THIN-FILM RC LINES WITH RESEMBLING OPEN-CIRCUIT CHARACTERISTICS*

12501

SYNOPSIS--A quantity is defined for comparing the low-pass voltage-transfer characteristics of non-uniform RC lines. This quantity is the frequency ratio of the 30-db and the 3-db points on the characteristic. Lines with the same frequency ratio are said to resemble one another.

Author

In a previous letter, it was pointed out that RC lines with the three general shapes can be analyzed in closed form and quantitative studies are possible without resorting to approximation techniques.[1] It is well known that many lines of the three general shapes can be made to have very similar open-circuit voltage-transfer characteristics. Although for all practical purposes, the difference among these similar lines is not discernable, we cannot say that these lines are identical. In fact, these lines may differ quite noticeably in other respects, such as their behavior with load or asymptotic performance at high frequencies.

Quantitative studies of shaped RC lines are difficult because of the lack of established standards for comparing these lines. For example, in studying the effect of load impedance on the performance of various lines that behave similarly at open-circuit, there is no established criterion to enable us to determine which lines are similar to each other and which ones are not. This author proposes that the following definition be used for this purpose:

All open-circuit voltage-transfer characteristics are normalized with respect to frequency such that their 3-db-loss points (ω_1) coincide. After this normalization, all lines whose 30-db-loss points (ω_2) occur at the same normalized frequency are said to <u>resemble</u> one another. (See Fig. 2 for examples of resembling lines.)

With this definition, the following three nonuniform lines have been computationally studied for their open-circuit performance.

(1) The exponential line: $r = r_o \epsilon^{\alpha x}$, $c = c_o \epsilon^{-\alpha x}$. Port 1 is at $x = 0$, and port 2 at $x = \lambda$.

(2) The trigonometric line: $r = r_o \csc^2 x$, $c = c_o \sin^2 x$. Port 1 is at $x = x_1$ and port 2 at $x = x_2$.

(3) The hyperbolic line: $r = r_o \operatorname{sech}^2 x$, $c = c_o \cosh^2 x$. Port 1 is at $x = x_1$ and port 2 at $x = x_2$.

Parameters of the exponential line that correspond to several integer values of ω_2/ω_1 have been obtained and are listed in Table 1. There are multitudes of parameters for the trigonometric and the hyperbolic lines that correspond to these values of ω_2/ω_1. These parameters are best presented as contour maps as shown in Fig. 1. In these graphs, points on contours of the same ω_2/ω_1 give RC lines that all resemble one another at open-circuit. The two dotted contours correspond to parameters of lines that resemble the uniform line.

To demonstrate how similarly these resembling lines behave, Fig. 2 includes three sets of magnitude and phase characteristics corresponding to three RC lines of vastly different shapes. Characteristics A correspond to the uniform line. Characteristics B correspond to a trigonometric line with $x_1 = 0.61342$ and $x_2 = 3.1400$. Characteristics C correspond to a hyperbolic line with $x_1 = -5.00$ and $x_2 = 1.78403$. Lines B and C

Table 1

Rate of cut-off ω_2/ω_1	Degree of taper $\alpha\lambda$	ω_1 (multiply by $1/r_0c_0\lambda^2$)
6	8.17756	18.10890
7	5.66067	11.84338
8	4.10056	8.52120
9	3.00722	6.49321
10	2.17777	5.13989
11	1.51332	4.17996
12	0.95975	3.46820
13	0.48483	2.92236
14	0.067947	2.49244
14.1746	0	2.42669
15	-0.30481	2.14641
16	-0.64328	1.86277
17	-0.95474	1.62664
18	-1.24478	1.42734
19	-1.51786	1.25707
20	-1.77769	1.10995

correspond to two extreme points on the dotted contours of Fig. 1. All characteristics correspond to other points on these contours are expected to lie between characteristics C and A of Fig. 2.

In conclusion, it is seen that even if the variations of r and c are very different, RC lines can be made to perform comparably at open-circuit. Since these lines can be analyzed in closed form, quantitative studies of the suitability of various shapings for different applications can be carried out mathematically.

