



## How to Measure the Magnetic Field Distribution of a PM Rotor

*A practical guide to mapping permanent-magnet rotors with magnetic field mappers and cameras*

Permanent-magnet (PM) rotors sit at the heart of brushless DC motors, synchronous servo drives, traction motors, and countless actuators. The torque ripple, cogging, efficiency, and acoustic noise of the finished machine are all written into one thing: the way the magnetic field is distributed around the rotor surface. Two rotors that pass a simple magnetization check can behave completely differently in a motor because their field distribution differs.

This article explains what field distribution means for a PM rotor, why it matters, and how to measure it accurately and repeatably using magnetic field mappers and magnetic field cameras — with reference to the instruments offered by [SENIS AG](https://www.senis.ch).

### What “field distribution” actually means

A magnetized rotor does not produce a single field value. It produces a vector field  $B = (B_x, B_y, B_z)$  that varies continuously over its surface and through the space around it. For a PM rotor, the quantities engineers usually care about are:

- **The radial component ( $B_r$ )** — the field pointing in and out of the rotor surface. This is the component that couples to the stator and produces torque, so its waveform around the circumference is the single most diagnostic signal.
- **The tangential and axial components** — useful for understanding skew, end effects, and leakage.
- **The pole pattern** — number of poles, the angular width of each pole, and the position of the transitions (zero crossings) between north and south.
- **Pole-to-pole and unit-to-unit consistency** — variation in amplitude or width between poles, which directly drives torque ripple and cogging.
- **Defects** — cracks, chips, inclusions, weakly magnetized zones, or assembly errors that distort the local field.

Measuring “the field distribution” therefore means capturing the three field components as a function of position over the rotor, then extracting these engineering parameters from the resulting map.

## **Why Hall-based mapping is the standard method**

The most direct and traceable way to capture a vector field in space is to move a calibrated 3-axis Hall probe across the region of interest and record  $B_x$ ,  $B_y$ ,  $B_z$  at each point, or to place an array of Hall sensors over the surface and read them all at once.

SENIS builds both approaches around its unique, patented three-dimensional Hall sensing — measuring  $B_x$ ,  $B_y$ ,  $B_z$  and the total field  $B_{total}$  at a single point, including in high-gradient fields where the field changes sharply across a small distance. Hall probes are calibrated in SENIS’ ISO 17025:2017 accredited laboratory, which is what makes the resulting numbers traceable rather than merely repeatable. Traceability is what lets a supplier and a customer agree that a rotor is in spec.

There are two practical architectures, and the right choice depends on whether you are in R&D, in the lab, or on a production line.

## Approach 1 — Scanning mappers

A scanning mapper holds the rotor and moves a 3-axis Hall probe along precise axes (rotation plus linear travel) on-the-fly, building up a dense 3D map point by point. Scanning trades speed for spatial flexibility and very high accuracy: you can map an arbitrary cylinder, ring, disc, or segment, at whatever resolution you need in a very short time.

SENIS offers several scanning mappers suited to PM rotors:

### MMS-1A-RS — general-purpose, high-end standard-size mapper

When you need the highest accuracy or want one instrument for many magnet types (flat, rectangular, rings, cylindrical, smaller rotors, etc.), this all-in-one system delivers:

- Magnetic field measurement accuracy: **0.1%**
- Field resolution: 40  $\mu\text{T}$  standard, 2  $\mu\text{T}$  optional
- Selectable calibrated ranges: 50 mT to 2 T
- Probe positioning repeatability:  $\pm 5.0 \mu\text{m}$  /  $\pm 0.025^\circ$
- In-situ automatic calibration
- Interchangeable probes (Hall, AMR for very small fields (nT-range), eddy-current for crack detection, touch stylus for simple dimensional measurements)
- Scanning volume: 125 × 125 × 150 mm



