NSTX

21-971211-CLN-01

TO: DISTRIBUTION
FROM: C NEUMEYER
SUBJECT: PLANNING FOR HHFW ANTENNA PDR

References:

[1] 71-971205-CLN-01, "Clarification Of NSTX Design Review Objectives & Procedures"
[2] NSTX-GRD-018-01, NSTX General Requirments Document
[3] 11-971117-CLN-01, "PFC Geometry"
[4] 13-970217-AWB-02, "Loads on CS Due to Plasma Disruption"
[5] "Magnetic Error Fields in NSTX", W. Choe, NSTX ECSR, July 30, 1996
[6] 30-971205-LED-001, "NSTX RF Antenna CDR"

In accordance with instructions outlined in [1] a meeting was held (R. Wilson, P. Bonanos, C. Neumeyer) to discuss deliverables at the PDR for the HHFW Antenna. In addition, areas in which the requirements definition is lacking were discussed. The purpose of this memo, following up on that meeting, is to document the agreed to deliverables and to provide clarification of the requirements.

Please note *Action* items indicated.

<u>*Requirements*</u>

1) Heat Loads on Antenna

a. During Operations

The working assumption has been that the only heat deposited from external sources on the antenna during a pulse will be that due to radiation from the plasma (no heating from the scrape off layer).

Action: M. Ono, please confirm the above assumption

Per the GRD [2] the total radiated power from the plasma during a pulse amounts to 1.8MW (30% of the 6MW heating power) in all plasma configurations. Assuming that this amount of power is evenly deposited on to the surface of hypothetical cylinder with radius $r = R_0+a = 1.533$m and length $l = 2$m corresponding to the height of the central vacuum vessel cylindrical section, as well as on disks at the two ends of the cylinder, the total area $A = A_{cyl} + 2*A_{disk} = 2\pi rl + 2\pi r^2 = 19.3 + 14.7 = 34.0\ m^2$, and the average heat flux $Q = 1.8/34.0 = 53\ kW/m^2$ during a pulse. The time averaged heat flux with a 5 second pulse once every 300 seconds is 0.880 kW/m^2.

Between pulses the center stack radiates the power which it has absorbed during pulses. For the natural divertor scenario the net power to the center stack amounts to 2.1 MW during the pulse [2]. The average with a 5 second pulse every 300 seconds is 35 kW. Assuming that (due to the directionality) the heat is all received by the same hypothetical cylinder above but not by disks at the ends, the average heat flux = 35/19.3 = 1.8 kW/m^2 .

So the radiative heat load consists of a steady component of 1.8 kW/m^2 due to the radiation from the inner wall, and a superimposed component of ≈ 50 kW/m^2 during a pulse. The total time averaged load is 0.88 + 1.82 = 2.7 kW/m^2 .

R0+a	1.533	m
Cyl Height	2.000	m
Acyl	19.264	m^2
Adisk	7.383	m^2
Prad (plasma)	1.800	MW
Qrad (plasma) on Acyl+2*Adisk	52.894	kW/m^2
Tpulse	5.000	sec
Trep	300.000	sec
Pravg (plasma)	30.000	kW
Qravg (plasma)	0.882	kW/m^2
Pcs	2.100	MW
Pcsavg	35.000	kW
Qcsavg on Acyl	1.817	kW/m^2
∑Qavg on Acyl	2.698	kW/m^2

The radiative power loads given above shall be taken as the heat load during operations.

Concerning the temperature of other components in the vicinity of the antenna during operations, the PFCs on the divertor and passive plates will be cooled using Dowtherm to 50C. The vacuum vessel temperature will be at approximately this temperature.

b. During Bakeout

During bakeout the surfaces of the PFCs on the inner wall, divertor, and passive plates will be heated to 350C [2]. The temperature of the vacuum vessel will range from 150C to 350C, depending on location. In the vicinity of the RF penetrations the temperature will be closer to the low end of the range. Thus, for bakeout it should be assumed that the antenna surfaces reach 350C and that the vessel is at 150C.

