OBSERVATIONS OF ALFVÉN RESONANCES IN TOKAPOLE II

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ABSTRACT

OBSERVATIONS OF ALFVÉN RESONANCES IN TOKAPOLE II*

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WE ARE EXPERIMENTALLY INVESTIGATING THE POSSIBILITY OF PERFORMING A HIGH POWER, LOW FREQUENCY (~1 MHz) RF HEATING EXPERIMENT UTILIZING THE SHEAR ALFVÉN RESONANCE IN A TOKAMAK-LIKE PLASMA. TO THIS END, WAVE PROPAGATION STUDIES HAVE BEEN PERFORMED IN TOKAPOLE II USING A 1.3 MHz OSCILLATOR WITH A MAXIMUM POWER OUTPUT OF 100 KW. TOKAPOLE II IS A TOKAMAK WITH A FOUR-NODE POLOIDAL DIVERTOR FORMED BY FOUR INTERNAL RINGS. THESE RINGS ALSO SERVE AS THE LAUNCHING STRUCTURE, ELIMINATING THE NEED FOR SPECIALLY CONSTRUCTED ANTENNAS. BY GROUNDING A RING TO THE TANK AT ONE OF ITS SUPPORTS, AND DRIVING ONE OF THE OTHER TWO SUPPORTS, RF CURRENTS CAN BE DRIVEN THROUGH THE RINGS, WITH THE CURRENT RETURNING THROUGH THE TANK ITSELF. THE THIRD SUPPORT REMAINS INSULATED AND UNUSED. DRIVING ALL FOUR RINGS IN PHASE PRODUCES AN OCTUPOLE FIELD. POLOIDAL MODE NUMBER CAN BE CHOSEN FROM M=1,2,OR 4 SIMPLY BY CHOOSING THE PROPER NUMBER AND PHASE OF THE RINGS DRIVEN. LOCAL MAGNETIC FIELD RESONANCES HAVE BEEN DETECTED USING MAGNETIC COILS INSIDE QUARTZ TUBES INSERTED DIRECTLY INTO THE PLASMA. THE RESULTS OF THESE INITIAL STUDIES WILL BE PRESENTED.

*WORK SUPPORTED BY USDOE.

PURPOSE

DRIVING SHEAR ALFVÉN WAVE RESONANCES HAS BEEN SUGGESTED AS A PROMISING PLASMA HEATING SCHEME. ONE OF ITS MOST ATTRACTIVE FEATURES IS THE POSSIBILITY OF USING ARBITRARILY LOW FREQUENCIES FOR HEATING. ENCOURAGING RESULTS HAVE BEEN OBTAINED IN STELLARATORS AND LINEAR DEVICES, BUT SO FAR NO HEATING EXPERIMENT HAS BEEN PERFORMED IN A TOKAMAK.

THE PURPOSE OF OUR EXPERIMENT IS TO DETERMINE EXPERIMENTALLY WHETHER WE CAN EXCITE SUCH RESONANCES IN THE TOKAPOLE II DEVICE, AND THUS WARRANT A HIGH POWER (~1 MW) HEATING EXPERIMENT.

IDEAL MHD PREDICTS THAT LOCALIZED $B_{POLOIDAL}$ RESONANCES WILL OCCUR AT SURFACES IN THE PLASMA ON WHICH THE CONDITION

$$f = \left|\frac{M}{Q} - N\right| \frac{B_{TOR}}{\sqrt{4\pi\rho}}$$

IS SATISFIED. HERE M AND N ARE RESPECTIVELY THE POLOIDAL AND TOROIDAL MODE NUMBERS OF THE EXCITED ALFVÉN WAVE. Q IS THE USUAL SAFETY FACTOR. ρ IS THE MASS DENSITY.

