

SC24 Magnetic Field Cancelling System



- **Makes the ambient magnetic field “OK” for the electron microscope**
- **Adapts to field changes within 100 μ s**
- **Touch screen intelligent user interface with automatic setup and DC reset**
- **Simultaneous AC & DC field display with choice of Tesla or Gauss units**
- **Mixes dual sensors to create virtual sensor “inside” the EM column**
- **Use AC sensors for cancelling 50/ 60 Hz AC line fields or:**
- **Use DC sensors for cancelling tram and train DC fields and 50/60Hz**
- **Built-in test field generator**
- **Ethernet and USB ports for remote operation and monitoring**

Overview

Electron microscopes have to operate in an ambient magnetic field comprising the earth’s field and fields radiated by electric power networks and electrical machines.

When the ambient field changes, the electron beam in the microscope is deflected, causing loss of resolution and image distortion. The SC24 system stabilises the field by dynamically creating nearly equal and opposite field changes, so microscope performance is much improved.

The SC24 system comprises a magnetic field control unit, one or two magnetic field sensors and three orthogonal axis multicore cables, that are installed in the room where the field is to be cancelled.

Three power amplifiers in the control unit drive currents through the cables to create a field of the opposite sign to the change in ambient field.

The magnetic field sensor measures the resulting field and real time negative feedback reduces the ambient field by the loop gain of the system.

The system is dynamic, automatically responding to field changes within 100 μ s.

Product Description

The SC24 is a fourth generation Magnetic Field Cancelling System, designed to improve the performance of electronic instruments which are sensitive to magnetic fields, such as electron microscopes and electron beam metrology tools.

The SC24 is an enhanced replacement for the SC20 system, which has an installed base of over 400 units world wide.

The field cancelling method is wide band analog negative feedback. An embedded microcomputer controls the system and digitises the fields for measurement but is not within the feedback loop.

Options for installation of the SC24 cables in the microscope room are shown on page 3.

The SC24 can use one or two AC sensors or one or two wideband DC sensors. Wideband DC sensors are only necessary when the ambient has bad DC fields, typically from DC powered trams or trains. The AC sensors are lower cost and slightly easier to use.

Typically for SEMs one magnetic field sensor is used, located near the bottom of the electron beam column. Typically for TEMs two sensors are used spaced about 300mm from either side of the electron beam column at the sample stage height.

The SC24 system does not cancel the field everywhere in the room. It creates a region around the magnetic field sensors where the field is much reduced. The volume of this region depends on the uniformity of the ambient field and the design of the field cables.

The SC24 user interface is a touch screen LCD display panel shown below. This is a typical display for an SC24 with one or two wideband DC sensors when the system is cancelling and the field is OK.

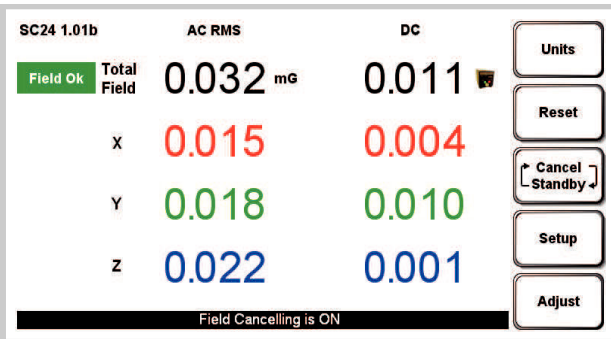


Fig. 1. Typical touch screen display

The five buttons control operation of the system.

The “units” button calls up the units sub menu to select RMS or pk-pk, Tesla or Gauss units. The choice of units has no effect on cancelling.

The reset button clears the “trip” indicators and resets the “zero field” operating point of the DC sensors.

The “cancel/standby” button turns cancelling on and off.

Magnetic field amplitudes are displayed with 100pT (1.0 μ Gauss) resolution. The DC field amplitudes are not displayed for AC sensors.

The magnetic field amplitudes are continuously monitored and compared with preset trip levels to provide “Field OK” indication.

