214-0075-01-01_00

RF BOOK

RF Note 74

May 29, 1981
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PROGRAM TRED 2

We have a plan to test the high Q 3-dee model as described in RF Note 69. 3-surplus transmitters have already been converted to work for this test. As one of the preparations for this test, I have reviewed and rearranged the program TRED 2 written last year, so that we could make an easy comparison: the test results with the calculated results.

Some calculated results of TRED 2 had been presented in RF Note 66, 67 and 68. We summarize here the programming of TRED 2 and the calculated results.

SCHEMATIC REPRESENTATION OF 3-DEE SYSTEM AND THE VARIOUS R's, L's & C's

Fig. 1 shows a single transmitter-to-dee system. The corresponding equivalent schematic diagram is given in Fig. 2. The transmitter stem and the dee stem are represented by the parallel LRC circuits. C3 and C4 are the coupler of the transmitter to transmission line, and the transmission line to dee, repectively, in order to achieve impedance matching. C2 is the additional capacitor required to avoid the turn-on problem near 20 MHz, described in RF Note 67.

Three of these circuits and 3-coupling capacitors of adjacent dees go into a total 3-dee RF system. The algebraic equations to get the values of various R's, L's and C's are listed in Table 1. Cl, Rl, L-C anode coupling, R5, C4, and C5 are from the previous calculations MSUDS and TRED 3. The transmitter output coupling L-C is as in the old scheme; we have changed to the capacitance coupler (see RF Note 66), and deduced the equations to get the values of C3, Ll in the C-coupling.

C6, C26 and C46 are the floating WYE capacitors which are transformed from the DELTA dee to dee coupling capacitors.

For 1-phase operation, no current flows through C6, C26 and C46 in the balanced 3-dee circuit at resonant frequency. However, for 3-phase operation, the currents flow through these capacitors and the phases of these currents are corresponding to each dee voltage which differ by 120^{o} from each other. Consequently, the voltage at the floating WYE center is zero. That is, these capacitors are connected parallel to the corresponding dee equivalent LRC circuit and it is necessary to compensate the values of L5, L25 and L45 in order to achieve resonance. The equation to derive the new value is given in (6) of Table 1.

We can get the table of the values of various R's, L's and C's as a function of the resonant frequency by using program 30000 in TRED 2.

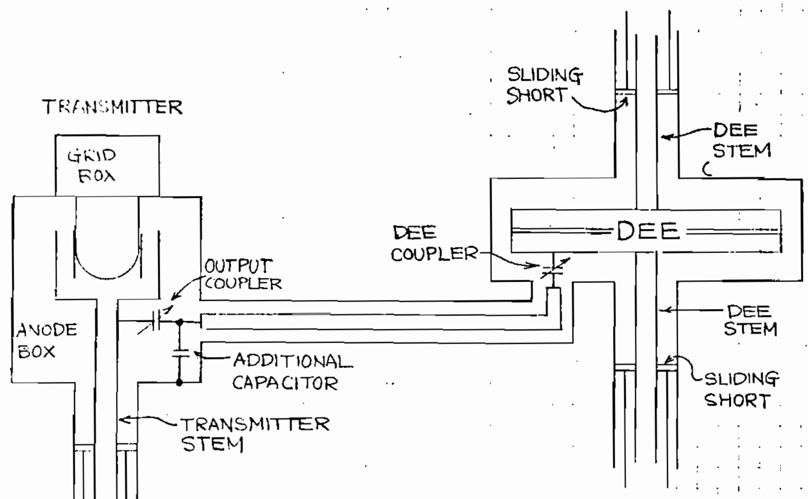


FIG. 1 SINGLE RF SYSTEM PICTORIAL

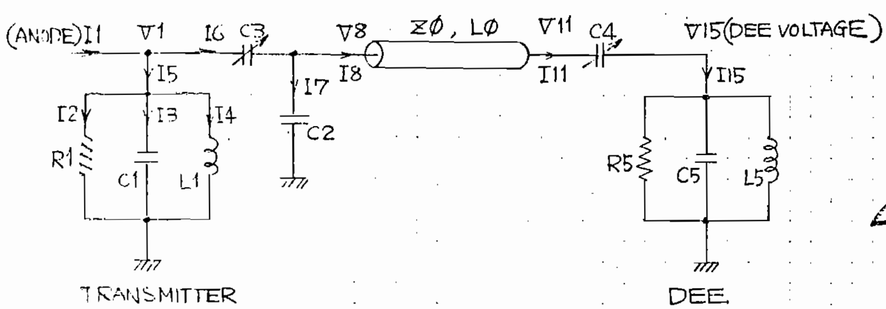
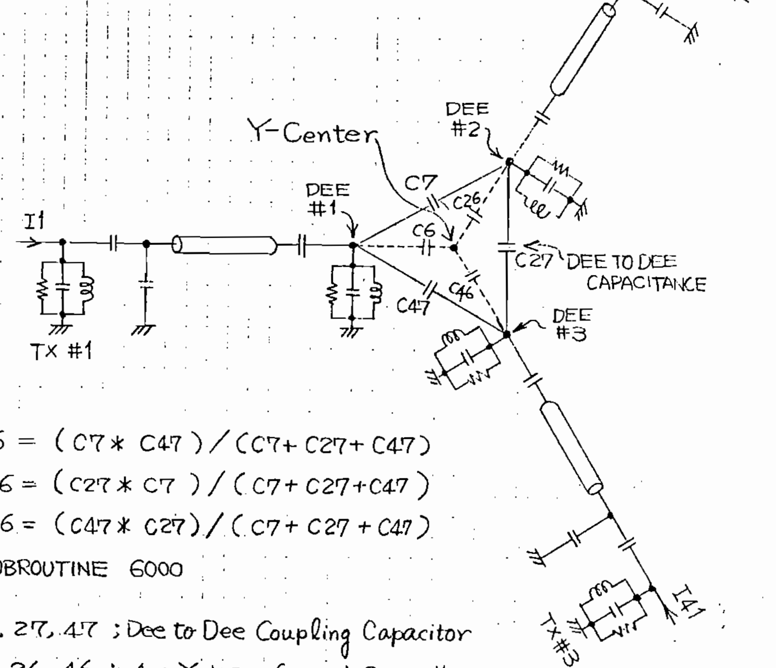


FIG. 2 SCHEMATIC REPRESENTATION OF SINGLE RF SYSTEM

FIG. 3
SCHEMATIC REPRESENTATION OF THE WHOLE 3-DEE RF SYSTEM & Δ–Y TRANSFORMATION



C6 = (C7 * C47) / (C7 + C27 + C47)
C26 = (C27 * C7) / (C7 + C27 + C47)
C46 = (C47 * C27) / (C7 + C27 + C47)
SUBROUTINE 6000

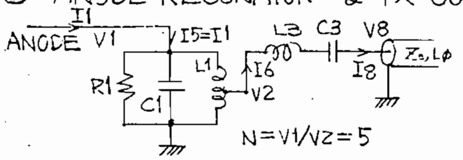
C7, 27, 47 ; Dee to Dee Coupling Capacitor
C6, 26, 46 ; Δ→Y transformed Capacitor

Δ
$C_{AB} = .2$
$C_{AC} = .15$
$C_{BC} = .004$

Y
$C_{B} = (.2 \times .004)/.354 = .0026$
$C_{A} = (.2 \times .15)/.354 = .085$
$C_{B} = (.004 \times .15)/.354 = .0017$

CALCULATION THE VALUES OF VARIOUS R's, L's & C's

① ANODE RESONATOR & TX OUTPUT L-C COUPLING (OLD SCHEME) [SUB 9000]



$R1 = 100 \times 10^3$

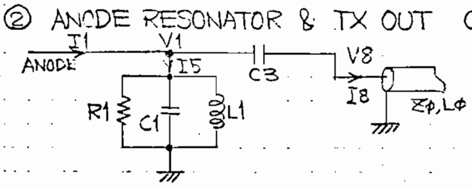
$C1 = (9.65\times10^{15}/F_\phi^2 + 1.292\times10^9/F_\phi + 112.36)\times10^{-12}$

$L1 = 1/(\omega_\phi^2 \times C1)$, $C3 = 1/(\omega_\phi^2 \times L3)$, $Z1 = 64$

$L3 = (.5\times10^{-12}\times F_\phi^2 - 2.95\times10^{-6}\times F_\phi + 481)\times Z1\times2.54/(3\times10^{10})$

Ref. TRED3, MSUDS,

② ANODE RESONATOR & TX OUT C COUPLING [SUB 9700]



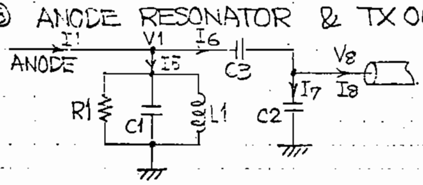
$R1 = 100\times10^3$, $C1 = (9.65\times10^{15}/F_\phi^2 + 1.292\times10^9/F_\phi + 112.36)\times10^{-12}$

$C3 = 1/(\omega_\phi \times Z_\phi \sqrt{V1^2/V8^2 - 1})$

$L1 = (\omega_\phi^2 \cdot C3^2 \cdot Z_\phi^2 + 1)/(\omega_\phi^2(\omega_\phi^2 \cdot C1 \cdot C3^2 \cdot Z_\phi + C1 + C3))$

Ref. RF Note #66, PROG 30200

③ ANODE RESONATOR & TX OUT C-C COUPLING [SUB 9800]



$R1 = 100\times10^3$, $C1 = (9.65\times10^{15}/F_\phi^2 + 1.292\times10^9/F_\phi + 112.36)\times10^{-12}$

$C2 = 100\times10^{-12}$, $D = \sqrt{C_2^2 + (V_1^2/V_8^2 - 1)\times(C_2^2 + 1/(\omega_\phi^2 \times Z_\phi^2))}$

$C3 = (C_2 + D)/(V_1^2/V_8^2 - 1)$

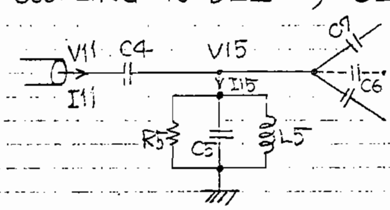
$L1 = \{1 + \omega_\phi^2 \cdot Z_\phi^2 \cdot (C_2 + C_3)^2\} / \left(\omega_\phi^2 \{(C_1 + C_3) + \omega_\phi^2 \cdot Z_\phi^2 [C_1(C_2 + C_3)^2 + C_2 \cdot C_3 \cdot (C_2 + C_3)]\}\right)$