MACHINE

PARAMETERS

FOUR NODE POLOIDAL DIVERTOR TOKAMAK

MICROWAVE PREIONIZATION

HOOPS AND PLASMA CURRENT DRIVEN INDUCTIVELY

MAJOR RADIUS - 50 CM

MINOR CROSS SECTION 44 x 44 CM

$B_{TOR} \cong 5$ KG

$I_{HOOPS} \cong 250$ KA

$I_{PLASMA} \cong 40$ KA

$T_i \cong 40$ eV

$T_e \cong 100$ eV

$n_e \cong 10^{13}$ CM^{-3}

PLASMA MINOR RADIUS $\cong$ 7 CM

$\tau_p \cong 4$ MSEC

$\tau_E \cong 300$ μSEC

BASE VACUUM = 1×10^{-7} TORR

TOKAPOLE II

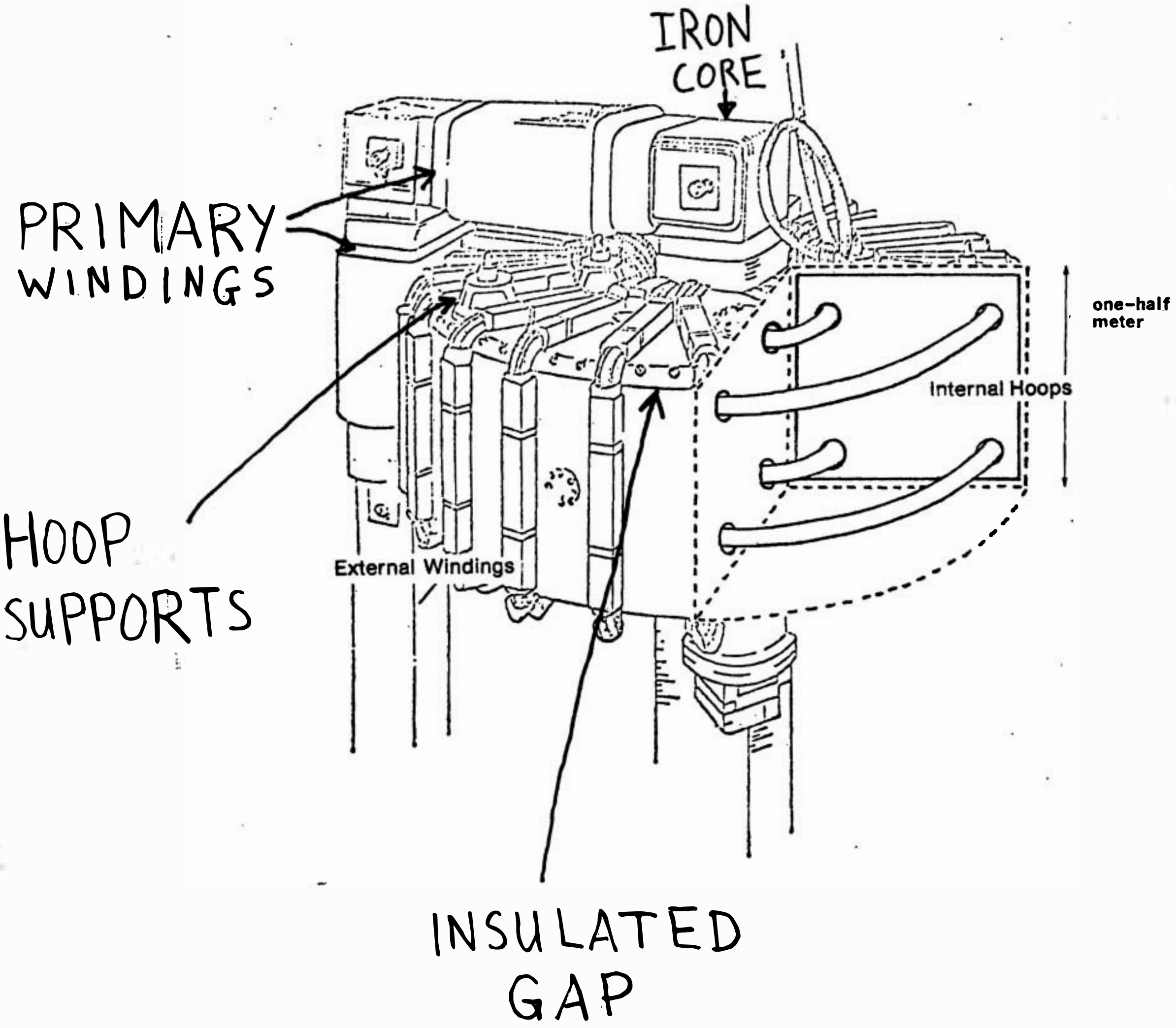


FIGURE 1

FLUX PLOT

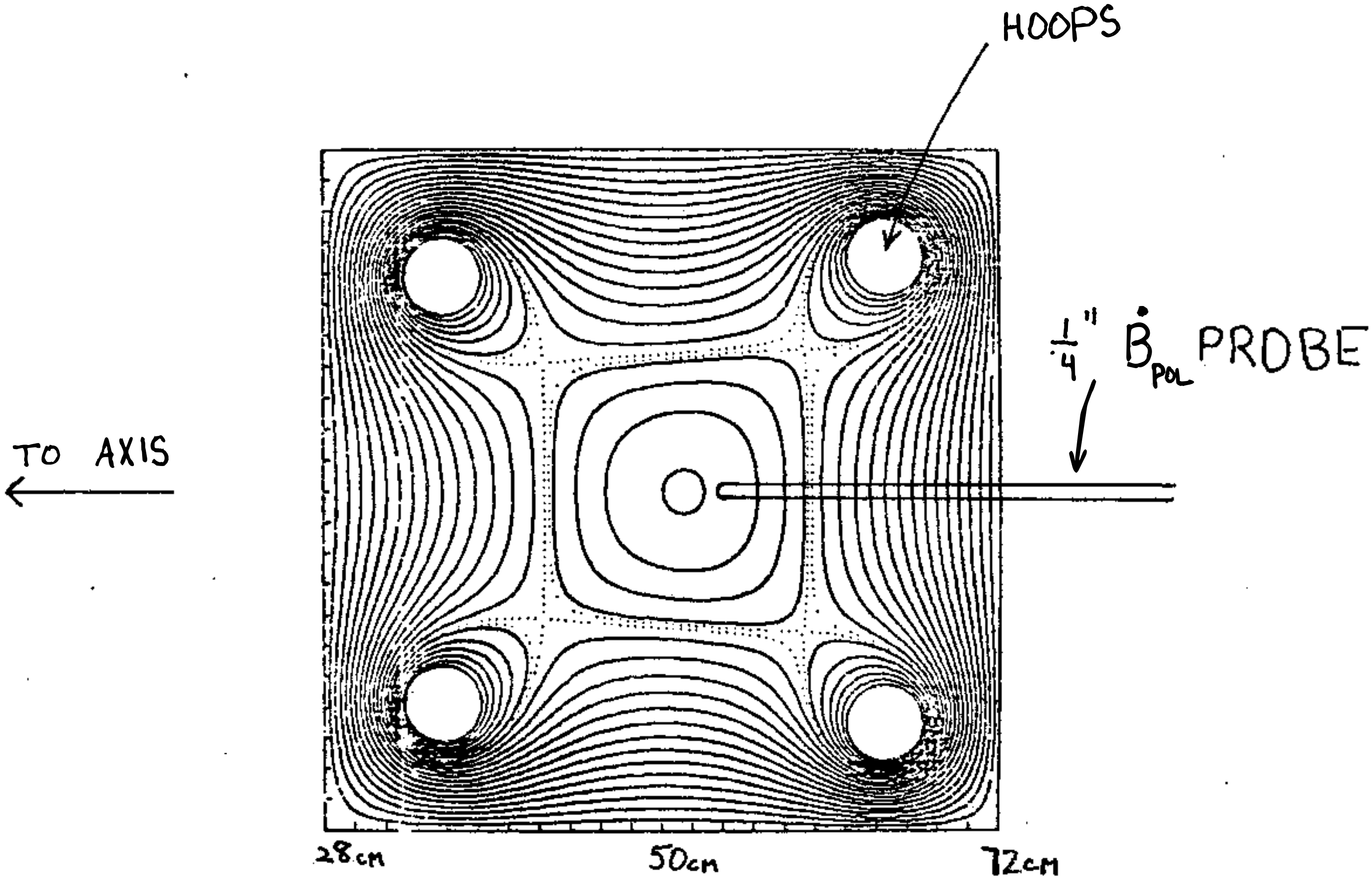
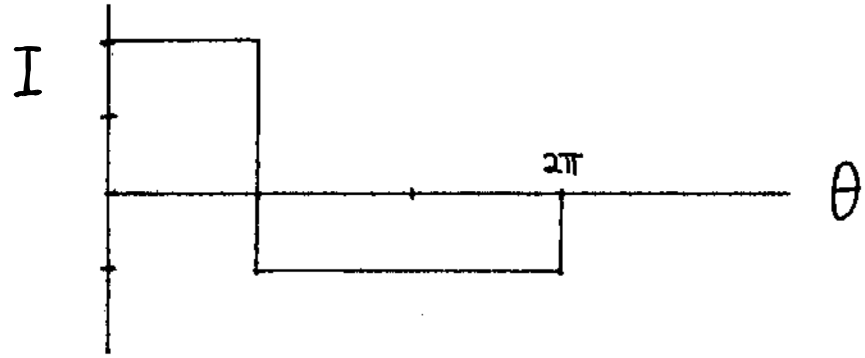


FIGURE 2

ANTENNA
TOROIDAL

CURRENT DISTRIBUTION



ALL FOURIER COMPONENTS EXCEPT N=0 AND MULTIPLES OF 3 ARE PRESENT.

