Star Quad Transmission Line Calculator

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Introduction

This calculator is a tool for designing a *star quad* open-wire balanced transmission line, also known as *quadro line* or as *four-wire cross-connected balanced feeder.*[1(pp401-402)] Such a line is similar to star quad microphone cable, but then open and straight.

Four open-wire conductors carry the two legs of the balanced line. These four conductors are arranged in a four-pointed star, forming a square. Opposite points of the star are connected together at each end of the cable to form each leg of the balanced circuit (Figure 1).

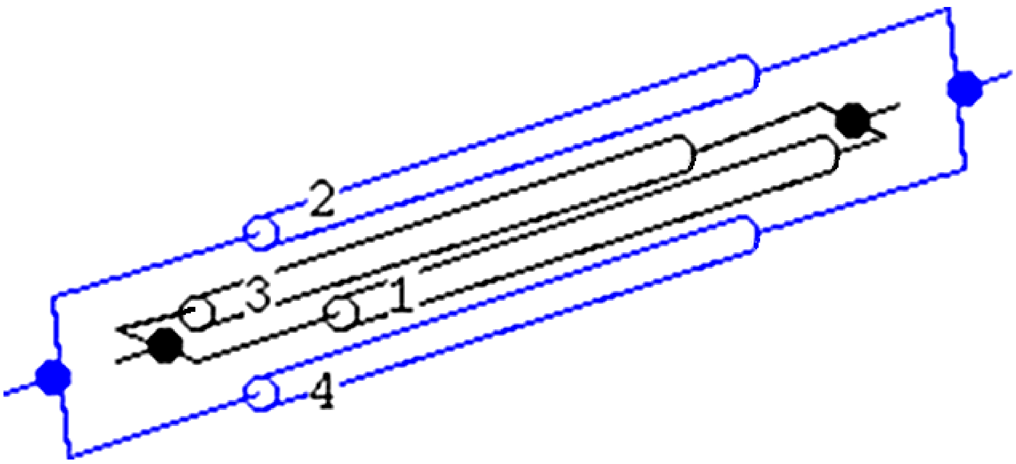

Figure 1: Connection diagram of the star quad transmission line. *Adapted from:* Screen (shield) mechanism for wire and cable, Mogami International Trading Inc., Japan.

Given the desired characteristic impedance Z_c and the diameter d of the four parallel circular conductors, the calculator yields the required diagonal distance D between the wire centres (Figure 2). The conductors being massive or hollow does not affect the characteristic impedance.

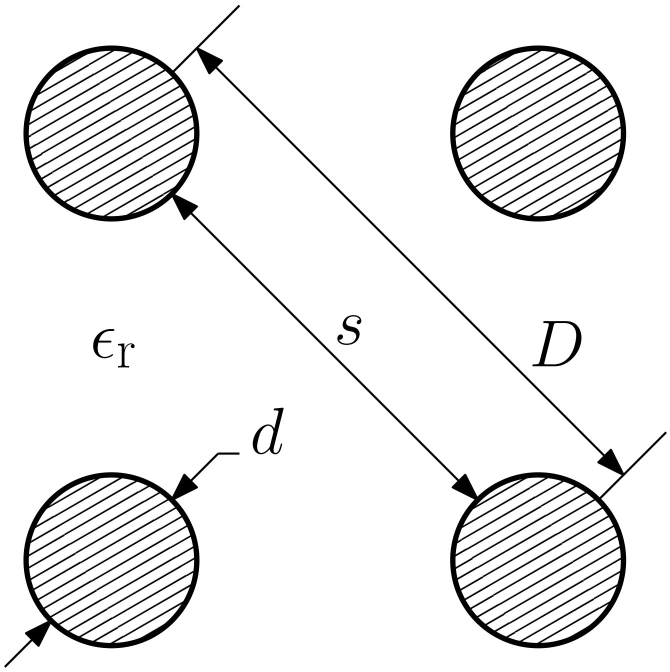

Figure 2: Dimensions of the star quad transmission line

Star quad open-wire transmission line offers a lower characteristic impedance than open-wire ladder line for the same separation between the wires. This renders constructing 200 Ω star quad line feasible, where it is not for ladder line. Below 300 Ω, the construction of twin-line becomes impracticable and, moreover, weather susceptible because of its tiny width. Star quad open-wire line is particularly useful for feeding any antenna involving a 4÷1 200 Ω balun; like many off-center fed dipole (OCFD) antennas and many large horizontal loop antennas.

