LOSSY, HYBRID COUPLED AMPLITUDE EQUALIZERS FOR NARROW BAND FILTERS

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ABSTRACT

The growing use of contiguous channel switched filter banks in applications such as signal identification has exposed a difficulty inherent to the use of the low Q filters which are incorporated into such assemblies.

The physically small filters which must be used possess low values of unloaded Q. This means that their passband characteristics are quite concave. Typical filters in the 1 GHz area with ripple bandwidths of 20 MHz might display actual 1 dB bandwidths of only three-quarters the ripple bandwidth, with 6 dB or more relative attenuation at the ripple band edges.

In signal identification applications, it is required that the network provide adequate amplitude discrimination between signals. This implies the use of many channels overlapping at points well inside their nominal ripple bandwidths. The resultant assemblies are excessively complex because of the required increase in number of filters and the associated switching complexity.

We propose the use of lossy, partially reflective equalizers in series with the filters that will provide amplitude responses complimentary to the filters in question. Because many of these applications are at frequencies where gain and noise figure are relatively cheap, the additional insertion loss added by the equalizer does not hurt. Thus, this complimentary loss function results in reduction of filter count and switching matrix complexity. Low VSWR is assured due to the quadrature hybrid symmetry and so the filter rejection characteristics are not affected. Determination of whether a signal is in one passband or another is accomplished by comparison of output levels from channels with flat amplitude characteristics. A larger output from one channel signifies the presence of a signal, without the ambiguity caused by the unequalized amplitude changes across the channel bandwidth. A design example will be presented in which equalizers are used to reduce the filter count from 14 to 10.

SECTION I. DESCRIPTION OF PROBLEM

A typical switched filter assembly is illustrated schematically in Figure 1. As shown, the filters consist of small lumped element or evanescent structures. The filters are integrated into the switch matrix as "drop-in" elements.

The total filter bank passband might be as narrow as 15% or 20% of the system center frequency with the filter bank splitting this bandwidth into as many segments as required to provide signal identification. Unequalized, as many as 14 filters might be required to provide the passband flatness necessary for signal identification.

A design parameter which comes into consideration is the requirement for providing a sufficiently large stopband to passband ratio. A typical filter will provide a 50 dB to passband ratio of not more than 2:1. To accomplish this, a typical filter will be of order 8, with a low-ripple Chebychev design.

The filters are also required to be rather close to the strobing switch ports to prevent parasitic length resonances from coming into play. Therefore, small "drop-in" filters are used. Small filters are realized through the use of lumped element or evanescent mode construction.

Figure 2 portrays insertion loss and return loss for 3 adjacent unequalized channels. It can be seen that the return loss characteristics are contiguous but that the amplitude response characteristics cross over at the 7 dB points. Thus, a difference in signal of 7 dB exists between the center of a given channel and its nominal edge. This limits the dynamic range over which it can be determined that a signal is or is not in the passband. To alleviate this problem, the solution of Section II is employed.

SECTION II. SOLUTION

The fundamental approach is illustrated in Figure 3. Here, a pair of lossy partially reflecting stubs are combined with a quadrature hybrid to provide

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symmetrical reflections which are complimentary to the filter amplitude response.

Lossy band reject filters havellong been used as amplitude equalizers for broadband TWT amplifiers. The elements for such equalizers are typically very low Q, thus providing a broadband, low VSWR absorptive notch. When this scheme is attempted on a narrow band basis, the required element Q values and consequent reflection coefficients are greater and it becomes impossible to provide a "through" patch with low VSWR.

The well known port match properties of a quadrature hybrid can be used to provide good input VSWR by ensuring that symmetrical reflections are excluded from the input port due to the phase addition and cancellation within the hybrid. If the stubs are fabricated as high Q elements (i.e. lossless) the depth of the notch would be too great to provide the required complimentary function. In Figure 3, a pair of lossy elements are connected directly to the quadrature hybrid and then to the filter. Each lossy element is in shunt with a path terminated in a short circuit to provide a 2-way pass through the equalizer, providing the almost unity reflection coefficient desirable near the passband edges. Through this means, the stub-hybrid reflections are maximum near the band edges and minimum at band center but with maximum absorption at band center - essentially complimentary to the filter amplitude response.

