Diagnosing SPT Problems

Introduction

This document is intended to be used by experienced Manufacturing Technicians, Field Engineers and their support personnel as a guide to diagnosis of problems detected by System Performance Test (SPT). For many of the test parameters, the approach to isolating a failure reported by SPT will be similar to that followed for TLT, so your experience with TLT will still be useful.

Z-Isocenter

If a Z-Isocenter failure is reported, it means that either the measured value was outside allowable absolute limits, the required change was too great or that image signal is much too small or absent. Failures are always based on the "Recommended Config New" value in the report. See file */usr/g/service/cclass/spt/cal.spt* for limits.

Outside Absolute Limits

Most likely cause is incorrect magnet or magnet shield type entered in the Service Config File (MRconfig.cfg on Lx).

Required Change Too Great

Bad landmark.

First time run of SPT after installing new hardware in a bay using config file values restored from previous bay load.

Running SPT on an uncalibrated system may cause this failure. SPT is only intended to be used to "touch up" Z-Isocenter calibration.

Low Signal

An abnormally small signal, or noise only image, will cause Z-Isocenter to fail. Such conditions can be caused by:

- Incorrect center frequency.
- Power off to resistive shim supply, if present.
- Missing phantom or incorrect landmark.
- Cradle unlatches from carriage while advancing to scan.
- Head coil quick disconnect not plugged in or defective head coil.
- Faulty TNF or TNF continuously blanked by oscillating preamplifier(s).
- Other hardware fault that prevents transmitting or receiving properly.

Grad Cal

If a Grad Cal failure is reported, it means that either the measured value was outside allowable absolute limits or that the required change was too great. Failures are always based on the "Recommended Config New" values in the report. See file */usr/g/service/cclass/spt/cal.spt* for limits.

Outside Absolute Limits

Default grad cal entries in config file.

Incorrect config file entries for hardware configuration.

Required Change Too Great

First time run of SPT after installing new hardware in a bay using config file values restored from previous bay load.

Running SPT on an uncalibrated system will cause this failure. SPT is only intended to be used to "touch up" Grad Cal calibration.

Faulty DQA-III phantom (usually Y axis). In the following illustration, compare thin outside line at top of phantom to wide outside line at bottom. The illustration shows that phantom internals are improperly centered in the phantom shell.

Faulty gradient driver power module or GRAM.

Faulty gradient coil.

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Grad Cal (continued)

Required Change Too Great (continued)

System Gain

If a System Gain failure is reported, it means that either the measured value was outside allowable absolute limits or that the required change was too great. Failures are always based on the "Recommended Config New" value in the report. See file */usr/g/service/cclass/spt/cal.spt* for limits.

Outside Absolute Limits

Faulty TNF.

Head only, failure to use new style head quick disconnect box with built-in isolation network.

Faulty preamplifier.

Head only, faulty quick disconnect box.

Faulty cables anywhere between the coil and receiver.

Faulty receiver.

Faulty T/R switch or hybrid splitter.

Faulty dynamic disable bias driver or T/R switch bias driver.

Faulty coil.

Required Change Too Great

First time run of SPT after installing new hardware in a bay using config file values restored from previous bay load.

Running SPT on an uncalibrated system will cause this failure. SPT is only intended to be used to "touch up" System Gain calibration.

Faulty TNF.

Faulty preamplifier.

Head only, faulty quick disconnect box.

Faulty cables anywhere between the coil and receiver.

Faulty T/R switch or hybrid splitter.

Faulty dynamic disable bias driver or T/R switch bias driver.

Faulty receiver.

Faulty coil.

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Magnet Shim

If a Magnet Shim failure is reported, it means that the measured value was outside allowable absolute limits. In the */usr/g/service/cclass/spt* directory see file *ge_s1.spt*, *ge_s2.spt*, *ge_s3.spt*, *ge_s4.spt*, *ge_s5.spt*, *ge_sx.spt*, *ge_sxc.spt*, *ge_max.spt* or *ox.spt* for limits applicable to your magnet type.

Run Grad Shim using LVShim

If only first order coefficients are out of specification, try running LVShim in Grad Shim mode with all SPT phantoms on the cradle. SPT Magnet Shim should now pass. If SPT Magnet Shim does not pass, but stand-alone LVShim does, stand-alone LVShim takes precedence over SPT Magnet Shim. Report the discrepancy and continue.

Long Eddy Currents

The Long Eddy Currents test in SPT is identical to Grafimage in TLT. See file */usr/g/service/cclass/spt/eddyl.spt* for limits. If results are outside allowable limits, perform appropriate eddy current and B_0 calibration procedure.

Important note: If linear, cross-term and B_0 eddy current calibrations measured by Grafidy are all within specification, then do not perform any corrective action based solely on SPT Grafimage results. Grafidy results take precedence over SPT Grafimage results when determining that a system is "within specification."

SNR

If an SNR Test failure is reported, it means that at least *one* of SNR or TG was found outside allowable limits. See file */usr/g/service/cclass/spt/snr.spt* for specifications.

Signal

If the system has previously passed the SNR test and no calibrations have been performed since the SNR test passed, consider the following:

Low signal can be caused by system performance parameters that affect imaging physics such as shim, eddy currents, severe instabilities or faulty Grad Cal. Poor RF amplifier linearity or exciter rho modulator missing bits could also degrade signal, but this is very rare.

Oscillating preamplifier(s) can cause the TNF to blank continuously or intermittently.

Faulty TNF.

Head only, failure to use new style head quick disconnect box with built-in isolation network.

Faulty preamplifier.

Head only, faulty quick disconnect box.

Faulty cables anywhere between the coil and receiver.

Faulty T/R switch or hybrid splitter.

Faulty dynamic disable bias driver or T/R switch bias driver.

Faulty receiver.

Faulty coil.

System Gain may be out of calibration, especially if this is a first time run of SPT after installing new hardware in a bay using config file values restored from previous bay load or if the system has not been calibrated at all.

Diagnosing SPT Problems

SNR (continued)

Noise

If the system has previously passed the SNR test and no calibrations have been performed since the SNR test passed, consider the following:

Screen room door not properly closed or faulty. Coherent noise test would also likely fail.

Faulty lighting in screen room. Coherent noise test would also likely fail.

Cover open or removed from SRI. Coherent noise test would also likely fail.

Hardware changes (usually additions) have been made that violate RF shield integrity. This could include special test cables, test equipment etc. in the screen room without proper filtering or shielding. Coherent noise test would also likely fail.

Faulty TNF.

Head only, failure to use new style head quick disconnect box with built-in isolation network.

Faulty preamplifier.

Excessive noise out of the RF amplifier when it is blanked. Generally seen in body mode only. Use TLT SNR noise only mode to check noise with RF amplifier output (before envelope feedback directional coupler) connected and disconnected. There should be no significant (< 1%) change in noise between the two conditions.

