Microwave Engineering

Notes & Tutorials

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Introduction

TODO - PUT SOMETHING RELEVANT HERE I wrote this document for the students studying Optical Communication Networks to have a nice set of notes, and correct reference code and graphs for the module. I hope that it is sufficient for this task and it helps all of your studies.
I spent have spent a lot of time developing the template used to make this LaTeX document, I want others to benefit from this work so the source code for this template is available on GitHub [1].

1 Some Things

TODO - PREVIOUS LESSONS

2 Impedance Matching

2.1 Part One

TODO - PART ONE

2.2 Part Two - Quarter-Wave, Binomial Multi-section, and Chebshev Multi-section Transformer

2.2.1 The Quarter-Wave Transformer

TODO - CIRCUIT DIAGRAMS OF TRANSFORMER CIRCUIT
TODO - PREAMBLE ABOUT THE TRANSFORMER

Pros:

- Simple Design
- Can be modified to be a multi-section transformer

Cons:

- It can only match real loads
- Single, central frequency design and operation range

TODO - GTRAPH OF REFLECTION COEFF. VS THETA = BETA times L

For a TEM Transmission Line TODO

2.2.2 Theory of Small Reflections

The quarter-wave shown, is useful as a transformer but it is limited in it's frequency range, it is however possible to cascade transformer sections to obtain more desirable frequency domain properties, this is accomplished using the theory of small reflections. We shall first study a single section.

Single Section Transformer TODO - CIRCUIT DIAGRAM FOR SINGLE SECTION

We can imagine that we have a single section of a transmission line which has an incident wave T_{12} and a reflected wave T_{21}, we can state that:

$$T_{21} = 1 + \Gamma_1$$
$$T_{12} = 1 + \Gamma_2$$

These imply:

$$\Gamma_1 = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$
$$\Gamma_3 = \frac{Z_L - Z_2}{Z_L + Z_2}$$
$$\therefore \Gamma_2 = -\Gamma_1$$
$$\implies T_{21} = \frac{2Z_2}{Z_2 + Z_1}$$
$$\& T_{12} = \frac{2Z_1}{Z_2 + Z_1}$$

We can see and imagine that these reflections will repeat an infinite number of times, the following diagram illustrates this:

TODO - Diagram of reflections

So what is gamma in this model?:

$$\Gamma = \Gamma_1 + T_{12}T_{21}\Gamma_3 e^{-2j\theta} + T_{12}T_{21}\Gamma_3^2\Gamma_2 e^{-4j\theta} \dots$$

This is more concisely stated as:

$$\Gamma = \Gamma_1 + T_{12}T_{21}\Gamma_3 e^{-2j\theta} \sum_{n=0}^{\infty} \Gamma_2^n \Gamma_3^n e^{-j2n\theta}$$

If the discontinuities of the above equations are small, i.e. $|Z_1 - Z_2|$ and $|Z_2 - Z_L|$ are small, this implies:

$$|\Gamma_1 \Gamma_2| \ll 1$$
$$\Gamma \approx \Gamma_1 + \Gamma_3 e^{-2j\theta}$$

Multi-Section Transformer So, now we can apply the previous formulas in a cascade, one after the other, to obtain more desireable frequency charateristics. However, there are some assumptions required in order to do this, all the lines involved must have an identical electrical length, θ. And, the load impedance, Z_L, must be bigger than the input impedance, Z_0, i.e. $Z_L > Z_0$. This assumptions are necessary so that the individual section impedances, Z_n, will decrease and the individual section reflection coefficients will be less than 0, i.e. $\Gamma_n < 0$. The diagram of the scheme of a Multi Section Transformer is shown below:

TODO - DIAGRAM OF MULTI SECTION TRANSFORMER

So given these conditions we can state:

$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 e^{-j2\theta} + \Gamma_4 e^{-j4\theta} + \cdots + \Gamma_n e^{-j2n\theta}$$

If he transformer is symmetrical, i.e.:

$$\begin{gathered} \Gamma_0 = \Gamma_n \\ \Gamma_1 = \Gamma_{n-1} \\ \Gamma_2 = \Gamma_{n-2} \\ \ldots \end{gathered}$$

This simplifies further to:

If n is even:

$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 e^{-j2\theta} + \Gamma_4 e^{-j4\theta} + \cdots + \Gamma_n e^{-j2n\theta}$$

If n is odd:

$$\Gamma(\theta) = \Gamma_0 + \Gamma_1 e^{-j2\theta} + \Gamma_4 e^{-j4\theta} + \cdots + \Gamma_n e^{-j2n\theta}$$

Binomial, Multi-Section Transformer This type of transformer will give us the flattest response possible, at the expense of the overall bandwidth of the transformer:

$$\Gamma(theta) = A(1 + e^{-2j\theta})^n$$

References

[1] A. Wilson. (2021, Apr.) Academic report template. GitHub. (accessed: 16.07.2021). [Online]. Available: https://github.com/AS-Wilson/Academic-Report-Template/tree/dev-AS-Wilson