CURRENT OF N'th MODE $\propto \frac{1}{N}$

M = 4

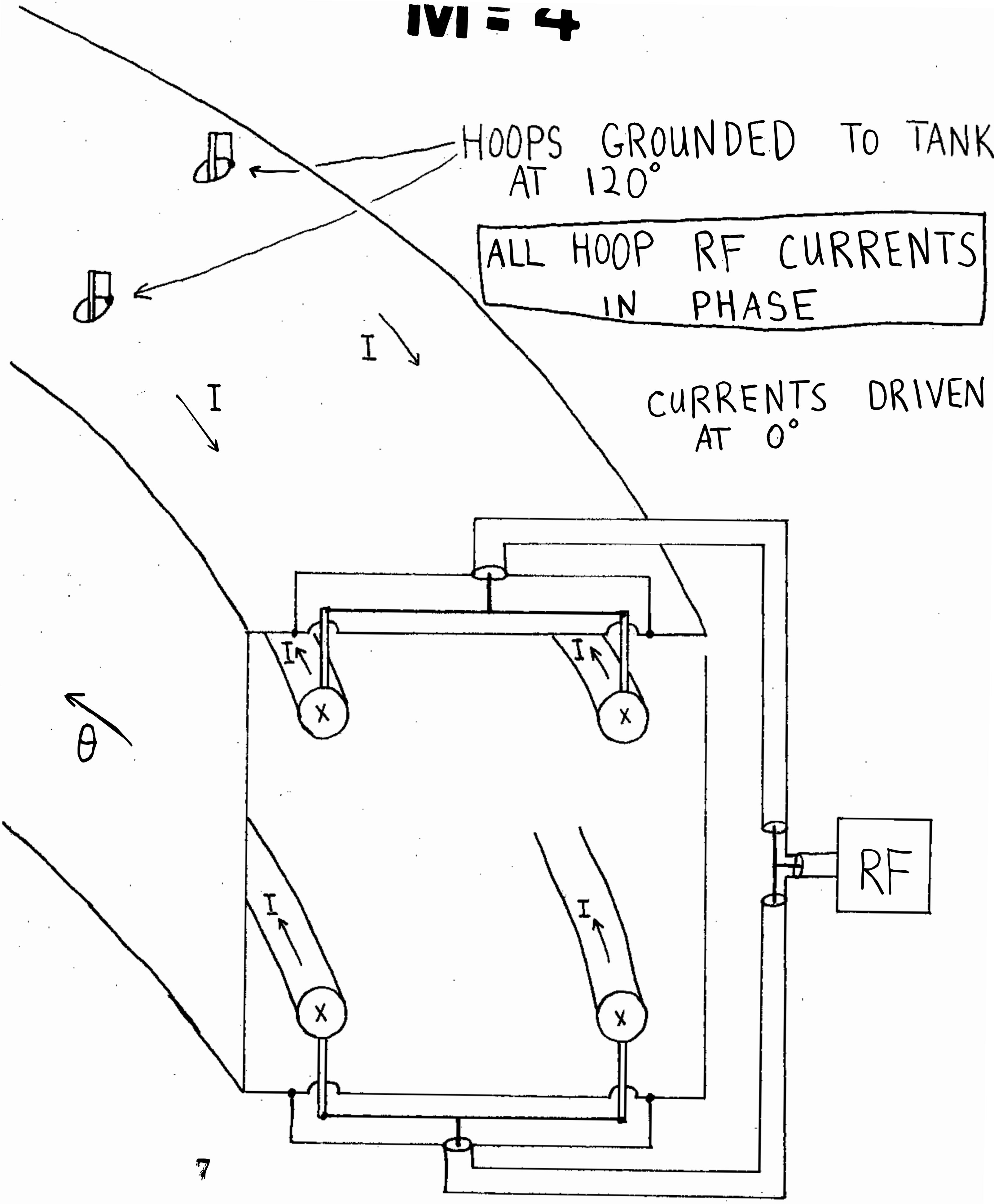

HOOPS GROUNDED TO TANK AT 120°
ALL HOOP RF CURRENTS IN PHASE
CURRENTS DRIVEN AT 0°
I
I
I
I
I
I
θ
X
X
X
X
RF

FIGURE 3

M=2 CASE 1

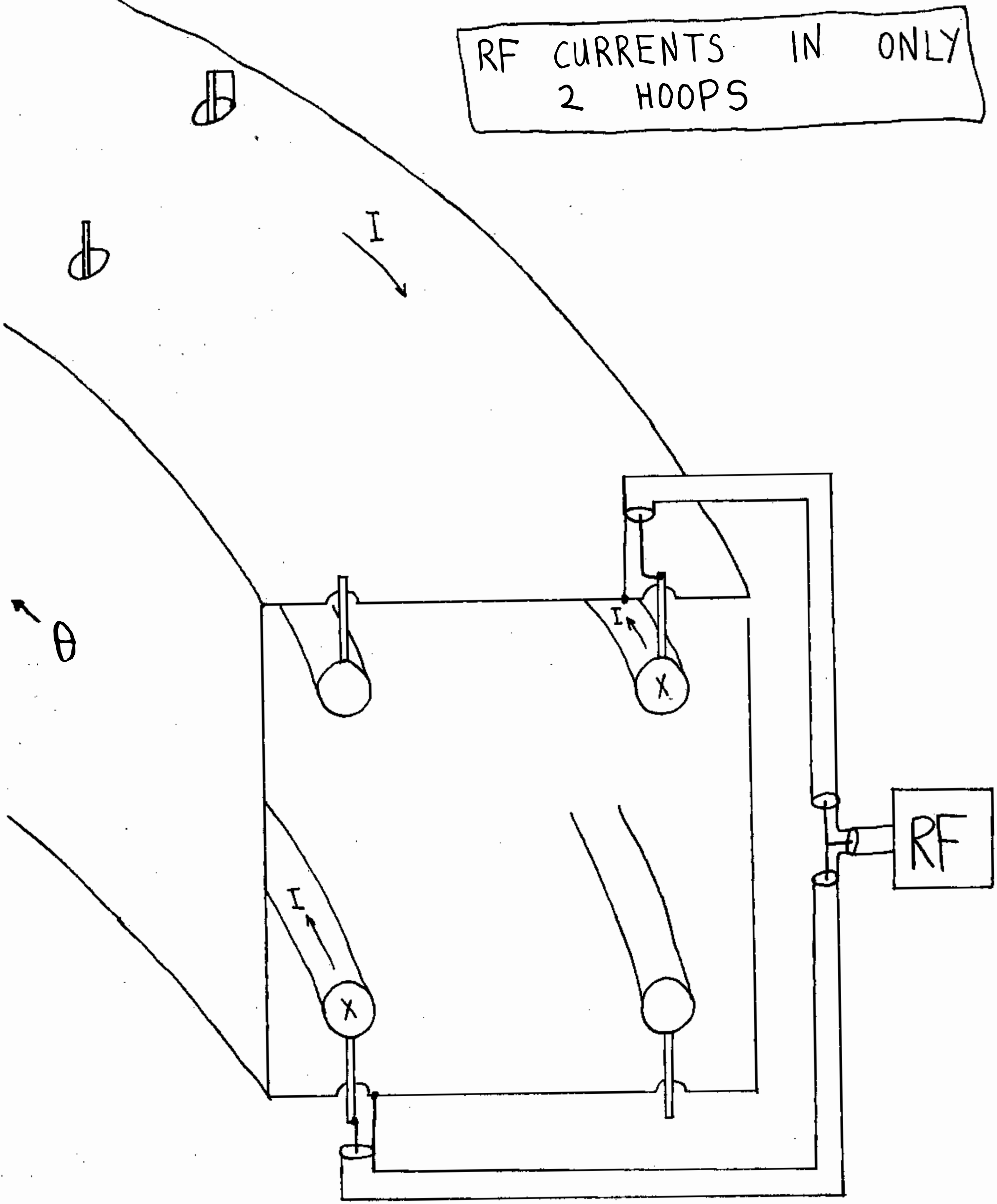


