Princeton Plasma Physics Laboratory
NSTX Machine Proposal

Title: MHD Spectroscopy Checkout		
OP-XMP-104	Revision: **0**	Effective Date: Expiration Date: *(2 yrs. unless otherwise stipulated)*

Proposal Approvals

Responsible author:	John W Berkery	Date **7/28/2015**
ATI (NSTX Physics Ops):	Dennis Mueller Digitally signed by Dennis Mueller Date: 2015.07.28 22:31:27 -04'00'	Date
RLM (NSTX Expt. Research Ops):	Stefan Gerhardt Digitally signed by Stefan Gerhardt DN: cn=Stefan Gerhardt, o=Physics, ou=PPPL, email=sgerhard@pppl.gov, c=US Date: 2015.07.28 15:03:36 -04'00'	Date

Responsible Division: **Experimental Research Operations**

Procedure Requirements
designated by RLM

	NSTX Work Permit		T-MOD (OP-AD-03)
	Independent Review		ES&H Review

RESTRICTIONS AND MINOR MODIFICATIONS
Approved by RLM

REVIEWERS (designated by RLM)		
Organization/Position	Name	Signature
ATI	D. Mueller	Dennis Mueller Digitally signed by Dennis Mueller Date: 2015.07.28 22:31:57 -04'00'
Test Director		
Independent Reviewer		
NB system		
RF systems		
FCPC systems		
Diagnostics		

TRAINING (designated by RLM)

Training required: No ■ Yes ☐ Instructor ____________________

Personnel (group, job title or individual name)	Read Only	Instruction	Hands-On

RLM ______________________________

NSTX MACHINE PROPOSAL

TITLE: MHD Spectroscopy Checkout	No. **OP-XMP-104**
AUTHORS: **J.W. Berkery, S.A. Sabbagh, Z.R. Wang**	DATE:

1. Overview:

MHD spectroscopy for resonant field amplification (RFA) measurements will be checked out, utilizing the new SPAs and running near the expected optimal applied frequency.

2. Justification:

Needed for various MS TSG experiments.

3. Plan:

MHD spectroscopy was utilized in NSTX to measure resonant field amplification (RFA) of applied n=1 AC magnetic fields and thereby determine the proximity to global stability boundaries [Berkery, J., *et al.*, Phys. Plasmas **21**, 056112 (2014)]. The optimal frequency in NSTX was around 30 Hz in the co-rotating direction (see figure, from Ref. [Sontag, A., *et al.*, Nucl. Fusion **47**, 1005 (2007)]), but often 40 Hz was used since a higher frequency is preferable [Berkery, J., *et al.*, Phys. Plasmas **21**, 056112 (2014)]. This technique will be used again in NSTX-U in various MS TSG experiments, and therefore the capability must be re-established. We will use the existing NSTX midplane coils to apply n=1 AC fields, the poloidal RWM magnetic sensors to measure the resulting field, and an existing analysis code to find the RFA.

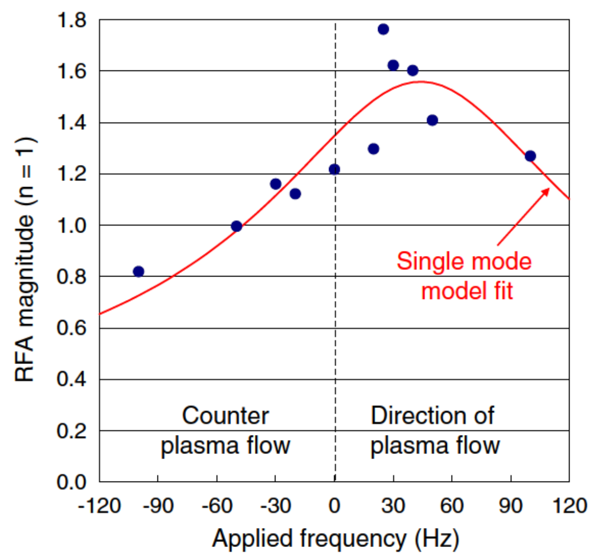


Figure 2. RFA magnitude of stable $n = 1$ RWM versus applied $n = 1$ non-axisymmetric field frequency.

