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Design and Analysis of Coaxial Transmission Lines

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Abstract

This paper attempts to design a coaxial cable using standard design formula. Simulation is done using empirical methods designing of coaxial transmission line. The coax is designed with a cut-off frequency of 1.25 GHz with TEM mode. The characteristic impedance of the coax is 50Ω. The aim here is to help the reader design a correct coaxial cable at the port of an antenna. Design formula for calculation of cut-off frequency, characteristic impedance, inductance and capacitance are revisited and implemented for the analysis and design of a 50ohm coaxial transmission line. Coaxial wire is also compared with other transmission line.

Keywords: *characteristic impedance, capacitance, inductance, coax*

1. Introduction

In many communication systems, it is often necessary to interconnect points that are far apart from each other. The connection between a transmitter and its antenna is a typical example of this. If the frequency is high enough, such a distance may well become an appreciable fraction of the wavelength being propagated. It then becomes necessary to consider the properties of the interconnected wires, since these no longer behave as short circuits. It will become evident that the size, separation and general layout of the system of the wires becomes significant under these conditions.

Transmission lines are considered to be impedance matched circuits designed to deliver power (RF) from the transmitter to the antenna, and maximum signal from the antenna to the receiver.

There are two types of transmission lines: balanced and unbalanced. Coaxial wire comes under unbalanced transmission lines. The parallel wire lines are employed where balanced properties are required, like in connecting a half wave dipole or a rhombic antenna. A coaxial line is used where unbalanced properties are required, such as the interconnection of a broadcast transmitter to its grounded antenna. It is also employed at UHF and microwave frequencies, to avoid risk of radiation from the transmission line itself.

Any system of conductors is likely to radiate RF energy if the conductor separation approaches half wavelength at operating frequency. This is far more likely to occur in parallel wire transmission lines than in a coaxial line, whose inner conductor is surrounded by the outer conductor which is invariably grounded. Parallel wires are never used for microwaves; whereas coaxial wires may be employed for frequencies upto 18 GHz. Coaxial lines have a higher limit on frequencies as opposed to waveguides.

Table 1 Comparison of Microwave Transmission lines

Characteristics	Coax	Waveguide	Stripline	Microstrip line
Preferred Mode	TEM	TE_{10}	TEM	quasi-TEM
Other modes	TM, TE	TM, TE	TM, TE	TM, TE
Dispersion	None	Medium	None	Low
Bandwidth	High	Low	High	High
Loss	Medium	Low	High	High
Power Capacity	Medium	High	Low	Low
Physical Size	Large	Very Large	Medium	Small

Fabrication Ease	Medium	Medium	Easy	Very Easy
Component Integration	Hard	Hard	Fair	Easy

2. Calculation and Design of Coaxial Line

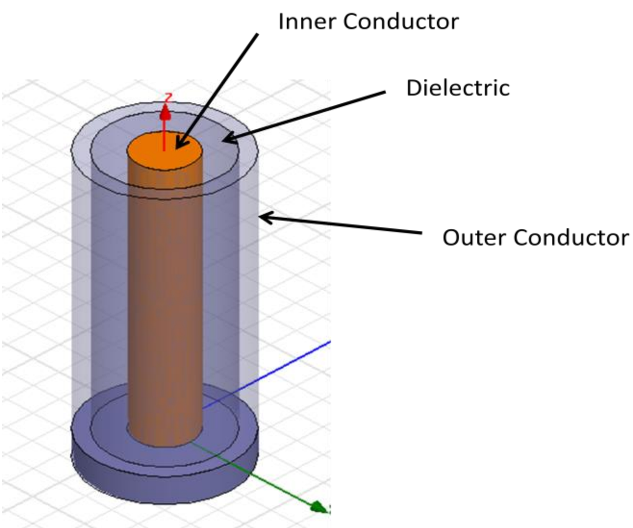

Fig. 1 Coaxial Cable

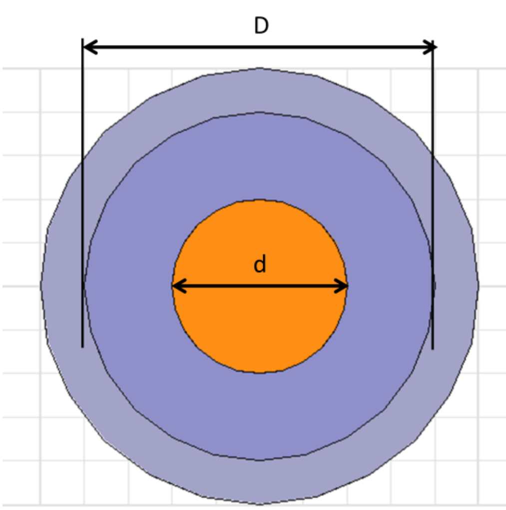

Fig. 2 Cross Section of Coax

Fig 1 shows the designed coaxial line using HFSS. Fig 2 shows the inner (d) and outer (D) diameter of the coaxial wire. A metal cap is also attached at the bottom of the coaxial cable.