FIGURE 4

ADJACENT HOOPS DRIVEN OUT OF PHASE

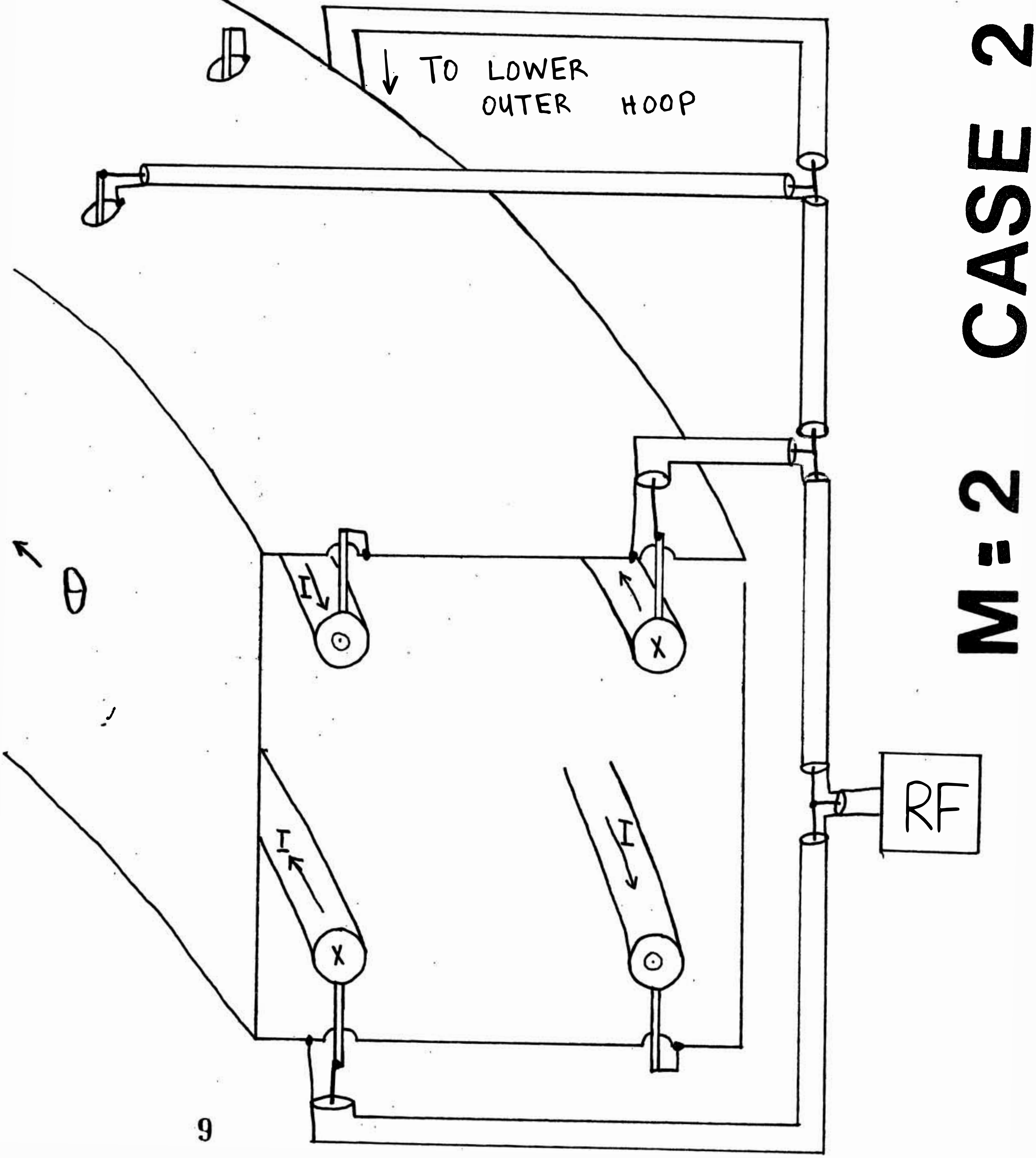


FIGURE 5

FIGURE 6

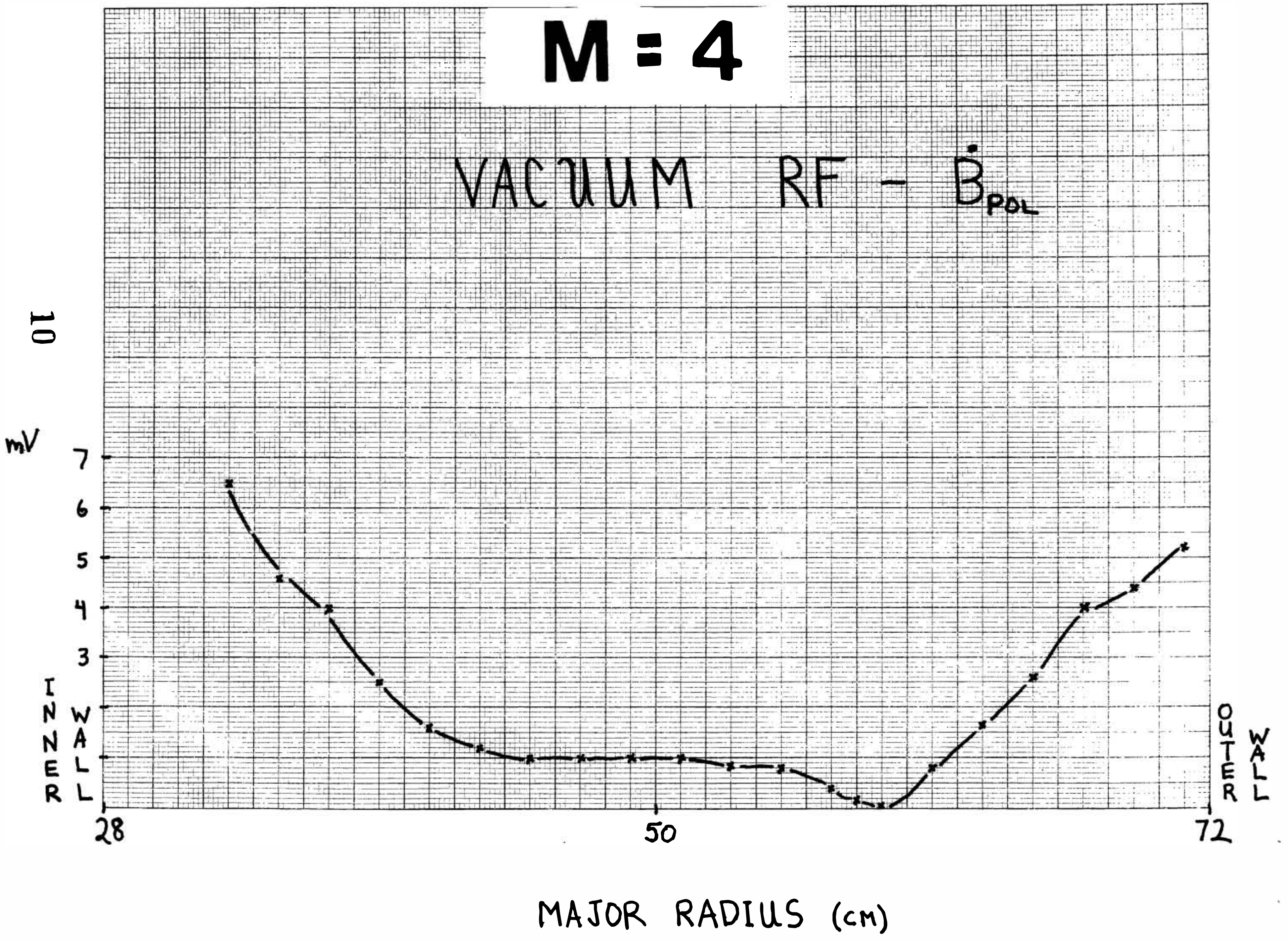

M = 4
VACUUM RF - $\dot{B}_{POL}$
mV
7
6
5
4
3
INNER WALL
OUTER WALL
28
50
72
MAJOR RADIUS (cm)

FIGURE 7