The SC24 has “one button” automatic setup. On setup it analyses the installation, reports installation problems and sets up the feedback loop gain and phase. All setup parameters are stored in non-volatile memory on power loss and on subsequent power up it re-tests the installation. If it find no changes it resumes operation in the pre-power loss state, otherwise it requests setup.

The “adjust” button enables entry to the adjustment menu (for expert users), typical display in Fig. 2. It also gives the option to “lock” the touch screen and reset the Ethernet password. When the screen is “locked” the five buttons are replaced by a new button that allows unlocking if pressed for five seconds.

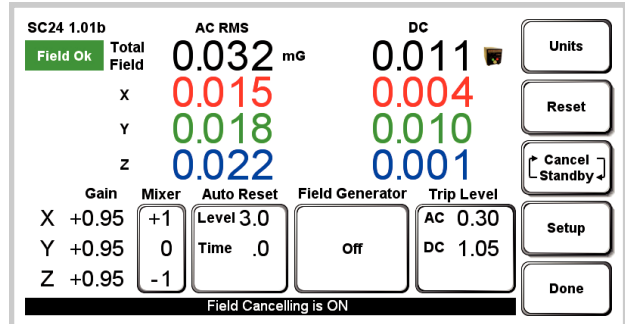


Fig. 2. Adjustment menu

The “Mixer”, “Auto Reset”, “Field Generator” and “Trip Level” touch buttons control the adjustments, described in the **Adjustment Details** section later.

Product Installation

The design of the cable installation in the microscope room involves a trade-off between cost, complexity and performance.

Figs. 3, 4 & 5 show the main design types. Fig 3. is the design with the best performance that is recommended for large TEMs and for all new-build microscope labs.

The dimensions of the dual loop cables have been optimised to make the cable fields uniform over the length of the microscope column for this size room. The SC24 specification refers to an installation with these dimensions.

We usually supply optimised custom sized cables to fit the customer’s rooms. The SC24 can only be used with cables supplied by Spicer Consulting.

In Fig. 3, the multi-core cables each make one turn and are shown in red, green and blue. The actual cables are black or grey and usually installed in white plastic conduits. Where the room has a false ceiling, parts of the cables may be installed above it.

In Fig. 3 the lower parts of the X & Y cables are shown buried below the floor. This is practical for new-build labs. Parts of the bottom Z cable also need to be buried at door openings. Burying the X & Y cables below the floor is recommended for a TEM with a Gatan Imaging Filter for good cancelling at GIF height.

