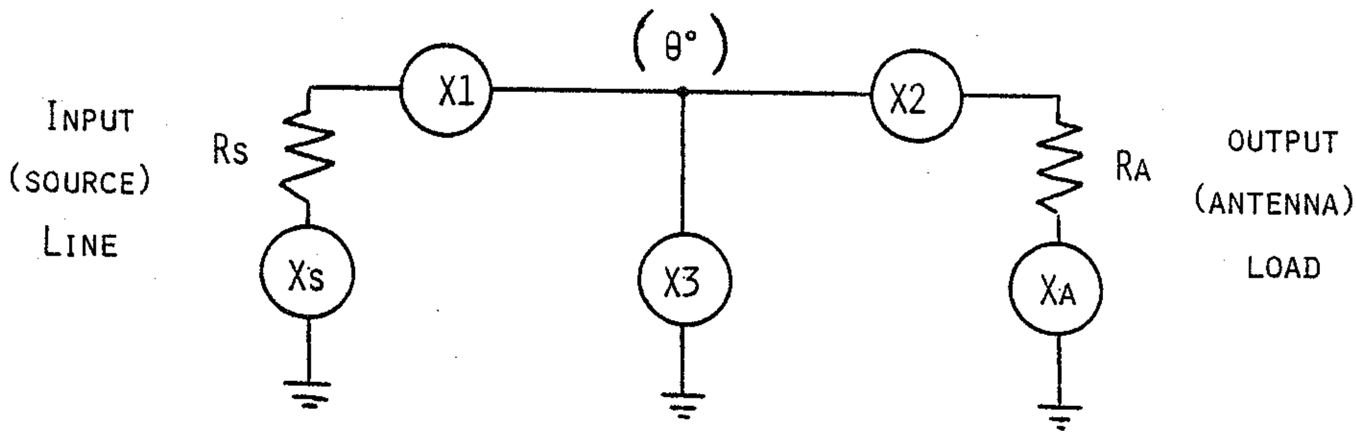
HOWARD & OTHER NETWORK INFORMATION:

GENERAL:

The attached information was prepared by George P. Howard, an authority on R.F. Network Designs to explain the differences between so called Howard and other types of networks.

DESIGN SHEET INFORMATION

(SYMBOL REFERENCES)



THE DESIGN SHEETS REFERENCE:

BRANCH 1 (THE INPUT ARM, X1) *

BRANCH 2 (THE OUTPUT ARM, X2) **

BRANCH 3 (THE SHUNT LEG, X3)

(R_A): ANTENNA RESISTANCE (OR ANY LOAD RESISTANCE)

(X_A): ANTENNA REACTANCE (OR ANY LOAD REACTANCE)

(R_S): TRANSMISSION LINE RESISTANCE (OR ANY DESIRED INPUT R_S)

(X_S): TRANSMISSION LINE REACTANCE (OR ANY DESIRED INPUT X_S)

(X1): INPUT ARM REACTANCE

(X2): OUTPUT ARM REACTANCE

(X3): SHUNT LEG REACTANCE

(R_P): THE EQUIVALENT PARALLEL RESISTANCE FOR A SERIES RESISTANCE AND REACTANCE

(THETA-T): THE NETWORK PHASE (DEGREES)

(TOTAL VOLT-AMPERE PRODUCT): THE SYSTEM'S STORED ENERGY

(Q): THE TOTAL SYSTEM STORED ENERGY; DIVIDED BY THE POWER, IN WATTS.

THE Q OF THE ANTENNA IS XA DIVIDED BY RA; THIS IS AN INHERENT QUALITY AND CANNOT BE CHANGED WITHOUT MODIFYING THE MANNER IN WHICH THE TOWER IS FED OR ITS BASIC PHYSICAL DIMENSIONS AND CONSTRUCTION.

THE NETWORK Q IS THE TOTAL SYSTEM Q MINUS THE ANTENNA'S Q.

* FOR AN L NETWORK, THIS ARM "DISAPPEARS;" BECAUSE IT INHERENTLY HAS A REACTANCE VALUE OF ZERO (WHEN RA IS <u>LESS THAN</u> RS AND THE DESIRED XS VALUE IS ZERO).

WHEN XS IS NOT ZERO, THE NETWORK CAN STILL BE DESIGNED TO PROVIDE AN X1 ARM OF ZERO REACTANCE. THIS PROVISION IS INCORPORATED IN THE DESIGN EQUATIONS.

** FOR AN RP NETWORK, THIS ARM "DISAPPEARS;" BECAUSE IT INHERENTLY HAS A REACTANCE VALUE OF ZERO (WHEN THE LOAD RP VALUE IS <u>GREATER THAN</u> THE DESIRED RS VALUE).

