

A Study of the Separatrix Topology in the Vacuum Configuration

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Purpose

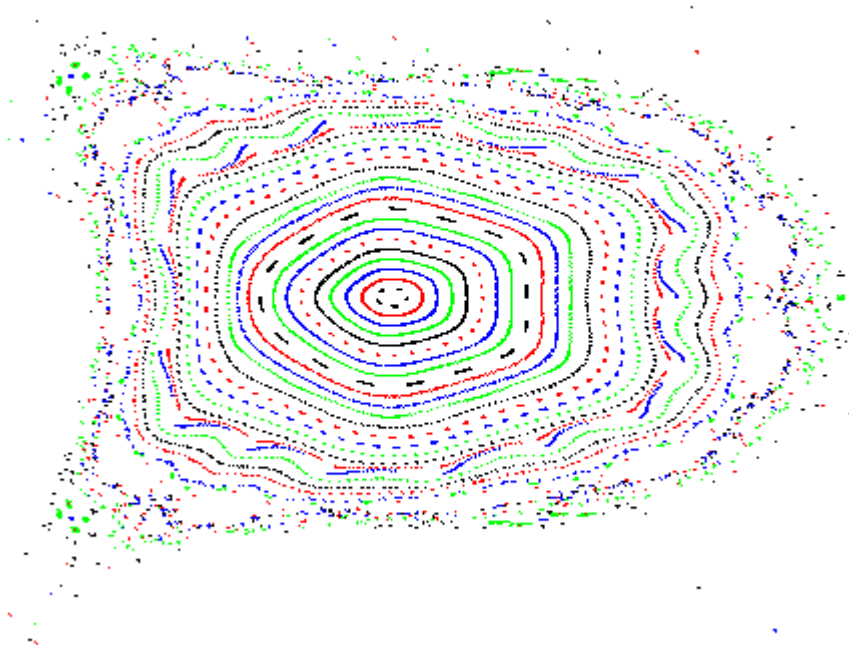
- Investigate the topology of the separatrix in vacuum (S1)
 - Grossman investigated topology at full current and full beta (S3)
 - Apply methodology used on Uragan-3M to study separatrix
 - Study one “surface” at a time
 - Move inboard and outboard in small (mm-size) increments
 - Determine if it would be interesting to apply to S3 studies
- Investigators
 - Vacuum study originally performed by Georgiyevskiy and Rudakov
 - Results confirmed by Brooks
 - Data presented from Brooks’ calculations

Results are qualitatively similar to Uragan-3M

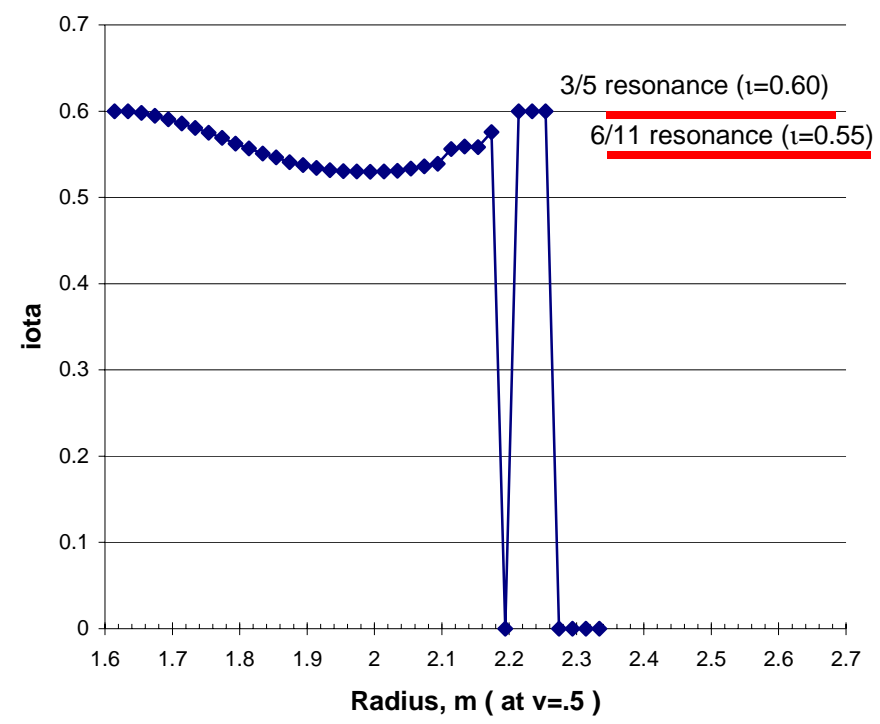
- A well-defined separatrix (the boundary between field lines circulating toroidally and those that do not) appears to exist and is defined by the $\iota=0.6$ ($3/5$) resonant surface
- Field lines outside the last closed (smooth) magnetic surface are long ($>1\text{km}$) even though stochastic until the $\iota=0.6$ surface is approached
- Smooth islands exist outside the stochastic region in the vicinity of the $\iota=0.6$ surface
 - Two (!) out-of-phase $3/5$ island chains are seen with smooth islands
 - Lengths are long if the field lines close to form smooth islands
 - Lengths are shorter if the field lines are in the stochastic region between smooth islands
- Outside the $\iota=0.6$ surface, field lines quickly stop circulating toroidally (wrapping around the coils?)

Methodology

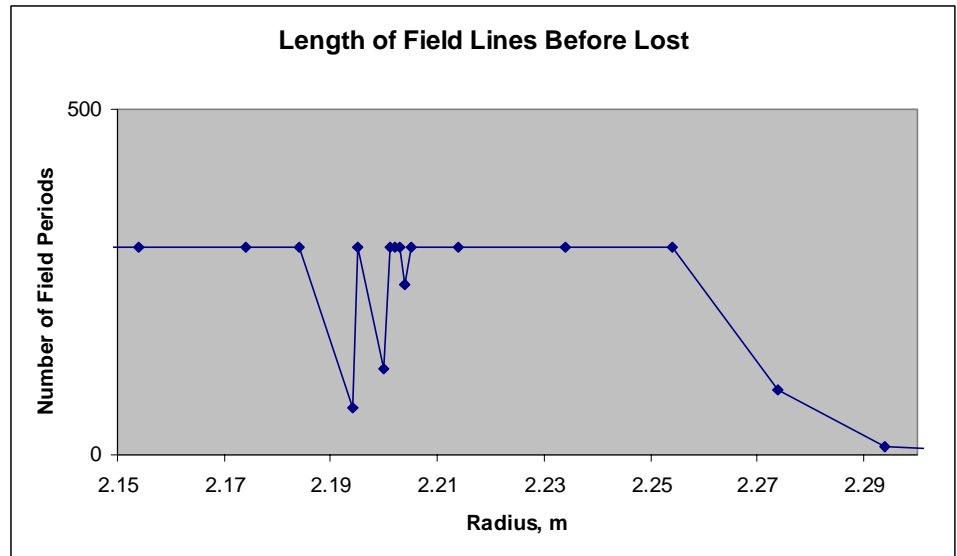
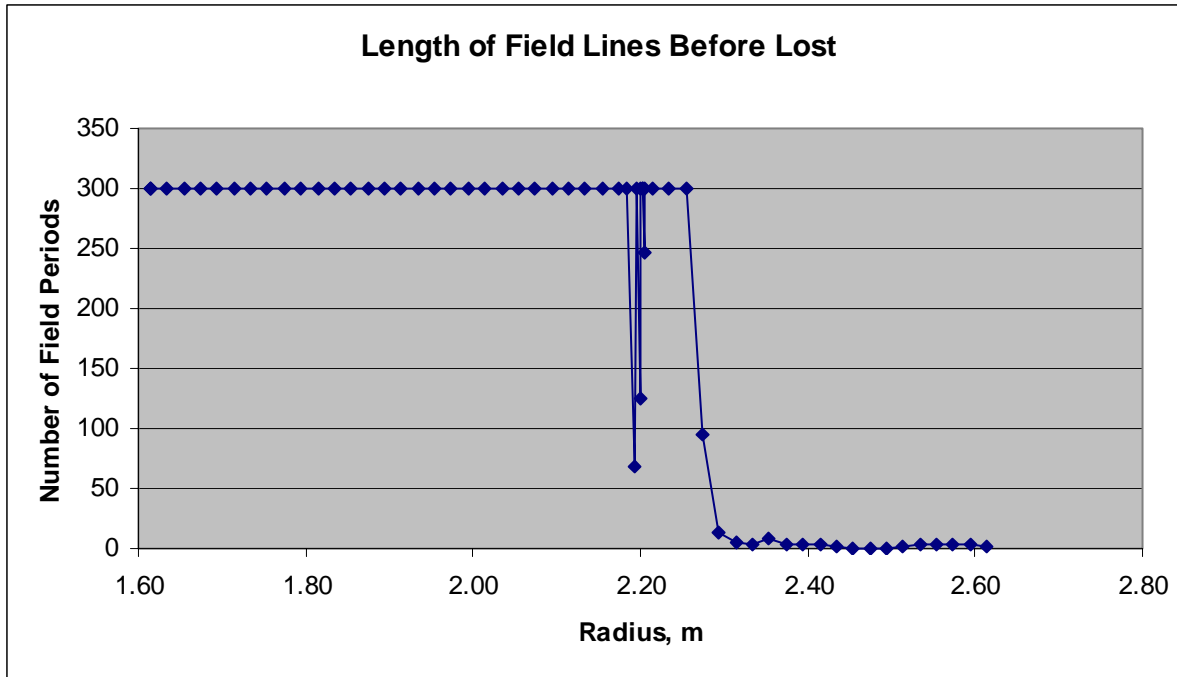
- Use field line tracing codes to map out field line trajectories
 - Field lines are “lost” when they cease to circulate toroidally
- Start on the outboard side near the LCMS at $v=0.5$
 - Map out single “surfaces” in small (mm-ish) increments
 - Calculate number of field periods up to 300 or until “lost”
- Repeat starting on the inboard side