Room Installation options

Fig. 3. Installation for TEMs and new Lab Builds

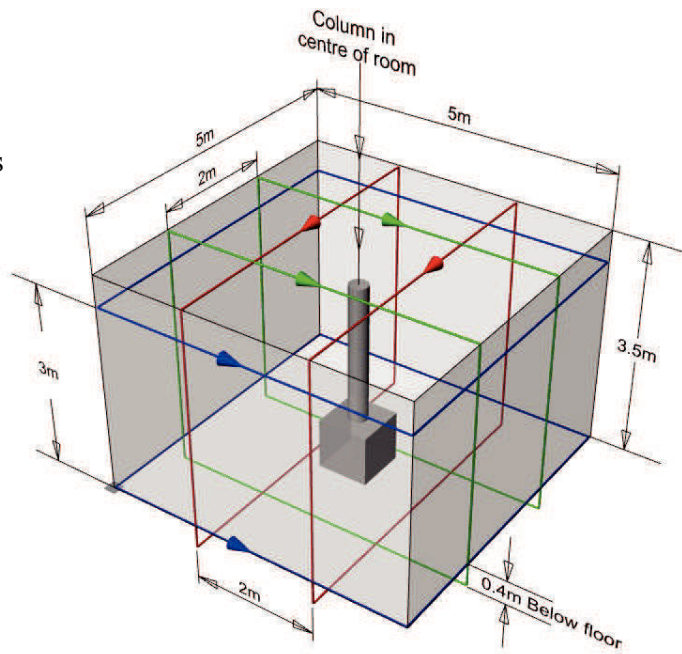


Fig. 4. Basic Installation for TEMs and SEMs

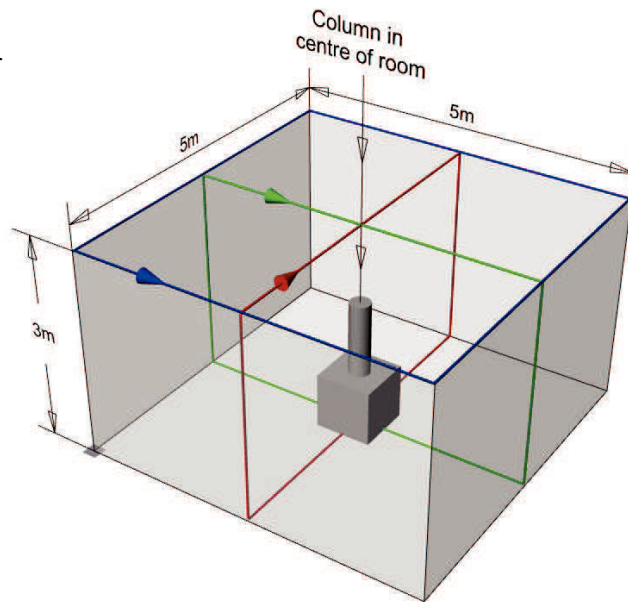
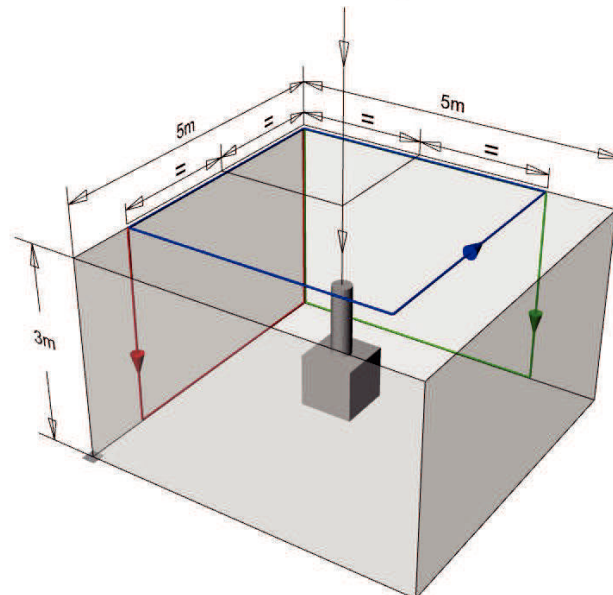


Fig. 5. Minimal Installation for SEMs



Notes:

- X cable loops: RED
- Y cable loops: GREEN
- Z cable loops: BLUE

For existing microscope installations where burying cables is not an option, the bottom sections of the cables can be at floor level and covered with suitable cable protectors. The X and Y cancelling performance at GIF height will be compromised.

Fig. 4 shows the second best cable installation. It has been used with Spicer Consulting Cancelling systems since the SC07 model was launched in 1991. It works best if the X & Y cables cross over directly above the microscope column. It requires cables on the floor covered with suitable cable protectors.

Fig 5. is the simplest, lowest cost installation. It usually does not require cables on the floor. The dynamic range and the cancelled volume are smaller because the cables are farther from the column. This installation makes larger fields in the adjacent rooms which may not be acceptable.

There are many Fig. 5 installations on Scanning Electron Microscopes. SEMs. have small columns so can tolerate the small cancelled volume. Their installations are typically “tuned” by adjusting the sensor position to find the sweet spot for best image improvement.

Sensors and mounts

Standard sensor mounts are shown below.



Fig.6
Sensor SC24/AC



Fig.7
Sensor SC24/DC+AC

With “Sensor SC24/AC” the SC24 provides useful cancelling from 2.5Hz to 5kHz. The ratio of the ambient field to the cancelled field is called the cancelling factor. It is a function of frequency and is greater than 50 at 60Hz. (Fig. 8)

With “Sensor SC24/DC+AC” the SC24 provides useful cancelling from DC to 5kHz. The cancelling factor is greater than 400 at DC and 100 at 60Hz.