Figure 7 illustrates a typical notch depth resultant from a stub impedance of 200 ohms and Q = 200. A stub of this type is fabricated in microstrip without needing lossy material or in suspended substrate using a thin coating of loss material epoxied along the length of the stub. Various circuits and (Z - Q) stub combinations are used, depending upon the level of equalization required. One of the most useful circuits has been found to be that of Figure 5 which can be derived from Figure 3 directly using standard transformations. (See Appendix.) It can be shown that a variety of notch depths and bandwidths can be provided.

In Figure 4, a lossless half-wave stub is terminated with a real resistor. This circuit is easier to adjust than the lossy element stubs because there are a greater variety of resistor values available than there are of loss constants for lossy elements.

The capacitively coupled circuit of Figure 5 can also be modified to include a real resistor termination connected to ground rather than a lossy short circuited element.

Figure 6 illustrates a composite response resulting from use of a narrow band equalizer in conjunction with a narrow band lossy filter.

A typical design example follows:
It is required to split the band 900-1100 MHz up into segments with each filtered portion providing not less than 50 dB relative attenuation 30 MHz below its upper 1 dB point and above its lower 1 dB point. A "1 dB point" is the 1 dB attenuation frequency relative to the center frequency loss. The presence of a signal in each channel is evaluated over the 1 dB bandwidth. A signal more than 1 dB down could be considered as present in another channel. The 50 dB/ripple bandwidth shape factor is about 2:1 which corresponds to an 8th order low-ripple design. For unloaded Q values of 500, the design results are tabulated below:

<u>Channel Type:</u> <u>Unequalized</u>
Midband Loss (dB): 5
Ripple BW (MHz): 20
Relative 1 dB BW (MHz): 14.5
No. Channels Required for /dB cross-over:

$$\frac{200}{14.5} = 13.8$$

so 14 required

<u>Channel Type:</u> <u>Equalized</u>
(Using Equalizer Response of Figure **6**)
Midband Loss (dB): 7.3
Ripple BW (MHz): 20
Relative 1 dB BW (MHz): 20
No. Channels Required for /dB cross-over:

10 required

TABLE I

DIVISION OF 200 MHz BAND CENTERED AT 1 GHz

A typical hybrid equalizer is shown in the photograph of Figure **8** . In this case case, the quadrature hybrid is a conventional stripline package while the equalizer stubs are in microstrip. A terminating chip resistor and overlap capacitor are used a la Figure 5 and text of Section II. The "drop-in" filter used with the equalizer is also shown in the photo. This filter is an 8-pole evanescent mode device with a ripple bandwidth of 20 MHz. Adjustment of the equalizer proceeds by trimming the terminating resistor. The circuit is relatively insensitive to grounding resistance but the ground should be accomplished using "plated through" holes to minimize the parasitic inductance. This inductance has the effect of increasing the effective length of the stub and down-shifting its center frequency.

SECTION III. CONCLUSION

The approach which we have described has been used successfully to equalize the amplitude characteristics of narrow band "drop-in" filters.

There may be other classes of narrow band devices which suffer from the same low Q resonance characteristics as the filters under consideration. It is possible that the partially reflecting, partially absorptive, hybrid coupled equalizers may find application in these cases because there are a wide variety of fabrication methods which can be employed to realize lossy stubs. It is straight forward to build such equalizers in virtually any TEM, hybrid or waveguide transmission line. Of particular interest might be equalization of narrow band waveguide filters.