Ref. RF Note #67, PROG 30400

④ TRANSMISSION LINE

$M(J+1) = L_\phi = 7.78434$, $Z(J+1) = Z_\phi = 75$, $V_\phi = 2.99792\times10^8$

⑤ COUPLING TO DEE, DEE EQUIVALENT & DEE TO DEE COUPLING



$R5 = (159 - 2.1 * F_\phi/10^6)\times10^3$ *specified*

$C4 = 1/(\omega_\phi \cdot Z_\phi \cdot \sqrt{R5/Z_\phi + 1})$ *var*

$C5 = (1.27\times10^{10}/F_\phi - 6.37\times10^{16}/F_\phi^2 - 51)\times10^{-12}$ *specified*

$L5 = 1/\{\omega_\phi^2 \cdot (C4 + C5)\}$ *var*

$C7 = .5\times10^{-12}$

⑥ COMPENSATION OF L5 FOR 3-PHASE CALCULATION

$A = \omega_\phi^2 \cdot \{\omega_\phi^2 \cdot C_4 \cdot R_5^2 \cdot (C_5 + C_6) + R_5^2 \cdot \omega_\phi^2 \cdot (C_5 + C_6)^2 + 1\}$

$B = -1 \cdot \{\omega_\phi^2 C_4 \cdot R_5^2 + 2 \cdot R_5^2 \cdot \omega_\phi^2 \cdot (C_5 + C_6)\}$, $D = B^2 - 4 \cdot A \cdot R_5^2$

$L5 = (-B - \sqrt{D})/(2 \cdot A)$ Ref PROG 30600

FOLLOWING SUBROUTINES ARE AVAILABLE TO SPECIFY THE PHASE OF ANODE & TO CALCULATE VARIOUS VALUES FOR EACH SCHEME.

PHASE	ANODE COUPLING		
	L-C (OLD)	C	C-C
IN-PHASE	SUB 10100	SUB 10200	SUB 10300
3-PHASE	SUB 10400	SUB 10500	SUB 10600

TABLE 1

CALCULATION TECHNIQUE AND PROGRAMMING

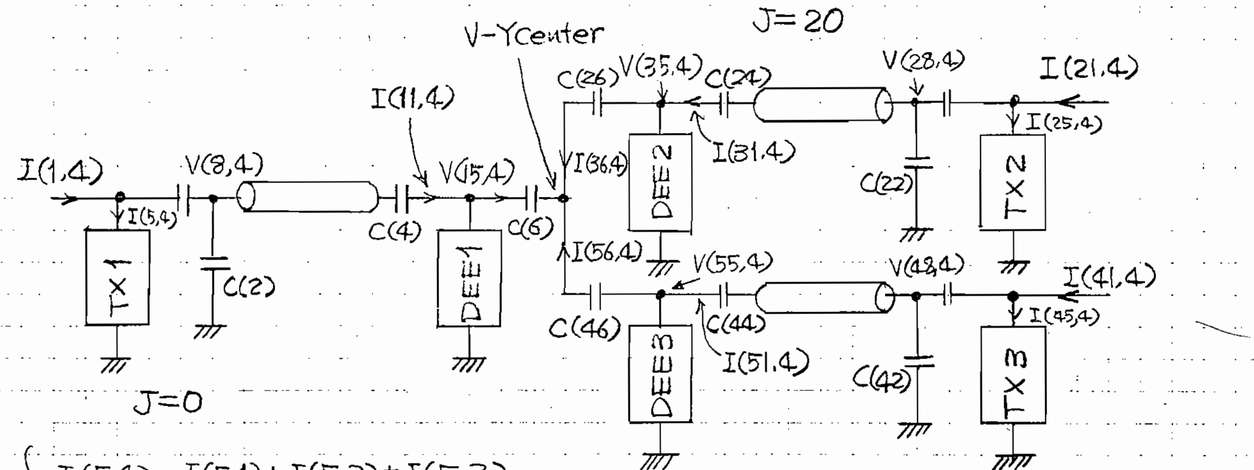
We are using the super position thorem to calculate the 3-dee system. By transforming DELTA to WYE the dee to dee coupling capacitors, 3-dee system consists of 3-leg circuit connected at WYE center. An anode current is put in one leg, and zero in the other two legs, and the currents and the voltages are calculated at all points in the circuits. This calculation is repeated for the two other anodes. The results of all three calculations are added vectorally to get the resultant values of various V's, I's and the phases when all 3-anode currents are put into the whole circuit simultaneously.

In TRED 2, the subroutine 7000 is used to find an impedance looking from the Y-center back to the anode. Two impedances which are given by subroutine 7000, and one leg circuit where the anode current is going into, are connected at the WYE center. Now we can calculate various V's, I's and the phases when an anode current is put into a leg circuit as shown in Fig. 4, using subroutine 8000. The repetition of this calculation and the summation vectorally are performed in subroutine 11000. I have written 6 subroutines to calculate and to combine the above subroutines, listed in Table 2.

SUBROUTINE	DISCREPTION
10700	1-DEE SYSTEM CALCULATION NORMALIZED BY CONSTANT ANODE CURRENT
10750	1-DEE SYSTEM CALCULATION WITH DEE VOLTAGE REGULATOR 100KV
10200	1-DEE SYSTEM ANODE VOLTAGE LIMITER 15KV
12000	3-DEE SYSTEM CALCULATION NORMALIZED BY CONSTANT ANODE CURRENT
12100	3-DEE SYSTEM CALCULATION WITH DEE VOLTAGE REGULATOR 100KV
12200	3-DEE SYSTEM ANODE VOLTAGE LIMITER 15KV

Table 2

SUBROUTINE 11ØØØ



$$\begin{cases} I(5,4)=I(5,1)+I(5,2)+I(5,3) \\ I(11,4)=I(11,1)-I(11,2)-I(11,3) \\ V(15,4)=V(15,1)+V(15,2)+V(15,3) \end{cases}$$

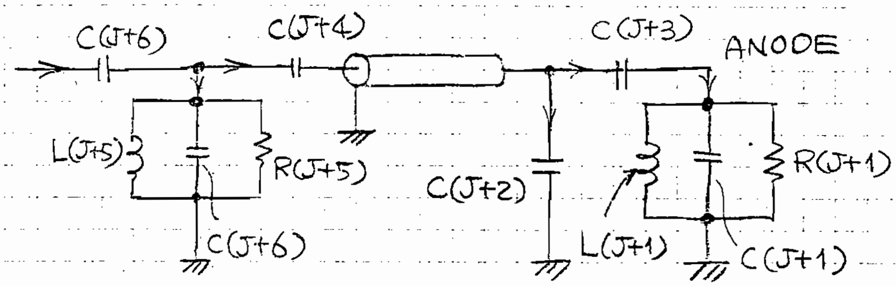
J=40

SUBROUTINE 7ØØØ

Impeadance

look at Y-center

$A(J+6)+iB(J+6)$



SUBROUTINE 8ØØØ

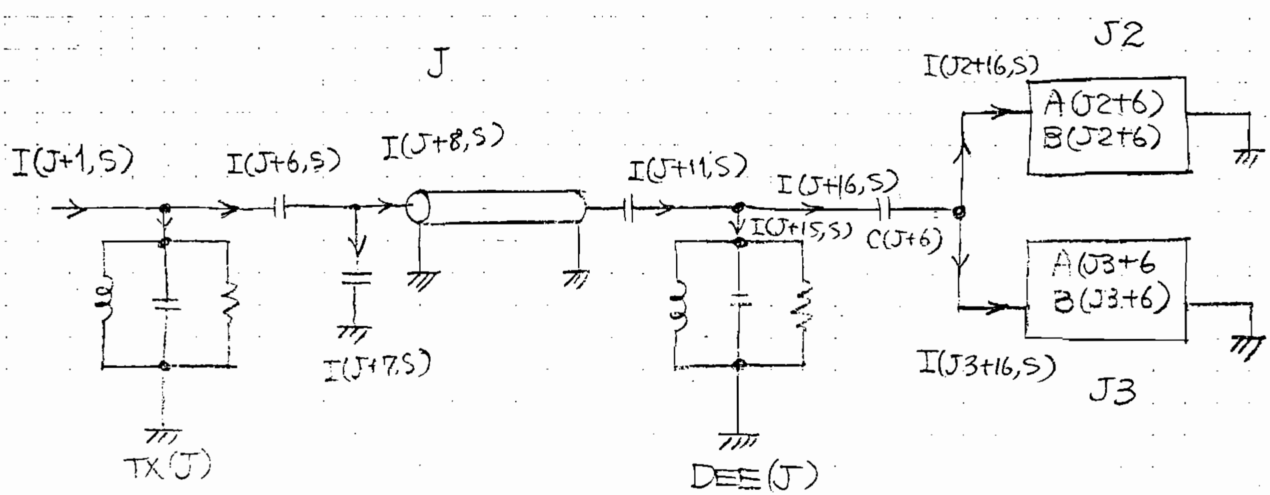


Fig 4 SUBROUTINES FOR CALCULATION

After selection of the subroutines listed in Table 1 to specify the transmitter output coupling and the operating phase, by combining the subroutines of Table 2, we can easily calculate V's, I's and the phases at various points of the 3-dee system, 1-dee system, 1-phase operation and 3-phase operation.

TRED 2 consists of various kinds of calculation routines and the required subroutines. The main routines are the calculation of the mode situation, scanning around the resonance frequency, the changes in 3-dee voltages and phases with detuning one of the 3-dees, and with changing an anode current to one of the 3 dees.

TRED 2 includes some other calculation routines and the diagnostic routines to make sure of the performance of many subroutines.

THE RESULTS OF 3-DEE CALCULATION

Table 3 and 4 are calculated results of the 3 phase normal mode operation scanning around 15 MHz. These results look like the same as TRED 3 which was described in RF Note 46, but these are calculated in the complicated 3-dee system using TRED 2 and we spent about 25 minutes of CPU execution time to print out this table. Otherwise, for one-dee system calculation as in TRED3, the results are printed out within 2 minutes, using the batch process of the BASIC language program.

The abbreviations in the table which weren't explained previously are P DEE, P CAP and I AN. P DEE is the absolute phase related to the phase of the anode current, P CAP is the phase difference between the voltage across the dee coupling capacitor, I AN are the anode currents in amperes.

In the program, the anode current is calculated to get the 100K volts at the dee at the resonant frequency $F\phi$, then the frequency is shifted to the lower limit of the scanning range, and the data is printed out at each frequency of over $\pi/40$ radian phase shift of the dee voltage. The printed values are those of the circuit for dee #2. Table 4 shows the same results with the anode voltage limiter at 15KV, to avoid excessive screen current of the transmitter tube.