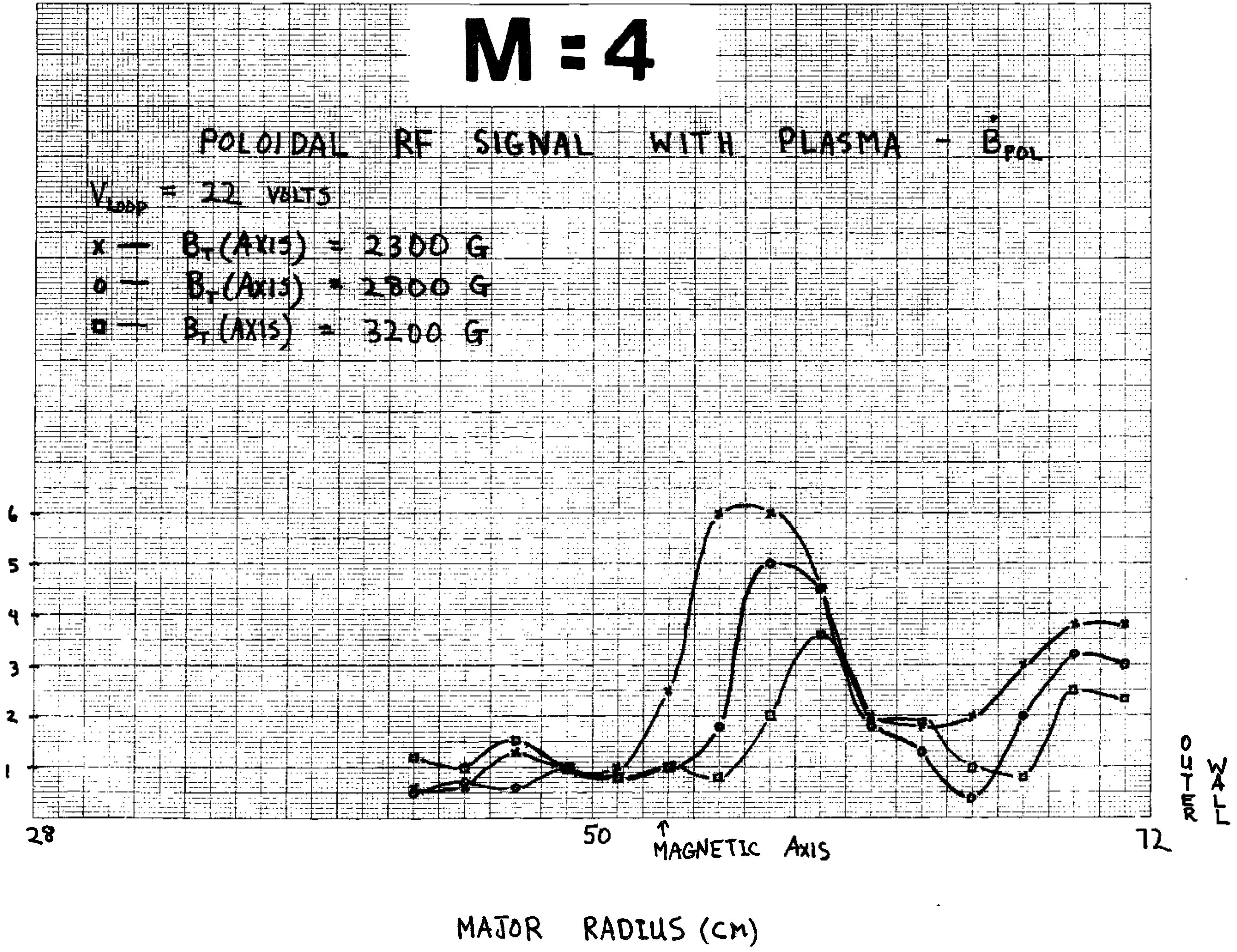

M=4
POLOIDAL RF SIGNAL WITH PLASMA - $\dot{B}_{POL}$
V_{LOOP} = 22 VOLTS
x — B_T(AXIS) = 2300 G
o — B_T(AXIS) = 2800 G
□ — B_T(AXIS) = 3200 G
6
5
4
3
2
1
28
50
72
↑ MAGNETIC AXIS
OUTER WALL
MAJOR RADIUS (CM)
11
V