Suppression of magnetic interference

Another highly desirable benefit of star quad open-wire transmission line is that, compared to twin line, it offers 10 to 30 dB suppression of magnetically induced interference.[2,3] This is due to both wire pairs forming loops around the center of the star, exposing exact equal loop areas to any interfering external magnetic field. Such a magnetic field will induce equal electromotive forces (voltages) and corresponding equal currents. These induced and interfering common mode currents will be ignored by the balun feeding the star quad line. Only differential mode signals will be converted by the balun into an asymmetrical signal.

This, again, is a useful feature for feeding OCFDs. Common mode currents induced on the feed line of an asymmetrical antenna will be effectively suppressed.

Construction

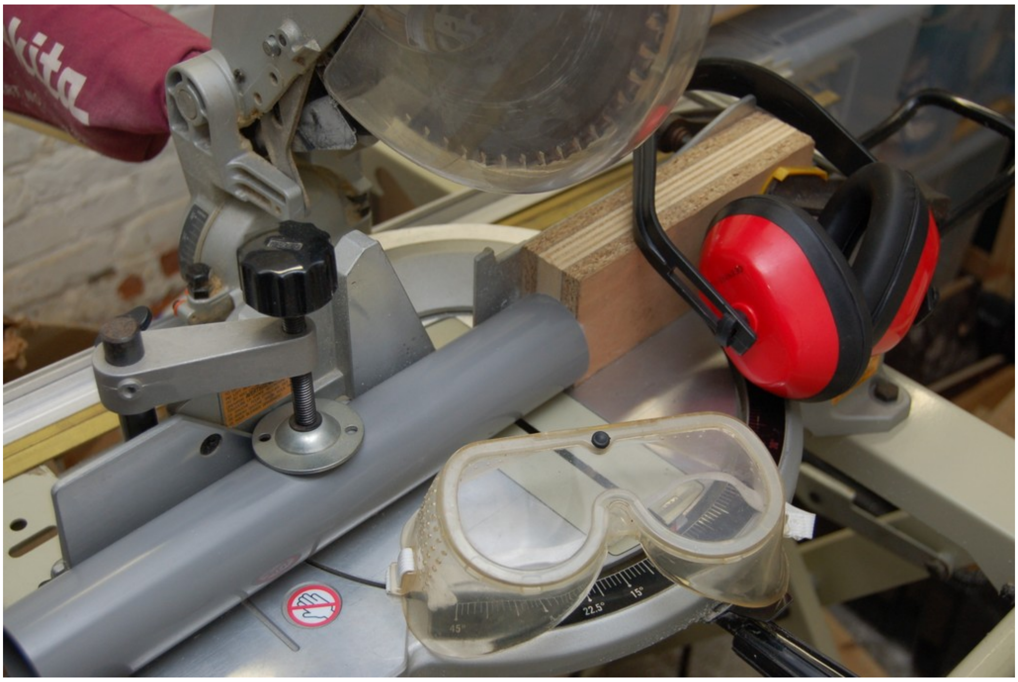

Figure 3: Cutting 36 mm lengths of thin-walled OD 50 mm PVC pipe with a mitre saw. A clamped block of wood at 36 mm from the saw blade serves as an end stop. Use personal protective equipment (PPE) when operating power tools.