2) Antenna Geometry

The antenna plasma facing surface shall conform to the outermost flux surface at R_0+a = 1.533 m on the midplane. The upper and lower ends of the of the antenna shall line up with the plasma facing surface of the primary passive plates. This surface is defined [3] by a line (swept toroidally 360 degrees) with endpoints at (r_1,z_1) = (124.506cm,108.479cm) and (r_2,z_2) = (143.000cm,53.000cm).

Action: M. Ono, please confirm the above assumption

3) Disruption

a. Plasma current decay rate is 0.166MA/mS (6 mS disruption) [4].

b. Background poloidal magnetic field

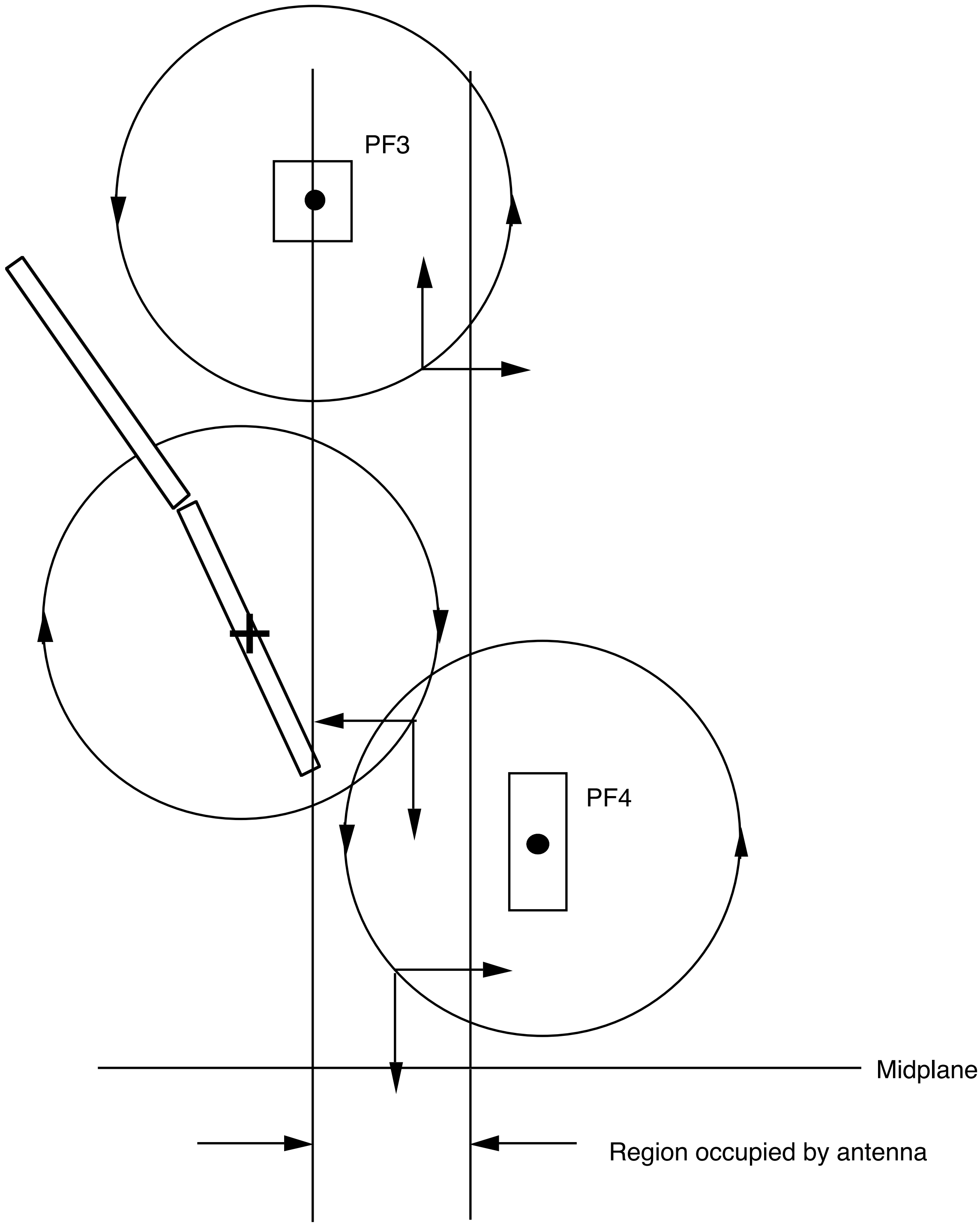
At the time that the disruption induced eddy currents reach their peak, Ip has reached zero. The background field in the vicinity of the antenna will be due mainly to the currents in the passive plates and in PF3 and PF4 (assume at peak rated current). From [4] the net peak plate current (above and below midplane summed together) is ≈ 300kA, and the currents in the passive plate (the primary and secondary plates each represented by two filaments) are as follows:

$$I_{s1} = 17.6kA$$
$$I_{s2} = 26.5kA$$
$$I_{p1} = 35.2kA$$
$$I_{p2} = 70.5kA$$

The following figure depicts the sense of the currents and fields produced by the plates and PF coils in the region of interest, following a disruption. The initial plasma current polarity is into the page. The post disruption plate currents are into the page, consisting with the conservation of flux. The PF currents are out of the page, consistent with a radial equilibrium prior to disruption.

It is noted that the maximum vertical field in the upper half plane as depicted would result from the sum of the contributions from the plate and PF4 currents, with zero PF3 current. Although there could be current in the lower PF3 coil even when the upper is zero, this would also tend to decrease the vertical field in the region of interest. Therefore the maximum vertical field will be taken to be the sum of the components from the plates and from PF4.

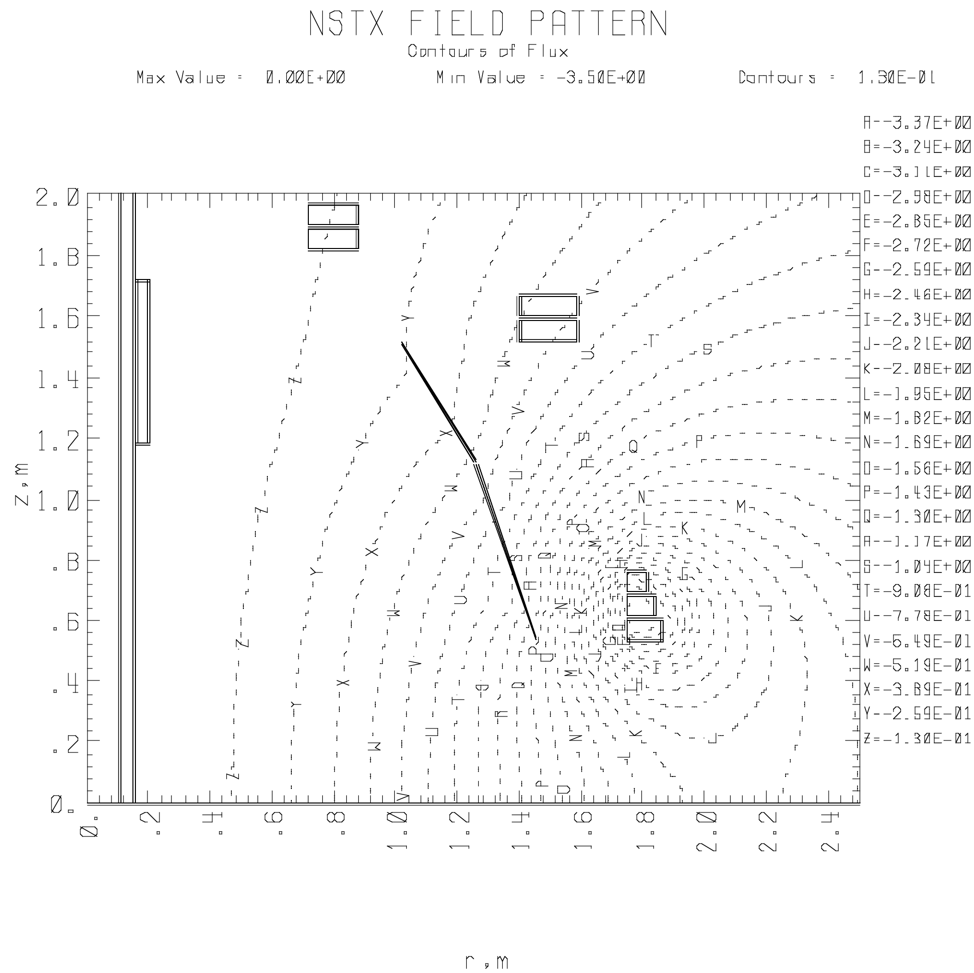
The maximum radial field in the upper half plane region of interest will result from full current in PF4 (the upper and lower coil currents must be equal since they are directly in series) and full current in PF3 upper coil but zero in the lower (the upper and lower PF3 coil currents can be different), and zero current in the plates (the fields due to the coils are stronger than those due to the plates). Therefore the maximum radial field will be taken to be the sum of the components from PF4 (upper and lower) and PF3 (upper only).

