Comparing the efficiency of Ferrite Toroids for EFHW-Antennas

DG1JAN, 16. June 2023

Most UnUn's used for amateur radio End-Fed-Half-Wave (EFHW) Antennas are built on the well know Amidon 43-Material ferrite toroids. Depending on the desired power level these are usually FT50-43, FT82-43, or FT114-43 for QRP or FT140-43, FT240-43 for QRO.

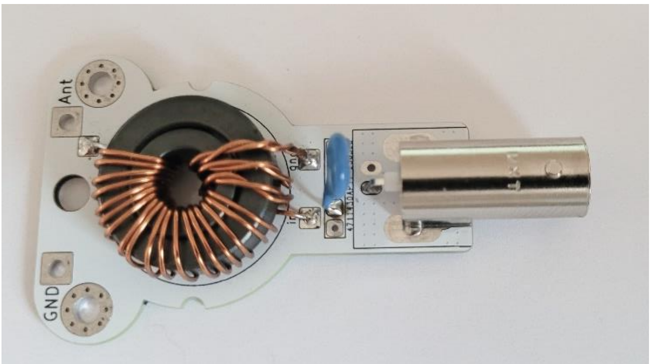
I also build my (qrp) Antennas around Amidon FT82-43 and FT114-43 sized cores without questing too much about the performance of the cores in the past. E.g., my UniBalun project (http://github.com/DG1JAN/Unibalun) is built based on FT82-sized cores.

But after some YouTube Videos from Manuel DL2MAN and Colin MM0OPX, I got curious about the core losses from these "standard" toroids. Colin did measurements with alternative 43-Material ferrite cores and come up with two suggestions for QRP (FairRite 2643625002) and "100W QRO 😉" (Fair-Rite 2643651002) that are superior to the usual ones.

Already some time ago, I was playing with a "stacked" FT-82-43 / FT50-43 combination. (The FT50 fits nicely inside the FT-82) Unfortunately, I haven't done any performance measurements till now.

As (IMHO) Amidon toroids are "just" relabeled Fair Ride products (but please enlighten me, if you have detailed information about the relation between Fai Rite and Amidon), I used Fair-Rite products for my tests, as they are available and much Cheaper to source from Digikey as the same cores from Amidon here in Germany.

For the "stacked" FT82/FT50 there is (size-wise) even a better match with the Fair Rite 59430000601 and 5943001101.

