Princeton Plasma Physics Laboratory **NSTX Experimental Proposal**		
Title: **Comparison of RFA Suppression With Different Sensors**		
OP-XP-1060	Revision: **0**	Effective Date: *(Approval date unless otherwise stipulated)* Expiration Date: *(2 yrs. unless otherwise stipulated)*

PROPOSAL APPROVALS	
Responsible Author: S.P. Gerhardt	Date
ATI – ET Group Leader: S. A. Sabbagh	Date
RLM - Run Coordinator: E. Fredrickson	Date
Responsible Division: Experimental Research Operations	

RESTRICTIONS or MINOR MODIFICATIONS (Approved by Experimental Research Operations)

NSTX EXPERIMENTAL PROPOSAL

TITLE: **Comparison of RFA Suppression With Different Sensors** No. **OP-XP-1060**

AUTHORS: **S.P. Gerhardt, S.A. Sabbagh, J.E. Menard** DATE:

1. Overview of planned experiment

The goal of this experiment is to compare and optimize RFA suppression using different types of magnetic sensors. B_R sensors with newly implemented compensations will be utilized for RFA suppressions; optimal setting, assuming that they exist, will be documented. The performance will be compared to RFA suppression with B_P sensors only, and the effect of combining the feedback will be studied. The aforementioned RFA suppression will likely be done by using the feedback system to cancel a deliberately applied n=1 error field; the response to the known OHxTF error field will also be documented. Time permitting, the frequency response of RFA suppression will be studied by using the RWM feedback system to cancel traveling waves of various frequencies.

2. Theoretical/ empirical justification

It is well known that n=1 error fields in tokamaks can cause performance degradation. At low density and β, the degradation is often results from the formation of a static magnetic island, in a process known as "error-field penetration". At higher beta, "resonant field amplification" (RFA), where the error field couples to the marginally stable resistive wall mode (RWM), can amplify the error field. This then leads to rotation braking, which can then destabilize the RWM. Hence, it is important to control these error fields.

One method to control error field relies on the detection and suppression of the plasma response to the error field via feedback, a process called "RFA suppression" or "Dynamic Error Field Correction" (DEFC). Indeed, the "standard" RWM feedback setting for NSTX derive many benefits DEFC, in addition to the fast feedback. However, both the previous RFA-suppression experiments in XP-701 and XP-823 and the "standard" feedback settings utilized mode detection with B_P sensors only. The B_R sensors may have additional benefits for DEFC, since many transients are filtered by the primary passive plates. However, uncompensated direct pickup of the intrinsic OHxTF error field in these sensors rendered them questionable for this application.

During outage between the 2009 and 2010 run campaigns, a new set of sensor compensations were implemented in the NSTX PCS. The first improvement involved compensating all B_R and B_P difference sensors for the direct OHxTF pickup, using the same model for the error fields as is applied in the offline analysis. This "OHxTF Compensation" will hopefully allow better detection of the slowly varying plasma response in the presence of the intrinsic error field. The second improvement involved compensations for the fields produced by eddy currents driven by time-varying SPA currents. This "AC Compensation" will hopefully allow cleaner detection of the non-axisymmetric distortion when the SPA currents are rapidly changing, for instance during fast RWM feedback, ELM triggering, or application of traveling waves.

For a given set of sensor measurements (and when limited to mid-plane coils), the important parameters for RWM feedback are the feedback gain and phase. Previous experiments have elucidated a "best" feedback phase of ~270° and gain ~1, for the static-only compensated B_P sensors. It is quite possible that with the new compensations, a different feedback phase may be optimal for the B_P sensors. There is limited experience with the use of the B_R sensors for feedback, though a single experiment with static-only compensated data did show improved shot performance with a feedback phase of ~290°. Determining the feedback phase and gain for the different sensor arrays is the purpose of this XP.

3. Experimental run plan

3.0: Off-line testing

The "miu" algorithm should be tested sufficiently before running the XP that all bugs are eliminated.

3.1: Sensor compensation test:

In the days leading up to the running of this XP, the following coil-only shots should be taken

Type	Example Shot #	Shot for XP
TF only	137505, 137732	
TF + Simple Bipolar OH	137648	
TF + Plasma like OH waveform	137650	

3.2: Development of reference shot (3 shots)

3.2.1 Load ~800 kA, B_T=0.45 T discharge, "2009 fiducial" shape. Use beta-control to achieve β_N~5.5. Discharge should suffer rotation collapse and RWM. Note that XP-701 used 1 MA and 0.44 T, while nice 800 kA high-β shots from J. Berkery's XP (133775) used 0.39 T.

3.2.2 If rotation collapse and RWM do not occur, then repeat discharge with either:

i) Increased power and β_N.

ii) Adding ~300 A of steady-state n=1 field (SPA-1 @ 300 A, SPA-2 @ 300 A, and SPA-3 @0 A). This adds to the intrinsic EF.

3.3: Phase and Gain Scan with B_R Sensors (10 shots)

3.3.1 Starting with a gain of 1, execute scan over B_R feedback phase and gain, as per the following table. Monitor pulse length (disruptivity) and rotation sustainment as a function of feedback phase.

Shot	Feedback Phase	Feedback Gain	
	270	1	
	90	1	
	180	1	
	360	1	

3.3.2: Repeat best case with OHxTF compensations turned off. Look for a reduction in the plasma rotation and/or increased disruptivity.

3.4: Phase and Gain Scan with B_P Sensors (8 shots)

Starting with a gain of 1, execute scan over B_P feedback phase and gain, as per the following table. Monitor pulse length (disruptivity) and rotation sustainment as a function of feedback phase.

