Microwave Measurements Laboratory

Components and Devices

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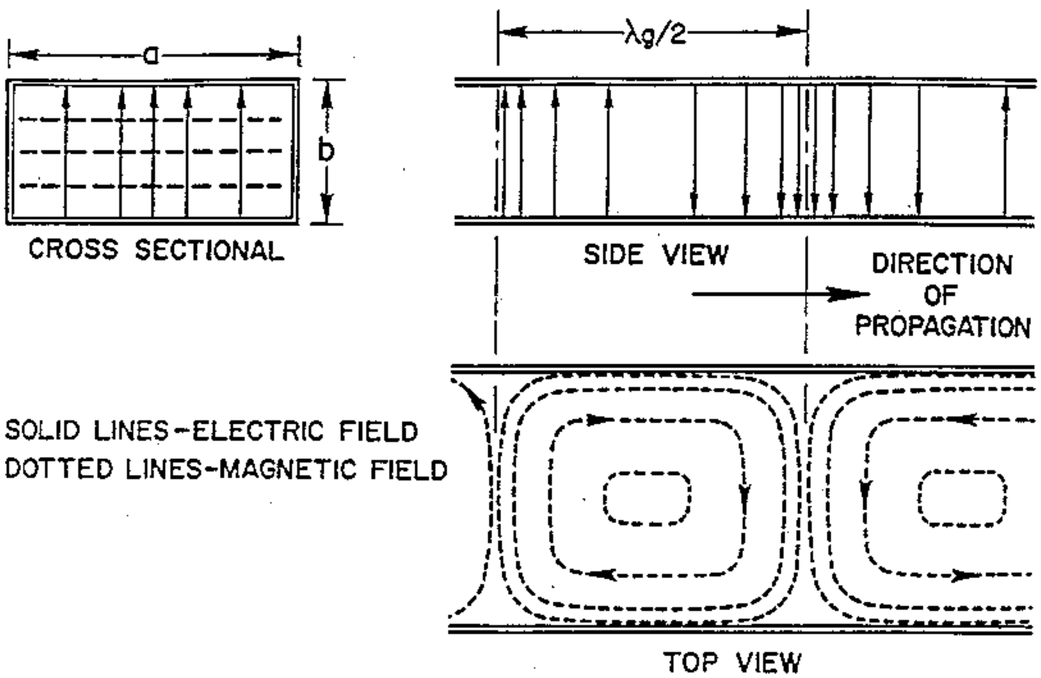
Rectangular Wave Guide



Advantages: **Low Loss, High Power**

Disadvantages: **Narrow bandwidth, bulky at low frequencies**

$$\lambda g = \frac{\lambda}{\sqrt{1 - \left(\frac{\lambda}{\lambda c}\right)^2}}$$

$$\lambda_{C_{TE10}} = 2a$$

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Rectangular Wave Characteristics

EIA Waveguide Designation Standard (RS-261-A)	JAN Waveguide Designation (MIL-HDBK-216, 4 January 1962)	Outer Dimensions and Wall Thickness (in inches)	Frequency Range in Gigahertz for Dominant $(TE_{1,0})$ Mode	Cutoff Wavelength λ_c in Centimeters for $TE_{1,0}$ Mode	Cutoff Frequency f_c in Gigahertz for $TE_{1,0}$ Mode	Theoretical Attenuation, Lowest to Highest Frequency in dB/100 ft	Theoretical Power Rating in Megawatts for Lowest to Highest Frequency*
WR-2300	RG-290/U†	23.250×11.750×0.125	0.32–0.49	116.8	0.256	0.051–0.031	153.0–212.0
WR-2100	RG-291/U†	21.250×10.750×0.125	0.35–0.53	106.7	0.281	0.054–0.034	120.0–173.0
WR-1800	RG-201/U†	18.250×9.250×0.125	0.425–0.620	91.4	0.328	0.056–0.038	93.4–131.9
WR-1500	RG-202/U†	15.250×7.750×0.125	0.49–0.740	76.3	0.393	0.069–0.050	67.6–93.3
WR-1150	RG-203/U†	11.750×6.000×0.125	0.64–0.96	58.4	0.514	0.128–0.075	35.0–53.8
WR-975	RG-204/U†	10.000×5.125×0.125	0.75–1.12	49.6	0.605	0.137–0.095	27.0–38.5
WR-770	RG-205/U†	7.950×4.100×0.125	0.96–1.45	39.1	0.767	0.201–0.136	17.2–24.1
WR-650	RG-69/U	6.660×3.410×0.080	1.12–1.70	33.0	0.908	0.317–0.212	11.9–17.2
WR-510	—	5.260×2.710×0.080	1.45–2.20	25.9	1.16	—	—
WR-430	RG-104/U	4.460×2.310×0.080	1.70–2.60	21.8	1.375	0.588–0.385	5.2–7.5
WR-340	RG-112/U	3.560×1.860×0.080	2.20–3.30	17.3	1.735	0.877–0.572	—
WR-284	RG-48/U	3.000×1.500×0.080	2.60–3.95	14.2	2.08	1.102–0.752	2.2–3.2
WR-229	—	2.418×1.273×0.064	3.30–4.90	11.6	2.59	—	—
WR-187	RG-49/U	2.000×1.000×0.064	3.95–5.85	9.50	3.16	2.08–1.44	1.4–2.0
WR-159	—	1.718×0.923×0.064	4.90–7.05	8.09	3.71	—	—
WR-137	RG-50/U	1.500×0.750×0.064	5.85–8.20	6.98	4.29	2.87–2.30	0.56–0.71
WR-112	RG-51/U	1.250×0.625×0.064	7.05–10.00	5.70	5.26	4.12–3.21	0.35–0.46
WR-90	RG-52/U	1.000×0.500×0.050	8.20–12.40	4.57	6.56	6.45–4.48	0.20–0.29
WR-75	—	0.850×0.475×0.050	10.00–15.00	3.81	7.88	—	—
WR-62	RG-91/U	0.702×0.391×0.040	12.40–18.00	3.16	9.49	9.51–8.31	0.12–0.16
WR-51	—	0.590×0.335×0.040	15.00–22.00	2.59	11.6	—	—
WR-42	RG-53/U	0.500×0.250×0.040	18.00–26.50	2.13	14.1	20.7–14.8	0.043–0.058
WR-34	—	0.420×0.250×0.040	22.00–33.00	1.73	17.3	—	—
WR-28	RG-96/U‡	0.360×0.220×0.040	26.50–40.00	1.42	21.1	21.9–15.0	0.022–0.031

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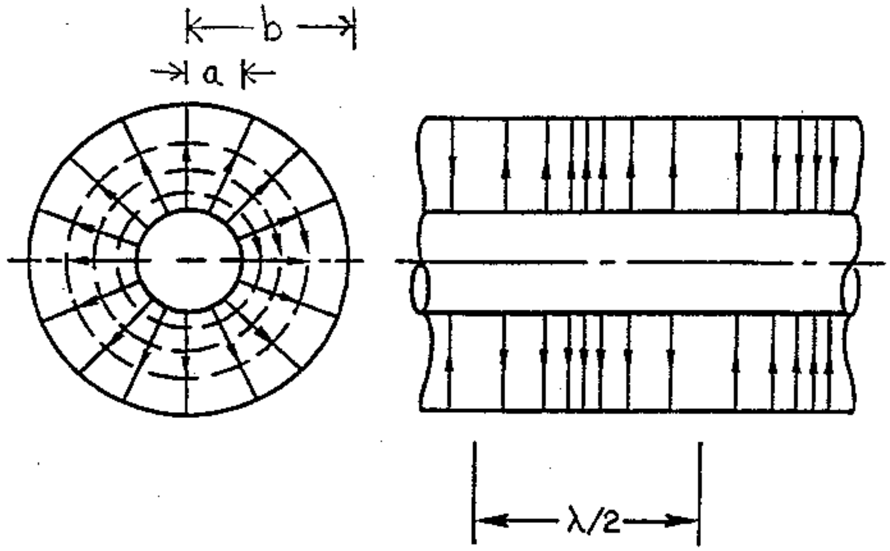
Coaxial Transmission Lines



