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Banner Health

MRI Artifact Troubleshooting

An Engineering Perspective for Artifact Identification and Resolution

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BANNER HEALTH

About the Speaker

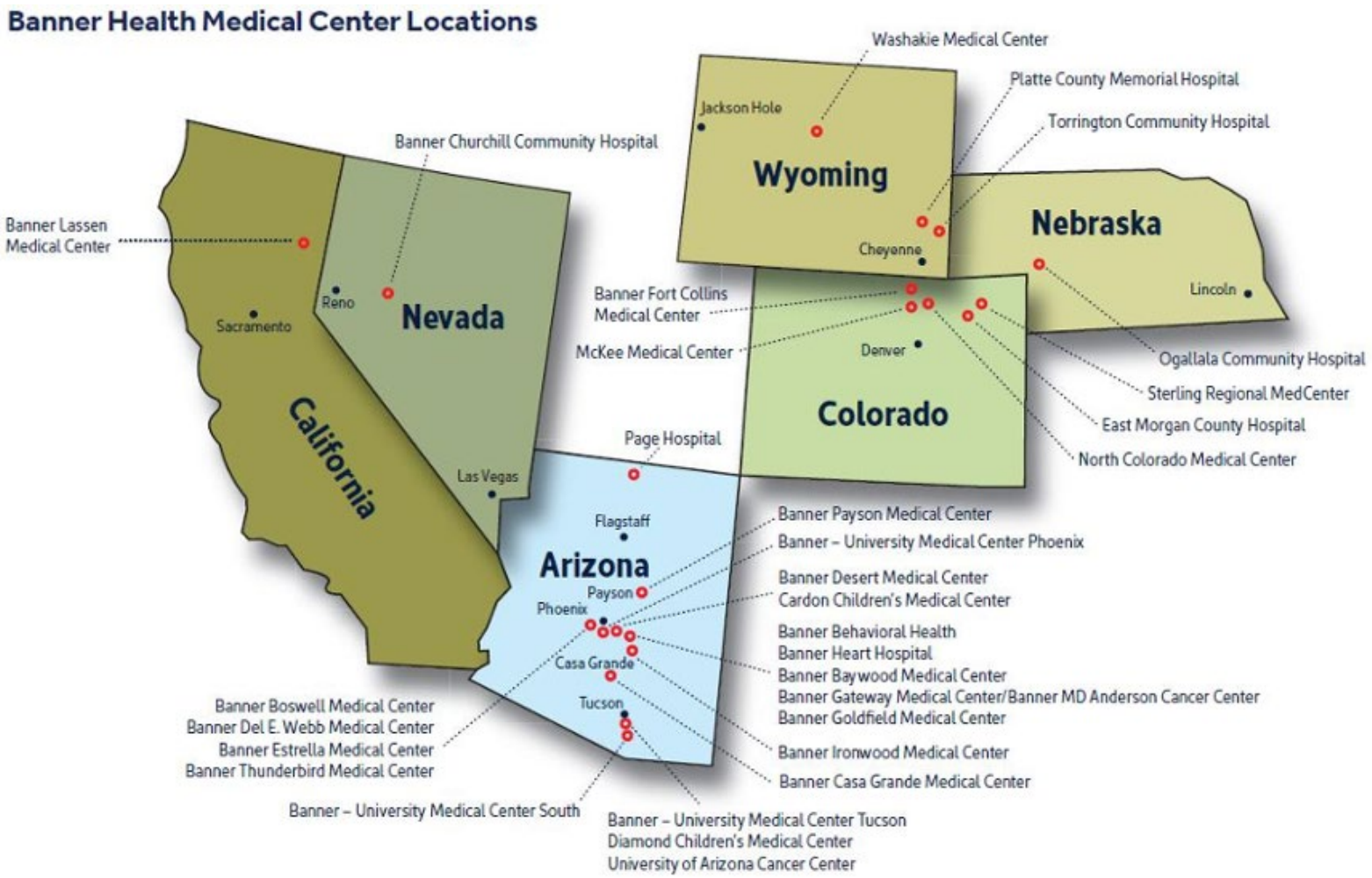


Sherman Abernathy
Director of Diagnostic Imaging Services
Technology Management/ ENTECH
Banner Health

Session Overview

- Introduction to Banner Health Technology Management/ ENTECH
- Designing a Partnership that Benefits Patient Care
- Designing a Program that Focuses on Partnership
- MRI Safety and its Impact
- Identifying and Classifying Artifacts
- RF Room Shielding and its Types
- The Magnetic Field
- The Wave Guide and Pin Panel
- RF Room Issues to Watch Out For
- Identifying Artifact Types
- Projectiles and Objects not Meant for the Magnet

Mission: “Making health care easier, so life can be better.”

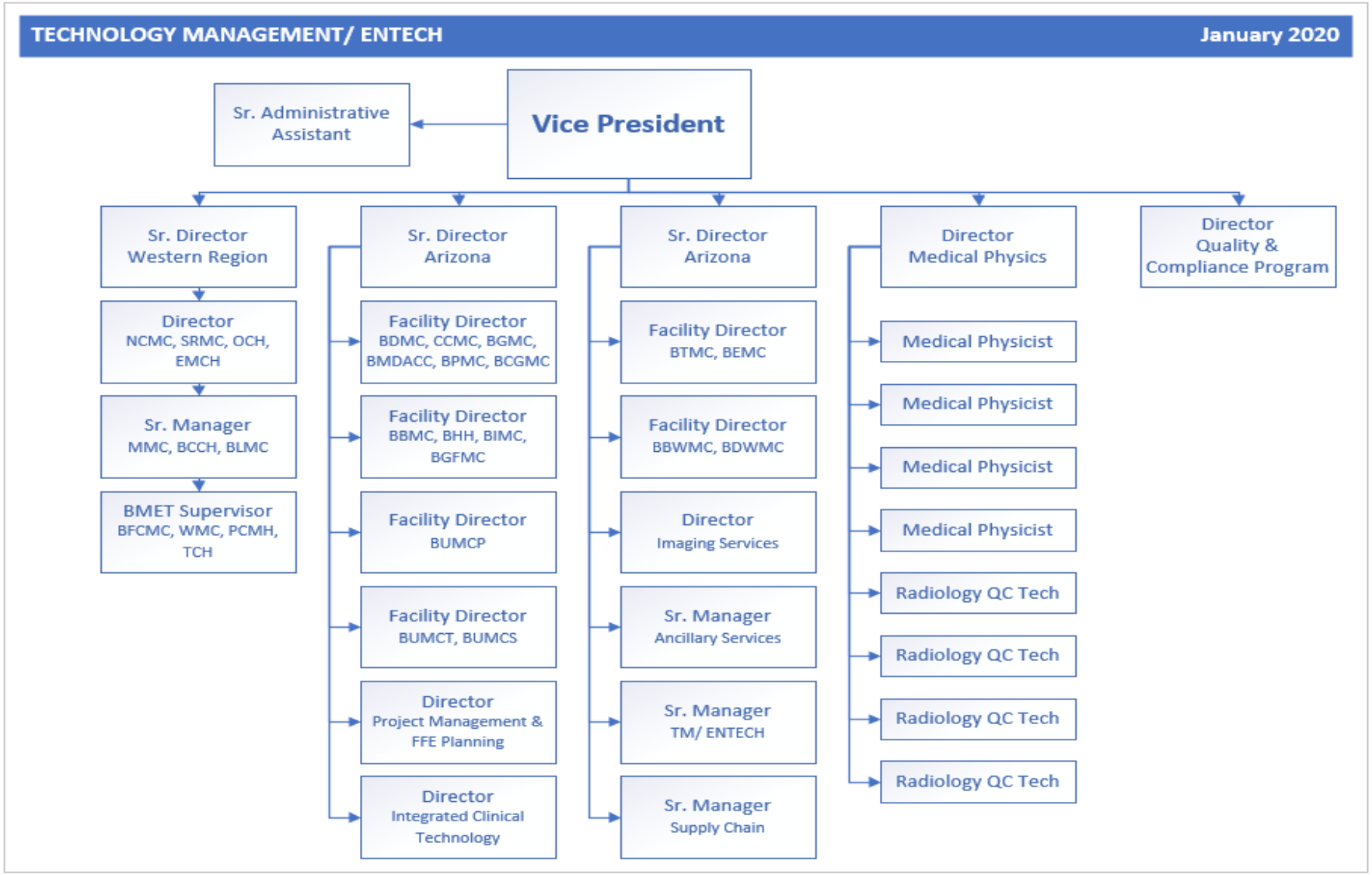


Banner Health is a non-profit health system in the United States, based in Phoenix, Arizona

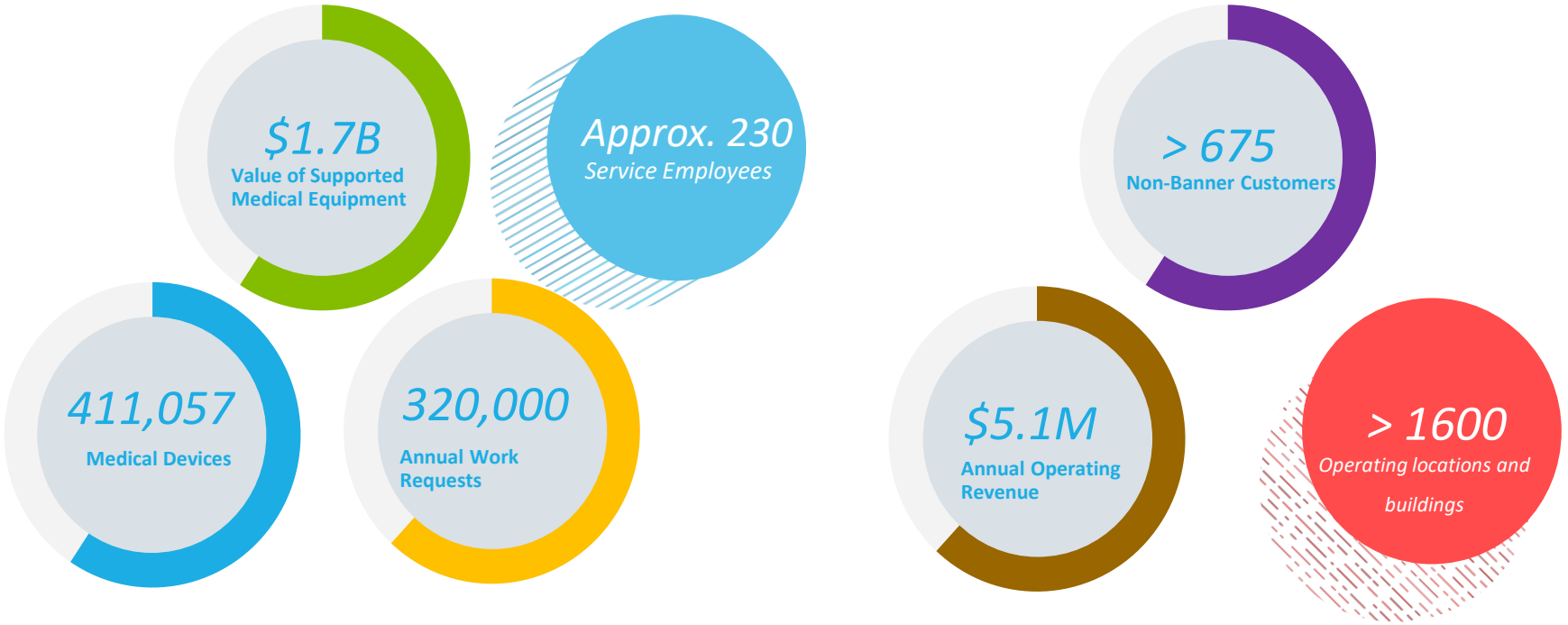
It operates 28 hospitals and several specialized facilities across 6 states

The health system is the largest employer in Arizona and one of the largest in the United States with over 50,000 employees.