Kendall L. Su

Georgia Institute of Technology

Atlanta, Georgia, U.S.A.

Footnote

*This work was supported by NASA under grant NGR-11-002-020

Reference

1. SU, K. L.: 'Hyperbolic RC transmission line,' Electronics Letters, 1965, **1**, p. 59.

Figure Captions

Fig. 1 a Contours of resembling trigonometric RC lines

b Contours of resembling hyperbolic RC lines

Fig. 2 a Magnitude characteristics of three resembling lines

b Corresponding phase characteristics of a

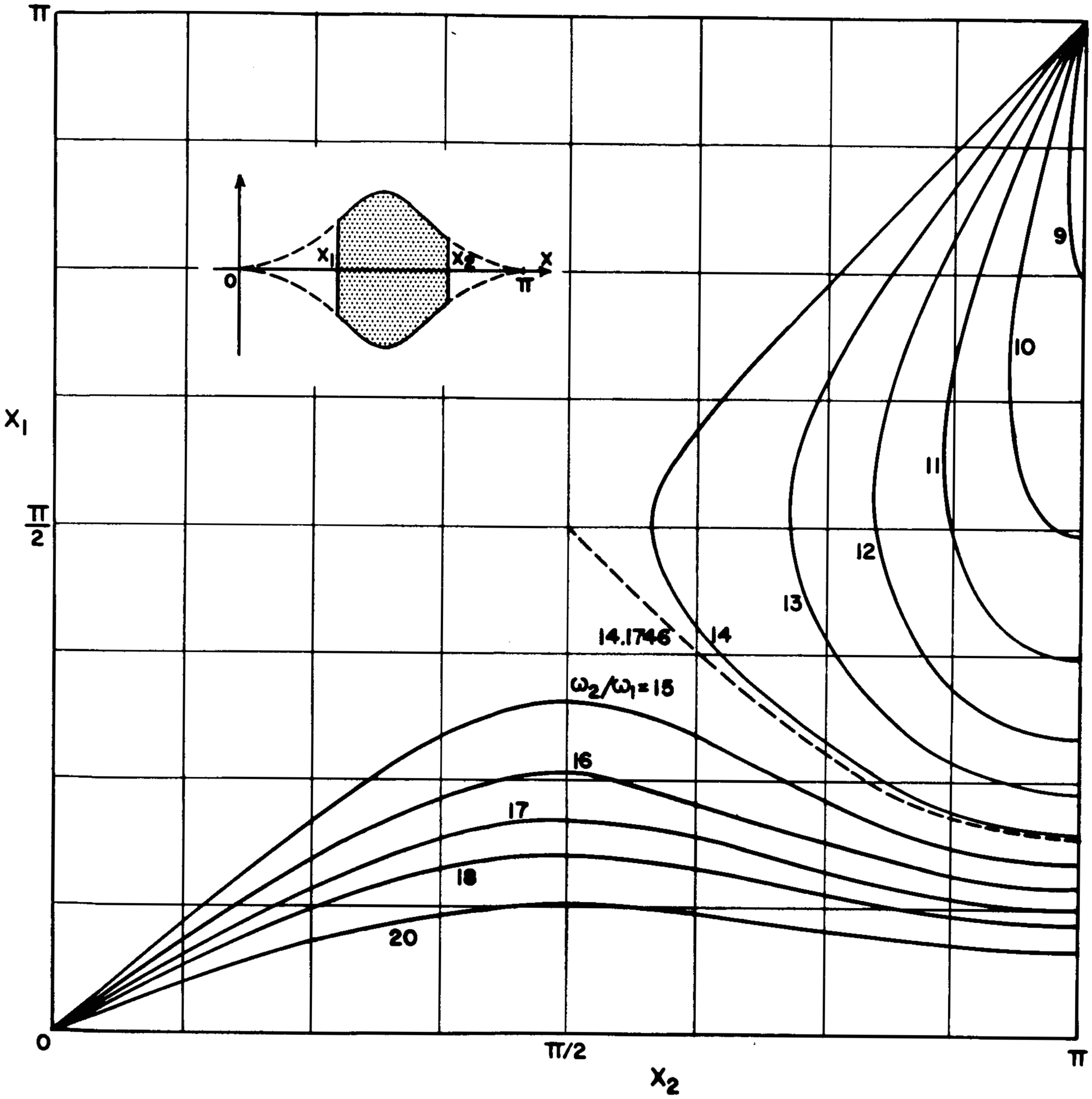

Fig. 1a Contours of resembling trigonometric RC lines

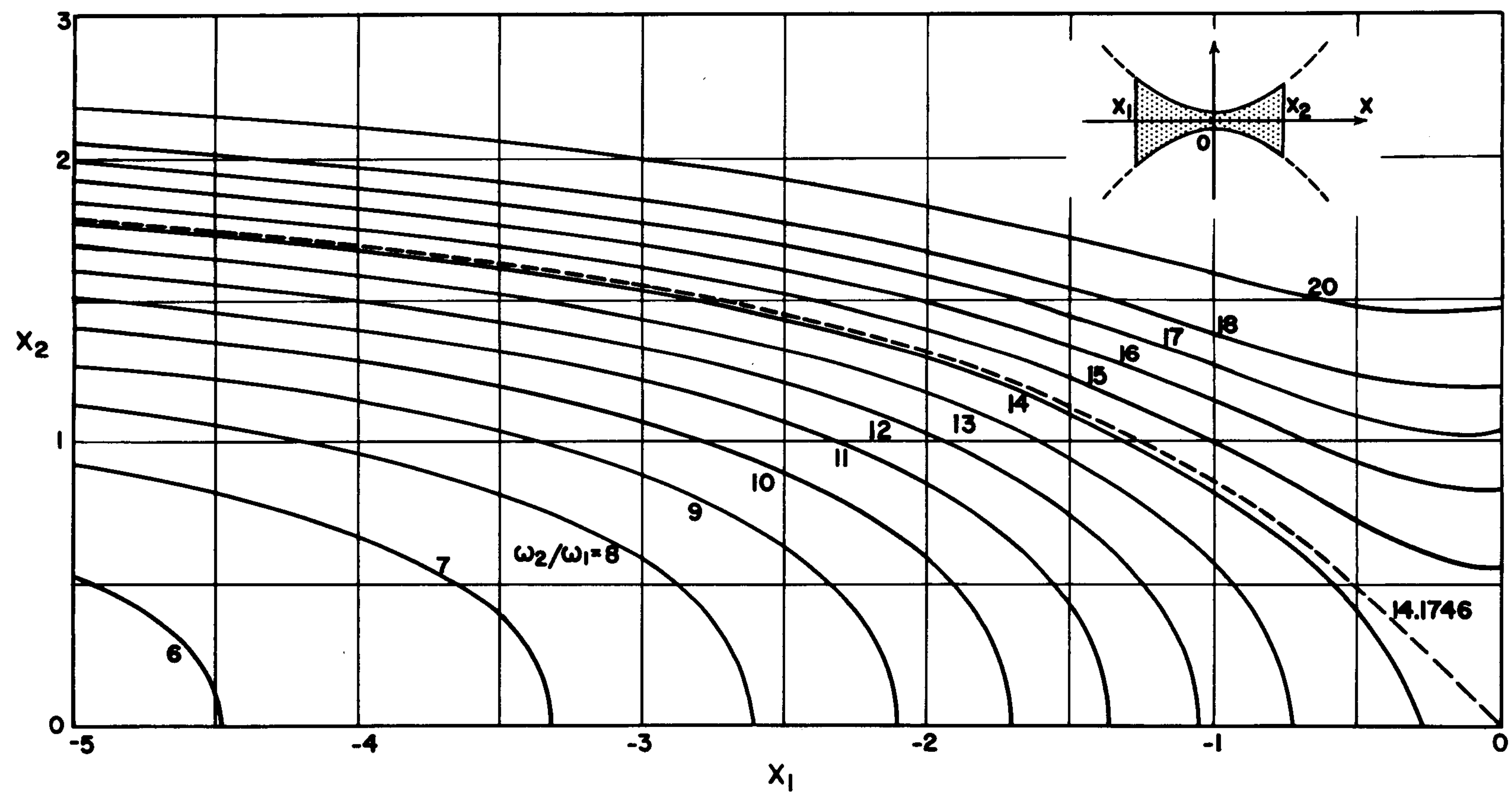

Fig. 1b Contours of resembling hyperbolic RC lines