Shot plan:

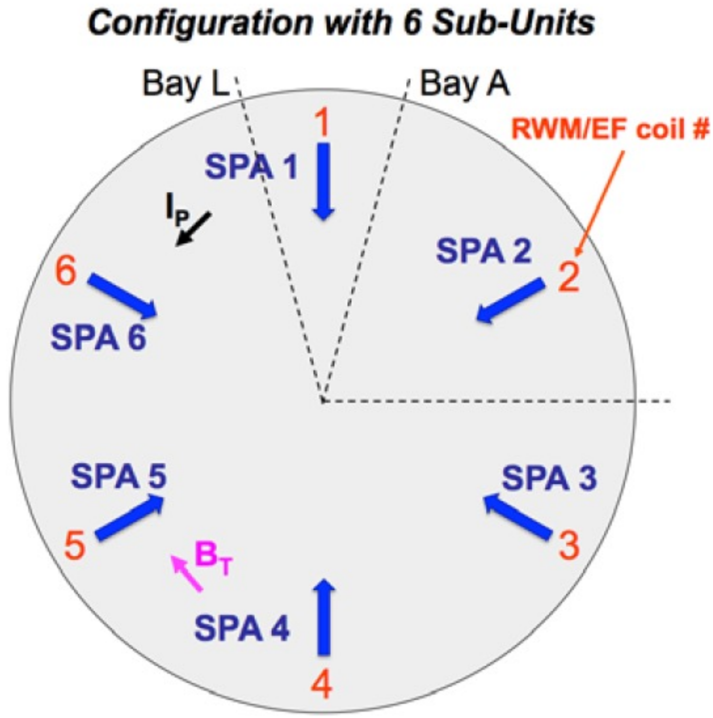
Using standard morning fiducial discharge (e.g. 1 MA plasma current, with ~1s flat top), we will change the beam mix to create two different β_N targets. A minimum of two shots in each target with three different frequencies will be applied. In all cases the amplitude of the applied n=1 AC SPA currents will be set high enough to give a clean measurement of the amplitude and phase of the resonant field amplification, but small enough to not lead to significant neoclassical toroidal viscosity-induced magnetic braking, or resonant mode locking. The default current will be set to 0.6 kA at +40 Hz (peak-to-peak 1.2 kA), and altered to satisfy these criteria, either based on experience from XMPs running before this one, or at the start of this XMP. The amplitude of the current will vary with frequency (because of attenuation) as shown in the table below, which is based on NSTX experience. After the first shot is taken, if the RFA is unclear/insufficient (or too large, for that matter) then all of the amplitudes will be scaled accordingly. The duration of each frequency, also stated in the table, will be sufficient to provide at least 10 periods for each frequency, the first one starting some short time after the flattop. For each of the frequencies, 0.25s duration will be sufficient, except for 20 Hz, which will require 0.5s.

Plasma with NBI power to produce β_N near no-wall limit ($\beta_N \sim 2.5$)
1) co-rotating: 40 Hz, 55 Hz, 70 Hz (1 shot)
2) counter-rotating: 55 Hz, 40 Hz, 20 Hz (1 shot)

Plasma with NBI power to produce β_N above no-wall limit ($\beta_N > 4.5$)
3) co-rotating: 40 Hz, 55 Hz, 70 Hz (1 shot)
4) counter-rotating: 55 Hz, 40 Hz, 20 Hz (1 shot)

Note that if the plasma disrupts before the three frequencies are obtained in a shot, we will repeat the shot with a different order to obtain the missing frequencies (also potentially adding more, for example if shot 1 gets 40 and 55 Hz, but not 70, we can repeat with the order 70 Hz, 60 Hz, 30 Hz etc…). Additionally, if the shots are not long enough to obtain the 0.5s of 20 Hz necessary, we may need to repeat with 20 Hz first. Because of these reasons, and the possibility of repeating the first shot due to insufficient amplitude, although four shots are listed above, we anticipate the XMP will take more like 6 shots to complete.

Below is a table of PCS inputs required for the six nominal frequencies to be used in the XMP. Inputs for other potential frequencies will be provided on the day of the XMP via an excel spreadsheet. To the right is a figure of the 6-SPA configuration of NSTX-U.



