Maintaining a stable environment for electron microscopy

Robert Christy, Senior Customer Support Scientist, Spicer Consulting, Eden Laboratory, Broadmead Road, Stewartby, Bedfordshire, MK43 9ND, England

Abstract

As new technologies continue to come to market, laboratories are expanding and investing in more and more electronic equipment. Every inch of the laboratory must be put to good use as space becomes ever-more precious. This busy setting, combined with the growth – and noise – of the surrounding urban environment, creates considerable problems for electron microscopists, as the quality of the results depends heavily on maintaining a stable operating environment, free from vibration and external magnetic fields. Prior to setting up a sensitive electron microscope, it is crucial that the area is meticulously surveyed, to ensure that the quality of the images produced is not affected by external factors.

Introduction

The local environment heavily influences the performance of any electron microscope; a location that is free from vibration and external magnetic fields is essential to avoid any movement of the electron beam and ensure optimum image quality. The key to establishing these stable environmental conditions is a scrupulous pre-installation site survey by either an independent service provider or the equipment supplier. This allows any pre-existing external factors likely to exert an adverse effect on the quality of the imaging to be identified. Typically, the survey will include measurement of acoustic levels, magnetic fields and floor vibrations in X, Y and Z directions, and direct comparison with the environmental specifications of the equipment to be installed. Action can then be taken to mitigate any unwanted interferences, for example, by installing a magnetic field cancelling system.

Sources of interference

Conditions within the room in which the electron microscope is installed are an obvious consideration with regard to the performance of the instrument, but the location of the building itself can also affect image quality. Interference can originate from a variety of sources, but the most commonly encountered problems can be attributed to vibrations through the floor or air – acoustic vibrations – or magnetic fields.

Anything that moves or rattles – whether regular or random – has the potential to create vibrations. Examples include electronic equipment, air currents from air conditioning systems, people walking around the laboratory, doors opening and closing, even traffic in the street, nearby railways or ocean waves. Magnetic fields can also arise from numerous sources, both within the building and externally. The major source of this kind of interference is power lines in the building walls, with magnetic fields across the world normally occurring at two main frequencies – 50 and 60 hertz. In addition, internal interferences can result from magnetic fields generated by other equipment, lights (particularly fluorescent tubes) or nearby lifts. External factors may also be involved, and it is important to consider the effect of vehicles, including trains and the electric trams that are growing in popularity in many urban areas. The magnetic fields generated from these can extend for hundreds of metres, unknowingly affecting electron microscope image quality.

Temperature is another crucial consideration. A stable temperature is vital for good performance, as variations can cause specimen drift in the microscope electronics and changes in the mechanical tolerances of components, which will impact on the instrument's imaging capabilities. The solution to the problems created by all these types of interference is to undertake a comprehensive site survey, to uncover any problems and allow suitable preventative measures to be taken.

Taking a close look

Laboratory space is increasingly at a premium. Equipment is squeezed into every available inch of the room, resulting in electron microscopists having to work in a crowded environment surrounded by other apparatus that depends on electricity to function, potentially impacting on image quality. Site surveys become ever-more important in this scenario, and play a crucial role when investing in microscopy instrumentation. A site survey can also help to troubleshoot and resolve issues arising at a later date; as cities and towns grow and become busier, so too do the levels of potential interference. On top of that, manufacturers' environmental specifications are becoming increasingly stringent as they strive to continually improve resolution and image quality, with top end microscopes with spectrometers only able to withstand up to 10 or 20 nanotesla of interference. It can be extremely challenging to find a suitable environment for electron microscopy.

How can interferences be overcome?

