SERVICE NOTE

Jan. 29, 2001

FILE TITLE Signa© Images / Artifacts SN 67038

DWEPI ARTIFACTS DUE TO GRADIENT COIL MECHANICAL ROCKING

Effectivity: All MR system configurations with Cx/K4 magnets (in a specific serial number sequence) capable of running Diffusion Weighted Echo Planar Imaging (DW-EPI_ scans. A few MR Systems with Cx magnets may experience this image artifact (extremely low probability). The Cx/K4 magnets in question are those magnets with a serial number in or between R0498 – R1055 and Q128 – Q255 (1.5T and 1.0T respectively).

Purpose: This document is intended to explain the phenomena found to be the source of the image artifacts unique to DW-EPI scans. When this imaging artifact exists, the combine DW-EPI images will exhibit a wavy worm type artifact across the phase encoding direction. These artifacts will typically cover most, if not all of the image. This artifact seen in the combined image is the result of a large signal void and/or "wormhole" in the R/L diffusion component images. This artifact is caused by excessive (physical) motion of the gradient coil.

Refer to Restricted Service Note 65043 to understand the various image quality issues associated with DW-EPI scans.

Mechanical rocking of the gradient coil is one root cause of a DW-EPI scan pixel void. The large diffusion pulse creates a static magnetic field that applies a force to the gradient coil (in the X, Y, or Z direction). The release of the diffusion pulse removes the force from the coil. In between pulses the coil returns to the geometric center of the magnet.

Product History:

Conquest and Cx/K4 Magnets – S/N

The gradient coil was bolted to the end flanges of the Conquest and Cx/K4 magnets for 2 main reasons: (1) the warm bore was reduced in thickness (to meet the light magnet requirement) and could no longer support the weight of the BRM or CRM gradient coils, and (2) the main field shim material was glued to the warm bore creating irregular and unpredictable surfaces. The gradient coil support consists of an aluminum extension plate (one per end) that bolts to the fiberglass portion of the gradient coil. The gradient coil is centered into the magnet bore. The aluminum extension plates are aligned to the aluminum coil support bracket. The extension bracket was then bolted to the coil support bracket. All Cx magnets and Cx/K4 magnets with serial numbers between R001 through R497 (1.5T) and Q001 through Q127 (1.0T) had the aluminum extension plate bolted to the coil support bracket. In addition, 2 upper radial supports (missing in photo Illustration 1 added in Illustration 7) were added to each end of the coil to prevent the coil from rocking from side to side during transportation.

Note

The foam rope was installed between the outer diameter of the gradient coil to focus the forced cooling air into the space between the inner gradient coil and the RF body coil cartridge.

ORIGINAL GRADIENT COIL SUPPORT
ILLUSTRATION 1

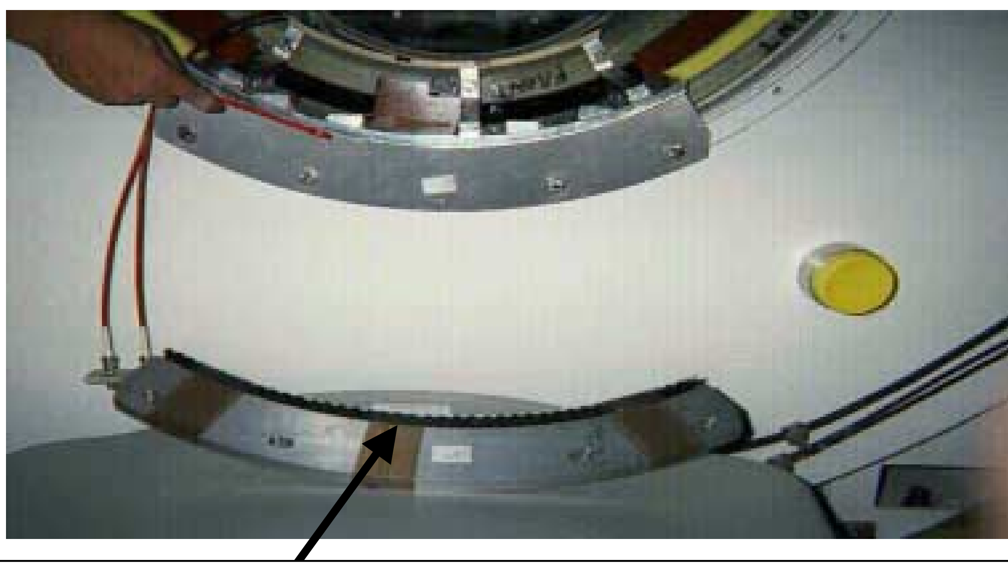
Gradient Coil Kit – Vibro-acoustic CTQ:

A new customer CTQ surfaced with the introduction of the Cx and early Cx/K4 magnet related vibro-acoustic noise issues. A simple means to control the gradient generated vibration from transmitting into the building floor is to provide vibration isolation of the gradient coil from the magnet. In early 1999, MR Engineering began sending gradient coil isolation kits to the field to resolve vibro-acoustic CSO's (level 4 alerts). NOTE: The gradient isolation kit (R4391JA for BRM's and R4391JB for CRM's) will ultimately be required to address the patient acoustic levels (i.e. the Quiet MR Scanner technology).

The gradient isolation kit consists of a low profile aluminum coil support bracket (one per magnet end), a layered matrix of an isolation material plus axial bumpers (hidden behind the aluminum coil support bracket). Also critical to the gradient isolation kit is the foam cord material between the magnet warm bore and the outer diameter of the gradient coil. The foam rope was changed from a gray colored rope to a stiffer 0.5-inch diameter black foam rope. Refer to Illustration 1 to locate the air seal. The air seal fills the gap between the coil outer diameter and the inner diameter of the magnet warm bore. The foam rope requires a uniform gap between the outer diameter of the gradient coil and the inner diameter of the magnet warm bore. Gaps that vary around the circumference of the gradient coil will result in a non-uniform mechanical support of the gradient coil to the magnet warm bore.