IF THE LOAD RP VALUE IS <u>LESS THAN</u> THE DESIRED RS VALUE, THE RP TYPE NETWORK CANNOT BE USED.

THE DESIGN EQUATIONS AUTOMATICALLY PROVIDE FOR XS VALUES OTHER THAN ZERO.

THE ANTENNA CURRENT, FOR BOTH TYPES, IS ALWAYS SHOWN IN THE BRANCH 2 COLUMN.

HOWARD'S EQUATIONS

DESIGN EQUATIONS FOR SYSTEM NETWORKS

(FOR CALCULATION PURPOSES, TREAT NEGATIVE RESISTANCES AS BEING POSITIVE)

1. FOR THE L TYPE NETWORK:

(THE DESIRED INPUT RP VALUE MUST BE GREATER THAN THE RA VALUE.)

IF IT IS NOT, USE THE RP TYPE NETWORK AND ITS EQUATIONS.

L TYPE NETWORK EQUATIONS:

LET $R_P = R_S + \frac{(X_S)^2}{R_S}$

$$\theta = \left[\pm \text{Arc Tan}\left(\sqrt{\frac{R_P}{R_A} - 1} \right) + \text{Arc Tan}\left(\frac{X_S}{R_S} \right) \right]$$

$$X3 = \frac{\sqrt{(R_A)\ (R_S)}}{\sin\theta}$$

$$X2 = \frac{R_A}{\tan\theta} - (X3) - (X_A)$$

2. FOR THE RP TYPE NETWORK:

(THE LOAD RP VALUE MUST BE GREATER THAN THE DESIRED RS VALUE.)

IF IT IS NOT, USE THE L TYPE NETWORK AND ITS EQUATIONS.

RP TYPE NETWORK EQUATIONS:

LET $R_P = R_A + \frac{(X_A)^2}{R_A}$

$$X1 = \left(\pm \sqrt{R_S\,(R_P - R_S)} \right) + (X_S)$$

$$\theta = -\left[\text{Arc Tan} \left(\frac{X1 - X_S}{R_S}\right) + \text{Arc Tan} \left(\frac{X_A}{R_A}\right) \right]$$

$$X3 = \frac{\sqrt{R_A\,R_S}}{\sin\theta}$$

3. FOR A TEE TYPE NETWORK:

$$X1 = \frac{R_S}{\tan\theta} - (X3)$$

$$X2 = \frac{R_A}{\tan\theta} - (X3) - (X_A)$$

$$X3 = \frac{\sqrt{(R_A)\,(R_S)}}{\sin\theta}$$

FOR HOWARD EOR TYPE NETWORK:

(EQUAL AND OPPOSITE REACTANCES FOR INPUT ARM AND SHUNT LEG)

$\theta = -90°$ FOR LAGGING PHASE

$\theta = +90°$ FOR LEADING PHASE

RESULTING INPUT $R_P = \frac{(X1)^2}{R_A}$

4. <u>FOR A TEE TYPE NETWORK:</u>

(WHERE THE INPUT IS A COMPLEX IMPEDANCE)

$$\theta 1 = \tan^{-1}\left(\frac{X_S}{R_S}\right)$$

$$\theta 3 = (\theta_T) + (\theta 1)$$

$$\angle A = (\pm 90°) - (\theta 3)$$

USE −90° IF θ_T IS TO BE PLUS
USE +90° IF θ_T IS TO BE MINUS

$$X4 = R_A \tan \angle A$$

$$X5 = R_S \tan \angle A$$

THEN THE REQUIRED NETWORK ARMS ARE:

$$X3 = \sqrt{\frac{(R_A)\ (R_S)}{\sin \theta 3}}$$

$$X2 = (X4) - (X3) - (X_A)$$

$$X1 = (X5) - (X3) + (X_S)$$

5. Equations For Calculating the Resulting Input Impedance of a Network:

(Treating all networks as Tee's. Where X1 and/or X2 could be zero; and X3 could be infinite)

$$\angle A = \text{Tan}^{-1} \left(\frac{(X_A) + (X2) + (X3)}{(R_A)} \right)$$

Then:

$$R_S = \frac{(X3)^2 \, (\text{Cos } A)^2}{(R_A)}$$

$$X_S = - \left(R_S \, \text{Tan} \angle A - (X3) - (X1) \right)$$

For the network's resulting Phase-Shift:

$$\theta = (\pm 90^\circ) - (\angle A) - (\theta 1)$$

Where: $\theta 1 = \text{Tan}^{-1} \left(\frac{X_S}{R_S} \right)$

For the ($\pm 90^\circ$):