Mission: “Making health care easier, so life can be better.”



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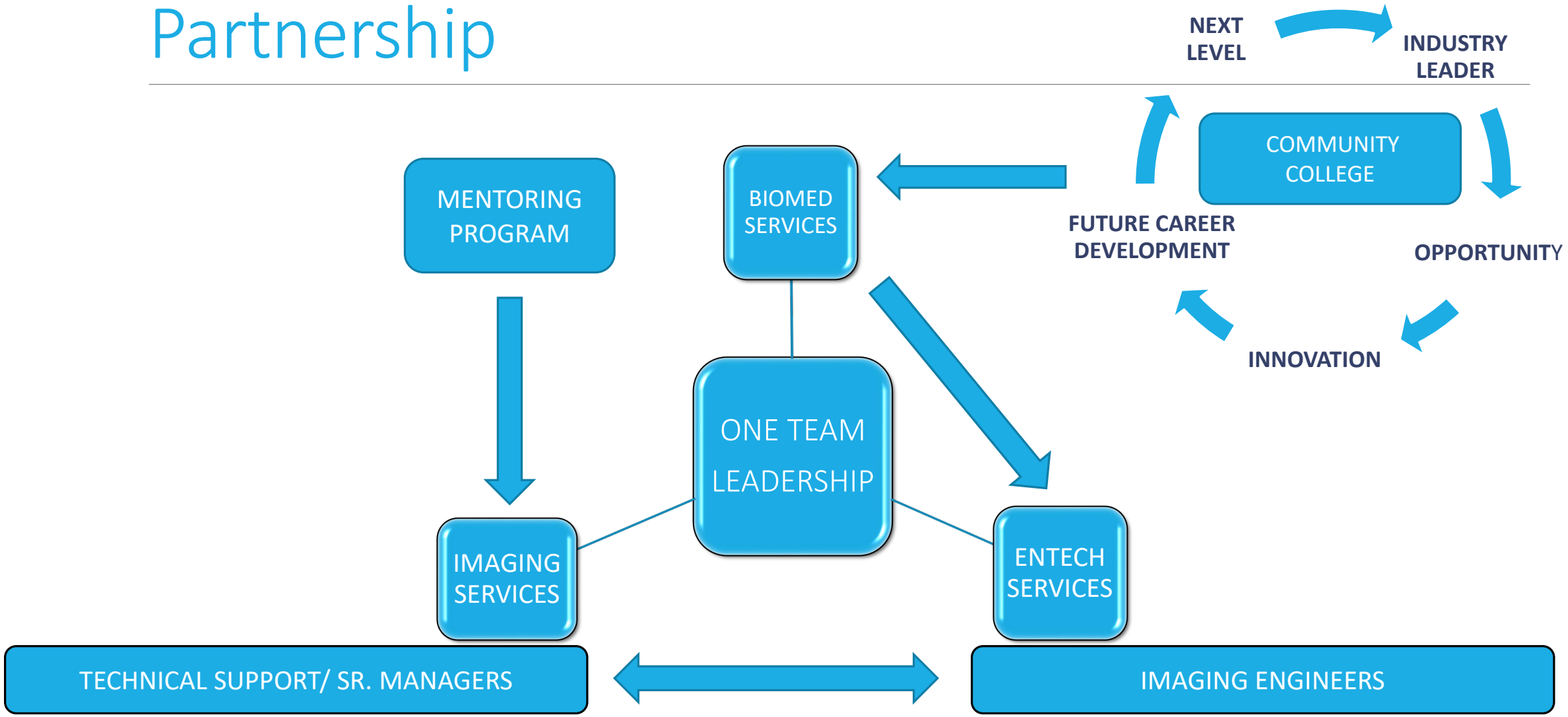


Designing a Partnership that Benefits Patient Care

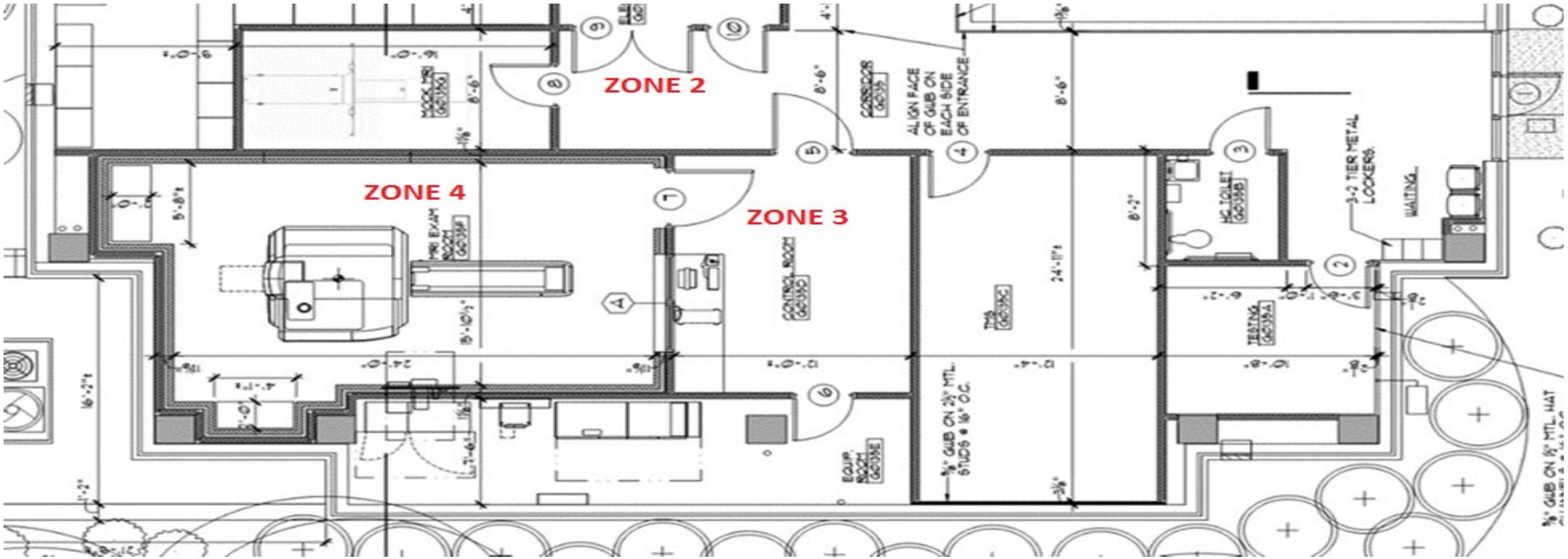


- Communication and training is key to building a successful support relationship.
- Being proactive to voiced issues and concerns builds confidence on both sides of the fence.
- Information is power - the more detailed the better the result.
- Trusting and building confidence in your support team will carry over.

Designing a Program that Focuses on Partnership



MRI Safety and its Impact

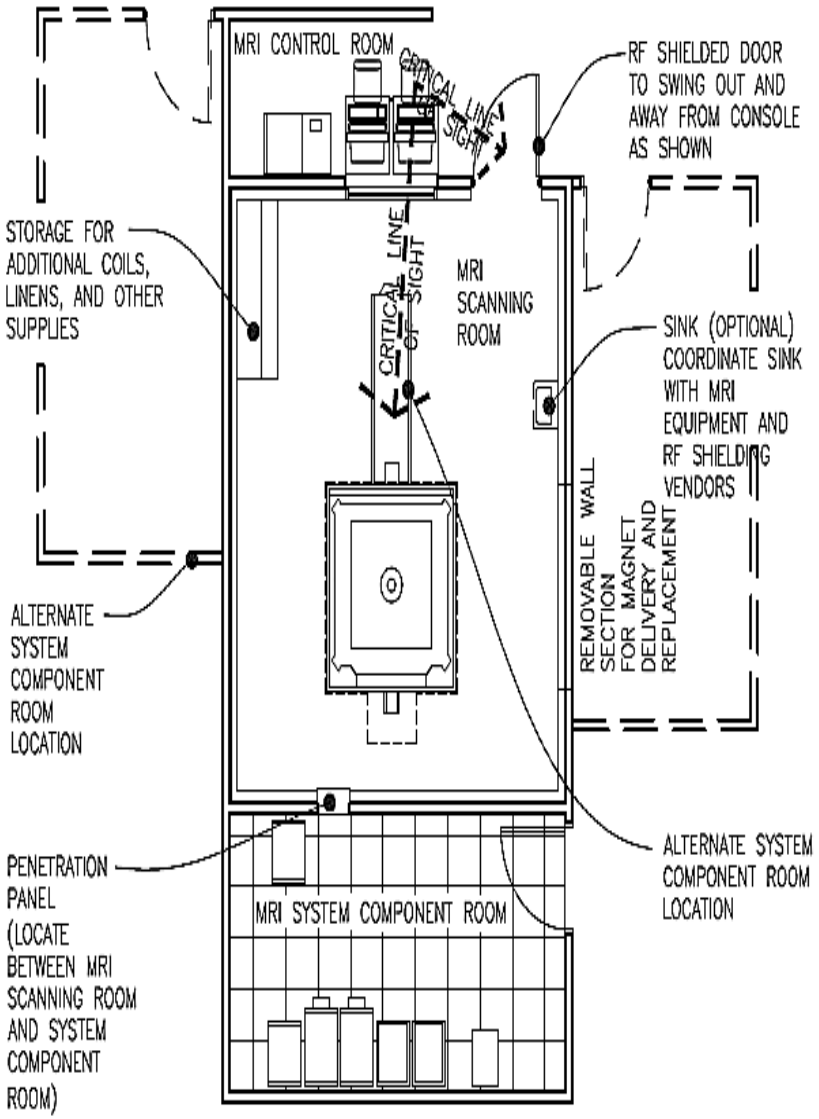


- Zoning for safety and environment control
- Ferro guards best safe practices
- Patient screening

MRI Compatible Metals

- Titanium. Orthopedic surgeons favor titanium implants for their strength and compatibility with body tissues. ...
- Cobalt-Chromium. Though cobalt has magnetic properties, implants such as coronary stents made of cobalt-chromium alloy have tested safe during an MRI. ...
- Copper. ...
- Stainless Steel.

THE MRI SCAN ROOM



- The entire room is shielded to prevent RF waves from entering or leaving the room - the shielding design is a faraday cage (a grounded metal screen surrounding a piece of equipment to exclude electrostatic and electromagnetic influences).
- Any type of metal can be used for room shielding. Aluminum and galvanized steel is commonly used. Wood panels wrapped in copper sheets are heavily used as well. The copper sheets are sometimes stapled or soldered together to make a continuous shield with no gaps.
- One issue with use of stapled copper panels is longevity. System upgrades including new purchases will include a variety of risks. Cost savings are significant when the same magnet and room enclosure are reused.
- If you've opened or closed the entry door to a magnet room and noticed a sound like a faint thunder or movement between the walls, it identifies loosely stapled copper panels. This also means that air pressure is created from flapping copper panels due to the door movement.
- This can result in intermittent zipper, ghosting, and noise artifacts across different types of studies.
- This can be repaired but less costly if identified prior to any system upgrade and new installs.