Head only, faulty quick disconnect box.

Faulty cables anywhere between the coil and receiver.

Faulty T/R switch or hybrid splitter. Try running PIN diode noise test.

Faulty dynamic disable bias driver or T/R switch bias driver.

Faulty receiver.

Faulty coil.

System Gain may be out of calibration, especially if this is a first time run of SPT after installing new hardware in a bay using config file values restored from previous bay load or if the system has not been calibrated at all.

SNR

If SNR is failing, either signal is too low or noise is too high. Refer to signal and noise sections for guidance.

TG

Most likely cause is RF amplifier gain calibration.

If RF amplifier gain calibration is verified OK, also consider:

Poor RF amplifier linearity due to faulty envelope feedback hardware.

Head only, failure to use new style head quick disconnect box with built-in isolation network.

Head only, faulty quick disconnect box.

Faulty cables anywhere between the coil and RF amplifier output.

Faulty T/R switch or hybrid splitter.

Faulty dynamic disable bias driver or T/R switch bias driver.

Faulty coil.

Diagnosing SPT Problems

Stability

SPT has two stability tests using the clinical Fast Spin Echo (FSE) and Fast Gradient Echo (FGRE) PSDs. As a very loose general rule, FSE stability, with its high RF duty cycle, is more sensitive to RF related problems while FGRE, which stresses primarily the gradient drivers, is more sensitive to gradient related problems. It must be emphasized, however, that this is by no means a hard and fast rule. If a Stability Test failure is reported, it means that at least *one* of Time Domain Echo Shift, Constant Phase Drift, or Magnitude Drift was found outside allowable limits at a slice location. In the */usr/g/service/cclass* directory, see files *fsestb.spt* and *grestb.spt* for specifications. Run the *whatFailed* utility to compare results to the limits.

Time Domain Echo Shift

The rate of phase accumulation during the readout window is proportional to the integral of the gradient field from the center of the RF 90° pulse for FSE or 30° pulse for FGRE to the center of the readout window. If the echo pops up exactly in the center of the readout window, the gradient integral is zero. Phase accumulation rate is positive if the echo is late and negative if it is early. SPT does not report the actual echo position, only how it shifts from view to view.

Echo shift errors are most likely to be caused by the readout gradient. See FGRE stability example on page 7. Also see FGRE stability example on page 12.

Body FSE echo shift failures have been traced to noisy LEM modules in GRAMs. The symptom is usually noisy plots perhaps with some small spikes.

RF transmit pulse errors have no appreciable effect on echo shift unless the RF errors are really huge. See page 13 for an FSE example of a serious problem in the RF amplifier. Note that time domain echo shift is only slightly affected.

Environmental vibration affects FSE stability much more than FGRE stability. See FSE stability example on page 11 - note that the disturbance affects constant phase offset drift much more than echo shift.

See page 14 for an FSE example in which gradient vibration was shaking dynamic disable box connectors on a 1.5T 5.4 system. The OnLine Center can assist you with running SPT stability on 5.4 systems.

Diagnosing SPT Problems

Stability (continued)

Constant Phase Drift

Early in each sequence, the spins in a slice are excited by an RF pulse (excitation). At this point the spins are all rotating in synchronism with some absolute phase. At receive time (readout), when the echo is refocused, the spins are again all rotating in synchronism with some absolute phase. Constant phase is the average absolute phase that is left over after the time domain echo shift is removed from each view (i.e. the echoes are moved to the exact center of the readout window). Constant phase drift occurs when the phase shift between excitation and readout changes from view to view.

Basically, anything that changes the magnetic field between excitation and readout can cause constant phase drift.

If the drift is small at isocenter but large and opposite in polarity at opposed off-isocenter slices, the problem is most likely to be caused by the slice select gradient. See example on next page. Also see FSE stability example on page 12.

If constant phase drift is similar at isocenter and off-isocenter slices, the problem is most likely to be caused by uncompensated long time constant B_0 eddy currents or external factors such as vibration, moving metal, oscillating resistive shim supply, etc. See example on page 8.

RF transmit pulse errors have no appreciable effect on constant phase drift unless the RF errors are really huge.

Environmental vibration affects FSE stability much more than FGRE stability. Constant phase drift is the parameter that is most sensitive to vibration. See FSE stability example on page 11.

RF transmit pulse magnitude errors do not have much effect on constant phase drift unless the RF errors are really huge. RF transmit pulse phase errors, on the other hand, can seriously affect constant phase drift. See page 13 for an FSE stability example caused by a faulty RF amplifier. Recent similar examples in MR Manufacturing were traced to the Erbtec solid state driver board.

See page 14 for FSE and FGRE examples in which gradient vibration was shaking dynamic disable box connectors on a 1.5T 5.4 system. The OnLine Center can assist you with running SPT stability on 5.4 systems.

Magnitude Drift

SPT compares mean magnitude of each view to mean magnitude of all views. The result is displayed as a percentage of mean magnitude of all views.

In general, magnitude problems are caused by RF transmit or receive faults. There are exceptions, of course. Severe gradient errors can also sometimes cause magnitude drift problems, especially if slice location is changing due to drift of the slice encoding gradient. See examples on pages 9 and 10.

Environmental vibration affects FSE stability much more than FGRE stability although the impact on magnitude results is not bad enough to impact image quality. See FSE stability example on page 11.

See page 13 for an FSE stability example caused by a faulty RF amplifier.

See page 14 for FSE and FGRE examples in which gradient vibration was shaking dynamic disable box connectors on a 1.5T 5.4 system. The OnLine Center can assist you with running SPT stability on 5.4 systems.

