

THE IMPEDANCE POWER TRANSFORMERS

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The power impedance transformer

The power impedance transformer is used to match the antenna impedance to the transmission line and is capable of handling the power in transit.

To minimize losses in the conductors and reduce parasitic effects, auto-transformers are constructed.

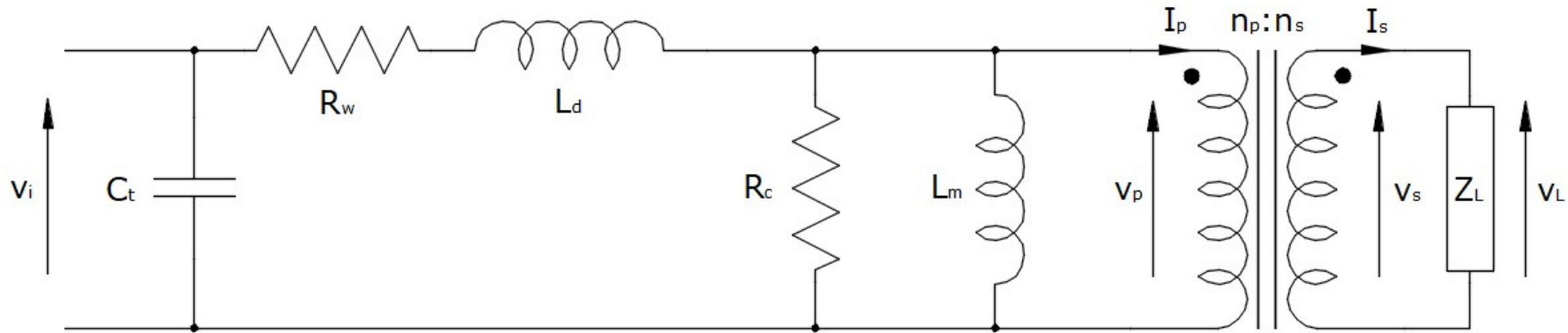
Transformers, or rather auto-transformers, can be built with ferrites of different shapes, but we radio amateurs more frequently use toroidal ferrites, binocular ferrites, and ferrite sleeves.

These shapes can be stacked or placed side by side to increase the cross-section of the magnetic material.



The model of a real RF transformer

The simplified model of a real power transformer is characterized by various components representing the parasitic elements of the actual device.



The model includes:

- C_t : Parasitic capacitance between turns, both in the primary and secondary.
- R_w : Resistance of the conductors in both the primary and secondary.
- L_d : Leakage inductance, resulting from magnetic fluxes that do not link the windings.
- R_c : Not a true resistance but represents losses in the magnetic material.
- L_m : Magnetizing inductance of the transformer.
- The ideal transformer.
- The load impedance Z_L .

The design of the power transformer

The design of a power transformer involves a completely different approach from that used for small-signal transformers (for reception). Indeed, the main enemy to combat is the heat developed by the transformer. The efficiency (η) of the transformer is the parameter that best reflects the ability to transfer energy from the primary to the secondary. In fact, efficiency is defined as the ratio of the incoming power (P) minus the losses (S) divided by the incoming power:

$$\eta = \frac{P - S}{P}$$

That said, the steps to be taken to create power transformers are six:

- 1) Decide on the best typology.
- 2) Choose the most suitable ferrite.
- 3) Select the conductors.
- 4) Verify the operating parameters with the spreadsheet.
- 5) Build the transformer.
- 6) Verify the performance with the VNA (Vector Network Analyzer).

1) Decide on the best typology

Choosing the best design is not a simple task, and often several trials are necessary. Essentially, one must minimize parasitic effects both in copper and magnetic material. It is crucial to minimize power dissipation to prevent overheating of the ferrite, which, if not dissipated, could exceed the Curie temperature.

The elements generating heat are the resistance of the conductors (R_w), due to the Joule effect, exacerbated by skin and proximity effects, and losses in the magnetic material (R_c), due to hysteresis and eddy currents.

