692E+02 |
| 12. | 13. | 0.6413E-08 | -.2919E+01 | 0.4887E-24 | -90.00 | 0.2919E+01 | 0.4887E+02 |
| 13. | 14. | 0.7291E-08 | -.3081E+01 | 0.6408E-26 | -90.00 | 0.3081E+01 | 0.6408E+02 |
| 14. | 15. | 0.7908E-08 | -.3119E+01 | 0.8058E-28 | -90.00 | 0.3119E+01 | 0.8058E+02 |
| 15. | 16. | -.2104E-08 | 0.7782E+00 | 0.2497E-30 | 90.00 | 0.7782E+00 | 0.2497E+02 |
| 16. | 17. | -.1334E-07 | 0.4644E+01 | 0.1851E-31 | 90.00 | 0.4644E+01 | 0.1851E+03 |
| 17. | 18. | -.1373E-07 | 0.4513E+01 | 0.2234E-33 | 90.00 | 0.4513E+01 | 0.2234E+03 |
| 18. | 19. | -.1349E-07 | 0.4200E+01 | 0.2582E-35 | 90.00 | 0.4200E+01 | 0.2582E+03 |
| 19. | 20. | -.2544E-07 | 0.7526E+01 | 0.5747E-37 | 90.00 | 0.7526E+01 | 0.5747E+03 |
| 20. | 21. | -.3744E-07 | 0.1055E+02 | 0.0000E+00 | 90.00 | 0.1055E+02 | 0.1000E+04 |
| 21. | 22. | -.3471E-07 | 0.9335E+01 | 0.0000E+00 | 90.00 | 0.9335E+01 | 0.1100E+04 |
| 22. | 23. | -.3010E-07 | 0.7744E+01 | 0.0000E+00 | 90.00 | 0.7744E+01 | 0.1133E+04 |
| 23. | 24. | -.3914E-07 | 0.9650E+01 | 0.0000E+00 | 90.00 | 0.9650E+01 | 0.1754E+04 |
| 24. | 25. | -.4718E-07 | 0.1117E+02 | 0.0000E+00 | 90.00 | 0.1117E+02 | 0.2520E+04 |
| 25. | 26. | -.3700E-07 | 0.8421E+01 | 0.0000E+00 | 90.00 | 0.8421E+01 | 0.2361E+04 |
| 26. | 27. | -.2435E-07 | 0.5336E+01 | 0.0000E+00 | 90.00 | 0.5336E+01 | 0.1858E+04 |
| 27. | 28. | -.2766E-07 | 0.5845E+01 | 0.0000E+00 | 90.00 | 0.5845E+01 | 0.2528E+04 |
| 28. | 29. | -.2998E-07 | 0.6117E+01 | 0.0000E+00 | 90.00 | 0.6117E+01 | 0.3286E+04 |
| 29. | 30. | -.1183E-07 | 0.2333E+01 | 0.0000E+00 | 90.00 | 0.2333E+01 | 0.1557E+04 |