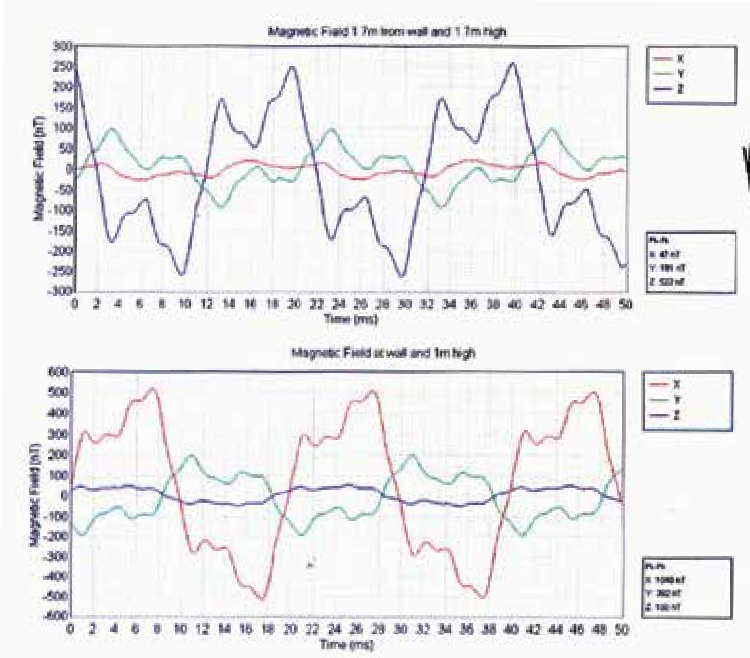
A new microscopy installation will frequently be within an existing building, sometimes to complement the equipment already in place or, on other occasions, as part of a new laboratory set-up. In this situation, it will generally be the case that little can be done about the current infrastructure and space constraints. Usually, the compromise will be to choose an installation site as far away from potential interferences as possible, and to install a magnetic field cancelling system.

New-build laboratories provide the opportunity to start with a blank sheet of paper and design an optimised microscopy facility. This allows engagement with all the interested parties from the outset, to ensure the incorporation of the optimal infrastructure. At the same time, the location of the laboratory can be carefully chosen to ensure that it is as far away as possible from both internal and external influences. This includes installing air conditioning units in a separate plant room away from the laboratory, routing electrical power cables to minimise any potential interference, and appropriate siting of other equipment to reduce the likelihood of affecting the microscopy instrumentation. Even the proximity of the car park can be selected to reduce interference due to traffic as much as possible.

A number of options are available to combat the severity of vibrations and counteract their effects. For example, concrete blocks can be used to isolate the microscope system from the rest of the building. This reduces the vibrations from building sway that transmit through the floor and into the structures of the microscope, causing them to resonate at different frequencies. Alternatively, active vibration isolation can be employed, which uses a platform of transducers to move the system in the opposite way and can respond rapidly enough to ensure that any phase lag is minimal.

Taking action

During a site survey, vibration and magnetic field interference should be measured from different locations and heights, to see how signals change amplitude in all three axes. This helps to locate the cause of any problems, making it easier to implement measures to reduce or eliminate interference. These measures may be as simple as relocating the microscope or taking out the cause of the interference. Alternatively, a cancelling system can be installed to improve microscopy performance, as demonstrated in the following examples.



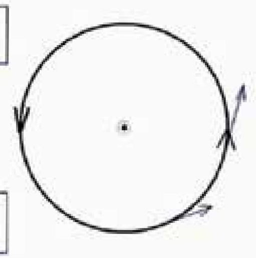


Figure 1A. Magnetic fields from power cables. The circle represents the field produced by current flowing in a wire. The two arrows show the tangential field produced at the two heights. At the height of the power cable the field is vertical, while at lower heights, the horizonal component dominates.

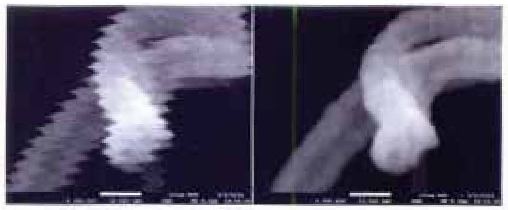


Figure 1B. The effect of a field cancelling system on interference caused by an AC field.

