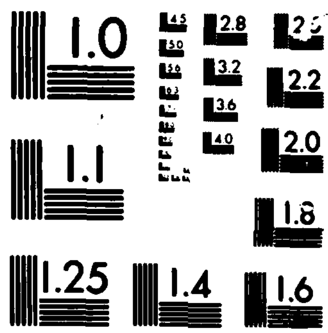
AD-A167 104 AVAILABLE LOSS FACTOR NOISE FACTOR AND EFFICIENCY OF A MISMATCHED TRANSMISSION LINE(U) MITRE CORP BEDFORD MA M M WEINER FEB 86 MITRE-M86-12 ESD-TR-86-240 1/1

UNCLASSIFIED F19628-86-C-0001 F/G 9/1 NL



MICROCOP' CHART

(12)

ESD-TR-86-240

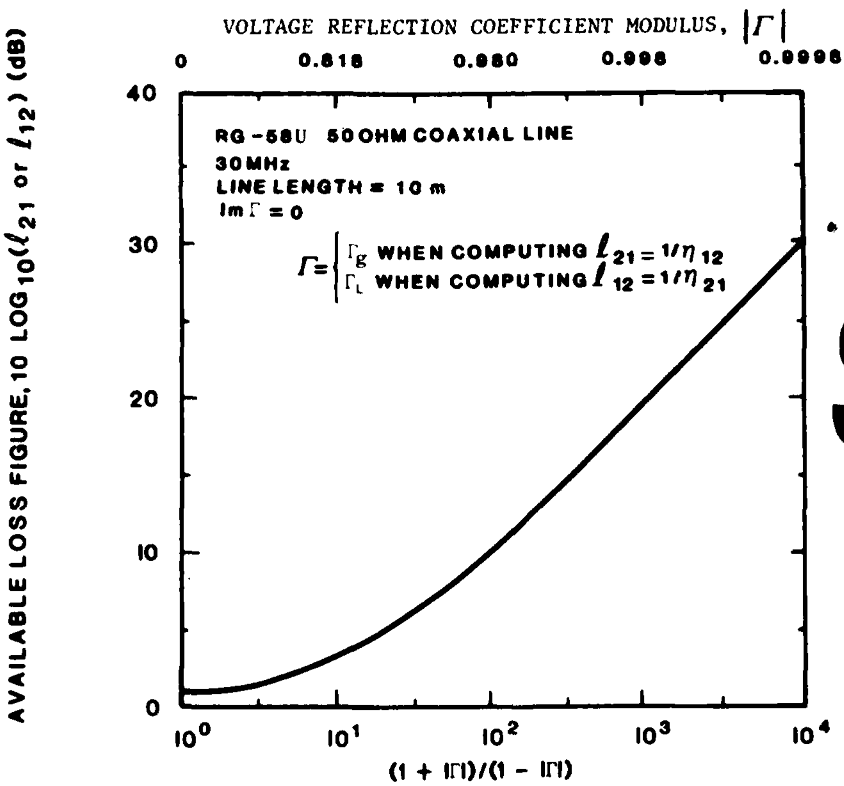
February 1986

M86-12

M. M. Weiner

Available Loss Factor, Noise Factor, and Efficiency of a Mismatched Transmission Line

AD-A167 104



DTIC ELECTE APR 24 1986 S D D

Approved for public release; distribution unlimited.

MITRE
Bedford, Massachusetts

DTIC FILE COPY

86 4 2? 005

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

AD-A167104

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release, distribution unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S): M86-12 ESD-TR-86-240	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION: The MITRE Corporation; 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State and ZIP Code): Burlington Road, Bedford, MA 01730	7b. ADDRESS (City, State and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION: Deputy Commander for (cont.); 8b. OFFICE SYMBOL (If applicable): TCVS	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: F19628-86-C-0001
8c. ADDRESS (City, State and ZIP Code): Electronic Systems Division, AFSC, Hanscom AFB, MA 01731-5000	10. SOURCE OF FUNDING NOS.: PROGRAM ELEMENT NO.: ; PROJECT NO.: 6480; TASK NO.: ; WORK UNIT NO.:
11. TITLE (Include Security Classification): AVAILABLE LOSS FACTOR, NOISE FACTOR, (cont.)	