Image quality was studied during the clinical trial of the kit. None of the clinical sites had a negative impact to the image quality. In most cases, the gradient isolation kit was found to improve eddy currents and reduce ghosting levels in a few scan sequences. The kit was introduced into the Cx/K4 magnet starting with magnet serial number R0498 (1.5T) and Q128 (1.0T). An RCAT (R4391JA for BRM's and R4391JB for CRM's) was created for the field to order should a site suffer from the vibro-acoustic noise issue.

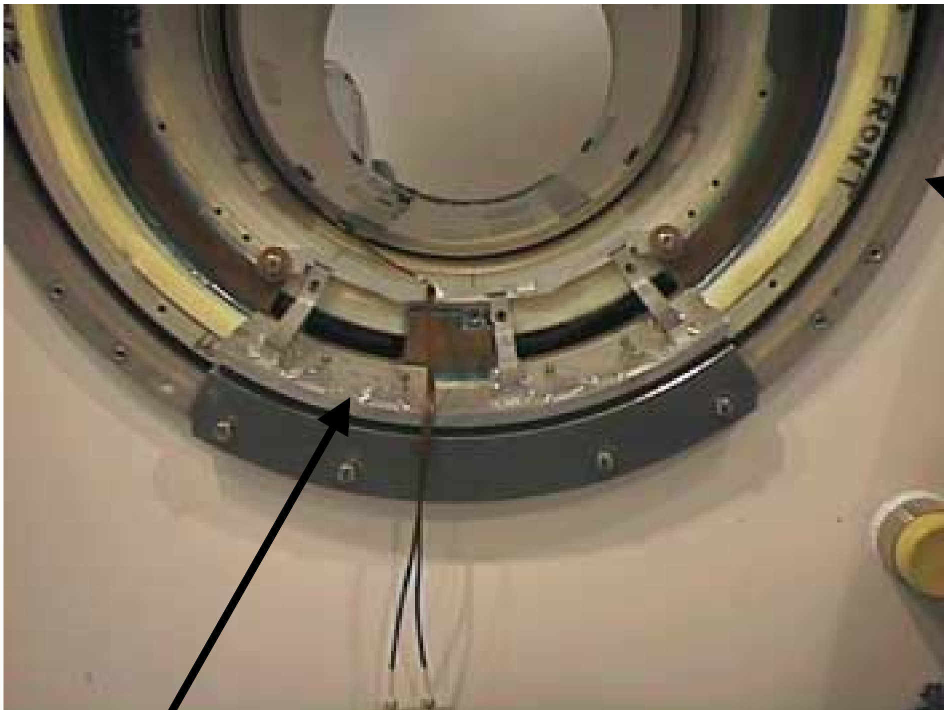
The following illustrations show the change in parts between the original product configuration and the change to the gradient isolation kit.



Gradient Isolation Kit – consisting of a low profile coil support bracket and a matrix isolation material.

GRADIENT ISOLATION KIT REPLACED THE HARD MOUNTED COIL SUPPORT

ILLUSTRATION 2



Air seal fills gap providing lateral coil support.

The layered matrix isolation material is sandwiched between the coil aluminum extension plate and the aluminum coil support bracket.

LCC MAGNET FIT WITH GRADIENT ISOLATION KIT
ILLUSTRATION 3

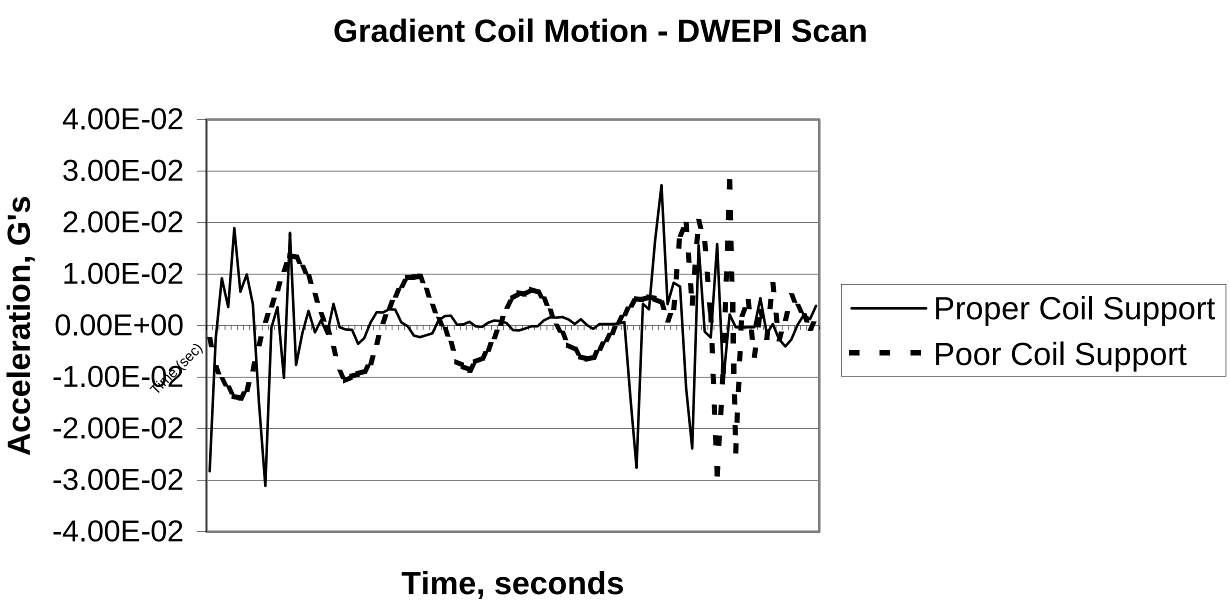
Note

THE AIR SEAL REQUIRES A UNIFORM GAP BETWEEN THE COIL OUTER DIAMETER AND INNER DIAMETER OF THE MAGNET WARM BORE.

DWEPI PIXEL VOID ARTIFACT:

Late 1999, a new customer image quality issue surfaced affecting DW-EPI scan sequences. Refer to Illustrations 5 and 6 for the artifacts generated. The primary root cause is due to the gradient coil rocking within the bore. Magnets with the original hard mounted gradient coil support have not experienced this artifact.