log Tangential : $\phi_3 = 0.9993$

Table 2

Ducking w/ D1 & D2

| N | NBAR | C | S | F(M**(N+2)) | GAMMA | FORLITZ | FQ0.39IN. |
|---|---|---|---|---|---|---|---|
| 0. | 1. | -.4857E-16 | 0.3469E-16 | 0.7414E-18 | 144.46 | 0.5969E-16 | 0.7414E-16 |
| 1. | 2. | 0.1288E-08 | -.3809E+01 | 0.5877E-03 | -90.00 | 0.3809E+01 | 0.5877E+01 |
| 2. | 3. | 0.1814E-08 | -.3577E+01 | 0.6854E-05 | -90.00 | 0.3577E+01 | 0.6854E+01 |
| 3. | 4. | 0.4739E-08 | -.7009E+01 | 0.1668E-06 | -90.00 | 0.7009E+01 | 0.1668E+02 |
| 4. | 5. | 0.8584E-08 | -.1016E+02 | 0.3003E-08 | -90.00 | 0.1016E+02 | 0.3003E+02 |
| 5. | 6. | 0.9216E-08 | -.9088E+01 | 0.3337E-10 | -90.00 | 0.9088E+01 | 0.3337E+02 |
| 6. | 7. | 0.1365E-07 | -.1154E+02 | 0.5262E-12 | -90.00 | 0.1154E+02 | 0.5262E+02 |
| 7. | 8. | 0.1313E-07 | -.9712E+01 | 0.5501E-14 | -90.00 | 0.9712E+01 | 0.5501E+02 |
| 8. | 9. | 0.1140E-07 | -.7494E+01 | 0.5272E-16 | -90.00 | 0.7494E+01 | 0.5272E+02 |
| 9. | 10. | 0.1484E-07 | -.8783E+01 | 0.7675E-18 | -90.00 | 0.8783E+01 | 0.7675E+02 |
| 10. | 11. | 0.1084E-07 | -.5828E+01 | 0.6326E-20 | -90.00 | 0.5828E+01 | 0.6326E+02 |
| 11. | 12. | 0.1308E-07 | -.6448E+01 | 0.8692E-22 | -90.00 | 0.6448E+01 | 0.8692E+02 |
| 12. | 13. | 0.1496E-07 | -.6807E+01 | 0.1140E-23 | -90.00 | 0.6807E+01 | 0.1140E+03 |
| 13. | 14. | 0.7291E-08 | -.3081E+01 | 0.6408E-26 | -90.00 | 0.3081E+01 | 0.6408E+02 |
| 14. | 15. | 0.7908E-08 | -.3119E+01 | 0.8058E-28 | -90.00 | 0.3119E+01 | 0.8058E+02 |
| 15. | 16. | -.2104E-08 | 0.7782E+00 | 0.2497E-30 | 90.00 | 0.7782E+00 | 0.2497E+02 |
| 16. | 17. | -.1334E-07 | 0.4644E+01 | 0.1851E-31 | 90.00 | 0.4644E+01 | 0.1851E+03 |
| 17. | 18. | -.1373E-07 | 0.4513E+01 | 0.2234E-33 | 90.00 | 0.4513E+01 | 0.2234E+03 |
| 18. | 19. | -.2597E-07 | 0.8088E+01 | 0.4972E-35 | 90.00 | 0.8088E+01 | 0.4972E+03 |
| 19. | 20. | -.2544E-07 | 0.7526E+01 | 0.5747E-37 | 90.00 | 0.7526E+01 | 0.5747E+03 |
| 20. | 21. | -.2364E-07 | 0.6660E+01 | 0.0000E+00 | 90.00 | 0.6660E+01 | 0.6317E+03 |
| 21. | 22. | -.3471E-07 | 0.9335E+01 | 0.0000E+00 | 90.00 | 0.9335E+01 | 0.1100E+04 |
| 22. | 23. | -.3010E-07 | 0.7744E+01 | 0.0000E+00 | 90.00 | 0.7744E+01 | 0.1133E+04 |
| 23. | 24. | -.3914E-07 | 0.9650E+01 | 0.0000E+00 | 90.00 | 0.9650E+01 | 0.1754E+04 |
| 24. | 25. | -.4718E-07 | 0.1117E+02 | 0.0000E+00 | 90.00 | 0.1117E+02 | 0.2520E+04 |
| 25. | 26. | -.3700E-07 | 0.8421E+01 | 0.0000E+00 | 90.00 | 0.8421E+01 | 0.2361E+04 |
| 26. | 27. | -.4209E-07 | 0.9224E+01 | 0.0000E+00 | 90.00 | 0.9224E+01 | 0.3212E+04 |
| 27. | 28. | -.2766E-07 | 0.5845E+01 | 0.0000E+00 | 90.00 | 0.5845E+01 | 0.2528E+04 |
| 28. | 29. | -.1093E-07 | 0.2229E+01 | 0.0000E+00 | 90.00 | 0.2229E+01 | 0.1198E+04 |
| 29. | 30. | -.1183E-07 | 0.2333E+01 | 0.0000E+00 | 90.00 | 0.2333E+01 | 0.1557E+04 |

$F_i$

$d_3 = 2.7494$

$d_7 = 2.7848$

Table 3