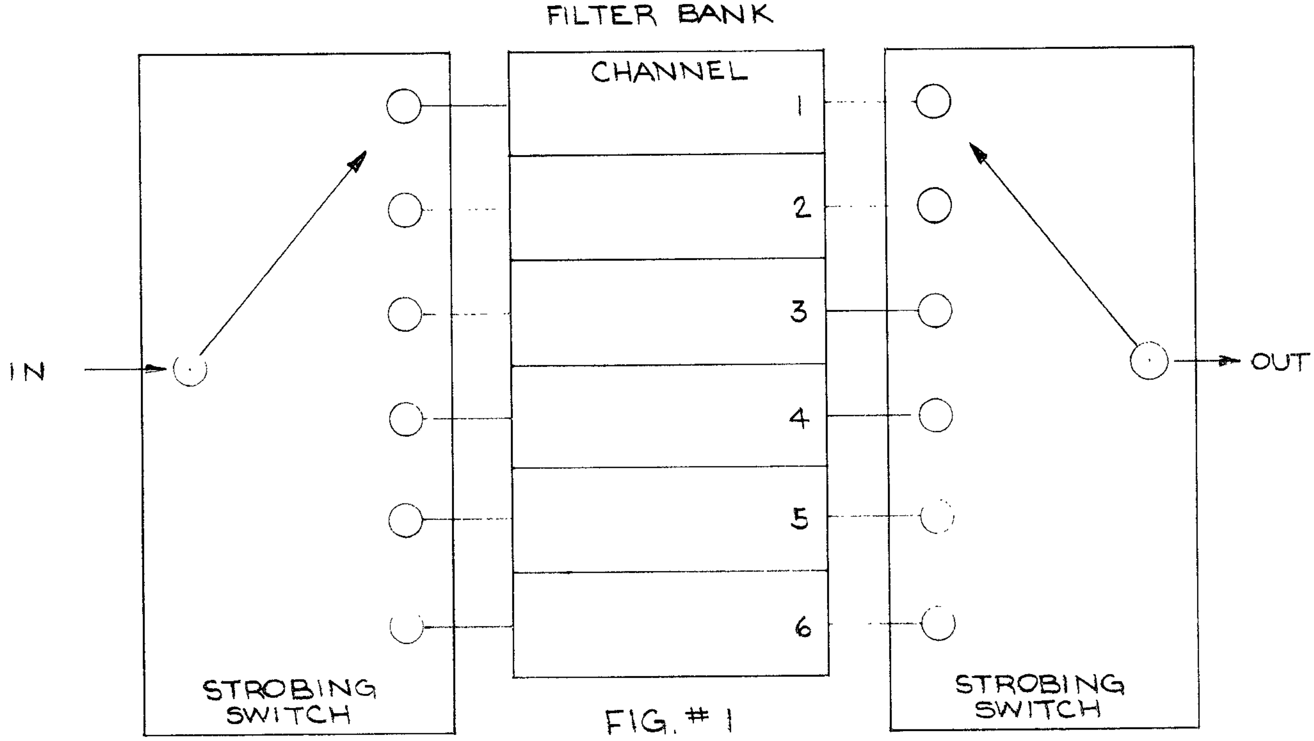

FIG. # 1
SWITCHED FILTER ASSEMBLY

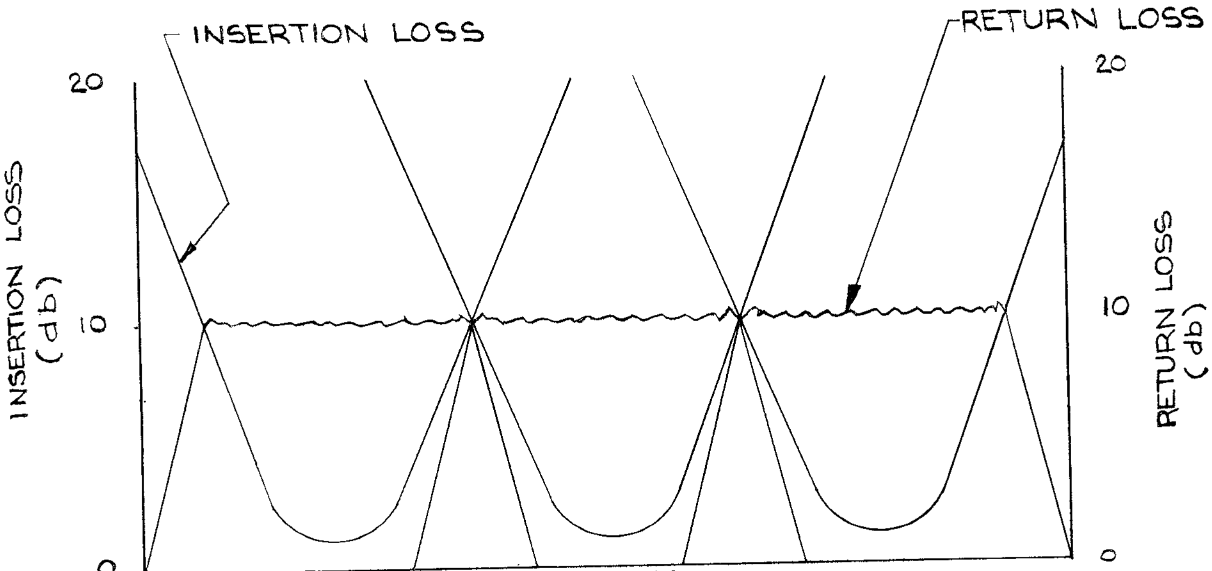

FIG. #2
RETURN LOSS AND AMPLITUDE OF CHANNELS WITHOUT EQUALIZATION