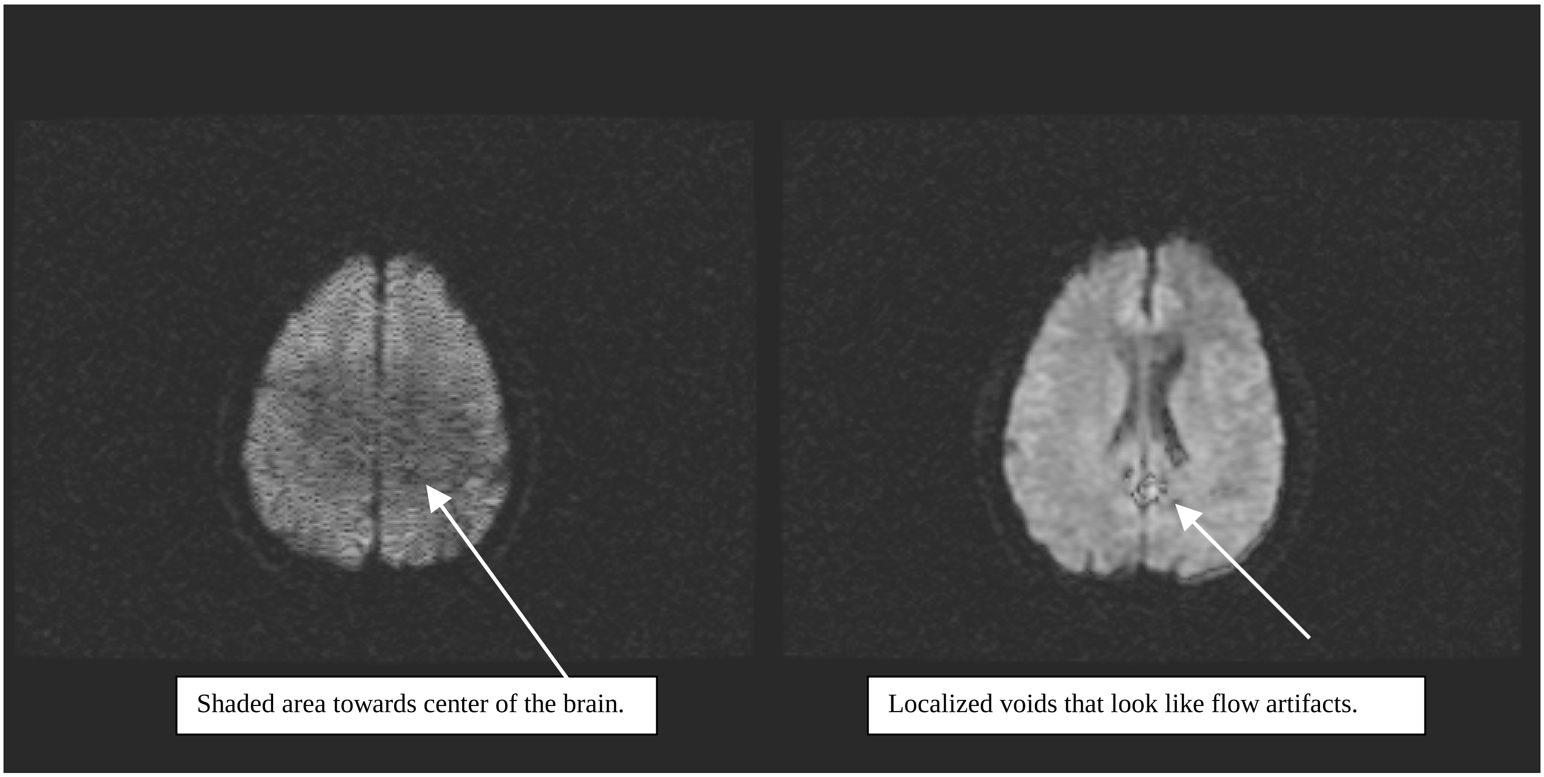
The DW-EPI scan applies a large static gradient pulse prior to data acquisition for image reconstruction. The large current applied to the gradient coil sets up a differential force between the magnet main field and the magnetic field generated in the gradient coil. Without lateral gradient coil support, the coil displaces in a direction opposed by the opposing gradient coil field and the main field. When the large current is removed, gravity allows the gradient coil to rock into a position of static equilibrium. When little or no coil support, primarily lateral support, exists, the coil will rock and decay proportional to the damping of the unstable gradient coil. The dashed curve in Illustration 4 shows the gradient coil motion after the diffusion pulse is removed, for a poorly supported coil. It is the large oscillatory motion that generates the pixel void. The solid curve is the gradient coil response for a coil properly supported. Notice the system has a small initial static offset and the coil damps to a rest position quickly. Where as the dashed curve clearly has a static offset that continues to oscillate until the next diffusion pulse is applied.



