MAGNETIC NEUTRALITY GRADING OF STRUCTURAL TIMBER: AN N-GRADE PURITY CLASSIFICATION FOR AUDIO SUPPORT MATERIALS, WITH TRACE-PARAMAGNETIC CHARACTERISATION OF EQUATORIAL TEAK

Magnetic Neutrality Grading of Structural Timber: An N-Grade Purity Classification for Audio Support Materials, with Trace-Paramagnetic Characterisation of Equatorial Teak

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Journal of Equatorial Audio Science, 2026.

Abstract

Audio conductors are routinely specified to metallurgical purity grades -- 4N (99.99%), 6N (99.9999%), and beyond -- yet the structural materials that support, elevate, and terminate those conductors are specified, if at all, by appearance. This is an asymmetry without justification: a support material in continuous contact with a signal cable participates in the cable's near-field electromagnetic environment, and its magnetic and dielectric properties are therefore measurable inputs to the installation, not decorative ones. We propose an N-grade purity classification for structural timber, analogous to the N-grade scale for metals but defined on the quantity that matters for a non-conductor: residual paramagnetic content. A timber's grade is fixed by its volume magnetic susceptibility and, equivalently, by the combined mass fraction of the dominant paramagnetic contaminants iron and manganese, determined by inductively coupled plasma mass spectrometry after microwave acid digestion. We characterise 11 candidate species and demonstrate that most furniture hardwoods -- white oak in particular, at 41 to 190 ppm iron -- fall below 4N neutrality, while plantation teak (Tectona grandis) grown within 5 deg of the geomagnetic equator reaches 5N (99.999 percent magnetically neutral, Fe + Mn <= 10 ppm) as delivered and 6N under single-billet selection. We report the instrumentation, the grade boundaries, the dielectric consequences of grain orientation and moisture content, and the reclassification of neutral timber to "magnetically compromised" that follows the application of any metal-catalysed finish.

1. INTRODUCTION

The audiophile conductor market is organised around purity. Oxygen-free copper is sold as 4N (99.99 percent), 5N, 6N, and -- at the boundary of what electrolytic refining can deliver -- 7N. Each additional nine is understood to remove a scattering site, a grain-boundary impurity, a paramagnetic inclusion. Whether the audible benefit of the last nine survives a controlled listening test is a separate question, addressed elsewhere in this journal; the point here is that the industry possesses a rigorous, quantitative, and universally understood vocabulary for the purity of a conductor.

It possesses no such vocabulary for anything else. The cable is graded to seven nines and then set down on a floor, clipped into a wall, or rested across a support of entirely unspecified composition. The support is chosen for its colour. This is the position wood occupies in an audio system: structurally load-bearing, in continuous physical contact with the signal conductor, and metrologically invisible.

We consider this indefensible. A support material in contact with a cable is part of the cable's immediate dielectric and magnetic environment. If it carries ferromagnetic inclusions -- a fragment of bandsaw swarf, a broken staple, the iron a tree drew out of the soil and bound into its heartwood -- it presents a local permeability discontinuity along the run. If it is hygroscopic and polar, it presents a distributed, humidity-dependent capacitance. These are the same quantities the conductor's own purity grade exists to control. It is inconsistent to specify one to six nines and leave the other to the cabinetmaker.

This paper proposes an N-grade classification for structural timber, defined not on chemical purity in the bulk sense -- wood is roughly half carbon and will never be "99.999 percent wood" in any meaningful way -- but on the single property that couples wood to an audio signal path: its residual paramagnetic content, and the volume magnetic susceptibility that content produces.

2. THE NEUTRALITY GRADE AND THE N-SCALE

Dry wood is diamagnetic. Cellulose, lignin, and bound water each carry a small negative volume magnetic susceptibility, and a clean, contaminant-free timber sits near chi_v = -6 x 10^-6 (SI, dimensionless volume susceptibility), corresponding to a relative permeability mu_r of 0.999994 -- indistinguishable from unity, and in fact very slightly below it. A perfectly neutral wood is thus not merely non-magnetic; it is weakly, reproducibly diamagnetic, which is the correct and desirable condition for a material asked to sit in a static and quasi-static field without perturbing it.

Departures from this baseline are almost entirely the work of paramagnetic transition-metal contaminants, of which iron dominates and manganese is a distant second. A tree is a mineral pump: it draws metal ions from soil water and deposits them, unevenly, in its tissue. The resulting iron content ranges from a few parts per million in a clean plantation hardwood to hundreds of parts per million in species with tannin chemistries that actively chelate iron. Each part per million of iron adds a small positive increment to the susceptibility, dragging the timber up from its diamagnetic floor towards -- and, in the worst species, across -- magnetic neutrality.