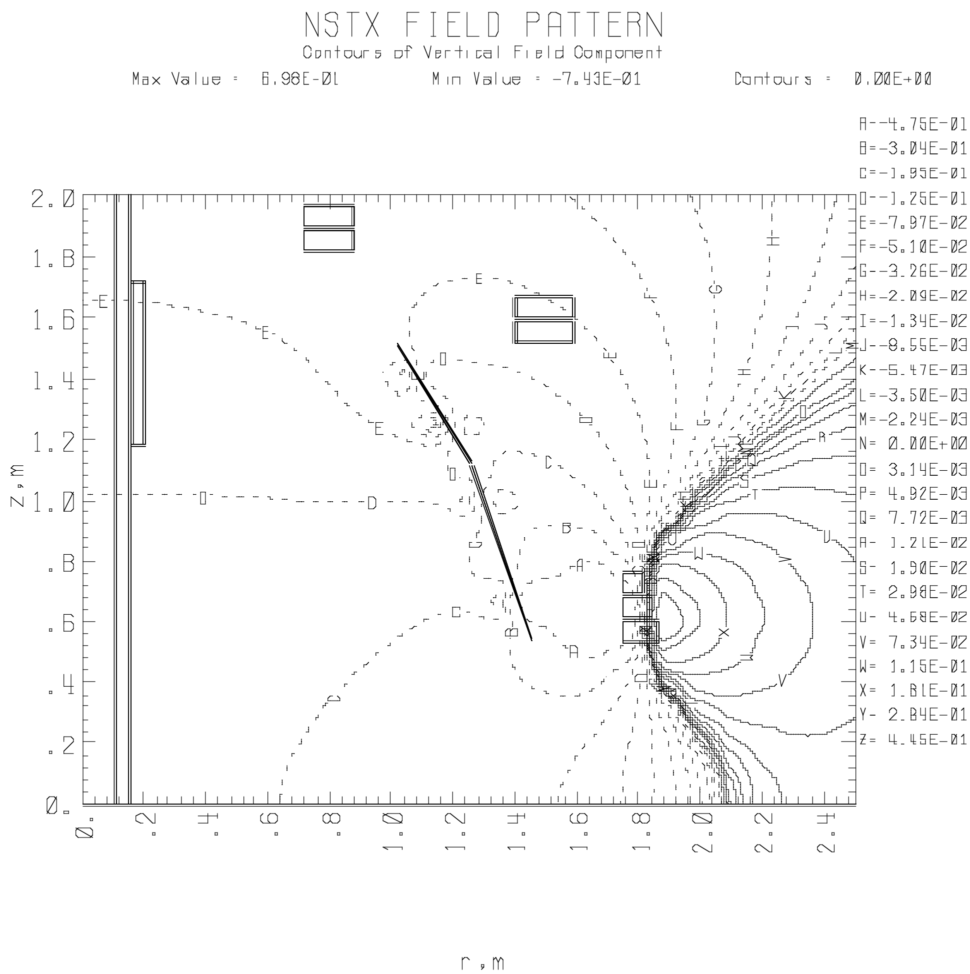


The currents, locations, and flux and field contours for the two worst cases are given in the following.