FIGURE 8

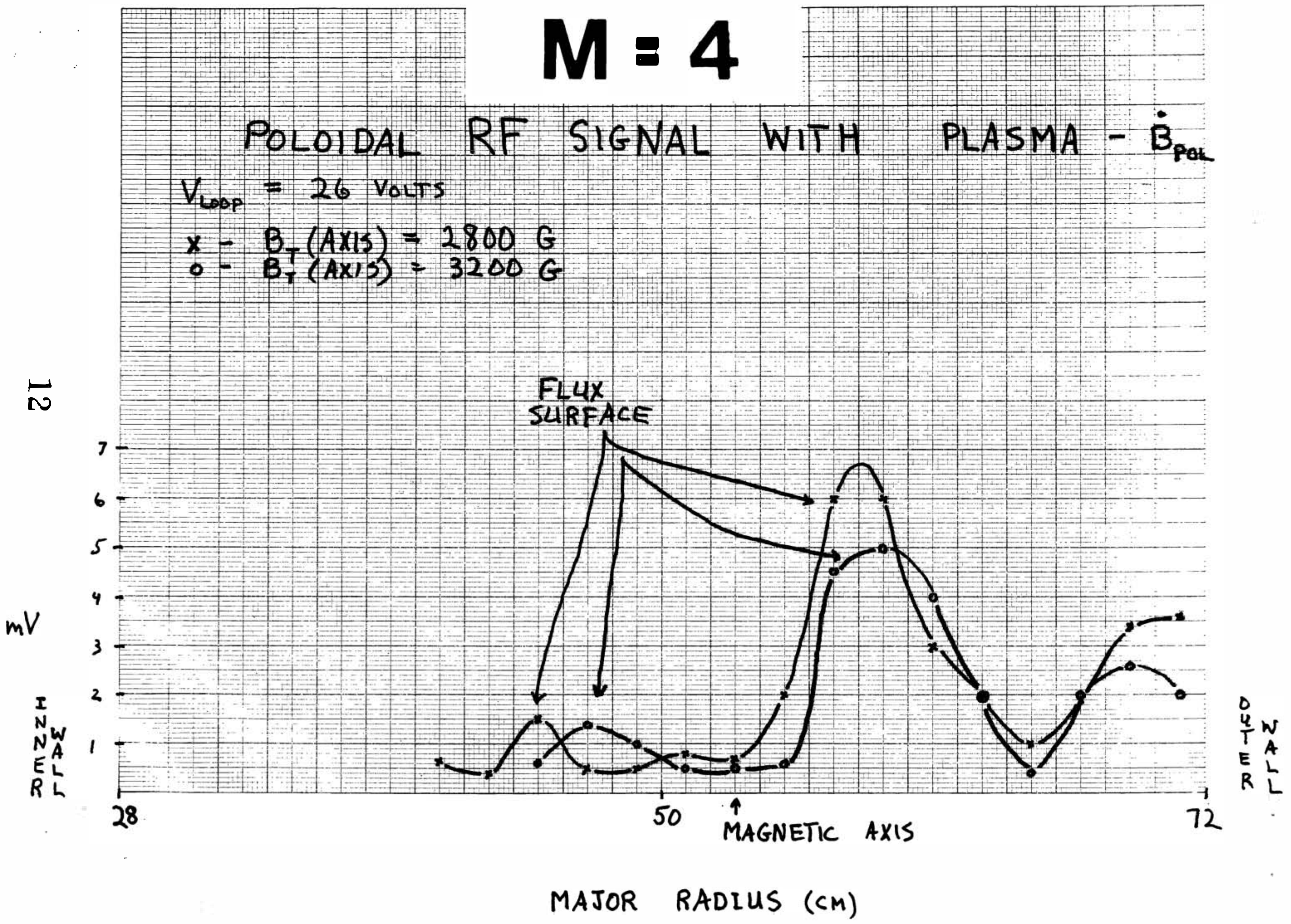
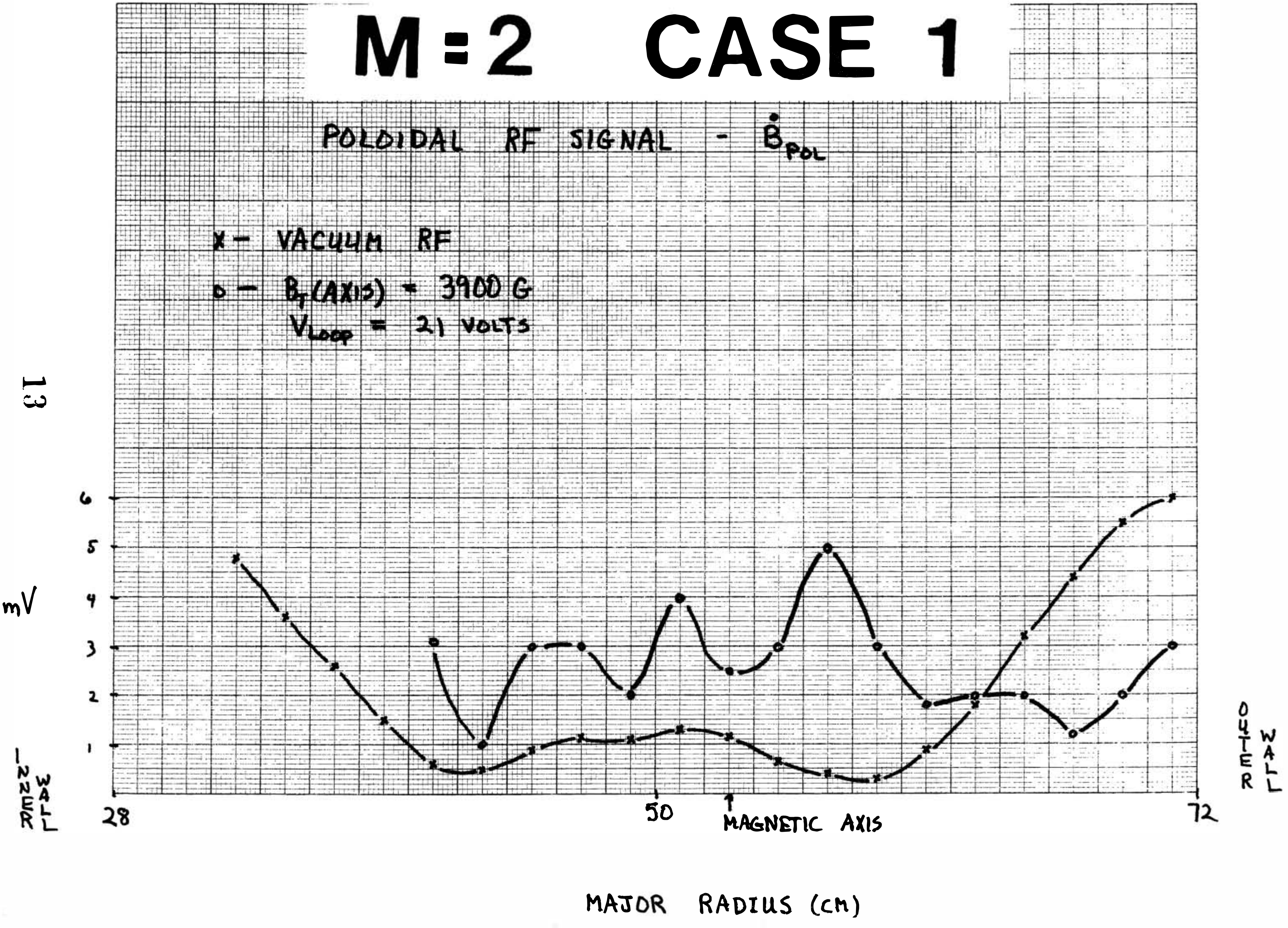

M = 4
POLOIDAL RF SIGNAL WITH PLASMA - $\dot{B}_{POL}$
V_{LOOP} = 26 VOLTS
x - B_T(AXIS) = 2800 G
o - B_T(AXIS) = 3200 G
FLUX SURFACE
mV
7
6
5
4
3
2
1
INNER WALL
OUTER WALL
28
50
72
MAGNETIC AXIS
MAJOR RADIUS (CM)