Power cables

Power cables can be a common cause of interference for electron microscopes. Running through many areas of a building, the live wire carries electrial current to an appliance, while the neutral cable completes the circuit to form a path for the current to flow back to the mains. These two wires should effectively cancel each other out. However, as the currents get larger, the current difference between the wires grows. This leads to large magnetic fields, as shown in Figures 1a and 1b.

Distribution boards

Distribution boards are central hubs that route the power coming directly into a building or lab around various circuits. They are also a source of large magnetic fields, and every effort should be taken to install an electron microscope as far away from them as possible. Figure 2 shows how the interference levels from distribution boards a small distance away from the microscope exceed the tolerance level of the instrument.

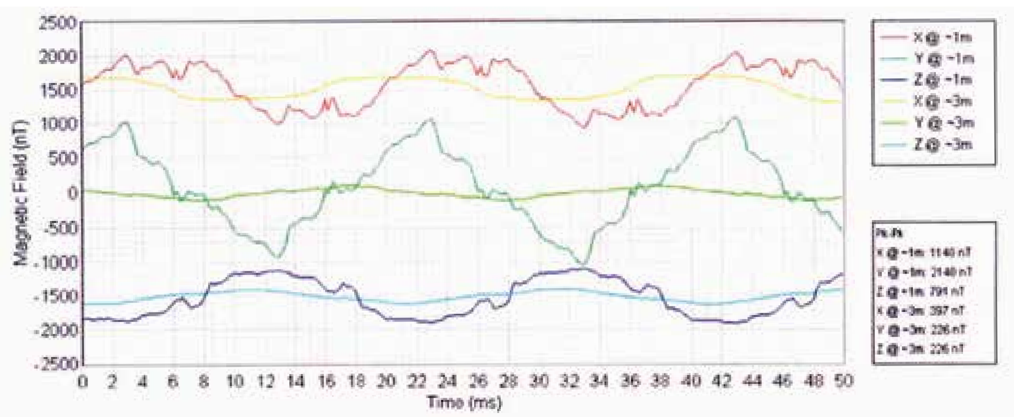


Figure 2. Magnetic fields from distribution boards.