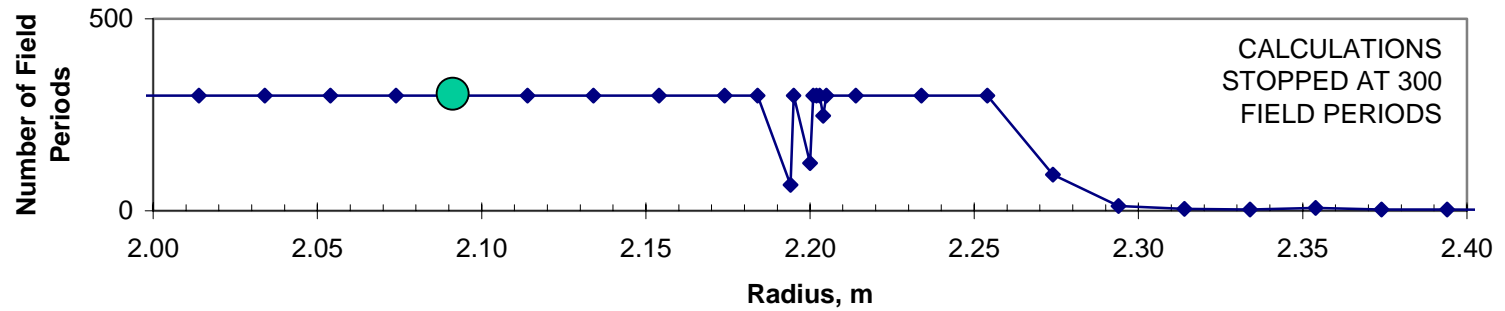
Iota Profile



Outboard Sequence

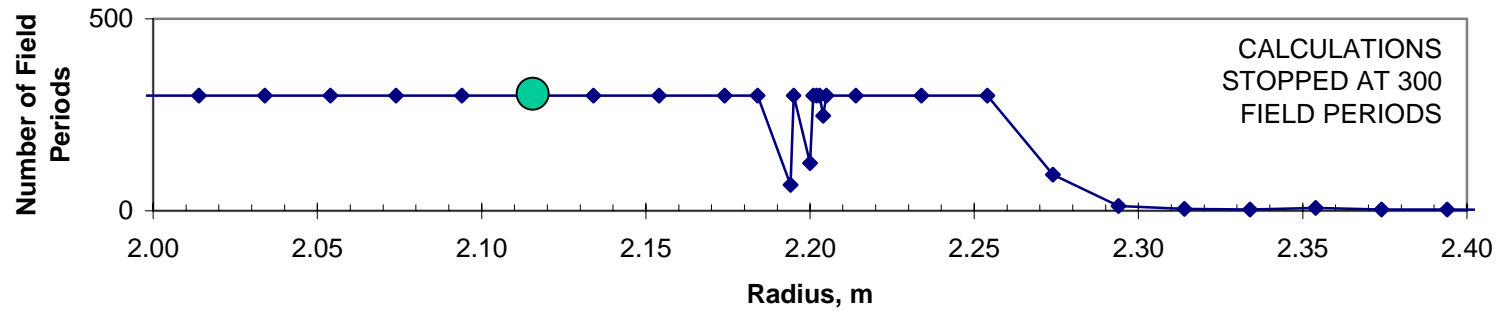


Length of Field Lines Before Lost



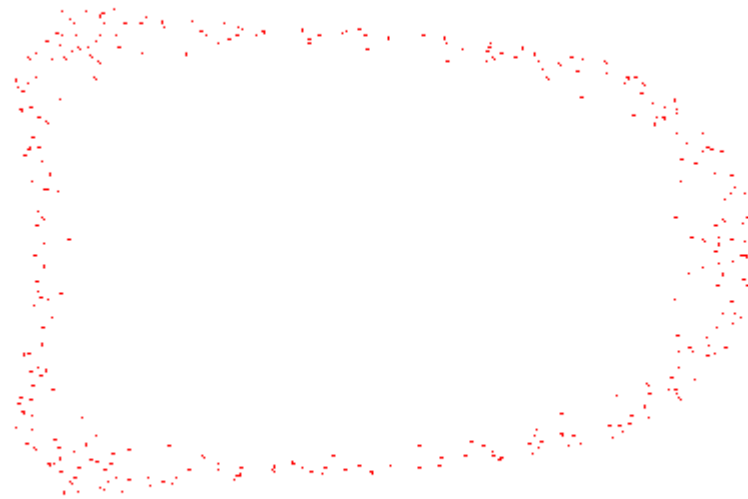
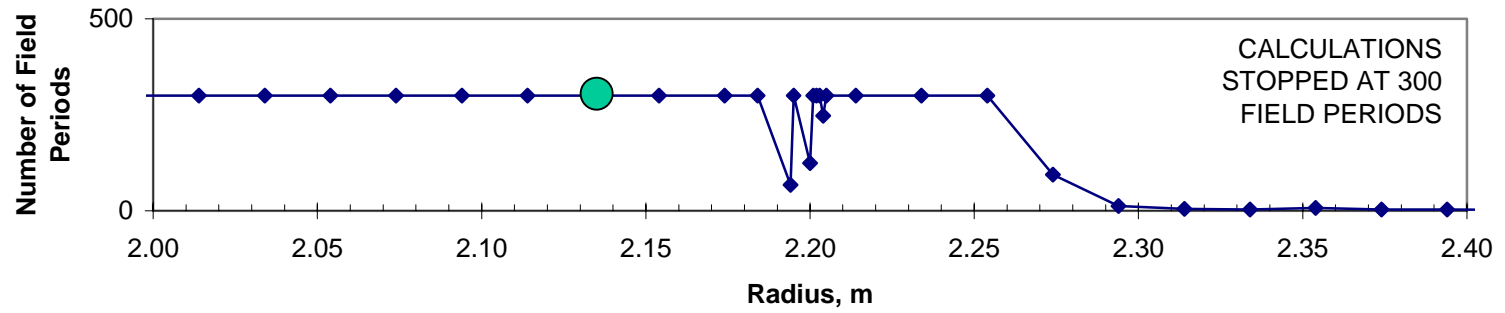
Field line traces smooth (thin) surface
Long length (>300 F.P.)

