

## Mag-03 and Mag690

# Bartington Instruments' magnetometers for use in magnetic field cancellation and custom field creation

This case study looks at how Bartington Instruments' Mag-03 and Mag690 fluxgate magnetometers are used in magnetic field cancellation systems, with particular reference to scanning electron microscopes (SEM). It also refers to the creation of a custom magnetic field for applications like compass calibration.

Electromagnets are used in SEM to control the direction and focus of the electron beam. External constant magnetic fields, like that of the Earth, can be taken into account during calibration and do not affect the control of the beam. Apart from such factors as building vibration and knocking the apparatus, problems arise when magnetic fields fluctuate. This can be caused by the magnetic field from the power grid, or a slowly changing magnetic field, for example from elevators or vehicles moving nearby.

The greatest problem comes from the alternating magnetic field produced by power cables. Mains electricity alternates at 50 or 60Hz, creating a magnetic field of the same frequency and sometimes second and third harmonics.

**Figure 1** shows the effect that an alternating magnetic field can have on the quality of SEM images.

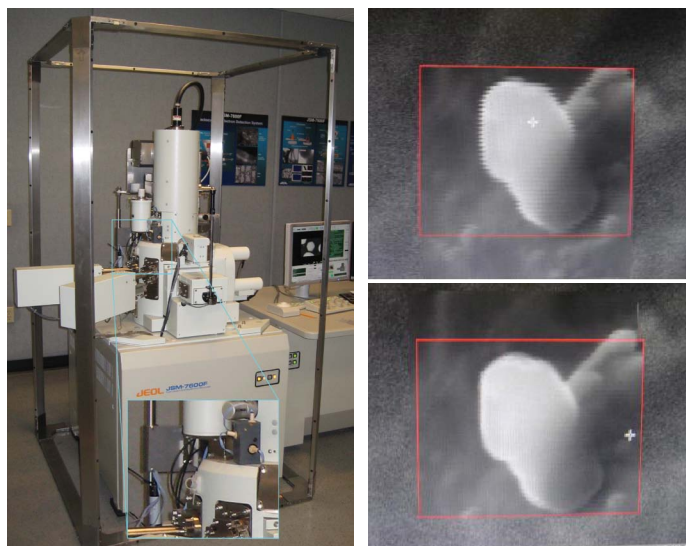
One way to cancel out this fluctuating magnetic field is by superpositioning onto the fluctuating field a second magnetic field of inverse amplitude and matching frequencies. This is produced by Helmholtz coils which surround the beam apparatus, cancelling out the ambient fluctuating field and creating a constant field around the microscope. Note that fluctuations are cancelled inside the Helmholtz coils but are increased outside the coils. Controlling the current through each coil allows control of the magnetic field experienced near protected equipment.

Technical Manufacturing Corp's (TMC) Mag-NetX system is predominantly for use with electron microscopes and combines Bartington Instruments' magnetometers, a control unit and Helmholtz coils. A Mag-03 sensor measures the magnetic field around the microscope and provides readings to the control unit. The control unit processes the measurements and converts them into a current which is sent through the Helmholtz coils.

### Comparison of sensors

The effectiveness of the cancellation field is dependent on the initial field readings. TMC has used Bartington Instruments fluxgate magnetometers, the Mag-03IE70v1 and the Mag-03MS70, for over five years. Bartington's new low cost Mag690 has also been tested by TMC alongside the Mag-03s for comparison.

The testing determined the levels of suppression of fields between 10 and 1400Hz. The range of interest was <200Hz as this would be the required cancellation range for 90% of cases. The three sensors were tested with the same cage using suppression feedback gains found automatically. The results showed excellent suppression for frequencies below 100Hz. The comparative results are shown in **Figure 2** overleaf.



**Figure 1.** The left hand image shows a typical Mag-NetX installation with Mag-03IE70v1 sensor. In the top right image the B field is not suppressed. In the bottom right it is suppressed with the Mag-NetX system. Scanning Electron Microscope, Magnification 70k.

