COMPACT HIGH POWER WIDE BAND COUPLER

H. F. Chapell

Sage Laboratories, Inc., Natick, Massachusetts

ABSTRACT

A technique is given to realize compact, broadband, high power TEM couplers. The basic approach is the summing of more than one signal to correct the 6 dB per octave slope of short TEM couplers.

INTRODUCTION

TEM coupled lines provide good high power couplers because of their freedom from intermodulation distortion and low losses. However, at low frequencies, a standard quarter wavelength long coupler is large. A short section of coupled line can be used, but it will have a 6 dB per octave coupling slope.

Prior methods, which use reactive shunt capacitance or series reactance to flatten the response, usually suffer from high coupled port VSWR and relatively high power termination dissipation at the high end of the leveled frequency band. Low coupling values are particularly difficult to achieve. For example, a short coupler giving 16 dB coupling at 100 MHz, would be about 10 dB at 200 MHz with a coupling loss of 0.5 dB and a probable coupling of approximately 20 dB after levelling. A flat 10 dB coupler would be out of the question.

This presentation describes another technique to flatten the normal 6 dB per octave amplitude response of short TEM mode couplers. The coupled port is impedance matched, and the thru path insertion loss can be limited to coupling loss and normal transmission line loss. The latter will be very small because of the short length of the primary line. A ten dB coupler covering an octave band is not a problem.

The technique is based on the combining of several coupled signals with their phase and amplitude proportioned to cancel the increase in coupling as the frequency increases.

SINGLE SUMMING PATH

Computed performance for this method is shown in Figure 1A for three values of summing path length. L3+L4 equal to zero yields the coupling curve of the basic 2.7 dB coupler with its normal 6 dB per octave rolloff at low frequencies.

Using the longer length summing paths, an octave band unit can have 10 +/- 0.65 dB coupling and a thru loss of less than 0.55 dB. The 1.3 dB peak to peak response is typical for any value of coupling. Thru path loss will decrease for weaker coupling values. (Thru path loss is primarily coupling "loss".)

Design

The primary coupler, A, is selected to provide the desired coupling near the lower edge of the pass band.

If couplers A and B have equal coupling, the coupling will cancel when the phase difference to the summing point is 180 degrees.

$$2*L1 + L3 + L4 = \lambda/2$$

where L1 is the primary coupler length, L3 is the transmission line separating the primary and auxilliary couplers, and L4 is the summing path length connecting the coupled port of the auxilliary coupler to the isolated port of the primary coupler.

Note that it does not matter if length L3 differs from length L4. In fact, L3 may have a length of 0. Keeping L3 short minimizes the resistive loss in the thru path. However, the coupled and main lines will be in phase quadrature at a point removed from the device when L3 is not equal to L4. (If L3 equals L4, the coupler and main line outputs are in phase quadrature at the device terminals).

The circuit length, including the summing path, approaches a quarter wavelength. However, the losses of L4 will not contribute significantly to main line loss. Therefore, small cross section transmission lines can be used for L4. In addition, L4 is a simple 50 ohm transmission line, not a coupled pair with attendant odd and even mode velocity matching concerns.

Measured Performance

Table I shows performance measured on a stripline assembly (Figure 1B). The device couples a relatively low power forward signal to the coupled port. It also handles 100 watts CW introduced to the main line "output" port. The null produced by the circuit helps minimize the coupler termination dissipation. There is close agreement between computed and measured coupling. The main line loss is less than 0.1 dB.

ATTENUATED SUMMING SIGNAL

The bandwidth of the simple device shown thus far can be improved by reducing the amplitude of the out of phase signal. Then, the summed signals will not null, but will provide a useful operating band extending thru the null frequency. The signal amplitude can be modified by changing the coupled signal level of one of the couplers (A shorter length, or a weaker quarterwave coupling, for example.) This approach can be advantageous if the overall losses, including coupling losses, are important.

Another method of reducing null depth is to retain equal couplings at A and B, but to insert a matched attenuator in the summing path. This provides a symmetrical structure which can be used as a bidirectional coupler. The padding in the coupled path maintains some directivity even if one of the coupled ports has a less than perfect load.

Using the pad approach, the bandwidth and ripple can be traded off simply by changing attenuation values as shown in Figure 2A. Using a 6 dB attenuator, the computed ripple is 1.6 dB peak to peak over a 2.8/1 bandwidth. The main line loss increases, as expected because of pad losses, to 0.25 dB excess over coupling loss for a 17 dB nominal coupler.

Breadboad Performance

To show the simplicity of the approach, a breadboard has been constructed using two 12 mm segments of WIRELINE™ 3 dB hybrids and a 6 dB lumped element attenuator in the summing path. The summing path is 310 mm of .086 diameter coaxitube. The performance of this breadboad unit (shown in Figure 2B) is summarized in Table II. The coupling agrees well with the computed values. Ie. less than +/- 0.8 dB ripple over a 2.9/1 bandwidth. Thru path loss of less than 0.2 dB also agrees well with computed values.

