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Balance and the Guanella 4:1 Transformer

This work examines the effect of balance and imbalance on a Guanella 4:1 Transformer (Figure 1). The issue arose from using a Guanella 200Ω : 50Ω transformer in an Off-Centre-fed-Dipole (OCFD) antenna and whether or not the transformer by itself will act a balun.

How to make a balun is not at issue here. All you need is a 1:1 balun at the input to the Guanella 4:1 Transformer to make a balun, but the need for that is doubtful in an OCFD, where the asymmetry of the dipole relative to the feed will inherently cause unbalance that a balun will probably not cure.

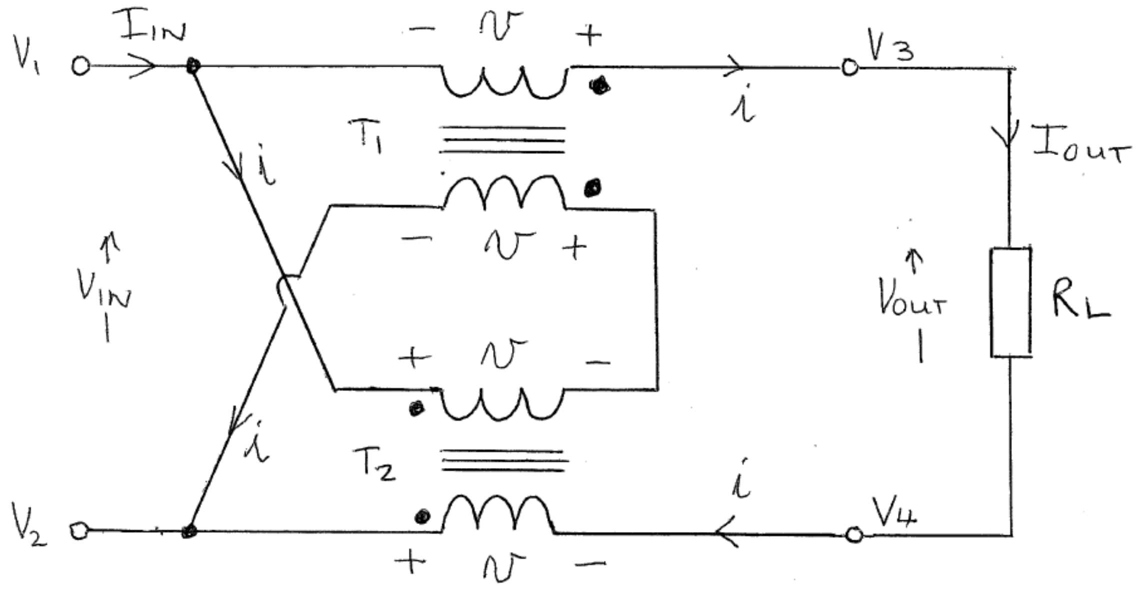

Figure 1: Guanella 4:1 Transformer

Voltage and Current Analysis

The low frequency behaviour of the transformer is easy to analyze and it adequately illustrates the relationship between the input and output voltages and currents. A high frequency analysis is more complicated and it gives essentially the same results as the low frequency analysis over the useful bandwidth of the transformer.

For low frequency analysis, the transformers are treated as ideal transformers, without leakage reactance.

The circuit of Figure 1 can be redrawn as in Figure 2 for an alternative and possibly more familiar view of the same problem.

If the two transformers/transmission lines T1 and T1 are tightly coupled and identical, then the winding voltages and currents are the same. Call the two, *v* and *i* respectively.

