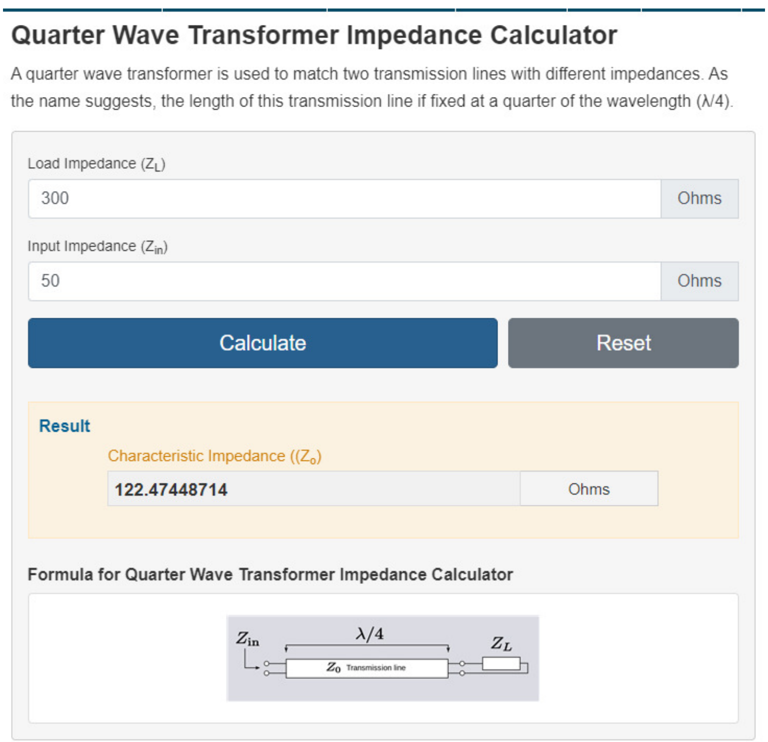
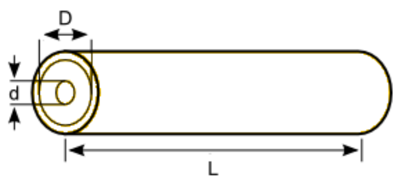
Folded Dipole 1/4 Wave Match

The following is a collection of information from various Internet sites compiled by MH VK2JMJ. The target is to construct a free standing side mounted folded dipole that could also be used on a boom for a Yagie.
At a centre frequency of 146.000 Mhz and interfacing 50 Ohms coax into a folded dipole.
The centre gap of the folded dipole is about 300 Ohms balanced.
The feed line is 50 Ohms unbalanced using RG213U.
Using an impedance transformer in the coax length requires a 1/4 wavelength of 122.5 Ohm coax. This is hard to get, so make your own.

Determine the 1/4 wave coax impedance required

https://www.everythingrf.com/rf-calculators/quarter-wave-transformer-impedance-calculator
This in-line length of 1/4 wavelength coax transforms the impedance and provides the un-balanced to balanced transformer. Enter the values of the load impedance as 300 and the input impedance as 50, <calculate> and the value a 122.474 is returned.





Verify the impedance calculation of the RG213U

https://www.everythingrf.com/rf-calculators/coaxial-cable-calculator

Using the actual measurements from the RG213U coax internals, d =2.25mm, D = 7.0mm. Some calculators use relative permittivity in the calculations. What is the relative permittivity of the typical RG213U ? Most specifications give a velocity ratio of 66%. Another site lists the following:

Polyimide	ER = 3.4
Polyethylene	ER = 2.25 (stated as PE, used in RG213U)
Teflon	ER = 2.1

A technical data sheet for RG213U states the inner diameter as 2.29mm, outer as 7.24 and presenting a PE = 2.25. Plugging this into the calculator produces 49.3 Ohms. Close enough.

Verify the impedance calculator using RG58U

A specification sheet was found for the RG58U. Use this data to verify the calculator returns a correct result. It returned an impedance of 45.9, proving the calculator seems to function correctly.

- Inner conductor = d = 0.935 mm
- Dielectric = D = 2.95 mm
- PE = ER = 2.25

Strip a length of RG213U to use as parts

Calculate the required 1/4 wavelength and add an extra amount and cut a length of RG213U. Strip the components out, centre with dielectric, braid and outer sheath.
300 / 146 / 4 = 513 mm. Cut a length at 600mm and strip it for parts.