Advantages: **High Bandwidth, Small size**
Disadvantages: **High loss, low power**

$$Z_o = 60\sqrt{\frac{\mu_r}{\varepsilon_r}}\ln\frac{b}{a}\Omega$$

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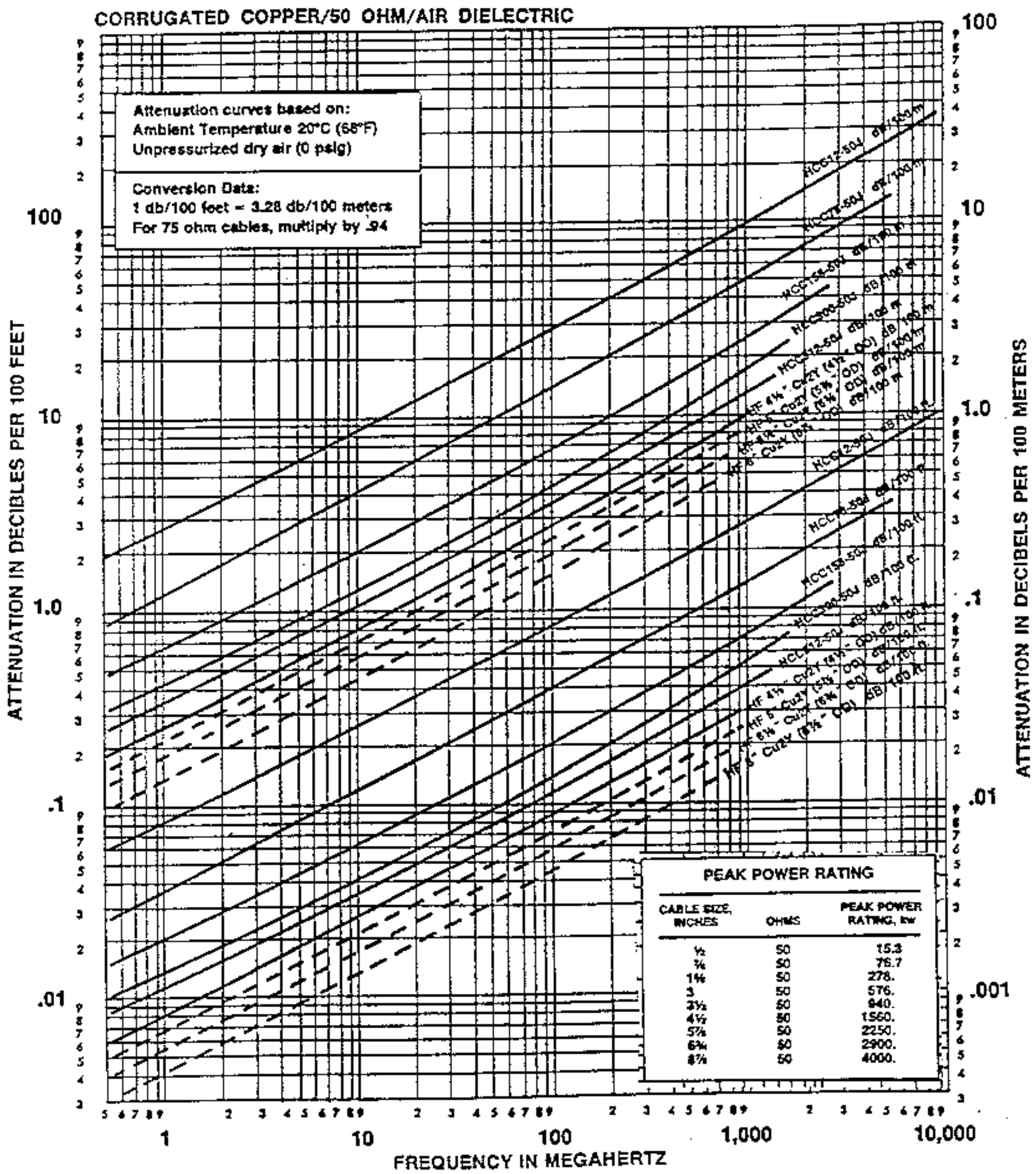
Coax Characteristics

Attenuation **Air Flexwell Cable**



CABLE SIZE, INCHES	OHMS	PEAK POWER RATING, kw
½	50	15.3
⅞	50	76.7
1⅝	50	278.
3	50	576.
3½	50	940.
4½	50	1560.
5⅝	50	2250.
6¾	50	2900.
8¾	50	4000.

Cablewave Systems

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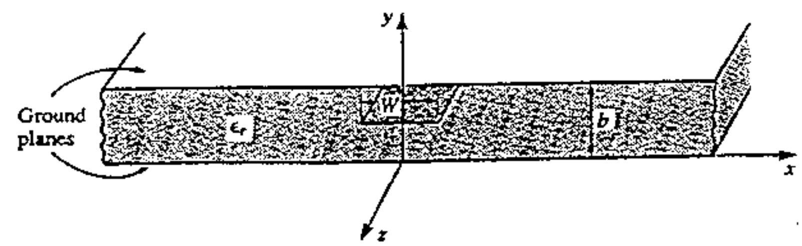
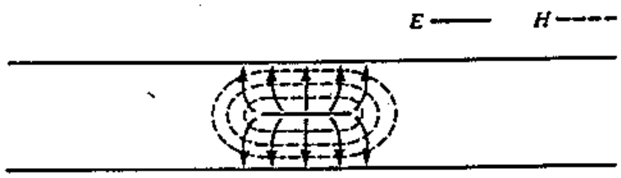
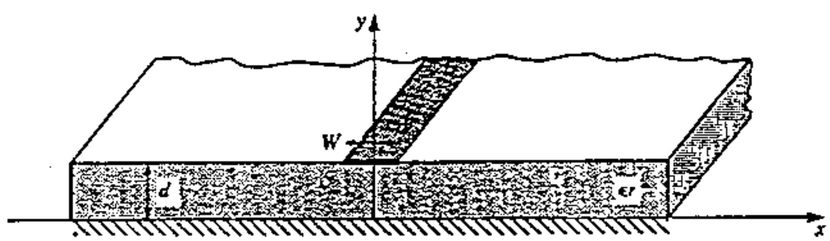
Stripline

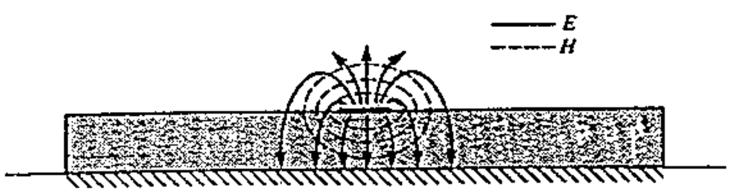




USED FOR
HYBRIDS
COUPLERS
FILTERS

Microstrip





USED FOR
AMPLIFIERS
MIXERS
FILTERS

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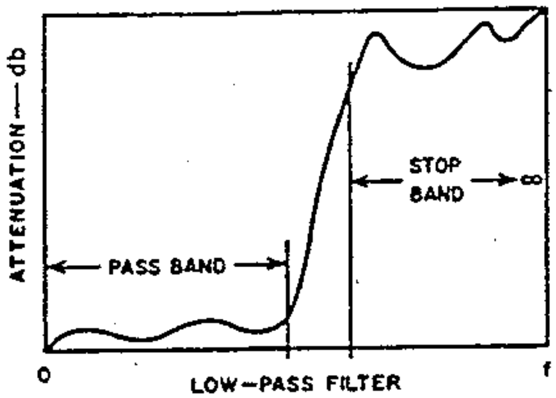
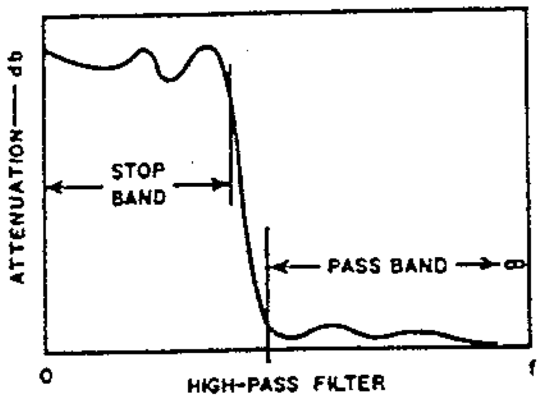
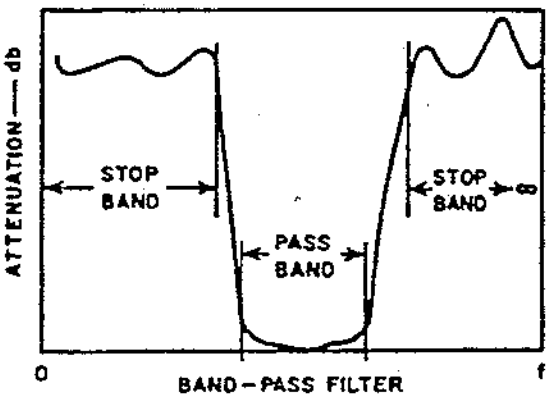
Filters