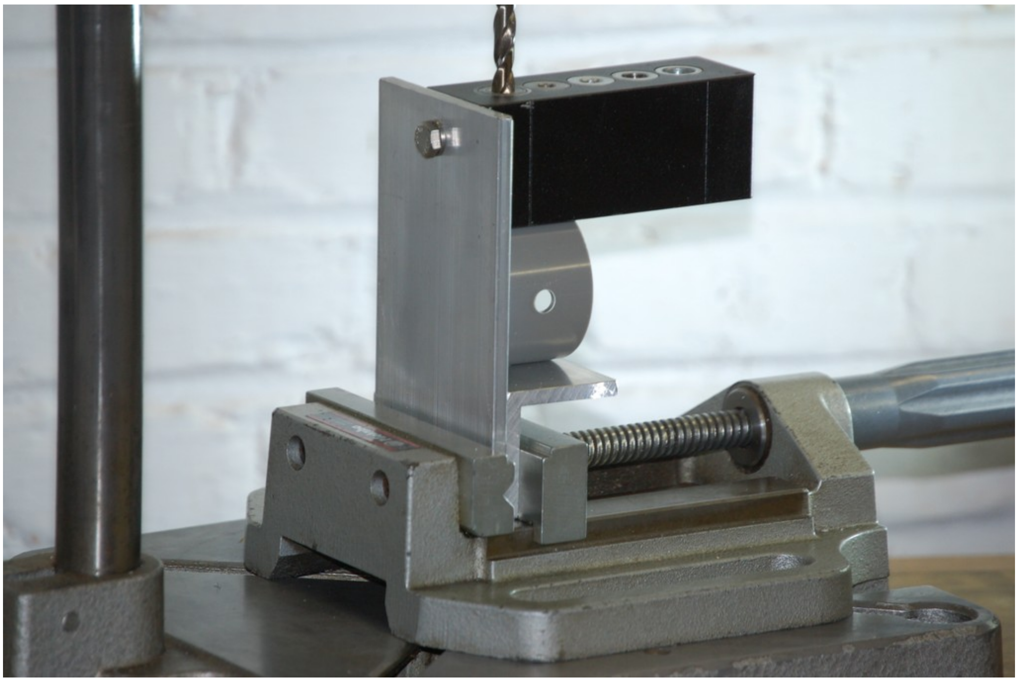

Figure 4: Drilling a PVC spreader for an open star quad line using a slightly modified V-block from Aliexpress. The V-block is screwed against an aluminium back panel. The pipe for the spreader is OD 50 mm thin-walled grey PVC. It fits snugly between the V-block and the pre-drilled aluminium angle stock. The PVC pipe is 36 mm wide, putting the first hole of the V-block at its center. Four holes are drilled two at a time with a ⌀7 mm HSS drill bit. Always drill vertically through a V-block and apply ample lubricant to prevent wear of the V-block drill cylinders.

TODO: Add a picture of the finished line.

Formulas

The following formula[1(p402),4(p151),5] approximates the characteristic impedance Z_c of a star quad open-wire parallel transmission line for $d \ll D$:

$$Z_c \approx \frac{138}{\sqrt{\epsilon_r}} \log_{10}\left(\frac{D}{d}\right) \tag{1}$$

Rearranging and solving (1) for D:

$$D = d \cdot 10^{\left(\frac{Z_c}{138}\sqrt{\epsilon_r}\right)} \tag{2}$$

$$s = D - d \tag{3}$$

where:
D: the centre to centre diagonal distance
d: the diameter of the circular conductors
Z_c: the desired characteristic impedance of the transmission line
ϵ_r: the relative dielectric constant of the surrounding medium (1.00054 for air)
s: the diagonal 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.star_quad.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. Edmond A. Laport. *Radio Antenna Engineering*. McGraw-Hill Book Company, Inc.; 1952. https://www.snulbug.mtview.ca.us/books/RadioAntennaEngineering/

2. *Evaluating Microphone Cable Performance & Specifications*. Canare Electric Co., Ltd. http://www.canare.com/UploadedDocuments/A Technical Paper - Evaluating Microphone Cable Perfrmance and Specifications.pdf

3. Benchmark Media Systems, Inc. Star-quad microphone cable demonstration. Published 2016. https://www.youtube.com/watch?v=9ckp5CYBBjE

4. Alois Krischke, DJ0TR. *Rothammels Antennenbuch*. 13th ed. DARC Verlag GmbH; 2013. https://darcverlag.de/Rothammels-Antennenbuch

5. RF Cafe. Transmission line equations. https://www.rfcafe.com/references/electrical/transmission-lines.htm