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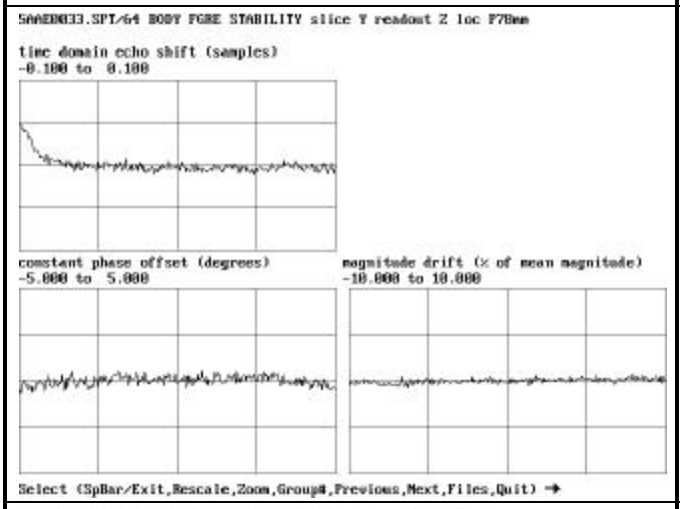
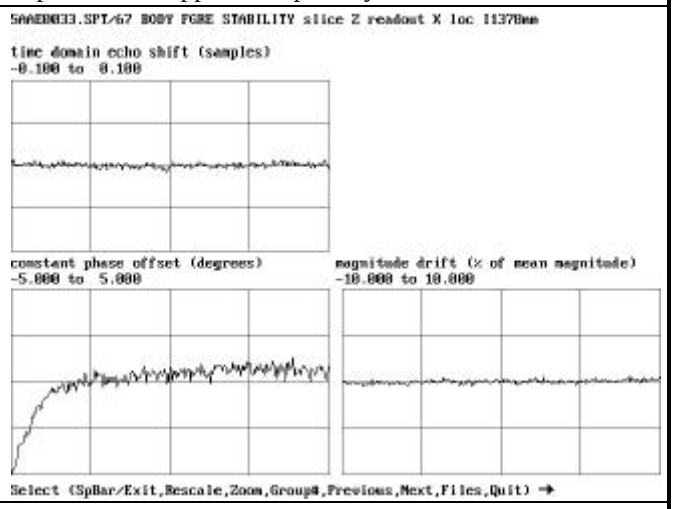
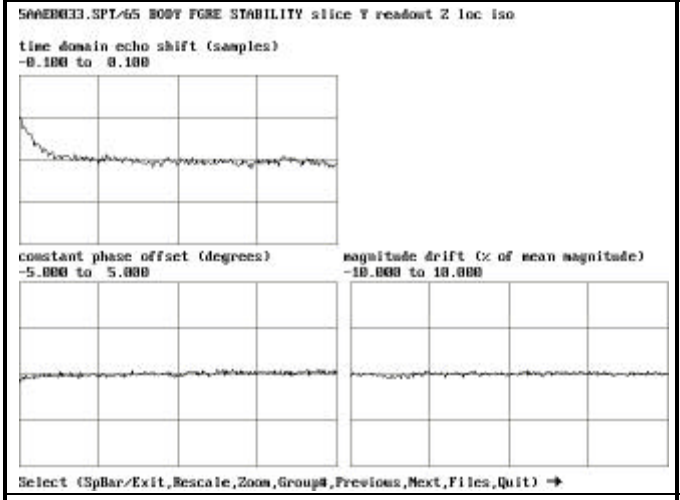
FGRE Stability Example -- Inadequately compensated long time constant eddy currents.

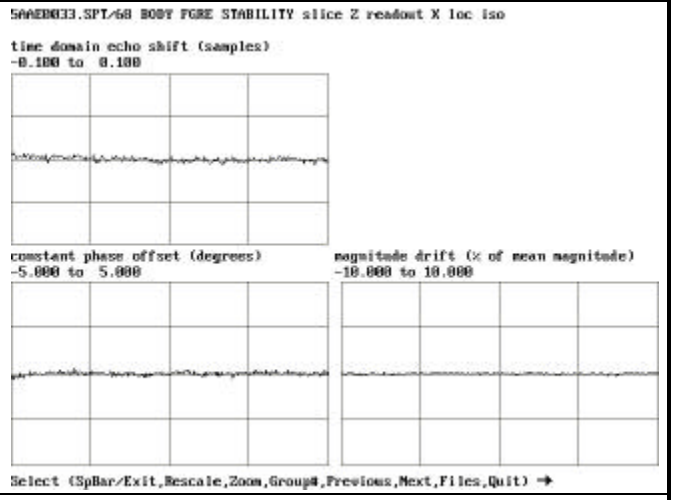
When Z is used for readout, effect on echo shift is not dependent on slice location.

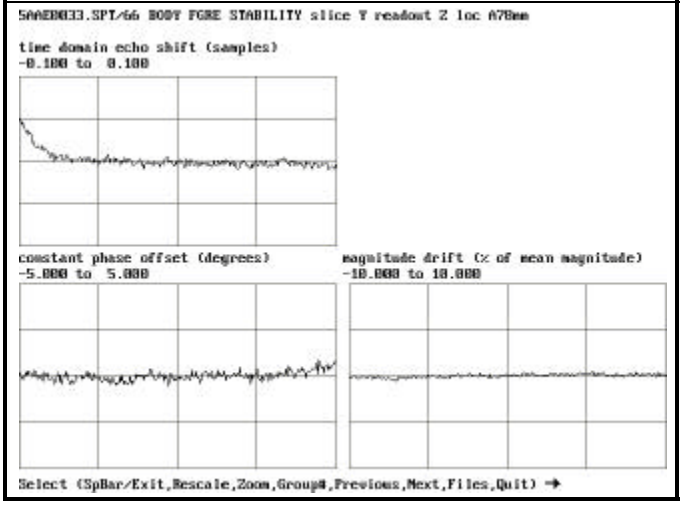
When Z is used for slice select, there is no effect at isocenter, but at opposed off-isocenter locations, the effect is present and opposite in polarity.