B_V Case....

Element	R(m)	Z(m)	ΔZ(m)	ΔR(m)	A-turns
Secondary Plate Filament 1 Upper	1.100	1.400	0.034	0.034	17600.0
Secondary Plate Filament 2 Upper	1.190	1.240	0.034	0.034	26500.0
Primary Plate Filament 1 Upper	1.310	0.998	0.033	0.033	35200.0
Primary Plate Filament 2 Upper	1.420	0.665	0.033	0.033	70500.0
Secondary Plate Filament 1 Lower	1.100	-1.400	0.034	0.034	17600.0
Secondary Plate Filament 2 Lower	1.190	-1.240	0.034	0.034	26500.0
Primary Plate Filament 1 Lower	1.310	-0.998	0.033	0.033	35200.0
Primary Plate Filament 2 Lower	1.420	-0.665	0.033	0.033	70500.0
PF4a Upper	1.783	0.728	0.068	0.068	-100000.0
PF4b Upper	1.795	0.647	0.068	0.092	-160000.0
PF4c Upper	1.807	0.566	0.068	0.115	-180000.0
PF4a Lower	1.783	-0.728	0.068	0.068	-100000.0
PF4b Lower	1.795	-0.647	0.068	0.092	-160000.0
PF4c Lower	1.807	-0.566	0.068	0.115	-180000.0