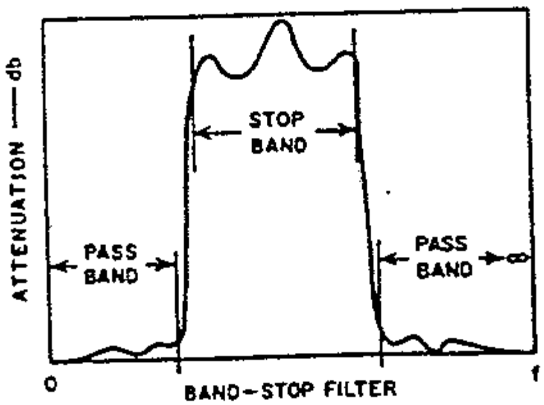
Lowpass



Highpass



Bandpass



Bandstop

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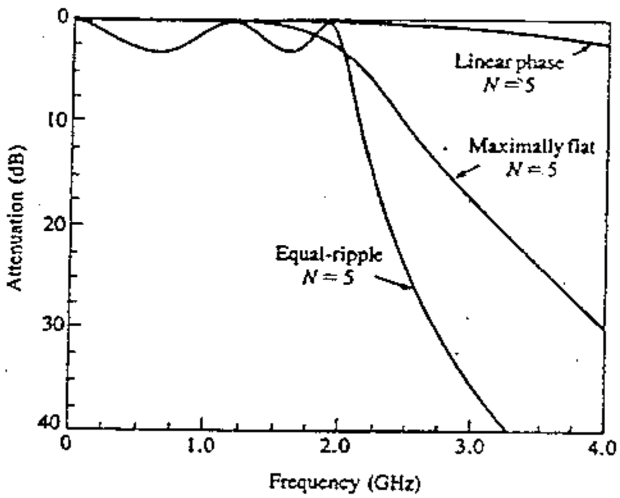
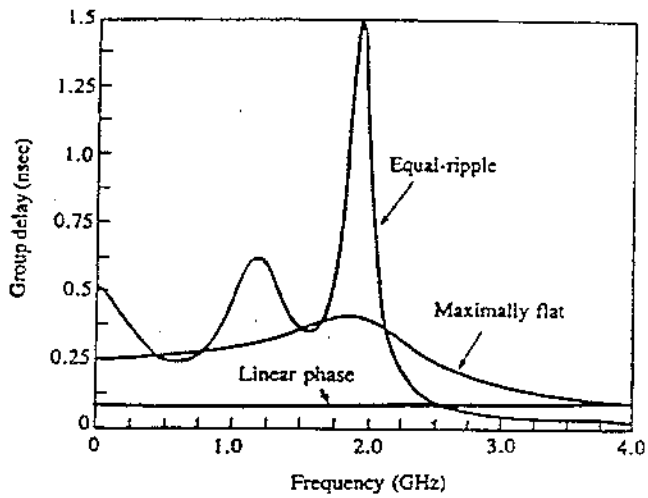
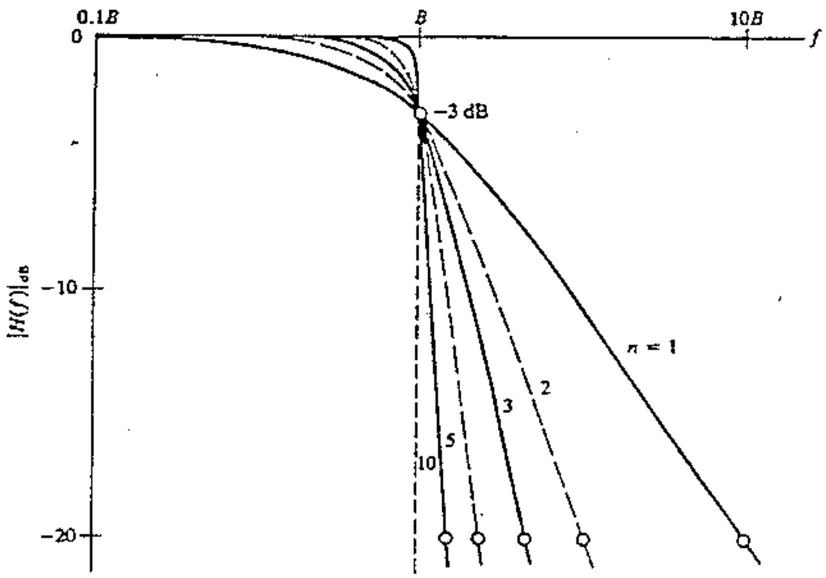
Filters Transfer Functions





Transfer function for Butterworth lowpass filters of order n:



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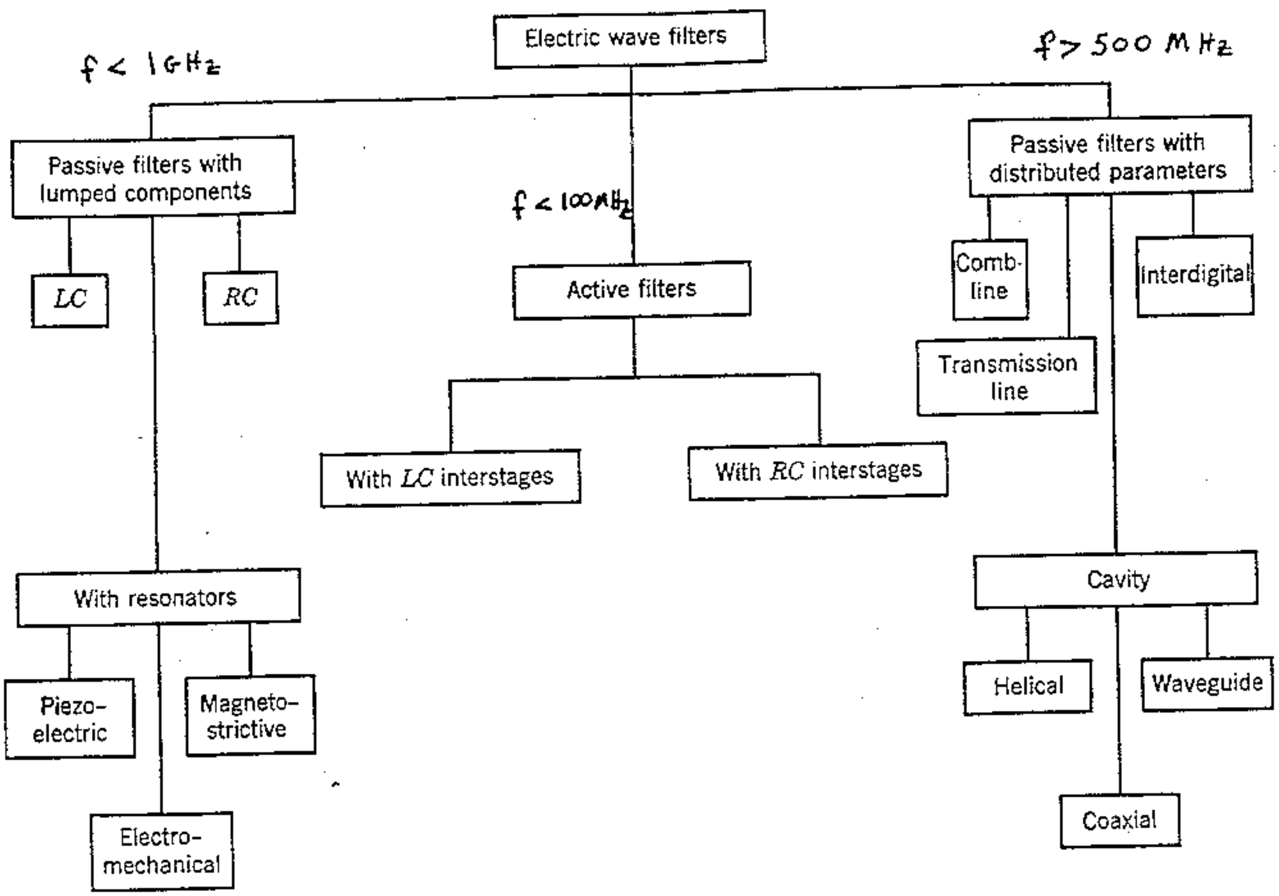
Filter Classifications