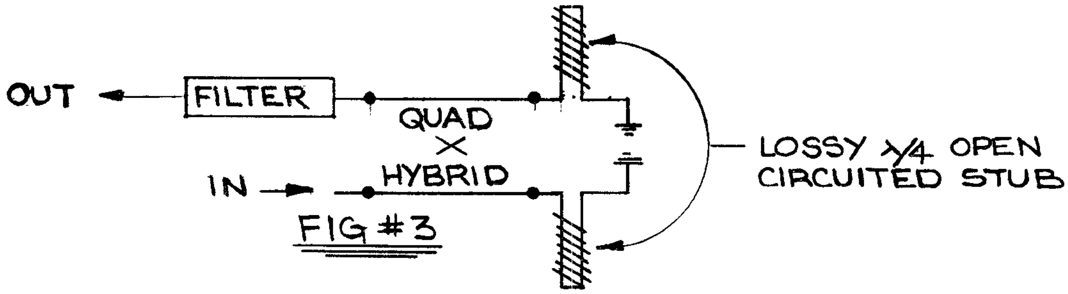

FIG #3

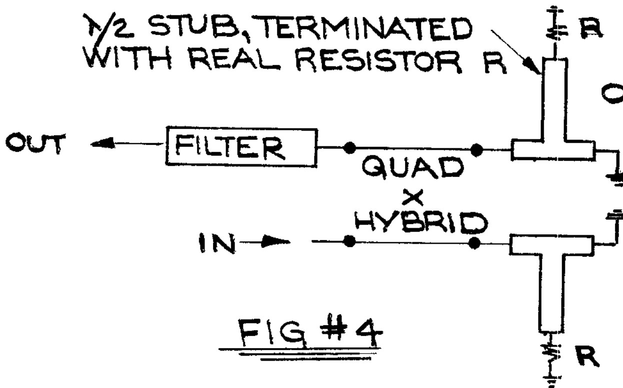

FIG #4

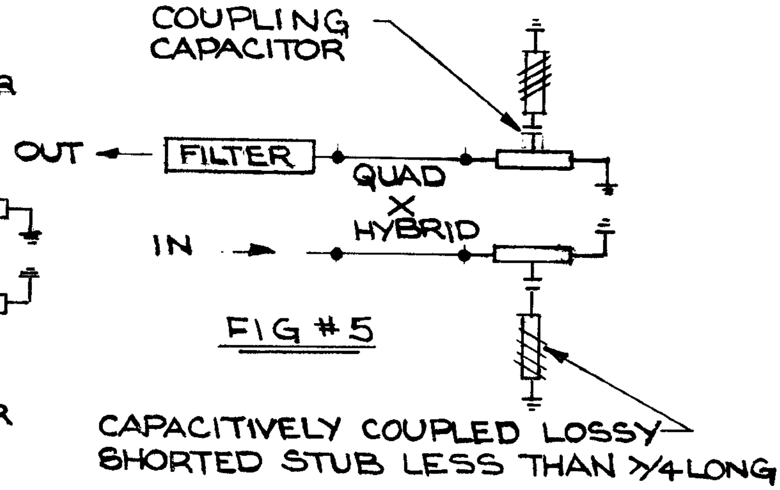

FIG #5

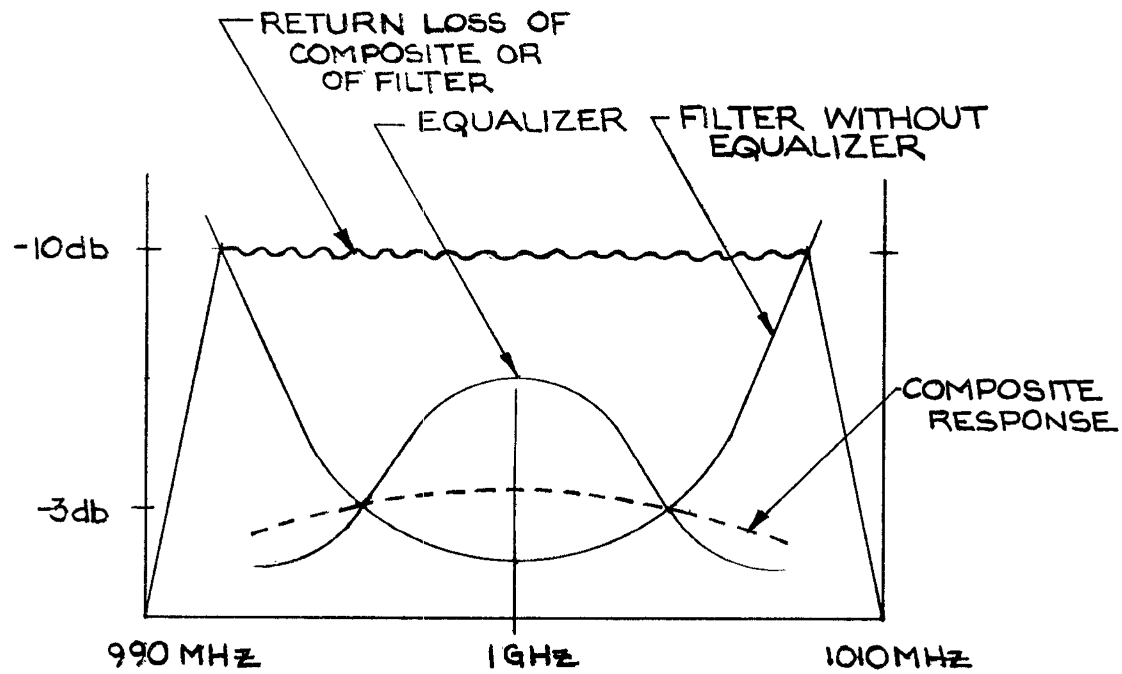

FIG. 6

NARROW BAND LOSSY