Identifying and Classifying Artifacts

- Survey questions:
  - Is the artifact intermittent or consistent?
  - Can the artifact be reproduced?
  - What type of study?
  - Is it consistent through the entire study or sequence dependent?
  - Have you tried another coil?
  - Coil specific – how long has it been occurring?
  - Is the artifact through the entire image or just within the scanned area of interest?

The answers dictate a certain process for the engineer;
This could mean getting a part on order before arriving on site;
Having the technician reboot the system prior to arriving on site;
Or calling the system down and not usable.

RF Room Shielding and its Types

RF ROOM SHIELDING TYPES

- Construction cost is usually the deciding factor for the type of shielding used in a project.
- Galvanized steel will have the most reliable and best longevity for any room setup. It is also the most expensive option.
- Copper panels and sheets soldered or stapled are the most popular options.

COPPER PANELS



COPPER SHEETS



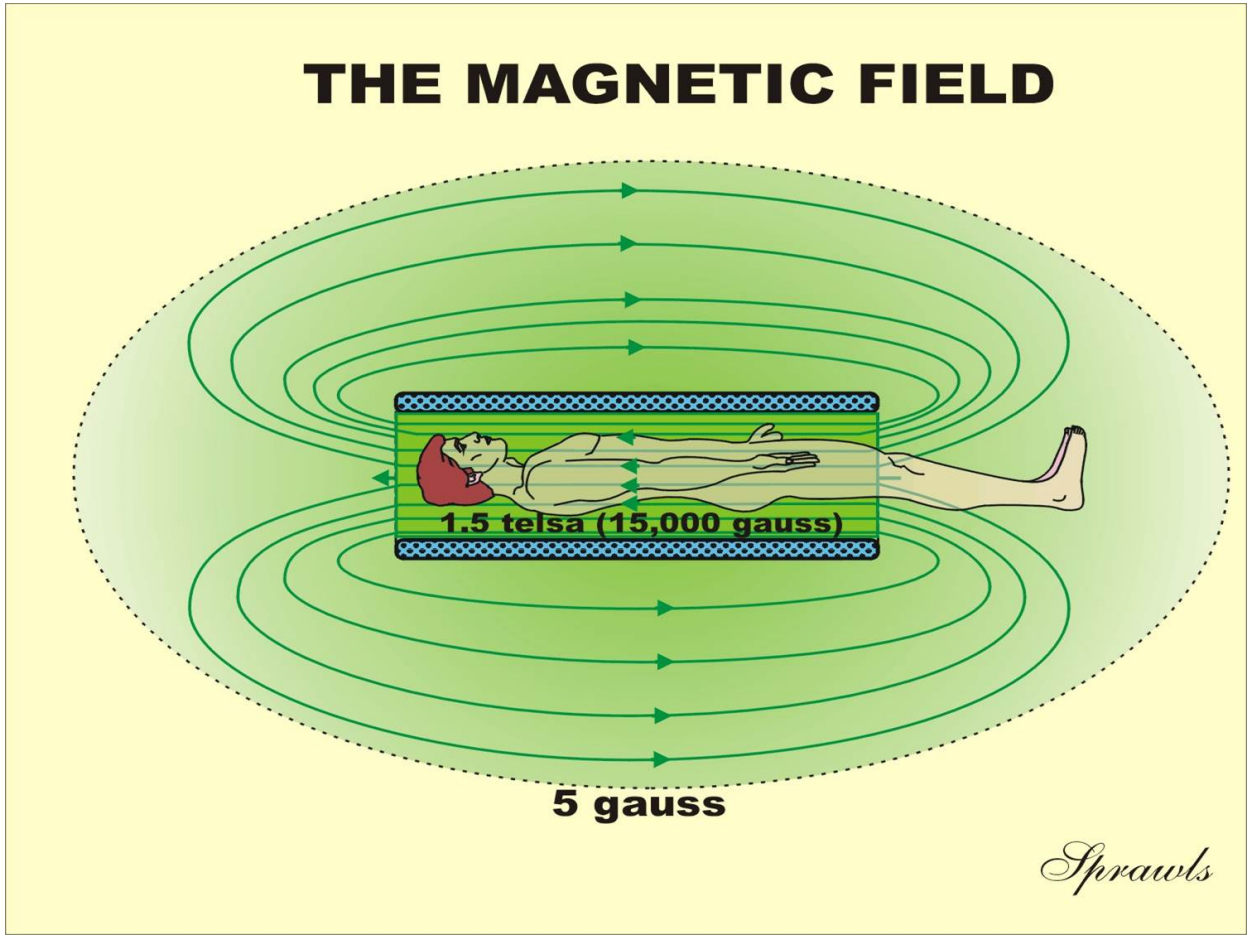
GALVANIZED STEEL



The Magnetic Field

Field Strength	Operating Frequency (MHz)	Assigned Range in US
0.3T	12.8	Maritime mobile
0.5T	21.3	Shortwave “ham” radio (15 m band)
1.0T	42.6	Land mobile
1.5T	63.9	Analog TV Channel 3 (USA)
3.0T	127.8	Civil aviation
7.0T	298.2	Mobile satellite

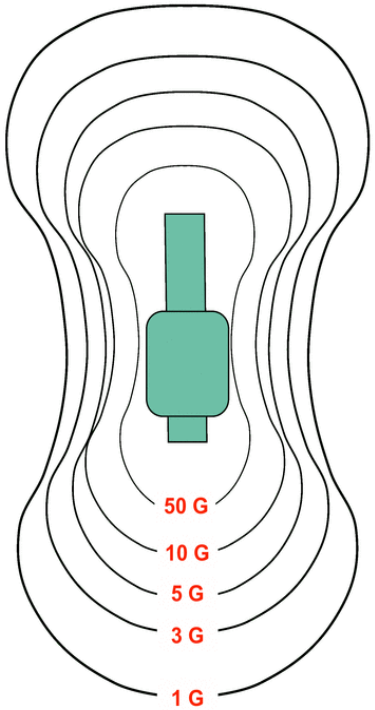
Containing and controlling the magnetic field is important to patient safety and system performance.



The Magnetic Field and Fringe Field

The peripheral magnetic field that extends outward from ISO-center several meters around, above and below the MRI scanner.

Best safe practices will show floor markings for gauss lines that can be used as reference for MRI safe devices (ventilators/injectors). Typical safe use area is the 3 to 5 gauss line.

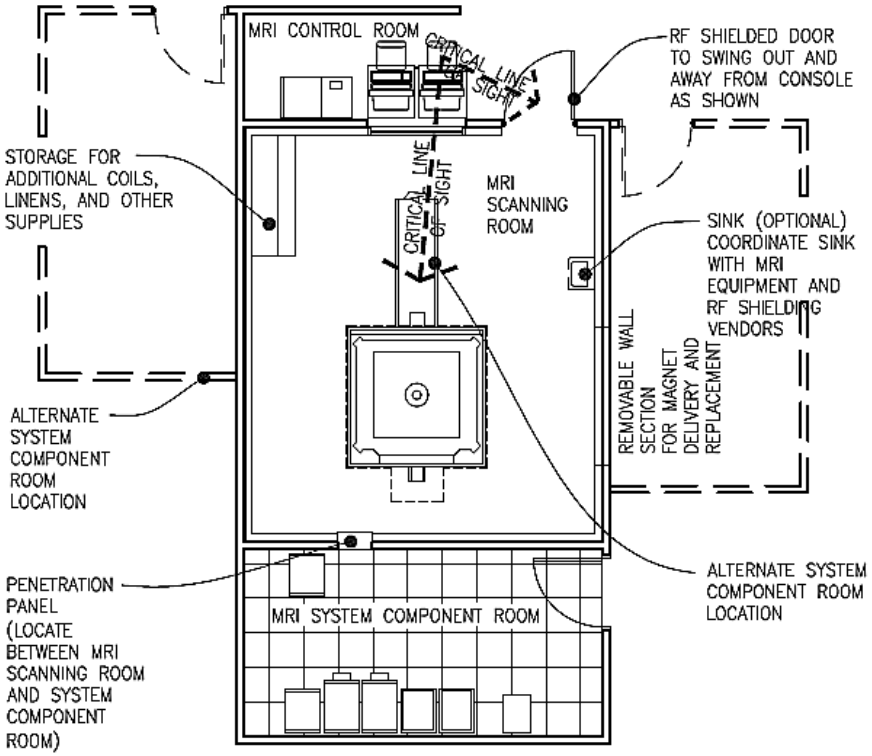


Room size will play a large factor for what additional.
Electromagnetic shielding will be needed if the fringe area extends beyond the room walls.

ELECTROMAGNETIC SHIELDING

Passive shielding methods consist of iron beams and steel plates incorporated into the walls and floors.
Active shielding - more common on newer systems use an additional set magnet windings that oppose a portion of the external fields.

The Scan Room Revisited

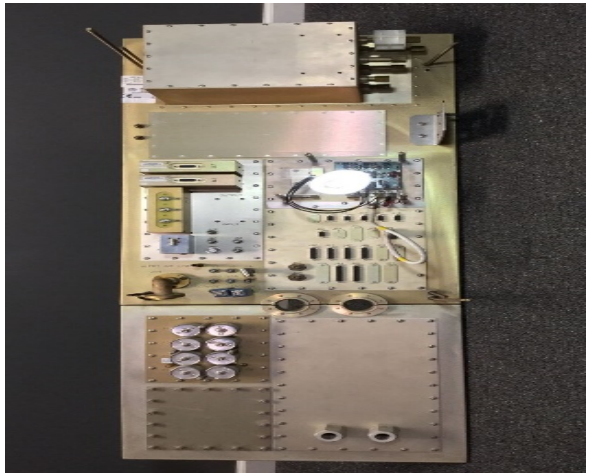


- The scan room is shielded against RF and electromagnetic interference yet we still have the need to control lighting, sound, environmental factors and control the system electrically.
- We need to insure the operating frequency of the system doesn't interfere with shared frequencies existing in the outside world.
- We accomplish this via Penetration "Panel/ Waveguides".

The Wave Guide and Pin Panel

- In order to ensure the magnet/ RF room remains isolated from any electrical interference we utilize the “pin panel/ wave guide” to bring in all cables entering and exiting the magnet room. The panel exist as a portal between the systems equipment room and the magnet room.
- Any cables carrying electrical current must pass the penetration panel via a filter.
- Fiber optic cables, hoses for pneumatic (air) or hydraulic (liquid) system can pass through the penetration panel via the wave guides.
- The cold head and the lines that run from the compressor in the equipment room thru the wave guide at the pin panel then to the magnet are also isolated to prevent RF energy escaping.