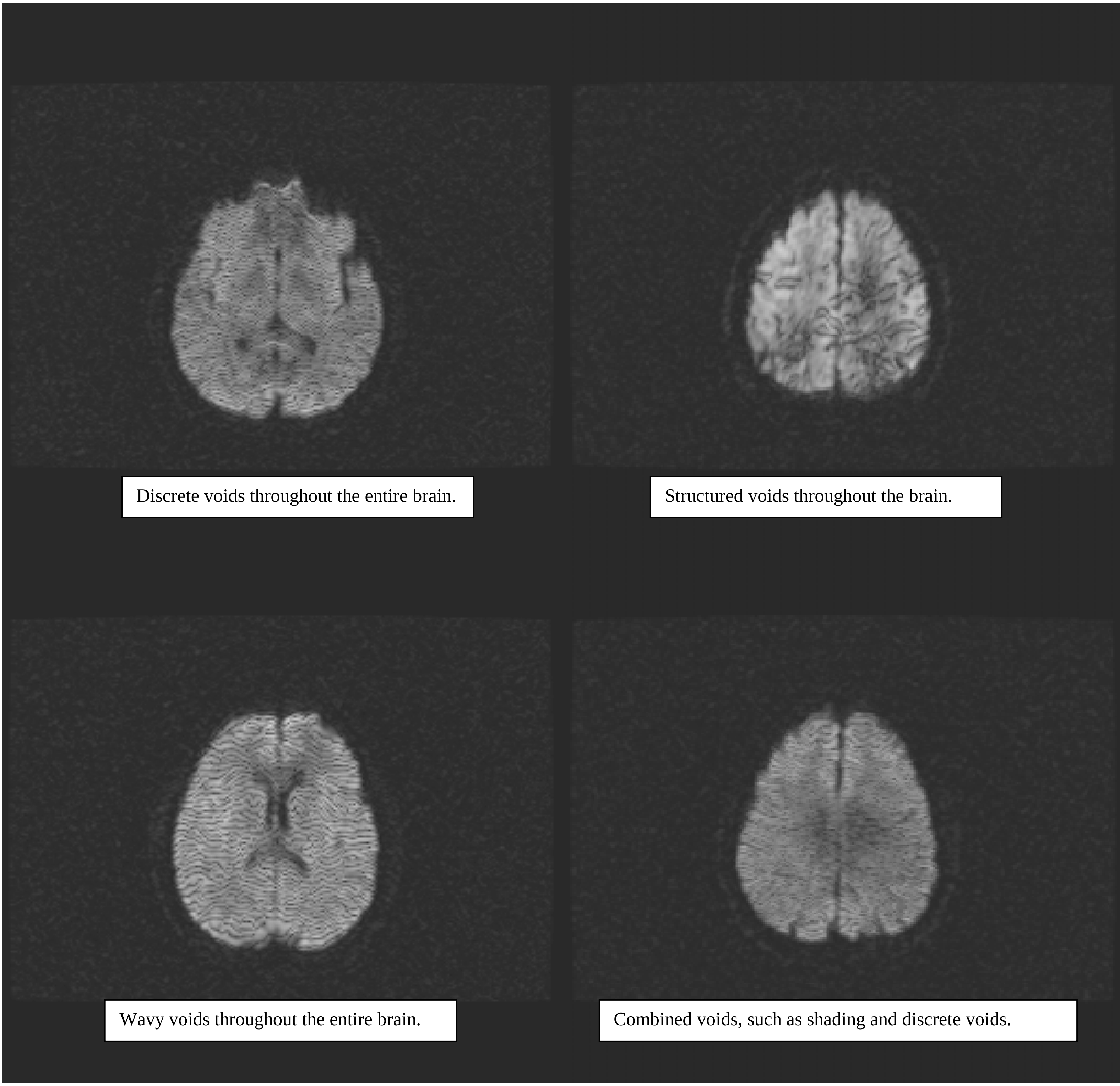
POTENTIALGRADIENT COIL MOTION DURING A DWEPI SCAN

ILLUSTRATION 4

The result of this motion can manifest itself in different ways, depending upon the amount of coil and patient movement as well as the anatomical region. Below are some examples of the different ways this artifact can appear.



EXAMPLES OF ARTIFACTS DUE TO GRADIENT COIL MOTION WITH DWEPI
ILLUSTRATION 5



Discrete voids throughout the entire brain.

Structured voids throughout the brain.

Wavy voids throughout the entire brain.

Combined voids, such as shading and discrete voids.

ADDITIONAL EXAMPLES OF ARTIFACTS DUE TO GRADIENT COIL MOTION WITH DWEPI SCANS

ILLUSTRATION 6

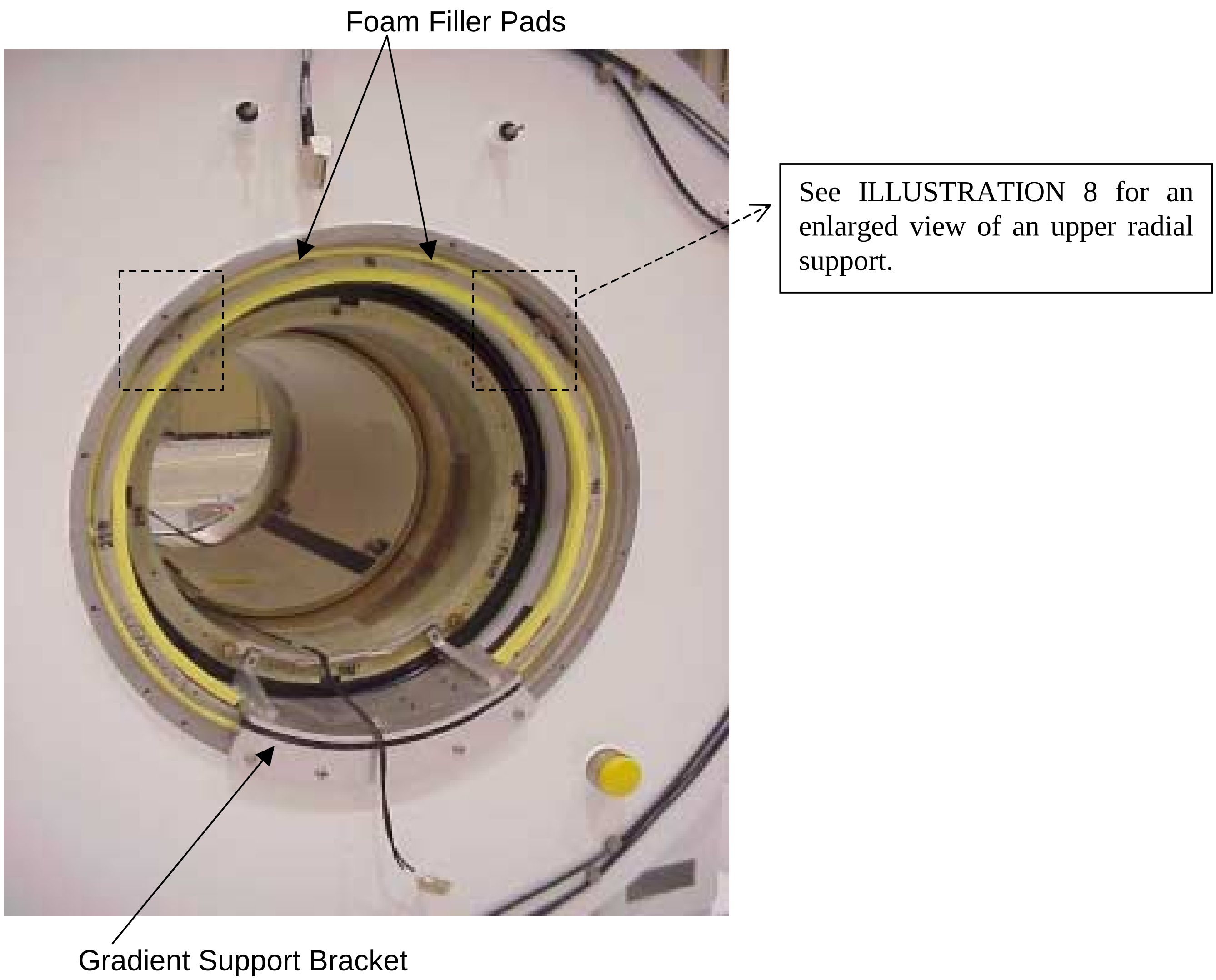
It is important to note that not all customers experienced this image quality issue (which is consistent with the initial image quality studies). It is estimated that approximately 20 sites have experienced this image artifact to date. In each case, the image quality issue was resolved by installing 2 upper radial supports (2 per end).