Shot	Feedback Phase	Feedback Gain	
	270	1	
	90	1	
	180	1	
	360	1	

3.5: Compensation of the Intrinsic EF **(5 shots)**

If the cases in 3.2 and 3.3 used 3-D fields from the RWM coils, not the intrinsic EF, then repeat the best case for each sensor combinations with the intrinsic EF only. Repeat the B_R feedback case with the OHxTF compensation turned off. Also try a case with B_P+B_R combined using the best settings for each. Be sure that discharge lasts into the phase of large intrinsic EF.

3.6: Time Dependent RFA Suppression: **(4 shots)**

Pick best RFA suppression scheme from 3.3 & 3.4. Add an n=1 traveling wave of various frequencies, likely with 1 kA amplitude. System should suppress the traveling waves.

TW Amp	TW Freq	Sensor Polarity	F.B. Gain	F.B. Phase	Shot
1kA	20				

4. Required machine, NBI, RF, CHI and diagnostic capabilities

This XP will utilize the standard high-δ, high-κ discharge used for the morning fiducial in 2009. The SPAs and RWM coils must be operational. The new "miu" algorithm must have been tested in the background and shown to work correctly.

5. Planned analysis

Analysis of the RWM sensor data will necessary. MSE constrained equilibrium reconstructions will be used for computing the beta limits with codes such as DCON. TRANSP analysis may also be completed for selected long-pulse shots.

6. Planned publication of results

Pending successful completion of the XP, these results will be used in PAC presentations, shown at the IAEA FEC, APS, and MHD mode-control workshop, and likely published in a journal such as Nuclear Fusion or Plasma Physics and Controlled Fusion.

PHYSICS OPERATIONS REQUEST

TITLE: **Comparison of RFA Suppression With Different Sensors** No. **OP-XP-1060**

AUTHORS: **S.P. Gerhardt, S.A. Sabbagh, J.E. Menard** DATE:

Brief description of the most important operational plasma conditions required:

High-β, long-pulse fiducial like discharge will be utilized. Confinement should be good enough to achieve β_N~6 with 6 MW input power with I_P~800 kA.

The new "miu" algorithm should have been tested and fully qualified. Also, control of the plasma β via neutral beam modulation may be incorporated.

Previous shot(s) which can be repeated:

Previous shot(s) which can be modified: Any high-κ, high-δ fiducial like discharge.

Machine conditions *(specify ranges as appropriate, strike out inapplicable cases)*

I_{TF} (kA): **0.4-0.44 T** Flattop start/stop (s): **Longest consistent with I^2t on the coil.**

I_P (MA): **800-900 kA** Flattop start/stop (s): **Longest possible**

Configuration: **Limiter / DN / LSN / USN**

Equilibrium Control: **Outer gap / Isoflux** (rtEFIT) **/ Strike-point control** (rtEFIT)

Outer gap (m): **10-15 cm** Inner gap (m): ~5 Z position (m): ~-2 cm

Elongation: **2.3-2.4** Triangularity (U/L): **0.5/0.75** OSP radius (m): high-δ

Gas Species: **D** Injector(s):

NBI Species: **D** Voltage (kV) **A: 90** **B: 70-90** **C: 70-90** Duration (s):

ICRF Power (MW): **0** Phase between straps (°): Duration (s):

CHI: **Off** Bank capacitance (mF):

LITERs: On Total deposition rate (mg/min): **20 total from two evaporators**

LLD: No Temperature (°C): **Unheated**

EFC coils: On Configuration: **Odd**

DIAGNOSTIC CHECKLIST

TITLE: **Comparison of RFA Suppression With Different Sensors** No. **OP-XP-1060**

AUTHORS: **S.P. Gerhardt, S.A. Sabbagh, J.E. Menard** DATE:

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
Beam Emission Spectroscopy		
Bolometer – divertor		
Bolometer – midplane array	√	
CHERS – poloidal		√
CHERS – toroidal	√	
Dust detector		
Edge deposition monitors		
Edge neutral density diag.		
Edge pressure gauges		√
Edge rotation diagnostic		
Fast cameras – divertor/LLD		
Fast ion D_alpha - FIDA		
Fast lost ion probes - IFLIP		
Fast lost ion probes - SFLIP		
Filterscopes		√
FIReTIP		
Gas puff imaging – divertor		
Gas puff imaging – midplane		
Hα camera - 1D		
High-k scattering		
Infrared cameras		
Interferometer - 1 mm		
Langmuir probes – divertor		
Langmuir probes – LLD		
Langmuir probes – bias tile		
Langmuir probes – RF ant.		
Magnetics – B coils	√	
Magnetics – Diamagnetism		√
Magnetics – Flux loops	√	
Magnetics – Locked modes		
Magnetics – Rogowski coils	√	
Magnetics – Halo currents		√
Magnetics – RWM sensors	√	
Mirnov coils – high f.		
Mirnov coils – poloidal array		
Mirnov coils – toroidal array	√	
Mirnov coils – 3-axis proto.		

Note special diagnostic requirements in Sec. 4

Diagnostic	**Need**	**Want**
MSE	√	
NPA – E‖B scanning		
NPA – solid state		
Neutron detectors	√	
Plasma TV	√	
Reflectometer – 65GHz		
Reflectometer – correlation		
Reflectometer – FM/CW		
Reflectometer – fixed f		
Reflectometer – SOL		
RF edge probes		
Spectrometer – divertor		
Spectrometer – SPRED		
Spectrometer – VIPS		
Spectrometer – LOWEUS		
Spectrometer – XEUS		
SWIFT – 2D flow		
Thomson scattering	√	
Ultrasoft X-ray – pol. arrays		√
Ultrasoft X-rays – bicolor		
Ultrasoft X-rays – TG spectr.		
Visible bremsstrahlung det.		
X-ray crystal spectrom. - H		
X-ray crystal spectrom. - V		
X-ray tang. pinhole camera		