214-0009-01-01_00

MSU Superconducting Cyclotron

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R.F. Note # 8

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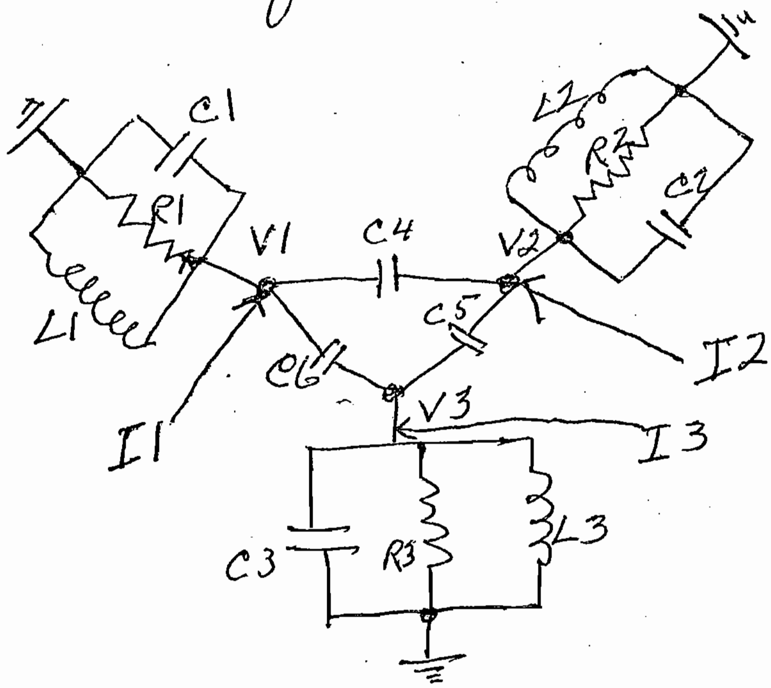
J. Riedel

Calculating for 3 ϕ operation.

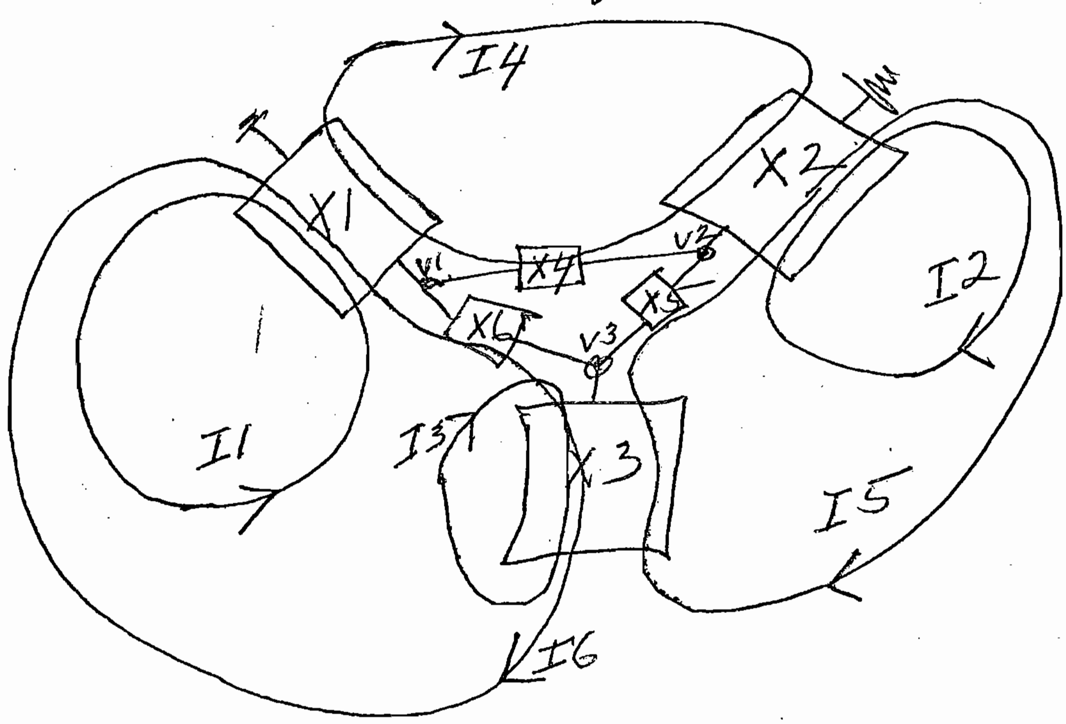
Preliminarily to calculating the ~~ϕ~~ 3 ϕ problem the following 5 pages give complete instructions to program a computer to do the zeroest order solution. This zero order setup assumes that ~~ea~~ one or each resonator is driven by a transmitter delivering current to the dees. Actually, this is exactly what the model reported ~~for~~ in note # 7 did. The results of the model testing were emminently satisfying and it is presumed ~~that~~ when and if the computer program prescribed in this note is run, the results will be in accord with the model results. This will be very interesting and instructive sans doubt.