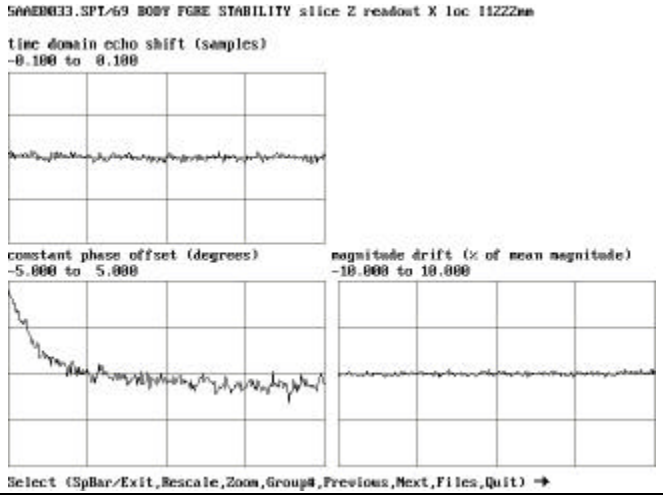












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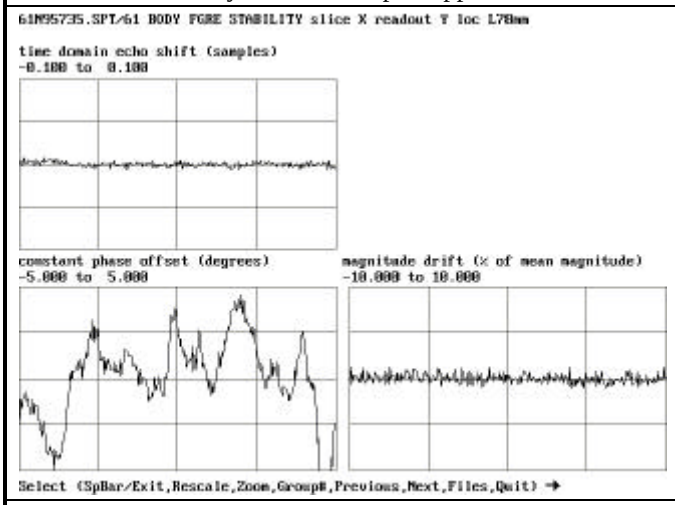
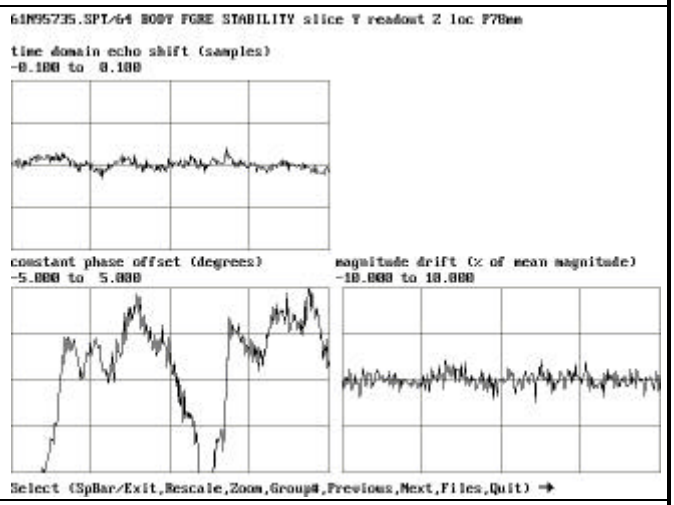
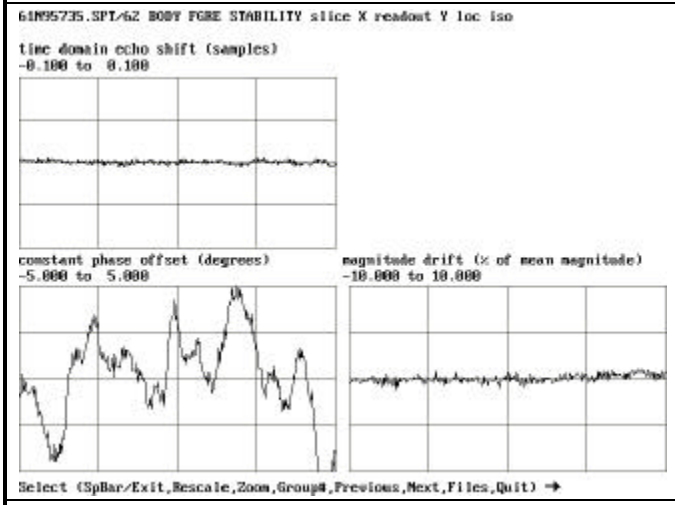
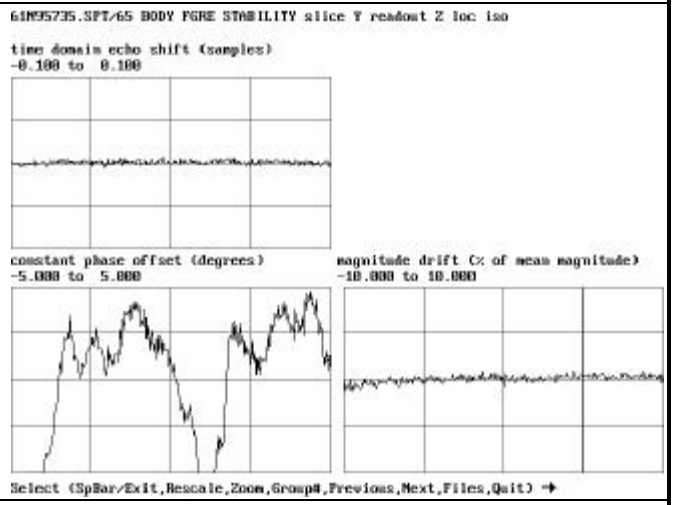
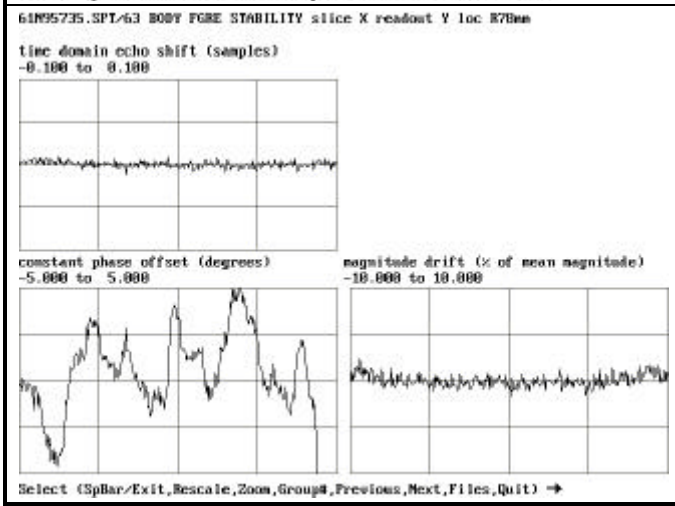
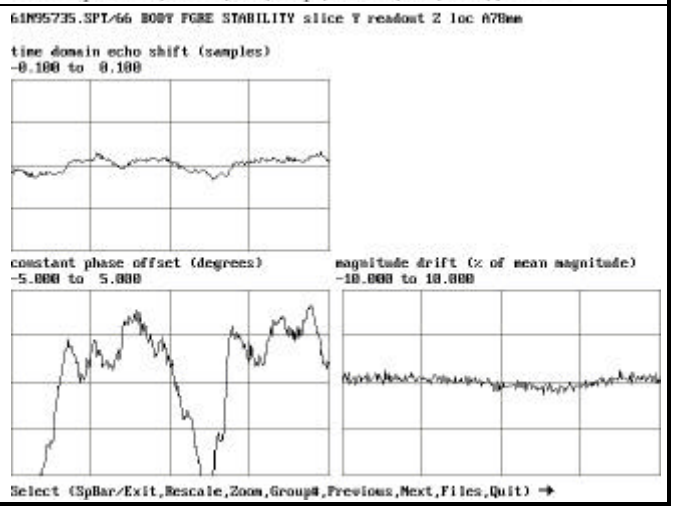
FGRE Stability Example -- Environmental magnetic field disturbance.