In Fig. 5 the curves are the impedance presented to the tube anode as a function of the frequency when the dee is multipactoring. We had presented these curves in RF Note 67. In that Note, we had explained two curves conversely by my plotting mistake. The highest impedance appears near the frequency of 3/4 λ to correspond with the length of the transmission line. As we described in that note, to avoid the turn-on problem the additional capacitor is added to the anode coupling circuit.

20150 GO SUB 10500
10:56 MAY 03 TRED2...

THREE-DEE SYSTEM NORMAL MODE SITUATION ***** TRED2 *****

F0= 12 MHZ Q= 5756.93
C1= 2.37082E-10 L1= 5.45578E-07 R1= 100000 C2= 0 L3= 0
C3= 3.68734E-11 Z0= 75 L0= 7.78434 C4= 4.18561E-12 C5= 5.64972E-10
L5= 3.08250E-07 R5= 133800 C6= 1.50000E-12 C7= 5.00000E-13

I1= 6.55836 A -120.000 DEG I21= 6.55836 A 0 DEG I41= 6.55836 A 120.000 DEG

FREQ	V DEE	P DEE	P CAP	R CAP	X CAP	W+	W-	V AN	P AN	R AN	X AN	I AN
0.00	1.00E+05	54.7	88.6	75.1	4.65E+11	7.47E+04	58.6	1.16E+04	-5.85E-02	1.77E+03	-1.73E+06	6.558
-60.0	7.82E+03	92.8	179.	2.52E+05	-1.84E+03	457.	5.71E+05	4.30E+04	-86.1	9.76E+04	-6.57E+03	6.558
-16.8	1.19E+04	88.3	176.	1.96E+04	-880.	1.05E+03	1.12E+05	1.75E+04	-87.9	7.43E+04	-2.66E+03	6.558
-6.48	2.40E+04	83.8	171.	2.96E+03	-415.	4.32E+03	7.95E+04	1.28E+04	-85.9	2.74E+04	-1.95E+03	6.558
-3.36	3.78E+04	78.9	163.	844.	-244.	1.07E+04	6.41E+04	9.70E+03	-79.5	8.11E+03	-1.51E+03	6.558
-1.92	5.19E+04	73.7	151.	323.	-168.	2.01E+04	5.03E+04	7.44E+03	-64.9	2.68E+03	-1.25E+03	6.558
-.960	6.90E+04	67.3	132.	136.	-144.	3.55E+04	3.34E+04	6.68E+03	-34.8	1.24E+03	-1.79E+03	6.558
-.480	8.20E+04	62.2	114.	89.4	-192.	5.03E+04	1.97E+04	8.00E+03	-14.0	1.26E+03	-5.06E+03	6.558
-.240	9.03E+04	58.8	102.	78.2	-338.	6.09E+04	1.03E+04	9.48E+03	-5.69	1.45E+03	-1.46E+04	6.558
.240	1.11E+05	49.5	75.7	79.9	349.	9.26E+04	-1.27E+04	1.44E+04	2.70	2.21E+03	4.68E+04	6.558
.480	1.24E+05	43.1	64.2	92.6	204.	1.15E+05	-2.71E+04	1.81E+04	2.57	2.76E+03	6.14E+04	6.558
.720	1.38E+05	35.2	54.5	113.	167.	1.42E+05	-4.19E+04	2.25E+04	-.412	3.42E+03	-4.77E+05	6.558
.960	1.51E+05	25.4	46.6	142.	158.	1.71E+05	-5.40E+04	2.74E+04	-6.18	4.20E+03	-3.88E+04	6.558
1.20	1.61E+05	13.9	40.4	179.	160.	1.94E+05	-5.78E+04	3.22E+04	-14.4	5.07E+03	-1.97E+04	6.558
1.44	1.65E+05	1.23	35.4	223.	167.	2.03E+05	-4.38E+04	3.61E+04	-24.3	6.05E+03	-1.34E+04	6.558
1.68	1.60E+05	-11.4	31.4	276.	178.	1.92E+05	-2.78E+04	3.83E+04	-34.7	7.11E+03	-1.03E+04	6.558
1.92	1.49E+05	-22.9	28.2	336.	191.	1.67E+05	-1.64E+03	3.88E+04	-44.3	8.25E+03	-8.47E+03	6.558
2.16	1.36E+05	-32.6	25.5	405.	206.	1.37E+05	2.25E+04	3.79E+04	-52.4	9.47E+03	-7.30E+03	6.558
2.40	1.21E+05	-40.5	23.3	481.	221.	1.10E+05	4.15E+04	3.65E+04	-58.9	1.08E+04	-6.49E+03	6.558
2.64	1.08E+05	-46.9	21.4	565.	238.	8.77E+04	5.51E+04	3.48E+04	-64.0	1.21E+04	-5.90E+03	6.558
2.88	9.69E+04	-52.0	19.7	657.	255.	7.02E+04	6.44E+04	3.31E+04	-68.1	1.35E+04	-5.44E+03	6.558
3.36	7.87E+04	-59.5	17.1	866.	291.	4.63E+04	7.49E+04	3.02E+04	-73.7	1.65E+04	-4.80E+03	6.558
3.60	7.16E+04	-62.3	16.0	982.	310.	3.84E+04	7.76E+04	2.90E+04	-75.8	1.80E+04	-4.56E+03	6.558
4.32	5.58E+04	-68.2	13.5	1.38E+03	369.	2.33E+04	8.11E+04	2.62E+04	-79.9	2.27E+04	-4.05E+03	6.558
5.28	4.27E+04	-73.1	11.1	2.02E+03	453.	1.36E+04	8.11E+04	2.36E+04	-82.9	2.91E+04	-3.63E+03	6.558
6.96	2.98E+04	-77.7	8.49	3.44E+03	613.	6.62E+03	7.82E+04	2.10E+04	-85.4	3.99E+04	-3.21E+03	6.558
10.8	1.71E+04	-82.2	5.50	8.15E+03	1.04E+03	2.20E+03	7.10E+04	1.80E+04	-87.4	5.96E+04	-2.75E+03	6.558
29.3	4.57E+03	-86.7	2.04	5.90E+04	6.26E+03	184.	4.99E+04	1.34E+04	-88.7	9.07E+04	-2.35E+03	6.558
60.0	1.90E+03	-88.1	.993	2.47E+05	-1.19E+04	27.1	3.22E+04	1.03E+04	-89.1	9.75E+04	-1.58E+03	6.558

50000 HALT

$C = \frac{X}{F} \Rightarrow X = FC \quad X = 4.424808 \times 10^{-4}$

TABLE 3

20150 GO SUB 10500
11:28 MAY 03 TRED2...

THREE-DEE SYSTEM NORMAL MODE SITUATION ***** TRED2 *****

F0= 12 MHZ Q= 5756.93
C1= 2.87.82E-10 L1= 5.45578E-07 R1= 100000 C2= 0 L3= 0
C3= 3.68734E-11 Z0= 75 L0= 7.78434 C4= 4.18561E-12 C5= 5.64972E-10
L5= 3.08250E-07 R5= 133800 C6= 1.50000E-12 C7= 5.00000E-13

I1= 6.55836 A -120.000 DEG I21= 6.55836 A 0 DEG I41= 6.55836 A 120.000 DEG

FREQ	V DEE	P DEE	P CAP	R CAP	X CAP	W+	W-	V AN	P AN	R AN	X AN	I AN
0.00	1.00E+05	54.7	88.6	75.1	4.65E+11	7.47E+04	58.6	1.16E+04	-5.85E-02	1.77E+03	-1.73E+06	6.558
-60.0	2.73E+03	92.8	179.	2.52E+05	-1.84E+03	55.7	6.96E+04	1.50E+04	-86.1	9.76E+04	-6.57E+03	2.289
-16.8	1.02E+04	88.3	176.	1.96E+04	-880.	777.	8.24E+04	1.50E+04	-87.9	7.43E+04	-2.66E+03	5.633
-6.48	2.40E+04	83.8	171.	2.96E+03	-415.	4.32E+03	7.95E+04	1.28E+04	-85.9	2.74E+04	-1.95E+03	6.558
-3.36	3.78E+04	78.9	163.	844.	-244.	1.07E+04	6.41E+04	9.70E+03	-79.5	8.11E+03	-1.51E+03	6.558
-1.92	5.19E+04	73.7	151.	323.	-163.	2.01E+04	5.03E+04	7.44E+03	-64.9	2.68E+03	-1.25E+03	6.558
-.960	6.90E+04	67.3	132.	136.	-144.	3.55E+04	3.34E+04	6.68E+03	-34.8	1.24E+03	-1.79E+03	6.558
-.480	8.20E+04	62.2	114.	89.4	-192.	5.03E+04	1.97E+04	8.00E+03	-14.0	1.26E+03	-5.06E+03	6.558
-.240	9.03E+04	58.8	102.	78.2	-338.	6.09E+04	1.08E+04	9.48E+03	-5.69	1.45E+03	-1.46E+04	6.558
.240	1.11E+05	49.5	75.7	79.9	349.	9.26E+04	-1.27E+04	1.44E+04	2.70	2.21E+03	4.68E+04	6.558
.480	1.03E+05	43.1	64.2	92.6	204.	7.93E+04	-1.87E+04	1.50E+04	2.57	2.76E+03	6.14E+04	5.443
.720	9.21E+04	35.2	54.5	113.	167.	6.35E+04	-1.87E+04	1.50E+04	-.412	3.42E+03	-4.77E+05	4.380
.960	8.29E+04	25.4	46.6	142.	158.	5.13E+04	-1.62E+04	1.50E+04	-6.18	4.20E+03	-3.88E+04	3.594
1.20	7.50E+04	13.9	40.4	179.	160.	4.21E+04	-1.25E+04	1.50E+04	-14.4	5.07E+03	-1.97E+04	3.053
1.44	6.84E+04	1.23	35.4	223.	167.	3.50E+04	-8.41E+03	1.50E+04	-24.3	6.05E+03	-1.34E+04	2.723
1.68	6.27E+04	-11.4	31.4	276.	178.	2.94E+04	-4.25E+03	1.50E+04	-34.7	7.11E+03	-1.03E+04	2.567
1.92	5.79E+04	-22.9	28.2	336.	191.	2.50E+04	-245.	1.50E+04	-44.3	8.25E+03	-8.47E+03	2.538
2.16	5.36E+04	-32.6	25.5	405.	206.	2.15E+04	3.52E+03	1.50E+04	-52.4	9.47E+03	-7.30E+03	2.593
2.40	5.00E+04	-40.5	23.3	481.	221.	1.87E+04	7.02E+03	1.50E+04	-58.9	1.08E+04	-6.49E+03	2.698
2.64	4.67E+04	-46.9	21.4	565.	238.	1.63E+04	1.03E+04	1.50E+04	-64.0	1.21E+04	-5.90E+03	2.829
2.88	4.39E+04	-52.0	19.7	657.	255.	1.44E+04	1.32E+04	1.50E+04	-68.1	1.35E+04	-5.44E+03	2.970
3.36	3.91E+04	-59.5	17.1	866.	291.	1.14E+04	1.84E+04	1.50E+04	-73.7	1.65E+04	-4.80E+03	3.254
3.60	3.70E+04	-62.3	16.0	982.	310.	1.03E+04	2.07E+04	1.50E+04	-75.8	1.80E+04	-4.56E+03	3.390
4.32	3.20E+04	-68.2	13.5	1.38E+03	369.	7.65E+03	2.66E+04	1.50E+04	-79.9	2.27E+04	-4.05E+03	3.759
5.28	2.71E+04	-73.1	11.1	2.02E+03	453.	5.48E+03	3.27E+04	1.50E+04	-82.9	2.91E+04	-3.63E+03	4.162
6.96	2.13E+04	-77.7	8.49	3.44E+03	613.	3.39E+03	4.00E+04	1.50E+04	-85.4	3.99E+04	-3.21E+03	4.692
10.8	1.43E+04	-82.2	5.50	8.15E+03	1.04E+03	1.53E+03	4.94E+04	1.50E+04	-87.4	5.96E+04	-2.75E+03	5.468
29.3	4.97E+03	-86.7	2.04	5.90E+04	6.26E+03	184.	4.99E+04	1.34E+04	-88.7	9.07E+04	-2.05E+03	6.558
60.0	1.90E+03	-88.1	.993	2.47E+05	-1.19E+04	27.1	3.22E+04	1.03E+04	-89.1	9.75E+04	-1.58E+03	6.558

