Metrolab MFC: Probe Array Normalization

Introduction

The magnetic field camera (MFC) works on the principle of magnetic resonance between a proton sample, the uniform magnetic field it is immersed in and the frequency modulation generated by the main unit. Its possible theoretical accuracy is good to the known value of the proton magnetic moment. In practice however, the accuracy of the data is equivalent to the accuracy of the internal clock of the main unit. The MFC is an array of these probes spread out over half a circle (or half an ellipse). Thus, as the MFC probe array is rotated 360°, the magnetic field along the surface of the sphere with diameter equal to that of the probe array is traced out. From Maxwell's equations, one can use the magnetic field map of the surface to generate coefficients (usually spherical harmonics) that describe the field at all points inside the mapped out surface. From these values a map of correction coefficients can be generated, which in turn can be used to give the maximum homogeneity inside the volume of space mapped out by the MFC probe array. A complete map is generated in about 15 minutes.

Why Normalize?

The MFC works on the principle of nuclear magnetic resonance. Thus, each of the probes measures the magnetic field to very high accuracy. However, if any magnetic material (even very small grains) is inside the probe array (PA), this will affect the magnetic field that one is trying to measure. Without normalization, one is measuring the magnetic field of interest plus any distortions from spurious ferrite material inside the PA. The point of normalization is to compensate for this effect. In normalization, the PA is placed in a magnet of the same field value for which the PA is designed. The PA is also oriented such that its diameter is along the axis of the magnet. Each of the probes in the PA are sequentially placed in the same position and a reading of the magnetic field is taken for each probe. An offset table is generated at the end of normalization and this table is used to take out the effects of any ferrite material inside the PA so that the PA is accurately measuring the magnetic field of interest. Before normalization can begin, one must check the magnet for stability over time (drift) and stability over space (homogeneity). If the stability for both is acceptable, then one can proceed with normalization.

Normalization

In order to normalize and generate the offset table, each probe in the probe array must take a reading of the exact same magnetic field value. This means that one has to ensure that each probe is taking a measurement from the exact same position in the magnetic field and that the field is not changing over time. A normalization jig (Normalization jig) is used to insure that each probe takes a reading in the same location within the magnetic field (accurate to ±1mm). Note that this is also discussed in the user manual on pg. 33.

I. Position normalization jig
   a. Position the normalization jig in the center of the superconducting solenoid magnet (plus or minus a few cm is OK). Please refer to Figures 1 and 2 at the end of this report.
   b. Ensure that the normalization jig is mounted on a firm table or stand
   c. It is important that the normalization jig and its stand does not move during the course of normalization. Use duct tape and/or foam to secure it to the magnet

II. Check magnet for homogeneity
   a. Place PA in center of magnet (i.e. at position 16, if using a 32 probe PA)
   b. In the Wmfctool9 software, verify that the 'No Storage' box is unchecked on the upper right side of the window. And choose the middle probe to store data (i.e. probe 16, if using a 32 probe PA).
   c. Let the MFC main unit warmup for 10 minutes before taking data
   d. Take a reading of 500 cycles.

e. Using the tab located above the data table, select 'Graph of NMR frequencies' and verify that the middle probes show a flat line. Do not worry about the probes at the ends as they are most likely outside the homogeneous region of the magnet
f. In the central area of the magnet, the homogeneity should not be worse than 10ppm/cm
g. Select 'Numberical field values' and look at the numerical data for all the probes and verify that there are no RMS values above 10 Hz (which would indicate spurious readings or drift)
h. Select the Graph of the middle probe you selected and visually verify that the RMS is less than 0.1 ppm
i. Save the file as 'serial number'_before.dat

III. Check magnet for drift
   a. If this is the first time using the magnet, drift must be checked carefully.
      i. As in step II-d, take a reading every five minutes over a period of half an hour, saving the files.
      ii. Compare the files and verify that the data for the individual probes at the different times are within 0.1ppm of each other
   b. If this is not the first time using the magnet and nothing has changed in the magnet, then it is sufficient to compare data taken 20 minutes apart (the approximate time to do a normalization) and verify that the average magnetic field reading for an individual probe is less than 0.1ppm.