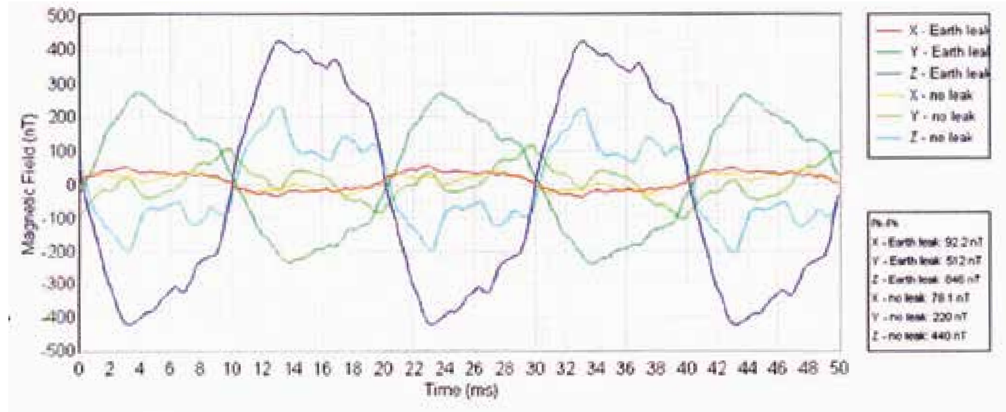


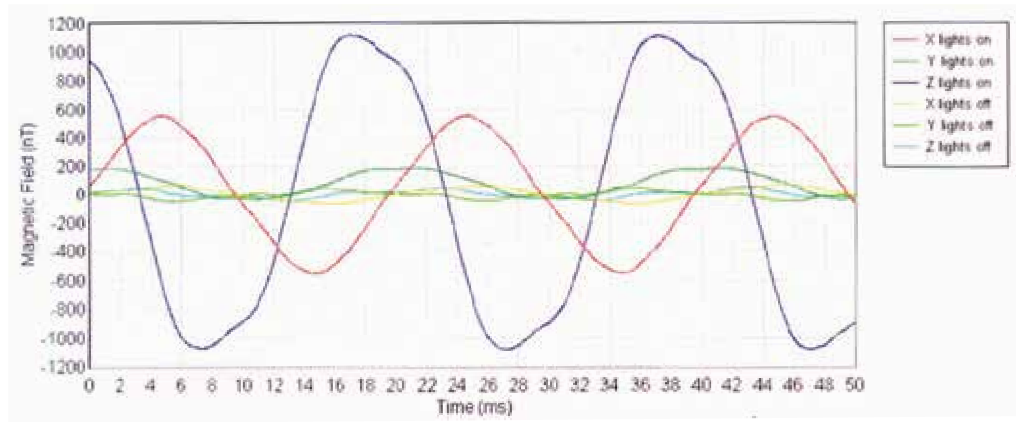
Figure 3. Magnetic fields from earth current leakage.

Earth leakage current

Site surveys may, from time to time, uncover problems in the power supply, as shown in Figure 3. Large leaks down the earth wire produce huge magnetic fields. These can often be identified by turning off different areas of power supply.

Lighting

Despite the fact that lights are frequently turned off in microscopy rooms during imaging, lighting remains a cause of interference, as demonstrated in Figure 4. As a rule, LEDs tend to be the best option, while fluorescent lights should be avoided. The simplest solution to overcome the problem is often to change the type of lighting.



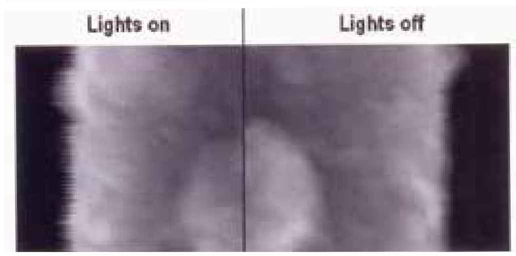


Figure 4. Magnetic fields from lighting. The microscope image on the left was taken with the lights on. The image demonstrates a high level of interference, shown by the jagged edge. This is reduced in the image on the right which was taken with the lights turned off.

Trains

The interference generated by trains depends on the distance between the tracks and the equipment, and is multiple orders of magnitude higher than can be tolerated by electron microscopes. The scheduled rail timetable results in regular activity that causes disruption not only due to vibrations from passing trains, but also from magnetic

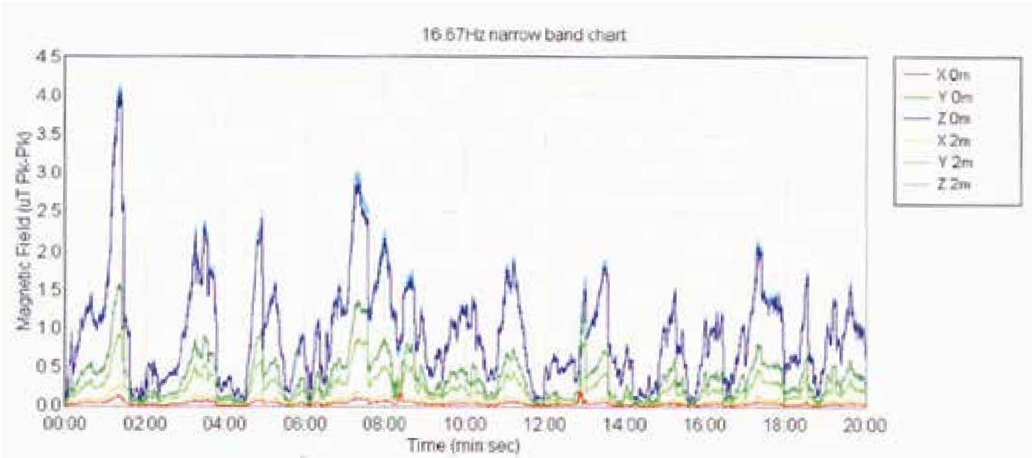


Figure 5A. Magnetic fields from trains. X and Y are the two horizontal axes while Z is the vertical axis. X is parallel to the track in this image.