Figure 1: MMS-1A-RS

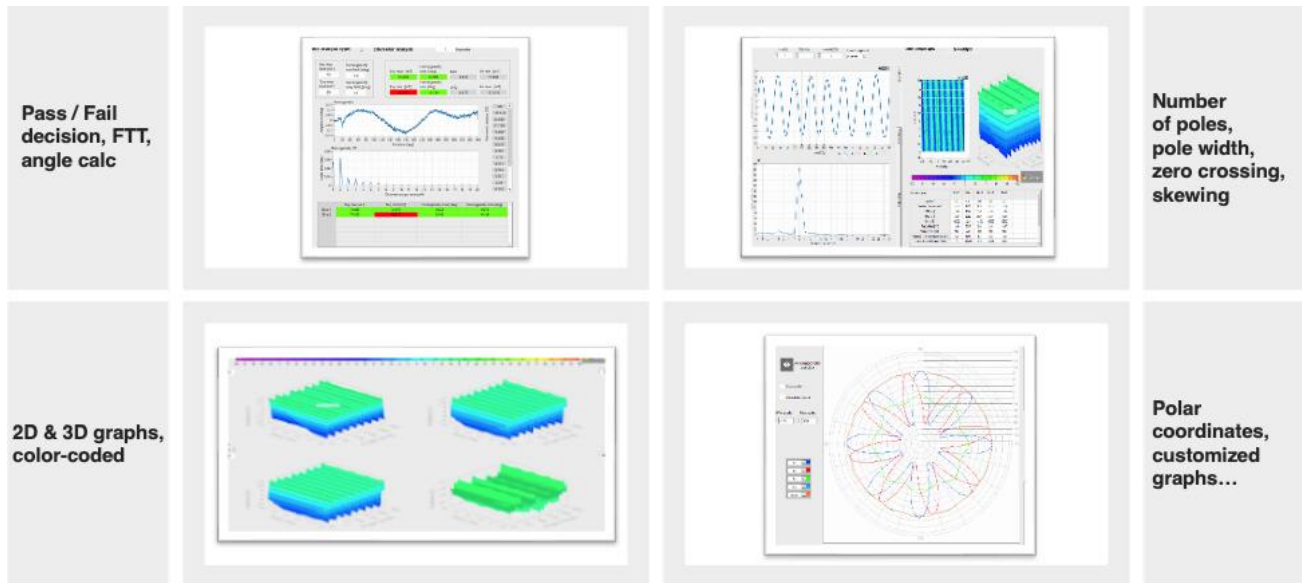


Figure 2: Mapper Software

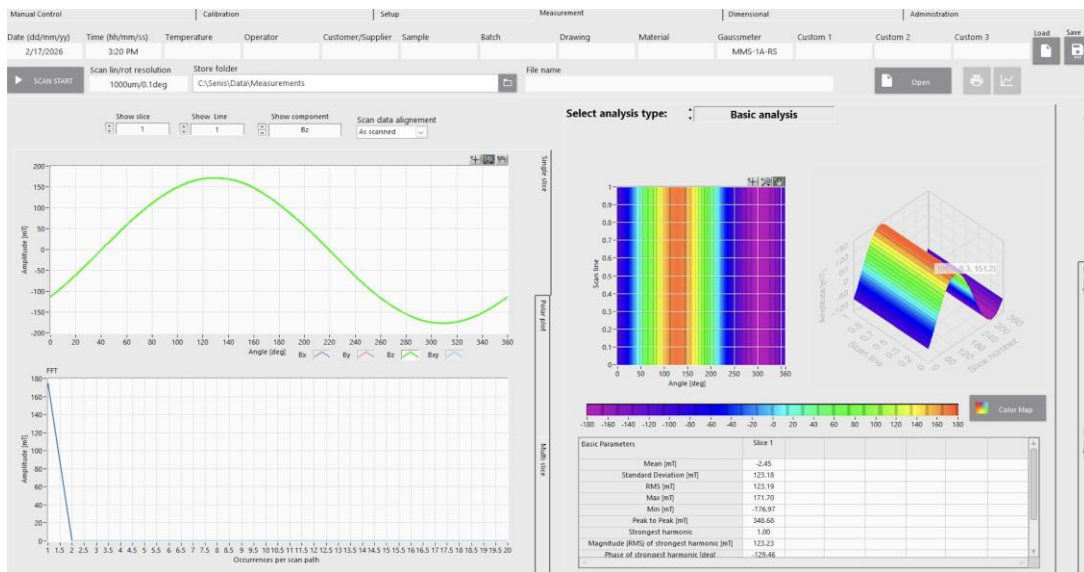


Figure 3: Mapper Software Analysis

## MMS-1X-RS — large-size mapper

A large-size version of the high-end mapper, with roughly a 500 mm scan range (with customization up to 1.5 m for very large and heavy rotors, cylinders or magnetic systems), for large rotors and magnetic assemblies that don't fit a standard-size machine.

The interchangeable-probe design matters for rotor work: the same machine can do non-contact field mapping with a Hall probe, in-contact mapping with a sliding probe, measurement of demagnetized parts with an AMR probe, and crack detection with an eddy-current probe, without rebuilding the setup.