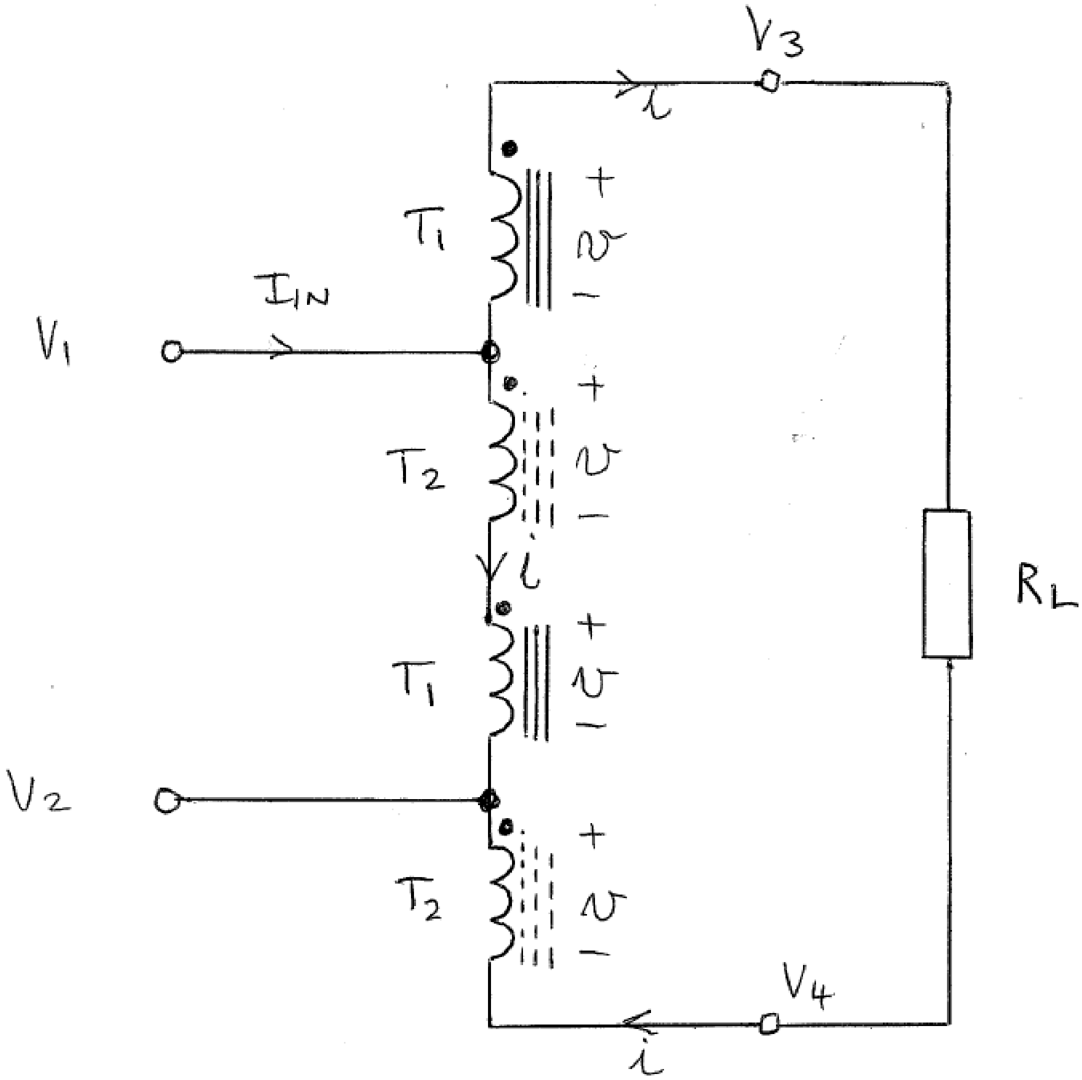

Figure 2: Alternative Circuit of the Guanella 4:1 Transformer

Voltages:

$$V_{IN} = V_1 - V_2 = 2v$$

$$v = \frac{V_1 - V_2}{2}$$

$$V_3 = V_1 + v$$

$$V_4 = V_2 - v$$

$$V_{OUT} = V_3 - V_4 = 4v = 2V_{IN}$$

$V_{OUT} = 2V_{IN}$ a 2:1 voltage transformation

Currents:

$$I_{IN} = 2i$$

$$I_{OUT} = i$$

$I_{OUT} = \frac{I_{IN}}{2}$ a 1:2 current transformation

From the voltages and currents you get the impedance:

$$R_{IN} = \frac{V_{IN}}{I_{IN}} = \frac{v}{i}$$

$$R_L = \frac{V_{OUT}}{I_{OUT}} = 4\frac{v}{i}$$

$R_L = 4R_{IN}$ a 4:1 impedance transformation

The Effect of Balance and Un-Balance

Definition: The two terminal voltages of a balanced port (input or output) are equal and opposite.

If this is not the case, then the port is not balanced.

Balanced Input

If the input is balanced 1V then

$$V_1 = 0.5\text{ V}$$

$$V_2 = -0.5\text{ V}$$

The winding voltage is

$$v = \frac{V_1 - V_2}{2} = 0.5\text{ V}$$

The output voltages are:

$$V_3 = V_1 + v = +1\text{ V}$$

$$V_4 = V_2 - v = -1\text{ V}$$

As the output voltages are equal and opposite, the output is also balanced.

Unbalanced input

If the input is un- balanced 1V <u>and</u> the output is floating (as in the OCFD antenna)

$$V_1 = 1\text{ V}$$

$$V_2 = 0\text{ V}$$

The winding voltage is

$$v = \frac{V_1 - V_2}{2} = 0.5\text{ V}$$

Then the output voltages are:

$$V_3 = V_1 + v = +1.5\text{ V}$$

$$V_4 = V_2 - v = -0.5\text{ V}$$

The output voltages are not equal and opposite, so the output is <u>not</u> balanced and this is not a balun.

Forced Output Balance

This is not applicable to the OCFD, but what if the output is forced to be balanced, by grounding the centre of the load? For example if instead of a 200Ω load, there are two 100Ω loads in series with the centre grounded.

The primary currents of T1 and T2 are equal because they are in series. If the transformers are identical or nearly so, then the secondary currents are also equal. This forces the output voltages to be equal and opposite and hence the output is balanced.

The previous equations remain valid but they need to be rearranged to solve for the input voltages

$$v = \frac{V_3 - V_4}{4}$$

$$V_1 = V_3 - v$$

$$V_2 = V_4 + v$$

For the balanced output, let

$$V_3 = +1\text{V}$$

$$V_4 = -1\text{V}$$

The winding voltage is

$$v = \frac{V_3 - V_4}{4} = 0.5\text{V}$$

The input voltages are

$$V_1 = V_3 - v = +0.5\text{V}$$

$$V_2 = V_4 + v = -0.5\text{V}$$

In this case the input is also balanced and you should not ground either of the input terminals.

Conclusion

The Guanella Transformer is inherently a balanced-to-balanced transformer. However if one of the input terminals is grounded and the load is floating, the load voltages will not be balanced.

The asymmetry of the OCFD will almost certainly unbalance both the input at the output of the Guanella 4:1 transformer, so it cannot be considered to be a balun. It is merely a transformer in that application.

Although not applicable to the OCFD, if the load is forced to be balanced, then the input side must also be balanced and neither input terminal should be grounded.

73, Vincent ZS6BTY