ESD-TDR-64-52

Group Report 1964-22

Proposal for 7.75 – 8.35 kMcps Diplexer Using Side-Wall Couplers and Cut-Off Guide

J. A. Kostriza

24 April 1964

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

J. A. KOSTRIZA

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:

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

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

3-61-2766

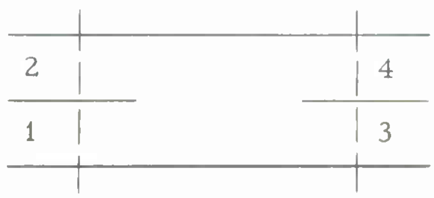

Fig. 1. Side-wall coupler port numbering convention.

Assume that a signal a_1 is incident on port 1; ports 3 and 4 are terminated in <u>identical</u>, <u>lossless</u> 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, $b_1 = \frac{1}{2} e^{j\theta} (a_1 - a_1) = 0$, 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 <u>above</u> f_1, all the power comes out of port 2.

Suppose now that a_1 is an incident signal (port 1) at a frequency $f_2 > f_c$.

If at f_2 the transitions from guides 3 and 4 to the guide with cut-off f_c are matched,

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

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,

$$b_3 = 0 \text{ and } b_4 = j a_1. \tag{3}$$

Figure 2 is a schematic of the above arrangement.

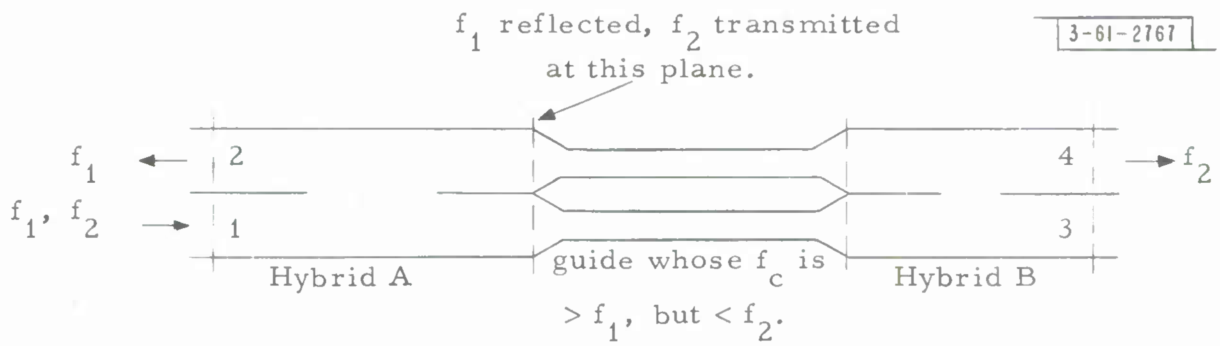

Fig. 2. Schematic of proposed diplexer using two side-wall hybrids and below cut-off guide interconnecting lines.

In Fig. 2 the transition from hybrid to interconnecting lines is indicated as a taper[1] of some sort. For a wide band at f_2 this might be necessary; however, for $\pm$ tens Mc band at f_2 it should be possible to use an abrupt junction (which is inductive[2]) 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 kMcps, f_2 = 8.35 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[3]:

$$\alpha = \frac{2\pi}{\lambda_c} \sqrt{1 - \left(\frac{f}{f_c}\right)^2} \quad \frac{\text{nepers}}{\text{unit length of } \lambda_c} \tag{4}$$

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[4]:

$$\alpha_c = \frac{R_s}{b\eta_1 \sqrt{1 - \left(\frac{f_c}{f}\right)^2}} \left[1 + \frac{2b}{a} \left(\frac{f_c}{f}\right)^2\right] \frac{\text{nepers}}{\text{unit length of b}}, \tag{5}$$

where a, b = dimensions of guide,

η_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", b = .497") and f = 7.05 kMcps, Eq. (5) gives 0.0273 db/ft. for C_u and 0.0525 db/ft. for Brass, using $\frac{R_s \text{ Brass}}{R_s C_u} = 1.92$. This disagrees with Microwave Engineers' Handbook[5] 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 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 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 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[6] is used, the over-all length might be about 8 to 9 inches.