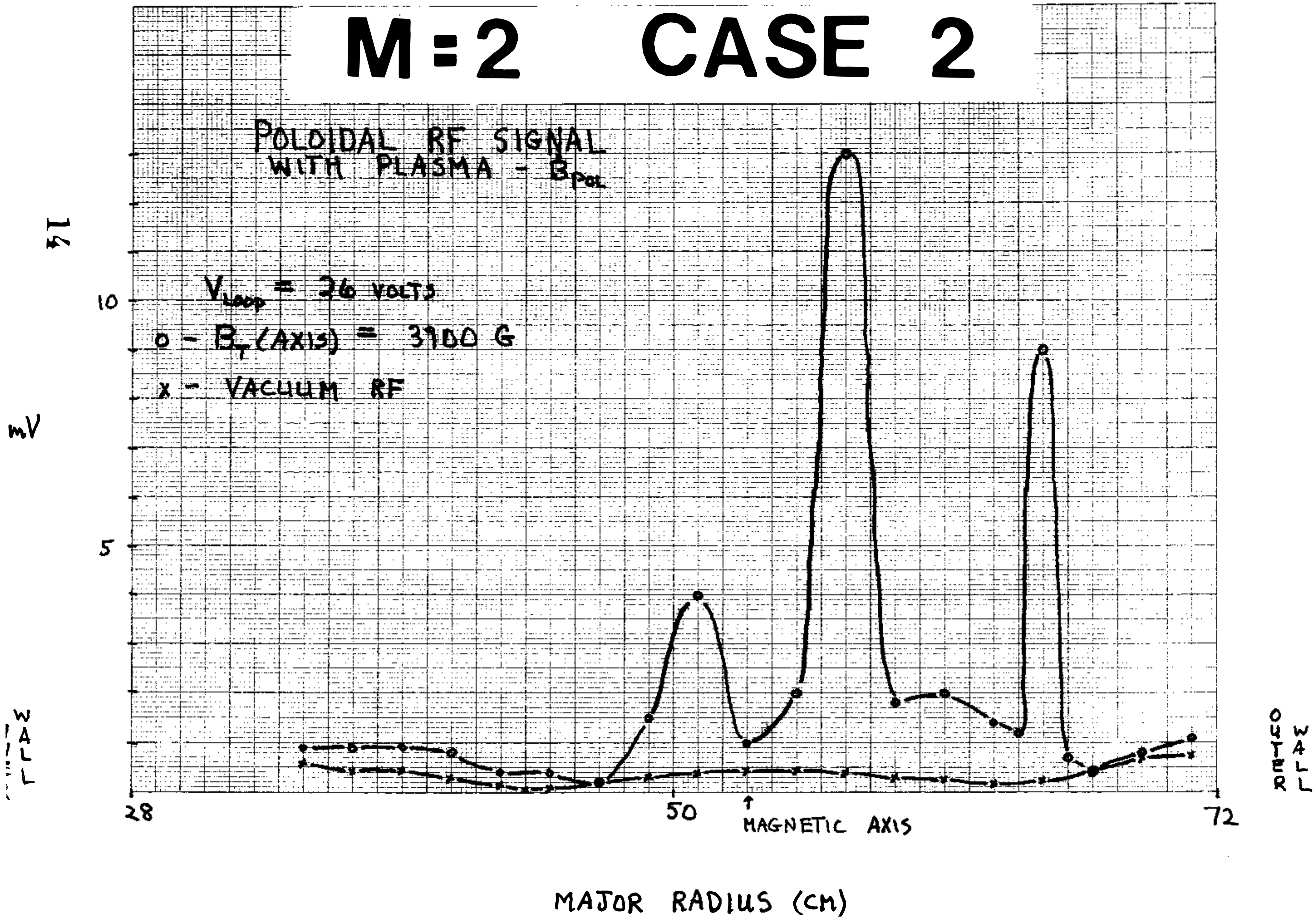
FIGURE 9



M=2 CASE 1

FIGURE 10

M=2 CASE 2



LOADING

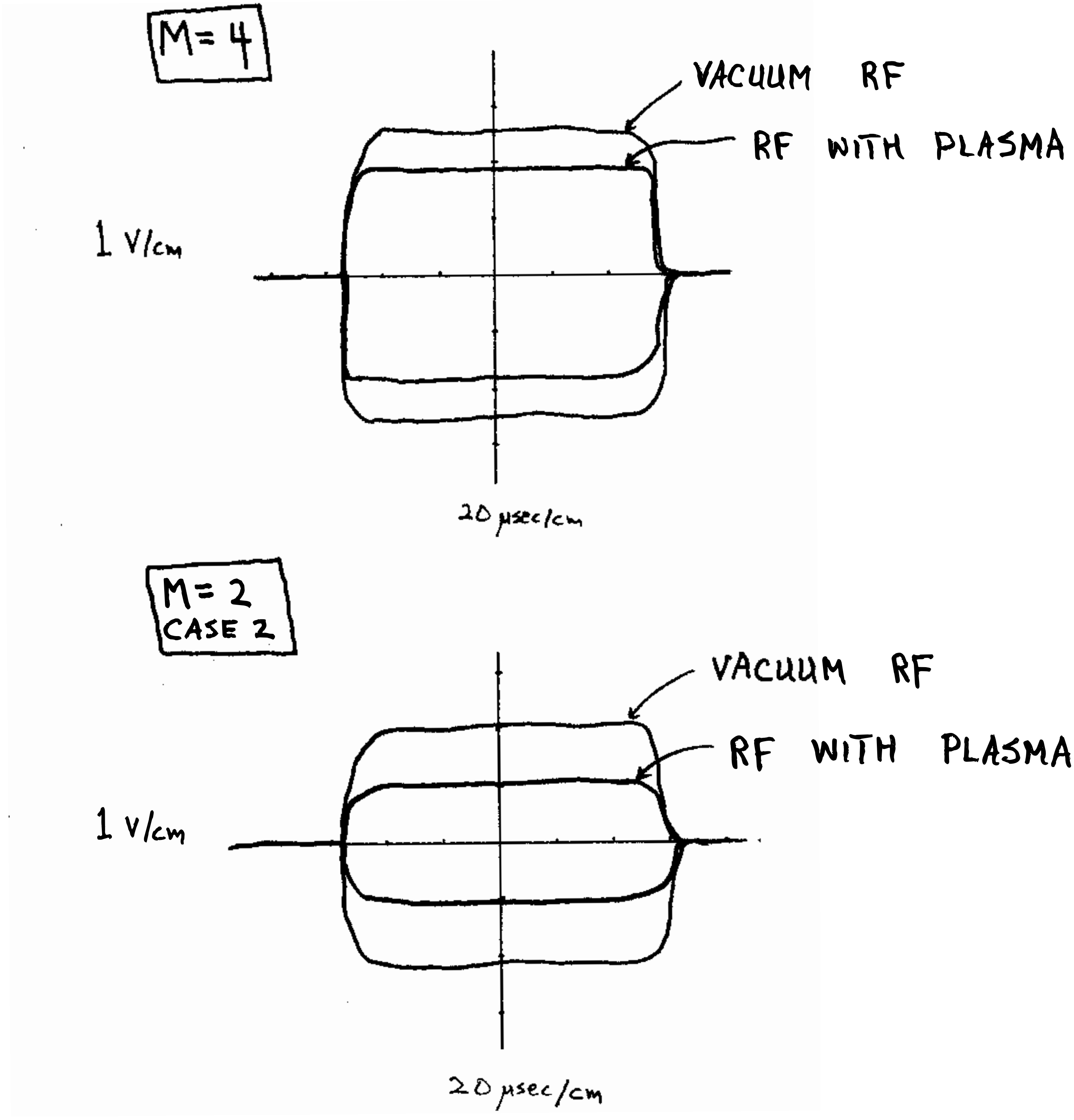
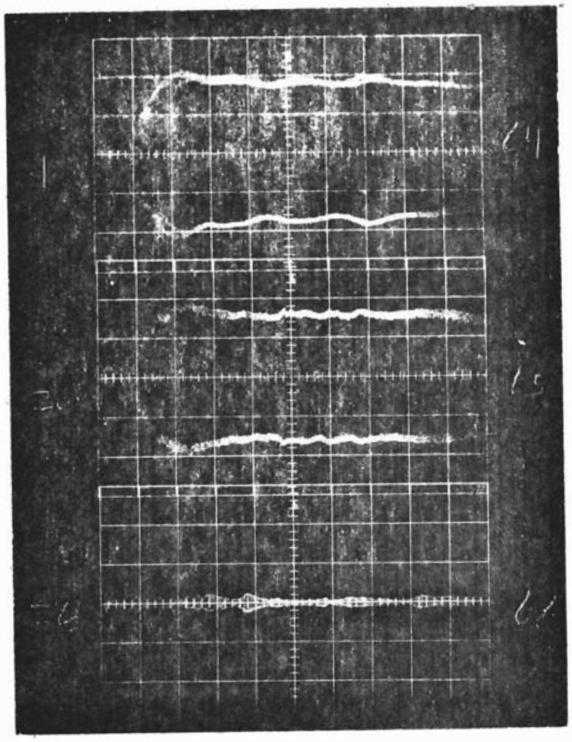


