

Application of Microwave Simulation Software ADS in Teaching Practice of Electromagnetic Field and Microwave Technology Course

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Abstract

Electromagnetic field and microwave technology is a basic course for communication engineering majors, which is highly practical and comprehensive. Especially the impedance matching theory in the basis of microwave technology, because it involves a large number of theoretical calculations and the application of Smith Chart, making this part of the content not only has the characteristics of abstract concept, and strong engineering practice. Therefore, in view of the problems in the course teaching, it is proposed to use the microwave simulation software ADS to achieve impedance matching on the Smith chart in the course practice, so that students can better understand this part of the content on the basis of theoretical study and combined with application. In the course of study, students' learning interest can be stimulated by introducing ADS software, thereby improving the quality of course teaching has been proven in practice teaching.

Keywords

Microwave technology; ADS; Impedance matching; Teaching practice.

1. Introduction

As a professional basic course of electronic communication, electromagnetic field and microwave technology mainly describes the electromagnetic field theory, transmission line theory, metal waveguide, microwave integrated transmission line, microwave network foundation and microwave components, and other circuit technologies related to RF and microwave [1-4]. Because the content of the course involves a wide range of knowledge, its prerequisite courses include circuit analysis, advanced mathematics, engineering mathematics, college physics, etc. As a basic course for engineering majors, it emphasizes application-oriented, typically including 5G technology represented by mobile communications and military communications. Therefore, with the rapid development of wireless communications, there is an increasing demand for radio frequency and microwave engineering talents. Learning this course well can not only provide a large number of RF and microwave professionals for the society, but also lay a good professional foundation for the students who are preparing for further study, which plays a positive role in the reserve of national microwave communication talents. [4-7]

2. Teaching Problems in the Curriculum

The emphasis and difficulty of the course in the electromagnetic field and microwave technology course is the application of impedance matching theory and Smith chart, which are also the principles and basic theories of microwave circuit design. And this part of the content involves many physical quantities, and the knowledge points are intensive. At the same time, compared with other professional courses in this major, because it covers a large number of abstract theories and formula calculations, the understanding and application of its knowledge

is the biggest challenge students face in studying this course. So, the teaching effect is not satisfactory.

Therefore, in view of the teaching problems in the electromagnetic field and microwave technology courses, the application of the microwave circuit simulation software ADS to practical teaching is proposed. The theoretical study and practical operation are closely linked, practical teaching is used to promote theoretical understanding, and the ADS software is used to solve the actual impedance matching problem.

3. Application of ADS in the Course

The impedance matching mainly involves establishing a topological structure between two designated ports, and at the same time using formulas to derive the parameters of the topological structure quantitatively, and then realize the impedance matching process between the two ports. In theory teaching, for the slightly simple structure, the parameters of topology structure can be calculated by formula, while for the slightly complex structure, because the theoretical calculation is too complex, and it is necessary to use the Smith Chart for impedance matching. However, in terms of reality, there will always be deviations when using a complete Smith chart for circuit design, resulting in inaccurate circuit parameter calculations, especially for students who are just learning this course, it is very difficult. As a result, students are unable to grasp the key content and make students feel boring.

The following will introduce two teaching cases in detail based on the ADS simulation software. Both are matched from 200Ω to 50Ω at the specified frequency point, but it is required to use two topological structures to achieve and obtain their circuit parameters. So that students can understand how to apply the theoretical content in practical engineering, so as to strengthen the transformation from theory to practice.

3.1. Design of Series $\lambda/4$ Impedance Transformation Matching

3.1.1. Theoretical Analysis

Using a single microstrip line for impedance matching can determine the circuit parameters through theoretical calculations. The calculation formulas involved are mainly based on the transmission line input impedance formula (1).

$$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)} \quad (1)$$

It can be found from the above equation that under the condition that the length of the microstrip line satisfies $\lambda/4$, the load, source and characteristic impedance satisfy the above equation relationship. Therefore, under the premise of the load and source impedance, the characteristic impedance of 100Ω can be quickly determined by using equation (1).

$$Z_0 = \sqrt{Z_{in} Z_L} = \sqrt{50 \times 200} = 100$$

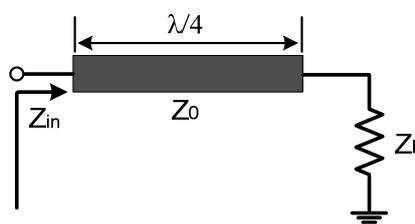


Figure 1. Series $\lambda/4$ impedance transformation topology

3.1.2. ADS Simulation Design

The above is the use of theoretical calculations to obtain the electrical parameters of the impedance matching network. If the ADS simulation software is used for circuit design, the circuit parameters can be determined more quickly, and the matching process can be seen. Figure 2 below shows a schematic diagram of using simulation software to design $\lambda/4$ impedance transformation matching. The specific implementation steps are as follows:

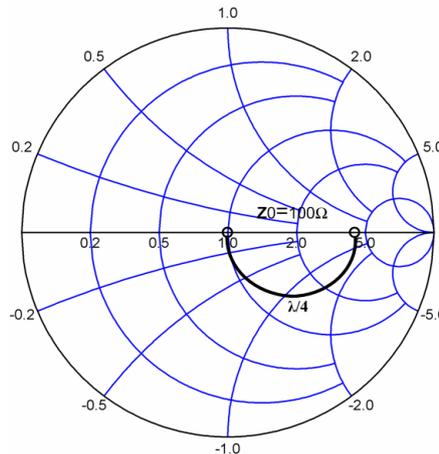


Figure 2. $\lambda/4$ impedance transformation matching

- (1) Enter the design interface of the ADS schematic diagram and select Smith Chart to set the basic parameters;
- (2) Set the frequency to 3.5GHz, the system characteristic impedance to 50 Ω , the source impedance to 50 Ω , and the load impedance to 200 Ω .
- (3) After the basic parameter setting is completed, the impedance value to be matched will be displayed in the Smith circle chart accordingly. According to the design requirements, the topology is a microstrip line of a quarter wavelength in series. Select a serial microstrip line, the software will automatically locate the load impedance point, and rotate clockwise around the constant wave coefficient circle. Therefore, according to the relationship between electric length and phase $\theta = l \times \frac{360}{\lambda}$, setting $\theta = 90$, we can find that the impedance just matches the semicircle. So far, the electrical parameters of series $\lambda/4$ impedance transformation network can be obtained.

3.2. Design of Open-Circuit Terminations Matching Network

3.2.1. Theoretical Analysis

Figure 3 below shows the open-circuit terminations microstrip line impedance transformation topology. The impedance matching frequency is still required to be 3.5GHz, so that the load impedance of $Z_L=200\Omega$ is matched to $Z_{in}=50\Omega$. Among them, the short-circuit terminations microstrip line TL2 causes the impedance to rotate counterclockwise around the conductance circle, changing the imaginary part of the impedance, and finally realizes that the impedance of the matching point is pure resistance. The terminal short-circuit line is also equivalent to a capacitance or an inductance, which mainly depends on its length l . The calculation formula involved is mainly based on the input impedance equation (1) of the transmission line after the load is added, that is, when the terminal impedance is 0, it can be expressed as follows:

$$Z_{in} = jZ_0 \tan(\beta l) \quad (2)$$

By analyzing formula (2), it can be seen that when the length l is taken as $\frac{2n\lambda}{4} \leq l \leq \frac{(2n+1)\lambda}{4}$, its impedance is inductive, so it can be equivalent to inductance; when the value of $\frac{(2n-1)\lambda}{4} \leq l \leq \frac{2n\lambda}{4}$ is taken, its impedance is shown as capacitive, so it can be equivalent to capacitance. Therefore, the open-terminal microstrip line also appears alternately inductive and capacitive.

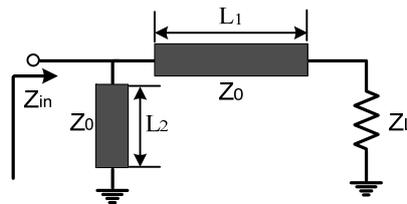


Figure 3. Short-circuit terminations impedance transformation topology

3.2.2. ADS Simulation Design

As shown in Figure 4 below, the impedance transformation diagram of short-circuit terminations microstrip line established in ADS software is shown. Compared with the terminal open circuit in the previous section, only the matching path of TL2 has changed, that is, it rotates counterclockwise to the center of the circle along the equal conductance circle with $y = 1$. Therefore, the length $L1$ and $L2$ can be obtained by reading out the phase changes corresponding to the two paths, so as to determine the circuit parameters.

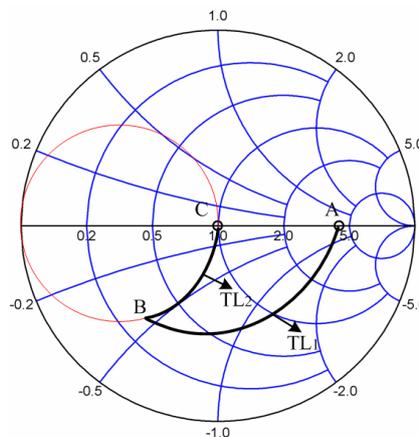


Figure 4. Diagram of short-circuit terminations impedance transformation

From the above two impedance matching examples, we can clearly see the application of the microwave simulation software ADS in impedance matching. Through the theoretical analysis and practical operation of impedance matching, it helps students to better combine theory and practice, and transform abstract and tedious theoretical derivation into vivid learning process. Therefore, the teaching effect of the course is improved to a certain extent.

4. Conclusion

This article applies the radio frequency and microwave simulation software ADS to the electromagnetic field and microwave technology courses. Taking the use of ADS software for impedance matching as a design example, two different topological structures are introduced. By intuitively presenting the obscure impedance matching theory in the teaching of software simulation, it guides students to transform theory into practice and stimulates their enthusiasm

for learning. Practical teaching proves that the introduction of ADS software in the teaching process can help students better understand and master the impedance matching theory in the course, thereby effectively improving the teaching quality of the course.

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