Figure 4: MMS-1X-RS

### MMS-2A-ROT — compact mapper for smaller cylindrical magnets

This is the most directly rotor-focused instrument. It maps rotors, disc, ring, and segment magnets with a 3-axis Hall probe positioned for **in-contact measurement**, with the sensitive volume only 0.5 mm from the magnet surface — important because the field detail you can resolve falls off quickly with distance, **by fully eliminating the rotor eccentricity**. Key specifications:

- Magnetic field measurement accuracy: 1%
- Selectable measurement ranges: 100 mT, 500 mT, 2 T
- Probe positioning repeatability:  $\pm 20 \mu\text{m}$  /  $\pm 0.05^\circ$
- Scanning volume: 155 mm along the Z (axial) direction, 55 mm radial
- Compact, light, and driven by the same Mapper software as the larger systems



Figure 5: MMS-2A-ROT

## Approach 2 — Magnetic field cameras (SENCAM)

A scanning mapper is precise and very flexible, but sequential. When you need to inspect a rotor or magnet in a fraction of a second — for example as an end-of-line check on a conveyor — a magnetic field camera captures the whole field image and analyses the magnetic field at once.

The SENIS SENCAM (SEN-3D-CAM) is a true 3-axis magnetic field camera. Instead of moving one probe, it uses a dense grid of thousands 3-axis Hall pixels to image Bx, By, and Bz across an area simultaneously:

- Measures all three components (Bx, By, Bz), not just the normal component
- Very high spatial resolution — about 16,000 pixels
- The smallest sensitive volume per pixel in its class,  $27\ \mu\text{m} \times 9\ \mu\text{m} \times 4\ \mu\text{m}$ , which lets it resolve fine pole transitions and small defects
- High image acquisition rate — about 7 images per second
- Multiple cameras can be tiled to cover larger areas
- Works both in the lab and inline in production

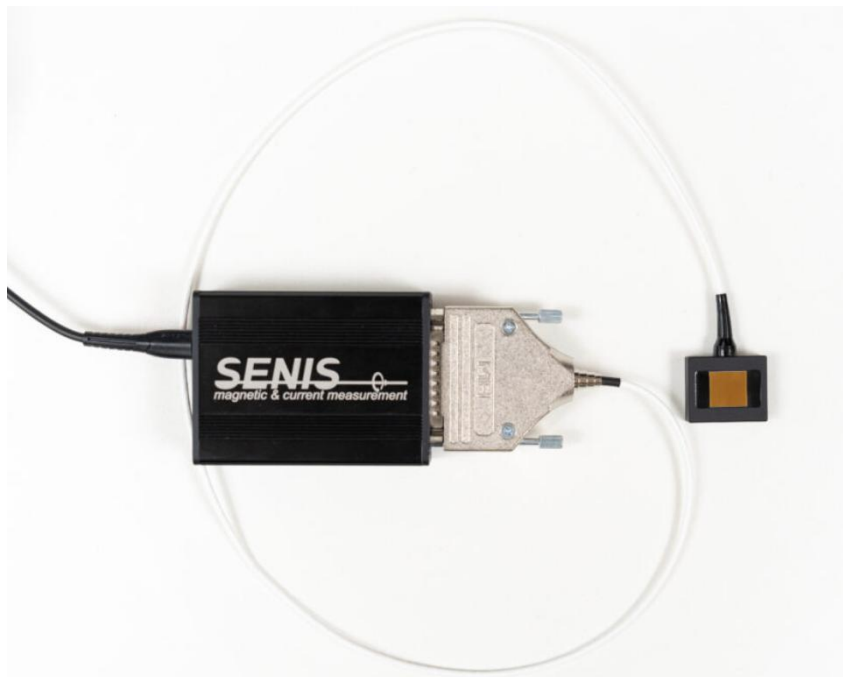


Figure 6: SENCAM

A SENCAM can also be combined with an optical camera (SEN-3D-CAM-OPT) in a patented configuration, so the magnetic field image is overlaid on the physical shape of the part — useful for detecting a field anomaly with a visible magnet contour.



Figure 7: SEN-3D-CAM-OPT

In practice (at SENIS' customers worldwide), R&D and incoming inspection often use a scanning mapper for the definitive, high-accuracy map, while production lines use a camera for high-throughput GOOD/BAD screening. Cylindrical rotor magnets can be inspected on the camera directly, or a camera can be carried on a portal mapper for larger parts.

## The measurement workflow, step by step

The exact motions differ between a scanning mapper and a camera, but the logical workflow is the same.

