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ALMATY UNIVERSITY OF POWER ENGINEERING & TELECOMMUNICATIONS

Department of Theoretical Bases of Electrical Engineering

CIRCUITS WITH DISTRIBUTED AND LUMPED PARAMETERS

Methodological guidelines and assignments for calculation graphical works № 1, 2 for the 5B070200 – Automation and Control baccalaureate specialty students

Almaty 2016

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Methodological guidelines and assignments for Calculation Graphical Works on "Circuits with the distributed and lumped parameters" discipline includes two Calculation Graphical Works for the next sections: "Calculation of two-port circuits" and "Calculation of transmission line with distributed parameters".

Manual also includes content and design requirements for calculation graphical works, schemes, original data of parameters of electric circuit's elements and methodological guidelines.

Methodological guidelines and assignments are intended for students, which are educated in English on 5B070200 – "Automation and Control" baccalaureate specialty.

18 illustrations, 6 tables, 6 items of references.

Reviewer: PhD B. I. Tuzelbaev

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Introduction

"Circuits with the distributed and lumped parameters" (CD&LP) discipline is the main basic obligatory discipline for the 5B070200 – "Automation and Control" baccalaureate specialty students.

CD&LP discipline objective: to study the theory of two-port circuits and transmission line with distributed parameters. This discipline is based on "Higher Mathematics" and "Physics" disciplines. CD&LP discipline is of a paramount importance for the formation of scientific outlook of specialists in the field of automation and control. The task of the discipline is to train the students, based on a knowledge of qualitative and quantitative aspects of the processes taking place in the various electrical devices, for successful and competent solving the problems that poses the special automation and control disciplines.

Calculation Graphical Works are essential components in the study "Circuits with distributed and lumped parameters" discipline. Performing CGW allows the student to apply theoretical principles, obtained during a study of the discipline, in practical calculations, to gain the skills of independent circuit analysis that ultimately contribute to the successful mastering of the CD&LP discipline.

This brochure contains assignments and methodological guidelines for two CGW on the main sections of the CD&LP discipline that intended for the 5B070200 – Automation and Control baccalaureate specialty students.

CGW № 1 is devoted to calculation of two-port circuits.

CGW № 2 is devoted to calculation of a steady state mode in the transmission lines with distributed parameters.

The options of original data are chosen by last and penultimate digits of the credit book number, the first letter of the student surname and by the year of enrolment (even or odd).

Content and design requirements

Calculation Graphical Work (CGW) should be included next sections:

a) title page (a template of the title page is represented on the next page);
b) contents;
c) introduction;
d) assignment;
e) procedure of calculation and graphical results presentation;
f) conclusion;
g) list of references;
h) appendices (if it is necessary).

The surname and initials, credit book number and academic group code of the student should be written on the title page (title page template is depicted on the next page).

The circuit diagram, original data and assignment text should be rewritten to the explanatory note completely unabridged.

Each stage of a calculation graphical work should be named. All tasks have to perform on only one side of a white paper sheet of size A4 with margins: top of 20 mm, bottom of 25 mm, left of 25 mm and right of 18 mm.

An explanatory note should be handwritten or by using Microsoft Word (font size 14 points, line spacing 1…1,5 line).

In an explanatory note, not only calculation formulas and final results, but also text with explanations and needed intermediate calculations, which allow understanding and verifying your actions are to be presented.

It is necessary to write appropriate units for the parameters, having a particular of dimension in the final results.

Put dots over complex parameters, which are time functions and underline complex parameters, which are not time functions, such as impedance and admittance.

Do not change of names of the nodes, parameters, resistors, inductances, capacitances and of the conditionally taken current and voltage positive directions.

The graphs of instantaneous values, phasor, topographic and circle diagrams should be performed on the inserted sheets of graph or checkered paper, or by using computer applications.

It is necessary to sign the name of coordinate axes and their units on the graph, also choose a scale so that would be convenient to use a graph or diagram.

The circuit diagrams should be numbered and done in pencil neatly by using a ruler or computer applications.

All pages should be continual numbering, beginning with the title page. The page number should be located in the middle of the sheet bottom.

The works, which do not satisfy the above-mentioned requirements, will not be given a permission for defense and will be returned for revision.