FIGURE 11

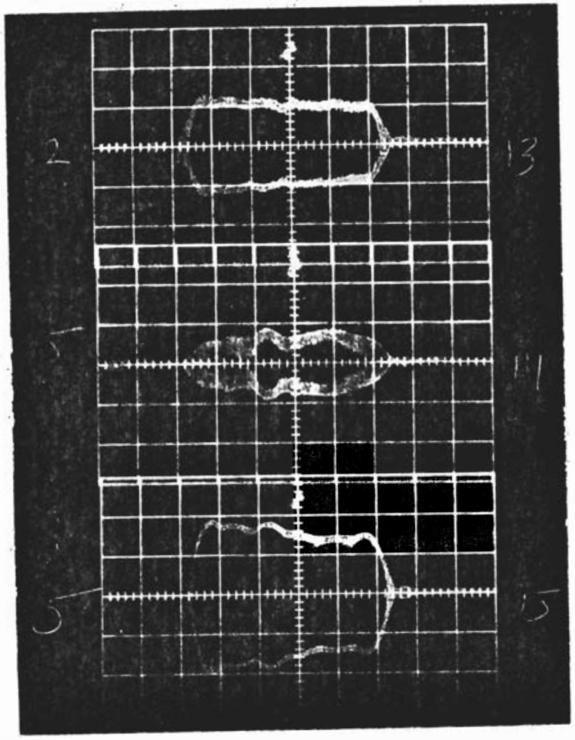
VACUUM RF

PLASMA & RF

PLASMA ONLY



10 μsec/cm

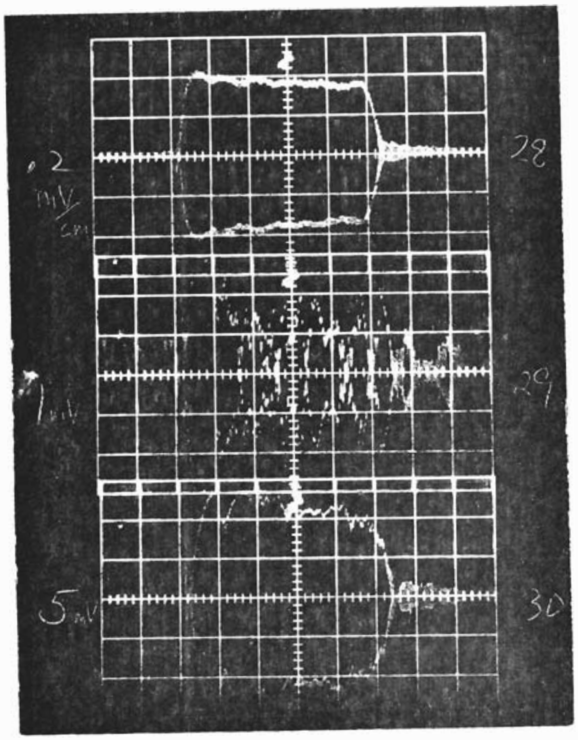


VACUUM RF

PLASMA & RF
B_T = 3200G

PLASMA & RF
B_T = 3900G

20 μsec/cm



VACUUM RF

PLASMA & RF
B_T = 3200 G

PLASMA & RF
B_T = 3900 G

20 μsec/cm

FIGURE 12

CONCLUSION

STRONG RESONANCES ARE OBSERVED WHICH ARE DEPENDENT ON ANTENNA PERIODICITY AND CONFINING MAGNETIC FIELDS. BOTH SPATIALLY LOCALIZED AND RESONANCE BANDS ARE OBSERVED.

FUTURE PLANS

COMPARE 2-D THEORY WITH EXPERIMENT.

INCREASE POWER TO OBSERVE HEATING.

FIGURE CAPTIONS

Fig. 1: Tokapole II cutaway drawing.

Fig. 2: Typical flux plot indicating squarish cross-section of the plasma and magnetic pick-up coil insertion location.

Fig. 3: Poloidal RF current distribution for m=4.

Fig. 4: Poloidal RF current distribution for m=2 using only two hoops.

Fig. 5: Poloidal RF current distribution for m=2 using all four hoops.

Fig. 6: Vacuum poloidal RF signal, m=4.

Fig. 7: Poloidal RF signal with plasma, m=4.

Fig. 8: Poloidal RF signal with plasma , m=4.(Different fields than Fig. 7.)

Fig. 9: Poloidal RF signal with plasma, m=2, case 1.

Fig. 10: Poloidal RF signal with plasma, m=2, case 2.

Fig. 11: Plasma loading effects on RF source output voltage measured at the hoop supports.

Fig. 12: Typical oscilloscope data pictures.