Parallel Circular Conductor Transmission Line Calculator

Serge Y. Stroobandt, ON4AA

Introduction

This calculator is a tool for designing balanced transmission lines with a specific desired characteristic impedance Z_c and made of parallel circular conductors of a given diameter d. Round open wire Lecher line, ladder or window line and twin-lead line are all balanced transmission lines which are frequently encountered as the feed line of severely mismatched multi-band wire antennas, especially the G5RV antenna. The conductors being massive or hollow does not affect the characteristic impedance.

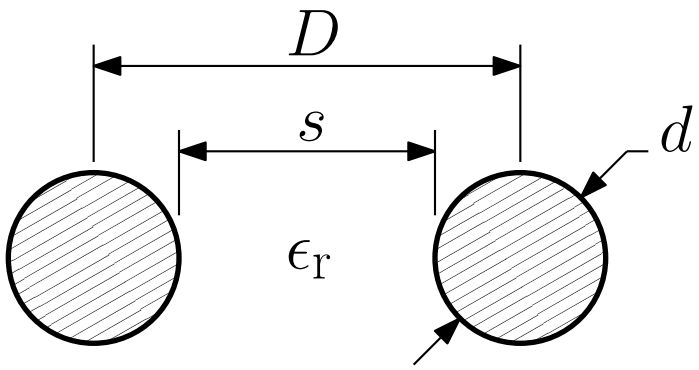

Figure 1: Parallel circular conductor transmission line; dimensions.

Construction

Here is an excellent construction suggestion by Leon Salden, VK3VGA. He devised a ladder line spreader built from durable and readily available materials; a black cable tie and black polyethylene (PE) irrigation extension tube. For smaller separation distances, black LED spacers can also be used.

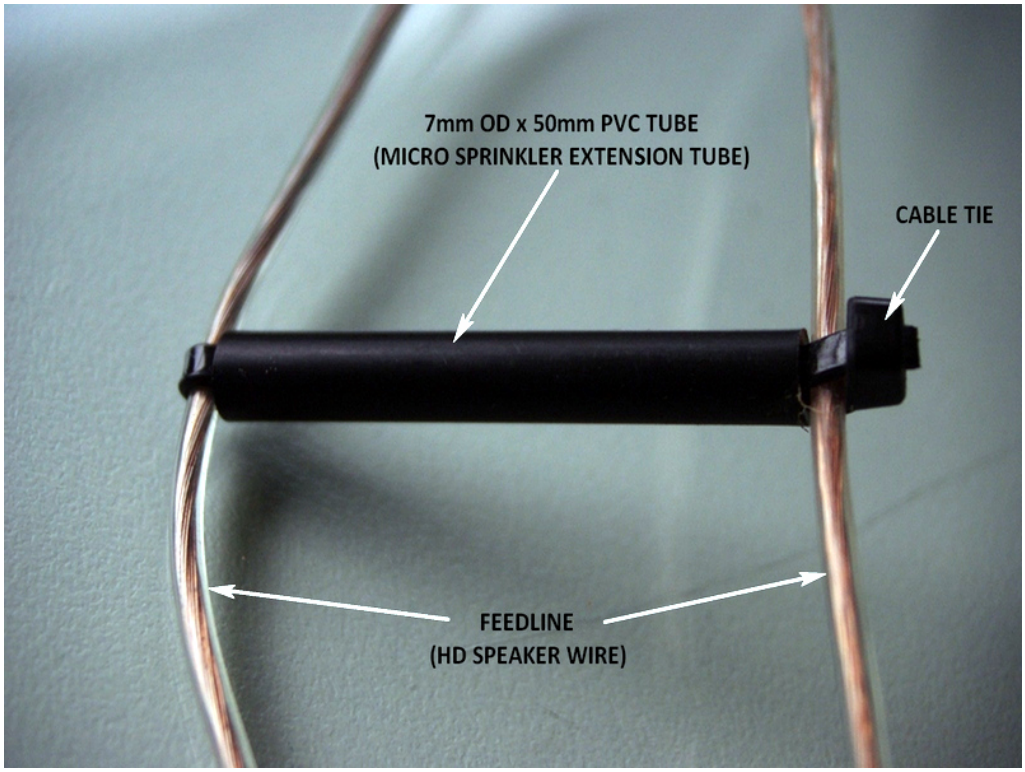

Figure 2: Ladder line spreader built from black irrigation extension tube and a cable tie.
Source: Leon Salden, VK3VGA

Formulas

Following formula can be derived for the characteristic impedance of a parallel wire transmission line:[1]

$$Z_c = \frac{Z_0}{\pi\sqrt{\epsilon_r}} \operatorname{acosh}\left(\frac{D}{d}\right) \tag{1}$$

The characteristic impedance of free space is exactly:

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} = \mu_0 \cdot c_0 \approx 376.73\,\Omega \tag{2}$$

where:
$c_0 = 299\,792\,458\,\frac{\mathrm{m}}{\mathrm{s}}$: the speed of light in free space
$\mu_0 = 4\pi \cdot 10^{-7}\frac{\mathrm{H}}{\mathrm{m}}$: the free space permeability
$\epsilon_0 = \frac{1}{\mu_0 c_0^2}$: the absolute permittivity of free space
Z_0: the characteristic impedance of free space

Rearranging and solving Eq. 1 for D:

$$D = d \cdot \cosh\left(\pi \frac{Z_c}{Z_0}\sqrt{\epsilon_r}\right) \tag{3}$$

$$s = D - d \tag{4}$$

where:
D: the centre to centre distance
d: the diameter of the circular conductors
Z_c: the desired characteristic impedance of the transmission line
Z_0: the characteristic impedance of free space
ϵ_r: the relative dielectric constant of the surrounding medium (1.00054 for air)
s: the space between the circular conductors

Brython source code

Here is the Brython code of this calculator. Brython code is not intended for running stand alone, even though it looks almost identical to Python 3. Brython code runs on the client side in the browser, where it is transcoded to secure Javascript.
License: GNU GPL version 3
Download: `zc.circular.py`

Measuring characteristic impedance

The characteristic impedance of a transmission line can easily be determined from two vector network analyser (VNA) measurements. This is explained in detail here.

References

1. Robert A. Chipman. *Theory and Problems of Transmission Lines*. McGraw-Hill Book Company; 1968.