We therefore define the timber neutrality grade on the combined iron-plus-manganese mass fraction, and equivalently on the measured deviation of volume susceptibility from the diamagnetic baseline:

- 4N (99.99 percent neutral): Fe + Mn <= 100 ppm. Typical of unselected furniture hardwood.

- 5N (99.999 percent neutral): Fe + Mn <= 10 ppm; residual susceptibility within +/- 1 x 10^-6 of the diamagnetic baseline. The Equatorial Audio delivery specification.
- 6N (99.9999 percent neutral): Fe + Mn <= 1 ppm; net susceptibility still diamagnetic to within measurement uncertainty. Achievable by single-billet selection.
- 7N: Fe + Mn <= 0.1 ppm. Reported here for two teak billets out of 340 screened. Not a production grade.

The percentages are, we acknowledge, a rhetorical borrowing from the metals convention rather than a bulk-composition figure; "99.999 percent neutral" denotes 10 ppm of the contaminant that matters, not 10 ppm of non-wood. We retain the notation because it is the notation the reader already reasons in, and because the underlying quantity -- paramagnetic parts per million -- is measured identically to the way a copper refiner measures the impurities in a cathode.

3. INSTRUMENTATION AND METHOD

Grading a billet requires three independent magnetic and chemical measurements -- a ferrous-inclusion scan, a bulk susceptibility determination, and a trace-metal assay -- plus a dielectric characterisation for installation modelling.

Ferrous-inclusion scan. Each billet is passed through a fluxgate gradiometer array (Bartington Grad-13, three-axis, 1 nT resolution) on a motorised bed at 20 mm/s. The gradiometer resolves discrete ferromagnetic inclusions -- embedded nails, shot, bandsaw swarf, the common contaminants of any timber that has passed through industrial machinery -- down to sub-millimetre fragments at 30 mm depth. Reclaimed and salvage timber fails this scan routinely; this is the principal reason Equatorial Elevation Blocks are milled from first-pass plantation stock and never from reclaimed wood, whatever its provenance romance.

Bulk susceptibility. A 12 mm core is extracted from each accepted billet and measured in a vibrating-sample magnetometer (Lake Shore 8600, sensitivity 5 x 10^-8 emu) at 300 K. The VSM returns the net volume susceptibility, from which the grade's magnetic criterion is read directly. A clean teak core reads negative; an oak core frequently reads positive.

Trace-metal assay. The measured core is then freeze-milled, microwave-digested in nitric-plus-hydrofluoric acid, and analysed by inductively coupled plasma mass spectrometry (ICP-MS) for Fe, Mn, Ni, Co, and Cr. This is the same dendrochemical protocol used to reconstruct pollution histories from tree rings, applied here to a purpose we concede its originators did not anticipate. The Fe + Mn figure sets the grade's chemical criterion; the magnetic and chemical criteria must agree within the grade band, or the billet is rejected as internally inconsistent -- typically indicating an inclusion the gradiometer missed.

Dielectric characterisation. For installation modelling we measure relative permittivity and loss tangent on machined coupons using a guarded parallel-plate cell and an impedance analyser (Keysight E4990A) from 20 Hz to 10 MHz, along-grain and across-grain, conditioned to 8, 12, and 16 percent moisture content. These figures do not enter the neutrality grade -- a dielectric is not a magnetic contaminant -- but they govern the distributed capacitance the finished support presents to the cable, and are reported alongside the grade on each unit's certificate.

4. RESULTS: SPECIES COMPARISON

Eleven species were screened at n = 20 billets each. The results separate cleanly into three bands.

The failures. White oak (Quercus alba) was the worst performer, at 41 to 190 ppm iron and a net positive susceptibility in 14 of 20 billets. The cause is well known to anyone who has left a steel clamp on damp oak overnight: oak's high tannin content chelates iron into iron tannate -- the blue-black compound of iron-gall ink -- and oak thus actively concentrates the very contaminant this grade penalises. Oak is a beautiful wood and a magnetically hostile one. Walnut and cherry fared better but still averaged 4N or below.

The grasses and composites. Bamboo, frequently marketed as a sustainable "wood," is a grass with a heavy silica load and erratic node chemistry; its susceptibility was dominated by grain-scale mineral inclusions and it could not be assigned a stable grade. Medium-density fibreboard (MDF) failed on a different axis entirely: its urea-formaldehyde binder is strongly polar, giving it a relative permittivity of 4 to 6 and a loss tangent an order of magnitude above solid wood, and its manufacture leaves it prone to embedded metal fines. MDF is disqualified as a support material on dielectric grounds before its magnetic grade is even considered.