The first system to complain of the DW-EPI pixel void was found to have a very soft foam rope air seal between the magnet warm bore and the gradient coil outer diameter. A few months later more systems began to experience the same image artifact. A common root cause was linked to coils that either did not have the foam rope air seal installed, the rope foam fell out of position or the gap between the magnet warm bore and the coil outer diameter was too large on one side of the coil or the other.

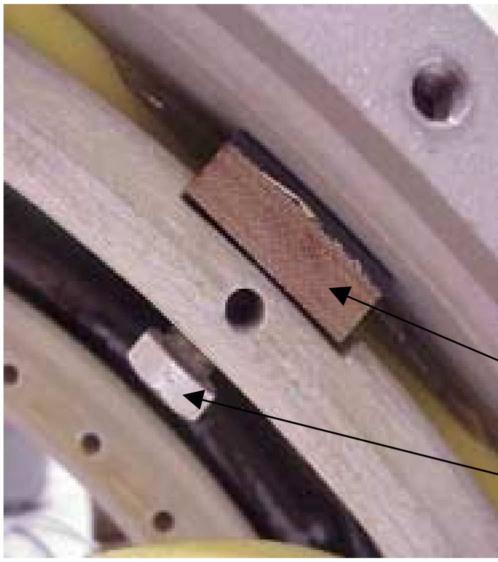
Solution:

The available solutions must provide a balance of image quality without impacting the vibro-acoustic solution. And ultimately, the gradient coil support will be required for GEMS to introduce the Quiet MR scanner.

To resolve the gradient coil support issue, two (2) upper radial support members will be added to each end of the gradient coil. The radial supports consist of an M16 bolts and phenolic pads with a thin rubber backing. The M16 bolts thread into the end flange of the gradient coil radially outward. The phenolic pad will be pressed against the magnet warm bore as the bolt is threaded towards the magnet warm bore. The radial locations are at the 2 o’clock and 10 o’clock positions. Placing the supports at the positions will provide the gradient coil a lateral or side to side support and vertical or up and down support. Refer to Illustration 7 to understand the parts supplied with this kit (R4391JA for BRM’s and R4391JB for CRM’s) and Illustration 8 for an enlarged view of a properly install upper radial support.



END VIEW OF MAGNET W/ GRADIENT ISOLATION & UPPER RADIAL SUPPORTS
ILLUSTRATION 7



Enlarged View of Upper Radial Support
ILLUSTRATION 8

BRM Upper Radial Support Kit (included as part of 2242380 from RCAT R4391JA)

Piece Part	Number	Quantity	Description
1	2181231-2	4	Filler Pad Conquest – Die cut Insert
2	2174929-9	2	Open Cell Polyurethane Foam 112 inches long
3	2108933-2	4	Cap Screw, Special, Hex Head Metric SST 18-8, M16 Pitch 2, **Length 35 mm**
4	2212715-2	4	LCC **BRM** Mounting Pads

CRM Upper Radial Support Kit (included as part of 2247493 from RCAT R4391JB)

Piece Part	Number	Quantity	Description
1	2181231-2	4	Filler Pad Conquest – Die cut Insert
2	2174929-9	2	Open Cell Polyurethane Foam 112 inches long
3	2131956-2	4	Cap Screw, Special, Hex Head Metric SST 18-8, M16 Pitch 2, **Length 40 mm**
4	2131953-4	4	LCC **CRM** Mounting Pads

Installation Procedure

1) Install foam filler pads, part number 2181231-2 in top 2 pockets on gradient OD (outer diameter), see Illustration 7.
   This is done in 2 locations of the gradient coil, both the front and back.

2) Pull out 1/2" black rubber cord from between gradient and magnet bore down to the gradient support bracket.

3) Cut the rubber cord 3" (inches) past each side of the gradient support bracket and push the tails back in.

4) Insert the yellow or pink foam seal; part number 2174929-9 between the gradient and magnet bore, overlapping the remaining rubber cord at the bottom to form a good air seal.

5) Replace rubber cord on opposite end in same manner.

6) For BRM install cap screw part number 2108933-2 in the 2 positions indicated in Illustration 7. These will be installed at both ends of the gradient coil

   For CRM install cap screw part number 2131956-2 in the 2 positions indicated in Illustration 7. These will be installed at both ends of the gradient coil

7) For BRM install Bearing shim part number 2212715-2 with rubber against magnet ID (inner diameter) as shown in Illustration 8.

   For CRM install Bearing shim part number 2131953-4 with rubber against magnet ID (inner diameter) as shown in Illustration 8.

8) Tighten screws until snug (bearing shim doesn't move).

9) Then torque each screw <u>1/4 turn</u> past snug.