RF Room Issues to Watch Out For

ENTRY DOOR DAMAGE

1. Is the number 1 cause for image performance issues-don't allow wax or oils to be applied to any area of the door frame or jam. It is part of the room shield and its closure seals the loop of the isolated ground for the entire room shield

ZIPPER ARTIFACTS-DOOR LEAKS

1. Multi MRI suites-allowing units RF frequencies to crosstalk
2. Sound system incorrectly installed

BUILDING CONSTRUCTION

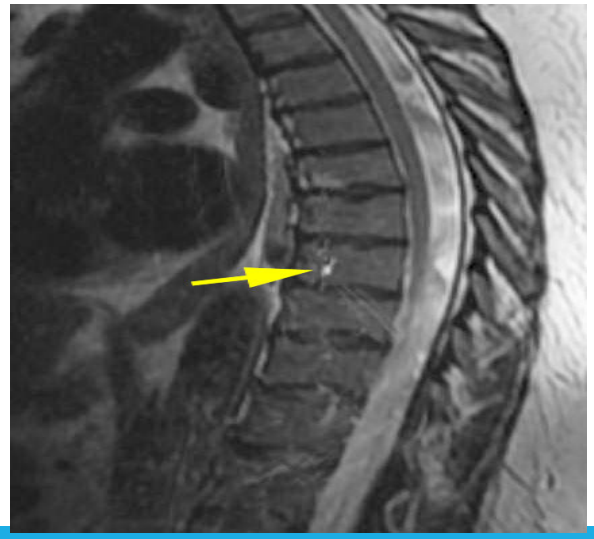
1. Cold head line vibrations
2. Room lighting updates or changes
3. Clogged waveguides in AC return vents

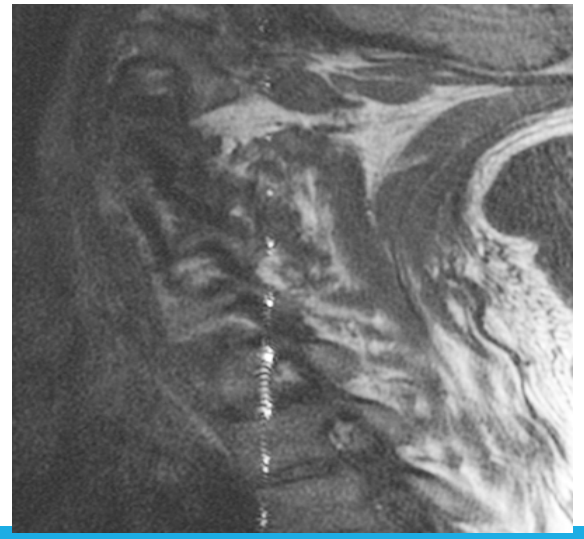
RF Leak or Zipper Artifact

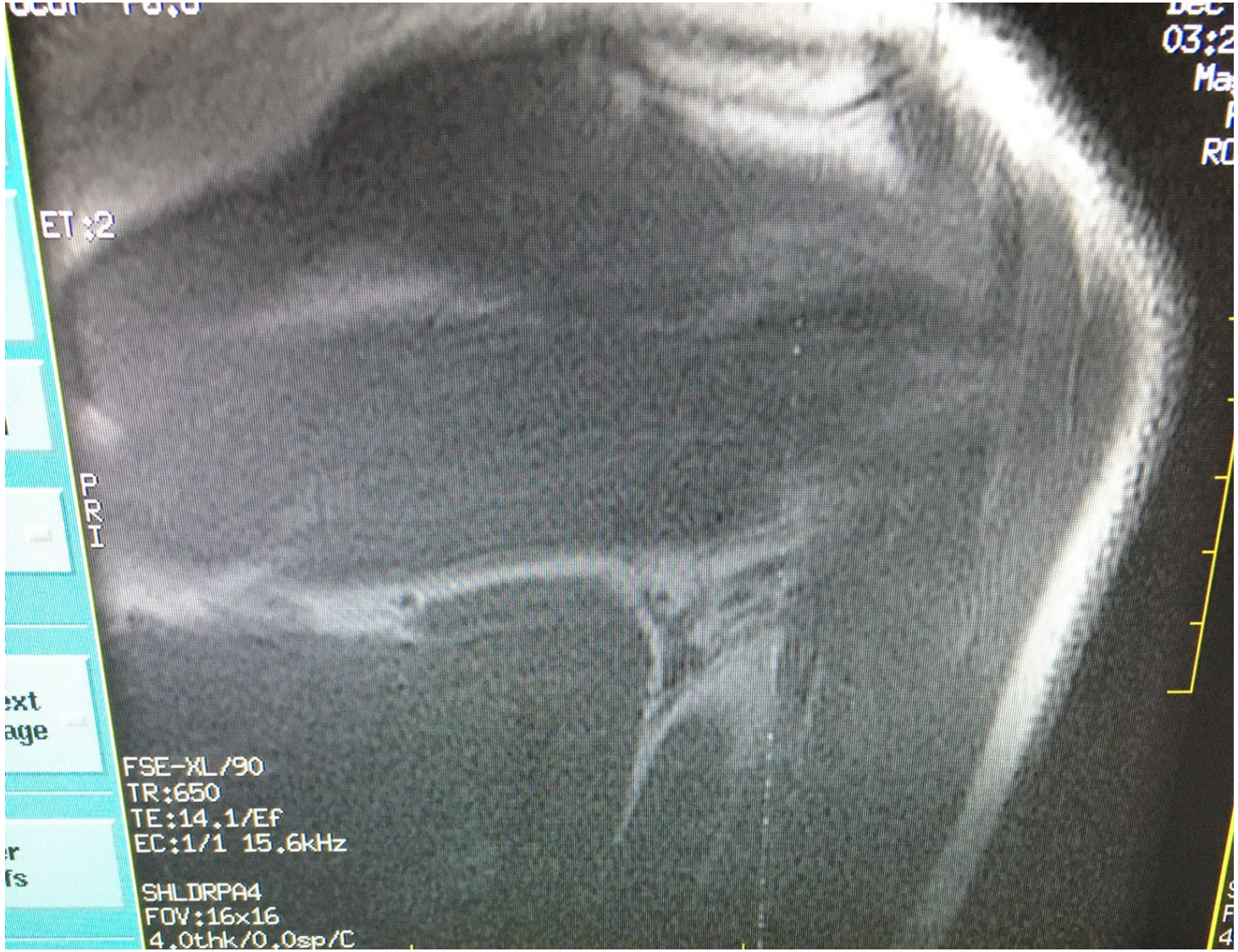
Zipper-like bands of spurious signal passing through the image result from a variety of causes, so no single maneuver may correct them all. The most common form of zipper artifact passes through the center of the image and is oriented in the phase-encode direction. This type of zipper artifact results from varying transmitter leakage ("feed-through") picked up by the receiver system. Perhaps the most common origin of this RF noise is an extraneous source that reaches the receiver coil because the door of the RF shielded scanner room has not been fully closed or its seal is defective. A second common cause is RF emission from anesthesia monitoring equipment (e.g., pulse oximeters) used within the scanner room.

Zipper-like artifacts oriented in the frequency-encode direction are usually caused by stimulated echoes from imperfect slice-selection profiles or improper RF-transmitter adjustments.