“Sensor SC24/DC+AC” contains small Helmholtz coils that surround its field sensing elements. They are used to offset the DC component of the ambient field including the earths field. At reset, the microcomputer in the sensor adjusts and remembers the currents in the coils to set the X, Y, Z sensor outputs to zero. The reset process takes 1 second. The sensor must be reset if it is moved.

The SC24 has two sensor inputs. It can work with one or two sensors. They must be the same type, AC or DC. The SC24 detects the sensor type to choose the correct filters in the cancelling feedback loop. If different types are plugged in, the SC24 reports a sensor error.

When there are two sensors the SC24 enables the mixer function. The two sensors are placed either side of the microscope column. The “mixed field” is a weighted combination of the sensor outputs, creating an adjustable “virtual sensor” between the two sensors.

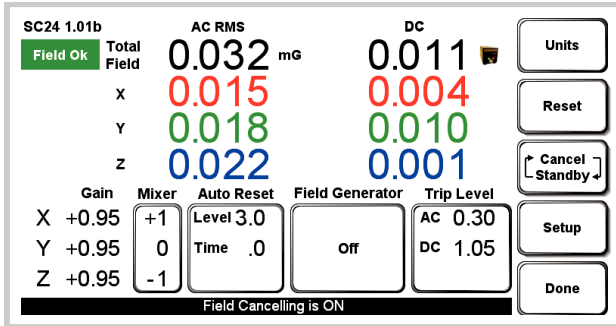
The mixer is adjusted by observing the microscope image and tuning for best image improvement. The mixed fields are displayed on the SC24 screen.

When an electron microscope changes magnification or imaging mode its magnetic lenses may create large DC changes in the ambient field that can overload the cancelling system. With two sensors that can be spaced away from the column the overload is less.

“Sensor SC24/AC” adjusts to the new DC level automatically but the transient may overload it for several seconds. There may be image position drift until the sensor adjusts.

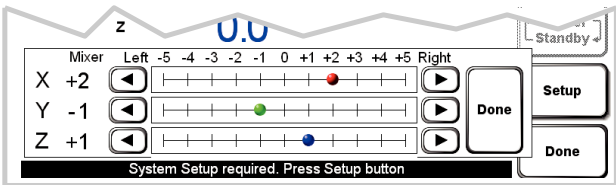
“Sensor SC24/DC+AC” responds to DC so a change in DC field that overloads the cancelling system requires a sensor reset to restart operation at the new ambient field level. The SC24 has an “Auto Reset” function, see the adjustment details section.

Adjustment details



“Setup” automatically sets the feedback loop gains and phases. The gain values are displayed for reference. There is no manual adjustment.

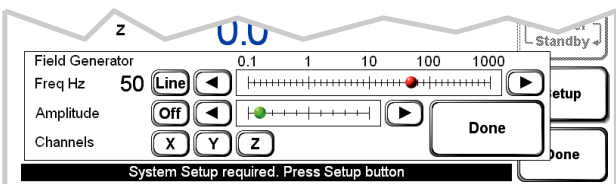
The “mixer” button opens a sub-screen with sliders to adjust the mixers, shown below. Run “setup” after adjusting the mixers (recommended).



The “Trip Level” button enables trip setting adjustment between 10nT and 200nT. The default trip levels are 25nT RMS (AC) and 100nT DC. The trip level has no effect on cancelling.

The SC24 has a built-in field generator that makes test fields using the cancelling cables. It uses the field generator during “setup” to measure the strength of the cancelling cables and determine the correct loop gain and phase.

The field generator can be used to make fields and test the sensitivity of the microscope to those fields. The fields can be sine wave at line frequency or square wave at the frequency selected using the sliders below. Square waves are low pass filtered at 1.6kHz. The test field can be connected to the selected axes.



Outside the adjustment screen the field generator is set to OFF. Inside the adjustment screen, it is possible to have field generation and field cancelling at the same time (for experts only).