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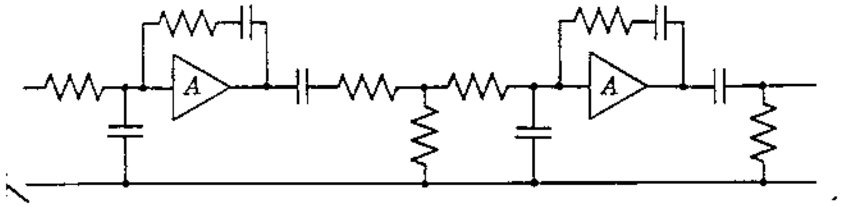
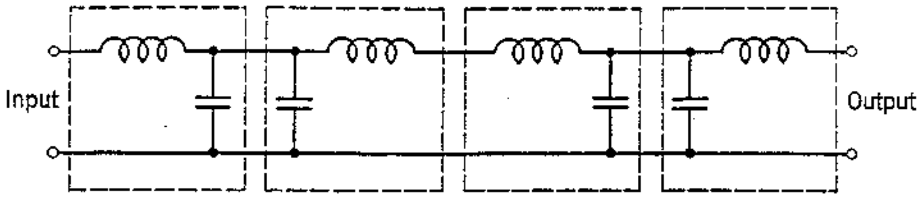
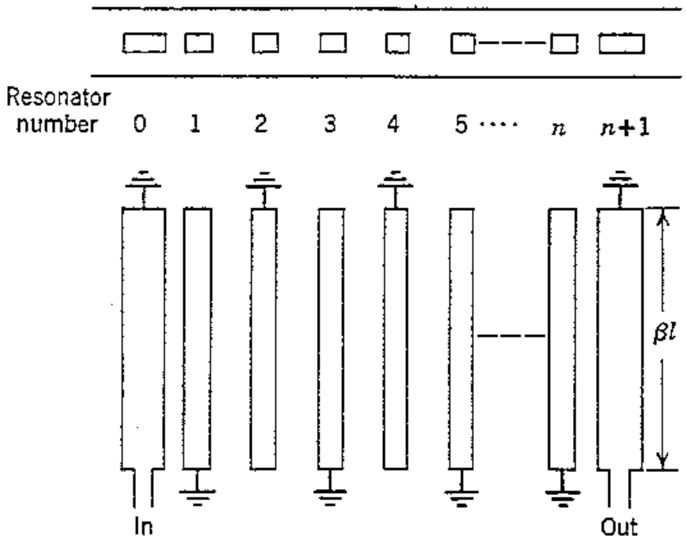
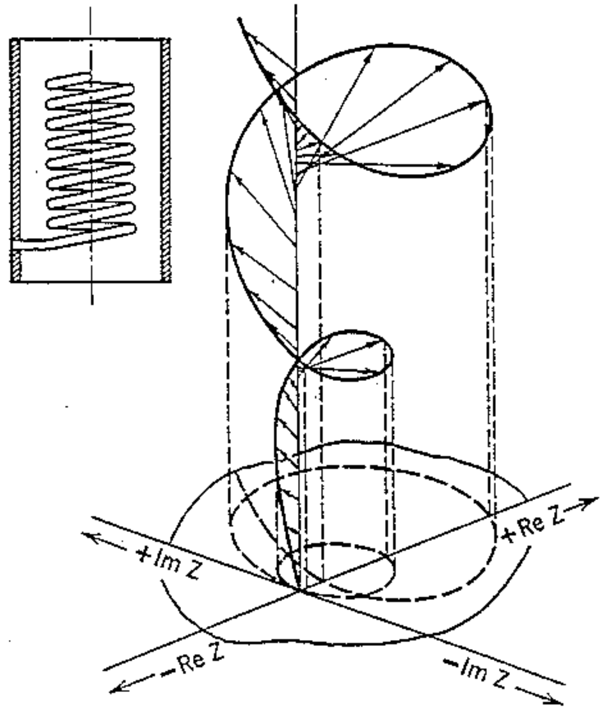
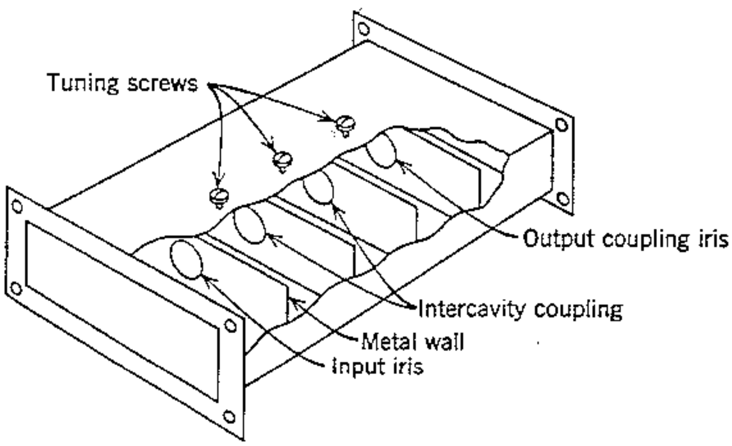
Filter Topologies

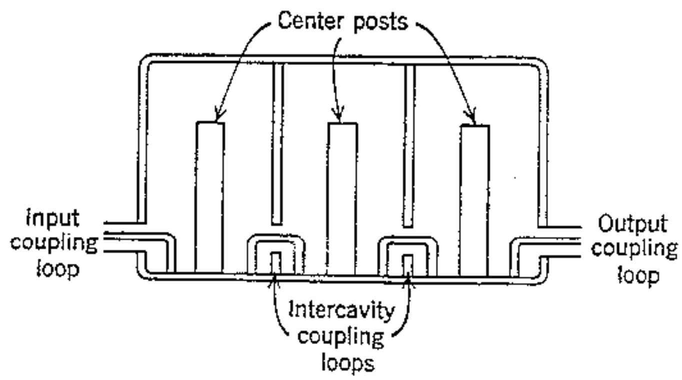












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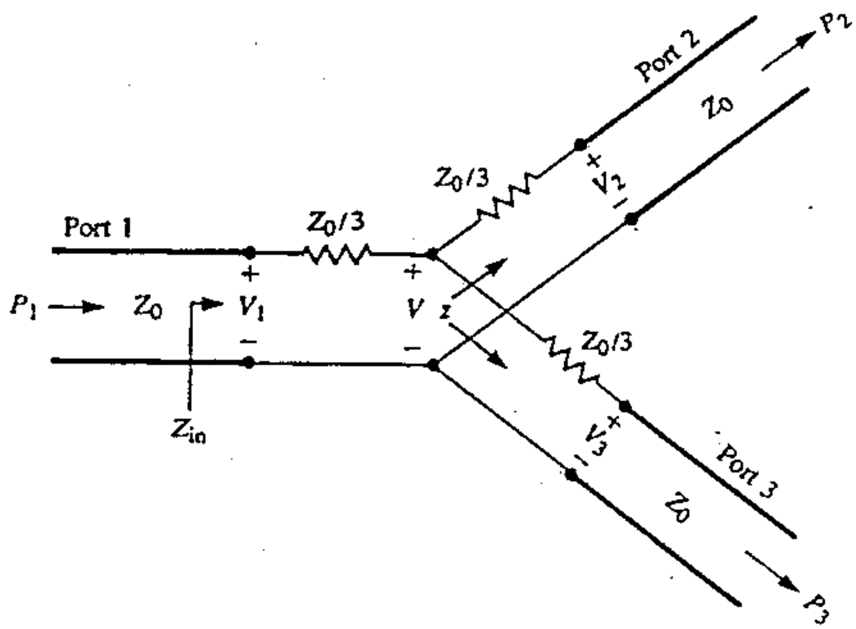
Resistive Power Splitter/Combiner



Advantages: **Multi Octave Broad Band**
Disadvantages: **High Loss, low isolation**