RF Leak

RF Leak Zipper

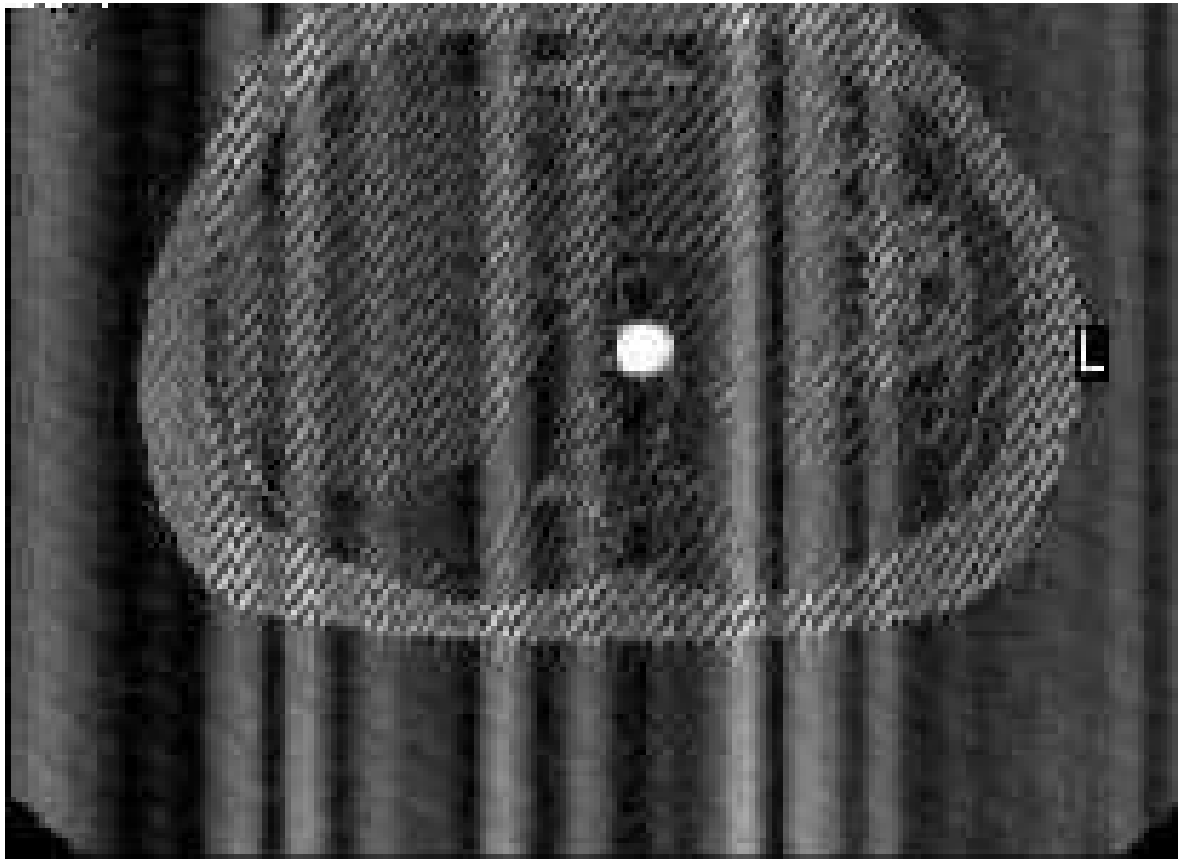
ARTIFACT THROUGH ENTIRE VIEW

NOTE DATA COLLECT COMPLETED

CHECK DOOR SEAL

ROOM LIGHTS

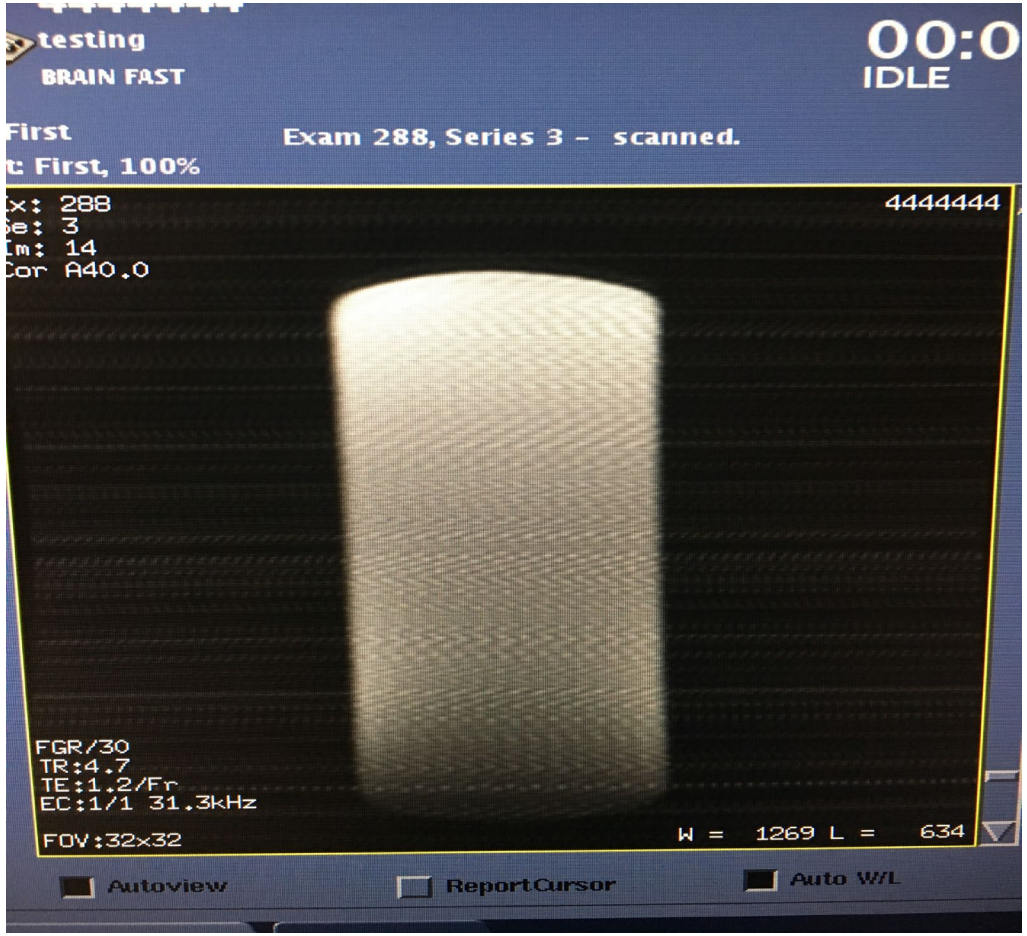
REMOVE ALL ELECTRICAL ITEMS FROM ROOM



Zipper Artifact – RF Leak at Room Door

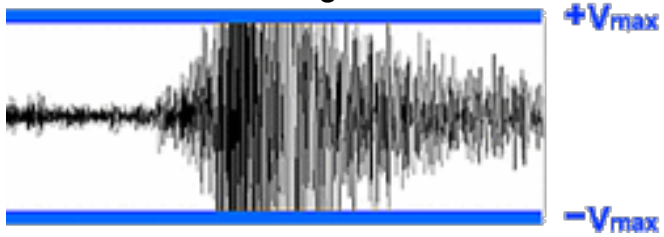
Noise entering the magnet room environment can be from multiple sources.

An adjacent system, led lighting, power sources. Address the source of the leak first.

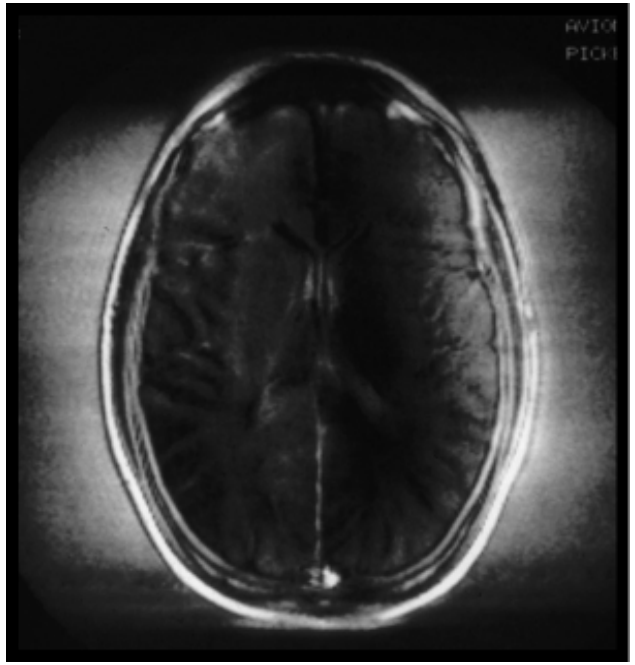


Data Clipping

Improper calibration of the receiver amplifier gain can result in data clipping and an eerie, phantom-like image with a gray background. This artifact occurs whenever the gain setting is too high and the RF-signal exceeds the upper and lower cut-off levels of the RF amplifier ($\pm V_{max}$). Careful recalibration and rescanning are the only means of overcoming this artifact.

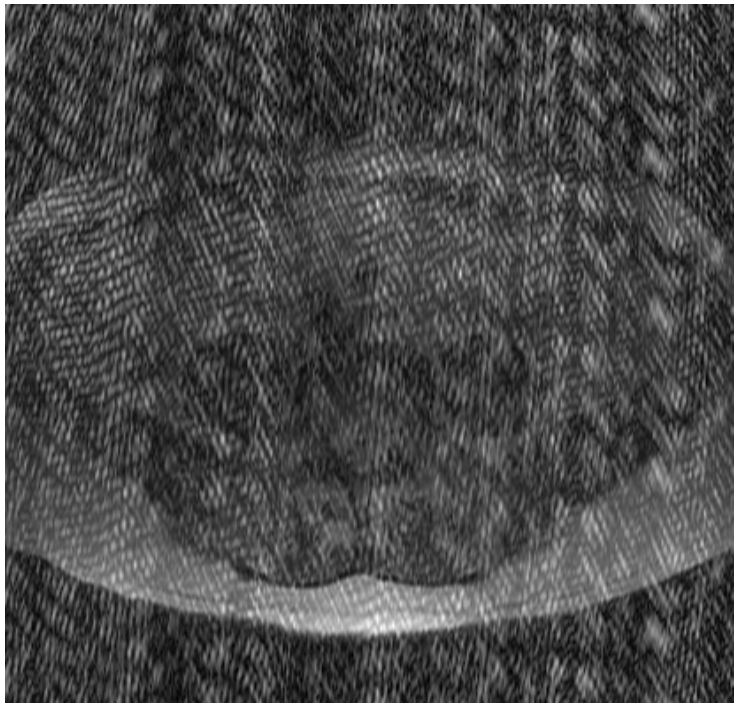


This is most times a result of electrical failure in the systems receiver chain or RF amplifier. The system will attempt to self-correct by signal boost or over driving the RF energy.

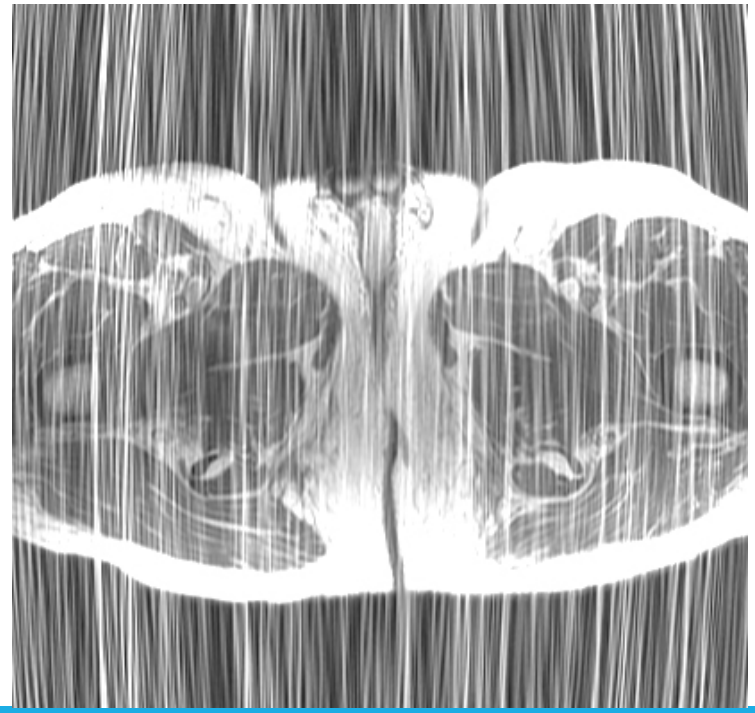


Data Error Artifacts

From time-to-time a random "glitch" occurs in the data processing chain resulting in an image containing multiple lines that may be arrayed in a crisscross or herringbone pattern. Several examples are shown. Often, simply reprocessing the raw data will remove this artifact and salvage an otherwise unreadable group of images.

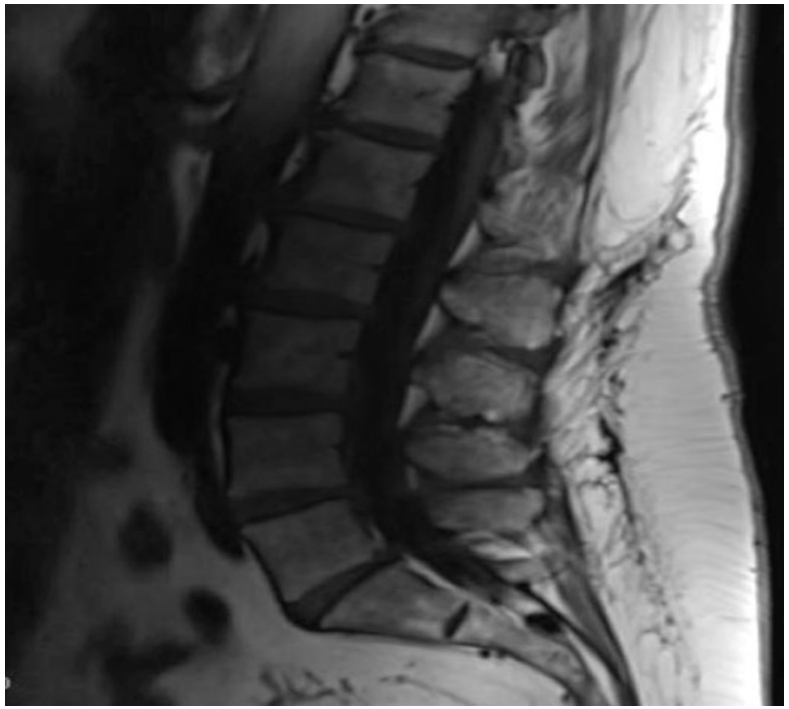




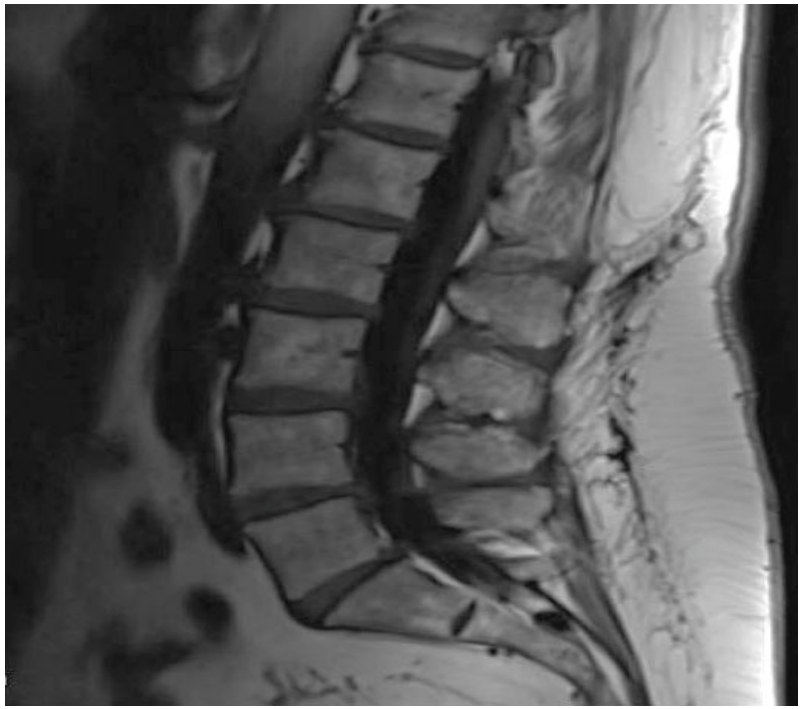


Surface Coil Flare

MR imaging is increasingly performed using arrays of small surface coils placed near or on the body, often in conjunction with parallel imaging. The advantage of using small surface coils is that they produce a higher signal-to-noise ratio (SNR) than would be possible from a larger, more distant coil. The disadvantage is non-uniformity of signal. The depth of penetration of coils is inversely proportional to their diameters. Signals arising superficially in the patient are accentuated, while those deep to the patient are attenuated. The resultant bright surface signal is sometimes referred to as ***surface coil "flare".***