12. PERSONAL AUTHOR(S): Weiner, M.M.			
13a. TYPE OF REPORT: Final	13b. TIME COVERED: FROM ____ TO ____	14. DATE OF REPORT (Yr., Mo., Day): 1986 February	15. PAGE COUNT: 11
16. SUPPLEMENTARY NOTATION			

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB. GR.	Antenna; Available Loss Factor; Efficiency; Electrically-Short Antenna (continued)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Exact expressions for the available loss factor, noise factor, and efficiency of a distributed linear transmission line are presented for arbitrary mismatch of its source and load impedances to the line's characteristic impedance. Numerical results are given for a low-loss coaxial line.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☒ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL: Diana F. Arimento	22b. TELEPHONE NUMBER (Include Area Code): (617)271-7454	22c. OFFICE SYMBOL: Mail Stop D230

DD FORM 1473, 83 APR   EDITION OF 1 JAN 73 IS OBSOLETE.   UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

8a. Tactical Systems.

11. AND EFFICIENCY OF A MISMATCHED TRANSMISSION LINE.

18. Impedance Mismatch
Load Impedance
Noise Factor
Noise Figure
Receiving Systems
Reciprocity
Signal-To-Noise Ratio
Source Impedance
Transmission Line
Transmission Line Length
Two-Port Network
Voltage Reflection Coefficient

February 1986

M86-12

M. M. Weiner

Available Loss Factor, Noise Factor, and Efficiency of a Mismatched Transmission Line

CONTRACT SPONSOR ESD
CONTRACT NO. F19628-86-C-0001
PROJECT NO. 6480
DEPT. D-54

Approved for public release;
distribution unlimited.

MITRE
The MITRE Corporation
Bedford, Massachusetts

Abstract

Exact expressions for the available loss factor, noise factor, and efficiency of a distributed linear transmission line are presented for arbitrary mismatch of its source and load impedances to the line's characteristic impedance. Numerical results are given for a low-loss coaxial line.

*This work was sponsored by the Electronic Systems Division, Air Force Systems Command, Hanscom Air Force Base, Massachusetts.

For a distributed linear transmission line (see figure 1) with a matched source and load, the available loss factor ℓ, noise factor f referenced to an arbitrary noise temperature T_{ref}, and efficiency η are related and given by [(1)-(3)]

$$\ell = f = 1/\eta = \exp(2\alpha d); \; Z_g = Z_L = Z_o^*, \; T_n = T_g = T_{ref} \qquad (1)$$

where

α = line's attenuation constant (nepers/m)

d = length of the line (m)

Z_g, Z_L = impedances of the source and load, respectively (ohms)

Z_o = characteristic impedance of the line (ohms)

T_g, T_n = ambient temperatures of the source impedance and line, respectively.

The purpose of this letter is to give exact expressions and numerical results of ℓ, f, η for arbitrary mismatch of the source and load impedances to the line's characteristic impedance.

The available loss factor ℓ of a passive linear two-port network is defined as[(1)]

$$\ell_{21} = s_{i1}/s_{o2}, \; 1 \leq \ell_{21} \leq \infty \qquad (2)$$

where s_{i1} and s_{o2} are the available powers at the input port 1 and output port 2, respectively. The subscript 21 denotes that the input port is port 1 and the output port is port 2. The available loss factor ℓ_{21} is a function of the source impedance and output impedance (looking back at the input) but not its load impedance. Generally, $\ell_{21} \neq \ell_{12}$ unless $Z_g = Z_L$ or the network is lossless (contains no dissipative elements) in which case $\ell_{21} = \ell_{12} = 1$.