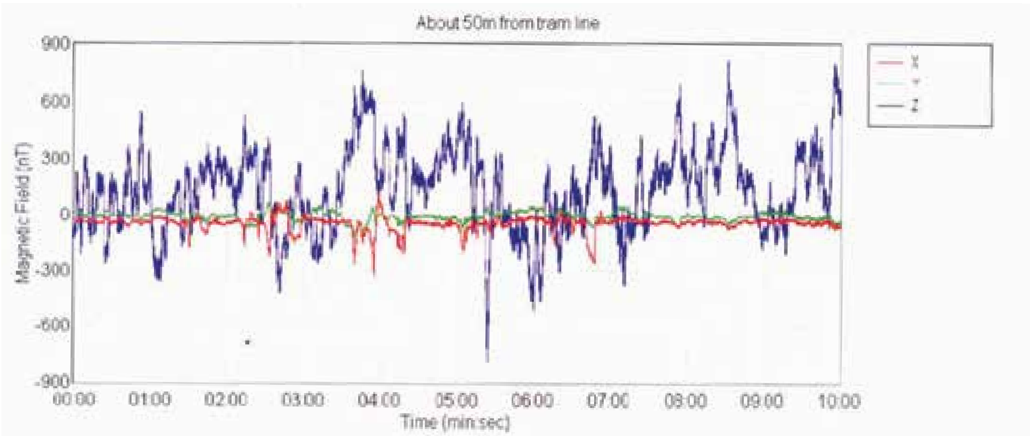


Figure 5B. Magnetic fields from trams.

fields running along the power lines, which affect instruments hundreds of metres away.

Trains in different countries – and even regions within countries – run at varying frequencies and voltages, producing an array of magnetic fields. A survey conducted outside a lab on the embankment next to a 16.67 Hz railway line in Germany demonstrated the extent of the interference coming from the lines supplying power to passing trains (Figure 5a). Vibration levels, which may also have an impact on image quality, were not determined.

Figure 5b shows readings taken 50 metres from a tram line set on a hill. The slope influences the degree of interference, depending on whether a tram is moving up or down the slope. The implementation of a cancelling system overcame this issue, allowing a microscope to be installed.

Underground train systems

Both vibrations and magnetic fields should be measured when studying the effects of an underground railway system. Figure 6 shows the results of a survey conducted near to the tracks. A constant base level of interference was observed, which peaks when trains go past, as seen by the spikes at 3, 6, 19 and 28 minutes. As the frequency of public transport systems increases due to demand, so does the level of interference. Cancelling systems are frequently needed to overcome the effects of the world becoming busier.

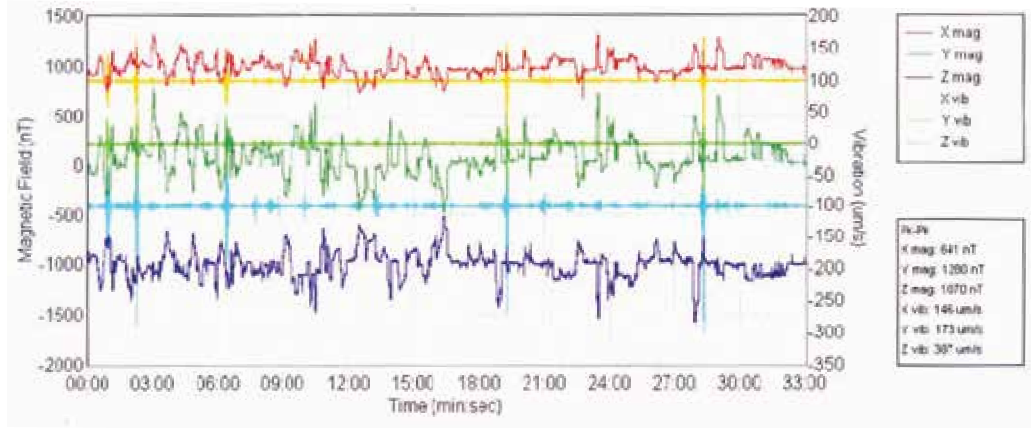


Figure 6. Magnetic fields from trams and trains. The three magnetic axes show how interference from power cables is constantly changing. Vibration bursts can be seen when trains are closest, and demonstrates how magnetic interference can be high when vibration level is low.