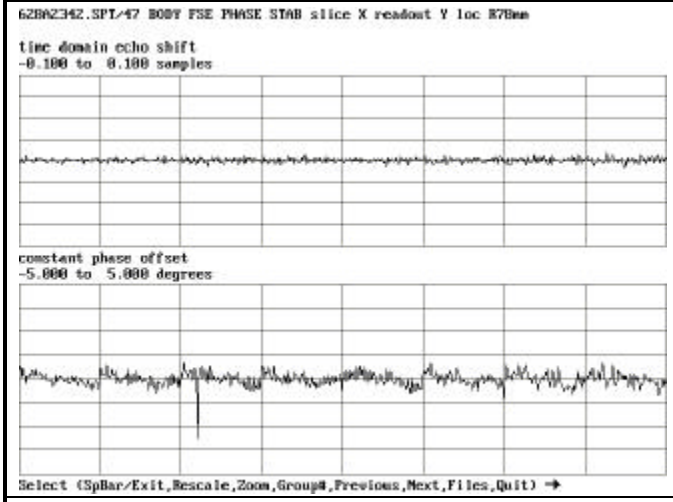
Slice X, readout Y case. Note that slice location and slice axis have essentially no effect on plot appearance.	Slice Y, readout Z case.
	
	
	

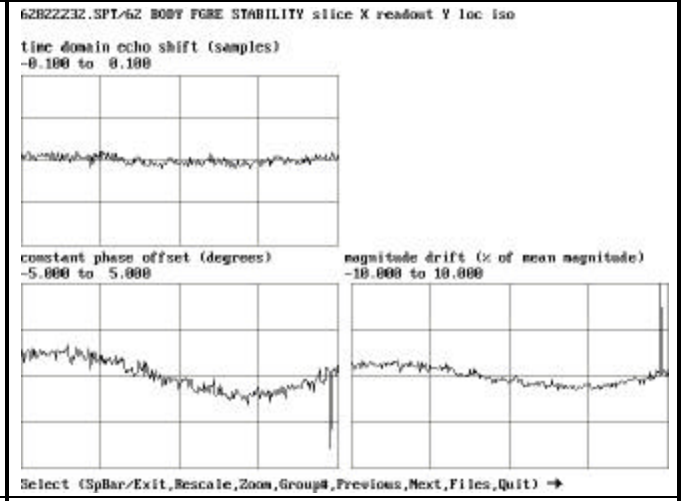
Diagnosing SPT Problems

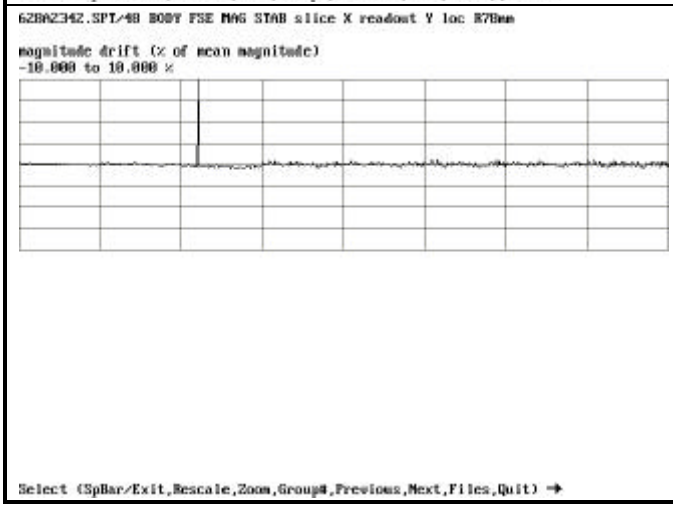
FSE & FGRE Stability Example -- Magnitude and constant phase spikes caused by body preamplifier.

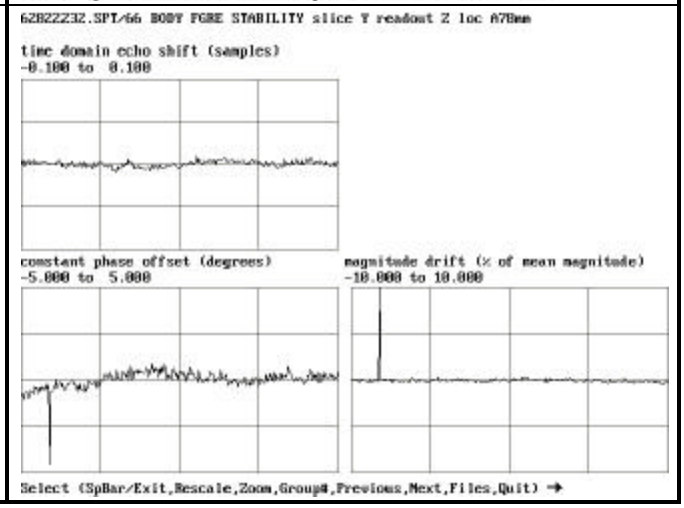
It is *very* important to note that the spikes do *not* propagate in the echo train after the initial event. This means that the event occurred during *receive* time since the "physics" was *not* affected. Therefore, the problem *must be in the receive chain*.

It is not possible to determine if spikes in FGRE stability plots were caused by an event during transmit time or receive time.