50000 HALT

TABLE 4

51

25.68

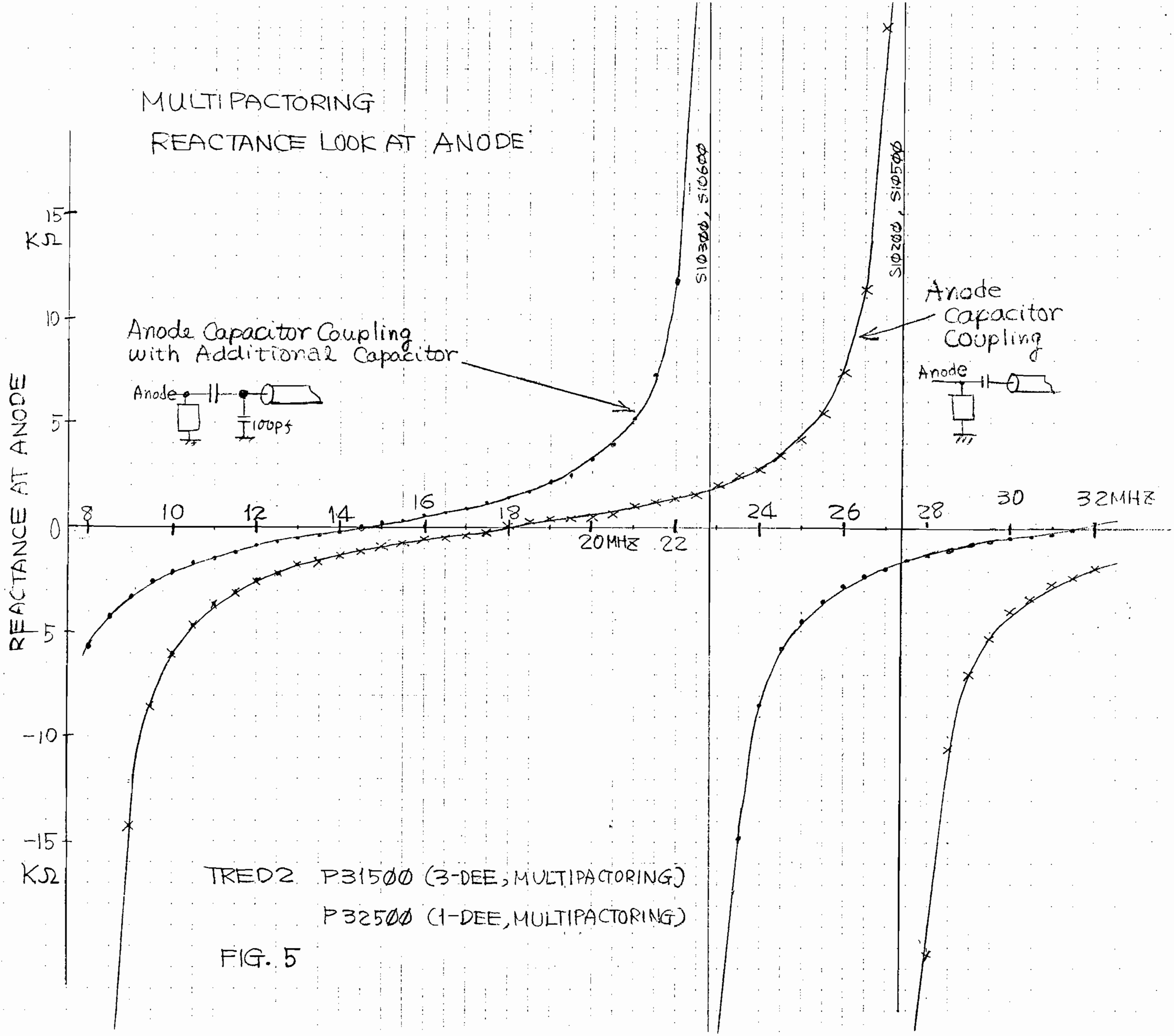

MULTIPACTORING
REACTANCE LOOK AT ANODE
REACTANCE AT ANODE
15 KΩ
10
5
0
5
-10
-15 KΩ
8
10
12
14
16
18
20MHz
22
24
26
28
30
32MHz
S10300, S10600
S10200, S10500
Anode Capacitor Coupling with Additional Capacitor
Anode
100pf
Anode Capacitor Coupling
Anode
TRED2 P31500 (3-DEE, MULTIPACTORING)
P32500 (1-DEE, MULTIPACTORING)

FIG. 5

CALCULATION OF BASIC 3-DEE CONFIGURATION

Fig. 6 is the calculated results of the basic-3-dee configuration which includes the WYE transformed dee to dee capacitors without the transmission lines and the transmitter anode resonators. Three constant currents are fed immediately to the dees. When 3 phase currents are fed to the dees, the effects caused by detuning DEE#2 appear as assymetric curves at DEE#1 and DEE#3, both in phase and amplitude changes. Otherwise for 1 phase operation, all changes at the 3 dees have very similar behavior. Fig. 6 (b) shows the changes in the amplitudes and the phases at the 3 dees, when the source current to DEE#2 is changing by .8 through 1.2 amps.

Fig. 6 actually shows the important features of 3ϕ and 1ϕ operation. For 3ϕ operation, detuning one dee results in a factor of ten change in that dees phase with respect to the other dees; and while the amplitude change in the detuned dee follows the universal resonance curve, the other dees amplitudes change assymetrically but by the same magnitude. But for 1ϕ operation, detuning one dee results in equal linear phase change in all dees, and equal universal resonance change in all amplitudes.

Changing the source current to one dee hardly causes a phase change in that dee, for 3-phase operation but causes a linear (but opposite slope) change of 20 times as much in the other dees. This same current change in one dee causes its amplitude to change linearly, but the other dees change amplitude by only 1/10 as much.

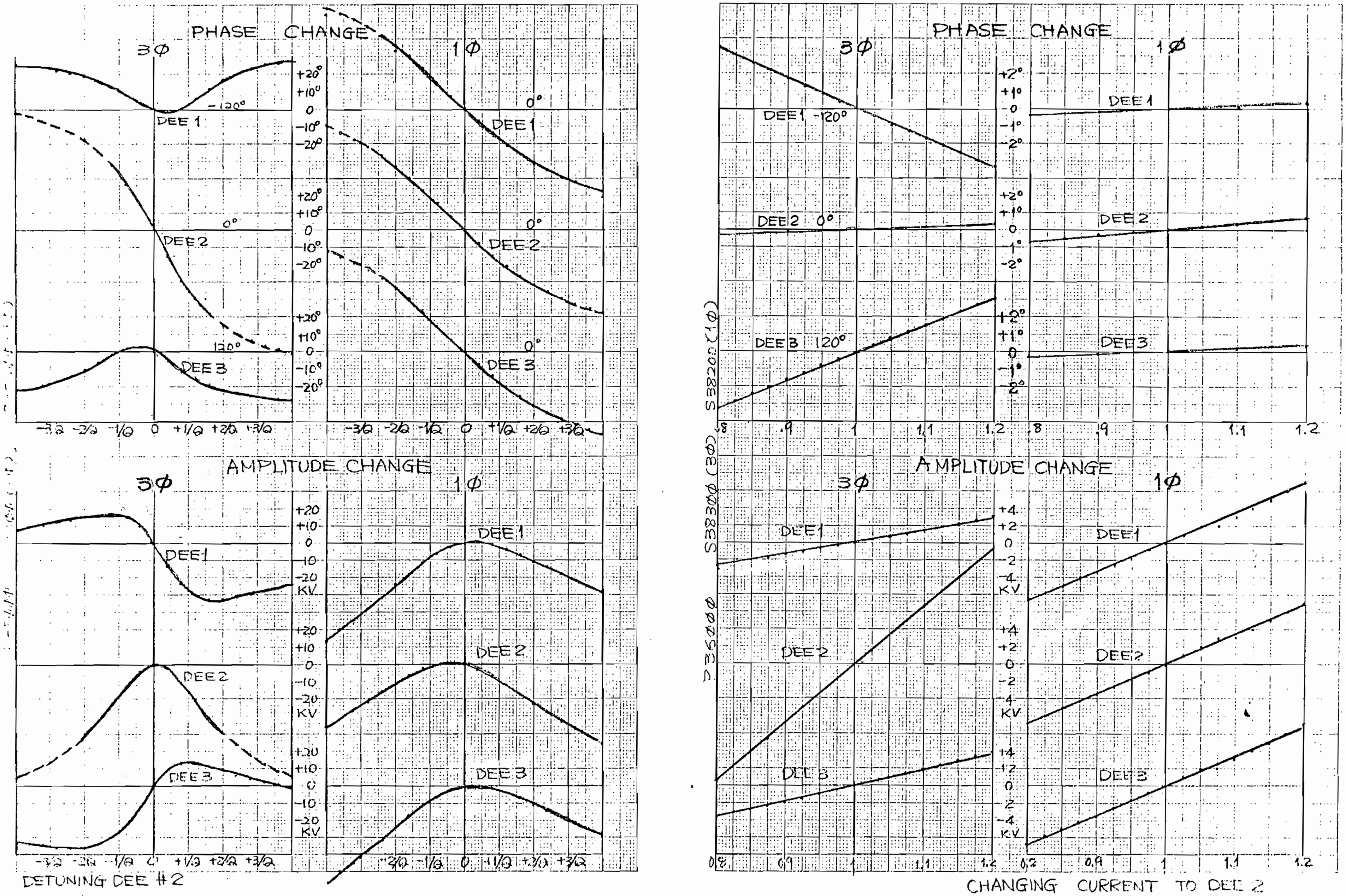
For in phase operation, changing source current to one dee changes all amplitudes equally linearly.