NOTE

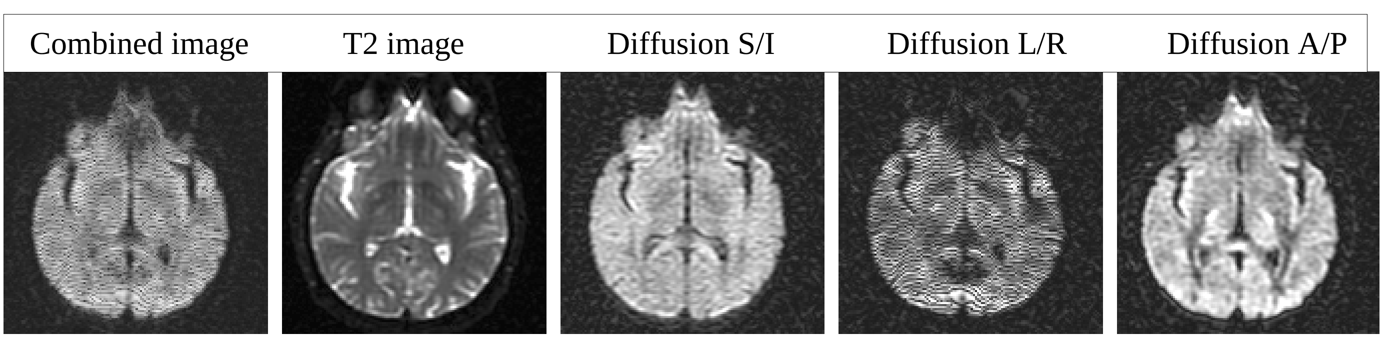
The gradient coil must have a uniform gap (between the outer diameter of the gradient coil and the inner diameter of the magnet warm bore). The coil can be centered using the upper radials. Inserting an upper radial on the side of the gradient coil with the smallest gap. Tighten the cap screw until the coil is centered. Then proceed inserting the remaining 3 upper radials. After each of the remaining 3 upper radials are in the snug position, loosen the original upper radial, then hand tighten to the snug position. Each upper radial must then be torqued ¼ turn past the snug position.

Troubleshooting strategy:

Although Engineering was able to recreate the artifacts on volunteers in-house, these artifacts could not be recreated on phantom scans. Therefore to determine if a site is experiencing the diffusion voids due to the mechanical rocking of the gradient coil one must save the intermediate component images. Typically this isn't available to most clinical users, unless they have a research key or “geservice” is used as the patient id (e.g. when an FE is trying to recreate the problem.) Once in research mode, the "recon all" option will become available in the Diffusion Options setup in the scan prescription. Select this prior to scanning in order to have the component diffusion images reconstructed.

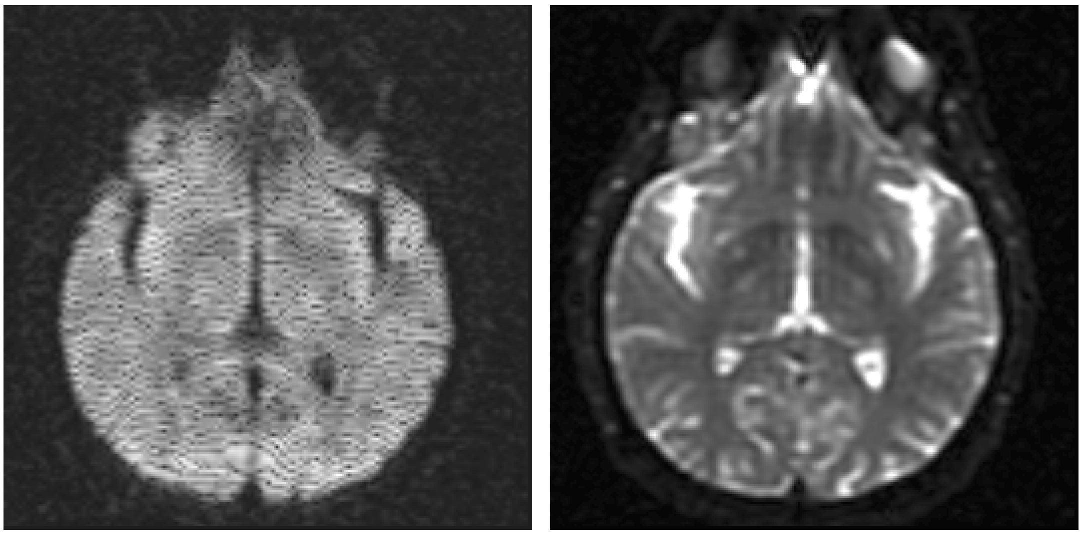
Voids due to the mechanical rocking of the gradient coil will typically show up in the component image that was acquired when the diffusion gradient was applied in the Left/Right direction. If the mechanical movement is large enough (as in the examples of this Service Note, where all coil support was removed), in may additionally be seen on another axis, such as when the diffusion gradient was applied A/P.

The following Illustrations (9 through 13) are used to demonstrate how to diagnose diffusion voids that are caused by mechanical motion of the gradient coil. As mentioned earlier these artifacts are not reproducible on phantom scans and therefore clinical or volunteer scans are needed. Also as we mentioned earlier, you must look at the component images. Normally only the combined image (the vectored sum of the 3 component images) along with a T2-weighted EPI image are displayed to the user. The component images are the actual images acquired while the diffusion-sensitizing gradients are applied. Each component image differs only in which physical axis the diffusion gradient is applied (X, Y or Z). To view the component images “recon all” must be selected from Diffusion options area, prior to the scan. This option is available only if the site has a research key or “geservice” is used as the patient id. When “recon all” is selected all the images from the diffusion scan are displayed, see Illustration 9.