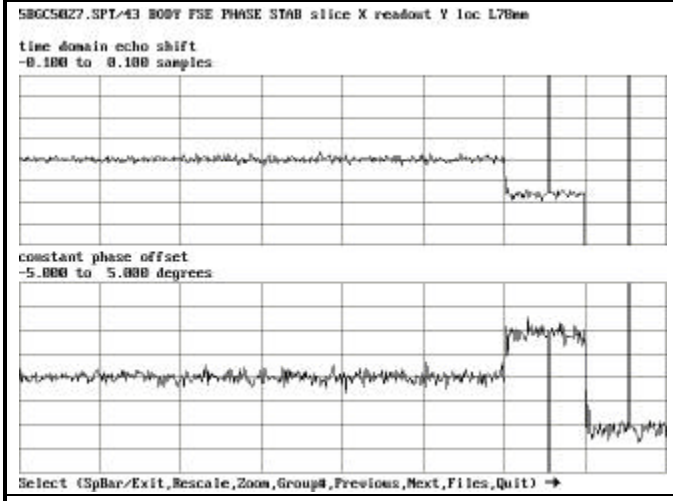


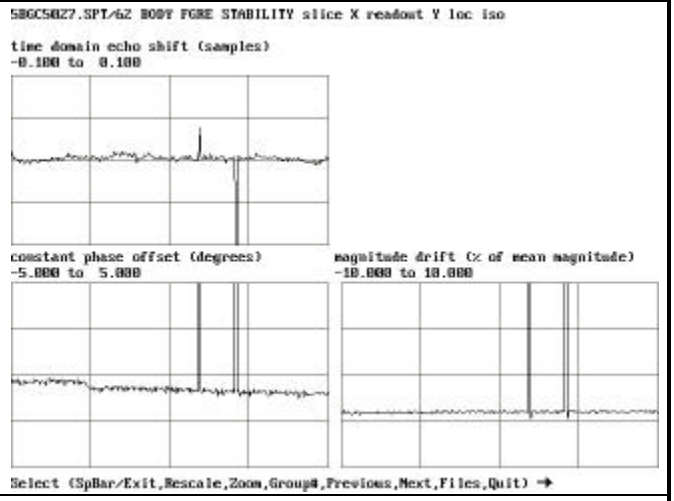
Diagnosing SPT Problems

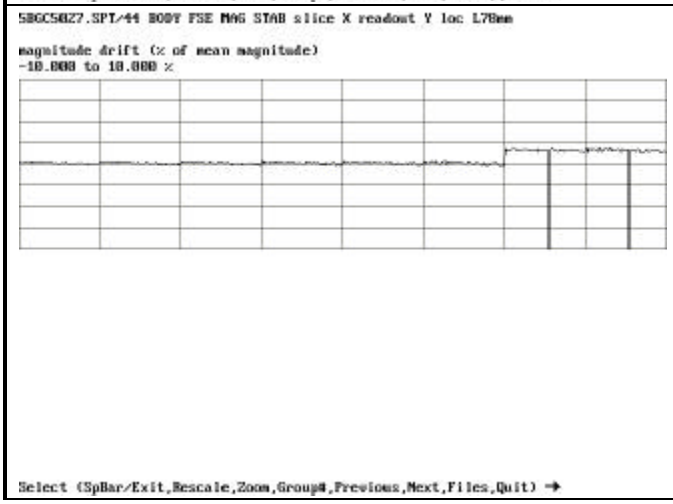
FSE & FGRE Stability Example -- Spikes caused by defective IPG.

It is *very* important to note that the spikes *do propagate* in the echo train after the initial event. This means that the event occurred during transmit time since the "physics" *was* affected. The peak-to-peak magnitude error was *100.3 %* which suggests that entire views of data were missing.

It is not possible to determine if spikes in FGRE stability plots were caused by an event during transmit time or receive time.







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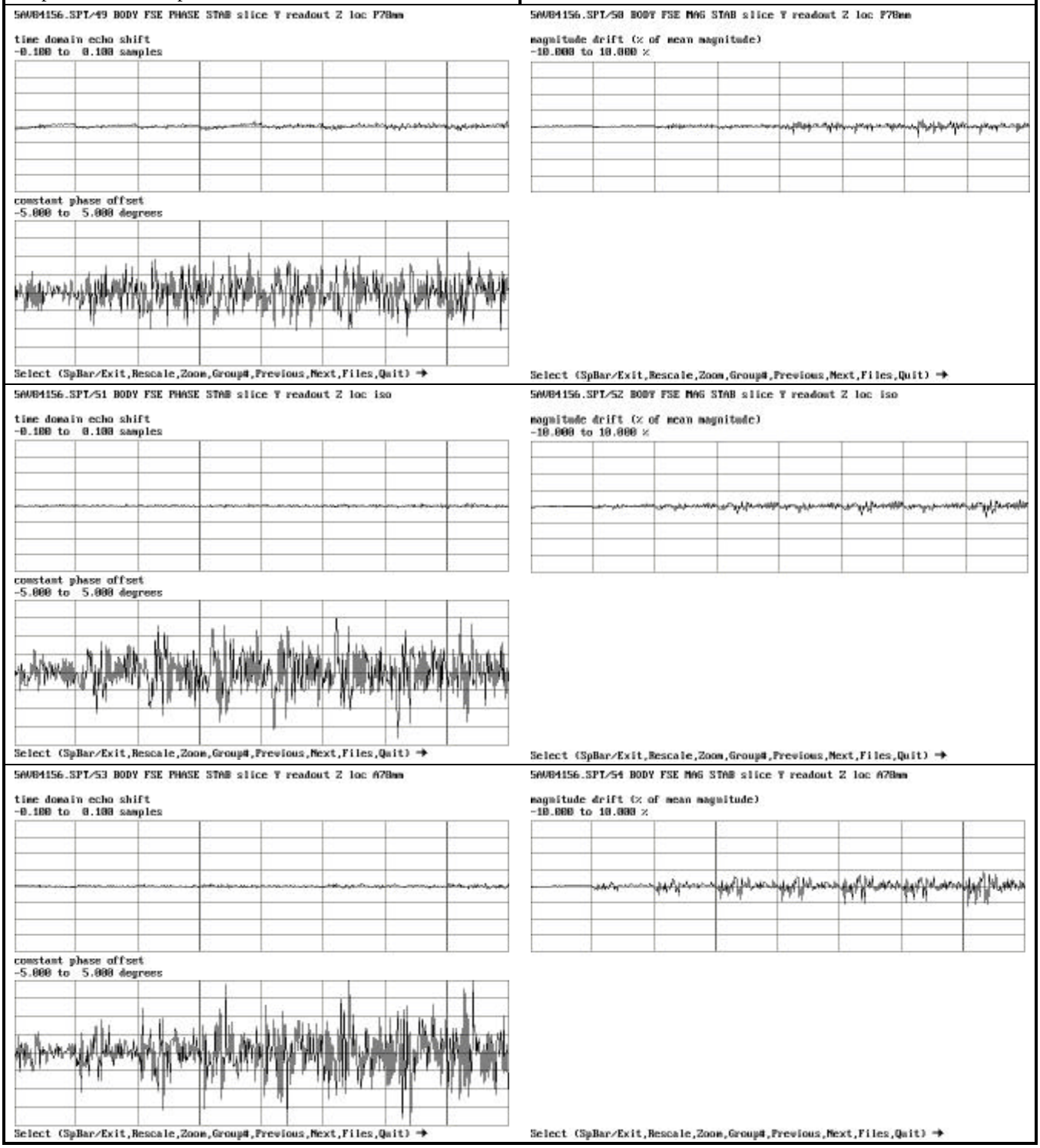
FSE Stability Example -- High vibration caused by rotating machinery on floor above magnet.

Phase plots from FSE stability test. Results are similar on all planes. Coronal plane is shown since it was worst.	Corresponding magnitude plots from FSE stability test.