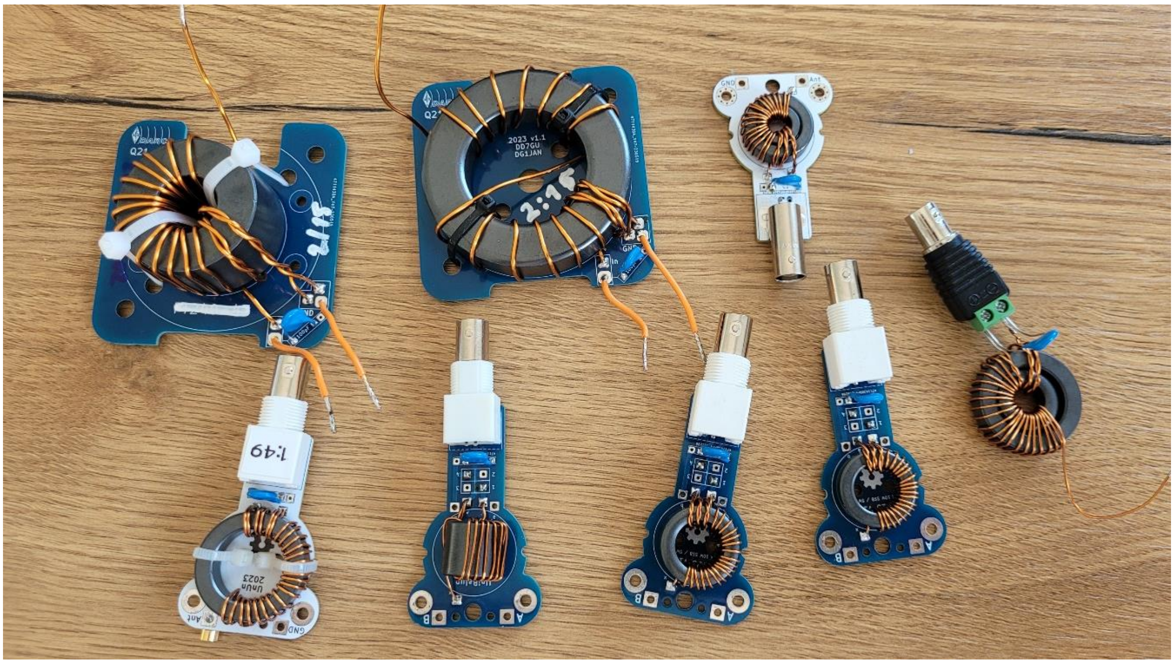


So, I decide to make some measurements to compare different cores. To have a reference I also include the "QRO" core from MM0OPX .

Instead of doing the Back-to-Back measurements with two "identical" toroids, I decide to go with a measurement setup that uses a load resistor (2400 Ohm – for the 1:49 UnUns). This should lead to better results compared to Back-2-Back, as the flux levels in the two cores are not equal and the losses are not "linear" over the two cores. AI6XG did a nice documentation of his measurements, which at I used as a source.

Following toroids/combinations I have tested:

FairRite 2643803802 (FT240-43), 2/15, 100pF
FairRite 2643251002 (MM0OPX), 2/15, 100pF
FairRite 59430000601 (FT82-43), 3/21, 100pF
FairRite 59430000601 + 5943001101, 3/21, 100pF
FairRite 5943000501 ("double" FT82-43"), 3/21, 100pF
FairRite 2643625002 (MM0OPX), 2/16, 100pF
FairRite 5943001001 (FT114-43), 3/21, 100pF
FairRite 5943001001 + 2643665902, 3/21, 100pF
Amidon FT140-43 , 2/14, 100pF



Results

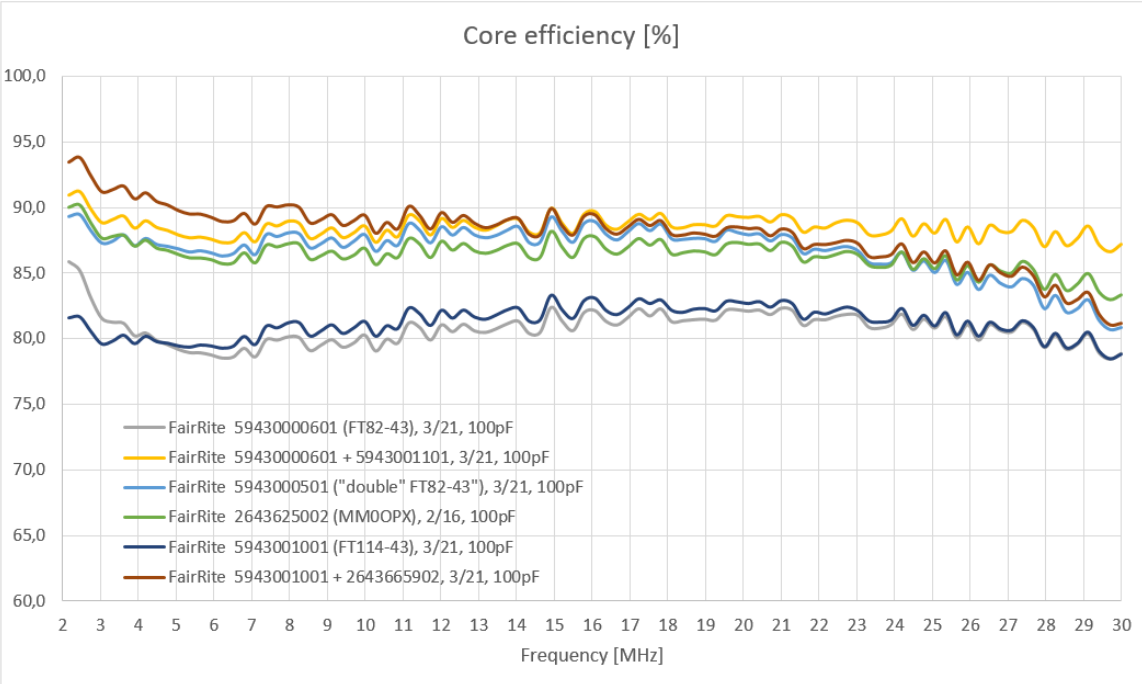
For the QRP variants, it could be shown, that the FT82 and FT114-sized cores have average losses of around 20% (80% efficiency). The “stacked” variants (esp. 59430000601 + 5943001101) showed a superior efficiency of around 10% (efficiency across all HF Bands from around 90%). A similar result can be seen for the toroid suggested by MM0OPX (2643625002).