Thus, for 3ϕ operation, detuning one dee has a criterion for retuning while the amplitude loops fight, and changing the source current to one dee also has a clear criterion for correction while the phase loops fight. Who will win? Well, the amplitude loop is 1000 times faster than the phase loop, so it will win and God will be satisfied.

But for 1-phase operation, obviously, different criteria for regulation will have to be used than 3-dee operation.

All changes were calculated for the frequency range of 10 through 30 MHz, and the curves representing the amplitude or the phase changes have almost the same shapes within this frequency range.

These results agree with the calculated results using E CAP which was described in RF Note 8 and 9.



(a) DETUNING DEE #2

FIG. 6

(b) CHANGING SOURCE CURRENT TO DEE #2

DETUNING DEE #2 AND CHANGING ANODE CURRENT TO DEE#2

Fig. 7,8, and 9 show the changes in the phase and the amplitude at each dee voltage of the whole 3 dee system that includes the transmission lines, the transmitter anode resonators and 3-dees when DEE #2 is detuning from -4/Q to +4/Q. The changes are remarkable as a function of the operating frequency. Near 19.26 MHz, the frequency which corresponds to $\lambda/2$ of the transmission line, the curves agree with the curves of the basic 3-dee configuration described in the previous paragraph, both for 3 phase and 1-phase operation as shown in Fig. 7.

Fig. 8 shows the curves for 3 phase, near the frequency corresponding to $\lambda/4$ and $3/4\lambda$ of the transmission lines. At 8 and 28 MHZ, the changes in both phase and amplitude are not so much. At 10 MHz and 30 MHz, the phase changes at DEE#1 and DEE#2 have very similar shapes.

Fig. 9 presents the curves for IN PHASE operation near the $1/4\lambda$ and $3/4\lambda$ frequency. The smallest changes are at 8 and 28 MHz. The phases of all 3 dees are always within $\pm 1^{\circ}$ at any operating frequency.

We calculated the detuning situation of the other scheme of the anode coupling with an additional capacitor, and got many curves of similar shapes, but the curves were shifted to about 2 MHz lower frequency.

Fig. 10 shows the phase and the amplitude changes of each dee voltage when the anode current for DEE#2 is changing. Both for 3 phase and 1 phase operation, the curves are almost the same as the changes of the basic 3 dee configuration shown in Fig. 6 (b), except near the $1/4\lambda$ frequency.

In order to get the information to find which dee is mistuned for 1 phase operation, we have tried to printout the voltages, currents, and phase at various points and to calculate some other situations. An example of those calculations is shown in Fig. 11. The curve D shows the changes with the DEE#2 detuning of -4/Q. The curves A show what occurs when adjusting only DEE#1, B shows the changes resulting from adjusting DEE#1 and DEE#2 simultaneously with detuned DEE#2. (More discussion on RF Note 68)

DETUNING DEE #2 AND CHANGING ANODE CURRENT TO DEE#2

Fig. 7,8, and 9 show the changes in the phase and the amplitude at each dee voltage of the whole 3 dee system that includes the transmission lines, the transmitter anode resonators and 3-dees when DEE #2 is detuning from -4/Q to +4/Q. The changes are remarkable as a function of the operating frequency. Near 19.26 MHz, the frequency which corresponds to λ/2 of the transmission line, the curves agree with the curves of the basic 3-dee configuration described in the previous paragraph, both for 3 phase and 1-phase operation as shown in Fig. 7.

Fig. 8 shows the curves for 3 phase, near the frequency corresponding to λ/4 and 3/4λ of the transmission lines. At 8 and 28 MHZ, the changes in both phase and amplitude are not so much. At 10 MHz and 30 MHz, the phase changes at DEE#1 and DEE#2 have very similar shapes.

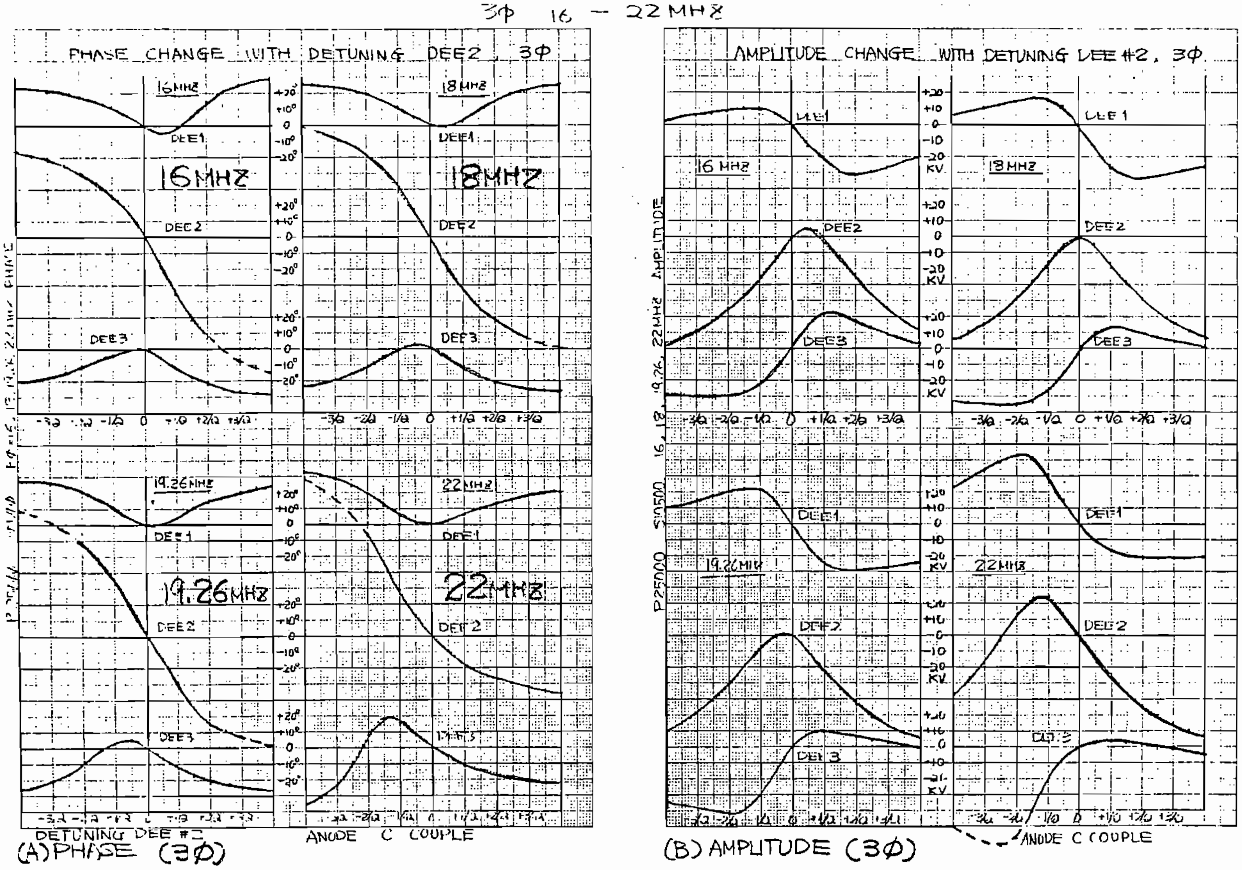
Fig. 9 presents the curves for IN PHASE operation near the 1/4λ and 3/4λ frequency. The smallest changes are at 8 and 28 MHz. The phases of all 3 dees are always within $\pm 1^{\circ}$ at any operating frequency.

We calculated the detuning situation of the other scheme of the anode coupling with an additional capacitor, and got many curves of similar shapes, but the curves were shifted to about 2 MHz lower frequency.

Fig. 10 shows the phase and the amplitude changes of each dee voltage when the anode current for DEE#2 is changing. Both for 3 phase and 1 phase operation, the curves are almost the same as the changes of the basic 3 dee configuration shown in Fig. 6 (b), except near the 1/4λ frequency.

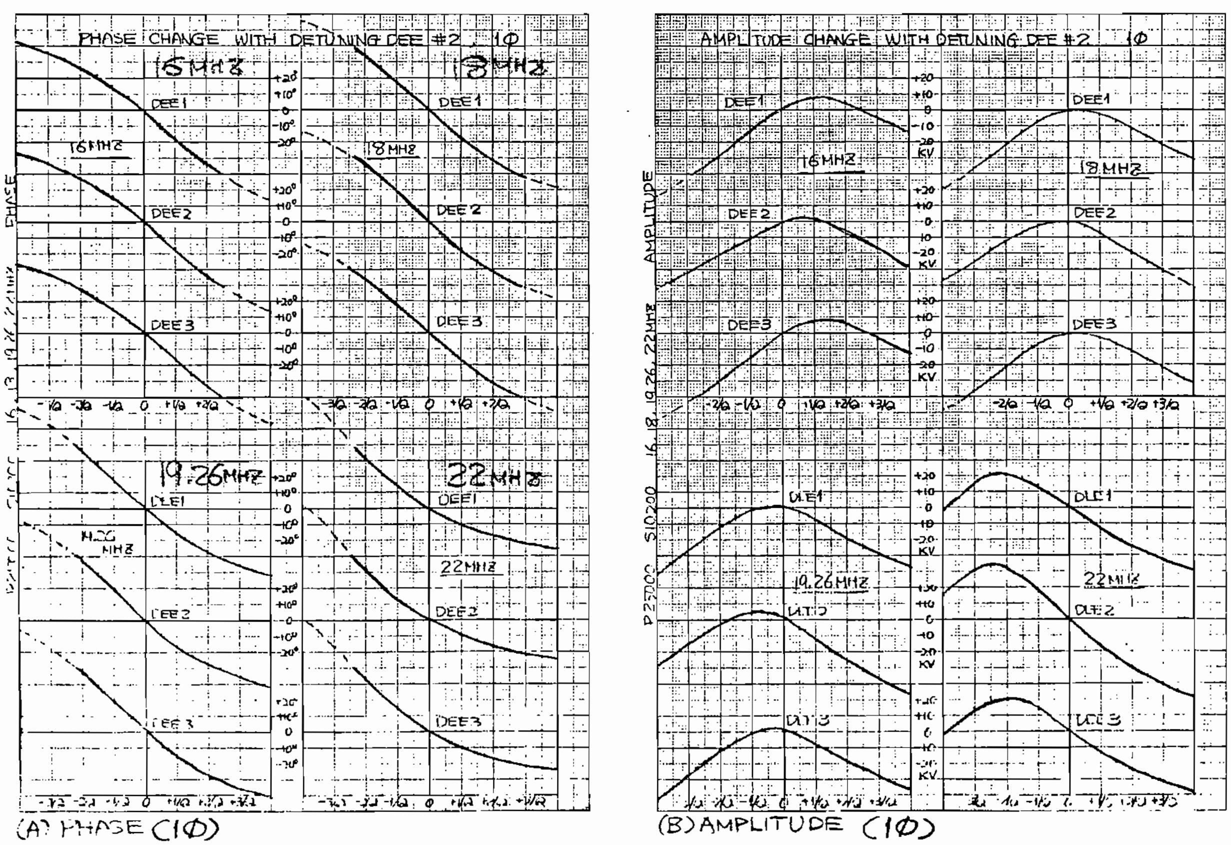
In order to get the information to find which dee is mistuned for 1 phase operation, we have tried to printout the voltages, currents, and phase at various points and to calculate some other situations. An example of those calculations is shown in Fig. 11. The curve D shows the changes with the DEE#2 detuning of -4/Q. The curves A show what occurs when adjusting only DEE#1, B shows the changes resulting from adjusting DEE#1 and DEE#2 simultaneously with detuned DEE#2. (More discussion on RF Note 68)