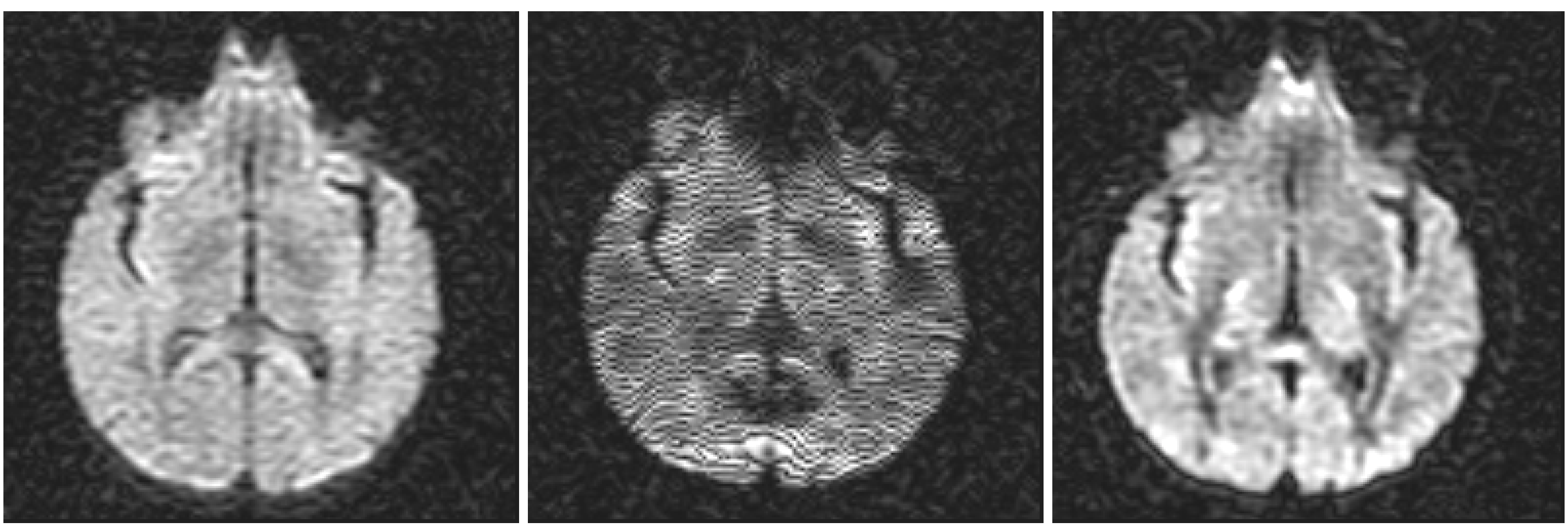
IMAGES ORDER WHEN RECON ALL IS SELECTED FROM DIFFUSION OPTIONS
ILLUSTRATION 9

Zooming in on these images to further illustrate the nature of the artifact you can see that the artifact will always be in the combined image but not in the T2 image, since there was no diffusion pulse applied.



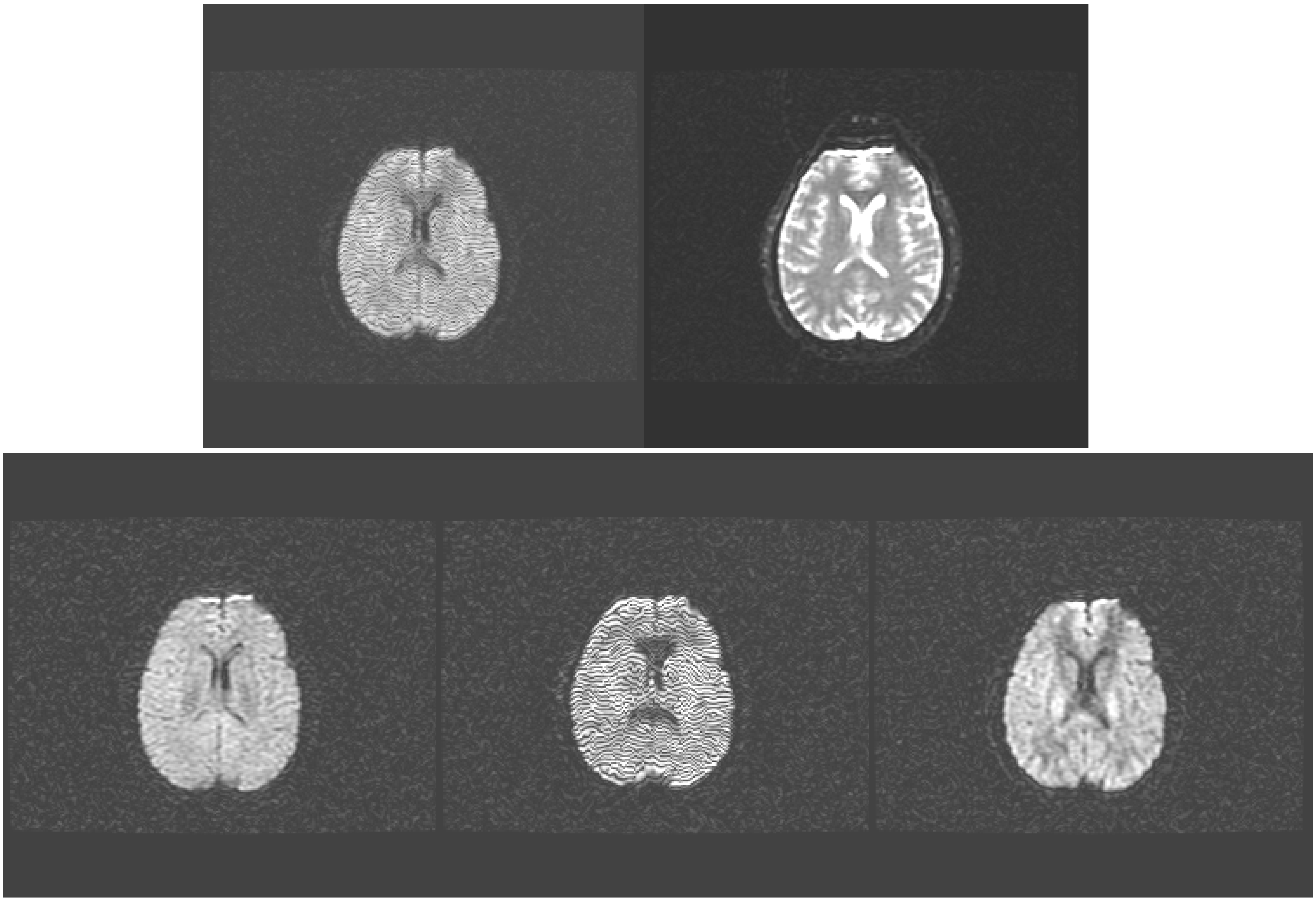
THE COMBINED AND T2 IMAGES
ILLUSTRATION 10

Examination of the components images show that that artifact occurred when the diffusion gradient was applied along the physical X-axis (L/R), see Illustration 11.