Therefore, in choosing the typology, it is essential to consider those that use:

- Autotransformers; primarily because they minimize losses in conductors.
- Fewer turns; always to reduce parasitic effects in general.
- Multi-strand lines; to reduce the proximity effect.
- Ferrites with a low permeability value (μ''); which is the parameter indicating losses in the magnetic material.
- Finally, those indicating the real efficiency of the transformer; which should not be less than 90%.

However, navigating through the multitude of designs available online is not easy. Personally, I recommend the projects presented by Sevick in the book '**Transmission Line Transformers Handbook**' published by Amidon Associates Inc, because I have always found them excellent.

2) Choose the most suitable ferrite

As I have already mentioned, the best ferrite is the one that, in the field of use, has the highest magnetic permeability (μ') and the smallest magnetic loss factor (μ'').

In HF, ferrites of grades such as:

- 52 (also known as K),
- 61,
- occasionally 43 for lower bands, are usually used.

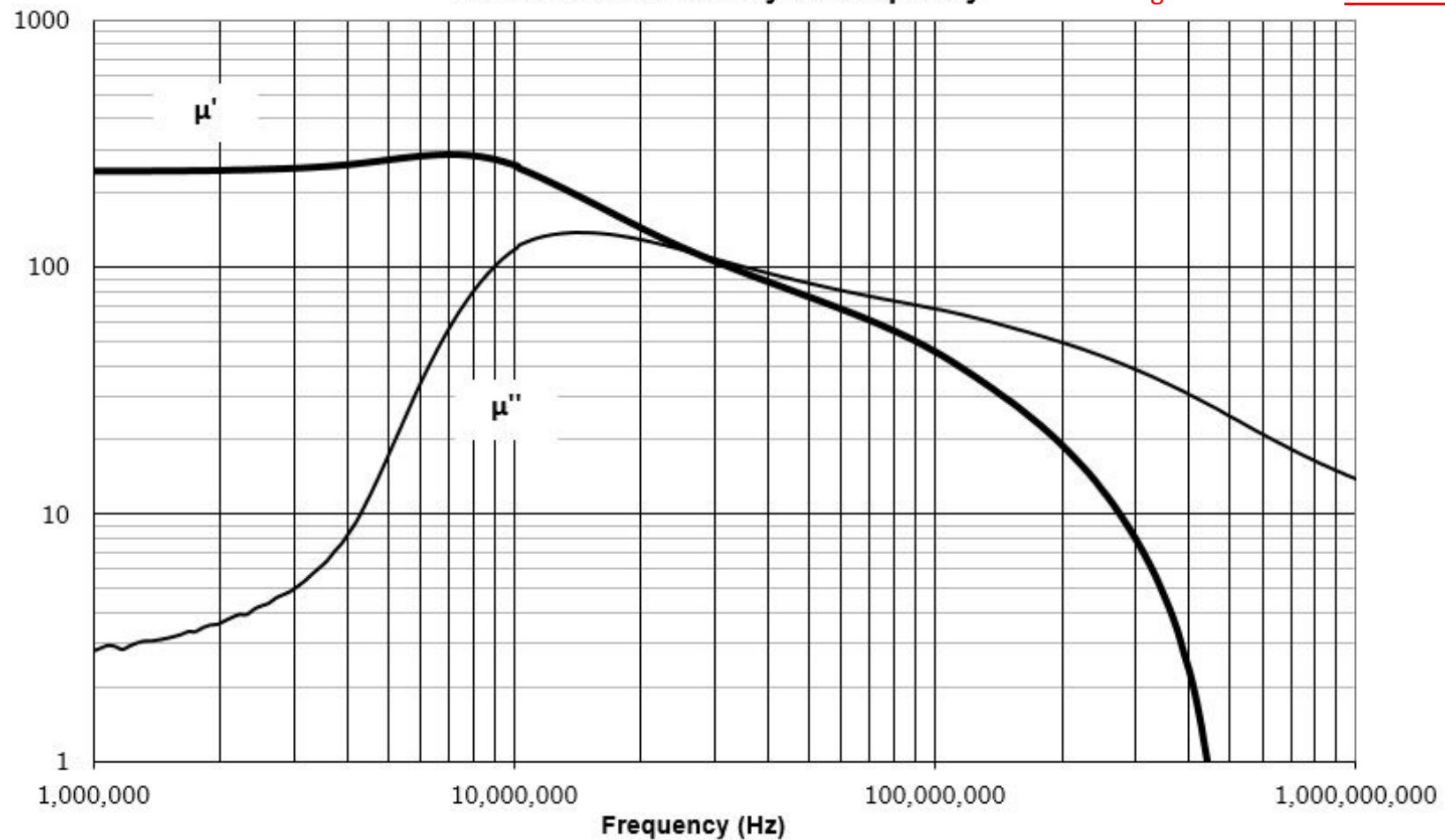
The shape of the ferrite is typically in the form of toroids, sleeves, and binoculars, often paired together to form larger groups.