1. **Define the goal.** Decide what you need: a full surface map for R&D and FEM validation, a pole-pattern check for incoming inspection, or a fast GOOD/BAD decision at end of line. This sets the required accuracy, resolution, and cycle time, and therefore the instrument.
2. **Fixture and reference the rotor.** Mount the rotor so its mechanical axis is well defined and repeatable. For a scanning mapper this means establishing the center and axis of rotation; small centering errors show up as a once-per-revolution ripple in the data, so this step is worth doing carefully. The mapper's software can automatically detect/quantify the rotor's eccentricity.
3. **Set the measurement distance and range.** Place the probe or camera at the intended standoff — for SENIS' mappers it can be with the probes sensitive volume at only 0.5 mm from the surface. Choose the field range (e.g. 100 mT, 500 mT, or 2 T) to match the magnet so you use the full dynamic range without clipping.
4. **Define the scan or image region.** On a scanning mapper, specify the cylindrical surface and the angular and axial step size — finer steps resolve more detail at the cost of time. On a SENCAM, select the rows and columns of pixels you actually need.

5. **Acquire the data.** The mapper records  $B_x$ ,  $B_y$ ,  $B_z$  at every point as it rotates and translates the probe; the camera captures the field image at once. Calibrated 3-axis sensing means each point is a true vector, not a single projected value.
6. **Visualize and analyze.** The SENIS Mapper software builds a 3D map of the field in real time and offline, and runs the analysis automatically.
7. **Decide and archive.** Apply your tolerances to get a GOOD/BAD result, and store the traceable dataset for trending and supplier correlation.

## What the software extracts from the map

Raw field data is only useful once it becomes engineering parameters. The SENIS Mapper software is designed to do exactly this for multipole magnets and rotors, generating a 3D map of the field and then computing:

- **Number of poles** — automatic pole counting
- **Pole width** — the angular extent of each pole, and the spread between poles
- **Zero crossings** — the precise angular position of each north–south transition
- **Magnetic angle and angle error** — how far the magnetic pattern deviates from the ideal, critical for rotors used in position sensing and for commutation accuracy
- **Field homogeneity** — how uniform the field is, pole to pole and over the surface
- **GOOD/BAD decisions** — pass/fail against your defined limits
- **Crack and defect detection** — including cracks in magnetized magnets and in non-magnetized blanks

For a PM rotor specifically, the radial-field waveform around the circumference is usually the headline result: its amplitude tells you magnetization strength, its shape (how close to sinusoidal or trapezoidal) predicts back-EMF and torque ripple, the spacing of its zero crossings reveals pole-position errors, and any local distortion flags a cracked or weak segment.

## Practical tips and common pitfalls

- **Mind the standoff.** Field detail decays rapidly with distance from the surface. Measuring closer (in-contact where possible) preserves the high-spatial-frequency information that distinguishes a good rotor from a marginal one. Always compare measurements taken at the same distance.
- **Control centering.** For rotational scans, an off-center axis injects an artificial once-per-revolution variation. Establish and verify the center of rotation before mapping.
- **Measure all three components.** A normal-component-only instrument can miss tangential and axial features that matter for skew and end effects. Only true 3-axis sensing in a single point, with compensated axes non-orthogonality (SENIS' patents), insures an accurate capture of the full vector field.
- **Match the range to the magnet** so you use the full dynamic range without saturating.

- **Keep it traceable.** ISO 17025-calibrated probes let you compare results across instruments, sites, and suppliers, and defend a GOOD/BAD decision.
- **Validate simulation against measurement.** Mapping is the natural way to confirm that an FEM model of a new rotor matches the real magnetized part — closing the loop between design and production.
- **Pick the tool for the stage.** Use a high-accuracy scanning mapper (MMS-1A-RS, MMS-1X-RS, MMS-2A-ROT) for R&D and definitive characterization; use a SENCAM camera for fast, high-volume inline screening.

## Choosing the right instrument — quick guide

Need	Recommended SENIS instrument
Dedicated, compact rotor / ring / disc / segment mapping	<b>MMS-1A-RS</b> and <b>MMS-2A-ROT</b> — 0.1% or 1% accuracy, in-contact probe
Highest-accuracy, multi-purpose lab mapping	<b>MMS-1A-RS</b> — 0.1% accuracy, interchangeable probes
Large rotors and magnetic assemblies	<b>MMS-1X-RS</b> — large-size, ≈500 mm (or higher) range
Fast, full-field imaging / inline production screening	<b>SENCAM SEN-3D-CAM</b> — 3-axis camera, 16k pixels, ~7 images/s
Crack detection on magnets and blanks	Eddy-current probe on a mapper, or customized defectoscope

## Conclusion

Measuring the magnetic field distribution of a PM rotor is not about reading a single field value — it is about capturing the full  $B_x$ ,  $B_y$ ,  $B_z$  vector field over the rotor surface and turning it into the parameters that predict motor behavior: pole count and width, zero-crossing positions, magnetic angle error, homogeneity, and defect maps. Calibrated 3-axis Hall mapping is the established way to do this with the accuracy and traceability that quality and R&D engineers need.