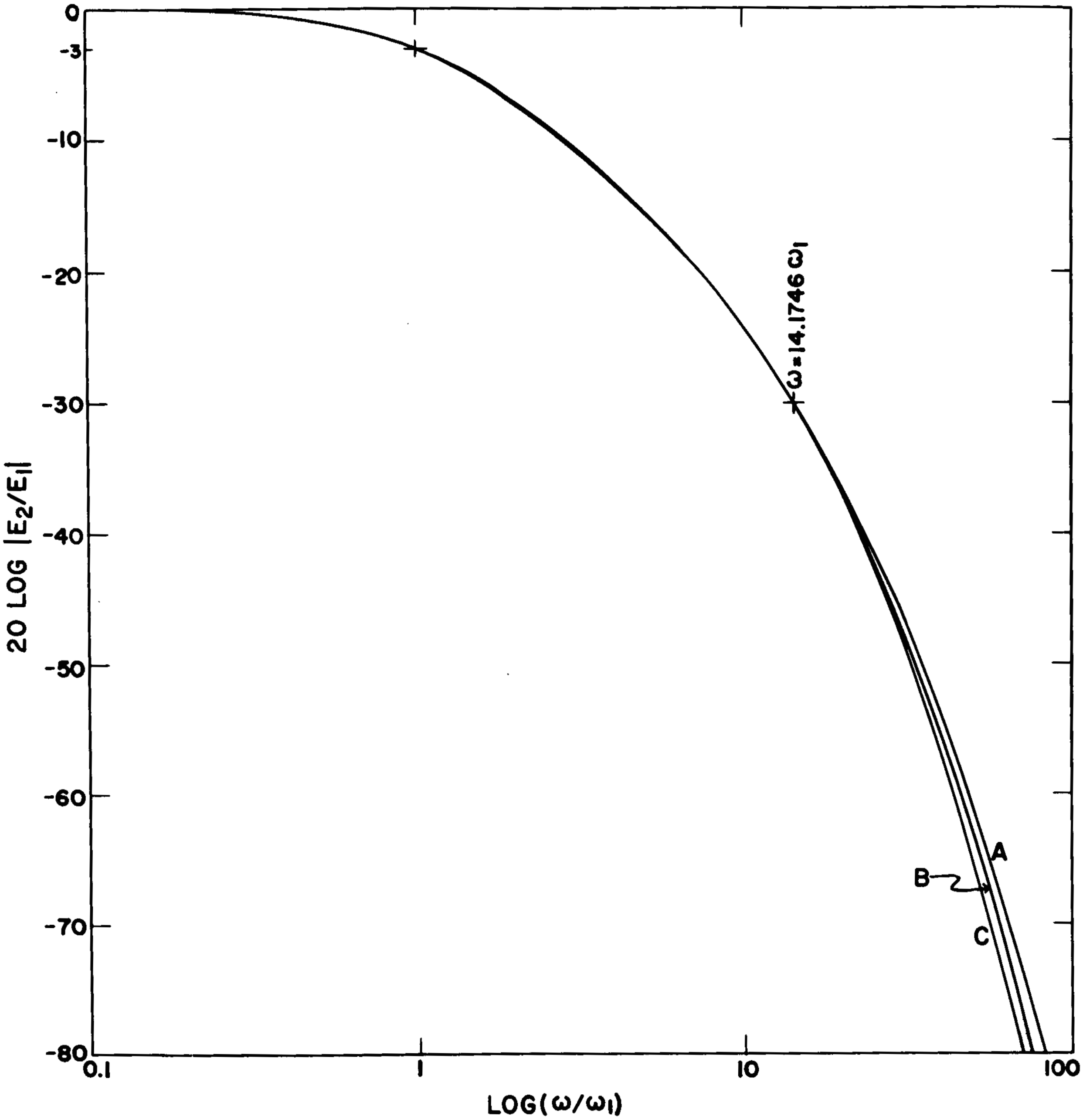

Fig. 2a Magnitude characteristics of three resembling lines

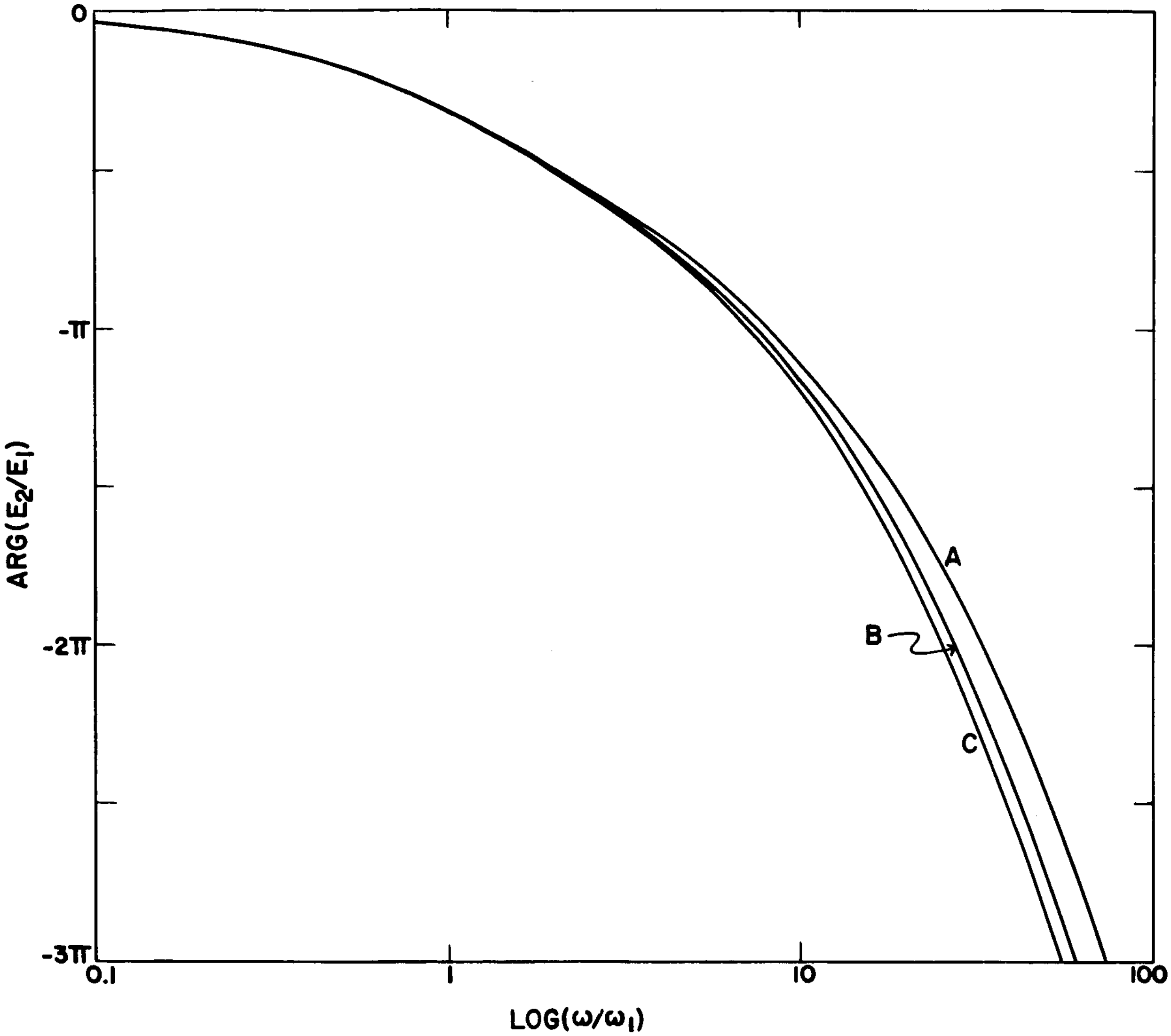

Fig. 2b Corresponding phase characteristics of a