IV. Normalization Procedure
   a. Read and save the EEPROM content to a file (i.e. 'serial number'_before.epa)
   b. Be sure no crane, forklift, elevator or similar thing is operating around the magnet during normalization
   c. Click on PA normalization under the advanced tab, check that the relative measurement tolerance is set to 0.1ppm with 50 cycles and follow the directions (you start in position one and proceed to the end of the probe array)
   d. Save the EEPROM content to a file using the EEPROM utilities (under the advanced tab). Save file as 'serial number'_before.epa
   e. If one or more of the probes was out of tolerance then you will need to hit the normalization tab and go through the process one more time. The computer screen will show 'Out of Tolerance'. Note that if it is a new PA, the normalization will automatically have to be done twice.
   f. If normalization was successful (i.e. all probes are within 0.1 ppm) then you are done. The computer screen will show 'Pass'. The normalization file is automatically saved when you exit.
   g. Save the EEPROM content to a file (i.e. 'serial number'_after.epa)
   h. As in step II-d take a reading and save this file as serial number'_after.dat and compare this file with the one taken before normalization to check magnetic drift
   i. Email the files to james@gmw.com

   NOTE: Five files in total should be generated (_before.dat, _before.epa, .norm, _after.epa, _after.dat

V. Trouble Shooting
   a. In step II, if the graph of the individual probes has an upward curve to it than the main unit has not had enough time to warm up.
   b. If some of the probes give a field reading in the magnetic field but the ones on the end(s) are reading zero or very high RMS values, then most likely part of the PA is outside the area of homogeneity for the magnetic field. Make sure the probe array is well centered in the magnet.

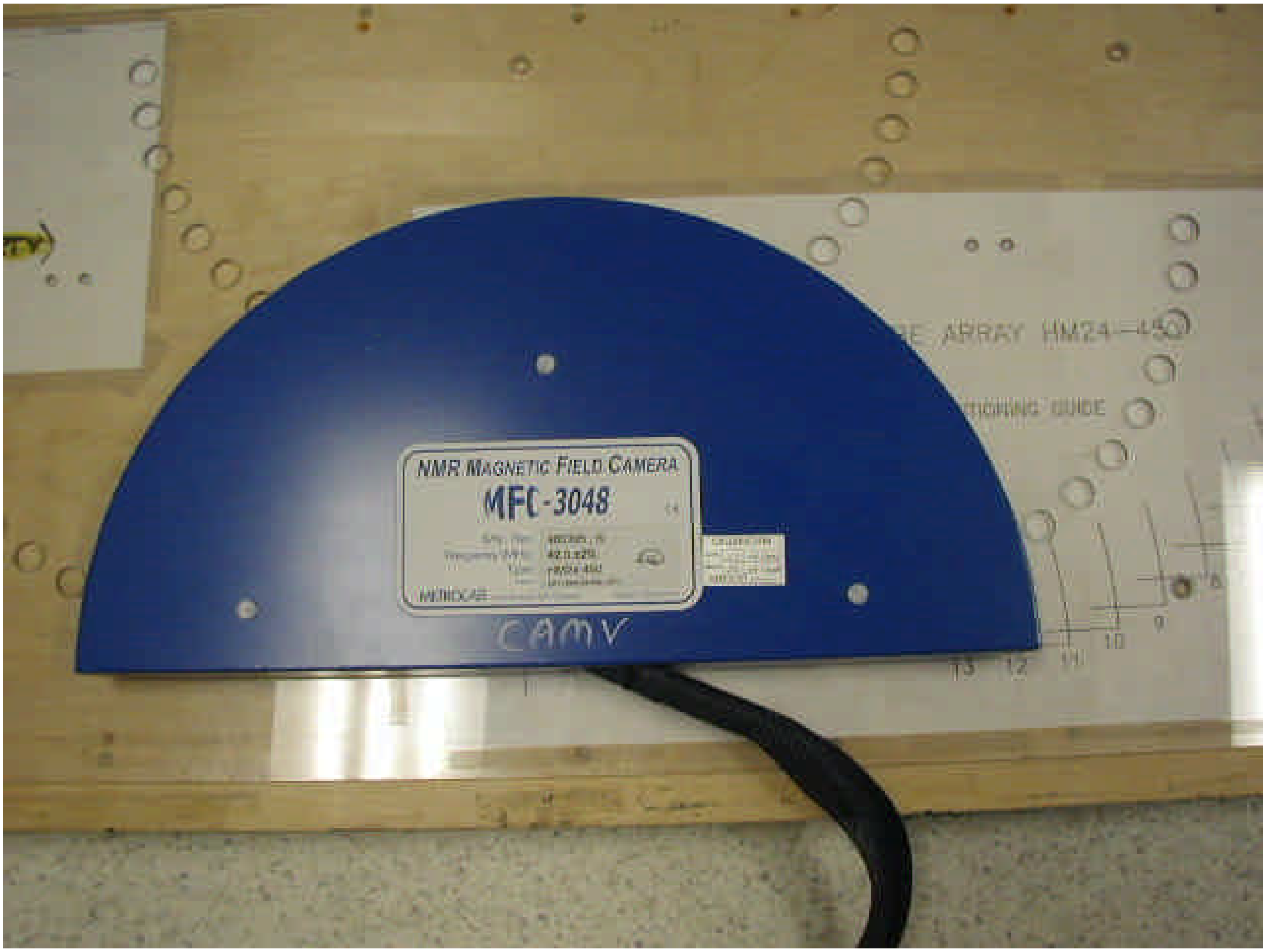

Figure 1: Probe Array resting in the middle position on the normalization jig.