- Centre conductor diameter = d = 2.22 mm
- Diameter of dielectric = D = 7.0 mm
- Polyethylene dielectric ER = 2.25 (stated as PE, used in RG213U)
- Braid
- Outer sheath, 10.5mm outside diameter.
- Use a bench vice to pull the centre conductors out of the PE dielectric.

If you have strength and talent, draw out the centre conductors without removing the braid or sheath.

What impedance is the coax ?

VK2JMJ has found different methods to determine the impedance of the home made coax. The only element that is controlling the impedance of the home made coax from the recovered parts of the RG213U is the diameter of the centre core. Reducing the conductor size increases the coax impedance.

Method 1, Using the calculator

VK2JMJ found a single core solid electrical 240Vac switch wire in the junk pile with a diameter of 1.00 mm. With this value in the calculator an impedance value of 118 Ohms was returned. Experiment with other single core conductors found in your junk pile. A single core conductor is easier to slide back into the dielectric than twisted smaller conductors.

Method 2, Calculate from L & C in a length

Coax has inductance in the length of the centre conductor and capacitance in length from the centre conductor to the outer braid and some resistance in length. This method requires a device to measure capacitance and measure inductance and ignore the resistance.

https://www.jackenhack.com/cable-impedance-how-to-measure/

This dude proposes to measure the inductance and then measure the capacitance and slam the results into a calculator. It can be argued that a short length of coax will be hard to measure accurately and good test equipment is required.

Method 3, Using a non inductive variable resistor

Using a simple variable resistor (a pot) and a signal generator and a CRO display.

https://www.jackenhack.com/diy-coaxial-collinear-antenna-ads-b-sdr-receiver-measuring-cable/

Send a square wave down the coax. See the propagation delay on the CRO display to the end and the return time of the pulse (being either a short circuit or an open circuit at the far end). The theory being that the coax has created a transmission line transporting the pulse away from the generator. A time delay separates the generator from the end of the coax under test. The pulse travelling in the unknown impedance of the coax (transmission line) will not be reflected when the impedance of the coax matches the impedance of the load. The load pot being a resistive plate with a wiper blade will have very little capacitance and very little inductance so the pot is presenting something close to a pure resistance. Slide the wiper until very little reflection is seen, indicated by a flat top of the original square wave on the CRO display. Disconnect the pot and measure the D/C resistance of the pot to determine the coax impedance. It can be argued that this method will only function correctly on a long length of coax.

Method 4, Using the VNA

Hard to find when using COPY-TUBE. Finally found someone who get's it right and explains the concept quite well.

https://www.youtube.com/watch?v=hqKLFbNYRZc

This fellow is using a 1/4 wave transformer concept. The author explains a need to determine the lowest and highest frequency that the VNA sweep needs to generate. The VNA is programmed to generate a sweep of frequencies slightly greater than the expected 1/4 wave length of the coax under test. The VNA is then calibrated to 50 Ohms for the sweep range programmed and is then connected to the coax under test. The far end of the coax is terminated with a 50 Ohm dummy load.

A 1/4 wavelength of coax is required, however there is no need to cut the coax to a short length for the test. A longer length of coax will have a lower sweep top frequency to achieve a 1/4 wave.

Control the VNA sweep results to determine where the impedance trace crosses onto the centre resistive trace line of the smith chart for the first time. The frequency displayed is at the 1/4 wave length and the impedance displayed is the impedance of the 1/4 wave length of coax that is presented to the VNA.

What happened ? The 1/4 wave length of coax, at the frequency generated by the VNA has created a 1/4 wave transformer. The far end 50 Ohms impedance has been altered by the 1/4 wave transformer of the unknown coax. The impedance of the far end 50 Ohms, via the transformer, is presented to the VNA and displayed. This is the impedance of the coax.

What method to use ? The calculator will be good enough

Using accurate callipers, the centre conductor can be measured. The on-line calculator is the easiest and most suitable for the short length of coax required. Any errors will result in stray capacitance or inductance that will be combined to the construction errors of the dipole. The stray errors are later corrected by other elements and structures that will interact with the dipole in the final installation.

Construction

Insert the single solid strand into the space inside the dielectric PE. Try to keep the replacement as straight as possible. Insert the dielectric into the braid and insert the assembly into the recovered sheath of the RG213U. If you were think ahead and just pulled the centre conductor out and keeping the braid and dielectric and sheath intact, then inserting the new centre conductor is simple.

