A simple miniature magnetic probe with inherent electrostatic rejection

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A modification of a basic center-tapped magnetic probe design has been developed wherein subtraction of capacitive signals is carried out by the probe itself. The electrostatic rejection of this probe is compared with other typical designs.

Inductive magnetic probes are often used to measure oscillating magnetic fields in plasma.[1–3] The sensitivity of a magnetic probe to electrostatic potentials ("capacitive pickup") is usually an important consideration. Center-tapped construction of such a probe, shown in Fig. 1(b), helps to minimize capacitive pickup with respect to a simply wound probe [Fig. 1(a)]. This relies on the fact that inductive pickup changes sign when a measurement coil is rotated 180° while capacitive pickup does not. The two signals from such a probe are then subtracted, giving twice the inductive signal and greatly reducing any capacitive signal. The subtraction usually takes place at some remote distance from the probe tip.

We present a modification of this basic design as shown in Fig. 1(c). Winding *A* is grounded at one end [Fig. 1(d)] and provides the signal to a 50-Ω system at its other end. Winding *B*, wound bifilar with winding *A*, is grounded at the opposite end to winding *A*. The other end of winding *B* is connected to ground through a small 50-Ω resistor so that this winding has the same load impedance as winding *A*. This provides a system where a center-tapped coil and a subtraction transformer are effectively one. The design remains effectively "center-tapped," with one of the windings shown in Fig. 1(b) moved so as to totally overlap the other.[4] Only one of the windings, however, contributes inductive signal [winding *A* in Fig. 1(c)]. Capacitive pickup creates currents in opposite directions in windings *A* and *B*. The induced magnetic field from the capacitive currents in winding *B* therefore opposes that in winding *A*. The close coupling between the two windings, with the mutual inductance equaling the self-inductance, thus acts to subtract capacitive signals from winding *A*, reducing capacitive pickup in comparison with a single winding. If necessary an extra turn can be wound on winding *B* to compensate for less than ideal coupling. As with all inductive magnetic probes, $\omega < R/L$, where $R(=50\ \Omega)$ is the impedance of the system, L is the inductance of the probe windings, and ω is the desired frequency response.

This design eliminates both the need to propagate two signals from the probe tip and the need for a subtracting transformer or differential amplifier. Construction is simplified by the single signal design, allowing the use of a single ultraminiature 50-Ω semirigid coaxial cable to transfer signals from the probe tip.

The magnetic sensitivity of such a probe, 2 mm diameter and 3 mm long with winding *A* having ten turns, is shown in Fig. 2. Both a singly wound probe and a center-tapped probe (using a hybrid combiner for subtraction) of equal size and corresponding number of turns display very similar magnetic sensitivity. This is measured using a two-turn, 24-mm-diam Helmholtz coil. The windings of each probe are connected to a 2.2-mm-diam, 50-Ω semirigid coaxial cable. The ratio of capacitive pickup to an applied oscillating potential, normalized to each probe's magnetic sensitivity at a given frequency, is also shown in Fig. 2. This is measured using a 12-mm-diam metal cup with internal insulation. The insulation has a 7-mm-diam hole along the axis of the cup to allow a probe access to the center of the cup. The apparatus is enclosed in a grounded box with coaxial signal feeds to reduce interference from signals propagating along the coaxial cable's outer conductor. Such currents can penetrate into the measurement circuit if braided coaxial cable is used or if connections are used in which the outer conductor makes contact at only a few points. Attention to such detail was found to be as important in experimental situations as it was in the test apparatus. The electrostatic rejection of the probe presented here, approximately a factor of 10 improvement over a singly wound probe, lies within a factor of 2 of the

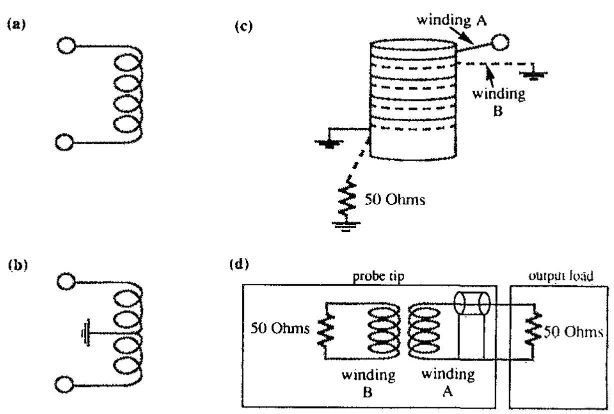

FIG. 1. (a) A simply wound magnetic probe, (b) a common center-tapped probe, and (c), (d) the modified probe design.

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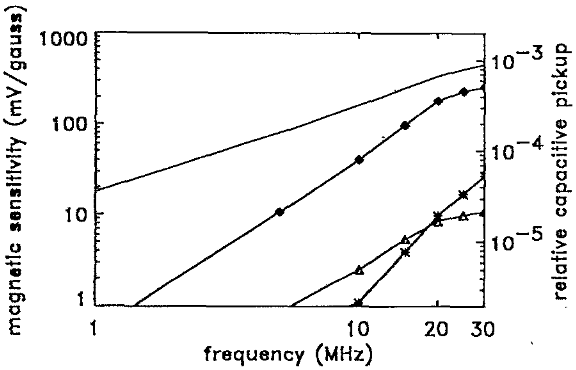

FIG. 2. The magnetic sensitivity (plain line) of a magnetic probe of the construction presented here. Also shown is the relative capacitive pickup of such a probe (Δ), a singly wound probe (◊) and a traditional center-tapped probe (*) (subtraction carried out using a hybrid combiner).

center-tapped probe design over the tested frequency range.

Probes of similar construction were used to measure magnetic wave fields in the helical axis stellarator SHEILA[5] at the Australian National University. A six-wire electrostatic shield, being relatively transparent to magnetic flux, was placed over the probes to enhance electrostatic rejection. The probes were inserted into the plasma through ~7-mm-i.d. glass sheaths. The small size of the probes allowed good spatial resolution and minimized disturbances to the plasma.

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