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Department of Theoretical Bases of Electrical Engineering

CALCULATION GRAPHICAL WORK № __

on the "Circuits with distributed and lumped parameters" discipline

____

(Title of the calculation graphical work)

____

5B070200 – "Automation and Control" baccalaureate specialty

Done by ___________________________ student of the ______________ group

(Student's Surname & Initials) (Academic group code)

Checked by ____

(Teacher's academic degree, academic rank, Surname & Initials)

___________ _________________ "_____" "_____________" 201__ y.

(Score) (Teacher's signature) (Date)

Almaty 201__ y.

1 CGW № 1. Calculation of two-port circuits

The two passive two-port circuits are connected in cascade. Circuit diagrams of the two-port circuits and parameters of their components are given.

The original numerical data and numbers of schemes of two-port circuits are presented in tables 1.1…1.3 for variety of options.

The options of original data are chosen by last and penultimate digits of the credit book number, the first letter of the student surname and by the year of enrolment (even or odd).

1.1 Assignment

Calculate:

1) *A* – parameters of each two-port circuits.

2) *A* – parameters of the connection in cascade of two-port circuits by two ways:

a) by using *A* - parameters of each of circuits;

b) to make equivalent two-port circuit as *T*- or π-section by equivalent transformations.

3) Secondary parameters of the equivalent two-port circuit ($\underline{Z}_{c1}$, $\underline{\gamma}$, *a* and *b*) by two ways:

a) by using *A* – parameters;

b) by using the impedances of idle and short-circuit modes.

4) The input impedance relatively to the input terminals of two-port circuit when connecting to the output terminals of load's resistor R_L.

5) The input impedance relatively to the output terminals of two-port circuit when connecting to the input terminals of source's resistor R_S.

Table 1.1

Enrolment year	Last digit of the credit book number									
even	1	2	3	4	5	6	7	8	9	0
odd	0	9	8	7	6	5	4	3	2	1
1st two-port circuit scheme №	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.1	1.2
L, mH	10	15	25	60	50	40	30	20	20	25
f, kHz	25	30	16	20	30	20	25	15	30	10

Table 1.2

Enrolment year	Penultimate digit of the credit book number									
even	1	2	3	4	5	6	7	8	9	0
odd	0	9	8	7	6	5	4	3	2	1
R, kΩ	15	30	20	12	20	10	20	25	40	20
R_L, kΩ	20	16	25	35	30	20	30	16	10	30

Table 1.3

Enrolment year	First letter of the surname									
even	БЛЦ	КХ	ВМЧ	ГНШ	ДОЯ	ЕПР	ЖСЗ	ТЭИ	УЮФ	АЩ
odd	КХ	ВМЧ	ГНШ	БЛЦ	ЕПР	ДОЯ	ТЭИ	ЖСЗ	АЩ	УЮФ
2^{nd} two-port circuit scheme №	1.9	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.12	1.15
C, μF	0,1	0,3	0,2	0,4	0,5	0,6	0,7	0,8	0,9	0,6
R_S, kΩ	0,2	0,19	0,18	0,17	0,16	0,15	0,14	0,13	0,12	0,11

Options of the two-port circuit diagrams:

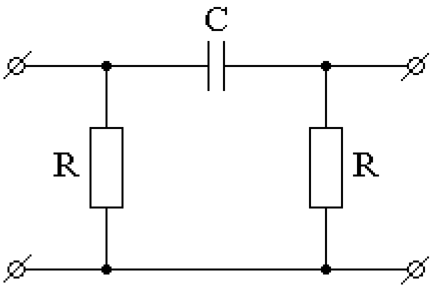


Figure 1.1

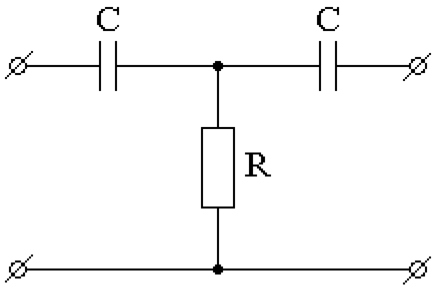
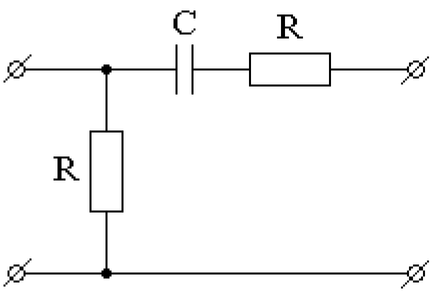