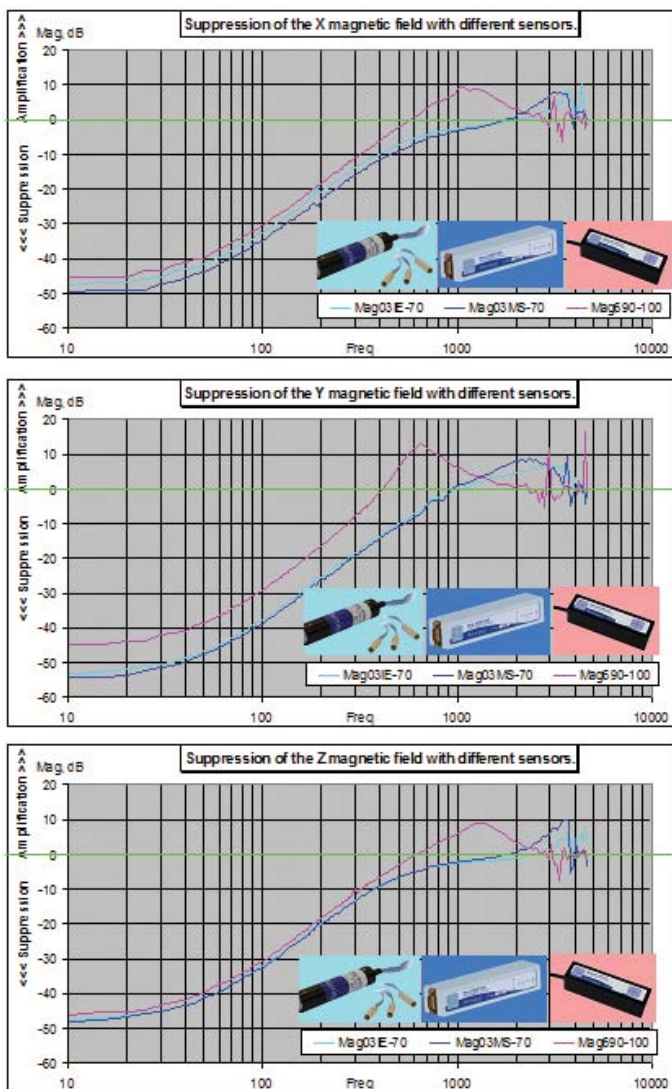


Figure 2. Performance plots by axis.

The two Mag-03 (Mag-03IE70v1 and Mag-03MS70) plots consistently show matching responses. Predictably the Mag690-MX100 does not perform to the same standard at higher frequencies, due to a slower bandwidth of 1kHz compared to the 3kHz of the Mag-03 sensors. However, where cancellation is only required below 200Hz, the Mag690 is sufficient.

### Cost and physical parameters

The Mag690 is approximately a third of the price of the Mag-03 range, but the maximum suppression bandwidth is lower, around 500-600Hz.

The construction of the Mag690 and the Mag-03MS70 make them harder to position. Sensors are placed as close to the centre of the Helmholtz coil as possible, but due to saturation of the axes from the strong magnets on many electron microscopes, options for positioning three axes

in one place can be limited. The flexibility offered by the construction of the Mag-03IE70v1 means that the sensor heads can be positioned in different locations to avoid saturation.

### Creation of custom field

Sometimes there is a need to create a precision magnetic field up to a few Gauss, simultaneously suppressing environmental disturbance, for example to calibrate digital compasses or for research purposes. TMC's Mag-NetX system with the Bartington Mag-03MS sensor is capable of doing just this.

Creation of a precision field requires 'true' Helmholtz coils, to create a highly uniform field, and a high precision three-axis sensor with very good orthogonality. (Figure 3)

The properties of the Mag-03MS250 sensor make it a suitable choice for such a system.



Figure 3. True Helmholtz Coils required for precision field creation.

### Conclusion

TMC's Mag-NetX is a highly effective system for active cancellation of stray magnetic fields and for creating custom fields. It can be supplied with any of the sensors mentioned here, depending on the requirements of the individual customer. The Mag-03MS70 offers the best orthogonality between the axes, giving the truest vector field measurements; the Mag-03IE70v1 offers the most flexibility for positioning the axes, providing readings

closer to the electron beam; and the Mag690 offers the lowest price for systems requiring suppression of lower frequencies. The Mag-03MS250 is the best choice for field creation.

For more detailed information on cancellation systems and Bartington Instruments' products please contact [sales@bartington.com](mailto:sales@bartington.com).

## References

- [www.bartington.com/mag-03-three-axis-magnetic-field-sensor](http://www.bartington.com/mag-03-three-axis-magnetic-field-sensor)
- [www.bartington.com/mag690-low-cost-three-axis-magnetic-field-sensor](http://www.bartington.com/mag690-low-cost-three-axis-magnetic-field-sensor)
- [www.techmfg.com/products/magnetic/magnetx.htm](http://www.techmfg.com/products/magnetic/magnetx.htm)
- [www.micromagnetics.com/](http://www.micromagnetics.com/) (manufacturer of precision Helmholtz coils)
- [www.directvacuum.com/shopexd.asp?id=149](http://www.directvacuum.com/shopexd.asp?id=149) (seller of these coils)