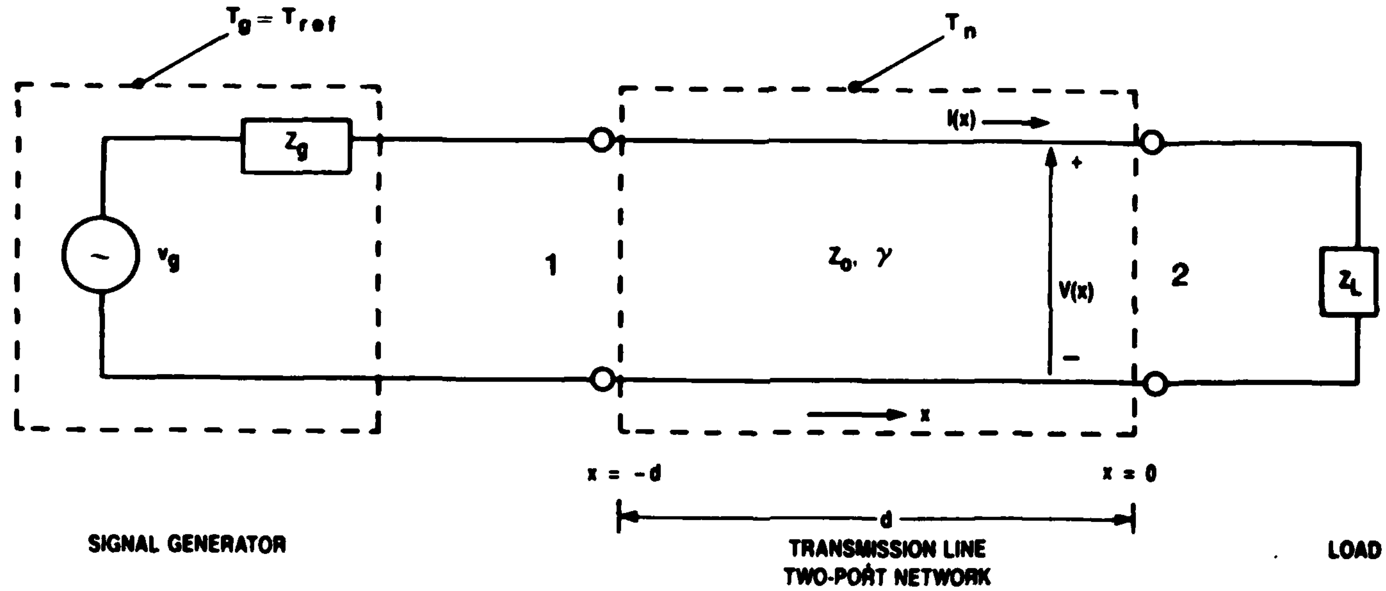


Figure 1. Transmission Line Two-Port Network

For the transmission line of figure 1, ℓ_{21} is given by[4]

$$\ell_{21} = \frac{\exp(2\alpha d)\left|1 - |\Gamma_g|^2 \exp(-4\alpha d) - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\mathrm{Im}[\Gamma_g \exp(-2\gamma d)]\right|}{1 - |\Gamma_g|^2 - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\mathrm{Im}\Gamma_g} \quad (3)$$

where

$\gamma = \alpha + j\beta$ = line's propagation constant

$\Gamma_g = [(Z_g/Z_o) - 1]/[(Z_g/Z_o) + 1]$ = voltage reflection coefficient of signal generator

For $\Gamma_g = 0$, $\ell_{21} = \exp(2\alpha d)$.

The line's noise factor f is related to the line's available loss factor ℓ_{21} by [2]

$$f = 1 + (\ell_{21} - 1)(T_n/T_{ref}),\ T_g = T_{ref} \quad (4)$$

where T_n, T_g, T_{ref} are defined in Eq. (1). For $T_n = T_{ref}$, Eq. (4) reduces to

$$f = \ell_{21},\ T_n = T_g = T_{ref} \quad (5)$$

The line's efficiency η is defined as[3]

$$\eta_{21} = p_{o2}/p_{i1},\ 0 \le \eta_{21} \le 1 \quad (6)$$

where p_{i1} and p_{o2} are the net transmitted time-averaged powers at the input port 1 and output port 2, respectively. The efficiency η_{21} is a function of the load impedance and input impedance but not its source impedance.