Figure 1.2



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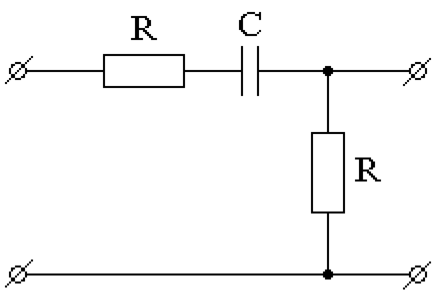

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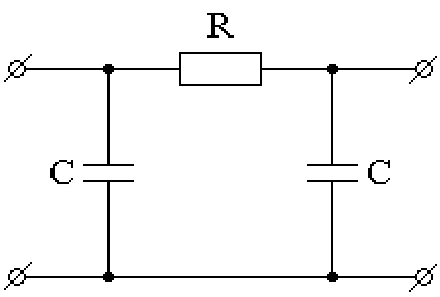

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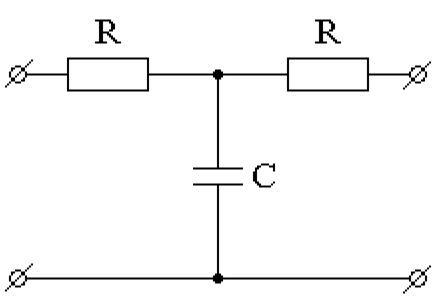

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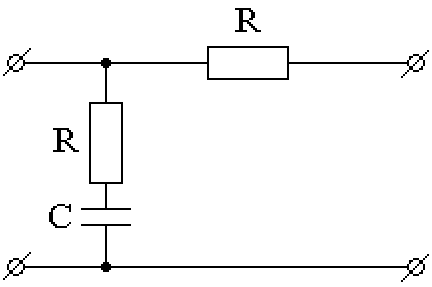

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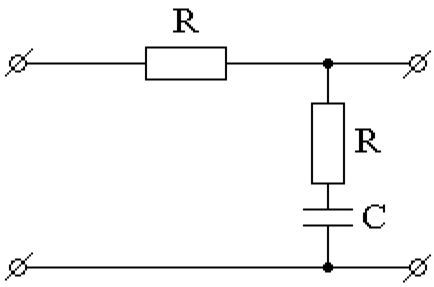
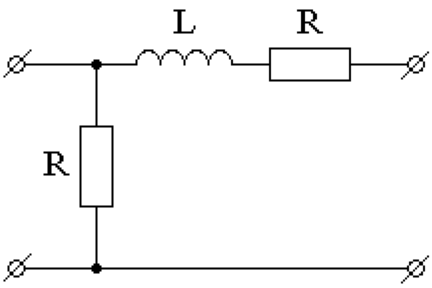


Figure 1.8



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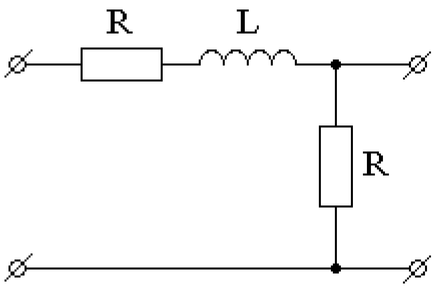


Figure 1.10

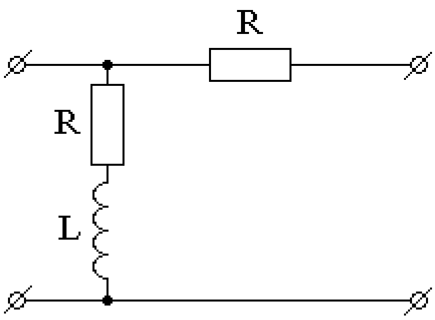
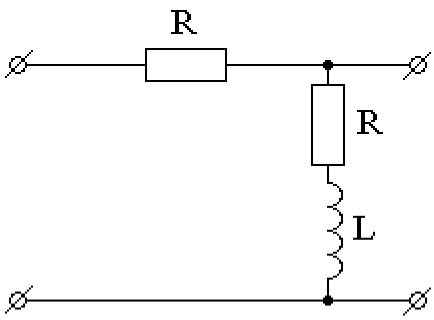