Length of Field Lines Before Lost



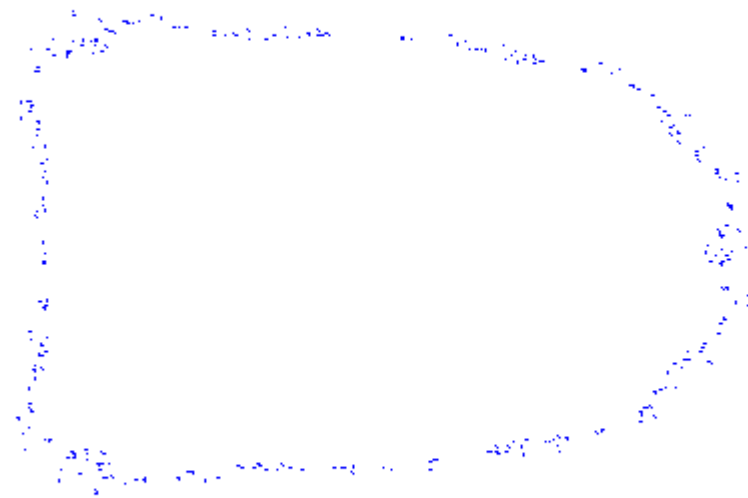
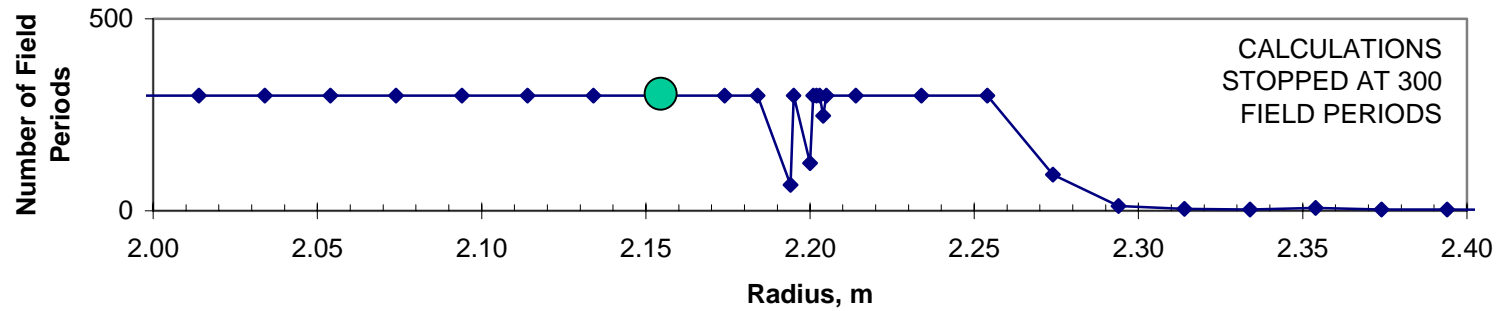
Traced surface becoming thicker
Length still long (>300 F.P.)

Length of Field Lines Before Lost



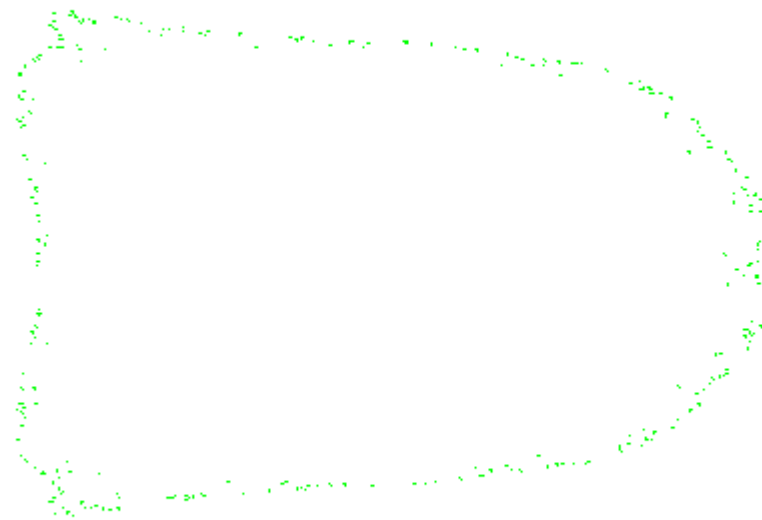
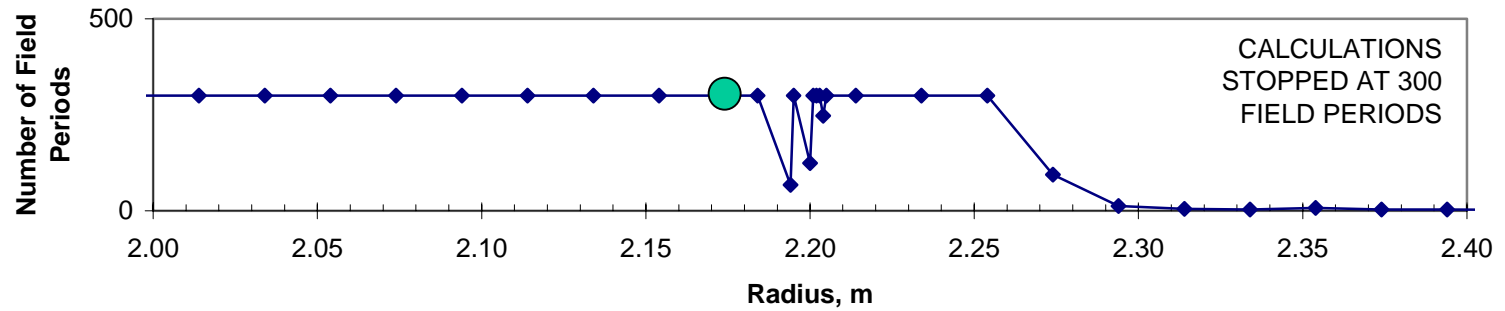
Traced surface is thick
Length still long (>300 F.P.)

Length of Field Lines Before Lost



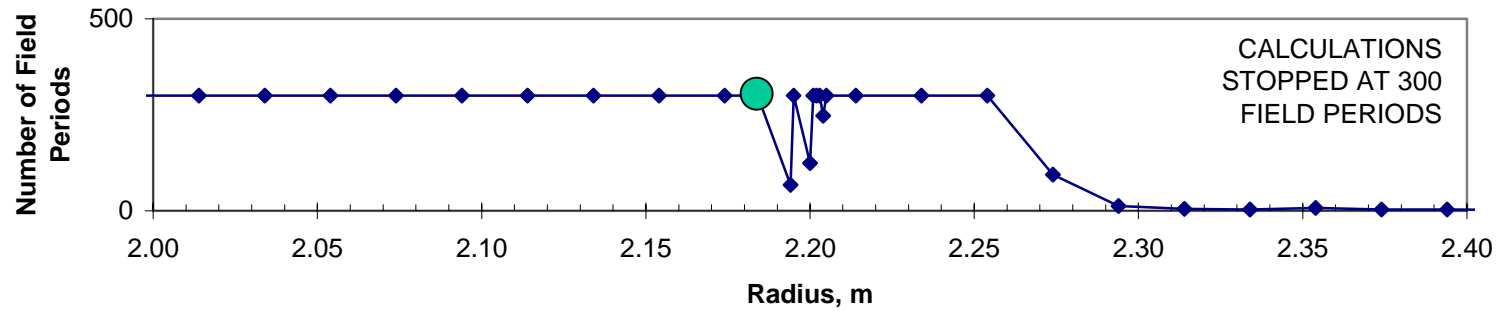
Traced surface is thick
Length still long (>300 F.P.)

Length of Field Lines Before Lost



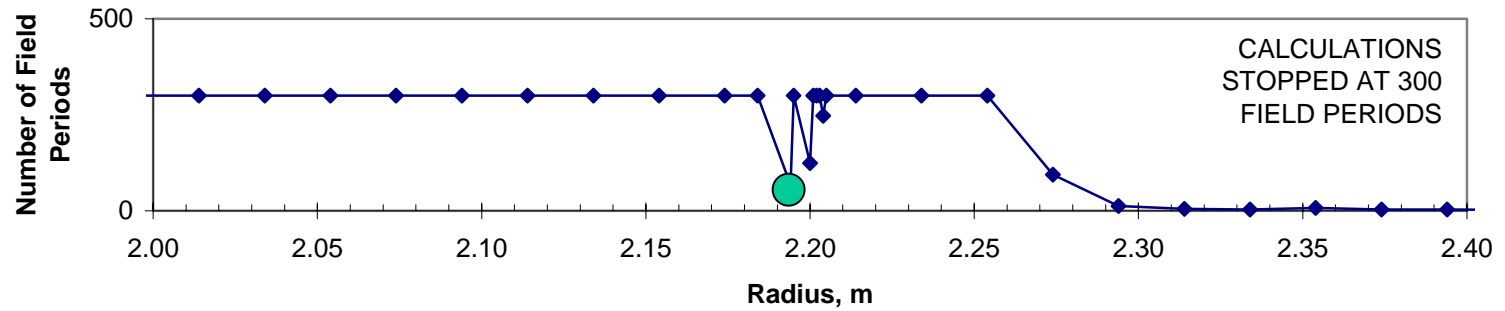
Traced surface is thick
Length still long (>300 F.P.)