3Φ 16 – 22 MHz



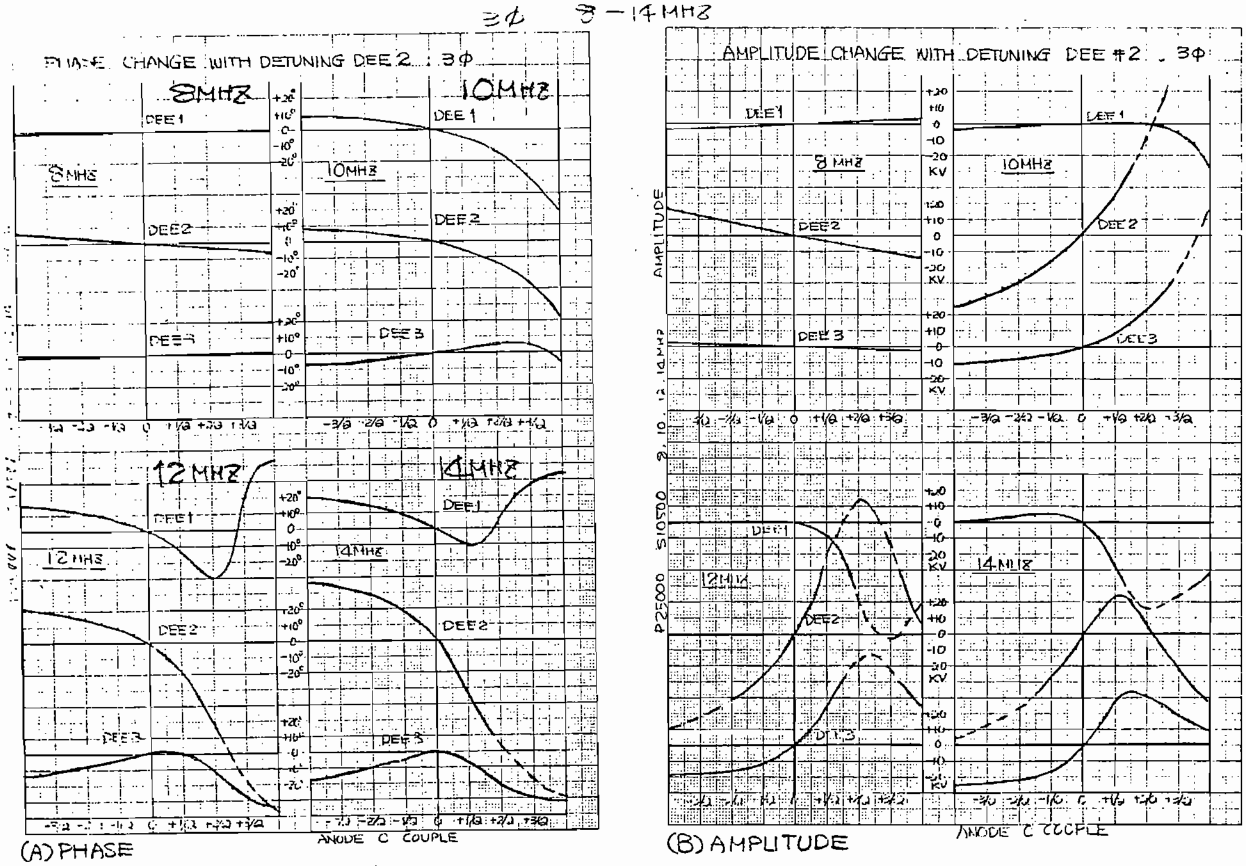
DETUNING DEE#2 3-PHASE.