USE OF EQUALIZER WITH FILTER

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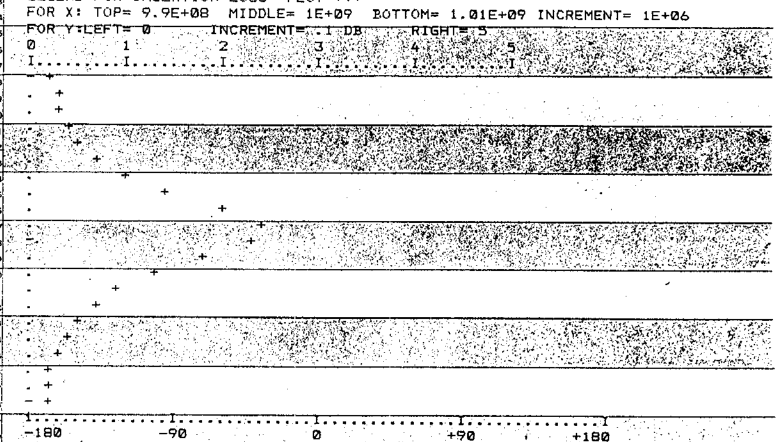
NARROWBAND HYBRID COPLED EQUALIZER WITHOUT MATCHING STUBS; Q=200 AT 1 GHZ.