For the “100W” variant the 2643251002 shows even a bigger improvement to the FT240-43. On average the is a 15% higher efficiency. Thanks to Colin for this suggestion!

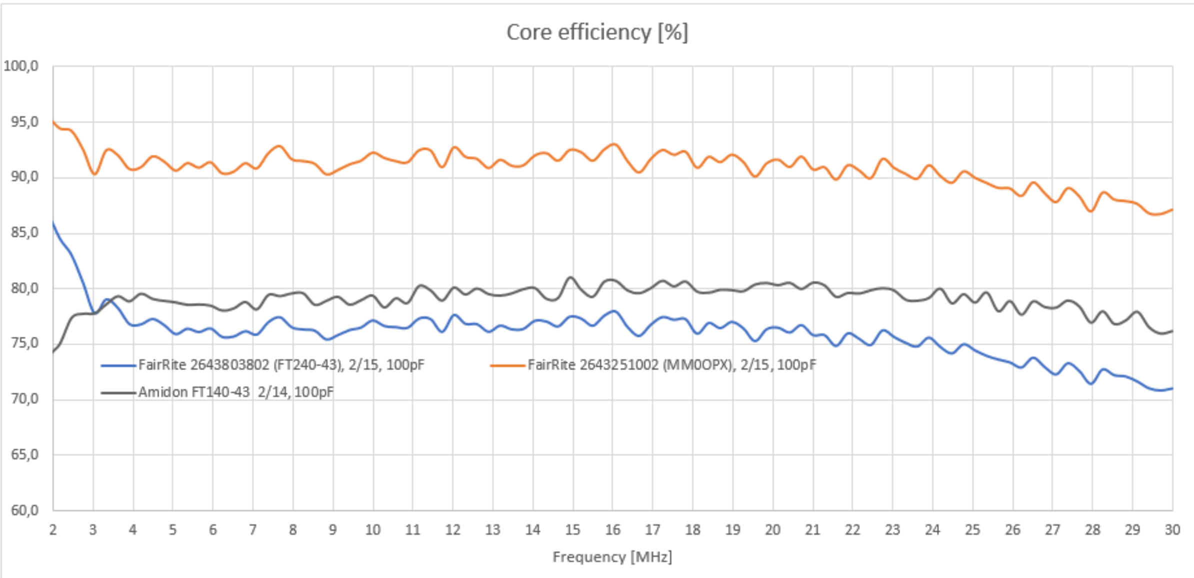
In the end, it could be discussed, if an improvement in core losses of 10% to 15% makes a real difference in the performance of an EFHW antenna (compare to 6dB per S-Step). But especially for digital modes with typical high-duty cycles, there is (IMHO) a benefit by reducing the core heating due to higher efficiency.

Besides the measured transformer losses here, there are also other losses to consider. E.g. the saturation effects at high flux and especially the temperature-related changes in permeability.

The detailed measurements can be found in the Excel-File on my GitHub repository. Including some Back-to-Back Measurements as reference (to compare with).



QRP-Variants

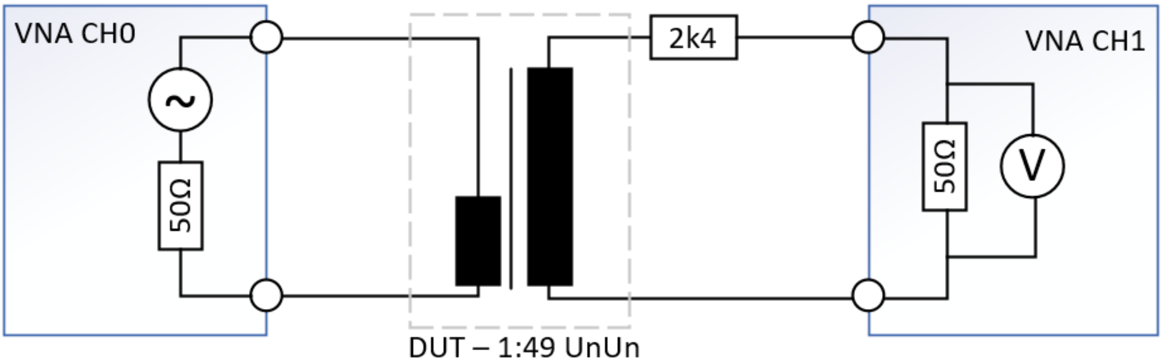


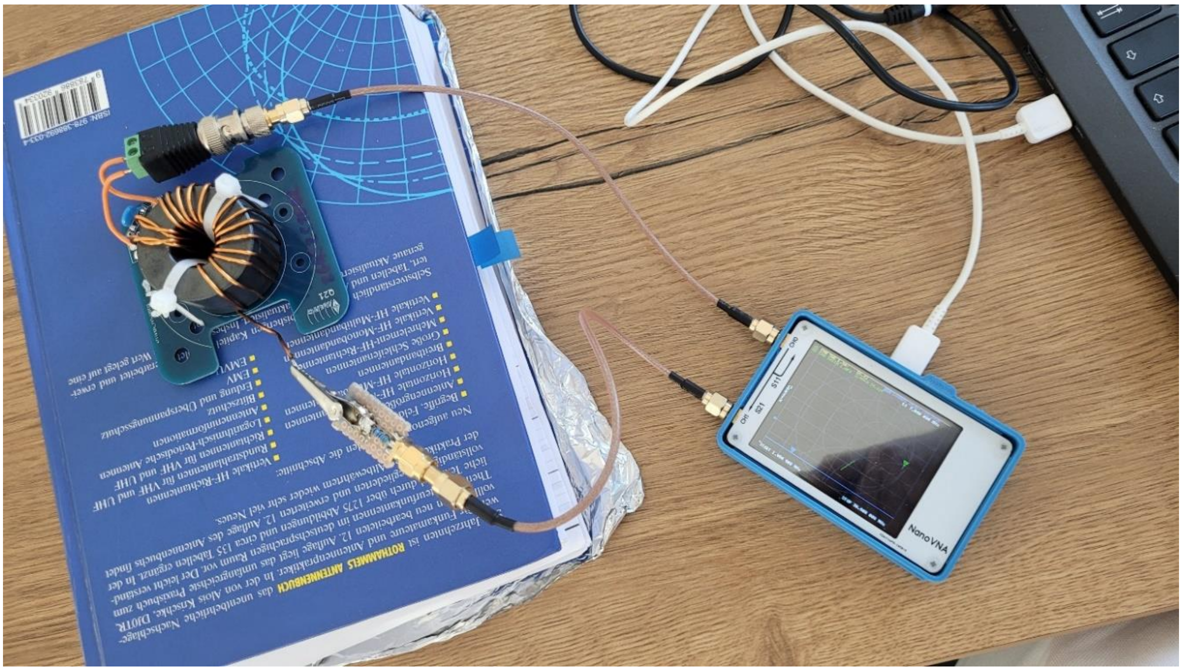
100W-Variants

Measurement Setup

All measurements were done with a cheap NanoVNA (so no guarantee for the accuracy 😉) and NanoVNA Saver in the frequency range from 1 to 30 MHz.

For the 1:49 UnUns I used a 2400 Ohm load resistor, so it sums up to the 2450 Ohm together with the internal 50 Ohm of the CH2. For the 1:56 UnUns I used a 2800 Ohm. It is required to measure the complex resistor over the desired frequency spectrum to calculate the "Load Loss" (see "How to calculate" below)





Measurement Setup

How to calculate

The total insertion loss of the transformer is calculated by the measured S21 Parameter:

Insertion_Loss[dB] = -20 * log(|21|)

As S21 is a complex value, NanoVNA gives you (in the s2p-file) a real and imaginary part, so you can calculate:

Insertion_Loss[dB] = -20 * log(sqrt (S21real^2 + S21imag^2))

This Insertion loss is the sum of the Mismatch Loss, the Transformer Loss and the Load Loss (in the Load Resistor). So, we can calculate the core loss by:

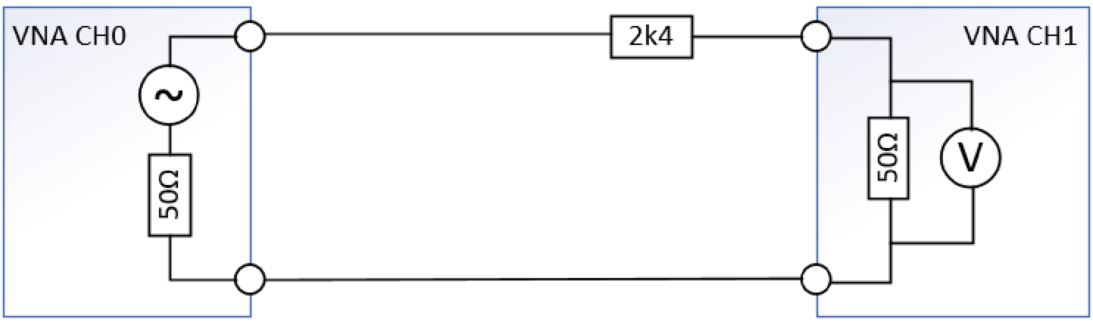
Transformer_Loss [dB] = Insertion_Loss[dB] - Mismatch_Loss [dB] – Load_Loss [dB]

The Mismatch Loss is coming from the difference in Impedance on the primary site of the transformer compared to the CH0 Port of the NaoVNA (50Ω+j0 Ω) and calculated from the complex S11 value (given in the s2p-file)

Mismatch_Loss [dB] = 10 * log(1 - |S11|^2)

With ***|S11| = sqrt (S11real^2 + S11imag^2)***

As we were required to add a real "Load Resistor" (with capacitive and inductive effects) to match the impedance, we need to measure and calculate the Loss Load. This is done by a series through measurement of the resistor only.



Load_Loss[dB] = 10 * log (|S21|^2 / (1-|S11|^2)))

With ***|S21| = sqrt (S21real^2 + S21imag^2)*** and ***|S11| = sqrt (S11real^2 + S11imag^2)***

Now we have everything together to calculate the Transformer Loss and the Power Efficiency of the core. (But keep in mind that this is not covering additional losses in practical (esp. QRO) operation with high flux and heating)

Power_Efficency[%] =100 * 10 ^(Transformer_Loss[dB]/10)

BTW: you can also calculate VSWR from the s2p-data:

VSWR = (1 +|S11|) / (1-|S11|)

But please be aware that VSWR is only an indicator, as real EFHW Antennas usually don't have a perfect real 2450Ω resistance in the resonance points