For a sinusoidal excitation, the net transmitted time-averaged power p(x) at an arbitrary position x along the line is given by [3],[5]

$$p(x) = \frac{1}{2} G_o |V_+|^2 \exp(-2\alpha x)\left\{1 - |\Gamma_L \exp(2\gamma x)|^2 + 2\frac{B_o}{G_o} \mathrm{Im}\left[\Gamma_L \exp(2\gamma x)\right]\right\} \tag{7}$$

where

V_+ = complex voltage amplitude of the forward traveling wave at $x = 0$

$\Gamma_L = [(Z_L/Z_o) - 1]/[(Z_L/Z_o) + 1]$ = voltage reflection coefficient of load

$G_o = \mathrm{Re}(1/Z_o)$

$B_o = \mathrm{Im}(1/Z_o)$

Noting that $B_o/G_o = -\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)$, $p_{o2} = p(0)$, and $p_{i1} = p(-d)$, the efficiency η_{21} is given by

$$\eta_{21} = \frac{1 - |\Gamma_L|^2 - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\mathrm{Im}\Gamma_L}{\exp(2\alpha d)\left\{1-|\Gamma_L|^2\exp(-4\alpha d) - 2[\mathrm{Im}(Z_o)/\mathrm{Re}(Z_o)]\mathrm{Im}\left[\Gamma_L \exp(-2\gamma d)\right]\right\}} \tag{8}$$

For $\Gamma_L = 0$, $\eta_{21} = \exp(-2\alpha d)$.

A comparison of Eq. (8) with Eq. (3) yields the results

$$\ell_{21} = 1/\eta_{12} \tag{9}$$

$$\ell_{12} = 1/\eta_{21} \tag{10}$$

where η_{12} and ℓ_{12} are the line's efficiency and available loss factor, respectively, when the load Z_L at port 2 is interchanged with the source Z_g. Eqs. (9) and (10) are valid for any linear, reciprocal two-port network[6].

For the conditions of Eq. (1), $f = \ell_{21} = \ell_{12} \equiv \ell$ and $\eta_{21} = \eta_{12} \equiv \eta$. For such conditions, Eqs. (3), (4), and (9) reduce to the results given by Eq. (1).

The effect of impedance mismatch upon the available loss factors ℓ_{21} or ℓ_{12} is shown in figure 2 for a 10m length of RG-58U 50 ohm coaxial line at 30 MHz and $\mathrm{Im}\Gamma = 0$. The voltage reflection coefficient $\Gamma = \Gamma_g$ when computing ℓ_{21} and $\Gamma = \Gamma_L$ when computing ℓ_{12}. The available loss figure = $10 \log_{10}(\ell_{21}$ or $\ell_{12})$ is increased by 3 dB when Γ is increased from 0 to approximately 0.8. The available loss figure is increased by 10, 20, and 30 dB for $|\Gamma| = 0.980$, 0.998, and 0.9998, respectively.

The available loss figures of RG-58U line at 30 MHz for $\Gamma = 0$, 0.9991, and 0.9991 exp (-j0.100) are 8×10^{-5} dB, 0.04 dB, and 1.5 dB, respectively, for a line length of 10^{-2}m and 0.08 dB, 10.7 dB, and 26.5 dB, respectively, for a line length of 1m (see figure 3).