Lifts

Lifts are everywhere, particularly in larger facilities, and are often closer to the laboratory than they appear; a lengthy walk to the microscopy room may, in fact, be circuitous, ending just a few metres away from a lift. Ascending and descending lifts cause interference gradients that constantly change with height (Figure 7). This results in images that wander and jump around the screen due to large changes in magnetic fields. It is even possible for site survey readings to identify which floor a lift is on. Generally, the installation of a cancelling system is the only option.

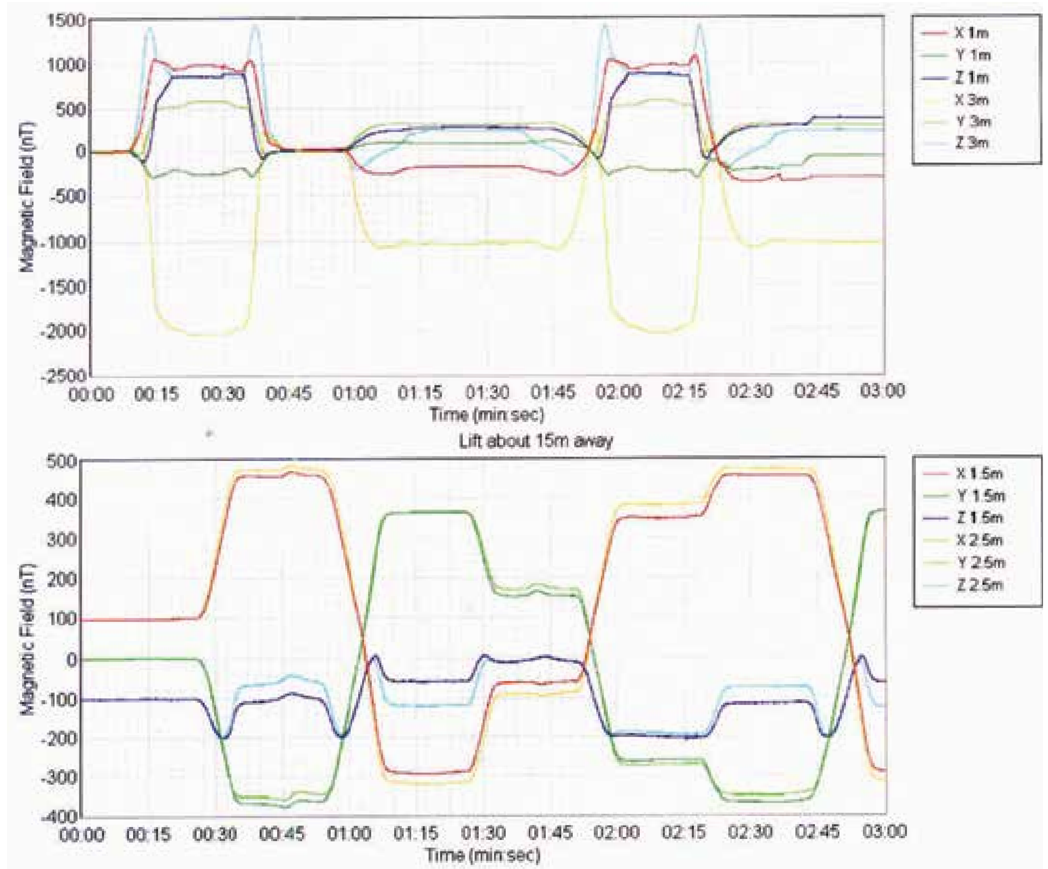


Figure 7. Magnetic fields from lifts.

