

INTERDIGITATED STRIP-LINE QUADRATURE HYBRID

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Hybrids are frequently used as components in microwave systems or sub-systems such as balanced mixers, balanced amplifiers, phase shifters, attenuators, modulators, discriminators, measurement bridges, etc. An ideal hybrid is a four-port junction with properties such that a wave incident in port one couples equal power into ports two and four but none into port three, see Figure 1. Hybrids are classified according to the phase shift between the two outputs. There are two basic types: 180° hybrids and 90° (quadrature) hybrids. The latter are also called 3-dB directional couplers.

The increasing use of thin-film microwave circuitry has created a need for small, low-loss hybrids which can be easily fabricated on microstrip. This has led to the introduction of this new class of directional couplers.

Interdigitated microstrip couplers consist of three or more parallel strip-lines with alternate lines tied together. A single groundplane, a single dielectric, and a single layer of metallization are used. Thus the approach is eminently suited for monolithic or hybrid, thin film, microwave, integrated circuitry. Tight coupling is achieved much easier than with non-interdigitated edge-coupled lines. Fabrication and tolerance problems make it well-nigh impossible to build non-interdigitated 3 dB edge-couplers. Also, current crowding at the edges, which can result in high loss, is much less severe for the interdigitated coupler.

Previously, tight coupling in directional couplers for microwave integrated circuits has been achieved by

(a) Broadside coupling
(b) Re-entrant sections
(c) Tandem sections
(d) Branch-line couplers

Choices (a) and (b) require multi-layer circuitry which is extremely difficult to build on ceramic or monolithic substrates. Choices (c) and (d) have a narrower bandwidth and require much

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larger substrate areas than single-section coupled-line couplers.

A quadrature hybrid for S-band has been fabricated on a 40-mil single layer alumina dielectric, Figure 1. The metali-
ization consists of thin film gold plated up with gold. A
single quarter-wave section of four lines is used. The lines
are 4.5 mils wide, the spaces 3.0 mils. The cross-overs were
made with three each thermo-compression bonded 0.7 mil gold
wires.

In designing this coupler, special care was taken to
minimize the effect of bonding-wire inductance and to maintain
electrical symmetry. Good performance of a quadrature coupler,
i.e. high isolation, high return loss, and exact 90° phase
difference, are dependent on good symmetry, as can be shown
from fundamental theoretical considerations. Therefore, some
of the cross-overs were made at the center of the coupled
section rather than at the ends. This layout also makes possi-
ble the use of multiple cross-overs, reducing bonding-wire
inductance.

Extensive tests were made on the coupler. Some of the
results are shown in Figures 2 and 3. Imbalance, the ratio of
outputs, was less than 0.25 dB between 2.1 and 3.9 GHz, see
Figure 2. The insertion loss referenced to a 50 ohms system
was less than 0.13 dB between 2.0 and 3.9 GHz, Figure 2. This
includes losses due to mismatch and finite directivity. The
directivity was above 27 dB for the whole band. The return
loss was over 25 dB between 2.2 and 4.0 GHz, see Figure 3. Most
of this mismatch was due to the transition between the strip-
line and the coaxial measurement system since standard commer-
cial connectors were used. The irregularity of the curve in
Figure 3 would indicate as much. The phase difference between
output ports was within 2° of 90°.

The hybrid has been used in a balanced amplifier of the
type proposed by R.S. Engelbrecht. Use of this technique was
successful in reducing the maximum VSWR at the input and output
from 2.7 to 1.2.

In conclusion, a high performance quadrature hybrid for
S-band has been built on alumina microstrip. Loss, isolation,
VSWR, balance, and phase relationships are excellent over a
40% bandwidth.
FIGURE 1. INTERDIGITATED 3-dB COUPLER

FIGURE 3. COUPLER RETURN LOSS
REFERENCES:


![Graph](image)

**FIGURE 2. COUPLER RESPONSE AND INSERTION LOSS**