(all n = 1)	SPA unit	Duration (s)	frequency (Hz)	Period (s)	Offset (kA)	# of periods	Peak-to-peak amp. (kA)	Start phase (deg)	Vertex interval (s)
1) 40 Hz co-rotating	1	0.25	40	0.025	0	10	1.2	-120	0.001
	2	0.25	40	0.025	0	10	1.2	-60	0.001
	3	0.25	40	0.025	0	10	1.2	0	0.001
	4	0.25	40	0.025	0	10	1.2	60	0.001
	5	0.25	40	0.025	0	10	1.2	120	0.001
	6	0.25	40	0.025	0	10	1.2	180	0.001

2) 55 Hz co-rotating	1	0.25	55	0.018182	0	13.75	1.37	-120	0.001
	2	0.25	55	0.018182	0	13.75	1.37	-60	0.001
	3	0.25	55	0.018182	0	13.75	1.37	0	0.001
	4	0.25	55	0.018182	0	13.75	1.37	60	0.001
	5	0.25	55	0.018182	0	13.75	1.37	120	0.001
	6	0.25	55	0.018182	0	13.75	1.37	180	0.001

3) 70 Hz co-rotating	1	0.25	70	0.014286	0	17.5	1.4	-120	0.001
	2	0.25	70	0.014286	0	17.5	1.4	-60	0.001
	3	0.25	70	0.014286	0	17.5	1.4	0	0.001
	4	0.25	70	0.014286	0	17.5	1.4	60	0.001
	5	0.25	70	0.014286	0	17.5	1.4	120	0.001
	6	0.25	70	0.014286	0	17.5	1.4	180	0.001

4) 55 Hz counter-rotating	1	0.25	55	0.018182	0	13.75	1.37	0	0.001
	2	0.25	55	0.018182	0	13.75	1.37	-60	0.001
	3	0.25	55	0.018182	0	13.75	1.37	-120	0.001
	4	0.25	55	0.018182	0	13.75	1.37	-180	0.001
	5	0.25	55	0.018182	0	13.75	1.37	-240	0.001
	6	0.25	55	0.018182	0	13.75	1.37	-300	0.001

5) 40 Hz counter-rotating	1	0.25	40	0.025	0	10	1.2	0	0.001
	2	0.25	40	0.025	0	10	1.2	-60	0.001
	3	0.25	40	0.025	0	10	1.2	-120	0.001
	4	0.25	40	0.025	0	10	1.2	-180	0.001
	5	0.25	40	0.025	0	10	1.2	-240	0.001
	6	0.25	40	0.025	0	10	1.2	-300	0.001

6) 20 Hz counter-rotating	1	0.5	20	0.05	0	10	0.97	0	0.001
	2	0.5	20	0.05	0	10	0.97	-60	0.001
	3	0.5	20	0.05	0	10	0.97	-120	0.001
	4	0.5	20	0.05	0	10	0.97	-180	0.001
	5	0.5	20	0.05	0	10	0.97	-240	0.001
	6	0.5	20	0.05	0	10	0.97	-300	0.001

Table for completed shots:

Low beta	co-rotation	40 Hz	
		55 Hz	
		70 Hz	
	counter-rotating	55 Hz	
		40 Hz	
		20 Hz	
High beta	co-rotation	40 Hz	
		55 Hz	
		70 Hz	
	counter-rotating	55 Hz	
		40 Hz	
		20 Hz	

4. Required machine, beam, ICRF and diagnostic capabilities:

Magnetics, especially the RWM sensors, are of course, required. This XMP should be run after "Magnetics Calibration" by Myers and "Software test for n=1 RWM and error field control with 6 SPAs" by Gerhardt, and after a good H-mode plasma has been established.

The target plasma is a longer-pulse high-β H-mode, to be provided at run time:

Target Shot Number:__________________

5. Sign off at run time:

5.1 Permission to Proceed: ______________________________

Physics Operations Head

5.2 Documentation of results:

Documentation of the results completed, attached to proposal and sent to Ops. Center with copies to Cognizant Physicist and Head of Physics Operations.

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Cognizant Physicist/Test Director