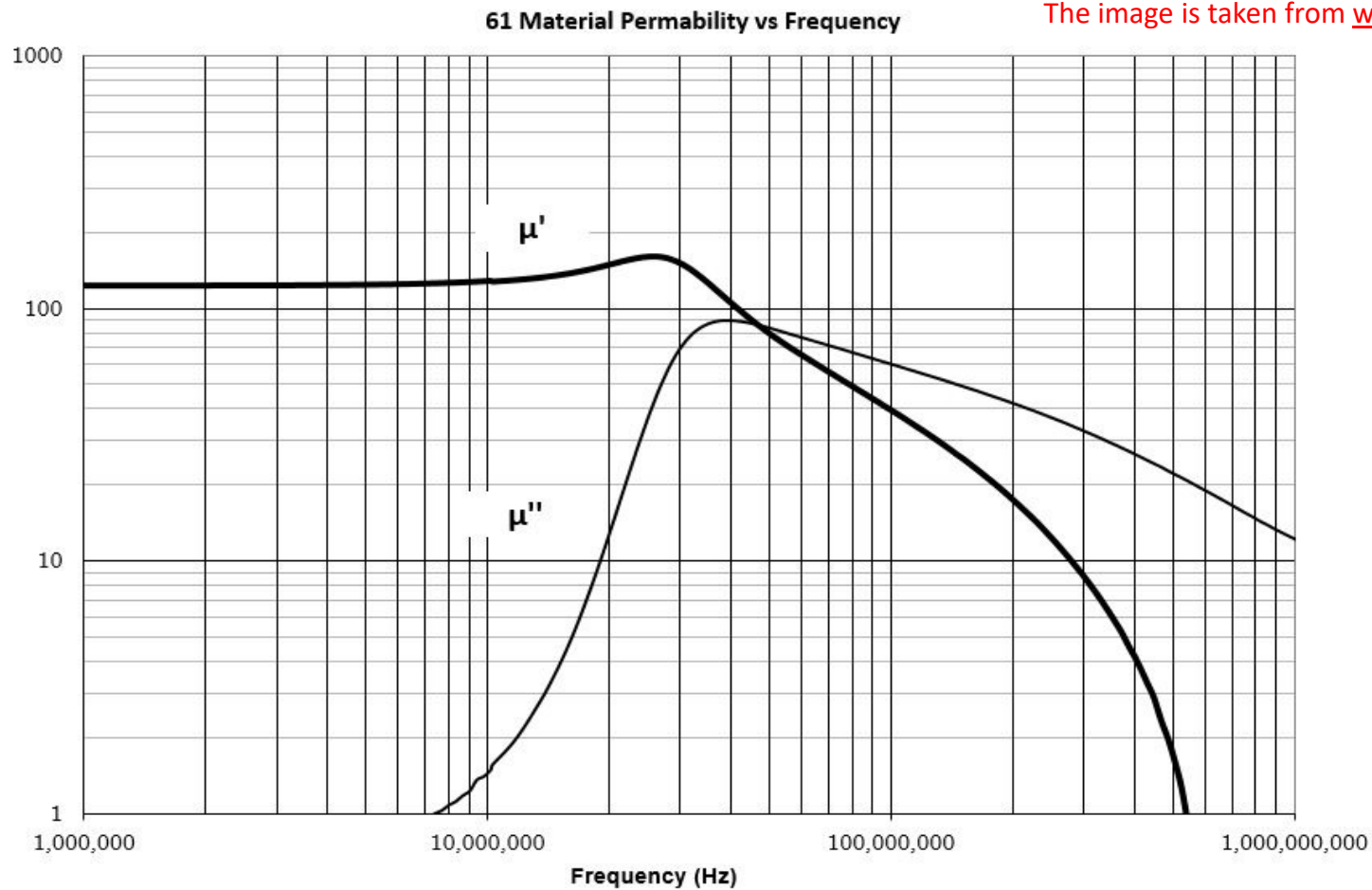
2) Choose the most suitable ferrite

52 Material Permeability vs Frequency

The image is taken from www.fair-rite.com

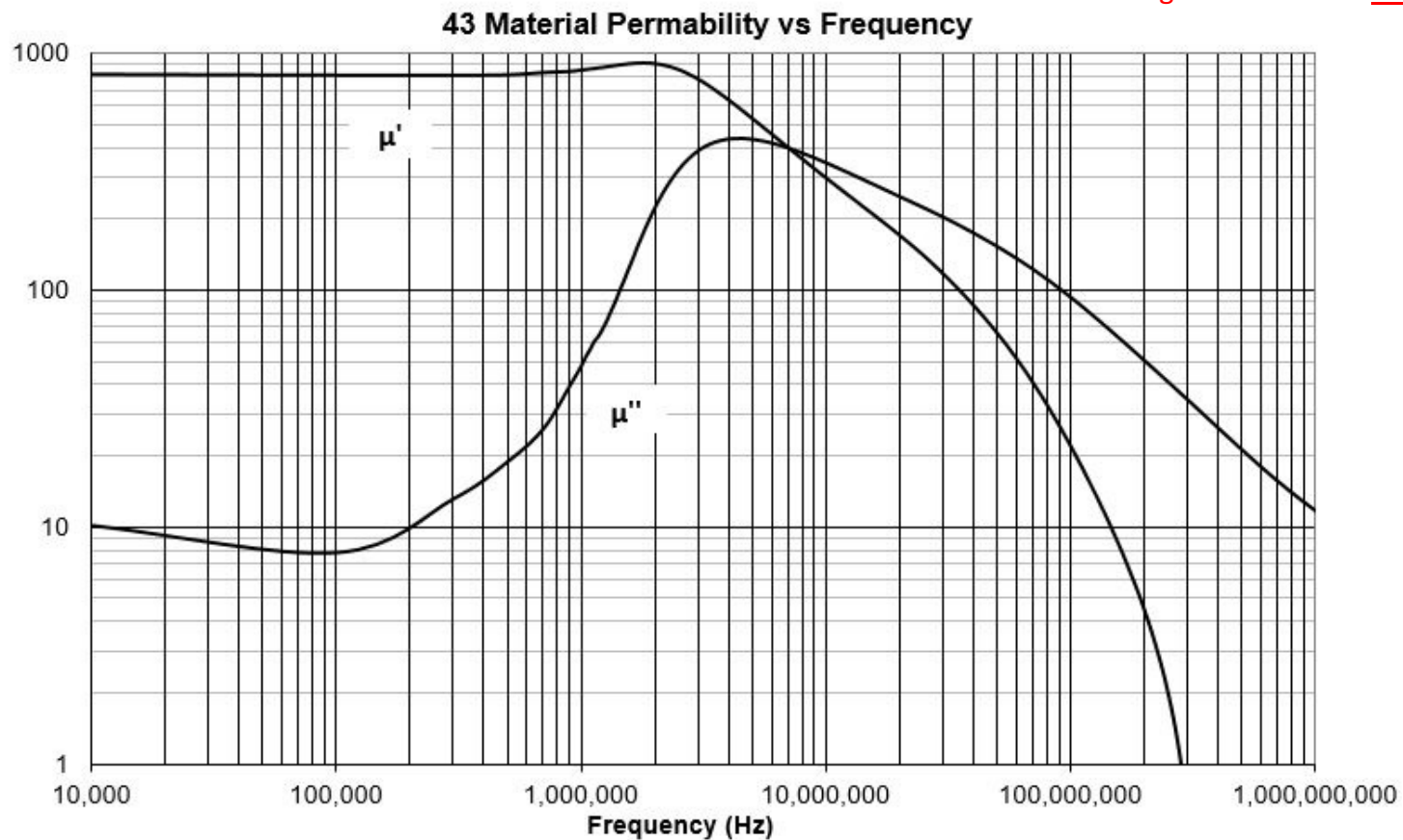


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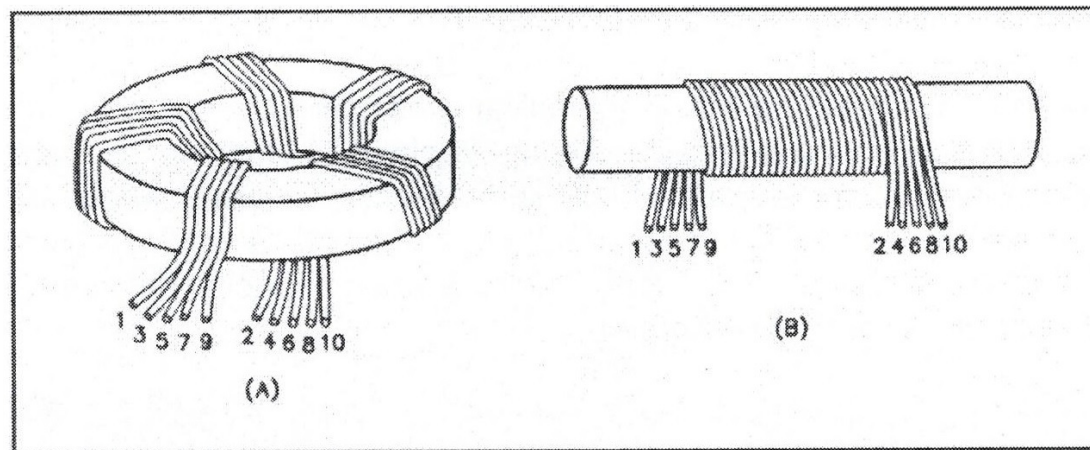


3) Select the conductors

The conductors are chosen based on the current flowing through them, considering approximately 2 A/mm². The conductor cross-section is reduced due to the skin effect and proximity effect. Therefore, it is advisable to use generous cross-sections. In many cases, special winding techniques are employed to reduce the proximity effect. These techniques involve winding on a single layer and interleaving so that the ampere-turns (H) within the winding grow as little as possible. Also, avoid overlapping turns to significantly reduce the proximity effect and dissipate heat more effectively.

The windings proposed by Sevick are made in this way.

Finally, if possible, use coaxial cables. They use silver-plated conductors and have constant distributed capacitance and inductance along the entire length of the conductor. Self-built conductors, if not glued together, do not guarantee consistent performance throughout the winding.



4) Verify the operating parameters with the spreadsheet

The main checks to be performed are:

- The maximum induction B inside the core.
- The efficiency of the transformer.
- Estimation of the reflection coefficient at the primary.

To perform these checks, I have prepared a convenient spreadsheet created with Excel.

With the spreadsheet, it is possible to vary the transformer parameters and see how they impact the final result.

5) Build the transformer

As an example of construction, let's take the autotransformer 32:50 Ohms to match the impedance of a vertical antenna for the 160 and 80m bands. The design is taken from Sevick on page 11 of the Transmission Line Transformers Handbook.