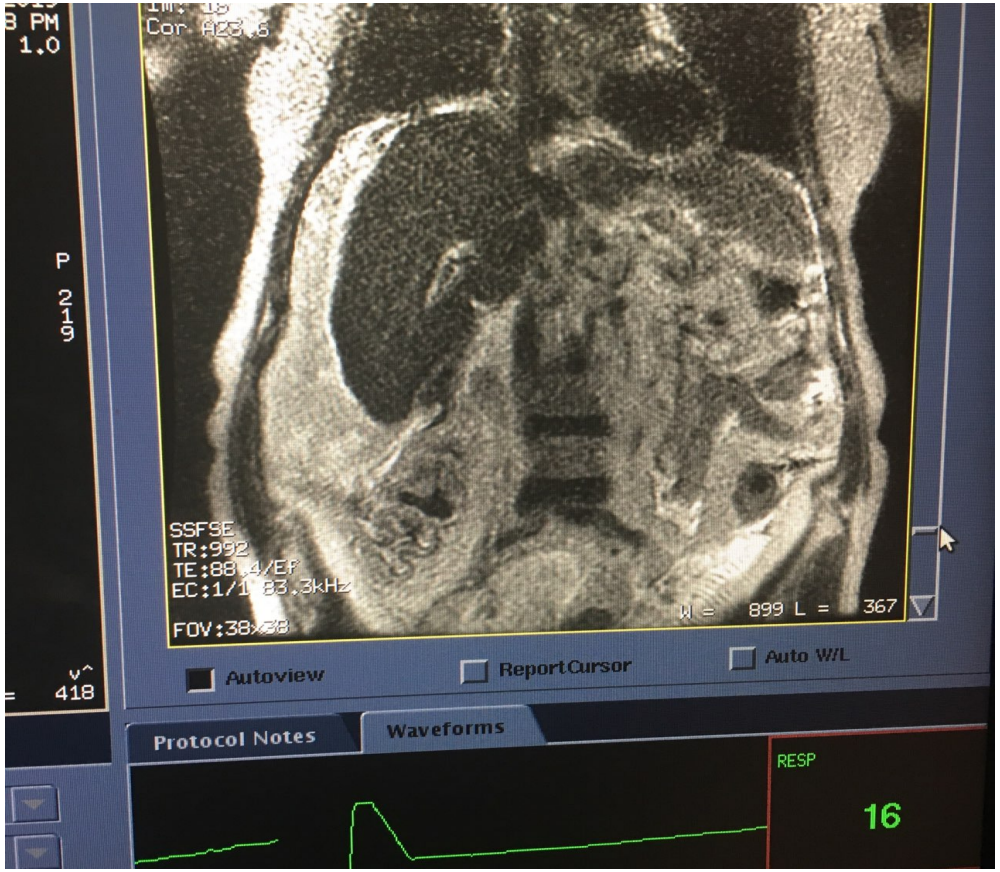
- Surface coils have highest sensitivity near the body surface, producing too-bright signal "flare" on images
- Correction methods
  - Pre-acquisition sensitivity mapping: PURE/CLEAR
  - Post-acquisition filtering: SCIC



Post processing filtering offers the best resolution for coil flare (SCSI) surface coil intensity correction – this application offered by all vendors and recommended for regular use in spine, extremity and body imaging.

NOISE ARTIFACTS

2 very similar looking images-the left was the result of a room lighting upgrade where the vendor drilled thru the RF shield in the ceiling resulting in a RF leak.
The right is a coil electrical failure, an internal diode had a voltage leak.
One item to note the left photo shows a snowy appearance thru the entire image while the right is more specific to an area.

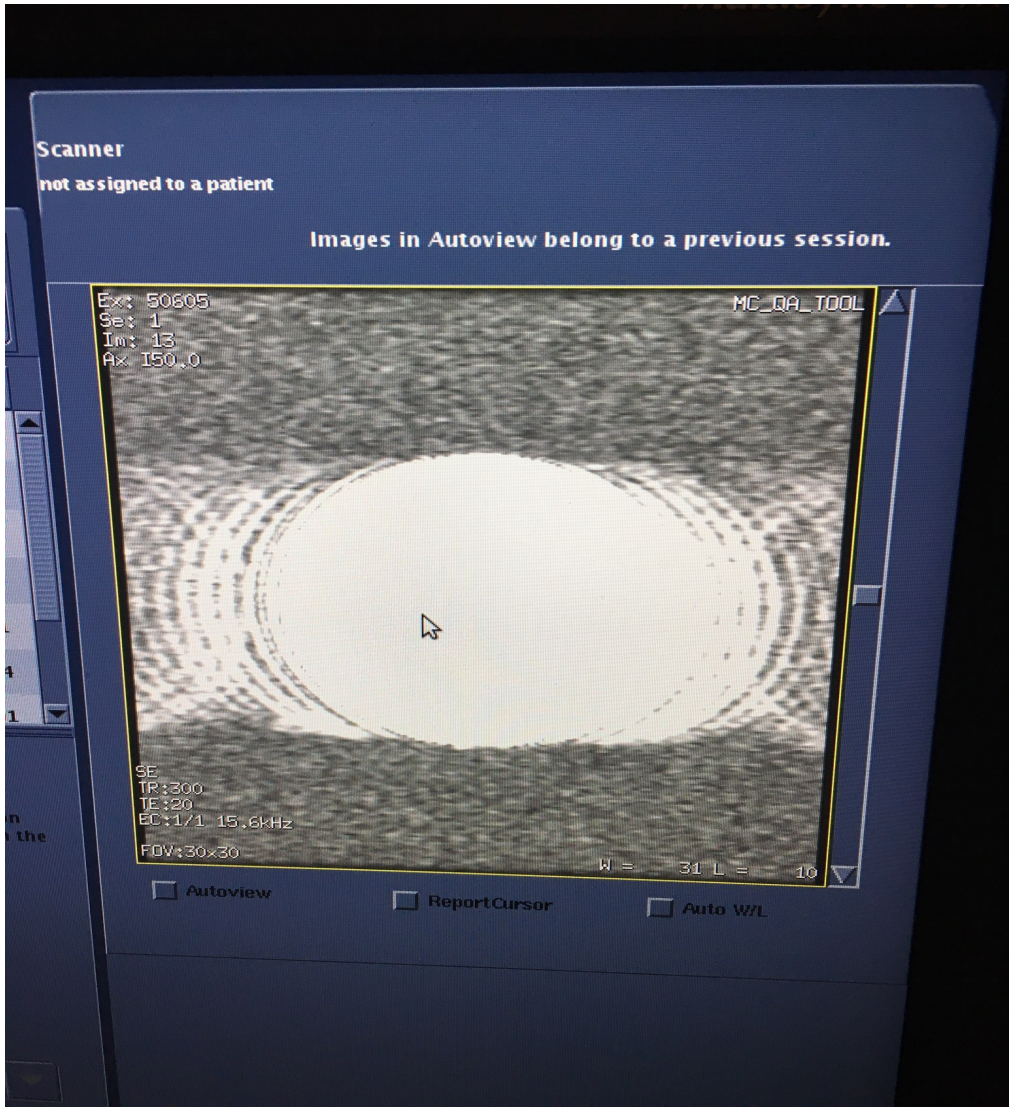




Instability/ Noise

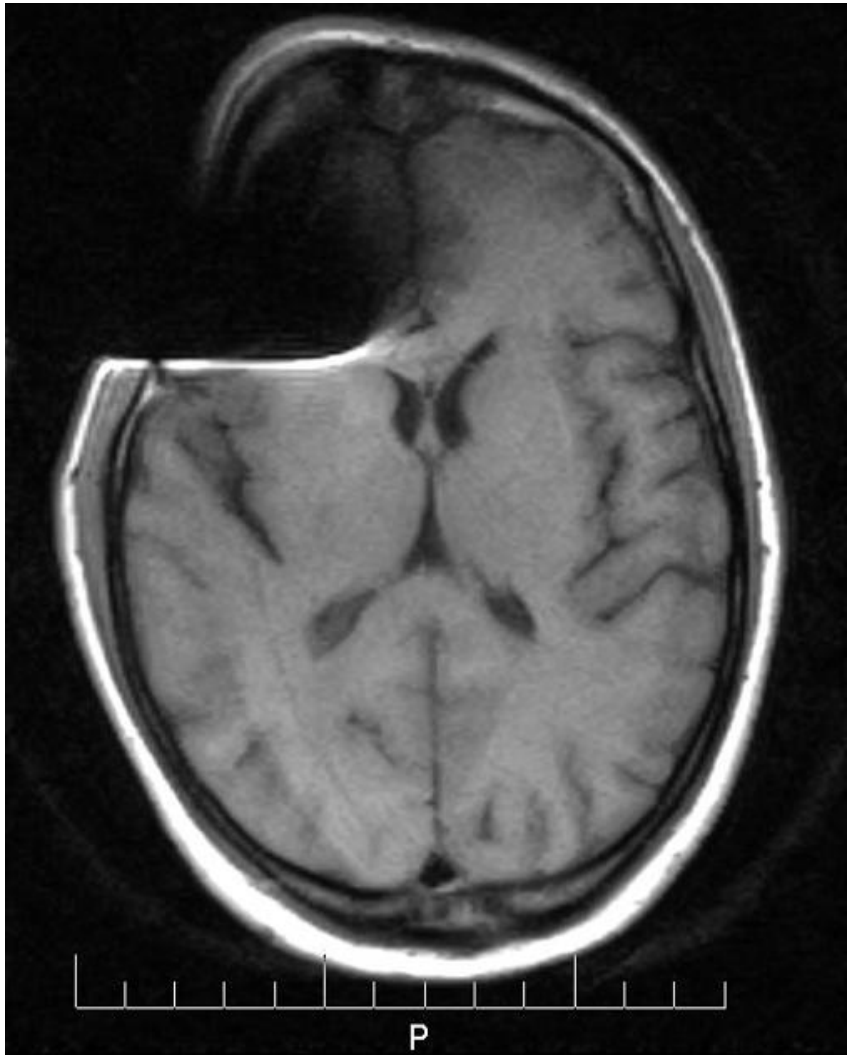
Diagnostic images were normal on this system but unable to pass ACR imagery. One could see the fluid in the ACR phantom constantly in movement then when the video monitor was windowed up one could see instability in the frequency direction.

This was the result of a construction project that had a large cooling fan relocated directly above the MRI suit on the buildings roof. It created enough vibration to feedback thru the walls and ceiling.