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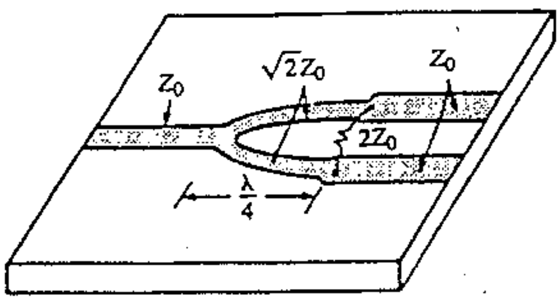
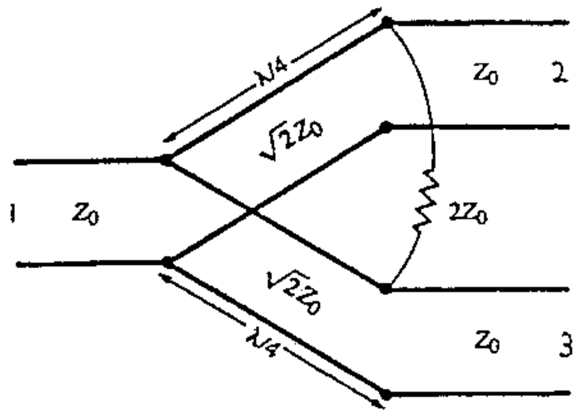
Wilkinson Power Splitter/Combiner





$$\text{S parameters} = \begin{bmatrix} 0 & \frac{-j}{\sqrt{2}} & \frac{-j}{\sqrt{2}} \\ \frac{-j}{\sqrt{2}} & 0 & 0 \\ \frac{-j}{\sqrt{2}} & 0 & 0 \end{bmatrix}$$

Advantages: **All ports matched and isolated, low insertion loss**

Disadvantages: **Octave bandwidths typical**

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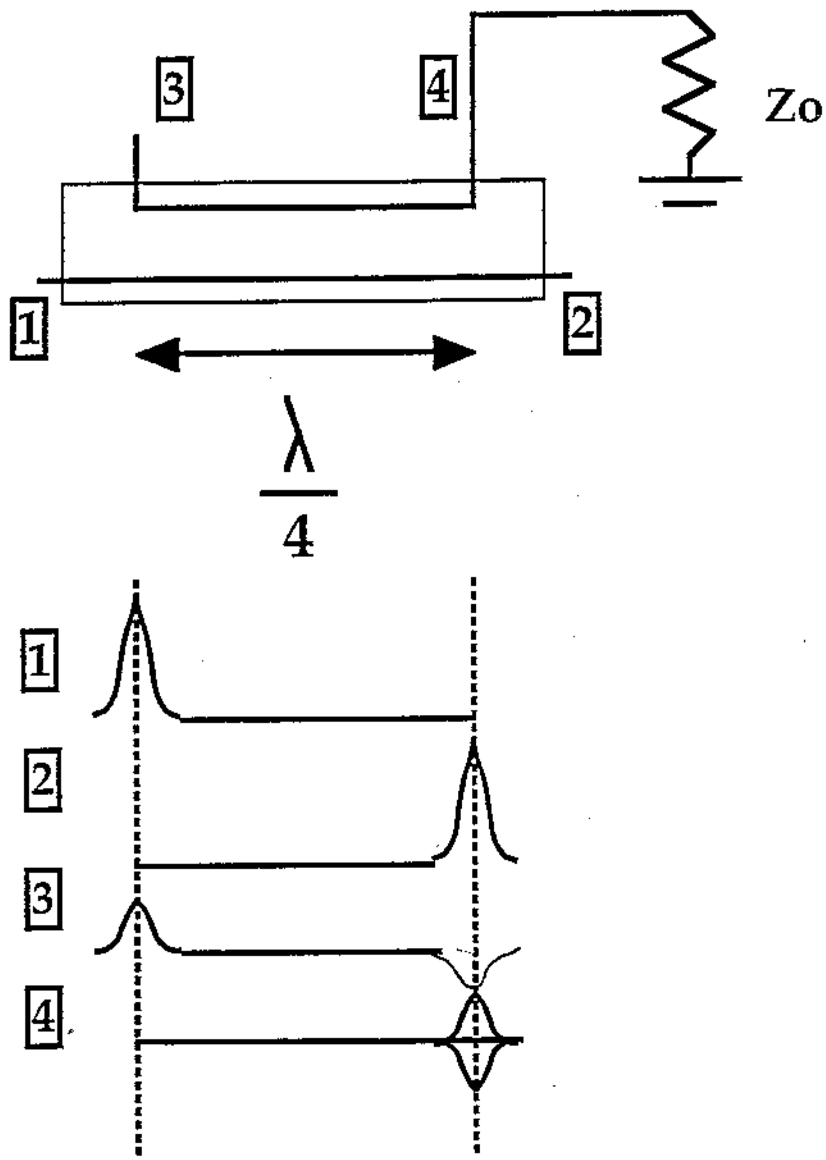
Directional Coupler



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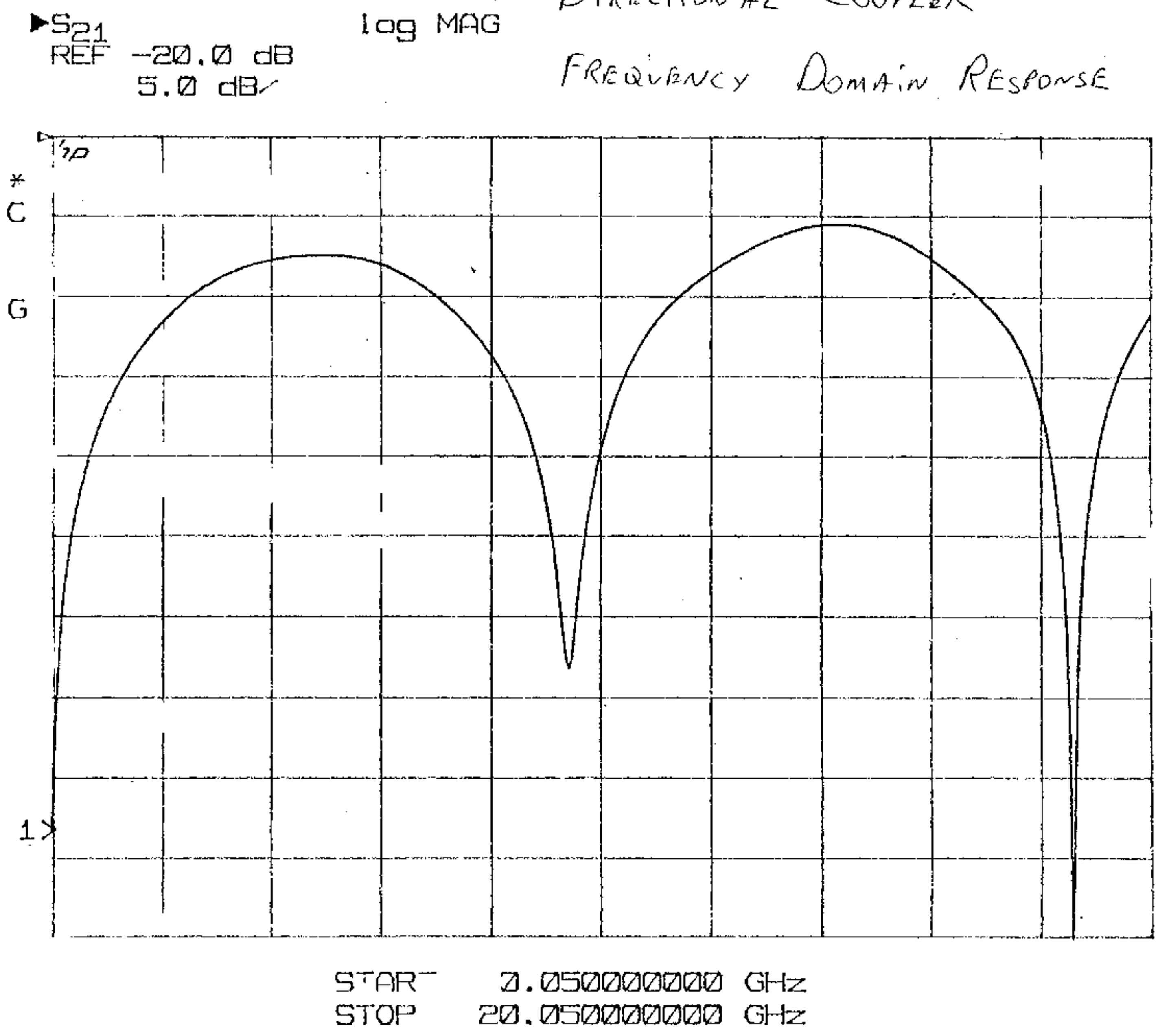
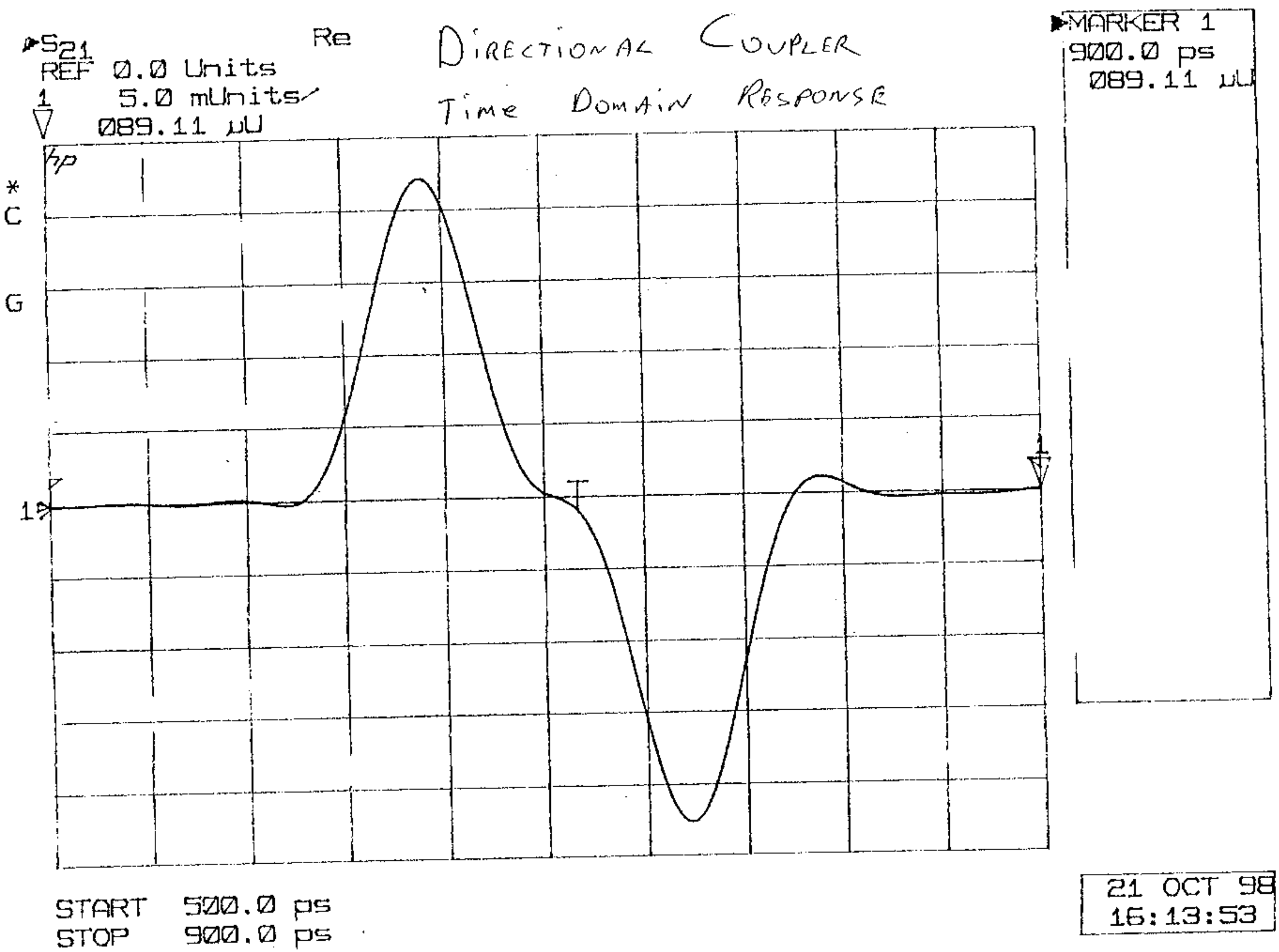
Directional Coupler