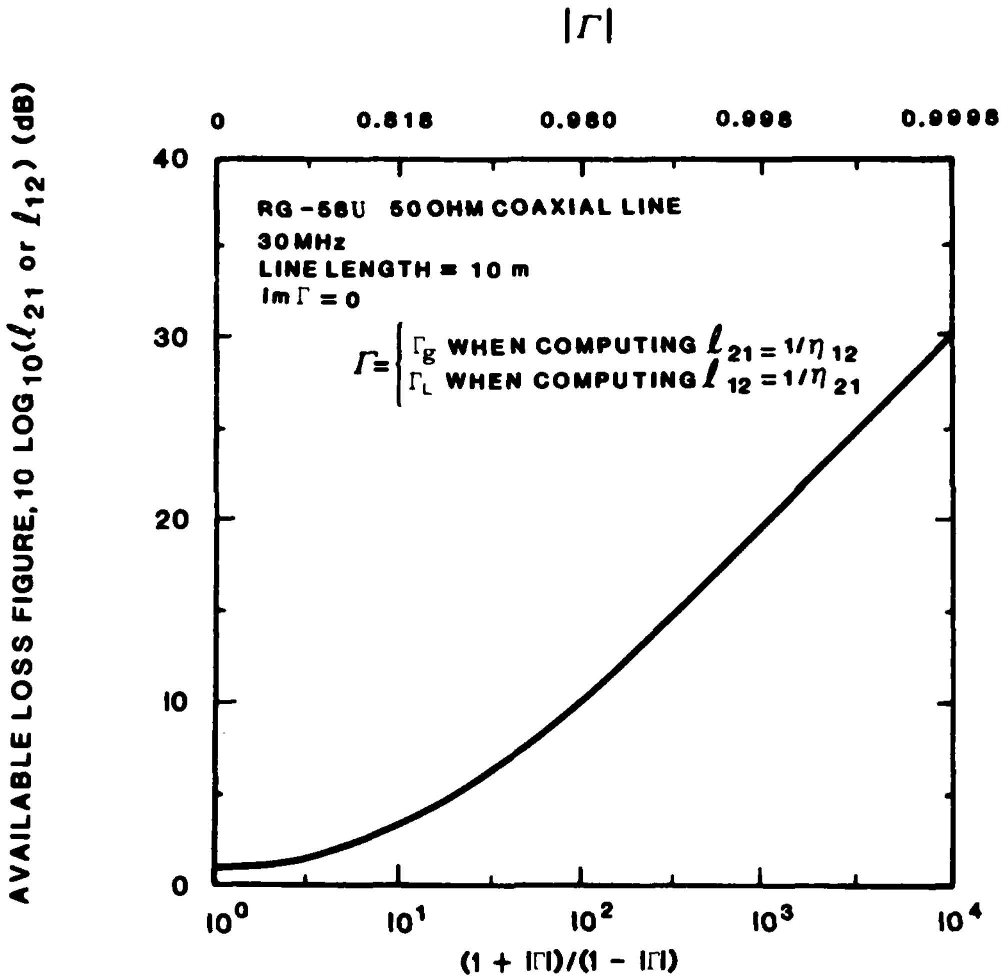


Figure 2. Available Loss Figure Dependence Upon Voltage Reflection Coefficient Γ

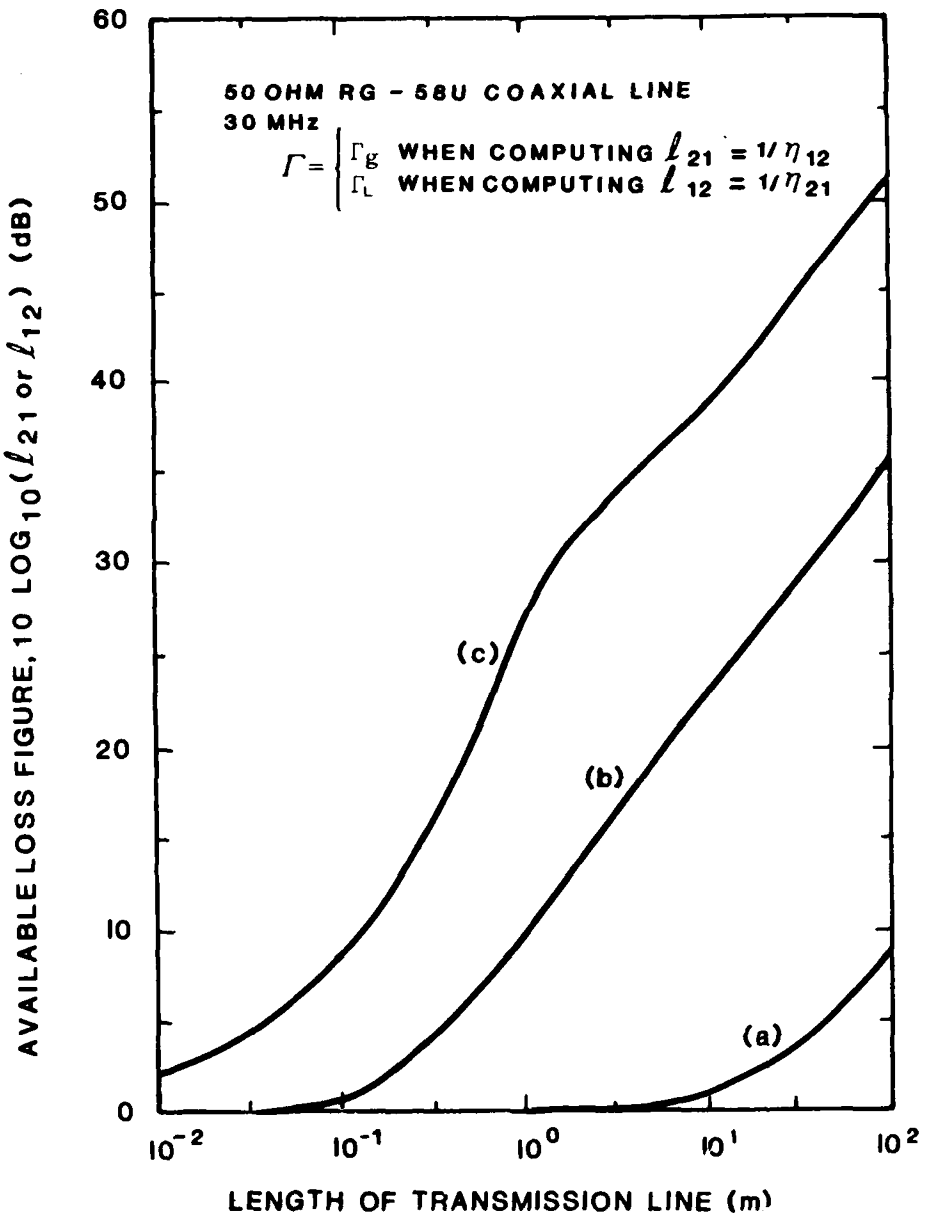


Figure 3. Available Loss Figure Dependence Upon Line Length
(a) $\Gamma = 0$
(b) $\Gamma = 0.9991$
(c) $\Gamma = 0.9991 \exp(-j\ 0.100)$

REFERENCES

1. C.C.I.R., "Operating Noise Threshold of a Radio Receiving System," 11th Plenary Assembly, Oslo, Norway (1966), Report 413, Int. Radio Consultative Committee, International Telecommunication Union, Geneva, Switzerland, 1967, Annex 1, Eq. (b).

2. op. cit. 1, Eq. (f).

3. ITT, "Reference Data for Radio Engineers," Indianapolis, Ind.: Howard Sams, 1983, 6th ed., pp. 24-8 - 24-11.

4. M.M. Weiner, "Effect of Antenna Impedance Mismatch on the Signal-to-noise Ratio of a Radio Receiving System," The MITRE Corporation, Bedford, MA, ESD-TR-85-136, NTIS AD A159070, Appendix ID, Eq. (I-48), July 1985.

5. R. Adler, L. Chu, and R. Fano, "Electromagnetic Energy Transmission and Radiation," New York, NY: John Wiley, 1960, p. 186.

6. M.S. Ghausi, "Principles and Design of Linear Active Circuits," New York, NY: McGraw-Hill, 1965, p. 65. In Eqs. (3-83) and (3-85), the power gain $G_p \equiv \eta_{21}$ and the available power gain $G_A \equiv 1/\ell_{21}$. If the load and source are interchanged so that $G_p = \eta_{12}$ and if $k_{21} = k_{12}$ (condition for reciprocity), then Eqs. (3-83) and (3-85) are identical.

END
FILMED

5-86

DTIC