Length of Field Lines Before Lost



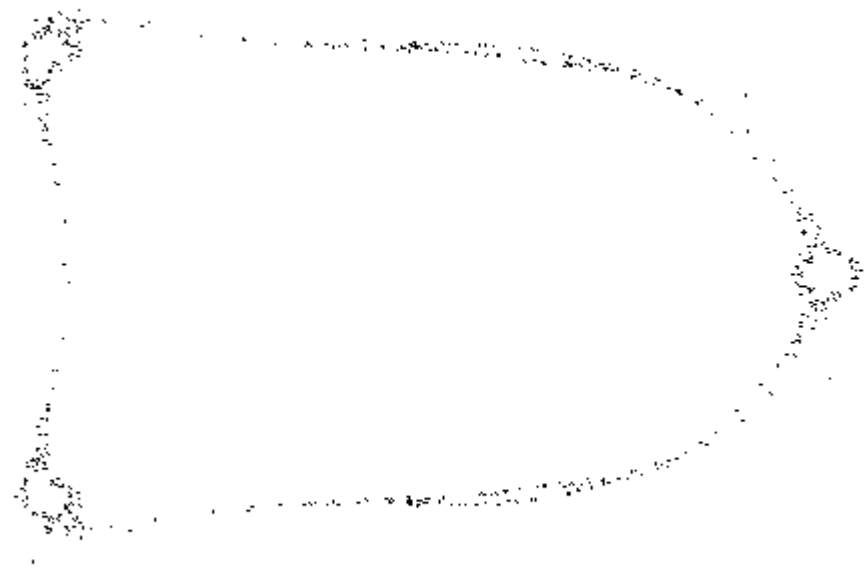
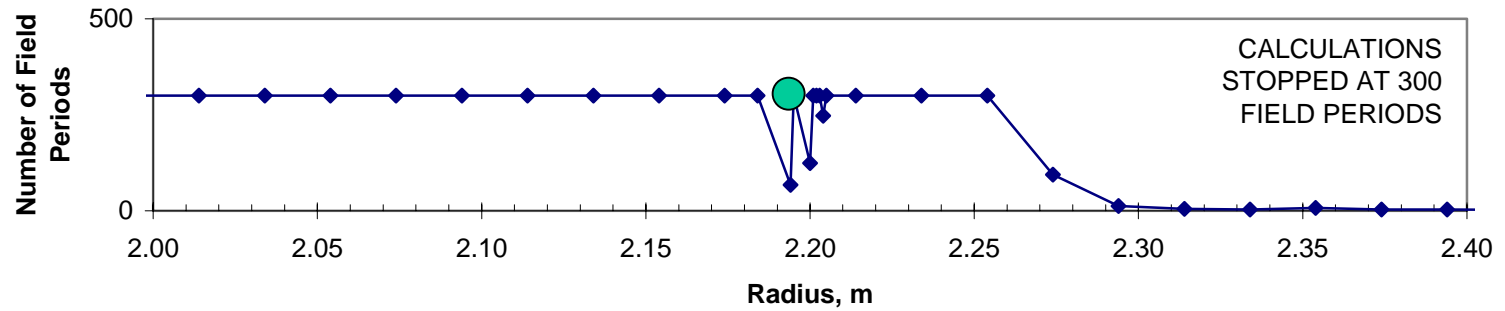
Traced surface is thick but with smooth outer boundary
Length still long (>300 F.P.)

Length of Field Lines Before Lost



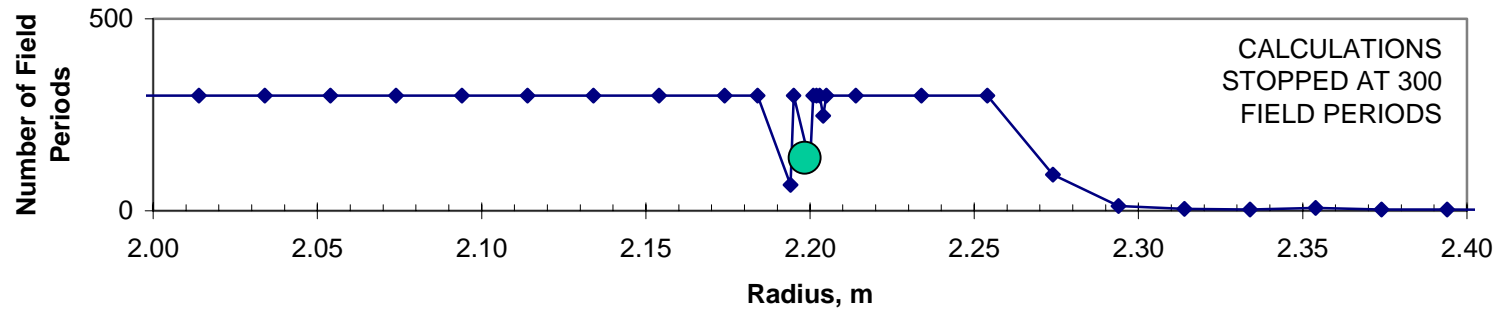
Features of 3/5 resonance start to be seen
Length drops to under 100 F.P.

Length of Field Lines Before Lost



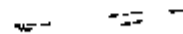
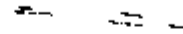
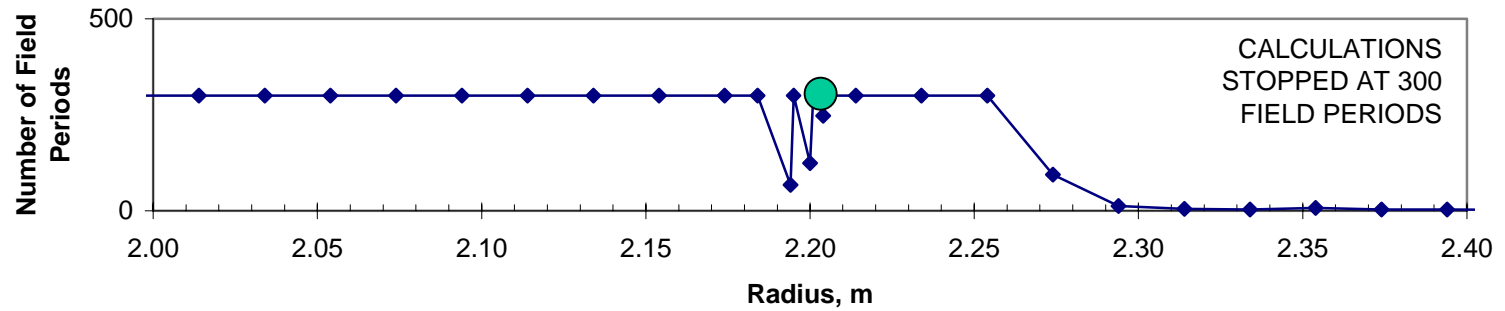
Features of 3/5 resonance clear
Length increases to >300 F.P.

Length of Field Lines Before Lost



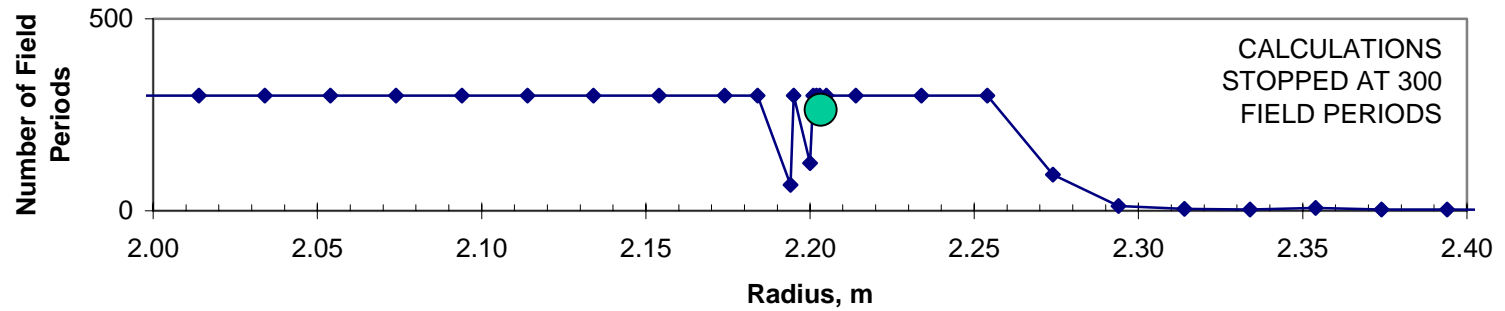
Features of 3/5 resonance fuzzer
Length drops to <200 F.P.