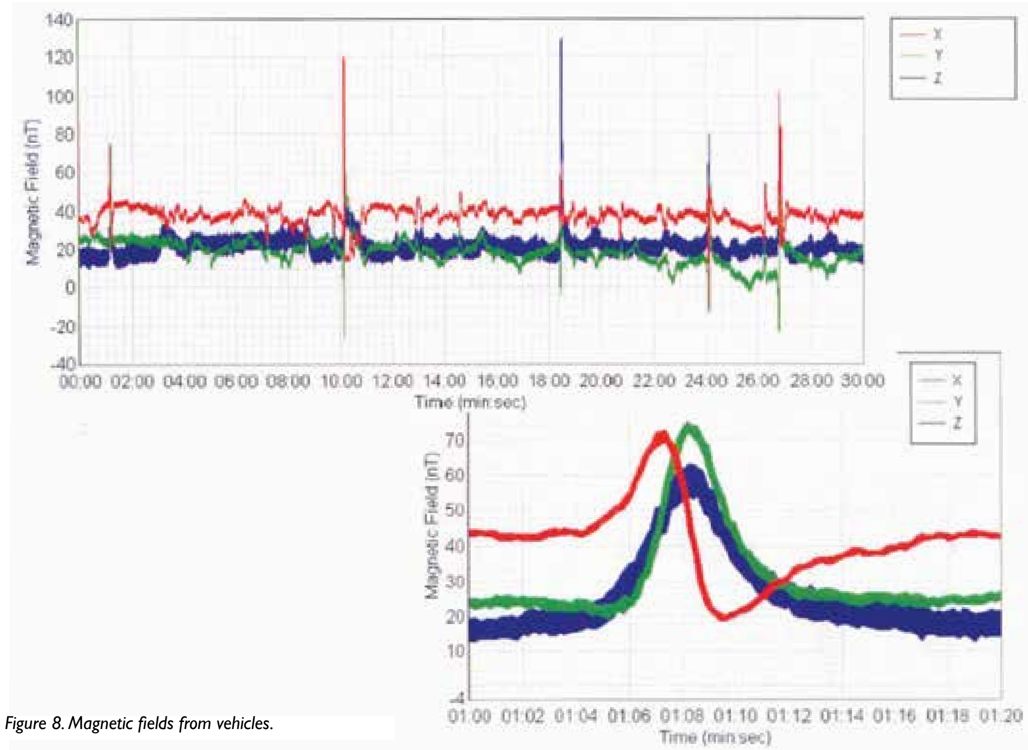


Figure 8. Magnetic fields from vehicles.

Vehicles

Vehicle movements are a common source of interference where microscopy rooms are situated close to roads or car parks. Heavier vehicles, such as lorries, or the regular passing of buses, result in larger peaks in interference, as demonstrated by the spikes seen in Figure 8. It is becoming increasingly difficult to find areas that are not in close proximity to roads, and a field cancelling system is often required to overcome these disturbances.

Magnets

Large systems built around magnets – such as NMR platforms – are designed to keep as much of the field inside as possible, and therefore the extent of their effect should, in theory, be minimal. However, this can only be confirmed by conducting a site survey. Figure 9 shows how, even at a distance of 25 metres from the microscope, the field is multiple orders of magnitude above what can be tolerated. In this situation, the microscope and magnet should be moved further apart.