Fig 7 DETUNING DEE #2, FΦ = 16 – 22MHz



DETUNING DEE #2 IN PHASE

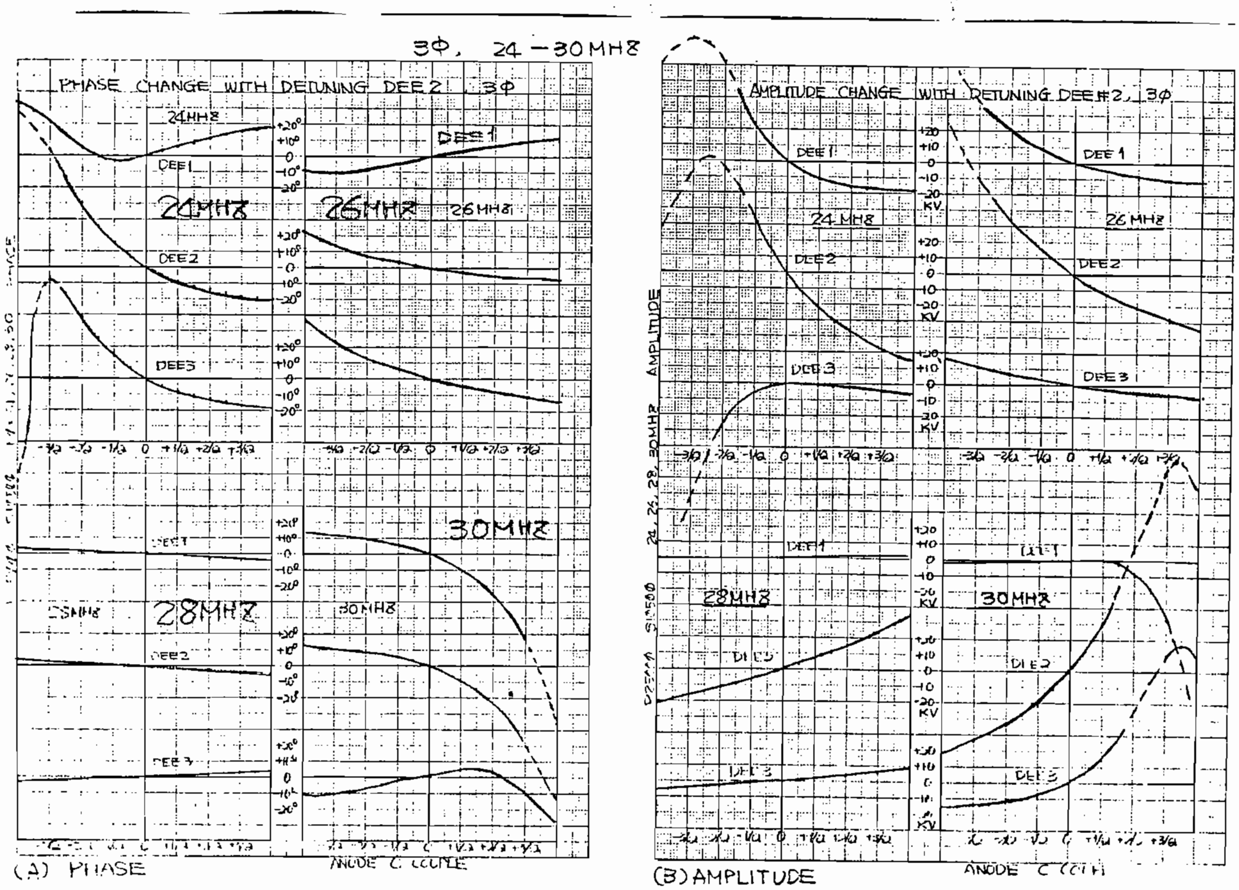
3φ 3-14 MHz



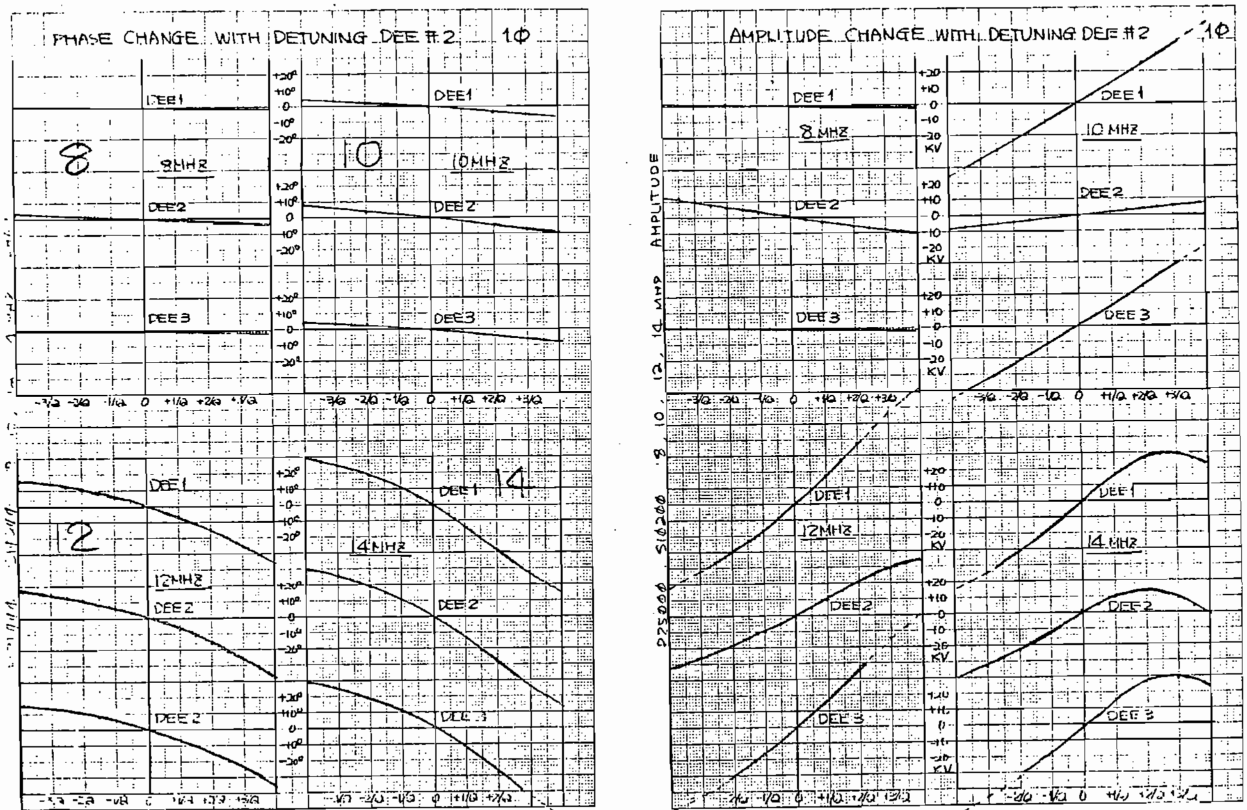
DETUNING DEE #2, 3-PHASE

Fig 8 DETUNING DEE #2, 3 PHASE

3φ, 24-30 MHz



DETUNING DEE #2, 3-PHASE

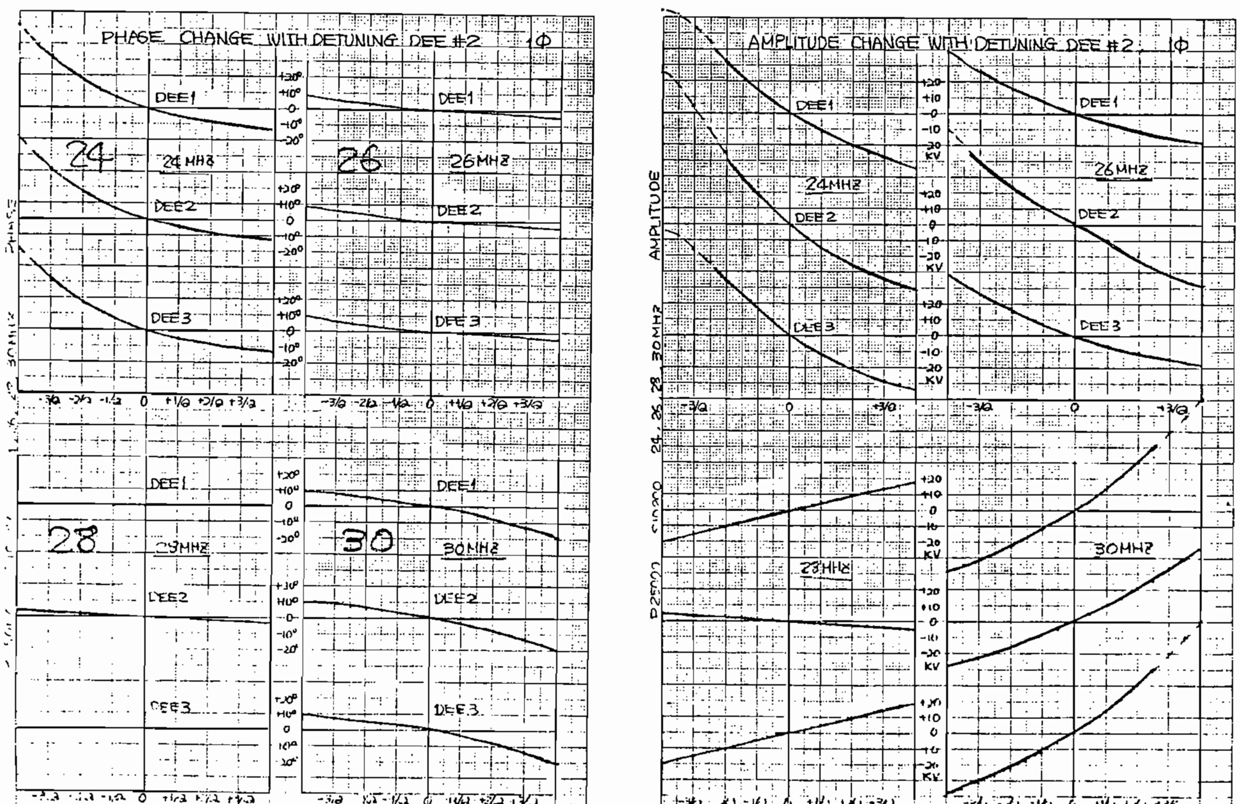


(A) PHASE

(B) AMPLITUDE

DETUNING DEE #2 , IN PHASE

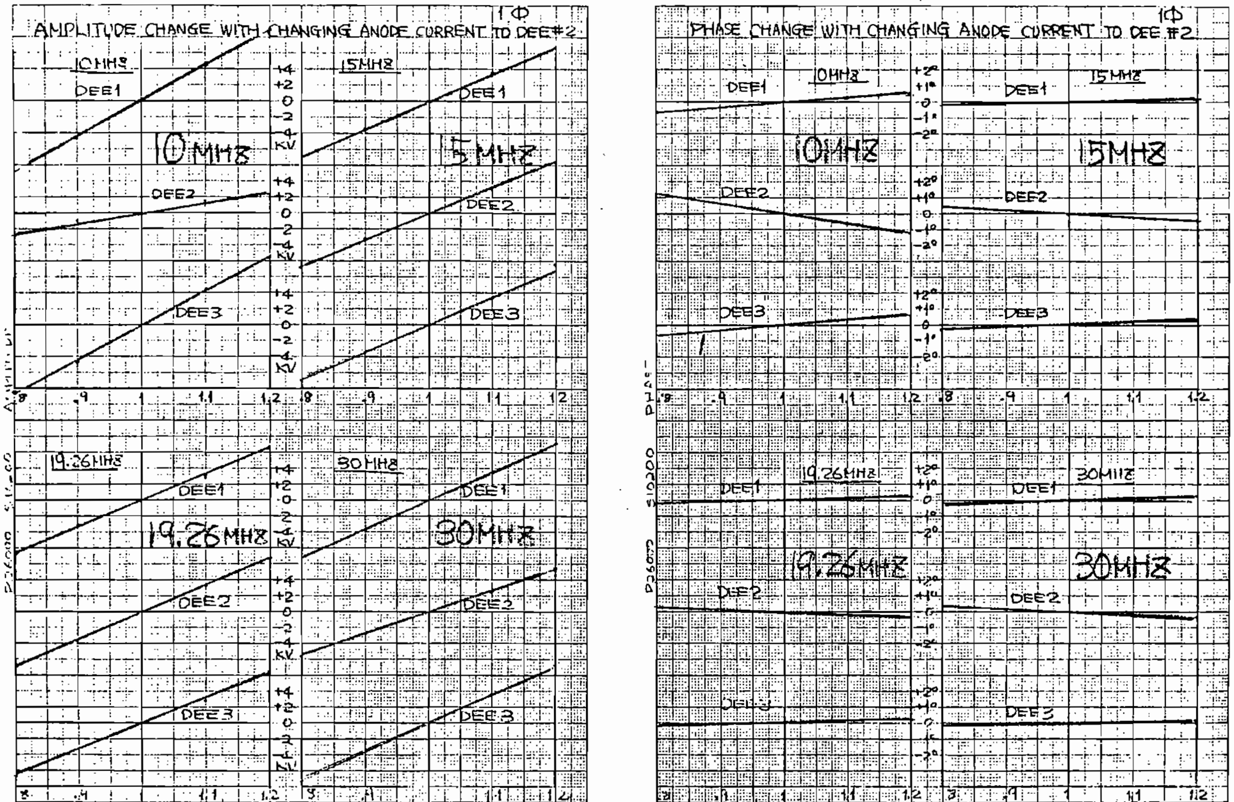
Fig 9 DETUNING DEE #2 , IN PHASE



(A) PHASE

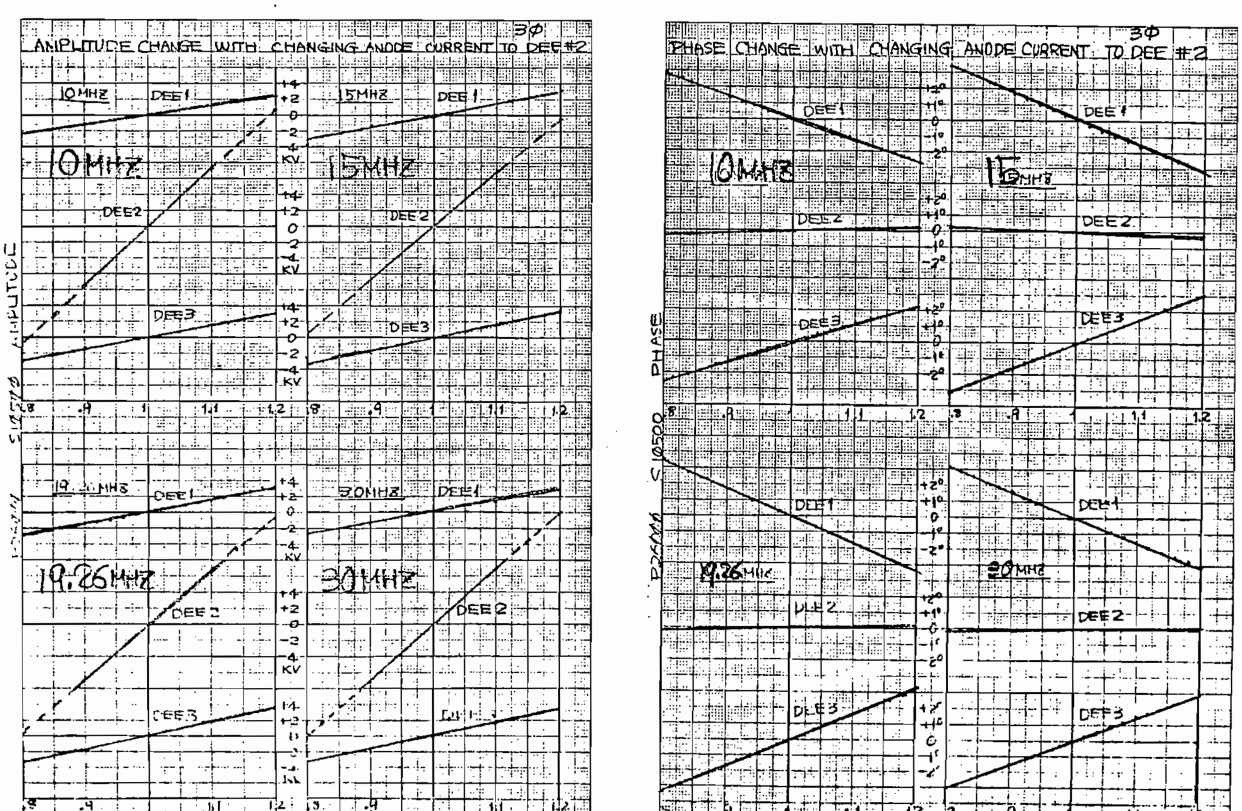
(B) AMPLITUDE

DETUNING DEE #2 , IN PHASE



(A) AMPLITUDE CHANGE (IN PHASE) (B) PHASE CHANGE (IN PHASE)