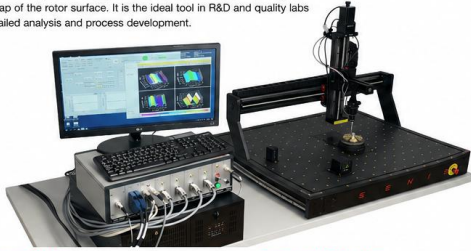
Scanning mappers such as the SENIS MMS-1A-RS, MMS-1X-RS and MMS-2A-ROT deliver dense, high-accuracy maps for development and characterization, while the SENCAM magnetic field camera brings full-field imaging speed to production lines. Together they let a manufacturer validate a design against simulation, qualify incoming magnets, and screen every rotor at end of line against the same traceable standard.

For full specifications, datasheets, application notes, and example measurements, see the SENIS mappers and cameras at [www.senis.swiss/mappers](http://www.senis.swiss/mappers).

**CASE STUDY**  
**Measuring PM Rotors with SENIS Mappers and Camera**  
From high-accuracy R&D characterization to high-speed production inspection

**SENIS MAPPER (MMS-2A-ROT)**  
**High-Accuracy Characterization of PM Rotors**

The SENIS Mapper with a 3-axis Hall probe provides a full 3D magnetic field map of the rotor surface. It is the ideal tool in R&D and quality labs for detailed analysis and process development.



**Key Specifications**

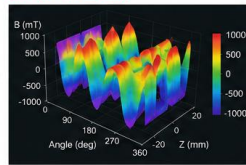
- Magnetic field measurement accuracy: 1%
- Selectable measurement ranges: 100 mT, 500 mT, 2 T
- Probe positioning repeatability:  $\pm 20 \mu\text{m}$  /  $\pm 0.05^\circ$
- Scanning volume: 155 mm (Z axial)  $\times$  55 mm (radial)
- 3-axis Hall probe with 0.5 mm sensitive volume from surface

**Typical Outputs**

- Radial (Br), tangential (Bt) and axial (Bz) field components
- Pole pattern, pole width and zero-crossing positions
- Pole-to-pole consistency and torque ripple indicators
- Local defect detection (chips, cracks, weak zones)

**Use in Practice**  
R&D teams use the Mapper to optimize magnet design, evaluate suppliers, and deeply understand how the field distribution drives motor performance.

**Example 3D Field Map**



**SENIS CAMERA (SENCAM – SEN-3D-CAM)**  
**High-Speed Inspection for Production**

The SENIS 3-axis Magnetic Field Camera captures Bx, By and Bz simultaneously over the entire area in a fraction of a second. It is the perfect solution for end-of-line inspection on the production floor.



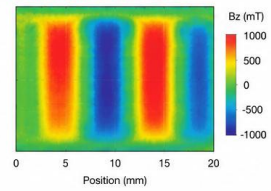
**Key Specifications**

- True 3-axis measurement: Bx, By, Bz
- High spatial resolution: ~16,000 pixels
- Smallest sensitive area:  $27 \mu\text{m} \times 5 \mu\text{m} \times 4 \mu\text{m}$
- High speed: ~7 images per second
- Selectable region of interest for fastest speed
- Works in lab and in-line on production

**Typical Outputs**

- Full-field image of Bx, By, Bz
- Instant visualization of pole pattern and defects
- Pass/fail decision based on field thresholds
- Statistical process control data

**Example 2D Field Image (Bz)**



**Use in Practice**  
Production lines use the Camera for 100% inspection of rotors at high speed, ensuring consistent quality and detecting defects that affect performance.

**Together in the Process** Use the Mapper to understand and optimize. Use the Camera to control and guarantee. Together, SENIS Mapper and SENCAM provide a complete solution from development to production.

Understand the field  
 Detect defects  
 Ensure quality  
 Improve performance

Figure 8: Case Study

*This article is for educational purposes. Instrument specifications are summarized from SENIS AG product documentation; confirm current figures against the manufacturer's latest datasheets before specifying equipment.*