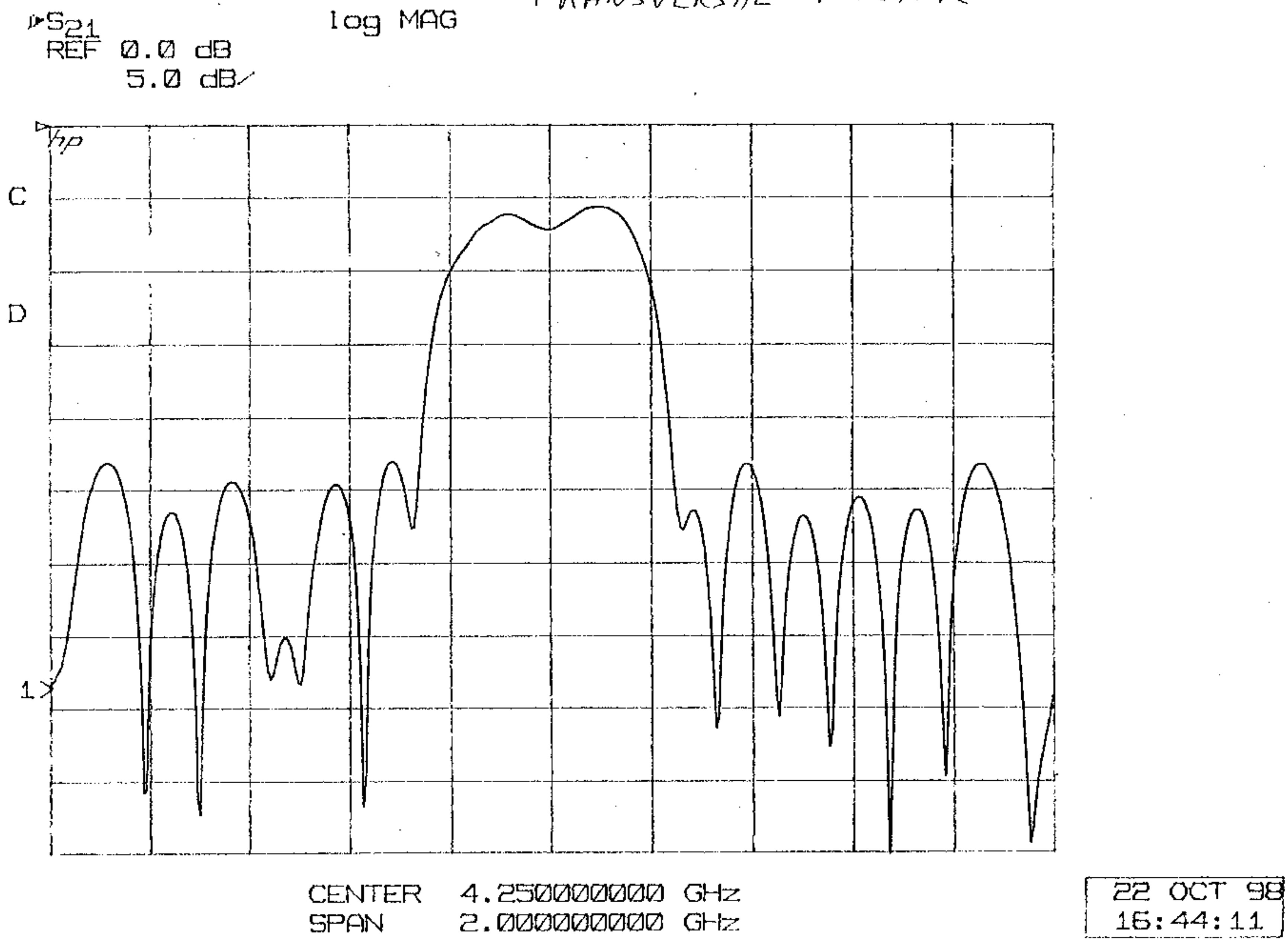
Frequency Domain Response



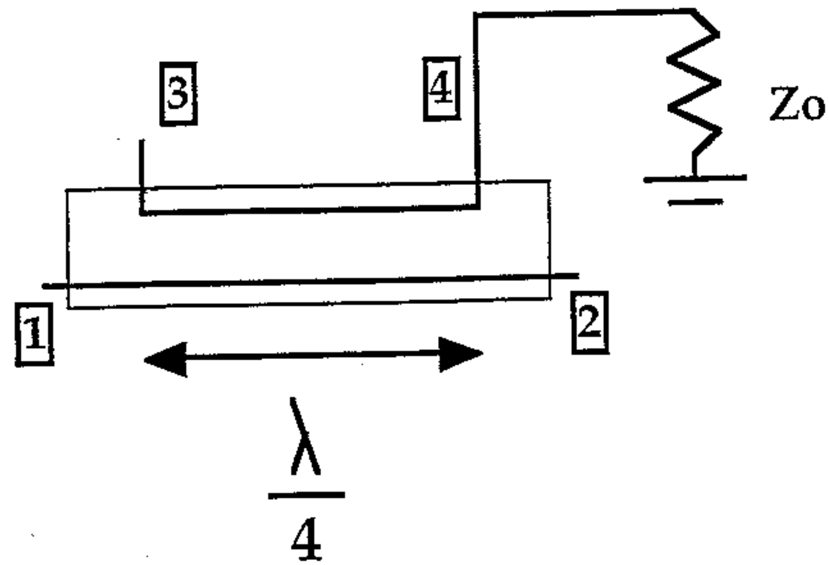
21 OCT 98
16:10:05


S21
Re
REF 0.0 Units
5.0 mUnits/
089.11 µU
Directional Coupler
Time Domain Response
MARKER 1
900.0 ps
089.11 µU
*
C
G
1
START 500.0 ps
STOP 900.0 ps
21 OCT 98
16:13:53