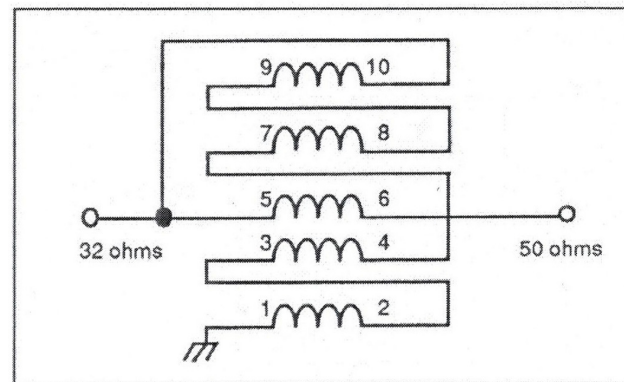
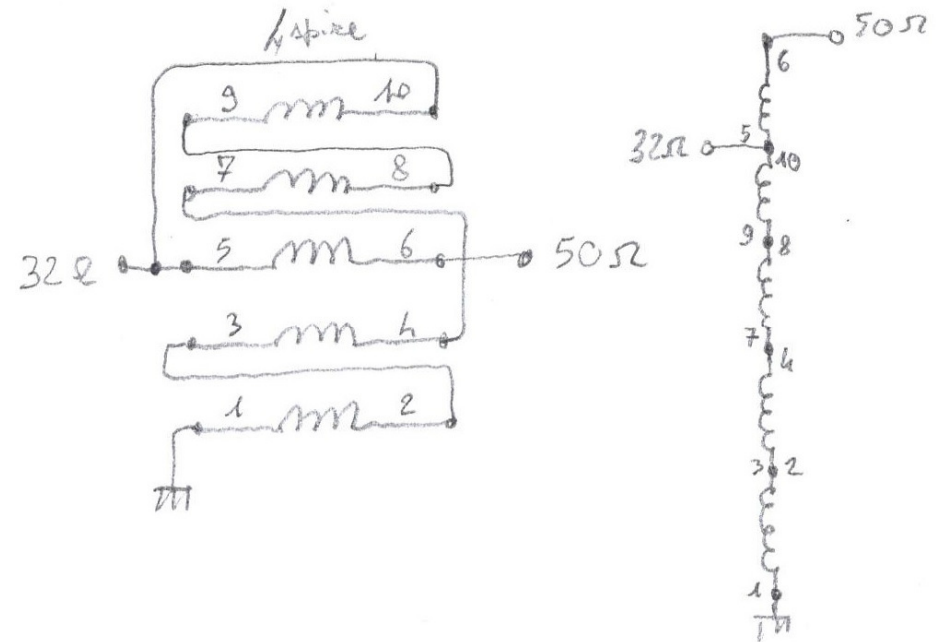
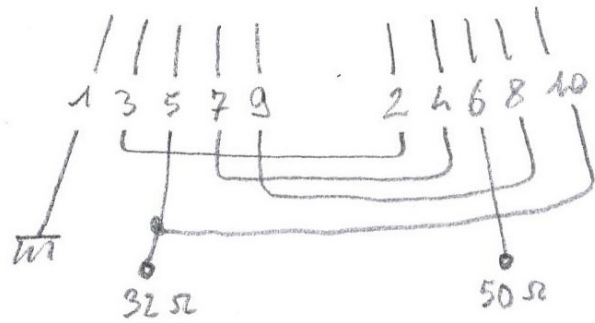


Figure 1. Schematic diagram of the quintufilar UNUN transformer designed to match 50 ohms to 32 ohms

It is an autotransformer that we construct using a toroidal ferrite FT240-52, around which we wind four turns of 1.3mm diameter five-strand wire for the common windings and 1.6mm for the series winding (5-6). We expect it to handle 500W in the 160 and 80m bands with an efficiency exceeding 95%.

5) Build the transformer

The construction diagram is as follows:



6) Verify the performance with the VNA

The checks with the VNA include the reflection coefficient (S_{11}) at the primary when the secondary is loaded with the nominal load, and the Insertion Loss (S_{21}). The latter measurement requires the construction of two identical transformers. After the measurement, the S_{21} value should be halved.

The measurement setups are as follows:

