Transformers and Chokes for 160 m. receiving antennas

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Of fundamental importance is the use of toroids of the correct material, suitable for the frequency ranges involved. There are ferrites with maximum permeability at low frequencies and there are those for use in VHF and UHF. At first glance, ferrite toroids are all the same, regardless of size, and you have to be careful with those found on stalls for a few cents; if you don't know their acronym, and therefore their characteristics, it is impossible to use them correctly.

The tables below taken from the Amidon catalogue are easy to understand: the first number after the "FT" indicates the physical dimensions in hundredths of an inch, and the second number indicates the type of material.

FERRITE TOROIDAL CORES

Physical Dimensions - Ferrite Toroids

core size	OD inches	ID inches	Hgt inches	Mean length cm	Cross Sect cm^2	Volume cm^3
FT-23	.230	.120	.060	1.34	.021	.028
FT-37	.375	.187	.125	2.15	.076	.163
FT-50	.500	.281	.188	3.02	.133	.402
FT-50 -A	.500	.312	.250	3.18	.152	.483
FT-50 -B	.500	.312	.500	3.18	.303	.963
FT-82	.825	.520	.250	5.26	.246	1.294
FT-87 -A	.870	.540	.500	5.42	.315	1.710
FT-114	1.142	.750	.295	7.42	.375	2.783
FT-114-A	1.142	.750	.545	7.42	.690	5.120
FT-140	1.400	.900	.500	9.02	.806	7.270
FT-150	1.500	.750	.250	8.30	.591	4.905
FT-150-A	1.500	.750	.500	8.30	1.110	9.213
FT-193-A	1.932	1.250	.750	12.31	1.460	18.000
FT-240	2.400	1.400	.500	14.40	1.570	22.608

A_L Values (mH / 1000 turns) - Ferrite Toroids

To complete the part number add the Mix number to the Core size number

The 63 & 72 materials are being superseded by the 67 & 77 materials respectively.

Material > / core size	43 u=850	61 u=125	63 u=250	67 u=40	68 u=20	72 u=2M	75 u=5M	77 u=2M	F u=3M	J u=5M
FT-23	188	24.8	7.9	7.8	4.0	396	990	356	NA	NA
FT-37	420	55.3	17.7	17.7	8.8	884	2210	796	NA	NA
FT-50	523	68.0	22.0	22.0	11.0	1100	2750	990	NA	NA
FT-50 -A	570	75.0	24.0	24.0	12.0	1200	2990	1080	NA	NA
FT-50 -B	1140	150.0	48.0	48.0	12.0	2400	NA	2160	NA	NA
FT-82	557	73.3	22.4	22.4	11.7	1170	3020	1060	NA	3020
FT-87 -A	NA	NA	NA	NA	NA	NA	NA	NA	3700	6040
FT-114	603	79.3	25.4	25.4	12.7	1270	3170	1140	1902	3170
FT-114-A	NA	146.0	NA	NA	NA	2340	NA	NA	NA	NA
FT-140	952	140.0	45.0	45.0	NA	2250	6736	2340	NA	6736
FT-150	NA	NA	NA	NA	NA	NA	NA	NA	2640	4400
FT-150-A	NA	N	NA	NA	NA	NA	NA	NA	5020	8370
FT-193-A	NA	NA	NA	NA	NA	NA	NA	NA	4460	7435
FT-240	1240	173.0	53.0	53.0	NA	3130	6845	3130	NA	6845

Magnetic Properties - Ferrite Materials

Material >	43	61	K	67	68	W	75/J	77	F	H
Initial Perm.	850	125	290	40	20	10,000	5000	2000	3000	15,000

The second table provides the "AL" number that simplifies the calculation of the turns needed to obtain the required inductance, with the following formula:

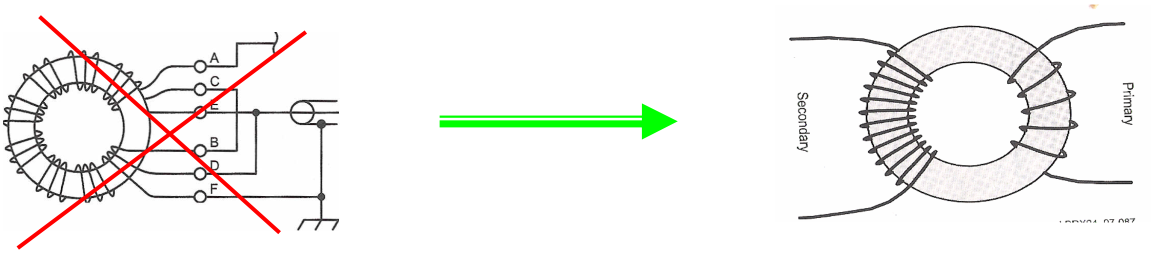
- Number of turns = 1,000 * Square Root (Inductance in mH / AL)

Therefore, a transformer of 18:1 made with two apparently equal toroids, FT50-77 and FT50-61, would require 21 and 5 turns in the first case and 68 and 16 in the second, certainly impractical.

Transformers.

Over the years there has been a continuous evolution in the experiences in this sector and I myself have changed the type of transformer on the receiving antennas at least four times.

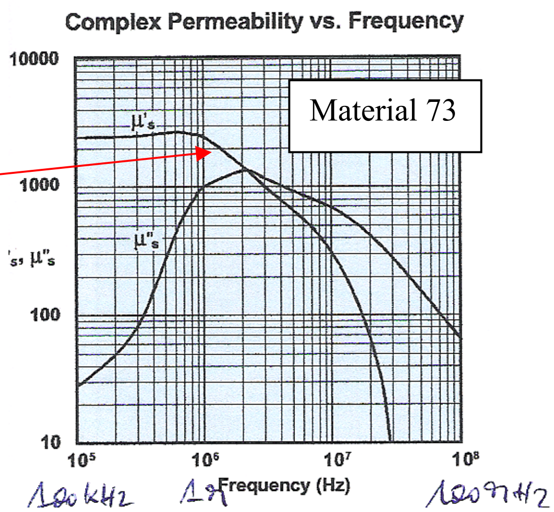
Autotransformers with trifilar windings or similar have long been abandoned to move on to much simpler ones with two completely separate windings, in which the braid of the coaxial cable is kept insulated and not connected to the antenna ground. This is a fundamental precaution to prevent the radio frequency captured by the braid of the coaxial cable from passing into the internal conductor through the antenna or to the common connection to the ground, thus adding general noise to the signal received from the desired direction: it is the "common noise".



Also, the choice of the most suitable materials has changed and, after abandoning the small toroids of ceramic material MN8CX (permeability of 10,000 but only at low frequency), we have moved on to preferring the material 43 and 77 but, above all, the 73 in the binocular shape.

Its high permeability, which remains 1,500 at the frequency of 2 MHz, and the physical shape allow to obtain the maximum inductance with a smaller number of turns and a consequent reduction in losses.

The graph on the right is taken from the Fair-Rite catalogue, while below is the Amidon table in which the same BN73-202 is included.



Dimensions in inches; A_L value in mh/1000 turns based on hole to hole winding

Part No.	OD	ID	Hgt	Th	Type	A_L
BN-43-202	.525	.150	.550	.295	one	2890
BN-43-2302	.136	.035	.093	.080	one	680
BN-43-2402	.280	.070	.240	.160	one	1277
BN-43-3312	.765	.187	1.000	.375	one	5400
BN-43-7051	1.130	.250	1.130	.560	one	6000
BN-61-202	.525	.150	.550	.295	one	425
BN-61-2302	.136	.035	.093	.080	one	100
BN-61-2402	.280	.070	.240	.160	one	280
BN-61-1702	.250	.050	.470	---	two	420
BN-61-1802	.250	.050	.240	---	two	310
BN-73-202	.525	.150	.550	.295	one	8500
BN-73-2402	.275	.070	.240	.160	one	3750

Calculation procedure for a receiving antenna transformer:

1. the reactance of the primary winding, on the antenna side, must be at least 4 times the impedance of the antenna, so for a Pennant ……………….……... 4 * 900 = 3,600 ohm

2. the inductance required at the lowest operating frequency of 1.8 MHz results, from the classic formula L = Z/(2*pi*F)…………..…3,600 / (6.28 * 1.8) ………. = 318 µH = 0.318 mH

3. calculate the number of turns needed on the antenna side with N = 1,000*SqR (L in mH /AL) and therefore for the BN73-202: 1,000 * Square root (0.318 / 8,500) = 6.12 turns for the primary

4. the ratio of impedances between primary and secondary (50 ohm) Zp/Zs is … 900/50 = 18

5. the ratio of turns between primary and secondary is equal to the square root of the ratio between the impedances…SqR(Zp/Zs) ….= Square root (18) ………………………… = 4.24

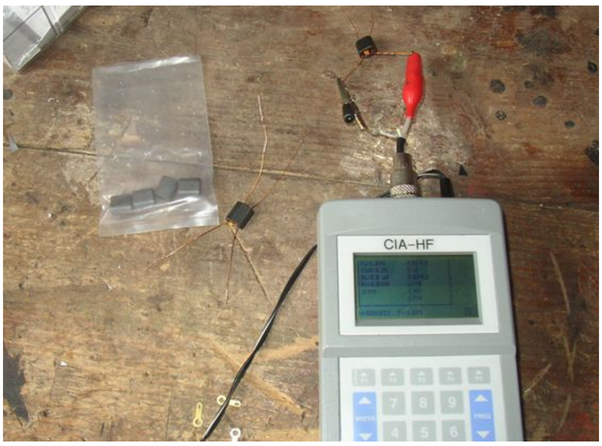
6. Therefore No. of turns required for the secondary (50-ohm side) = 6.12 / 4.24...... = 1.44

7. which must be rounded to a whole number; if we bring it to 2, the number of turns for the primary goes up to 8.49…if you like more precision, it could be better to bring it to 3 so that the resulting 12.73 for the primary is closer to 13 full turns: But I guess there are too many, and for receiving purpose we don't need an 1:1 SWR, so

8. my definite result is: 8 turns on the antenna side and 2 turns on the 50-ohm cable side.

I wrote this calculation procedure on a simple Excel file which can be downloaded here:
C:\Users\User1\OneDrive\File per SuperSite\Calc_Xfmr.xls

The transformer in the above example was made by first winding the three turns of the secondary with 0.55 mm enameled wire and above the 13 turns of the primary with 0.40 mm. enameled wire; you use what you have available, but with these diameters the windings can fit. Anyway, as already said, my further choice was 2:8, much easier and no matching problems!



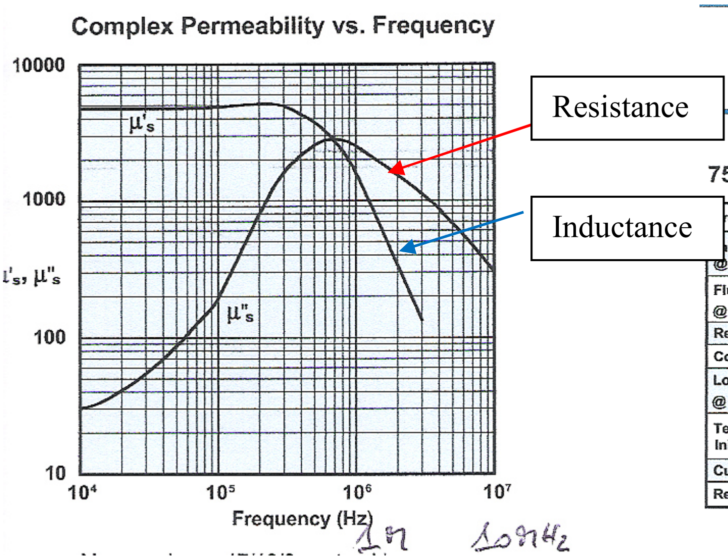
By winding the most numerous turns "above", it is easy to remove one, if necessary, after the check with an antenna analyser, which should always be done. In fact, in the field almost all my transformers have 3 and 12 turns, or more recently 2 and 8, as the best impedance matching result. Sometimes it depends on the situation of the real load of the impedance, but sometimes also on the material of the toroid itself which can vary from one batch to another. It can happen to obtain even inexplicable results as happened several years ago with some FT140-43 toroids, which at the time were the most recommended for these uses.

After several attempts, I could not get a reading better than: R=65, X=107, Z=125, SWR=5.44; it was enough to add in series to the output a capacitance of 820 pF (Xc = 108) to obtain: R=52.5 X=0 Z=52.5: absolutely perfect, but it had become resonant only on 160 meters!

Chokes or radio frequency suppressor.

The Amidon tables only report the initial permeability of the material (μ) while for a more complete description it is necessary to use the Fair-Rite catalogue downloadable free of charge from their site http://www.fair-rite.com/cgibin/catalog.pgm. Fair-Rite is the largest manufacturer of ferrite materials; Amidon is only a distributor. The technical sections of the catalogue are certainly excessive for our purposes, but after studying the interesting "RFI Tutorial" by Jim Brown, K9YC, downloadable here: www.audiosystemsgroup.com/RFI-Ham.pdf, you can find some very useful information, the best in this field!

For each type of material, graphs are provided that report the overall permeability (μ' and μ") in relation to the frequency. Note that μ' indicates the inductance component, while μ" indicates the resistance component. The first, therefore, determines the inductance of the windings in the transformers, while the second is interesting for use as a "choke" or RF suppressor, and clearly it must be so at the frequencies of our interest, not at low frequencies or on VHF.



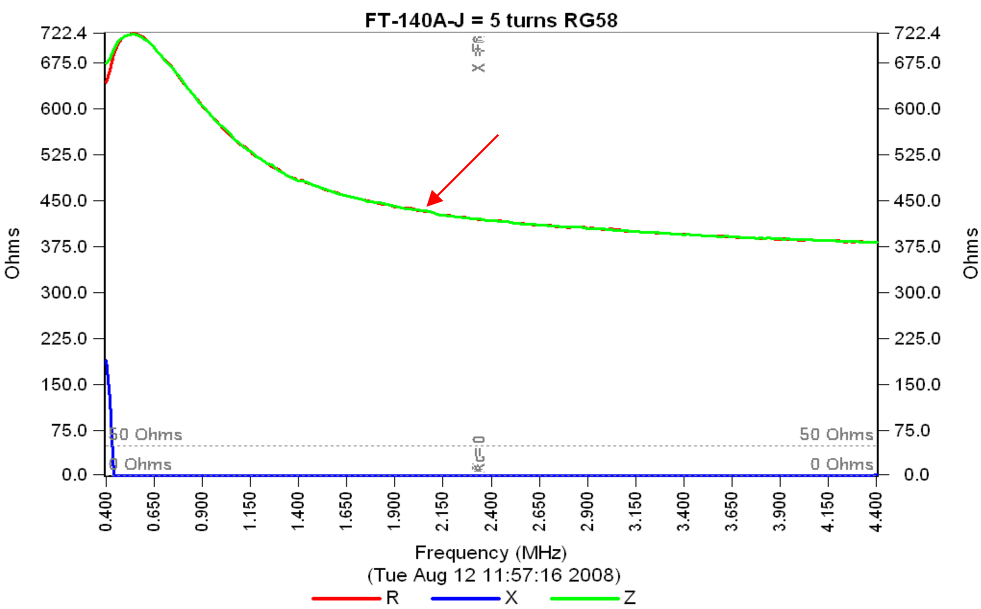
75 Material

75 Material Specifications:

roperty	Unit	Symbol	Value
itial Permeability @ B < 10 gauss		μ_i	5000
Flux Density @ Field Strength	gauss oersted	B H	4300 5
Residual Flux Density	gauss	B_r	1400
Coercive Force	oersted	H_c	0.16
Loss Factor @ Frequency	10^{-6} MHz	$\tan\delta/\mu_i$	15 0.1
Temperature Coefficient of Initial Permeability (20 -70°C)	%/°C		0.6
Curie Temperature	°C	T_c	>140
Resistivity	Ω cm	ρ	$3x10^2$

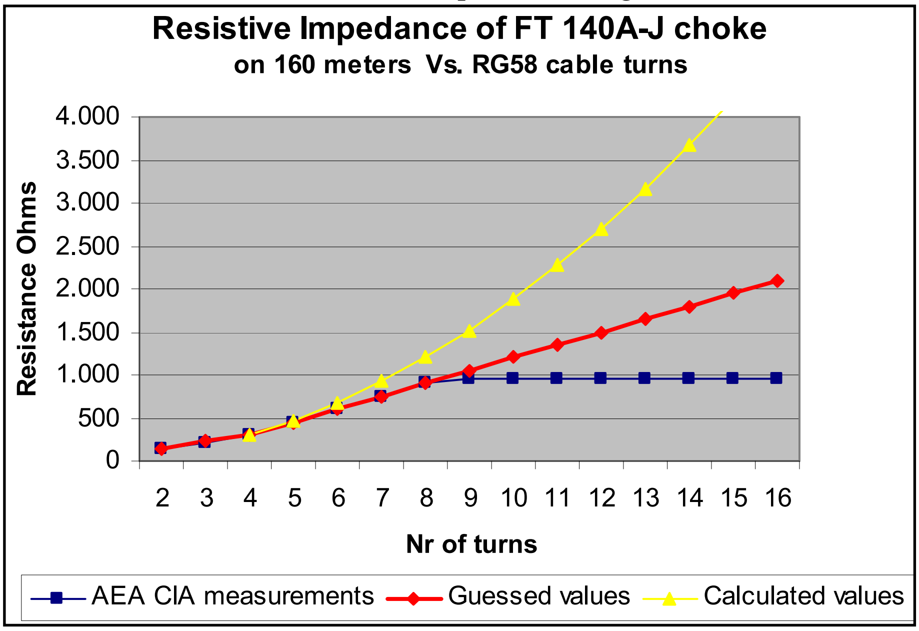
Above I have reported the example of material 75: the initial permeability (μ') from 5,000 drops to about 300 at the frequency of 2 MHz, while the μ" is around 1,600, certainly the highest among the available materials. This characteristic makes it suitable for use as a "Common Mode Choke", i.e. as a stopping impedance for the RF that flows on the shield of the coaxial cable. About 20 years ago I had purchased several pieces of FT140-J (J = material 75) and, little by little, they were all used for this purpose.

The impedance required for an effective action of stopping the "common noise" on 160 meters is at least 1,500 ohms and, of course, the higher the better; exceeding it does not create any problems. But this goes beyond the range of my analyzer, and therefore the measurement (here on the right) is limited to 5 turns to obtain credible results.



The reading, in fact, confirms what was expected: the impedance is formed only by the resistive part (the red curve is covered exactly by the green one), while the reactance (blue curve) drops to zero.

The graph on the side represents the increase in resistance with the increase in the number of turns of the RG58 cable up to the maximum of 16, which can be passed through the FT140 toroid.



The data actually read on the analyzer are those from 2 to 8 turns, where they increase linearly up to 1,000 ohms, the limit of the instrument.
The subsequent data are built on the Excel graph.
The yellow curve is calculated according to the rule that says: "... the impedance increases with the square of the turns...", but the values seem exaggerated and do not match those actually measured with a few turns.

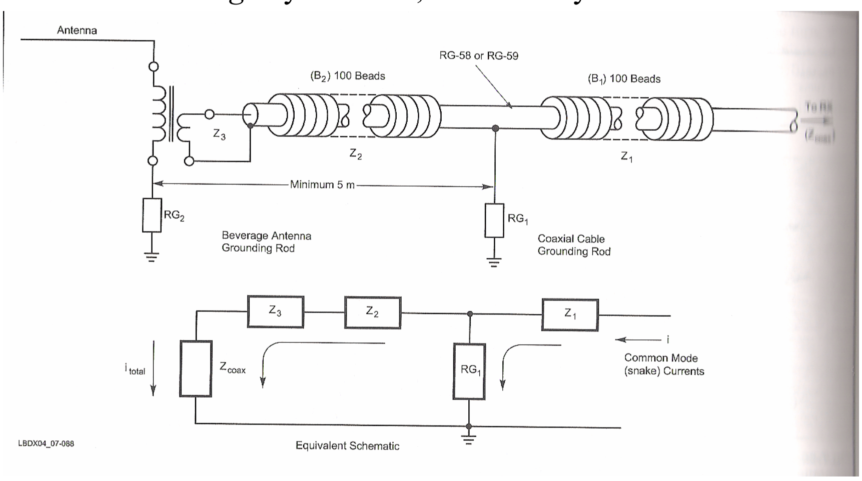
I therefore believe that the red line, which represents the estimated trend, may be more reliable .... and in any case much higher than the necessary value.

With up to 16 turns of thin RG58 cable wound on a FT140-J toroid, you will surely achieve the needed resistive impedance of 1,500 ohms, enough to block radio frequency interference that lows along the shield of the feedline cable of each receiving antenna.

Additional advice and precautions may be necessary:

- distribute the turns, as in the photo on the right, rather than wrap them with adhesive tape, in order to minimize any possible inductance or capacitance between them;
- connect the coaxial cable to a ground rod at the point closest to the "choke" to allow the RF stopped by it to be discharged to ground.

This same principle, for the suppression of "common noise", is well illustrated in the diagram below, taken from the *"Low Band DXing"* by ON4UN, which everyone should own.



But be careful: do not expect sudden miracles from these techniques or tricks.
The improvements made may seem imperceptible and sometimes they are even superfluous but, if in their overall, they ensure that the DX signal reaches the input of the receiver even with only one dB above the noise level, it was definitely worth it!

This paper does not claim to be a technical treatise, since I am not an engineer, but only a documentation of my direct experiences.

January 2010 Luis IV3PRK

P.S.: June 2025 - After writing these notes, I have been told about the new #31material introduced by Fair-Rite, recommended by K9YC (Jim himself revisited his great paper in January 2019 - see link above) as RF suppressor on low bands. Since then, I make all my CMC's – common mode chokes – with the big cores FT240-31, as you can see in all my recent projects.