TRANSVERSAL FILTER



Directional Coupler Characteristics



$$CouplingFactor = 10\log \frac{P1}{P3} dB$$

$$Directivity = 10\log \frac{P3}{P4} dB$$

$$Isolation = 10\log \frac{P1}{P4} dB$$

Isolation = Directivity + Coupling factor

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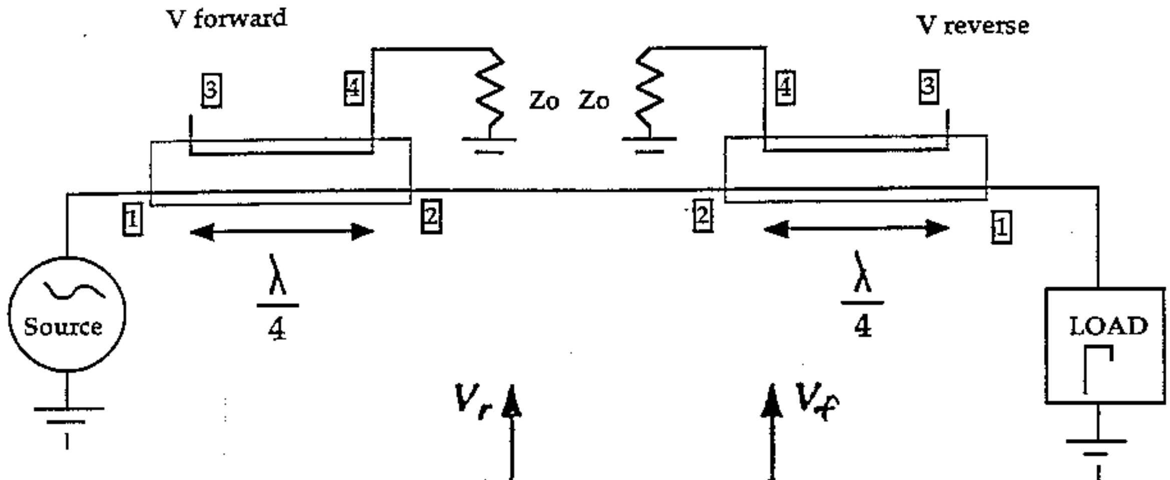
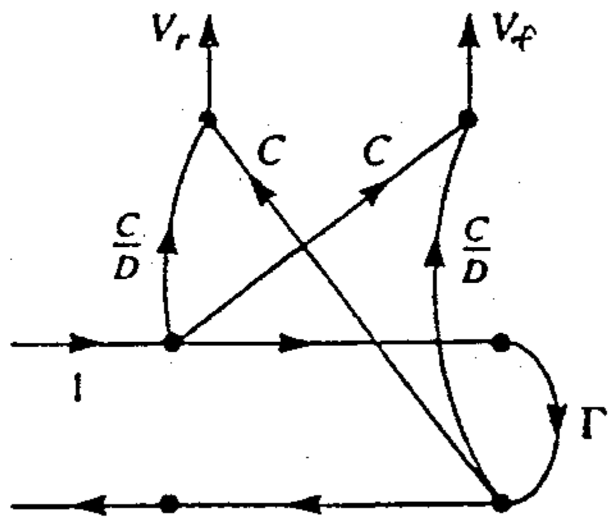
Reflectometer





$$V_f = C\left[1 + \frac{1}{D}\Gamma e^{j\theta}\right]$$

$$V_r = C\left[\Gamma e^{j\phi} + \frac{1}{D}\right]$$

$$\left|\frac{V_r}{V_f}\right|_{\substack{\min \\ \max}} = \frac{|\Gamma| \pm \frac{1}{D}}{1 \pm \frac{|\Gamma|}{D}}$$

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90 Degree Hybrids

STRIPLINE CIRCUIT DESIGN

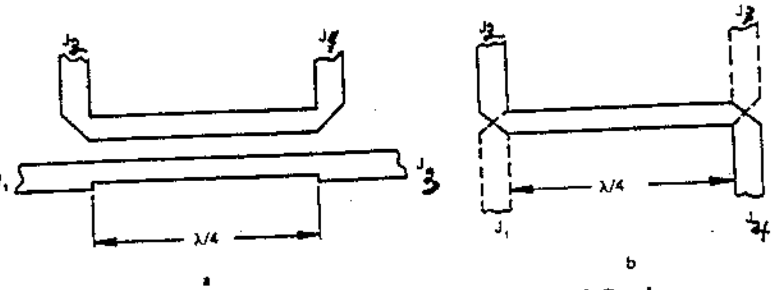


FIG. 5–1 Quarter-Wave Coupled-Line Directional Coupler Configurations

STRIPLINE CIRCUIT DESIGN

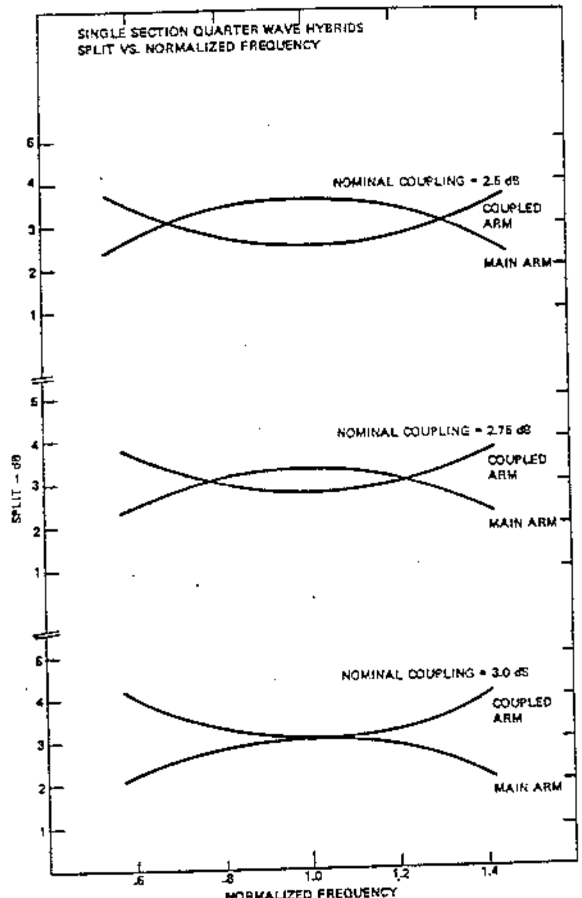
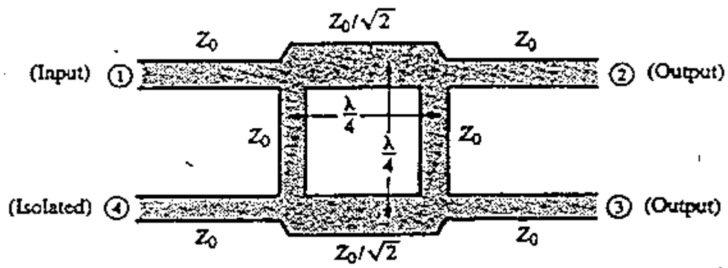


FIG. 5–5 Frequency Response for Several Single-Section Quarter-Wave 3.0 dB Hybrids for Varying Values of Nominal Coupling



$$[S_{90}] = \frac{-1}{\sqrt{2}} \begin{bmatrix} 0 & j & 1 & 0 \\ j & 0 & 0 & 1 \\ 1 & 0 & 0 & j \\ 0 & 1 & j & 0 \end{bmatrix}$$