Design formulae for coaxial cable design

$$Z_0(ohms) = \frac{138 \times \log_{10}\left(\frac{D}{d}\right)}{\sqrt{\varepsilon_r}} \quad (1)$$

$$C(pF) = \frac{7.354 \times \varepsilon_r}{\log_{10}\left(\frac{D}{d}\right)} \quad (2)$$

$$L\ (nH) = 140.4 \times \log_{10}\left(\frac{D}{d}\right) \quad (3)$$

$$fc\ (GHz) = \frac{11.8}{\sqrt{\varepsilon_r} \times \pi \times \left(\frac{D+d}{2}\right)} \quad (4)$$

Above formulae is used to find the inner and outer diameter of the coaxial line. The characteristic impedance of the coaxial line is mostly 50Ω. ε_r is the dielectric constant of the insulator between inner and outer conductor. Cut off frequency of the coaxial wire has a higher cut off when working on TEM mode. Coaxial line can also support TE and TM modes like waveguides in addition to TEM modes. In practice these modes are usually cut-off modes (evanescent) and also have only reactive effect near discontinuities or sources, where they are excited. It is is an important practice to be aware of the cut – off frequency of lowest order waveguide type modes to avoid propagation of these modes, Otherwise destructive effects may occur, due to superposition of two or more propagating modes with different propagation constants.

Formula for cut off frequency and for characteristic impedance is used to calculate the inner and outer diameters of the coaxial cable. The calculation is explained as below:

Let the characteristic impedance of coaxial line be 50Ω and ε_r=1 for free space between two conductors. Let the cut off frequency of the coax be 1 GHz.

From equation (1)

$$50 = 138 \times \log_{10}\left(\frac{\mathrm{D}}{\mathrm{d}}\right)$$

$$\log_{10}\left(\frac{D}{d}\right) = \frac{50}{138}$$

$$\frac{D}{d} = 2.3 \qquad (5)$$

Also from equation (4)

$$1 = \frac{11.8}{\pi \times \left(\frac{D+d}{2}\right)}$$

$$D + d = \frac{11.8 \times 2}{\pi}$$

$$D + d = 7.5 \qquad (6)$$

From equation (5) and (6)

$$D = 5.22mm, \; d = 2.27mm$$

The above calculations consider the capacitance and inductance to be zero at the operating frequency. The length of the coaxial wire is taken as 10 mm which is 10 times the operating wavelength. Equation (3) ignores that length also has a vital role in making the coax inductive because the length of the wire is not a very large fraction of wavelength in this paper.

Also to reduce the capacitance of the coax (equation (2)), the space between the inner and the outer conductor is filled with free space which is not practically possible.

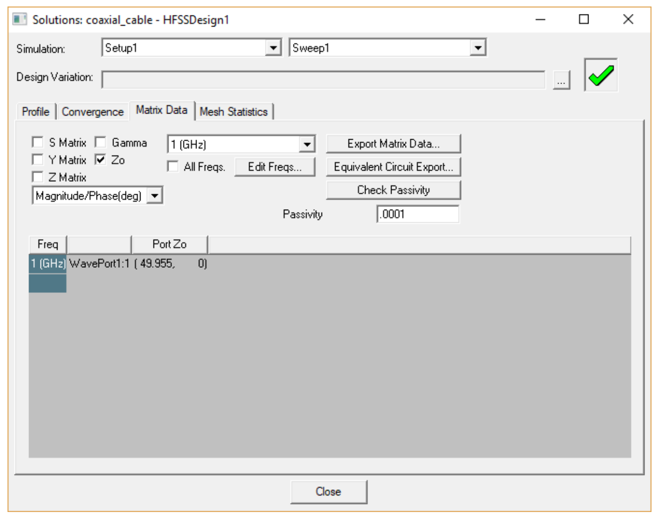

Fig. 3 Simulation Result

3. Conclusion

The simulation results comply with the calculations and the characteristic impedance of the coaxial line is nearly equal to 50Ω. The reactive part of this impedance is 0. This design methodology can help the scholars who are designing a probe fed microstrip patch antenna.

4. References

[1] D.M. Pozar, "Microwave Engineering", 2nd edition, John Wiley & Sons, Inc., Publication
[2] Samuel Y. Liao, "Microwave Devices and Circuits", 3rd edition, Pearson Education.
[3] Matthew N O Sadiku, "Elements of Electromagnetics", 3rd Edition, Oxford Press
[4] Kennedy and Davis, "Electronic Communication System" 4th edition, Mc Graw Hill
[5] Hayt, Buck, Akhtar, "Engineering Electromagnetics" 8th edition, Mc Graw Hill Edition

[6] M Kulkarni, "Microwave and Radar Engineering", #rd edition, Umesh Publication
[7] O Heaviside, "Electromagnetic Theory", vol 1, 1983, reprinted by Dover, New York, 1950
[8] Lord Rayleigh, "On the passage of electric waves through tubes", Philos. Mag. vol 43, pp 125-132, 1897, Reprinted in Collected papers, Cambridge University Press, 1902
[9] K. S. Packard, the Origin of waveguides: A Case of Multiple Rediscovery", IEEE Trans, Microwave Theory and Techniques, vol MTT 32, pp 961-969, Sept 1984
[10] D. D Grieg and H.F. Eaglemann, "Microstrip – A New Transmission Technique for Kilomegacycle Range", Proc. IRE vol 40, pp. 1644-1650, December 1952