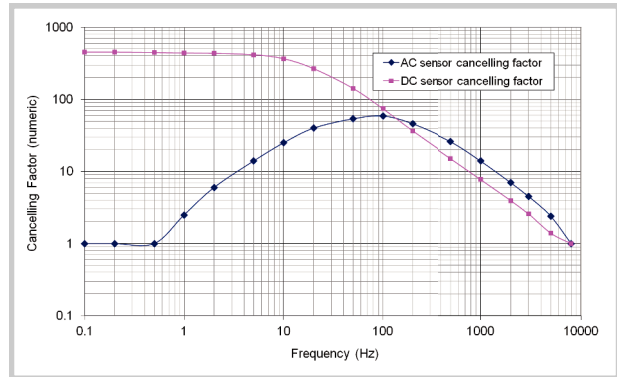
The “Auto Reset” button enables and disables auto reset and sets its sensitivity. When enabled, a small sensor icon appears on the main display (near the “units” button, Fig 1.)

Auto reset only happens when the SC24 is cancelling. It is triggered from the DC field level, which is usually near zero because the DC cancelling factor is large. During overload, the measured field rises abruptly, triggering auto reset.

To prevent nuisance resets “Auto Reset” delays before it resets the DC sensor. The overload field and time delay can be set. The defaults are 500nT and 5 seconds.

Cancelling Factor

The “cancelling factor” is the ratio of the ambient field to the cancelled field. A Graph of cancelling factor vs. frequency is below.



Networking

The SC24 has USB and Ethernet ports.

Software for installation on the customers computer network is in development and will be available shortly.

The software features will include operation of the SC24 over the network and long term recording of the system status and fields.

Specifications

UNITS	Gauss, Tesla, selectable
FIELD CANCELLING	
Co-ordinates	X, Y, Z rectangular Cartesian
Components cancelled	X, Y, Z fields
Measurement range (X & Y) ^{NOTE 1}	4.8 μ T pk-pk (installation Fig. 3)
Measurement range (Z) ^{NOTE 1}	3.3 μ T pk-pk (installation Fig. 3)
1. With Sensor SC24/AC	
Field cancelling factor	> 50 X at 50/60 Hz
Bandwidth	2.5 Hz - 5000 Hz
Cancelling noise limit (0.5 to 5000Hz)	0.6 nT RMS total
2. With Sensor SC24/DC+AC	
Ambient DC field limit	\pm 200 μ T max
Field cancelling factor	> 100 X at 50/60 Hz > 400 X at DC (incremental)
Bandwidth	DC - 5000 Hz
Cancelling noise limit (DC to 5000Hz)	0.7 nT RMS total
DC drift ^{NOTE 3}	< 2 nT/ 24 hours
FIELD MEASUREMENT	
Types	Real time field AC RMS and pk-pk DC incremental (Sensor SC24/DC+AC)
Display	
LCD touch screen	See product description
Sensor dynamic range	4.2 μ T pk-pk
Accuracy ^{NOTE 2}	\pm 1.0 % of reading \pm 1 nT
X, Y, Z real time field outputs	
Scaling	10 V/ μ T (1.0V/mG)
Range	\pm 12 Volts
Source resistance	10 k Ω
Connectors	3 x BNC
Bandwidth	25 Hz - 10 kHz (Sensor SC24/AC) DC - 10 kHz (Sensor SC24/DC+AC)
TEST FIELD GENERATOR	
Sine wave	AC line frequency (50/60Hz) - line locked
Square wave	0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, Hz
POWER	120/240 V 50/60 Hz, 100 VA

Note 1: Measurement range is stated with standard cancelling cables.
Larger range is available for extreme fields with custom cables.
Measurement range is stated at the nominal AC power input of 120 or 240 volts RMS
De-rate linearly for lower voltages

Note 2: Sensors are calibrated with 50 Hz, 1 μ T RMS square wave field.

Note 3: Drift (@23 $^{\circ}$ C \pm 2 $^{\circ}$ C, after 2 hour warm-up)