ARTIFACT FOUND ON IMAGE WITH DIFFUSION APPLIED L/R
ILLUSTRATION 11

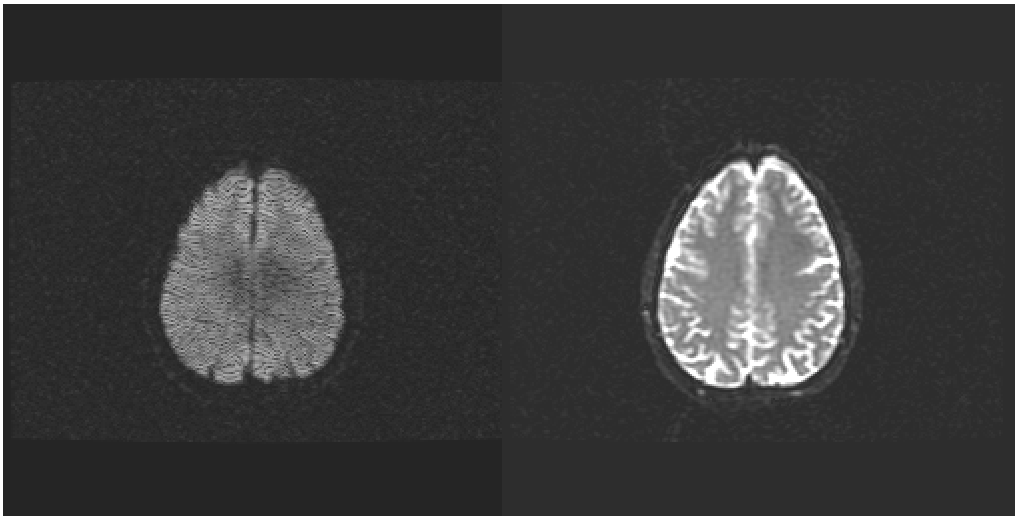
Below are more examples to illustrate that artifacts due to mechanical motion of the gradient coil are predominately seen on the component image where the diffusion gradient was applied L/R, which is the key for diagnosing this type of problem.

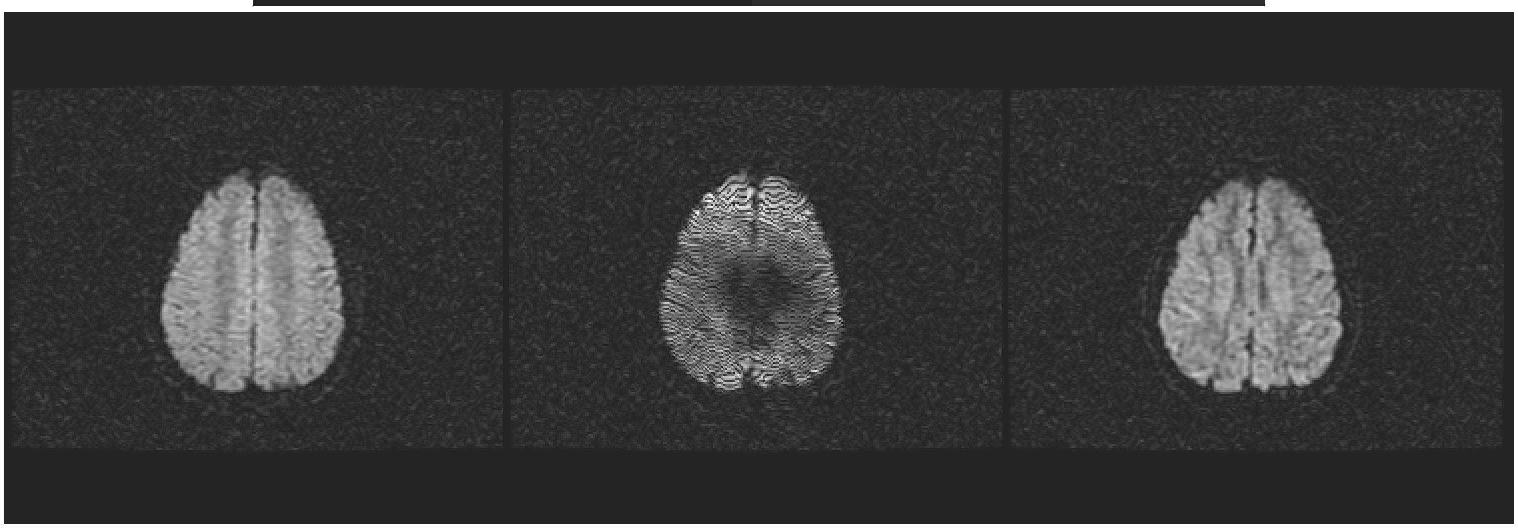


EXAMPLES, WITH COMPONENT IMAGES DEMONSTRATING GRADIENT COIL MOTION IN L/R DIRECTION

ILLUSTRATION 12

Additional examples:





EXAMPLES, WITH COMPONENT IMAGES DEMONSTRATING GRADIENT COIL MOTION IN L/R DIRECTION

ILLUSTRATION 13

Recommended Solution:

An RCAT (R4391JA for BRM's and R4391JB for CRM's) was created for the field to order should a site suffer from the vibro-acoustic noise issue. These RCATS now also include the radial supports. The solution to resolve this DW-EPI artifact is to order the appropriate RCAT and install the radial supports as described in pages 8 though 11 of this Service Note.

As of the middle of November 2000, magnets began shipping with the radial supports installed.

Acknowledgments: The authors wish to thank Scott Hinks from the Applied Science Lab, Bruce Collick and Don Kosak from Systems Engineering, John Ward from the OnLine Center and Ron Lochner from the GE Magnet Plant for their time and input to this Service Note.

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