However the real problem is many many times more complicated. If to the circuit depicted on the next page we add, instead of the IA, IB, IC, ~~coupling~~ drive capacitors and transmission lines of arbitrary lengths, and an additional 3 energy storing resonators at the 3 transmitters the computational problem is enormously increased. Given enough peacefull days in Arkansas, and especially if it ever rains, I will endeavor to outline the problem in a future note.

equivalent circuit



for analysis we write down another equivalent circuit



we start by defining the parameters

$F\phi = 3E7$

$W\phi = 2\pi F\phi$

$C1 = 3E\text{-}10$

$Q = 4E3$

$L1 = 1/(W\phi^{**}2 * C1)$

$R1 = Q * W\phi * L1$

$C4 = 5E\text{-}13$

and to start

$C2 = C3 = C1$, $L2 = L3 = L1$, $R2 = R3 = R1$

$C5 = C6 = C4$

$I1 = (30, 0)$ complex

$I2 = (0, 0)$ "

$I3 = (0, 0)$ "

XXXX and we solve for $N = 1$ to 3

first setting $(\omega^2 L(N) C(N) - 1) = K(N)$

$$X(N) = \frac{\frac{K(N)^2}{Q}\omega L}{\frac{K^2}{Q^2}+1} - j\,\frac{K\omega L}{\frac{K^2}{Q^2}+1} = A(N) + j\,B(N)$$

and for $N = 4$ to 6

$$X(N) = 0 - \frac{j}{\omega C(N)} = A(N) + j\,B(N)$$

Now we write down the 3 coupled loop equations which must be solved simultainously.

$$(I1+I4-I6)X1+(I4-I2-I5)X2+I4X4=0$$
$$(I5+I2-I4)X2+(I5-I6-I3)X3+I5X5=0$$
$$(I6+I3-I5)X3+(I6-I1-I4)X1+I6X6=0$$

the three unknowns are I4, I5 & I6
so we assemble them in order

$$I4(X1+X2+X4)-I5X2-I6X1=-I1X1+I2X2$$
$$-I4X2+I5(X2+X3+X5)-I6X3=I3X3-I2X2$$
$$-I4X1-I5X3+I6(X3+X1+X6)=I1X1-I3X3$$

which can be written in the form

$$A(1,1)I4+A(1,2)I5+A(1,3)I6=A(1,4)$$
$$A(2,1)I4+A(2,2)I5+A(2,3)I6=A(2,4)$$
$$A(3,1)I4+A(3,2)I5+A(3,3)I6=A(3,4)$$

where the A's are complex numbers.
the solution to the above is straightforward resulting in, for N=4 to 6

$$I(N)=A(N)+jB(N).$$

Next we solve for the three voltages

$V1 = (I1 + I4 - I6) X1$

$V2 = (I2 - I4 + I5) X2$

$V3 = (I3 - I5 + I6) X3$

and for N = 1 to 3 we can write

$V(N) = \cancel{A}\ B(N) + j D(N)$

Here it is appropriate to have the computer make a simple check.

$$\left.\begin{array}{l} V4 = V1 - V2 \\ V5 = V2 - V3 \\ V6 = V3 - V1 \\ V7 = -I4 X4 \\ V8 = -I5 X5 \\ V9 = -I6 X6 \end{array}\right\} = C(N) + j D(N)$$

and check to see that V4, V5, V6 = V7, V8, V9 by Printing out, for N = 1 to 9 the C(N) & D(N).

if all is well we proceed:

for N = 1 to 3 we ~~take~~ convert to Polar

$E(N) = \sqrt{C(N)^2 + D(N)^2}$ and

$J(N) = \text{atn } D(N)/C(N)$ but with if and go to statements look at the signs of C(N) & D(N) so that J(N) is in the correct quadrant. this is done by subt. or adding π as necessary.

we print out ~~B~~ ~~for~~ for N = 1 to 3, E(N), J(N)

Now go back to line XXXX on P2 where we decide how to scan the spectrum.

we scan the frequency range from

~~$F = F_o + \frac{3F_o}{Q}$ to~~

$$F = F_o\left(1 + \frac{3}{Q}\right) \text{ to } F_o\left(1 - \frac{C4}{C1} - \frac{3}{Q}\right)$$

and at the end of a ~~calculation~~ the first calculation print out

int F/100, Int E(1), Int(deg(J1))
Int E(2), Int(deg(J2))
Int E(3), Int(deg(J3))

and tag for N=1 to 3, J(N) = J(N+3)
then run into the next F
and after calculating everything, ask if, for N=1 to 3, ~~J(N)~~ abs(J(N) − J(N+3)) < 10°
if it is less we skip the print out and go to the next F, otherwise print out before going to the next F.

Step size, to start is FΦ/10Q
after looking with interest at the results we make C2 = C2(1+Q)
C3 = C3(1−Q)
and re-run. Depending on the results we try various settings for C1 & C2.
Thus we exhaust the system for driving with only 1 transmitter.
Now we go back, first making C1=C2=C3
and set I1 = (10, 0), I2 = (10, 120) I3 = (10, −120) (polar).
and scan again. Then vary the C's or L's