Length of Field Lines Before Lost



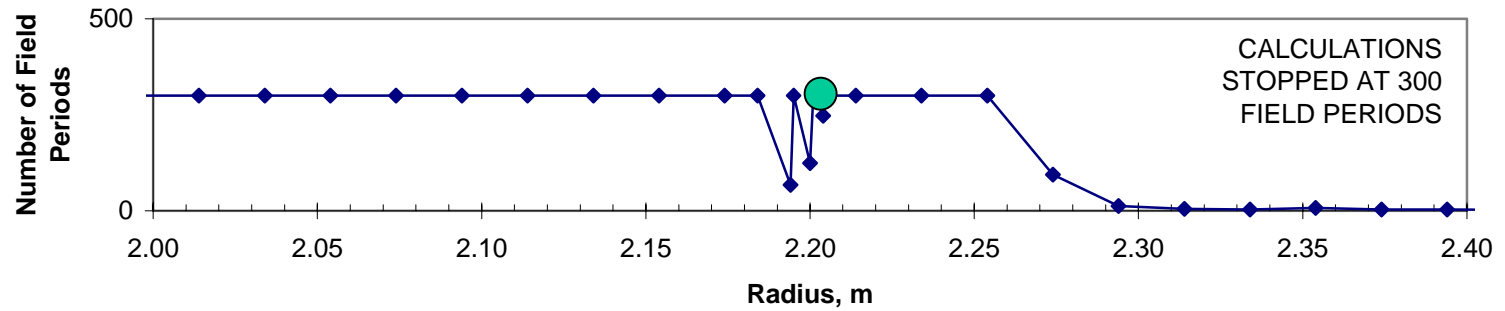
Field lines form $m=5$ islands within $m=5$ islands
Length increases to >300 F.P.

Length of Field Lines Before Lost



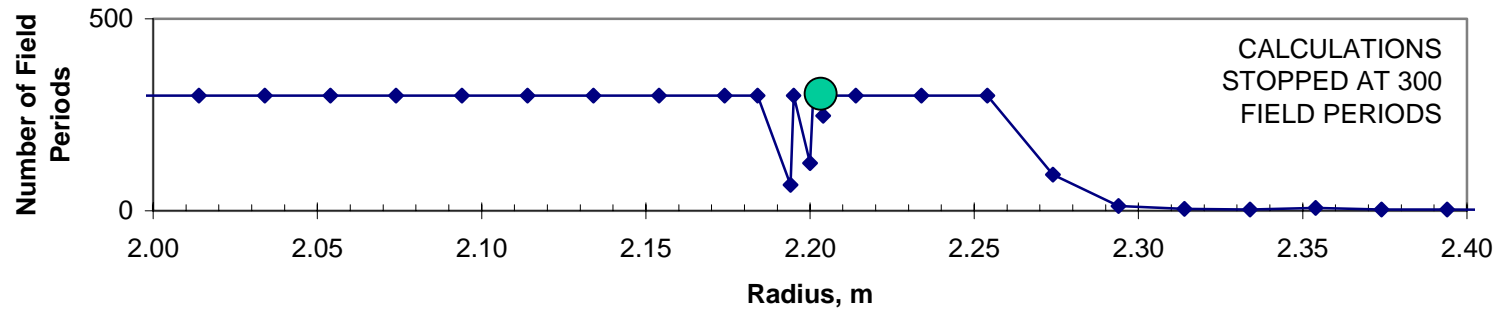
3/5 island structure apparent
Length stays near or above 300 F.P.

Length of Field Lines Before Lost



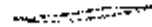
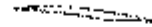
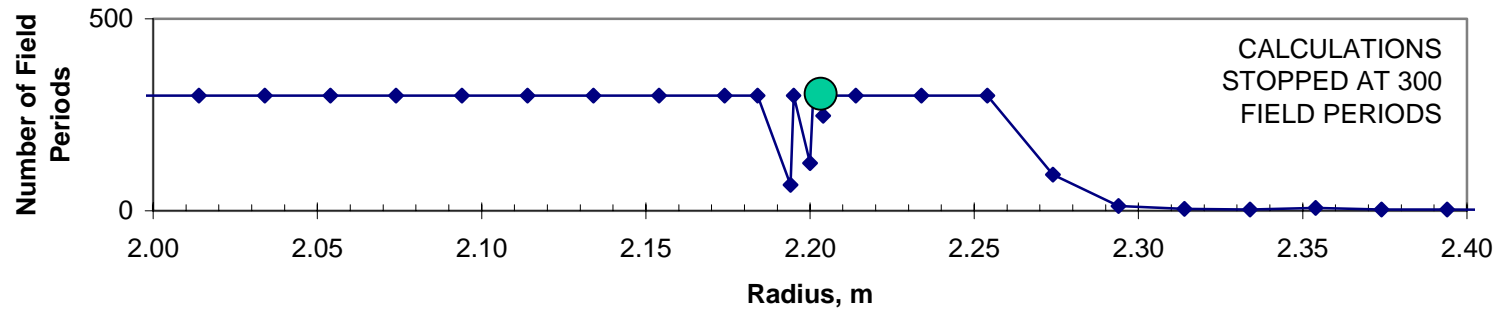
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Length of Field Lines Before Lost



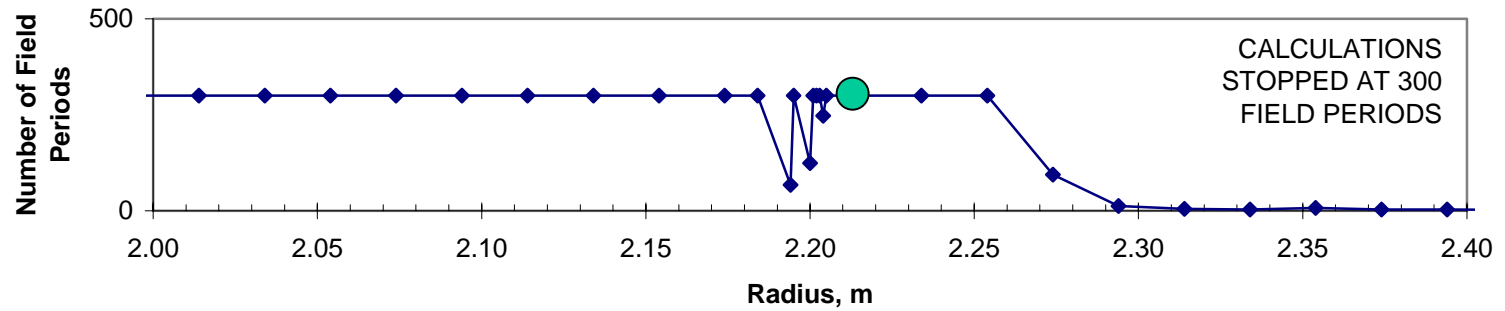
3/5 island structure apparent
Length stays near or above 300 F.P.

Length of Field Lines Before Lost



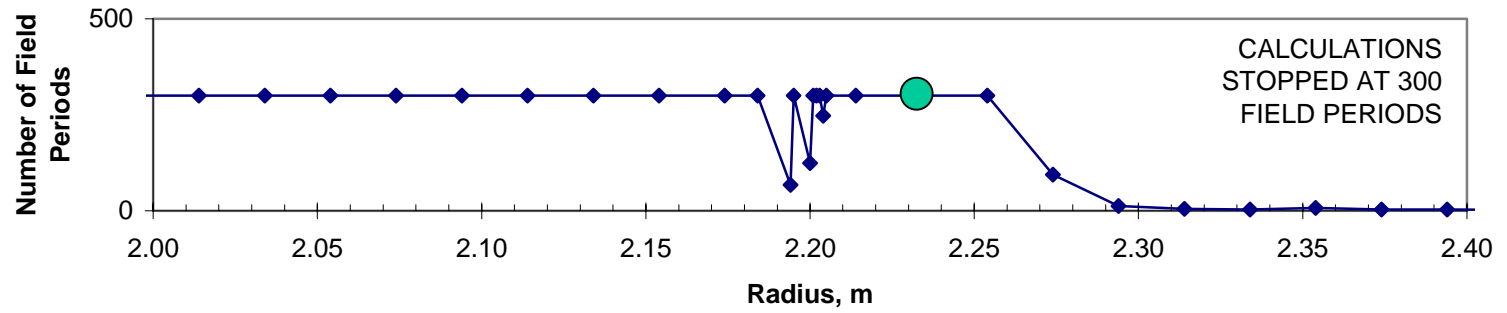
3/5 islands very smooth
Length above 300 F.P.

Length of Field Lines Before Lost



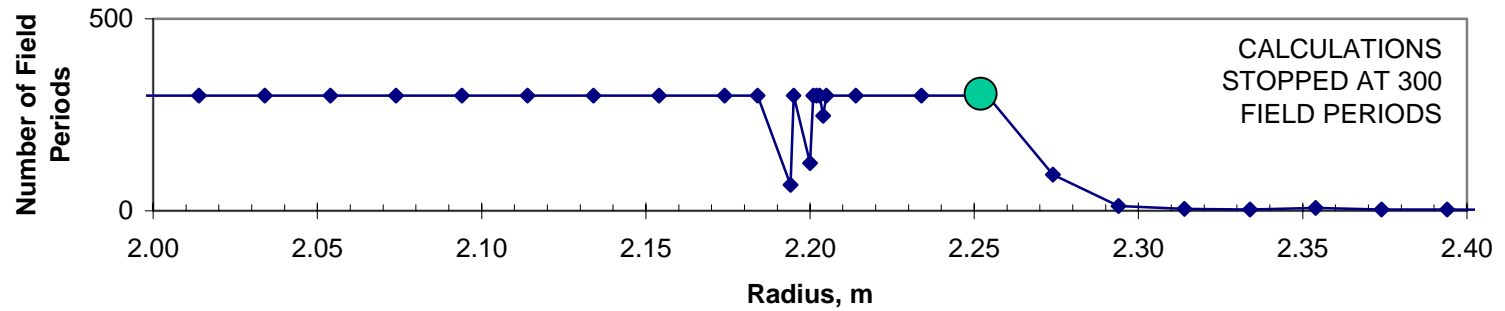
$m=4$ islands seen within $m=5$ islands
Length stays above 300 F.P.