Use $+90^\circ$ if X3 is plus

Use -90° if X3 is minus

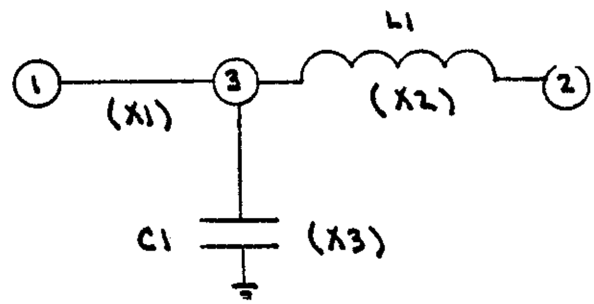
6. Equations For Calculating A Transmission Line's "Equivalent Tee Network."

(For a lossless line with a pure resistance characteristic impedance)

$$X1 = X2 = \left| Z_0 \tan\left(\frac{\theta}{2}\right) \right|$$

$$X3 = -\left| \frac{Z_0}{\sin\theta} \right|$$

EXAMPLES OF NETWORK COMPUTATIONS:



NETWORK: L Network

INPUT RA,XA,RS,DEGREES ? 5,-75,50,-71.565,

```
                          -71.565°
                          (DEGREES)
       ********    X1    ***************    X2    ********
RS + J 0.         -0.000        *         90.000       RA + J XA
(SOURCE)                        *                        (LOAD)
                                *
 50 j0                          *                       5 - j75
                                *
                               X3
                             -16.667
```

INPUT FREQ.(MHZ.), POWER(WATTS) ? 0.62,507,

	BRANCH 1 [INPUT]	BRANCH 3 [SHUNT]	BRANCH 2 [OUTPUT]
REACTANCE	-0.000	-16.667	90.000

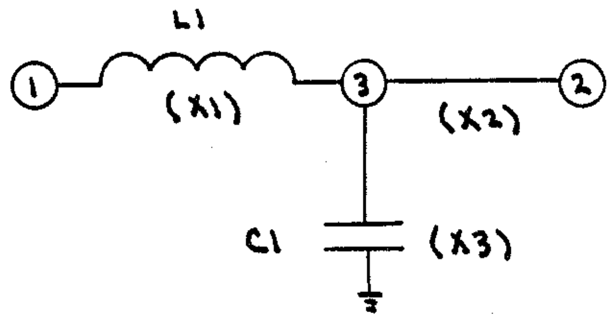
PFD OR MICRO-H	***********	15402.085	23.103
RMS AMPS	3.184	9.553	10.070
MODULATED AMPS	3.900	11.700	12.333
RMS VOLTS	0.000	159.217	906.278
PEAK VOLTS	0.000	450.333	2563.342

TOTAL VOLT-AMPERE PRODUCT 10647.002

Q 21.000

NETWORK SET-UP INFORMATION

	BRANCH 1	BRANCH 3	BRANCH 2
COMPONENTS :	None	C1	L1
MEASUREMENT: (REF. POINT)	1⟶3	3⟶Grnd	3⟶2
GR BRIDGE (DIAL X)	-0.00	-10.33	55.80
DELTA BRIDGE (DIAL X)	-0.00	-26.88	145.16



NETWORK: R_p Network

INPUT RA,XA,RS,DEGREES ? 25,100,50,-145.904,

```
                              -145.904°
                              (DEGREES)
          ########    X1     ###############   X2     ########
RS + J 0.            136.930        #          -0.001          RA + J XA
(SOURCE)                            #                           (LOAD)
                                    #
  50 j0                             #                          25 j100
                                    #
                                   X3
                                 -63.069
```

INPUT FREQ.(MHZ.), POWER(WATTS) ? .98,3460,

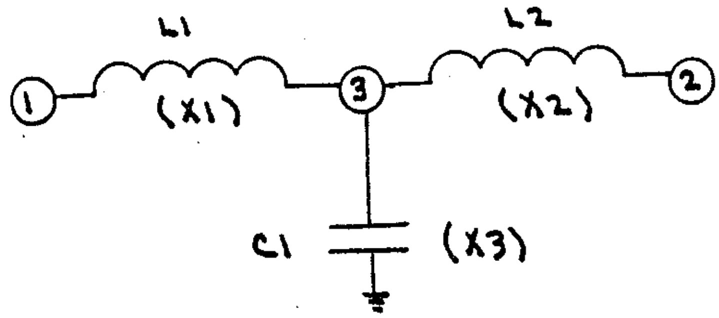
	BRANCH 1 [INPUT]	BRANCH 3 [SHUNT]	BRANCH 2 [OUTPUT]
EACTANCE	136.930	-63.069	-0.001
PFD OR MICRO-H	22.238	2575.003	###########
RMS AMPS	8.319	19.227	11.764
MODULATED AMPS	10.188	23.548	14.408
RMS VOLTS	1139.072	1212.635	0.006
PEAK VOLTS	3221.782	3429.851	0.018