Use the VNA to determine Electrical length

Cut the home made coax to a 1/4 wave electrical length at the centre frequency of 146 Mhz. Allow 10 mm fly leads at both ends for some terminations. The result should be slightly shorter than the calculated 1/4 wavelength of 300 / 146 / 4 = 513 mm. The VNA will show a VSWR dip when the centre conductor is attached and the braid is grounded to the VNA ground. An open circuit at the far end is only one possible method to use. Mine worked out 475mm.

Construction and Design

This design terminates the 122 Ohm coax to the 300 Ohm dipole centre in a plastic box. The box will hold the element firm and the box will attach to the boom. The coax impedance transformer feed will exit the box and terminate to a 50 Ohm connector at the rear of the support structure. There is no need to ground the Zero Ohms point of the other side of the folded dipole, but you may if it suits you boom design.

Assemble the in-line coax Balun transformer

Solder the 1/4 wave length of re-built RG213U centre conductor to the single side of the element that is the shortest. Solder the outer braid of the 1/4 wave length to the other end of the element. The extra centre conductor length adds to the shorter side, thus extending it. Use zinc screw on tabs to the aluminium and solder the Cu cores to the tabs.

At the feed line end of the 1/4 wave coax, fit a suitable 50 Ohm socket to connect the feed line and protect the socket in a small box. Terminate and solder the 1/4 wave to the socket. The small box may be metal and grounded to the boom or plastic. It could be argued that the feed line outer braid is protected above ground so the junction of the 50 Ohm and 122 Ohm coax should be above ground and held within a plastic box.

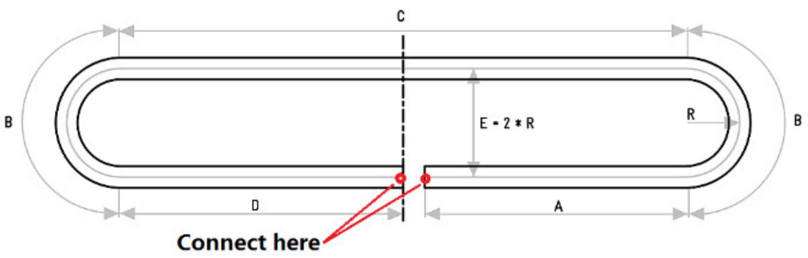
Using a folded dipole calculator

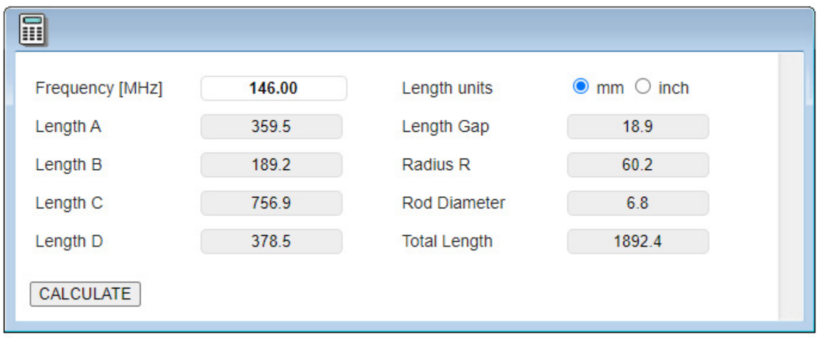
https://www.changpuak.ch/electronics/Dipole_folded.php

Explanation of the difference between dimensions D and A is required. It could be considered that these should be exactly half of C, less 5mm to allow for internal connections. However the extra pig tail of the coax internal conductor will be adding to the length of dimension A, thus returning A back to a correct length. This also requires that the end of the home made coax shield terminate very short to the end of D.

Folded Dipole Calculator

To be combined with a Yagi Uda Antenna or used as is.