Length of Field Lines Before Lost



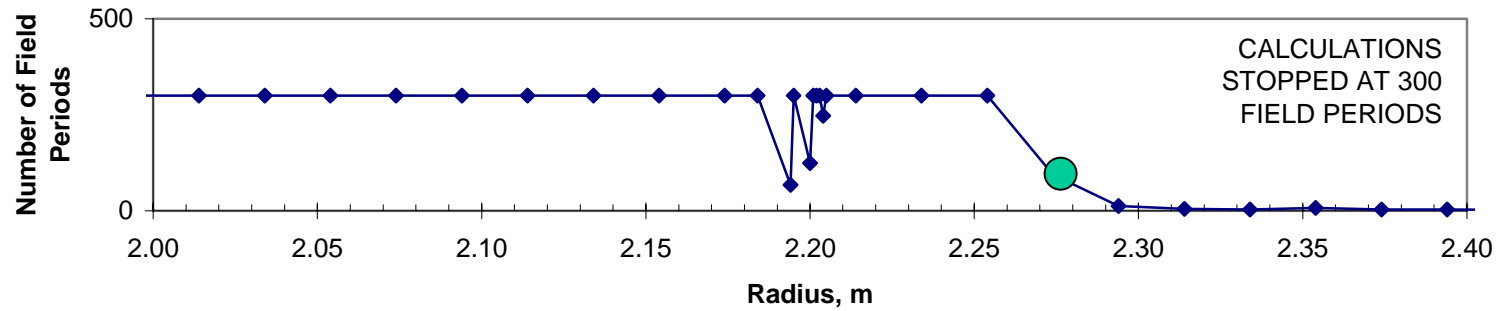
O-point of $3/5$ island chain
Length stays above 300 F.P.

Length of Field Lines Before Lost



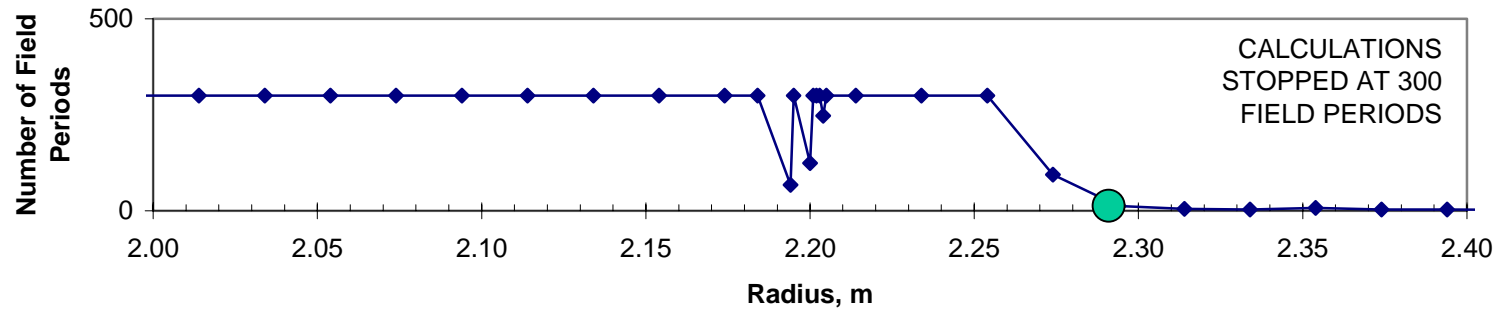
Back to the $m=4$ islands within the $m=5$ islands
Length stays above 300 F.P.

Length of Field Lines Before Lost



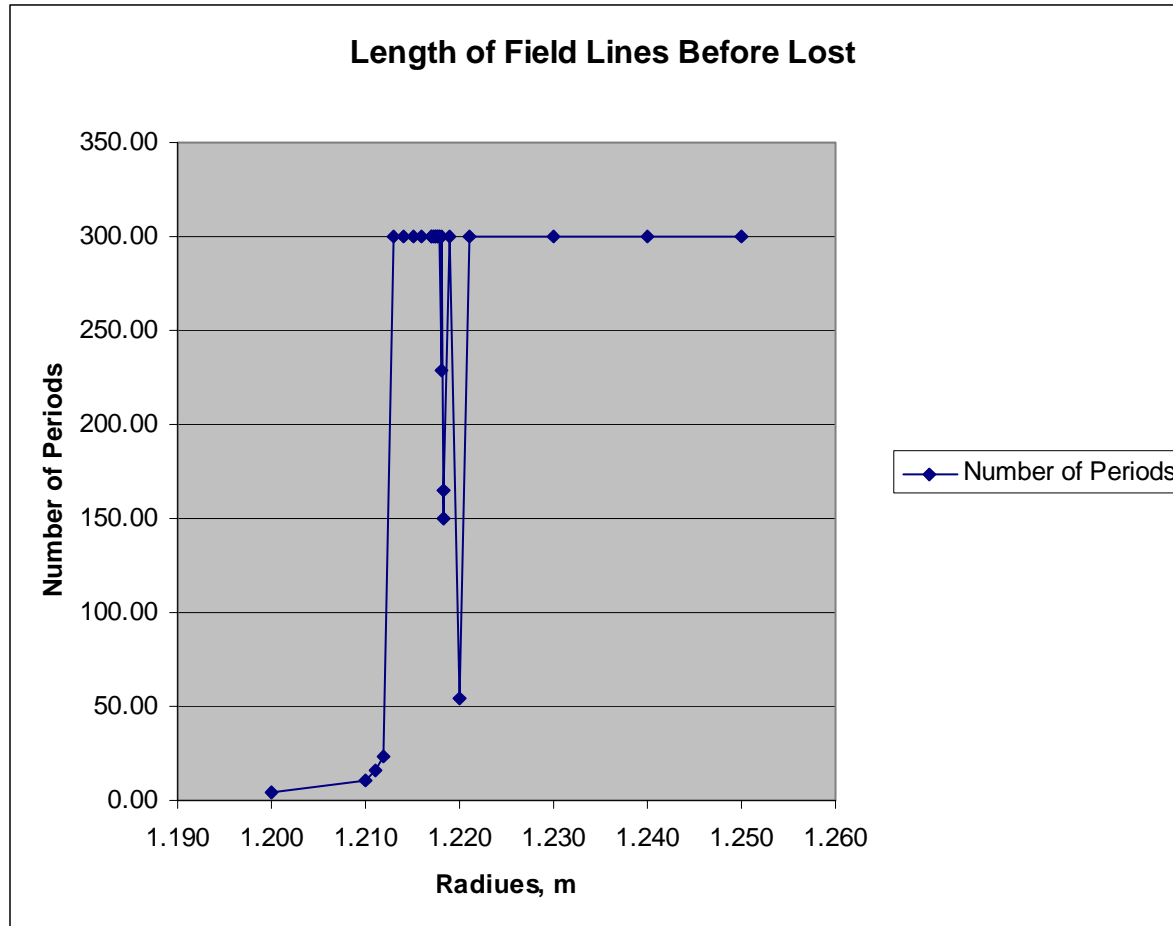
3/5 island structure becoming fuzzy
Length quickly drops below 100 F.P.