	RL	50
1	PTL	Z0= 200 LENGTH= 7.5 VELOCITY= 1
2	TR	1E+09
0		200
	RS	.25

FREQUENCY (HZ)	INSERTION LOSS (DB)	ANGLE	RETURN LOSS (DB)	ANGLE	INPUT IMPEDANCE REAL	+J(REACT)
9.9000E+08	-0.21	+4.4	-0.45	+170.9	0.93	-2.83
9.9100E+08	-0.26	+4.9	-0.54	+170.0	0.90	-2.53
9.9200E+08	-0.32	+5.4	-0.66	+168.8	0.87	-2.22
9.9300E+08	-0.41	+5.9	-0.83	+167.5	0.85	-1.92
9.9400E+08	-0.54	+6.6	-1.07	+166.0	0.82	-1.62
9.9500E+08	-0.74	+7.3	-1.45	+164.1	0.81	-1.31
9.9600E+08	-1.03	+7.8	-2.05	+162.3	0.79	-1.01
9.9700E+08	-1.45	+7.7	-3.02	+161.4	0.78	-0.70
9.9800E+08	-1.97	+6.0	-4.44	+164.1	0.78	-0.40
9.9900E+08	-2.36	+1.7	-5.72	+175.1	0.77	-0.09
1.0000E+09	-2.26	+356.4	-5.35	-169.7	0.77	0.21
1.0010E+09	-1.77	+353.1	-3.85	-162.4	0.78	0.52
1.0020E+09	-1.27	+352.2	-2.60	-161.6	0.79	0.82
1.0030E+09	-0.90	+352.4	-1.79	-163.1	0.80	1.12
1.0040E+09	-0.65	+353.0	-1.29	-164.9	0.82	1.43
1.0050E+09	-0.49	+353.7	-0.97	-166.6	0.84	1.73
1.0060E+09	-0.38	+354.3	-0.76	-168.1	0.87	2.03
1.0070E+09	-0.30	+354.9	-0.61	-169.3	0.89	2.34
1.0080E+09	-0.24	+355.3	-0.51	-170.3	0.93	2.64
1.0090E+09	-0.20	+355.7	-0.43	-171.2	0.96	2.94
1.0100E+09	-0.16	+356.1	-0.38	-171.9	1.00	3.24

R. SNYDER 12/01/83
NARROWBAND HYBRID COPLED EQUALIZER WITHOUT MATCHING STUBS; Q=200 AT 1 GHZ.
LEGEND FOR INSERTION LOSS PLOT +++
FOR X: TOP= 9.9E+08 MIDDLE= 1E+09 BOTTOM= 1.01E+09 INCREMENT= 1E+06
FOR Y: LEFT= 0 INCREMENT= .1 DB RIGHT= .5



