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Prepared under Electronic Systems Division Contract AF 19(628)-500 by
Lincoln Laboratory
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Lexington, Massachusetts
The work reported in this document was performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the U.S. Air Force under Contract AF 19(628)-500.
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

PROPOSAL FOR 7.75 – 8.35 kMcps DIPLEXER
USING SIDE-WALL COUPLERS AND CUT-OFF GUIDE

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Group 61

GROUP REPORT 1964-22

24 APRIL 1964

LEXINGTON MASSACHUSETTS
ABSTRACT

A diplexer may be made using two side-wall couplers interconnected by cut-off guides. Isolation is controlled by the length of the interconnecting lines. A sample design is worked out for 7.75 – 8.35 kMcps in full- and half-height WR-112 guide.

Accepted for the Air Force
Franklin C. Hudson, Deputy Chief
Air Force Lincoln Laboratory Office
PROPOSAL FOR 7.75 - 8.35 kMcps DIPLEXER USING SIDE-WALL COUPLERS AND CUT-OFF GUIDE

The scattering matrix, $S$, for an ideal side-wall coupler is given by:

$$S = \frac{1}{\sqrt{2}} \begin{bmatrix}
0 & 0 & 1 & j \\
0 & 0 & j & 1 \\
1 & j & 0 & 0 \\
j & 1 & 0 & 0
\end{bmatrix}$$

(1)

The terminal or port numbering convention for the coupler is shown in Fig. 1.

![Fig. 1. Side-wall coupler port numbering convention.](3-61-2766)

Assume that a signal $a_1$ is incident on port 1; ports 3 and 4 are terminated in identical, lossless reflection factors $\Gamma_3 = \Gamma_4 = e^{j\theta} = \frac{a_3}{b_3} = \frac{a_4}{b_4}$. The reflected amplitude at port 1, $b_1 = \frac{1}{2} e^{j\theta} (a_1 - a_4) = 0$, and $b_2 = j e^{j\theta} a_1$. All the power incident on port 1 emerges out of port 2, if $\Gamma_2 = 0$.

But a lossless reflection factor, $|\Gamma| = 1$, is realized by a "long" section of guide below cut-off. So, if a signal of frequency $f_1$ is applied at port 1, and ports 3 and 4 are terminated in symmetrical sections of guide whose cut-off frequency, $f_c = f_{c3} = f_{c4}$, is above $f_1$, all the power comes out of port 2.

Suppose now that $a_1$ is an incident signal (port 1) at a frequency $f_2 > f_c$. 1
If at $f_2$ the transitions from guides 3 and 4 to the guide with cut-off $f_c$ are matched,

$$b_3' = \frac{a_1}{\sqrt{2}} \text{ and } b_4' = \frac{ia_1}{\sqrt{2}},$$

so that the emergent signals at ports 3' and 4' (in small guide) are of equal amplitude and phase quadrature.

If $b_3'$ and $b_4'$ are in turn fed into a second hybrid, similar to Fig. 1, then for ports 3 and 4 of the second hybrid,

$$b_3 = 0 \text{ and } b_4 = j a_1.$$

Figure 2 is a schematic of the above arrangement.

In Fig. 2 the transition from hybrid to interconnecting lines is indicated as a taper of some sort. For a wide band at $f_2$ this might be necessary; however, for ± tens Mc band at $f_2$ it should be possible to use an abrupt junction (which is inductive) but tuned out with a capacitive screw, followed by a quarter-wave transformer.
Anticipated Attenuation Values for Rectangular Guide — It is assumed that the hybrids are in WR-112 guide; \( f_1 = 7.75 \text{ kMcps}, \ f_2 = 8.35 \text{ kMcps}. \) \( f_c \) of interconnecting lines must be between \( f_1 \) and \( f_2 \).

The isolation between port 2 and port 4 (Fig. 2) at \( f_1 \) would be dependent upon the attenuation of interconnecting lines when the lines are below cut-off, i.e., \( f_1 < f_c \). The relation is:

\[
a = \frac{2\pi}{\lambda_c} \sqrt{1 - \left(\frac{f_1}{f_c}\right)^2} \text{ nepers/ unit length of } \lambda_c
\]

(4)

Figure 3 is a plot of Eq. (4) with \( f_c \) varying between 7.83 and 8.33 kMcps. An isolation of 3 to 5 dB/cm may be realized, depending on choice of \( f_c \).

60 dB of isolation would be given by approximately 15 cm length of guide.

At \( f_2 \), between ports 1 and 4, there will be dissipative loss due to conductor loss. For \( f_2 > f_c \) the relation is:

\[
a_c = \frac{R_s}{b \eta_1} \sqrt{\frac{f}{1 - \left(\frac{f_c}{f}\right)}} \left[ 1 + \frac{2b}{a} \left(\frac{f_c}{f}\right)^2 \right] \text{ nepers/ unit length of } b
\]

(5)

where \( a, b = \) dimensions of guide,

\( \eta_1 = 377 \) ohms for air dielectric,

\( R_s = 2.61 \times 10^{-7} \sqrt{f} \) ohms/square for Cu.
For WR-112 guide \((a = 1.122\text{"}, \ b = .497\text{"})\) and \(f \sim 7.05\ \text{kMcps}\), Eq. (5) gives 0.0273 db/ft. for \(C_u\) and 0.0525 db/ft. for Brass, using

\[
\frac{R_{s\ Brass}}{R_{s\ Cu}} = 1.92.
\]

This disagrees with Microwave Engineers' Handbook which quotes 0.0412 db/ft. for Brass. Since Eq. (5) gives pessimistic values, no correction will be made. Figure 4 is a plot of Eq. (5) for \(f = 8.35\ \text{kMcps}\) and \(f_c\) varying from 8.0 to 8.3 kMcps, for Cu WR-112 guide as well as for half-height WR-112 guide. For \(f_c = 8.05\ \text{kMcps}\) the anticipated loss is 0.11 db/ft. for full height guide and 0.16 db/ft. for half-height guide.

From Fig. 3, at \(f_c = 8.05\ \text{kMcps}\), 60 db isolation requires about 6 inches, so that for two hybrids and 6-inch interconnecting lines no more than 1/2 db insertion loss should be anticipated at \(f_2\).

If an abrupt 180° E-plane bend is used, the over-all length might be about 8 to 9 inches.
Fig. 3. Computed attenuation for rectangular guide below cut-off — ideal guide.
Fig. 4. Computed attenuation due to conductor loss for rectangular copper guide — above cut-off.
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