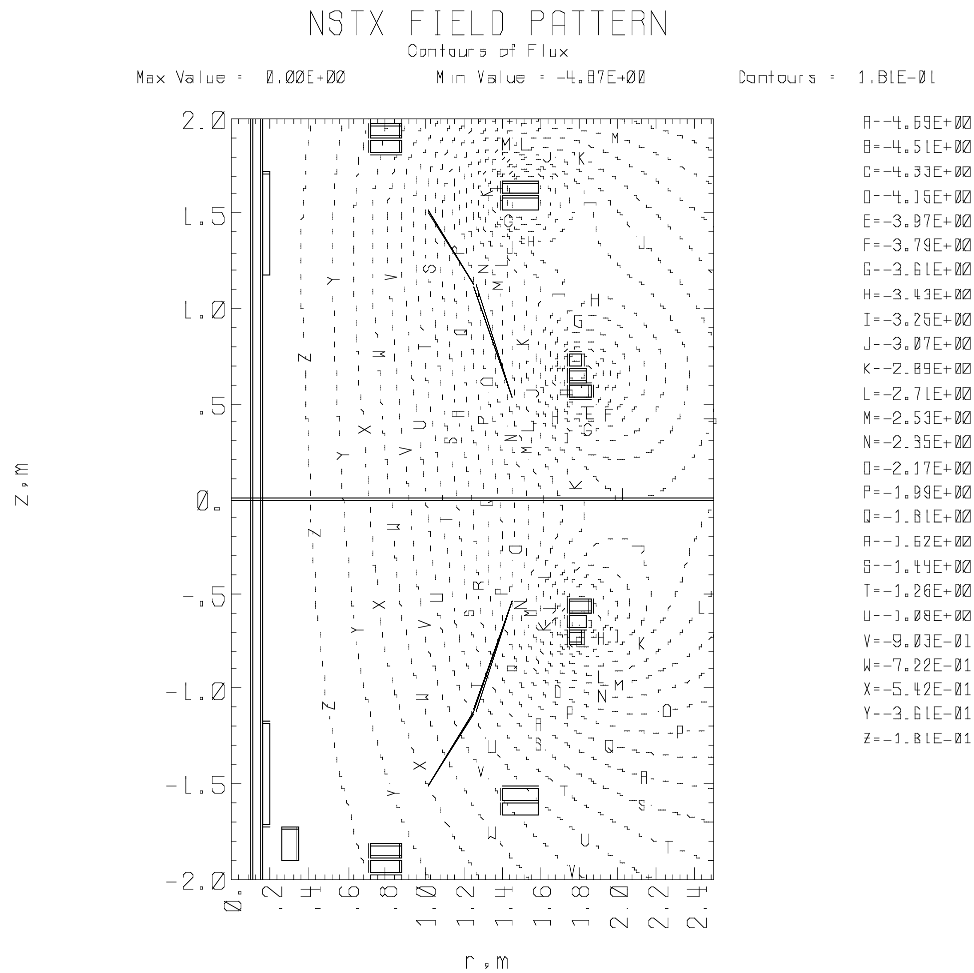

NSTX FIELD PATTERN
Contours of Flux
Max Value = 0.00E+00
Min Value = -3.50E+00
Contours = 1.30E-01
A=-3.37E+00
B=-3.24E+00
C=-3.11E+00
D=-2.98E+00
E=-2.85E+00
F=-2.72E+00
G=-2.59E+00
H=-2.46E+00
I=-2.34E+00
J=-2.21E+00
K=-2.08E+00
L=-1.95E+00
M=-1.82E+00
N=-1.69E+00
O=-1.56E+00
P=-1.43E+00
Q=-1.30E+00
R=-1.17E+00
S=-1.04E+00
T=-9.08E-01
U=-7.78E-01
V=-6.49E-01
W=-5.19E-01
X=-3.89E-01
Y=-2.59E-01
Z=-1.30E-01
z, m
r, m



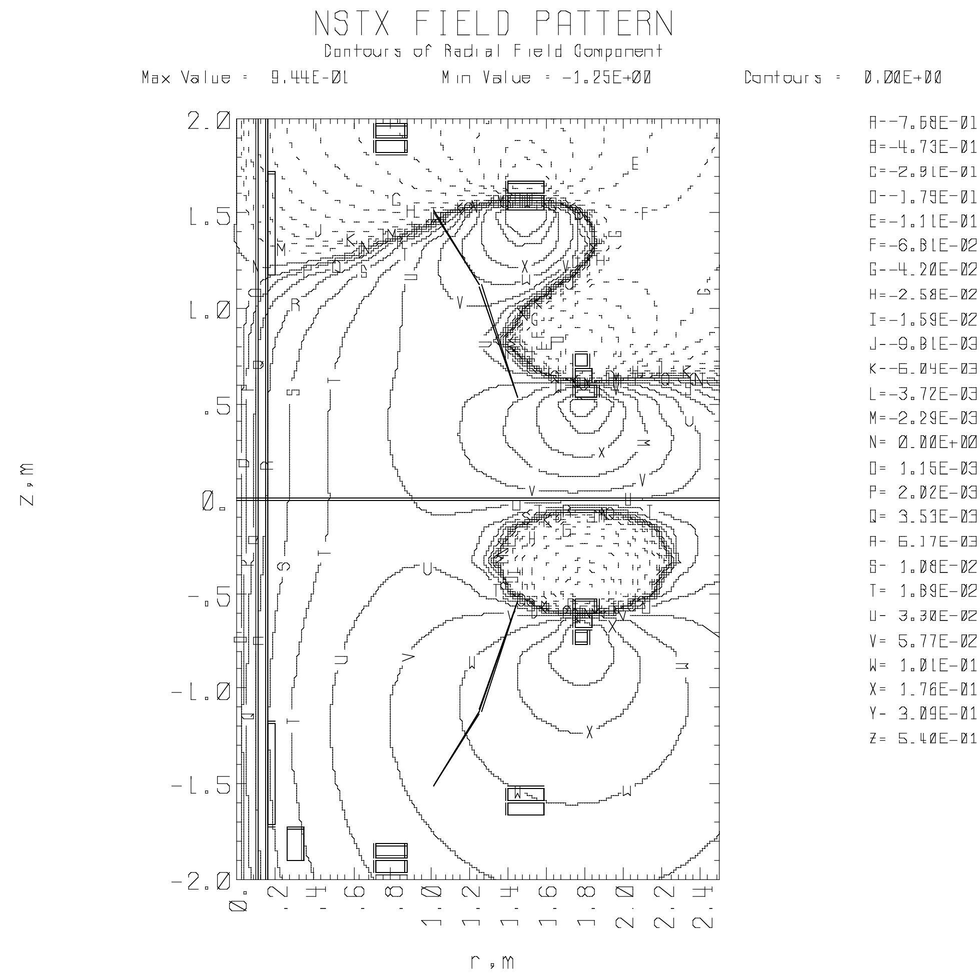
In the region of the antenna the B_v contours are A=-0.475T, B=-0.304T, C=-0.195T, and D= -0.125T.