Fig 10 CHANGING ANODE CURRENT TO DEE #2



(C) AMPLITUDE CHANGE (3 PHASE) (D) PHASE CHANGE (3 PHASE)

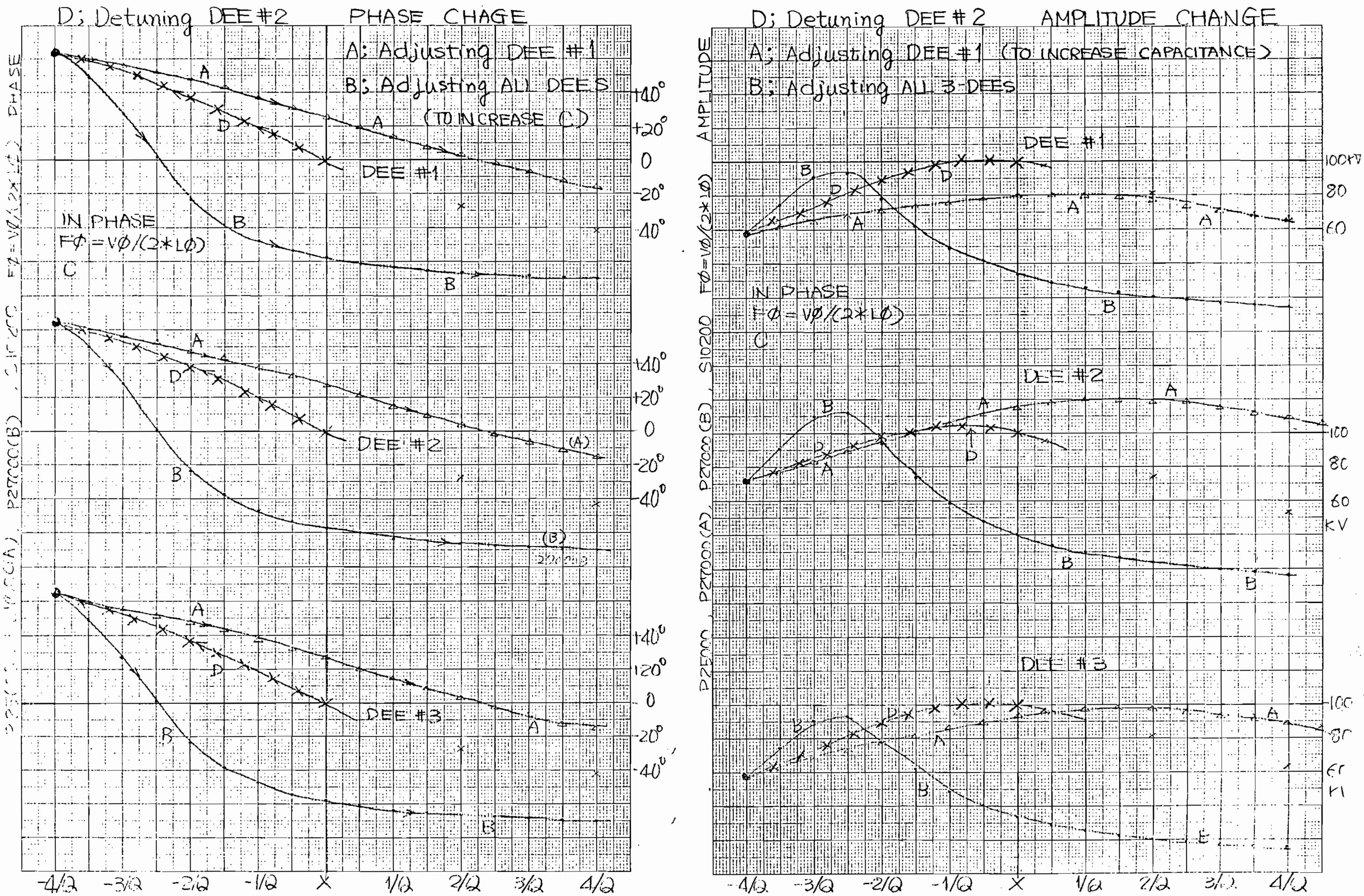

D; Detuning DEE #2
PHASE CHAGE
A; Adjusting DEE #1
B; Adjusting ALL DEES
(TO INCREASE C)
IN PHASE
FΦ=VΦ/(2*LΦ)
C
DEE #1
DEE #2
DEE #3
+40°
+20°
0
-20°
-40°
PHASE FΦ=VΦ/(2*LΦ)
-4/Q
-3/Q
-2/Q
-1/Q
X
1/Q
2/Q
3/Q
4/Q
D; Detuning DEE # 2
AMPLITUDE CHANGE
A; Adjusting DEE #1 (TO INCREASE CAPACITANCE)
B; Adjusting ALL 3-DEES
100KV
80
60
KV
AMPLITUDE FΦ=VΦ/(2*LΦ) S10200 , P27000(B) , P27000(A) , P25000

Fig 11

More than 10 possible calculation routines are imbedded in TRED2 using all the subroutines. In lines 110-990 these programs are documented and line 100 is to be used to select which routine to use. The entire listing of TRED2 requires 25 pages of line-printer paper. Anyone wishing to see the lisitng may do so by calling for the JOB Number 12325, then File TRED2.

```
00001 REM *** TRED2 *** SEPTEMBER 1980
00002 REM  THIS IS TRED2, INCLUDES MANY PROGRAMS LISTED BELOW. LINE 100 IS TO SELECT ONE OF THOSE PROGRAMS.
00003 REM  PUT THE PROGRAM LINE NUMBER FOLLOWING THE   GO TO   STATEMENT AT LINE 100.
00004 REM  ALL REQUIERED SUBROUTINES AND REVISED VESUB ARE INCLUDED IN TRED2.
00005 REM  REV.  MAY 10, 1981
00009 REM ------------------------------------------------------------------------------------------------------
00105 REM ------------------------------------------------------------------------------------------------------
00110 REM  LIST OF PROGRAMS IN TRED2
00120 REM  ABBREVIATIONS
00130 REM     NORM ; NORMAL OPERATING MODE                          MULT ; MULTIPACTORING MODE
00140 REM     3-PH ; THREE PHASE OPERATION                          1-PH ; IN PHASE OPERATION
00150 REM     L-C ; ANODE OUTPUT L-C COUPLING (OLD SCHEME)          C ; ANODE C COUPLE
00160 REM     C-C ; ANODE C COUPLE WITH ADDITIONAL C                FO ; RESONANT FREQUENCY
00170 REM
00180 REM
00190 REM
00200 REM  P20000 3-DEE SYSTEM   (A) NORM & (B) MULT MODE SITUATION AROUND FO,   NORM MULT 1-PH 3-PH L-C, C, C-C
00210 REM                       (SAME CALAULATION AS TRED3, RF NOTE #46)
00220 REM  P21000 1-DEE SYSTEM (A) NORM & (B) MULT MODE SITUATION AROUND FO, NORM, MULT, L-C, C, C-C
00230 REM
00240 REM  P22000 3-DEE SYSTEM, 1-TRANSMITTER TO DEE #2
00250 REM
00260 REM *P23000 NO PROGRAM
00270 REM
00280 REM *P24000 NO PROGRAM
00290 REM
00300 REM  P25000 3-DEE SYSTEM,  DETUNING DEE #2,
00310 REM
00320 REM  P26000 CHANGING ANODE CURRENT TO DEE #2,  FO=10 TO 30 STEP 5 3-PH, 1-PH, L-C, C, C-C
00330 REM
00340 REM  P27000 DECREASED C OF DEE #2, (A)INCREASING C OF DEE #1, (B)INCREASING C OF ALL 3-DEES,  FO=10 TO 30 STEP 5
00350 REM                                                              3-PH, 1-PH, L-C, C, C-C
00360 REM *P28000 NO PROGRAM
00370 REM
00380 REM *P29000 NO PROGRAM
00390 REM
00400 REM  P30000 VARIOUS  R'S,  L'S  &  C'S, FO=8 TO 32 STEP .5 , 3-PH, 1-PH, L-C, C, C-C
00410 REM
00420 REM  P31000 3-DEE SYSTEM NORM MODE DATA AT FO'S, FO=8 TO 32 STEP .5  1-PH, 3-PH, L-C, C, C-C
00430 REM
00440 REM  P31500 3-DEE SYSTEM MULT MODE DATA AT FO'S, FO=8 TO 32 STEP .5  1-PH, 3-PH, L-C, C, C-C
00450 REM
00460 REM  P32000 1-DEE SYSTEM NORM MODE DATA AT FO'S, FO=8 TO 32 STEP .5  L-C, C, C-C
00470 REM
00480 REM  P32500 1-DEE SYSTEM MULT MODE DATA AT FO'S, FO=8 TO 32 STEP .5  L-C, C, C-C
00490 REM *P33000 NO PROGRAM
00500 REM  P34000 3-DEE SYSTEM NORM VARIOUS V'S, I'S & PHASE AT FO'S,  FO=8 TO 32 STEP .5, 3-PH, 1-PH, L-C, C, C-C
00510 REM
00520 REM 35000-39900  3-DEE CALCULATION WITHOUT TX LINE, TX RESONATOR (.SAME RESULT AS ECAP, RF NOTE #8)
00530 REM
00540 REM  P35000 DETUNING DEE #2,  1-PH, 3-PH
00550 REM
00560 REM  P36000 CHANGING SOUCE CURRENT TO DEE #2,  1-PH, 3-PH
00990 REM ******************************************************************************************************
```