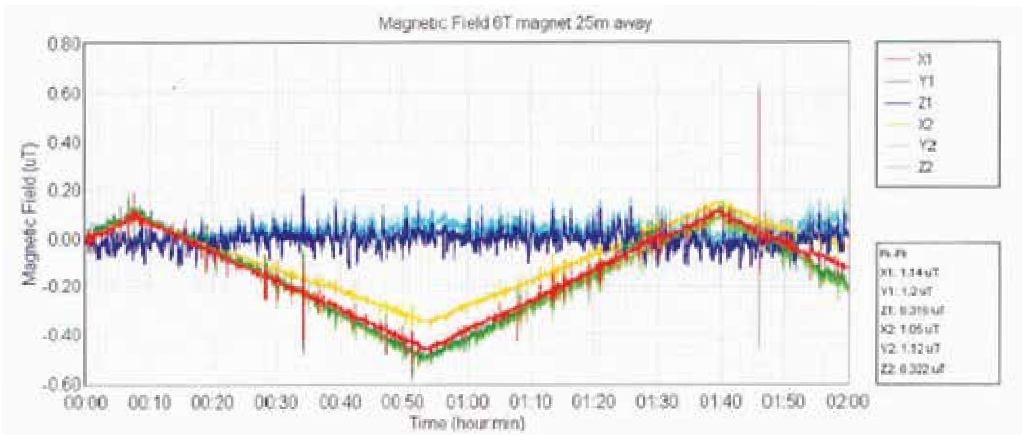


Figure 9. Magnetic fields from magnets.

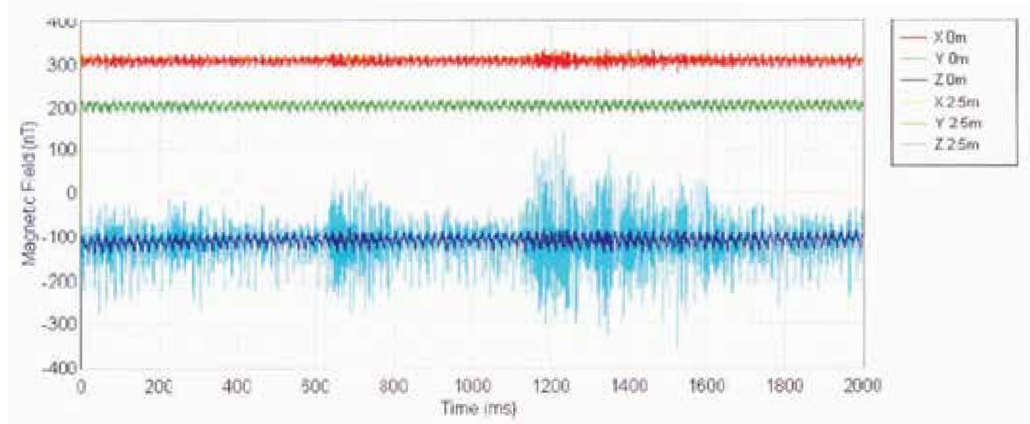


Figure 10. Magnetic fields from hearing loops.

Miscellaneous sources

As well as the scenarios discussed above, site surveys frequently uncover unexpected causes of interference. An example of this is shown in Figure 10. Readings were taken at three different heights in a microscopy room that had been converted from a lecture theatre. An unknown source was causing significant interference, and a survey was able to trace this to a hearing loop that had been left behind ceiling tiles, which was easily rectified by renovation work.

Conclusions

Without doubt, setting up and maintaining a stable microscopy environment is challenging, increasingly so as the world becomes a busier place. However, measures can be put in place to ensure that any interferences are mitigated. Thinking ahead and engaging in discussions with microscopy suppliers, site surveyors and, in the case of a new build, architects, at the earliest possible opportunity is crucial. Engaging the services of an experienced site surveyor with the right equipment is essential to identify both common and unusual causes of interference, and understand the magnitude of their effects. The surveyor can then advise on how best to counteract these problems. Carefully considering all eventualities will enable the creation of the most stable electron microscopy environment possible, be it in an existing facility or a newly set-up laboratory, allowing the highest quality imaging to be maintained.

Corresponding author details

Robert Christy, Customer Support Scientist
Spicer Consulting, Eden Laboratory, Broadmead Road, Stewartby, Bedfordshire, MK43 9ND, England
email: rkc@spicerconsulting.com
web: https://www.spicerconsulting.com

Biography

Robert Christy studied physical science at university and holds a PhD in Chemistry from the University of Kent at Canterbury. His role at Spicer Consulting is primarily customer support, performing environmental surveys and installations globally. Robert provides an independent service surveying magnetic fields, vibrations and acoustics prior to equipment installation, as well as post-installation troubleshooting. He also performs magnetic field surveys as part of the magnetic cancelling system installation process.