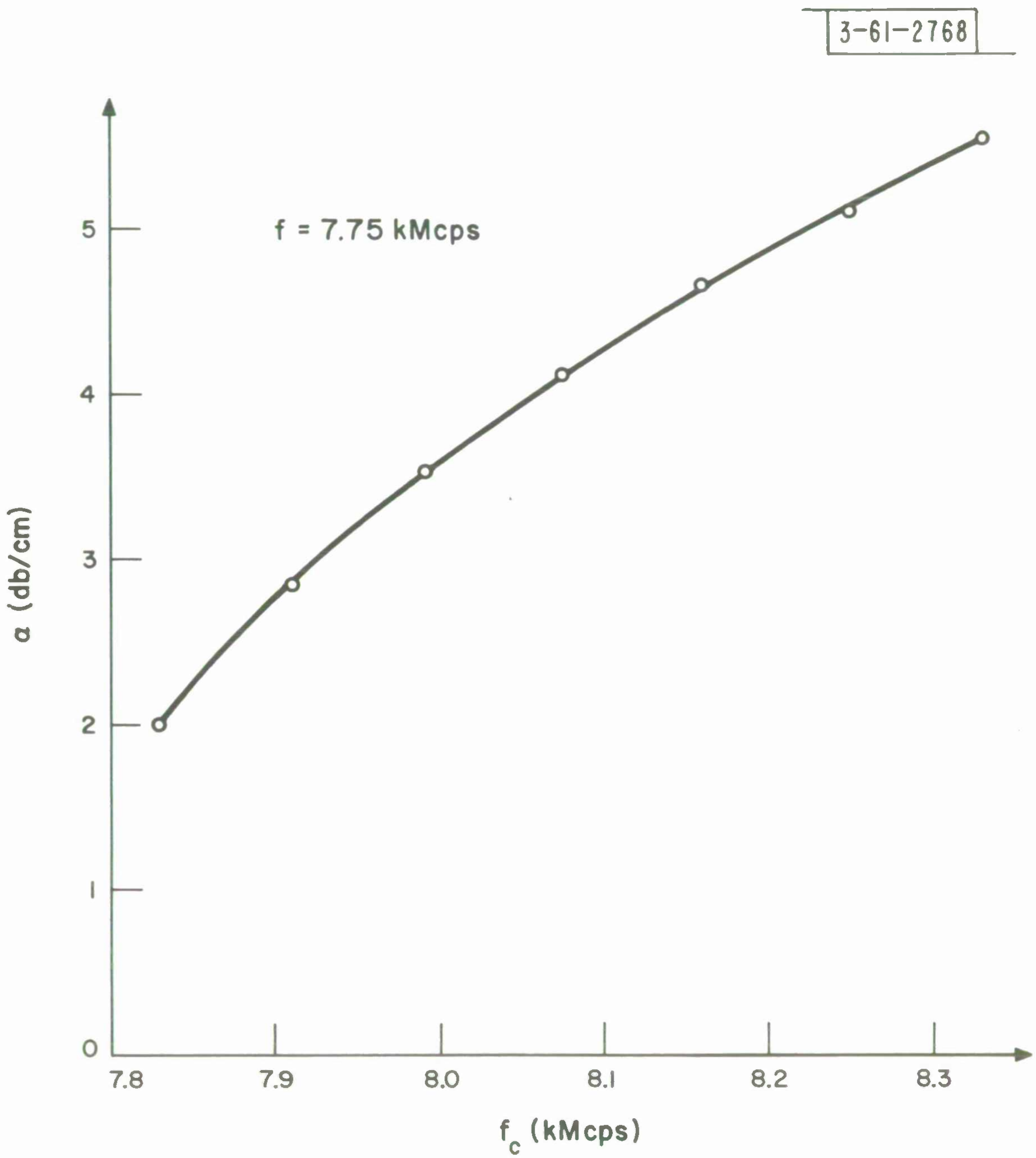

Fig. 3. Computed attenuation for rectangular guide below cut-off — ideal guide.