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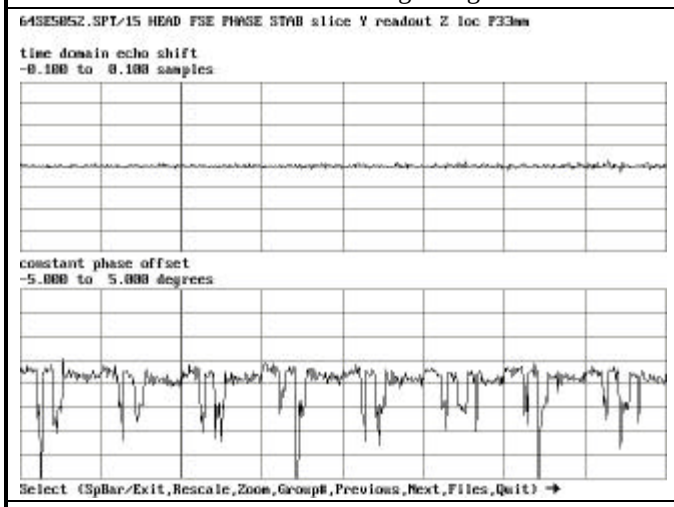
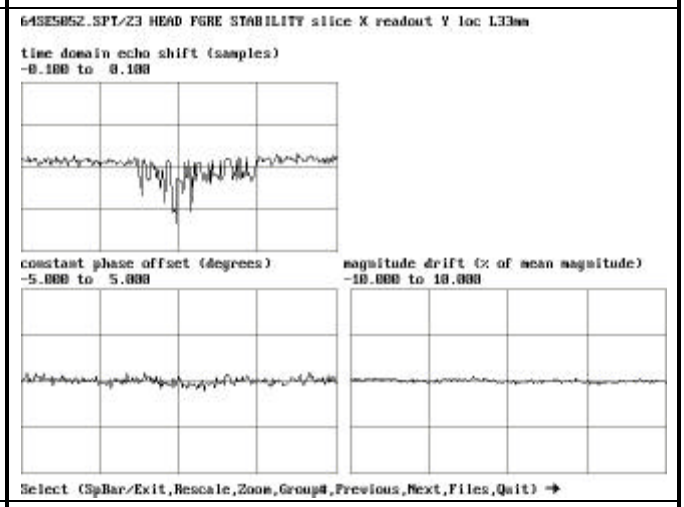
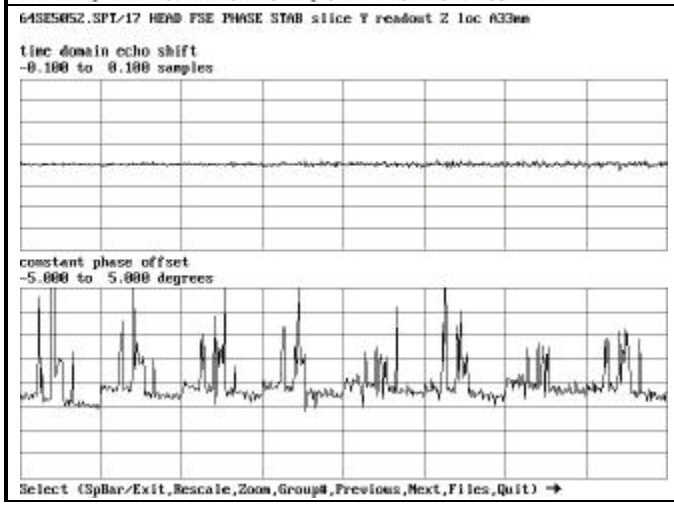
FSE & FGRE Stability Example -- Failures caused by defective Y axis GRAM.

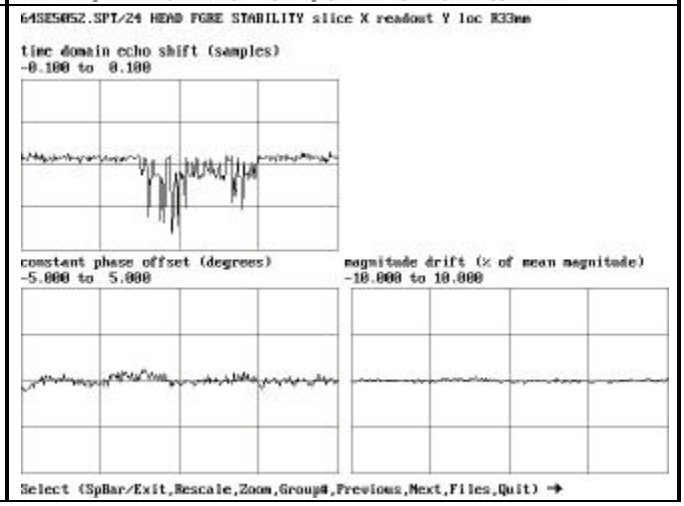
It is *very* important to note that the spikes *do propagate* in the echo train after the initial event. This means that the event occurred during transmit time since the "physics" *was* affected. Also notice that the polarity of the phase disturbance is inverted on opposite sides of isocenter. Since the events causing the instability occurred during transmit time and the phase error switches polarity on opposite sides of isocenter, the problem is virtually certain to be caused by the gradient driver hardware used for slice selection - in this case the Y axis GRAM was beginning to fail.

It is not possible to determine if spikes in FGRE stability plots were caused by an event during transmit time or receive time. However, since the primary effect is on time domain echo shift, it is highly likely that the gradient driver hardware used for readout is at fault - in this case the Y axis GRAM was beginning to fail.









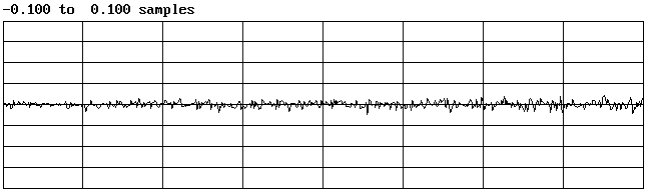
Diagnosing SPT Problems

FSE Example -- Failures caused by defective Erbtec RF amplifier.

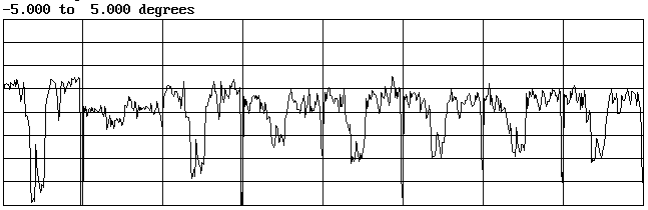
The FSE stability plots below demonstrate the effects of a defective RF amplifier. Note that time domain echo shift is hardly affected at all and that *both* constant phase and magnitude *are* affected significantly. Also note that disturbances propagate from echo to echo in the echo train, indicating a transmit-time failure. The first slice from each axis is shown but in the original file all body FSE results were similarly affected. FSE stability results were consistently excellent after the RF amplifier was replaced.

7C5F5543.SPT/43 BODY FSE PHASE STAB slice X readout Y loc L78mm

time domain echo shift
-0.100 to 0.100 samples



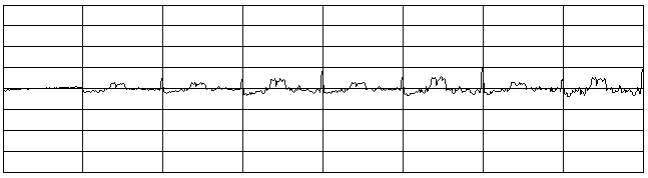
constant phase offset
-5.000 to 5.000 degrees



Select (SpBar/Exit,Rescale,Zoom,Group#,Previous,Next,Files,Quit) →

7C5F5543.SPT/44 BODY FSE MAG STAB slice X readout Y loc L78mm

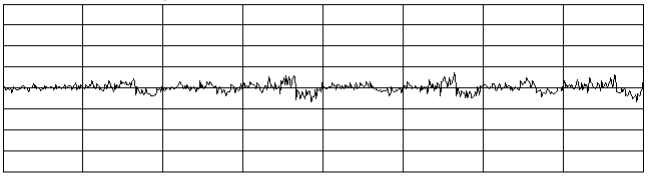
magnitude drift (% of mean magnitude)
-10.000 to 10.000 %