B_r Case...

Element	R(m)	Z(m)	ΔZ(m)	ΔR(m)	A-turns
PF3a Lower	1.495	1.634	0.068	0.186	-300000.0
PF3b Lower	1.495	1.553	0.068	0.186	-300000.0
PF4a Upper	1.783	0.728	0.068	0.068	-100000.0
PF4b Upper	1.795	0.647	0.068	0.092	-160000.0
PF4c Upper	1.807	0.566	0.068	0.115	-180000.0
PF4a Lower	1.783	-0.728	0.068	0.068	-100000.0
PF4b Lower	1.795	-0.647	0.068	0.092	-160000.0
PF4c Lower	1.807	-0.566	0.068	0.115	-180000.0



NSTX FIELD PATTERN
Contours of Flux
Max Value = 0.00E+00
Min Value = -4.87E+00
Contours = 1.81E-01
z,m
r,m
A=-4.69E+00
B=-4.51E+00
C=-4.33E+00
D=-4.15E+00
E=-3.97E+00
F=-3.79E+00
G=-3.61E+00
H=-3.43E+00
I=-3.25E+00
J=-3.07E+00
K=-2.89E+00
L=-2.71E+00
M=-2.53E+00
N=-2.35E+00
O=-2.17E+00
P=-1.99E+00
Q=-1.81E+00
R=-1.62E+00
S=-1.44E+00
T=-1.26E+00
U=-1.08E+00
V=-9.03E-01
W=-7.22E-01
X=-5.42E-01
Y=-3.61E-01
Z=-1.81E-01



In the region of the antenna the B_r contours are V=0.058T, W=0.101T, and X=0.176T.

c. Background toroidal magnetic field

The maximum rated toroidal field at R_0 = 85.4m is 6kG. The maximum field in the region of interest can be computed from this case.

4) Toroidal field ripple

Per the GRD [2]...

"The peak-to-average toroidal field ripple shall be ≤ 0.5% over the entire plasma cross section"

Calculations were performed by Physics (W. Choe) early in the NSTX project [5] which confirmed that this requirement was satisfied.

The ripple will be a bit higher beyond R_0 + a, but perhaps ignorably so, depending on the assessment of impact on the antenna design at the 0.5% level.

PDR Deliverables

Per [1] in accordance with the objectives of a PDR the following deliverables shall be provided in a documentation package available to the reviewers at least 3 working days prior to the review.

1) Resolution of CDR [6] chits.

2) Revised SRD (sections of WBS 21 SRD as applicable to the antenna). Ideally the SRD should be revised and the new revision signed off prior to the PDR. However a draft revision is acceptable.

3) Revised draft of SDD (sections of WBS 21 SDD as applicable to the antenna).

4) Assembly level drawings and layout (fabrication drawings not required)

5) Material selections

6) Preliminary results of calculations

a. Thermal performance

- operations
- bakeout

b. Disruption/forces/stresses

c. Seismic assessment

7) Updated cost and schedule estimate

Note: Implementation options shall not remain undecided; specific implementation plans shall be presented.

cc:

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P Heitzenroeder
M Ono
J Schmidt

NSTX File