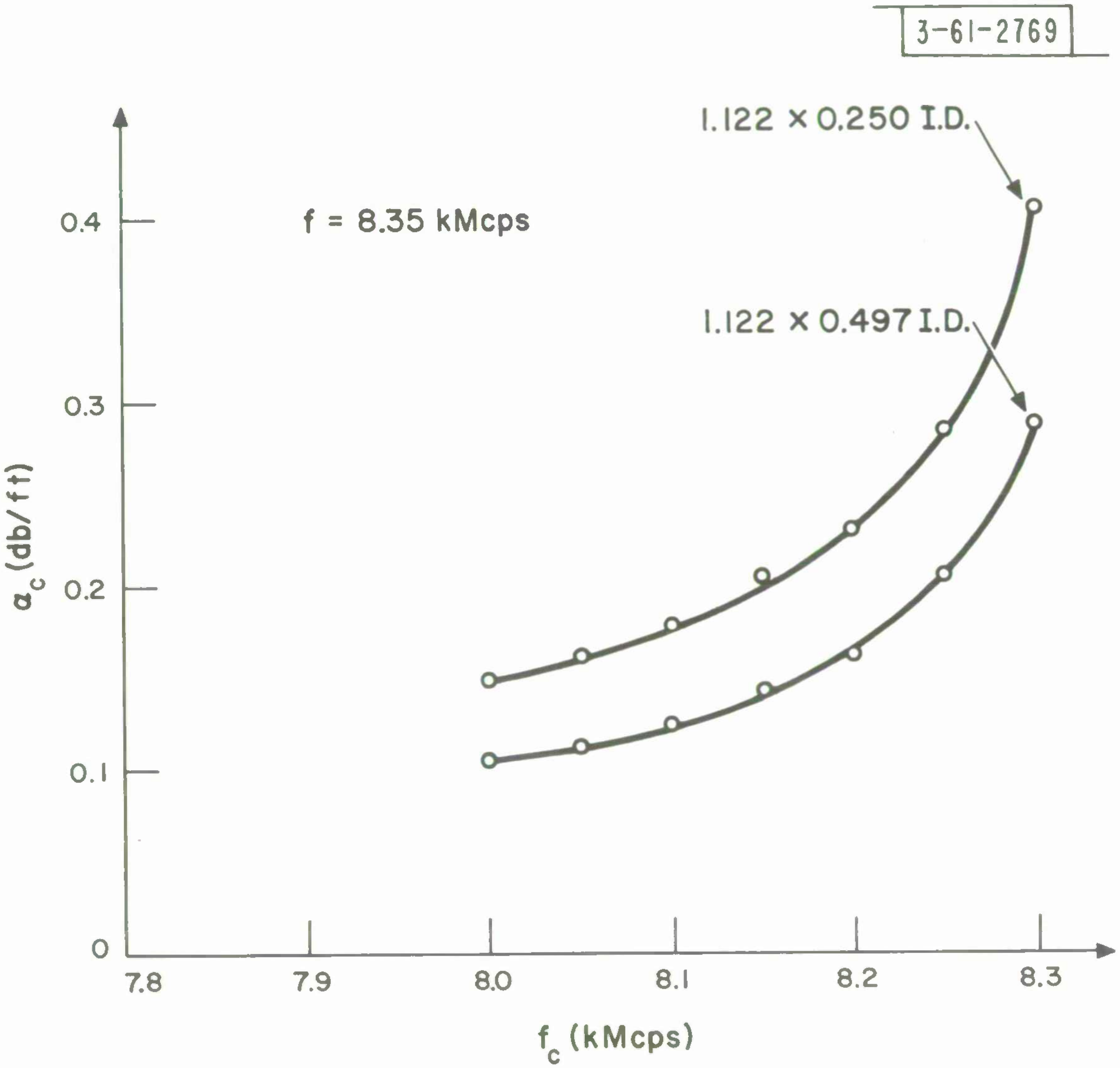

Fig. 4. Computed attenuation due to conductor loss for rectangular copper guide - above cut-off.

REFERENCES

1. E. N. Torgow, "Hybrid Junction - Cut-Off Waveguide Filters," Trans. IRE, PGMTT, MTT-7, 1, (January 1959).

2. N. Marcuvitz, Waveguide Handbook (McGraw-Hill, New York, 1951), p. 168.

3. S. Ramo and J. R. Whinnery, Fields and Waves in Modern Radio (John Wiley and Sons, Inc., New York, 1944), p. 371.

4. Ibid, p. 346.

5. Microwave Engineers' Handbook and Buyers' Guide (Horizon House — Microwave, Inc., Brookline, Massachusetts, 1964), p. 29.

6. J. A. Kostriza, "Diplexer Using Side-Wall Couplers in One-Half Height Large X-Guide," 1964-9 (U), Lincoln Laboratory, M.I.T. (17 January 1964).

DISTRIBUTION LIST

Division 6

G. P. Dinneen
W. E. Morrow

Group 61

L. J. Ricardi (10)
R. N. Assaly
W. C. Danforth
M. E. Devane
J. A. Kostriza
B. F. LaPage
C. A. Lindberg
J. B. Rankin
M. L. Rosenthal
A. Sotiropoulos
L. Niro
R. J. Pieculewicz

Group 62

P. Rosen (2)

Group 63

H. Sherman (2)

Group 64

P. E. Green

Group 66

R. T. Prosser

Group 21

P. C. Fritsch

Division 3

J. Ruze

Division 4

H. G. Weiss

Group 44

J. L. Allen (2)

Group 45

W. W. Ward

Group 46

C. W. Jones
K. J. Keeping

Division 7

J. F. Hutzenlaub

Group 71

E. W. Blaisdell