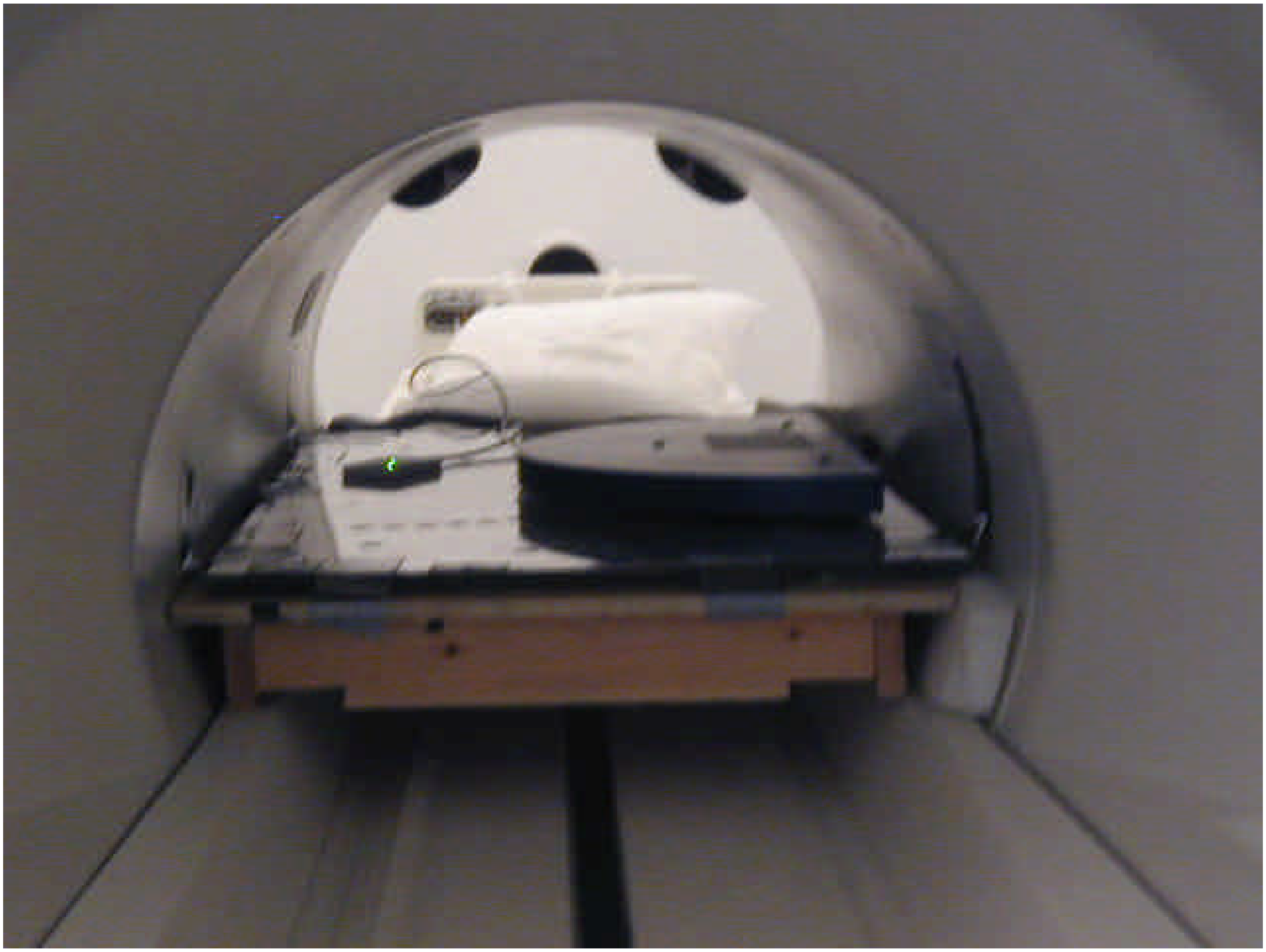

Figure 2: Probe array on normalization jig in the center of the magnet

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