LEGEND FOR PHASE ANGLE PLOT ***

FIG. 7

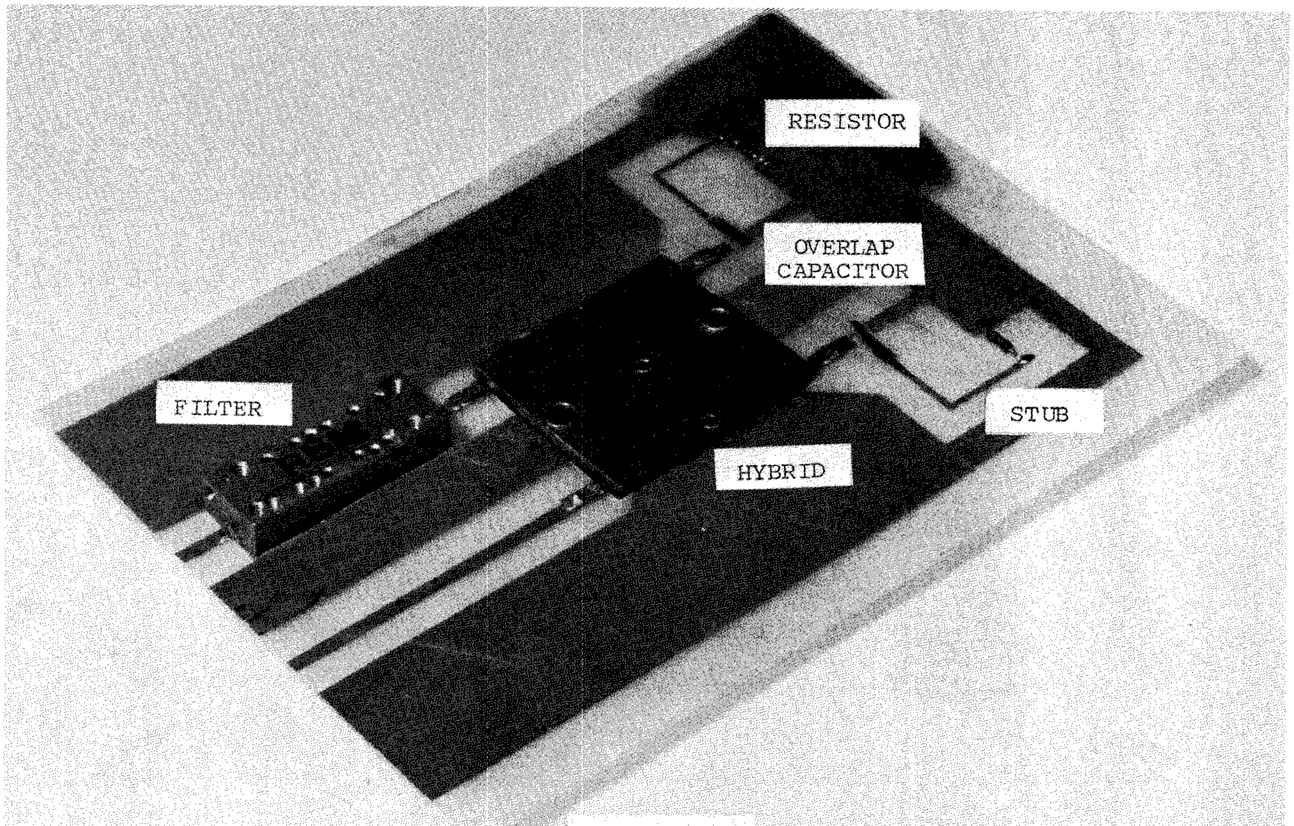
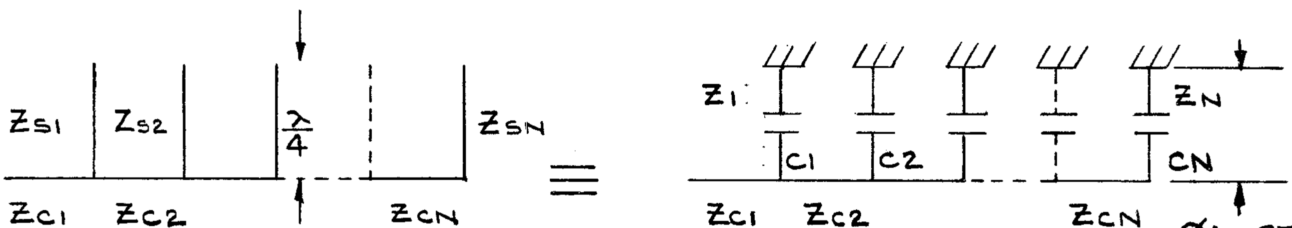


FIGURE 8



ØL = STUB LENGTH NOT INCL. CAPACITOR

RESONATOR SLOPE PARAMETER $= X_{Ji} = \frac{\pi}{4} Z_{si}$

RESONATOR SLOPE PARAMETER $= X_{Ji}$

APPENDIX:

EQUIVALENCE OF λ/4 OPEN CIRCUIT (O.C.) STUB FILTER TO SHORT CIRCUITED, CAPACITIVELY COUPLED STUB FILTER WITH EQUIVALENCE STUB LENGTH PLUS CAPACITOR PHASE SHIFT TOTALING λ/4

SEE EQS. (1) - (4)

(1) $X_{Ji} = \frac{\pi}{4} Z_{si}$

(2) $F(\phi_i) = \phi_i \sec^2 \phi_i + \tan \phi_i$

(3) $F(\phi_i) = \frac{2X_{Ji}}{Z_i}$

(4) $\omega_0 C_i = \frac{1}{Z_i \tan \phi_i}$