Figure 1.11



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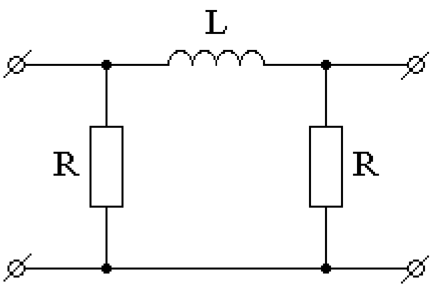
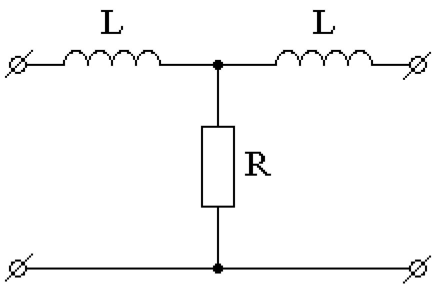


Figure 1.13



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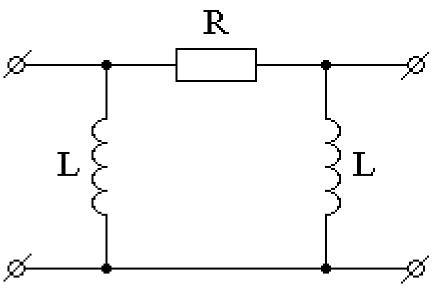

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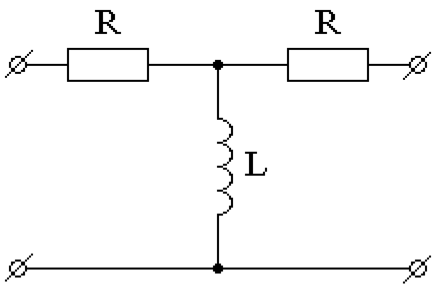

Figure 1.16

1.2 Methodological guidelines

The connection of two-port circuits in cascade is often used on practice in the devices of automations, telecommunications and telemechanics. The connection of two-port circuits in cascade is the one, when the first two-port output becomes the input of the second one, and so on, as shown in figure 1.17.

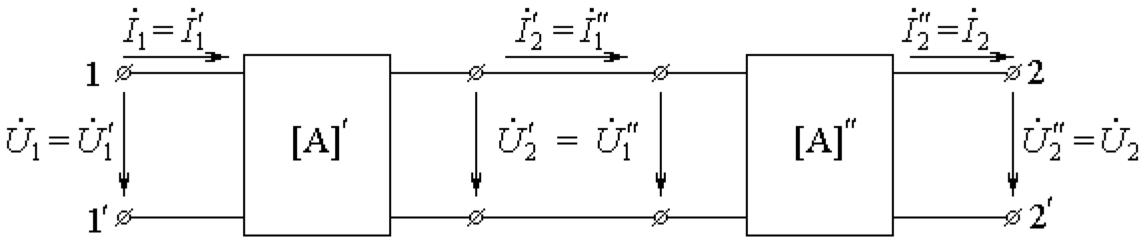

Figure 1.17

It is convenient to use *A* – parameters in order to determine the parameters of equivalent two-port circuit that is obtained as a result of cascade connection of several two-port circuits through the parameters of each of them. A matrix of *A* – parameters of the equivalent two-port circuit is defined as the product of matrices of *A* – parameters of individual each two-port circuits connected in cascade.

$\underline{A}_{11}$, $\underline{A}_{12}$, $\underline{A}_{21}$, $\underline{A}_{22}$ are complex constants of a particular two-port circuit and called as parameters. These parameters are often called as the transmission parameters and generally used for the analysis of two-port circuits.

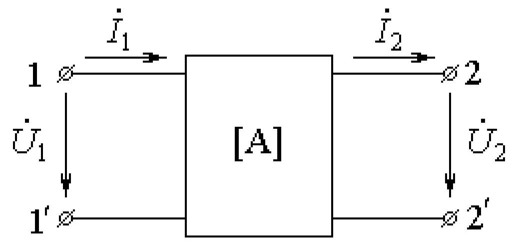

Figure 1.18

The coefficients of the two-port circuits can be determined by known voltages and currents of idling and short-circuit modes by the system of equations with *A*-parameters.

$$\begin{cases} \dot{U}_1 = \underline{A}_{11} \cdot \dot{U}_2 + \underline{A}_{12} \cdot \dot{I}_2 \\ \dot{I}_1 = \underline{A}_{21} \cdot \dot{U}_2 + \underline{A}_{22} \cdot \dot{I}_2 \end{cases}.$$

The coefficients of the passive two-port circuits are related by:

$$\underline{A}_{11} \cdot \underline{A}_{22} - \underline{A}_{12} \cdot \underline{A}_{21} = 1\,.$$

Any linear passive two-port circuit must satisfy this condition.