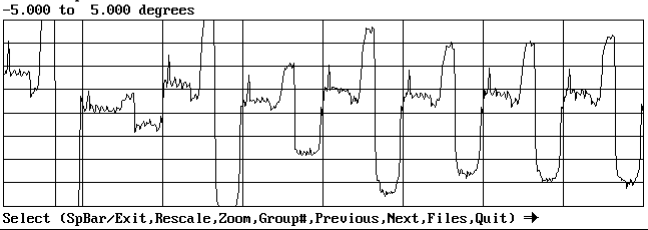
Select (SpBar/Exit,Rescale,Zoom,Group#,Previous,Next,Files,Quit) →

7C5F5543.SPT/51 BODY FSE PHASE STAB slice Y readout Z loc iso

time domain echo shift
-0.100 to 0.100 samples



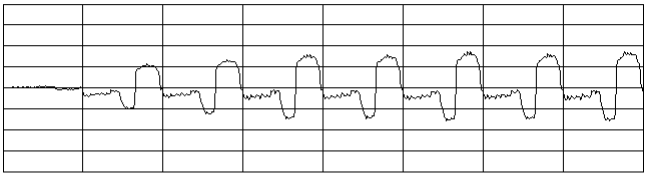
constant phase offset
-5.000 to 5.000 degrees



Select (SpBar/Exit,Rescale,Zoom,Group#,Previous,Next,Files,Quit) →

7C5F5543.SPT/52 BODY FSE MAG STAB slice Y readout Z loc iso

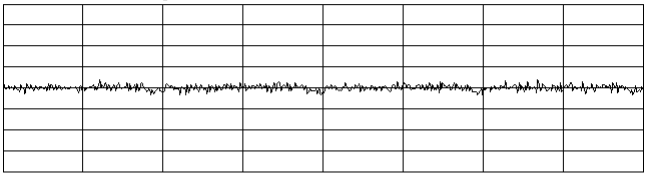
magnitude drift (% of mean magnitude)
-10.000 to 10.000 %



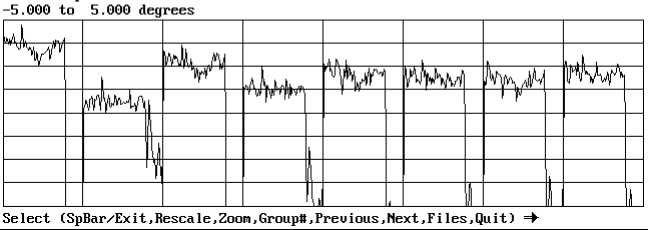
Select (SpBar/Exit,Rescale,Zoom,Group#,Previous,Next,Files,Quit) →

7C5F5543.SPT/55 BODY FSE PHASE STAB slice Z readout X loc I1378mm

time domain echo shift
-0.100 to 0.100 samples



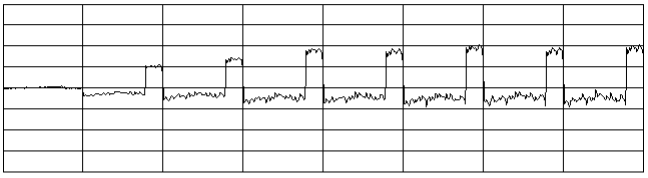
constant phase offset
-5.000 to 5.000 degrees



Select (SpBar/Exit,Rescale,Zoom,Group#,Previous,Next,Files,Quit) →

7C5F5543.SPT/56 BODY FSE MAG STAB slice Z readout X loc I1378mm

magnitude drift (% of mean magnitude)
-10.000 to 10.000 %

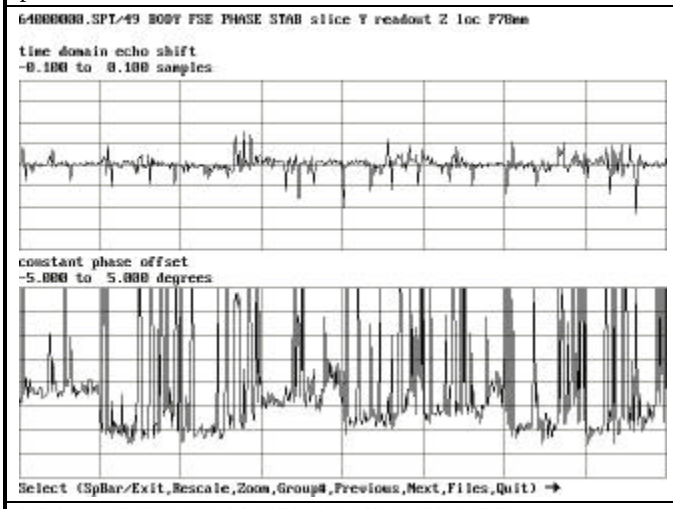


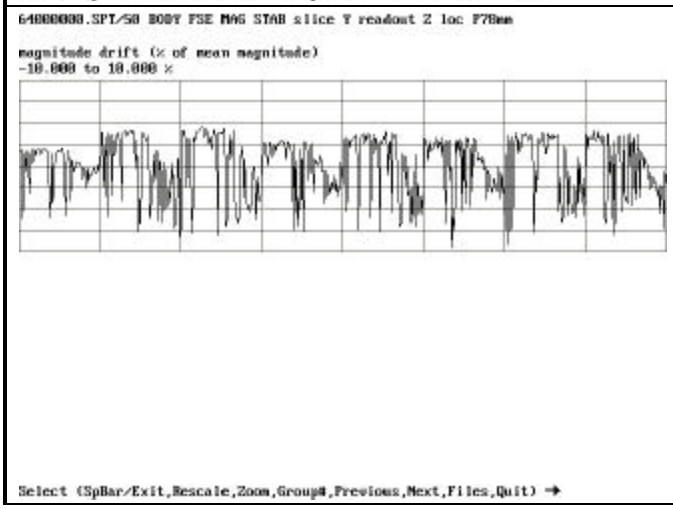
Select (SpBar/Exit,Rescale,Zoom,Group#,Previous,Next,Files,Quit) →

Diagnosing SPT Problems

FSE & FGRE Stability Example (5.4 System) -- Failures caused by loose dynamic disable box RF connectors on the body coil.

FSE stability results are very bad on all axes. Constant phase error *does not* change polarity with slice location. Spikes *do not* propagate through the echo train. These symptoms suggest a vibration induced RF receive time problem.





In the FGRE stability case, the worst instability was seen when the Z axis was used for slice select but again slice location had no impact on the results. When viewed in the context of the FSE stability results, FGRE results support the loose RF connection hypothesis.