Length of Field Lines Before Lost

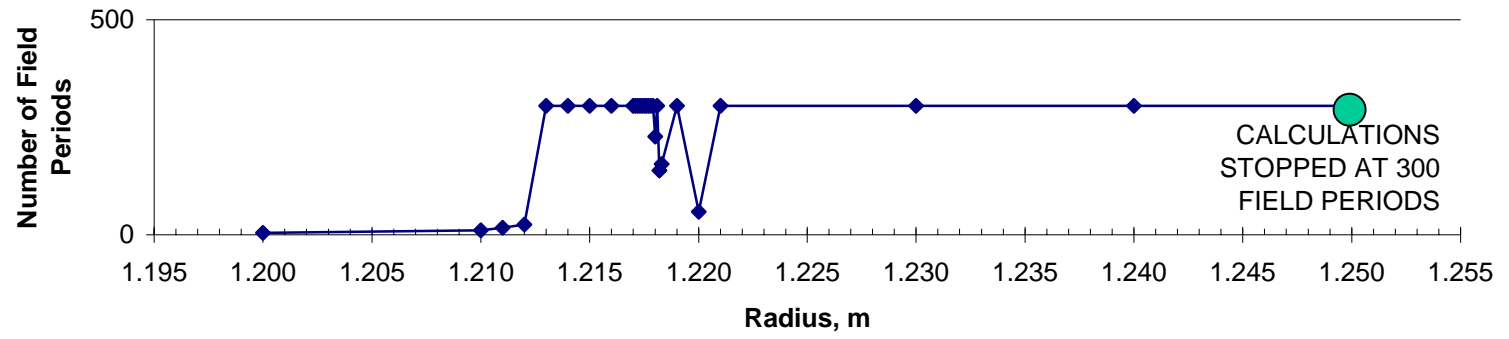


Outside 3/5 island chain
Length is near zero

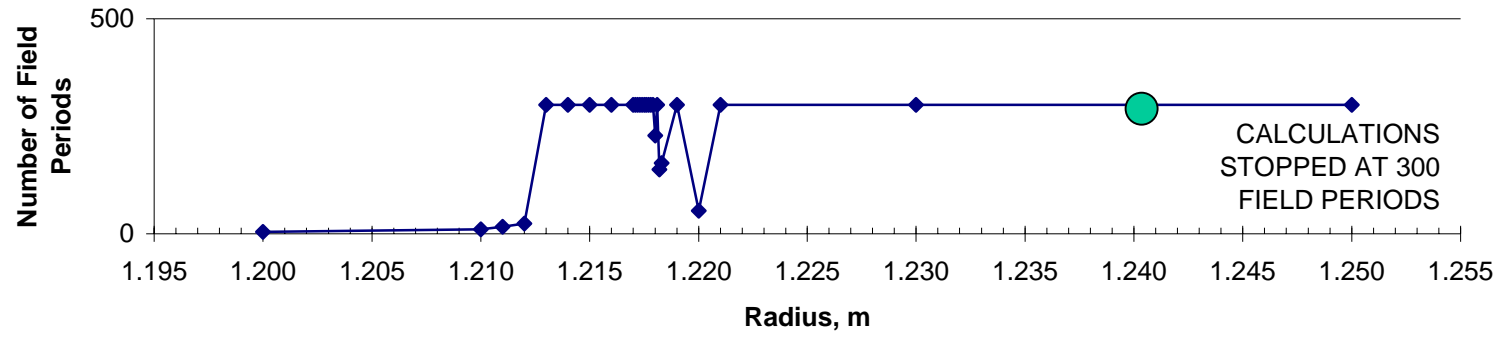
Inboard Sequence



Length of Field Lines Before Lost

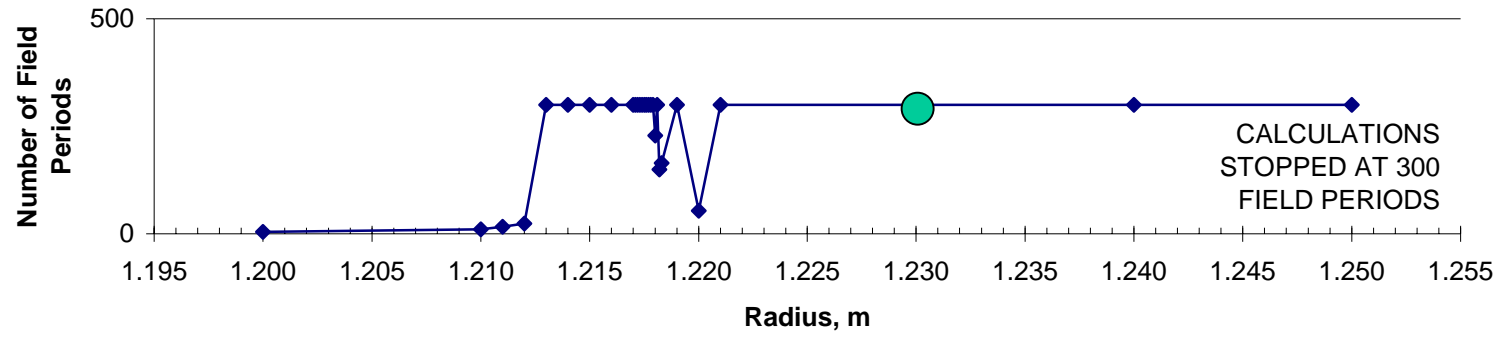


Length of Field Lines Before Lost



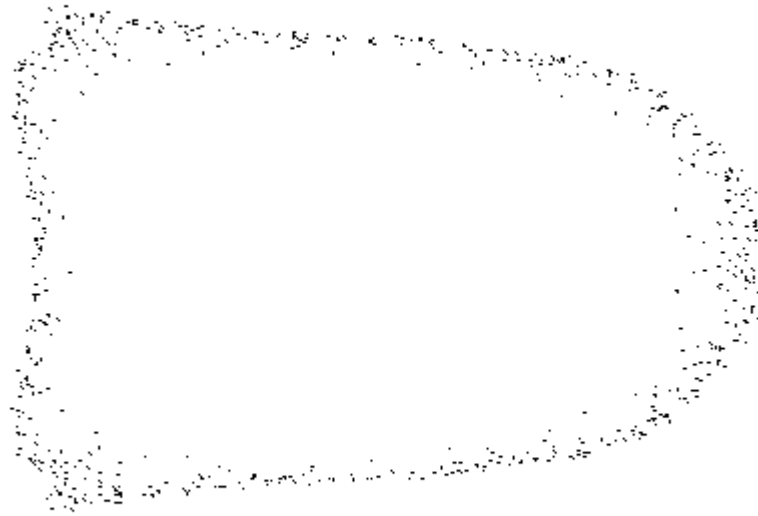
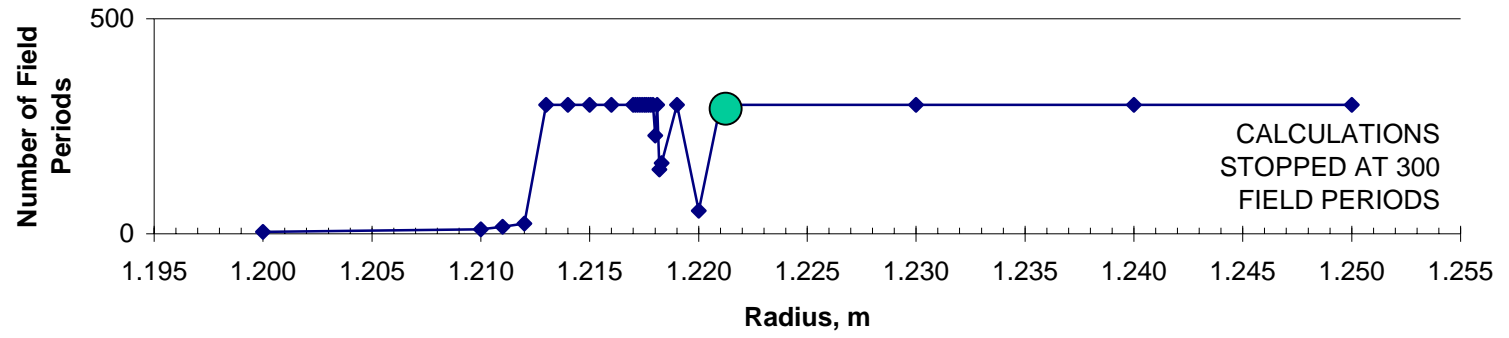
1.2400