The input impedance is one which is loading for the source connected to the input ($\underline{Z}_{in1}$) or to output ($\underline{Z}_{in2}$) of the circuit, respectively.

$$\underline{Z}_{in1} = \frac{\underline{A}_{11} \cdot \underline{Z}_l + \underline{A}_{12}}{\underline{A}_{21} \cdot \underline{Z}_l + \underline{A}_{22}} \ ,$$

$$\underline{Z}_{in2} = \frac{\underline{A}_{22} \cdot \underline{Z}_l + \underline{A}_{12}}{\underline{A}_{21} \cdot \underline{Z}_l + \underline{A}_{11}} .$$

The secondary parameters of two-port circuit, expressed through A – parameters:

$$\underline{Z}_{c1} = \sqrt{\frac{\underline{A}_{11} \cdot \underline{A}_{12}}{\underline{A}_{21} \cdot \underline{A}_{22}}} \ ;$$

$$\underline{Z}_{c2} = \sqrt{\frac{\underline{A}_{22} \cdot \underline{A}_{12}}{\underline{A}_{21} \cdot \underline{A}_{11}}} \ ;$$

$$\underline{\Gamma} = a + jb = \ln\left(\sqrt{\underline{A}_{11} \cdot \underline{A}_{22}} + \sqrt{\underline{A}_{12} \cdot \underline{A}_{21}}\right) .$$

In addition, the characteristic impedances $\underline{Z}_{1c}$ and $\underline{Z}_{2c}$ can be expressed through the short circuit ($\underline{Z}_{1sc}$) and idling ($\underline{Z}_{1oc}$) impedances:

$$\underline{Z}_{c1} = \sqrt{\underline{Z}_{1sc} \cdot \underline{Z}_{1oc}} \ ;$$

$$\underline{Z}_{c2} = \sqrt{\underline{Z}_{2sc} \cdot \underline{Z}_{2oc}} \ .$$

The characteristic propagation constant $\underline{\Gamma}$ via the short circuit ($\underline{Z}_{1sc}$) and idling ($\underline{Z}_{1oc}$) impedances is the following:

$$th\underline{\Gamma} = \sqrt{\frac{\underline{A}_{21} \cdot \underline{A}_{12}}{\underline{A}_{22} \cdot \underline{A}_{11}}} = \sqrt{\frac{\underline{Z}_{1sc}}{\underline{Z}_{1oc}}} \ ;$$

$$th\underline{\Gamma} = \sqrt{\frac{\underline{A}_{21} \cdot \underline{A}_{12}}{\underline{A}_{22} \cdot \underline{A}_{11}}} = \sqrt{\frac{\underline{Z}_{2sc}}{\underline{Z}_{2oc}}} \ ;$$

$$e^{2\underline{\Gamma}} = e^{2(a+jb)} = \frac{1 + th\underline{\Gamma}}{1 - th\underline{\Gamma}} \ ;$$

$$\underline{\Gamma} = a + jb = \frac{1}{2} \cdot \ln\left(\frac{1 + th\underline{\Gamma}}{1 - th\underline{\Gamma}}\right) .$$

2 CGW № 2. Calculation of transmission line with distributed parameters

The length of the line *l* and the primary constants of transmission line are given in tables 2.1…2.3: R_0, G_0, L_0 and C_0. Frequency *f*, current I_2 at the end of the line and the load resistance R_L are also known.

2.1 Assignment

Calculate:

1) The secondary constants of transmission line: $\underline{Z}_w$, $\underline{\gamma}$, α and β.
2) The voltage and current at the beginning of the line.
3) The active power at the beginning and at the end of the line, the line efficiency.

Assuming that the line has become lossless line, to calculate:

1) The secondary constants of transmission line: $\underline{Z}_w$, $\underline{\gamma}$, α and β.
2) The voltage and current at the beginning of the line.
3) The active power at the beginning and at the end of the line, the line efficiency.