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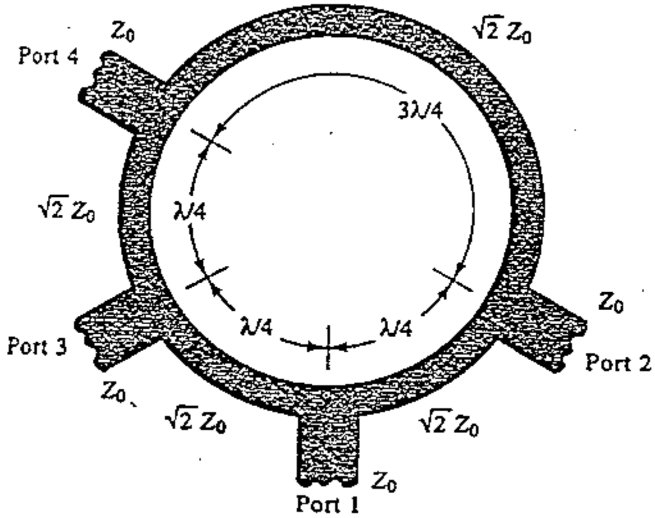
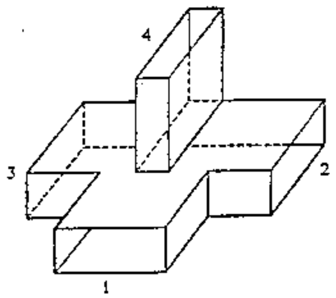
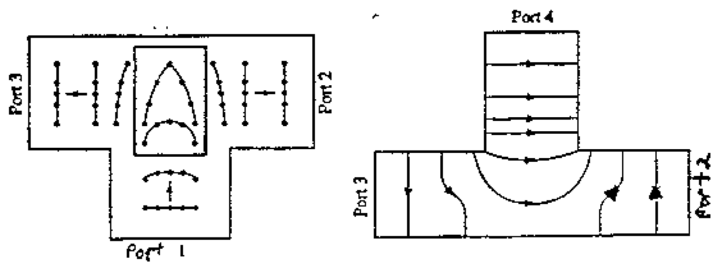
180 Degree Hybrids

Ring Hybrid





Waveguide Magic Tee



$$[S_{180}] = \frac{-j}{\sqrt{2}}\begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

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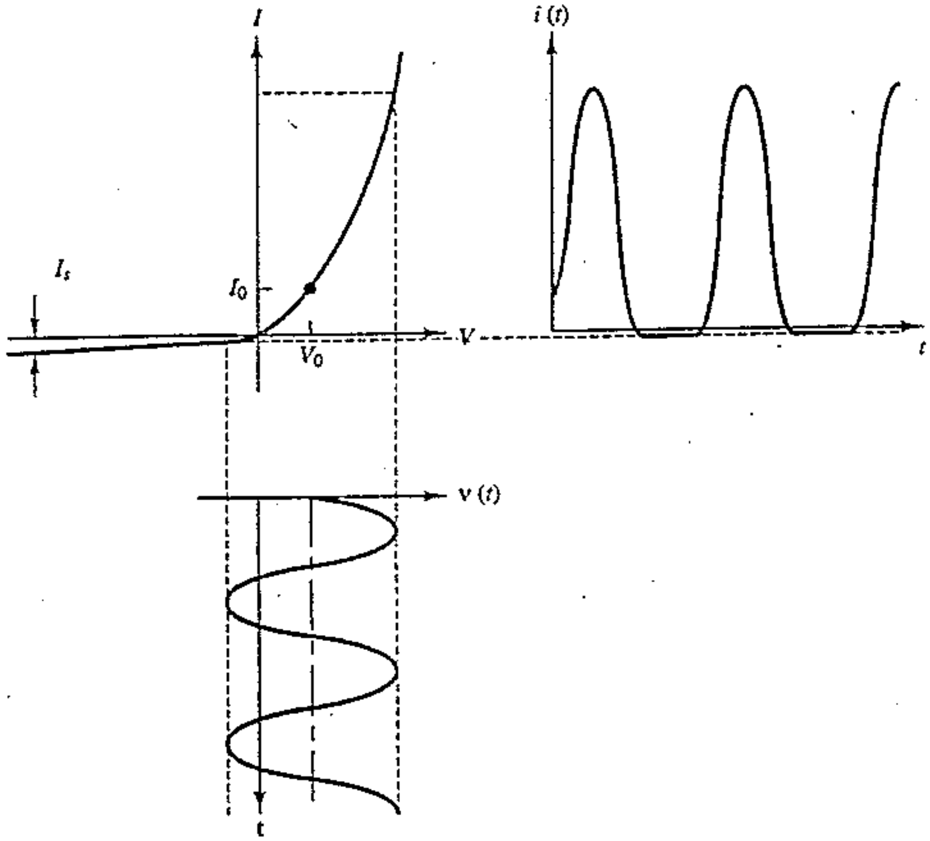
Diode Detectors



Square Law Detectors

$$i = a_o + a_1 v + a_2 v^2 + a_3 v^3 + \ldots$$

if

$$v = A\cos\omega t$$

$$i = a_1(A\cos\omega t) + a_2(A\cos\omega t)^2$$

$$i = a_1(A\cos\omega t) + \frac{a_2 A^2}{2}(1 + \cos 2\omega t)$$

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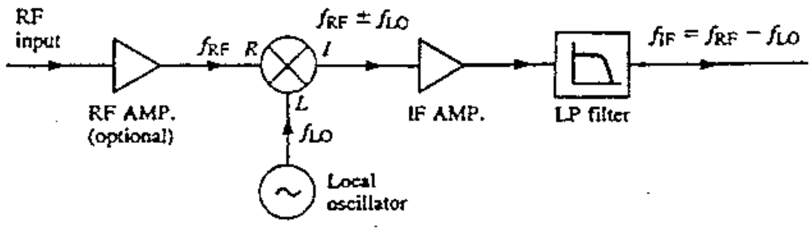
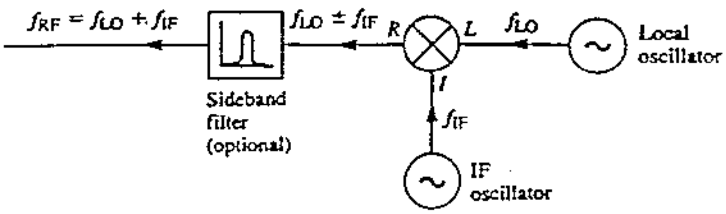
Mixers

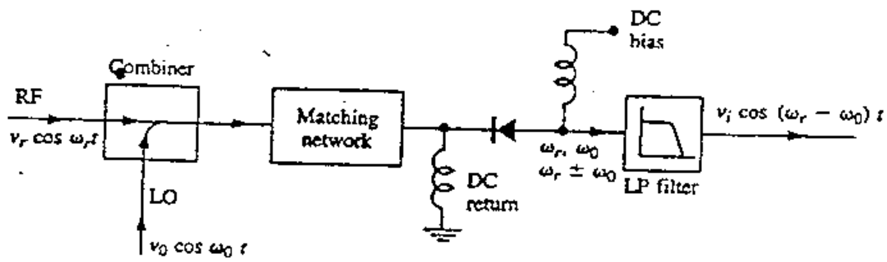
$$V_{out} \approx k\, V_{signal} V_{LO}[\cos(\omega_{LO} - \omega_{signal})t - \cos(\omega_{LO} + \omega_{signal})t]$$



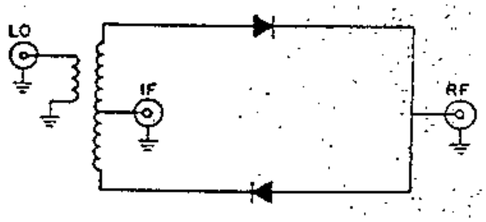
(a)



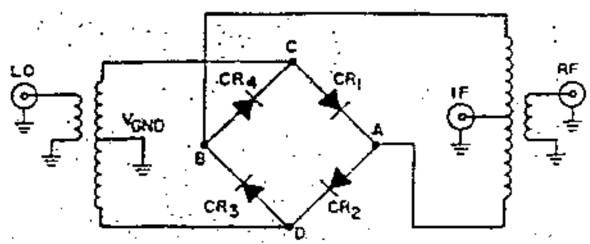
Single-ended
Simple design



Single Balanced
Improved input match
Isolation between RF and LO



Double Balanced
Improved Isolation between all ports
Suppresses even harmonics of RF and LO
Low conversion loss



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Cablewaves Systems, Catalog 600, 1986

Ralph J. Pasquinelli
Fermilab