MULTIPLE SUMMING SIGNALS

This process can be extended to multiple summing signals. Each added signal provides another point of compensation along the 6 dB per octave couling slope. The signals can be obtained from a group of couplers. With just two auxilliary couplers, the ripple is less than +/-0.9 dB over a 4.8/1 bandwidth (Figure 3) (As with other types, bandwidth can be reduced to obtain less ripple. Ie. +/0.25 dB over a 3.2/1 bandwidth is possible.)

The summing levels can also be adjusted to fit a desired coupling vs frequency response.

As an alternative to multiple auxilliary couplers with one summing path per coupler, multiple paths from just one auxilliary coupler can be summed using isolating power dividers and combiners. In this case, the amplitudes can be adjusted by a combination of unequal power combiners and attenuator pads. For weak coupling values, the power in the summing combiners is low and broad-band ferrite core devices could be used without problems.

SUMMARY

Summing techniques can be used to obtain compact high power low frequency directional couplers. The devices can have wide bandwidth and a large range of coupling values. Test data confirms the validity of the computed responses.

TABLE I MEASURED STRIPLINE PERFORMANCE

FREQ MHZ	COUPL DB	THRU DB	R.L. DB
90	25.9	0.03	47
110	24.6	0.03	48
130	23.6	0.06	48
150	22.9	0.06	46
170	22.4	0.07	44
190	22.3	0.07	40
210	22.4	0.07	37
230	22.8	0.06	35
250	23.6	0.06	33
270	24.7	0.06	31
290	26.5	0.03	30
310	29.7	0.04	29
330	35.6	0.06	29

TABLE II MEASURED BREADBOARD PERFORMANCE

FREQ MHZ	COUPL DB	THRU DB	DIRECTIVITY DB WITH LOAD	DIRECTIVITY DB WITHOUT
90	25.6	0.06	24	7
110	24.3	0.08	24	7
130	23.5	0.10	24	7
150	23.0	0.12	24	7
170	22.8	0.14	23	6
190	22.8	0.15	22	6
210	23.1	0.18	21	6
230	23.6	0.20	20	6
250	24.0	0.21	18	6
270	24.4	0.21	17	6
290	24.1	0.24	17	6
310	23.2	0.25	17	6
330	21.7	0.27	19	6

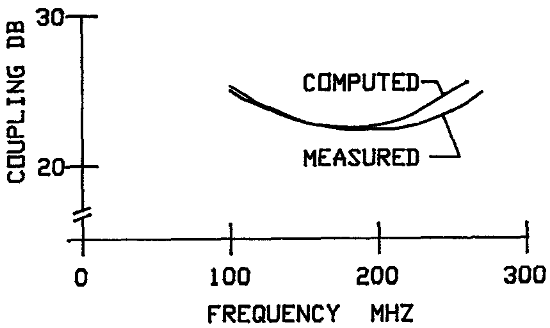
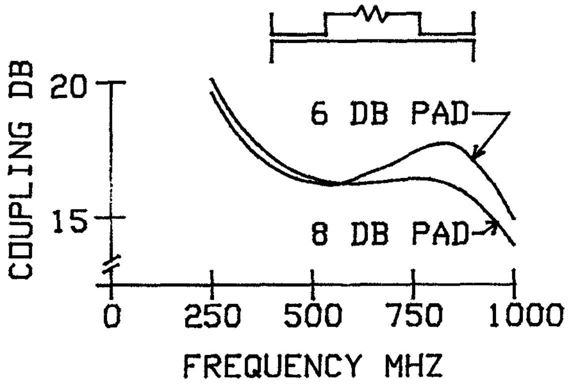


FIG 1B MEASURED VS COMPUTED DATA



COMPUTED COUPLING

FIG 2 ATTENUATED SUMMING

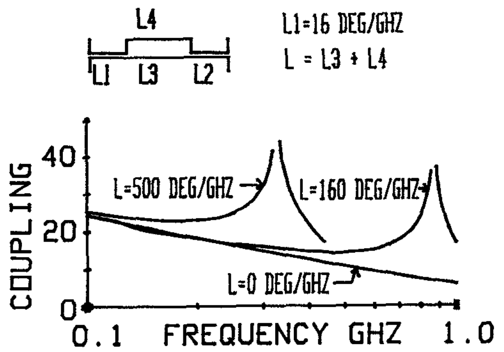


FIG 1A COMPUTED COUPLING

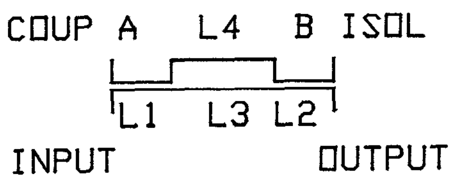


FIG 1 SINGLE SUMMING PATH

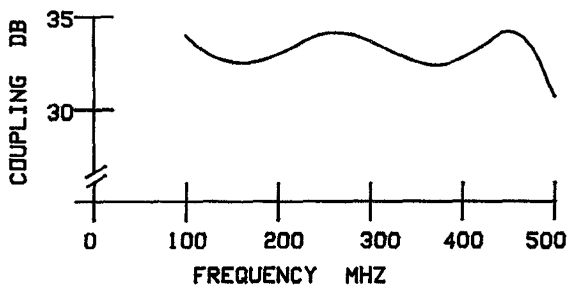


FIG 3 THREE SEGMENT COUPLER COMPUTED RESPONSE