SHIM Field Distortion

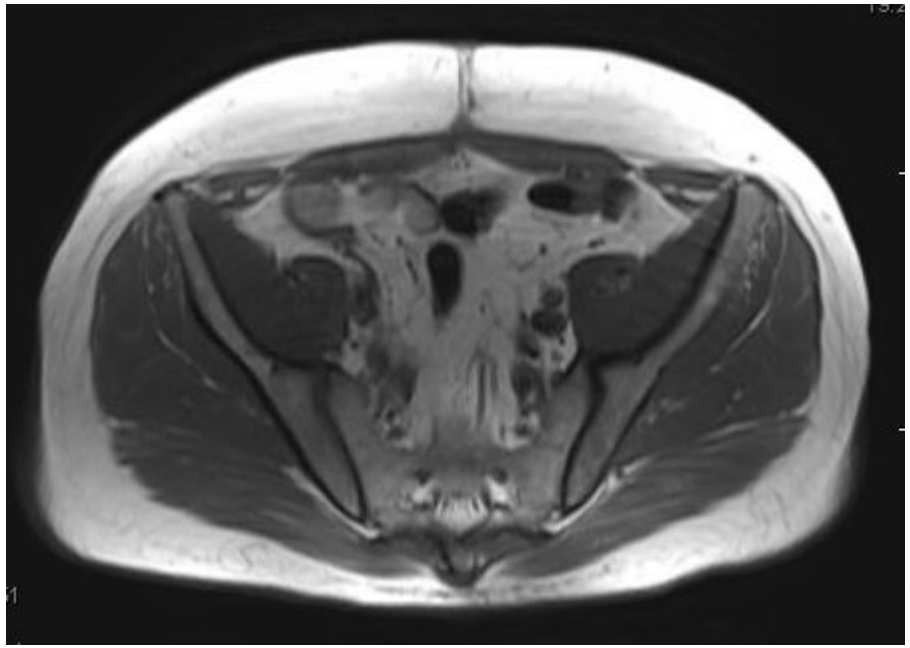
- Gradient shim has been disturbed.
- Usually causes are metal objects in magnet bore.
- Possible surgical implant device.
- But patient screening should rule out.



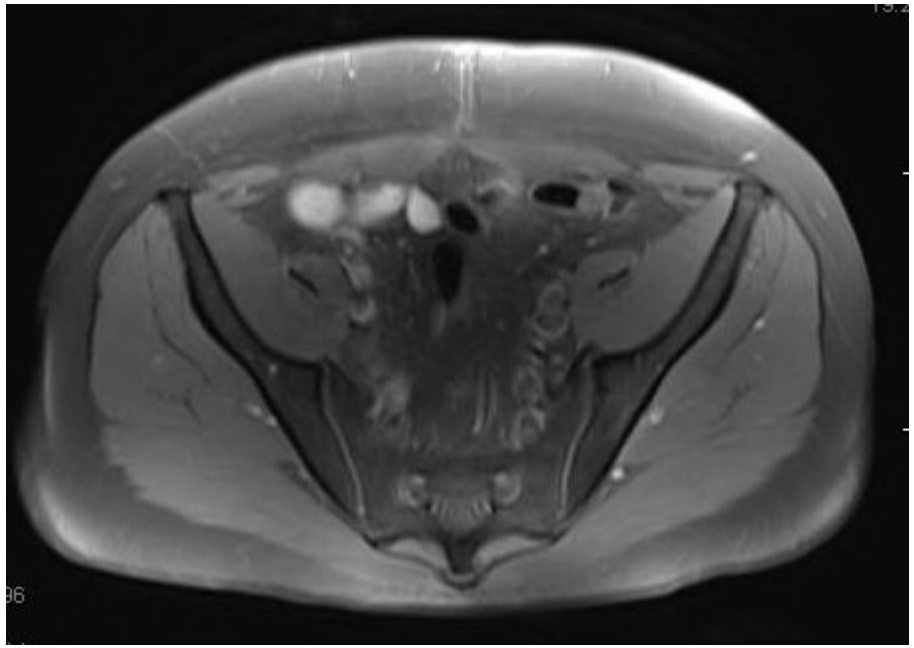
If no metal can be located in bore area then a gradient reshim will resolve the issue temporarily.

Fat Sat

Fat-Sat pulses are short-duration RF-pulses tuned to the resonance frequency of fat. They are applied immediately before the start of an MR imaging sequence. These chemically selective pulses cause the signal from fat to be nulled (saturated) while the water signal is relatively unaffected.



T1-weighted pelvis image without fat-sat. Fat is the brightest substance.



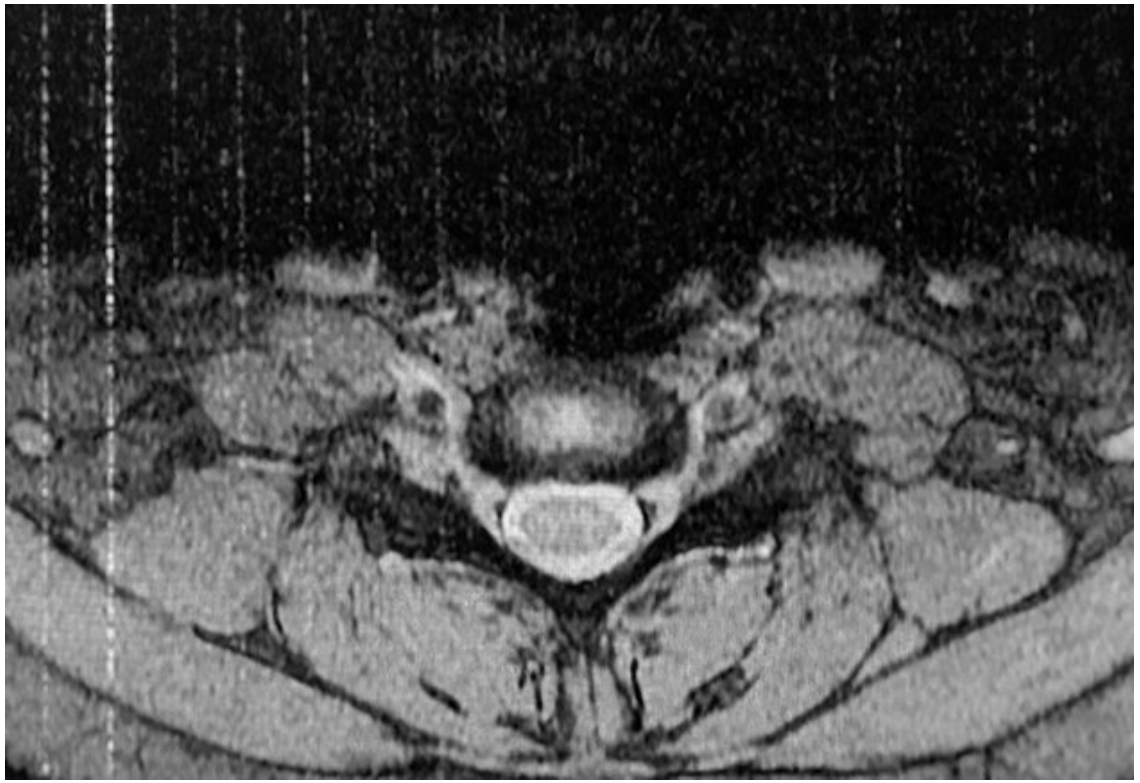
T1-weighted image with fat-sat. Note how muscle is now much brighter than subcutaneous fat or bone marrow

Shim issues or metal objects in the bore affecting shim will cause fat –sat issues.

Axial Studies Showing a Zipper Artifact from an RF Noise Source

The artifact is in the frequency direction with a possible 60 cycle pattern. This has a high chance of being a device inside the room, a power supply for an injector or ventilator or room lighting.





Coil Related Artifact

Body array coil on 1.5T MRI- signal loss and degradation

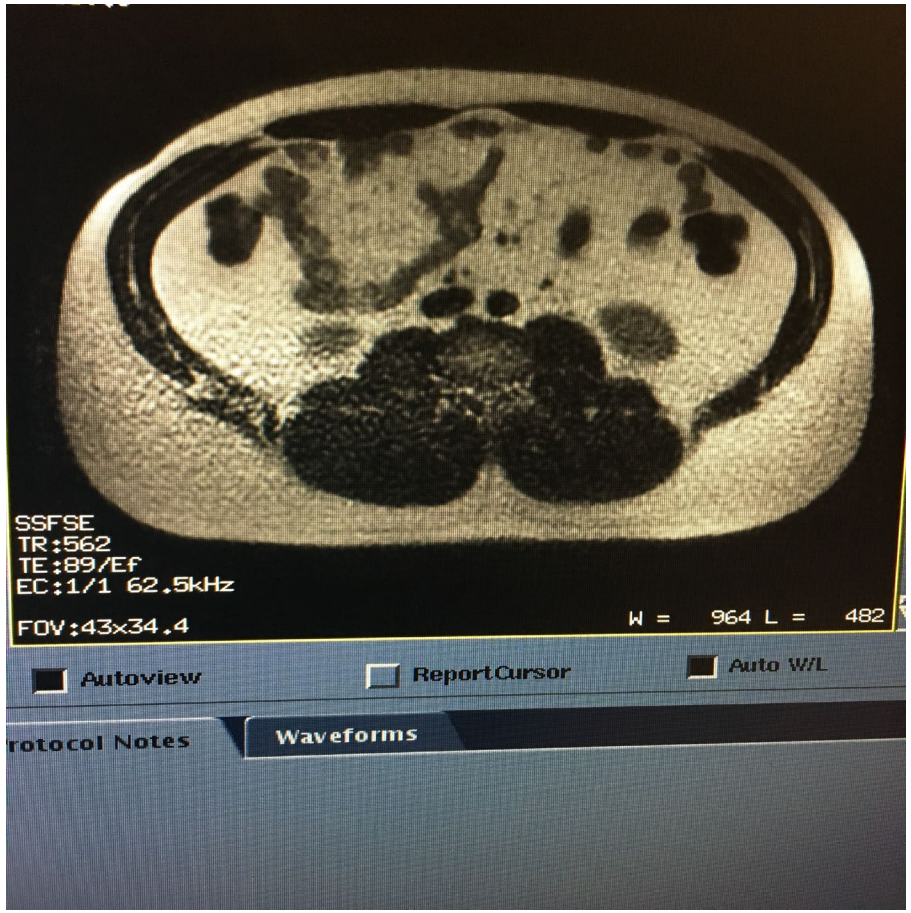
Possible internal electrical component failure within coil
Low RF energy or transmit gain issue