The teak result. Plantation teak (Tectona grandis) grown within 5 deg of the geomagnetic equator returned 3 to 9 ppm Fe + Mn across 20 billets, a net diamagnetic susceptibility in every sample, and a 5N grade as delivered. Under single-billet VSM-plus-ICP-MS selection, 31 of 340 screened billets met 6N and two met 7N. Equatorial teak's advantage is not mystical: it is fast-grown on managed, leached low-iron plantation soils, harvested young before deep-heartwood mineral accumulation, and free of the tannin-iron chemistry that penalises oak. Its dielectric constant of 2.1 at 12 percent moisture content is the lowest of any species tested and approaches that of the engineered foams used in RF fixturing.

5. THE FINISH PROBLEM

A timber's grade is a property of the timber, not of the object it becomes -- and the most common way to destroy a good grade is to finish the wood.

Nearly all oil, varnish, and lacquer finishes are cured with metallic driers: cobalt, manganese, and zirconium salts of naphthenic or 2-ethylhexanoic acid, added at a fraction of a percent to catalyse the oxidative crosslinking that hardens the film. Cobalt and manganese are both paramagnetic, and a drier loading of even 0.05 percent metal deposits, per square metre of finished surface, more paramagnetic mass than the entire underlying 5N billet contains. We measured a 5N teak coupon before and after a single coat of a conventional boiled-linseed finish: its surface-referred susceptibility rose from the diamagnetic baseline to a net positive value, reclassifying the coupon from 5N to below 4N. The wood did not change. The finish put the contamination back -- and put it precisely at the surface, in direct contact with the cable, which is the worst place for it.

This is the measured basis -- not an aesthetic preference -- for supplying Equatorial Elevation Blocks unfinished. A finish would undo, at the last step and in the most magnetically active location, the entire selection process that earned the billet its grade. The silver-grey patina that unfinished teak develops with age is elemental oxidation of the wood's own surface; it adds no paramagnetic metal, and is cosmetically a change and magnetically none.

6. GRAIN ANISOTROPY AND THE DIELECTRIC LOAD PATH

Wood is dielectrically anisotropic. Measured across our teak coupons, the relative permittivity along the grain exceeded that across the grain by 22 to 28 percent at 12 percent moisture content, and the loss tangent tracked the same axis. The physical cause is the aligned, tubular cell structure and the orientation of bound-water dipoles along the fibre. For a support material this anisotropy is not a nuisance to be averaged away; it is a design variable.

The cable rests in a cradle machined into the top of each block, so the dominant capacitive coupling between cable and support runs through the short vertical column of wood directly beneath the cradle. By milling each block end-grain-vertical -- growth rings visible on the top face, fibres running vertically along the load path -- we orient the lower-permittivity across-grain axis into the horizontal plane where the cable's field is strongest, and reserve the higher-permittivity along-grain axis for the vertical, load-bearing direction where it does no electrical harm and considerable mechanical good. The end-grain orientation was adopted originally for its compressive stiffness; the dielectric argument for it emerged from these measurements afterward, and independently confirms the choice.

Moisture content governs the whole picture. Permittivity and loss tangent both rise steeply with bound water, which is why every graded billet is kiln-dried at origin to 12 +/- 1 percent and why the maintenance schedule specifies an annual moisture check. A support that has absorbed its way from 12 to 18 percent moisture has changed its dielectric contribution more than any difference between species ever will.

7. DISCUSSION AND CONCLUSION

The N-grade scale proposed here is deliberately parasitic on a convention the reader already trusts. An audiophile who will pay for the sixth nine on a copper conductor has already accepted the premise that residual paramagnetic and scattering contamination, measured in parts per million, is worth controlling. We have done nothing more than apply that premise, and the same class of measurement, to the material the conductor rests against -- and found that the industry's habit of grading the metal to six nines while resting it on ungraded, iron-bearing, tannin-active hardwood is an asymmetry that does not survive being stated aloud.

Equatorial plantation teak reaches 5N neutrality as delivered, 6N under selection, and does so for reasons that are entirely prosaic: low-iron growth conditions, young harvest, no tannin-iron chemistry, low resin, and the diamagnetic baseline it shares with all clean wood. It is not a magical material. It is a clean one, measured, graded, and left unfinished so that it stays that way. Every Equatorial Elevation Block ships with its billet's grade, its Fe + Mn figure, and its as-measured susceptibility printed on the certificate. We invite the reader to ask any other maker of audio supports for the equivalent numbers, and to note the answer.

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