Fluxgate Magnetometer

A typical electromagnet, such as is used in a relay or machinery, has an iron core around which the current-carrying coil is wound. The coil's magnetic field is greatly strengthened by the iron, because the iron atoms (or arrays of such atoms arranged in crystals) are magnetic.

In ordinary iron, the magnetic axes of its atoms point in random directions, and the sum of their magnetic fields is close to zero. When current flows in the coil, however, its magnetic field lines up the magnetic axes of atoms in the core, and they add their magnetism to the one created by the electric current alone, making it much stronger.

But there exists an obvious limit to the process: when all atoms are lined up, a condition known as the saturation magnetization of the iron, the iron core can provide no further help. If one further increases the current in the coil, the magnetic field only increases by the amount due to the electric current itself, with no contribution from the core. Materials exist--certain ferrites--where saturation occurs abruptly and completely, at a stably defined level. If a large enough alternating current is driven through a coil wrapped around a core of such material, the core's magnetic polarity flip-flops back and forth, and saturation occurs in each half of the cycle, in symmetric fashion.

If however such an electromagnet is located in an existing magnetic field, directed (entirely or in part) along the axis of the ferrite core, that symmetry is upset. In the half of the cycle in which the field of the coil is added to the existing magnetization, saturation arrives a bit earlier, because it depends on the total magnetic intensity, external plus that of the coil. In the other half of the cycle, where the magnetization due to the coil opposes that of the existing field, it happens a bit later, because the sum of the two is somewhat weaker than the field of the coil alone. That asymmetry can be sensed electronically, and this is the basis of the operation of the fluxgate magnetometer.

It does not sound like a sensitive effect--but it can be made quite sensitive by various tricks (e.g. replacing the rod-like magnetic cores with rings). A typical intensity of the magnetic field near the Earth's surface is 50,000 nanotesla (nT), while the fluxgate aboard Voyager 2 has observed with fair accuracy the interplanetary magnetic field near Uranus or Neptune, typically 100,000 times weaker. The Voyager 2 instrument resides at the end of a long boom, keeping it away from the magnetic interference of the currents aboard the spacecraft. Even though such currents are quite weak, they create enough of a magnetic field to disturb the readings of the sensitive magnetometer.

Such instruments must be calibrated against known fields from a coil or in some other way.   Other types of electronic instruments also exist, e.g. those based on optical properties of certain metal vapors, but they are beyond the scope of this quick overview. Another kind is the proton precession magnetometer, briefly described in a lesson plan of the web course "From Stargazers to Starships" and involving the process of precession. It is the basis of "magnetic resonance imaging," a medical procedure for viewing "soft" internal organs which x-rays cannot observe, without any of the radiation damage which x-rays cause .

Post Script:
A little more about the Fluxgate magnetometer. I am not sure this will work any better than my oscope set up. The Fluxgate has been around a long time, since world war II in fact, where it was developed to use in aircraft to detect submarines. This is primarily a measurement tool for determining disruptions in a static magnetic field. You would need to view the output to see how fast it will respond to flux variations – my guess is not much faster than the driving oscillator frequency. Raising the driving oscillator frequency too high might run into some kind of internal blockage where the high driving frequency fails to deliver sufficient power to saturate the coil due to increase electrical and magnetic impedances. I think the ole' transformer or coil across the input of an oscope with an amp is still the best bet on this.