TOTAL VOLT-AMPERE PRODUCT 32791.094

Q 9.477

NETWORK SET-UP INFORMATION

	BRANCH 1	BRANCH 3	BRANCH 2
COMPONENTS :	L1	C1	None
MEASUREMENT: (REF. POINT)	1 → 3	3 → Grnd.	3 → 2
GR BRIDGE (DIAL X)	134.19	-61.81	-0.00
DELTA BRIDGE (DIAL X)	139.72	-64.36	-0.00



NETWORK: Tee Network

INPUT RA,XA,RS,DEGREES ? 210,-150,50,-60,

```
                                   -60°
                                (DEGREES)
          ********      X1     ***************     X2      ********
RS + J 0.            89.454           *        147.078          RA + J XA
(SOURCE)                              *                           (LOAD)
                                      *
  50 j0                               *                        210 - j150
                                      *
                                     X3
                                  -118.322
```

INPUT FREQ.(MHZ.), POWER(WATTS) ? 1.24,2310,

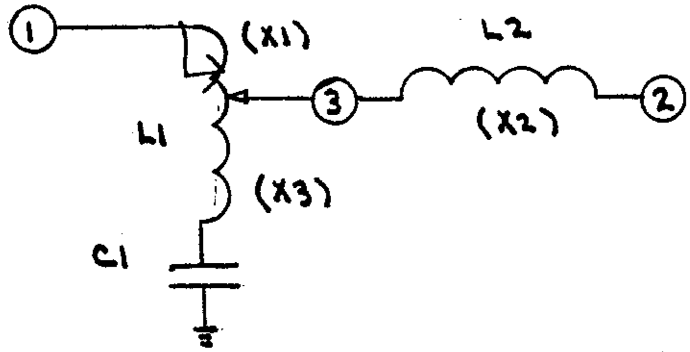
	BRANCH 1 [INPUT]	BRANCH 3 [SHUNT]	BRANCH 2 [OUTPUT]
REACTANCE	89.454	-118.322	147.078
PFD OR MICRO-H	11.481	1084.762	18.878
RMS AMPS	6.797	5.887	3.317
MODULATED AMPS	8.325	7.210	4.062
RMS VOLTS	608.025	696.559	487.803
PEAK VOLTS	1719.753	1970.165	1379.714

TOTAL VOLT-AMPERE PRODUCT 9851.276

Q 4.265

NETWORK SET-UP INFORMATION

	BRANCH 1	BRANCH 3	BRANCH 2
COMPONENTS :	L1	C1	L2
MEASUREMENT: (REF. POINT)	1 → 3	3 → Grnd	3 → 2
GR BRIDGE (DIAL X)	110.92	-146.72	182.38
DELTA BRIDGE (DIAL X)	72.14	-95.42	118.61



NETWORK: Howard EOR Network

INPUT RA,XA,RS,DEGREES ? 40,60,200,-90,

```
                                      -90°
                                   (DEGREES)
            ########     X1     ###############    X2    ########
 RS + J O,             89.443          *         29.443         RA + J XA
 (SOURCE)                              *                          (LOAD)
                                       *
  200  j0                              *                     40  j60
                                       *
                                       X3
                                    -89.443
```

INPUT FREQ.(MHZ.), POWER(WATTS) ? 1.5,1200,

	BRANCH 1 [INPUT]	BRANCH 3 [SHUNT]	BRANCH 2 [OUTPUT]
REACTANCE	89.443	-89.443	29.443
PFD OR MICRO-H	9.490	1186.271	3.124
RMS AMPS	2.449	6.000	5.477
MODULATED AMPS	3.000	7.348	6.708
RMS VOLTS	219.089	536.656	161.264
PEAK VOLTS	619.677	1517.893	456.125

TOTAL VOLT-AMPERE PRODUCT 4639.876

Q 3.867

NETWORK SET-UP INFORMATION

	BRANCH 1	BRANCH 3	BRANCH 2
COMPONENTS :	L1	L1/C1	L2
MEASUREMENT: (REF. POINT)	1→3	3→Grnd	3→2
GR BRIDGE (DIAL X)	134.16	-134.16	44.16
DELTA BRIDGE (DIAL X)	59.63	-59.63	19.63