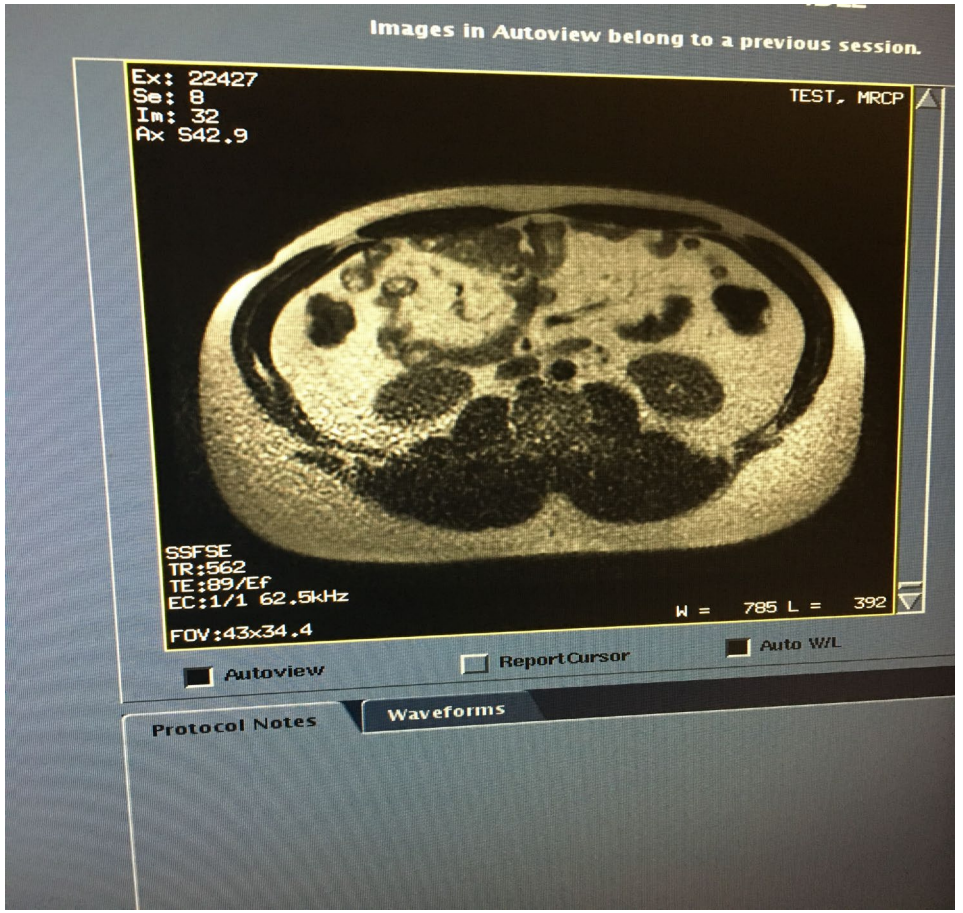




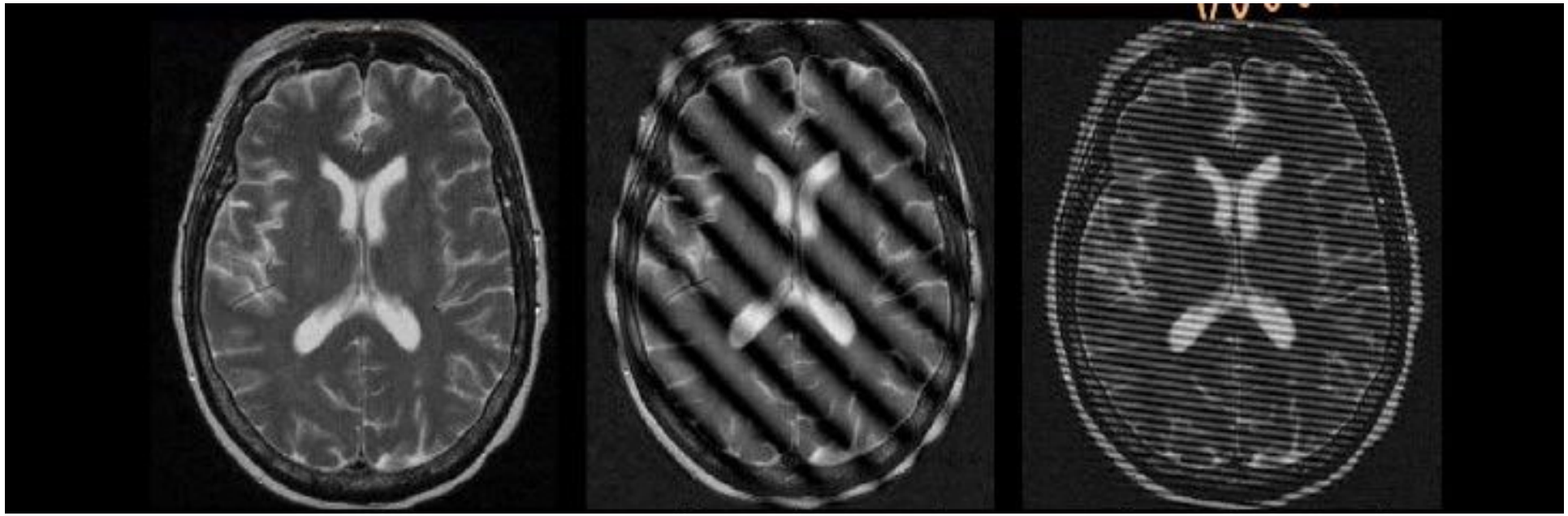
Coil Failure

SIGNAL LOSS –CABLE OR CONNECTION ISSUE
LOW RF/CHECK TRANSMIT GAIN



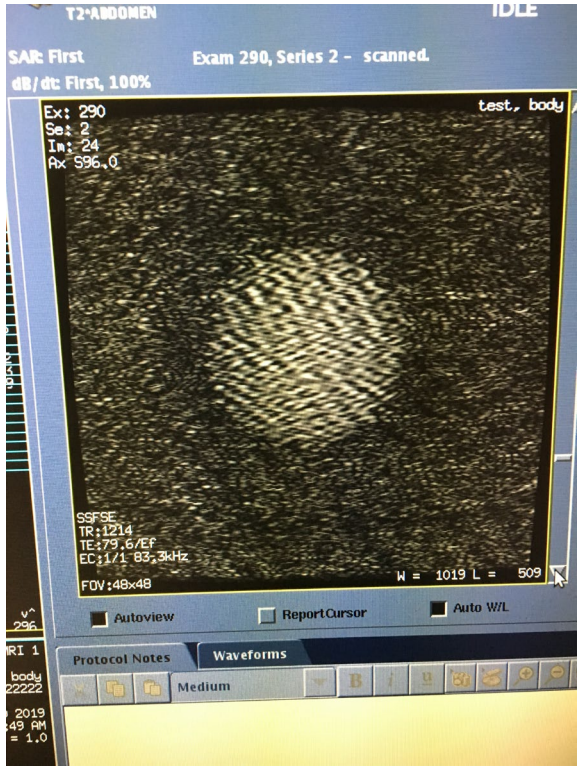


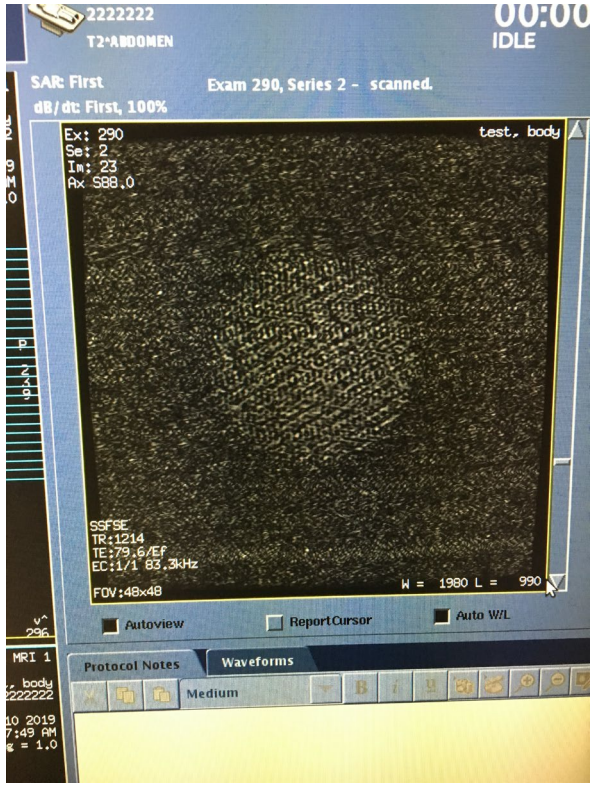
Spike Noise

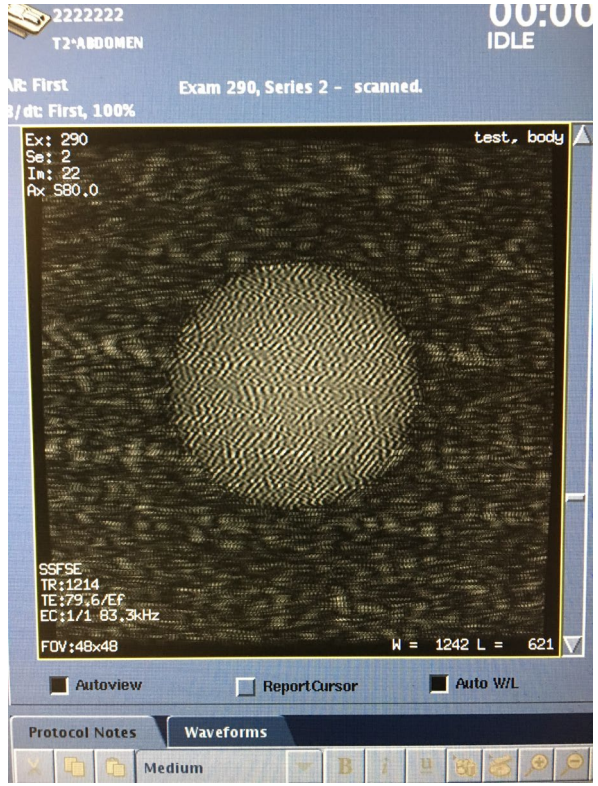


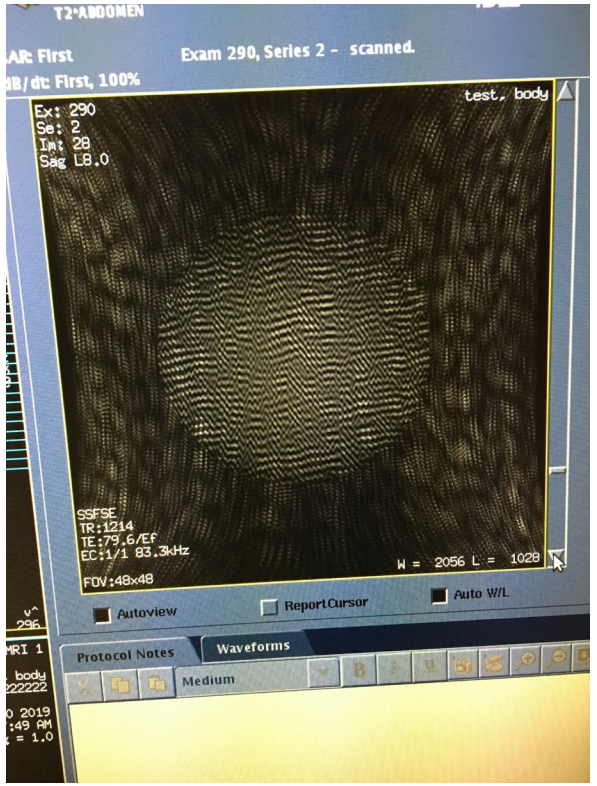
Typically a physical vibration of a loose component at or near the magnet-older systems encounter this issue more frequently.

Intermittent Zipper Artifact









White pixel diagnostics failed consistently

The heavier the item the more likely the magnet will need to be ramped down.
A light object or cart will come apart as it is pulled away from the field-be **prepared for projectiles**.
The magnetic field is strongest at the magnet bore near the center.
Best safe practice is to always ramp the magnet down-time consuming but the safest route.
Do not use the room entry doorway as a pulling point for a “come along” device. The door frame will be damaged.





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