Table 2.1

Enrolment year	Last digit of the credit book number									
even	1	2	3	4	5	6	7	8	9	0
odd	0	9	8	7	6	5	4	3	2	1
R_0, Ω/km	10	20	15	30	25	16	12	30	40	18
L_0, mH/km	20	12	18	28	30	35	40	15	8	25
f, Hz	30	15	20	10	16	15	45	50	30	20

Table 2.2

Enrolment year	Penultimate digit of the credit book number									
even	1	2	3	4	5	6	7	8	9	0
odd	0	9	8	7	6	5	4	3	2	1
G_0, μS/km	1,1	1,2	1,3	1,4	1,5	1,6	1,7	1,8	1,9	2,1
R_l, Ω	400	350	300	250	200	150	100	50	450	500

Table 2.3

Enrolment year	First letter of the surname									
even	БЛЦ	КХ	ВМЧ	ГНШ	ДОЯ	ЕПР	ЖСЗ	ТЭИ	УЮФ	АЩ
odd	КХ	ВМЧ	ГНШ	БЛЦ	ЕПР	ДОЯ	ТЭИ	ЖСЗ	АЩ	УЮФ
l, km	100	95	90	85	80	75	70	65	60	55
C_0, nF/km	4,0	4,5	5,0	5,5	6,0	6,5	7,0	7,5	8,0	8,5

I_2, mA	100	90	80	70	60	50	40	30	20	10

2.2 Methodological guidelines

A transmission line is a system of conductors connecting one point into another and along which electromagnetic energy can be sent. Thus, telephone lines and power distribution lines are typical examples of transmission lines; however, the term in electronics usually implies a line used for the transmission of radio frequency (r. f.) energy such as one from a radio transmitter to the antenna.

Each of the four transmission line constants R_0, L_0, C_0 and G_0, known as the primary constants, are uniformly distributed along the line.

The secondary characteristic line constants: $\underline{Z}_w$, $\underline{\gamma}$, α and β.

The propagation constant (or propagation coefficient) is a complex quantity given by $\underline{\gamma} = \alpha + j\beta$, where real part α is the attenuation coefficient, whose unit is the Nepers per unit of length (Np/km), and imaginary part β is the phase shift coefficient, whose unit is the radian per unit of length (rad/km).

$$\underline{\gamma} = \sqrt{Z_0 Y_0} = \sqrt{(R_0 + j\omega L_0)\cdot(G_0 + j\omega C_0)} = \alpha + j\beta .$$

At all points along an infinite line, the ratio of voltage to current is $\underline{Z}_w$, called the characteristic impedance (wave impedance):

$$\underline{Z}_w = \sqrt{\frac{\underline{Z}_0}{\underline{Y}_0}} = \sqrt{\frac{R_0 + j\omega L_0}{G_0 + j\omega C_0}} = z_C \cdot e^{j\theta} .$$

Knowing the current and voltage at the end of the line, one can determine the current and voltage at the beginning of the line:

$$\dot{U}_1 = \dot{U}_2 ch\underline{\gamma}l + \underline{Z}_w \dot{I}_2 sh\underline{\gamma}l ;$$
$$\dot{I}_1 = \frac{\dot{U}_2}{Z_w} sh\underline{\gamma}l + \dot{I}_2 ch\underline{\gamma}l .$$

For a lossless line, $R_0 = G_0 = 0$ the characteristic impedance $\underline{Z}_w$ is given by

$$Z_w = \sqrt{\frac{L_0}{C_0}} .$$

If losses R_0 and G_0 are neglected, the propagation coefficient $\underline{\gamma}$ is given by

$$\underline{\gamma} = j\omega\sqrt{L_0 C_0} = j\beta ,$$

i.e. attenuation coefficient $\alpha = 0$ and phase shift coefficient:

$$\beta = \omega\sqrt{L_0 C_0} \ .$$

References

Main references

1 Introductory Circuit Analysis / Robert L. Boylestad. – 13th edition 2015. – 1224 p.

2 Fundamentals of Electric Circuits / Charles K. Alexander, Matthew N. O. Sadiku. – 5th edition 2013. – 995 p.

3 John Bird. Electrical Circuit Theory and Technology. – Third edition, 2007. – 694 p.

Additional references

1 Зевеке Г. В., Ионкин П. А., Нетушил А. В., Страхов С. В. Основы теории цепей. – М.: Энергоатомиздат, 1989. – 528 с.

2 Шебес М. Р., Каблукова М. В. Задачник по теории линейных электрических цепей. – М.: Высшая школа, 1990. – 544 с.

3 Денисенко В. И., Зуслина Е. Х. ТОЭ. Учебное пособие. – Алматы: АИЭС, 2000. – 83 с.

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