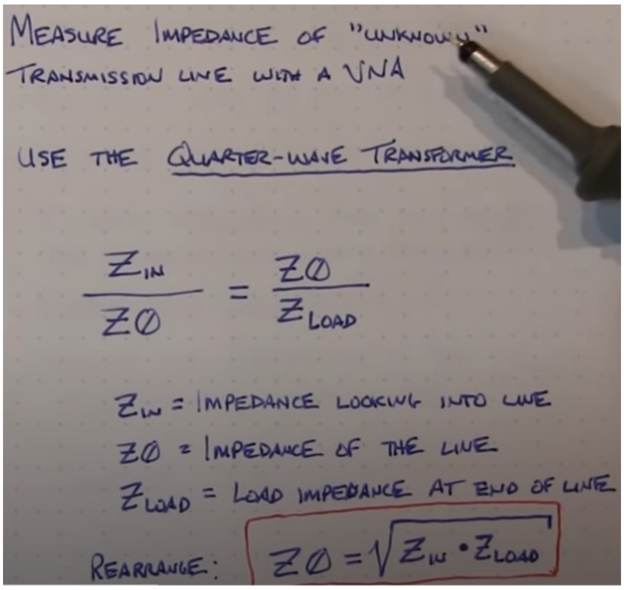
Notes:

Thin tube and small diameter is earier to bend. This design does not insert a RG213 or RG59 into the tube at the Zero Ohms point. If designing a 1/4 Wave transformer using a thiner coax, home made construction of the odd impedance size is difficult. Purchasing the correct impedance coax is difficult and expensive. A home made 1/4 wave transformer made from RG213 is easy, but the disadvantge being it can not be inserted into a tube when considering the bend radius of RG213.

1/4 wave Coax transformer Balun

During this research, the construction of this dipole was known to VK2JMJ, but it remained a mystery how the 1/4 wavelength of coax of a different impedance to the transmission line did not create a reflection point at the junction of the two coaxes. Finally, after the You Tube man using the VNA to determine the unknown coax impedance, the concept became very clear.

The 300 Ohms balanced of the folded dipole is transformed to 50 Ohms un-balanced, but only when the length of 122 Ohm coax is at an electrical length of a 1/4 wave. The centre frequency is a constant and the ER of the coax is a constant and the electrical length is therefore a constant. The only variable remaining is the diameter of the internal conductor that controls the impedance of the home made coax. The 300 Ohms balanced is transformed to 50 Ohms un-balanced at the feed line junction to the 122 Ohm 1/4 wave coax, so there is no reflection at that feed line junction.



Consider the VNA used to determine the impedance of the unknown coax that is terminated at the far end with 50 Ohms. Using the same formula, knowing 300 Ohms and 50 Ohms, the line impedance = 122.5 Ohms.

Experiments after construction

The folded dipole in free air will not present an exact and perfect match. The secret to a perfect match is understanding how the folded dipole element interacts with structures around it. This may be the mounting mask or other antennas nearby.

The easiest method to get a perfect match is to add a little inductance or capacitance by inserting a reflector element between the driven element and the mounting structure. Using a longer reflector adds inductance and adding shorter reflector adds capacitance. Experiment and vary the distance from the element for the perfect match.

If the folded dipole is to be used in a Yagie, very other element will impact on the folded dipole element's centre impedance. Refer to other VK2JMJ Yagie builds.

When using the VNA to tune the element on the structure (the boom) it is important that the VNA be at the rear coax connection. Once the Smith chart is indicating the 50 Ohms at the centre frequency, the VNA can be moved to the shack end.

No common mode currents were detected when using the 1/4 wave coax impedance transformer method.

Using the 1/4 wave coax transformer can (theoretically) match 50 Ohm to 300 Ohms. When using the 4:1 1/2 wave coax balun, 300 / 4 = 75 Ohms. However, when used on a boom structure, directors and reflectors push the centre impedance around so a perfect match is also possible. Refer to other VK2JMJ Yagie builds.

It could be argued that the 1/4 wave transformer balun for 146 Mhz is tidy where a single rebuilt RG213 connects between the boom socket and the driven element. For other 4:1 coax Baluns, the feed line and the 1/2 wave coax length that form the 4:1 Balun, cluster the connection at the boom connection to the driven element.

The BIG advantage of this construction is the ability to draw out the centre conductor of RG213 when a short 600 mm length is required and replace the centre conductor with a very common 1mm solid electrical cable, (switch wire).

Why use a folded dipole on a boom ? I have no idea to an advantage over a simpler design of two 1/4 wave elements that make a typical 1/2 wave driven element with a lower centre impedance that is easily matched with a 1/4 wave sleave (Bazooka style). The only advantage of the folded diople is a larger bandwidth, but that is defeated when placing the folded dipole to a Yagie structure and defeated again when using a 1/4 wave coax transformer Balun.

Other than that, of Course, Why Not !. Have a go !

VK2JMJ Albury

(END) VK2JMJ, October 2023