Length of Field Lines Before Lost

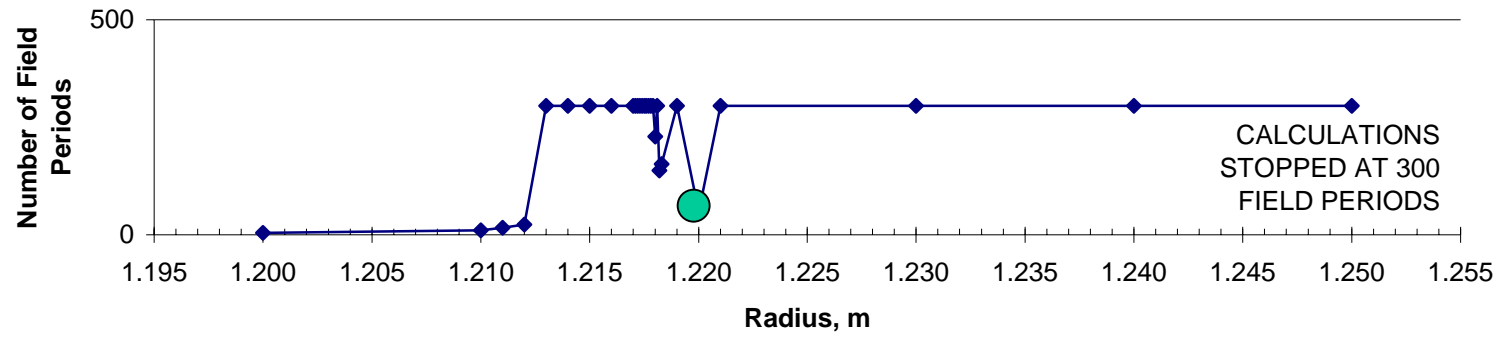


1.2300

Length of Field Lines Before Lost

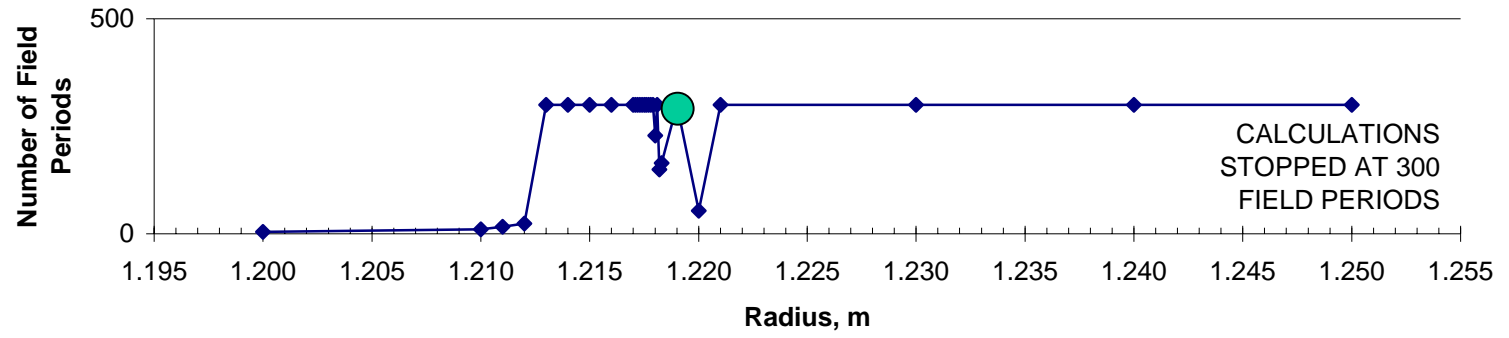


Length of Field Lines Before Lost

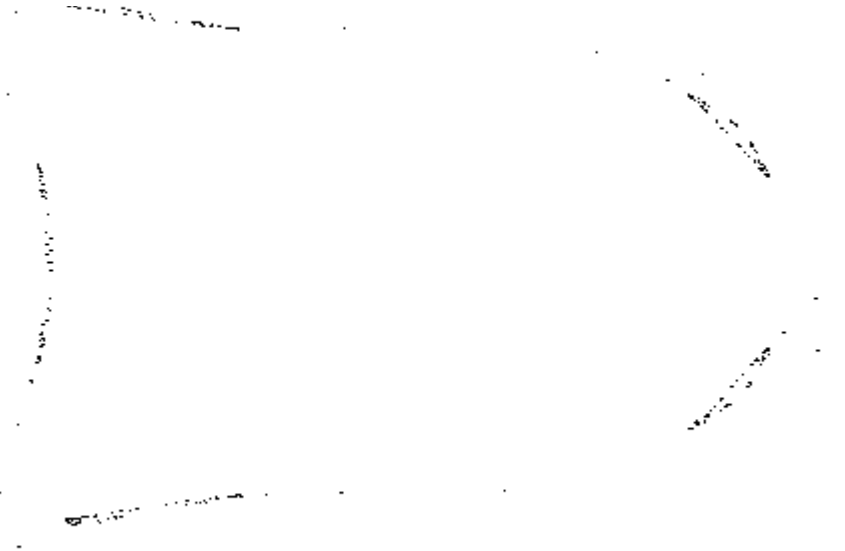
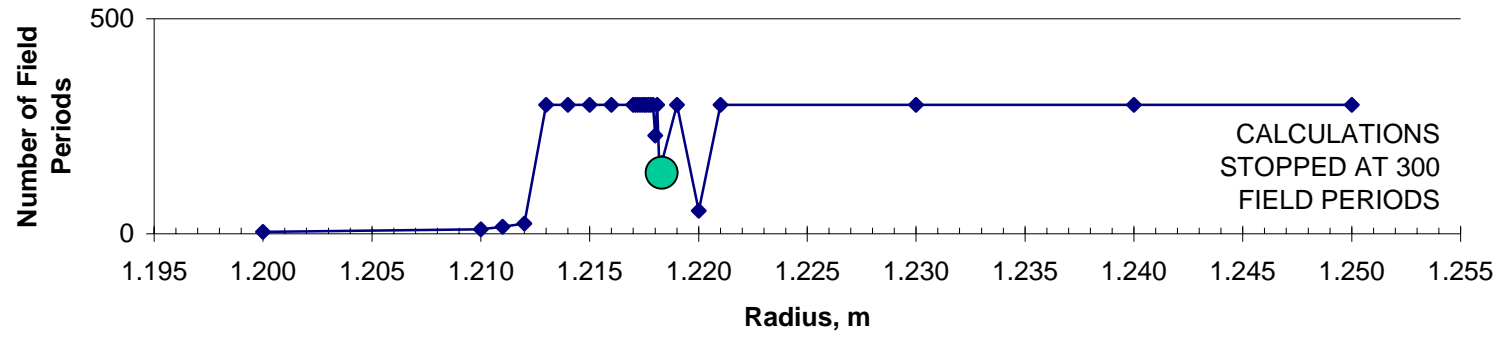


1.2200

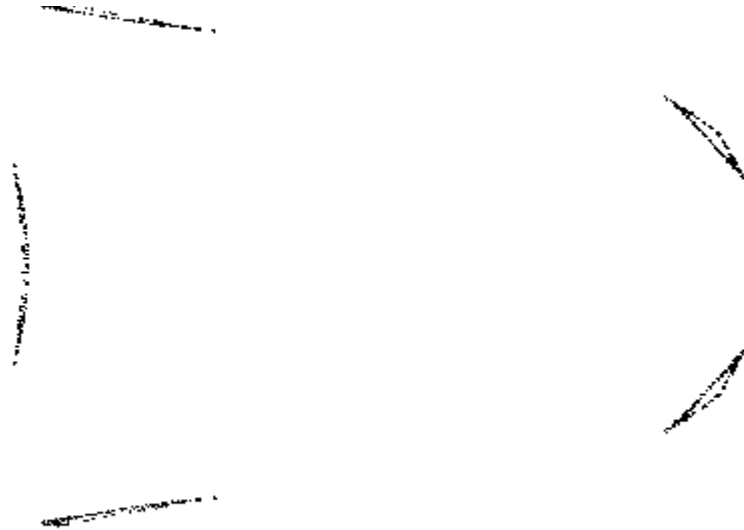
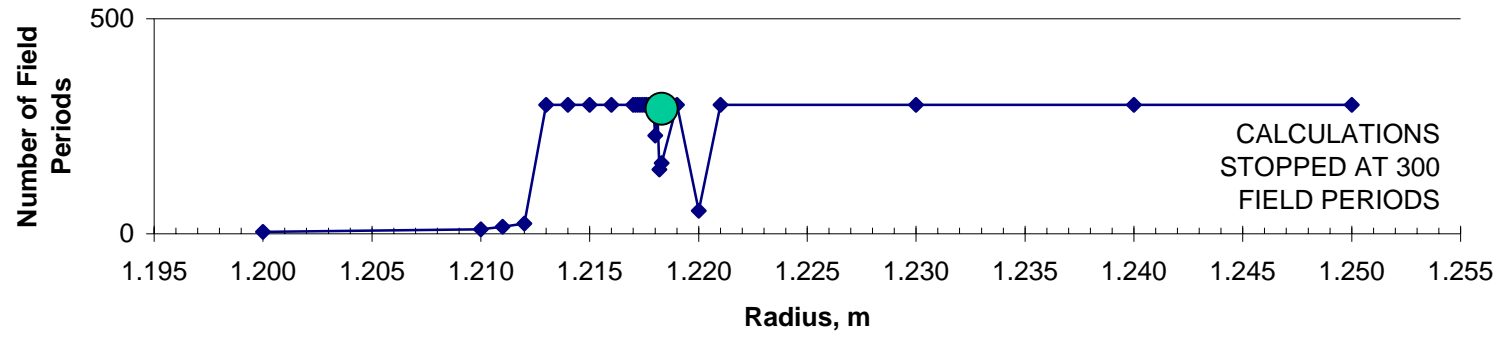
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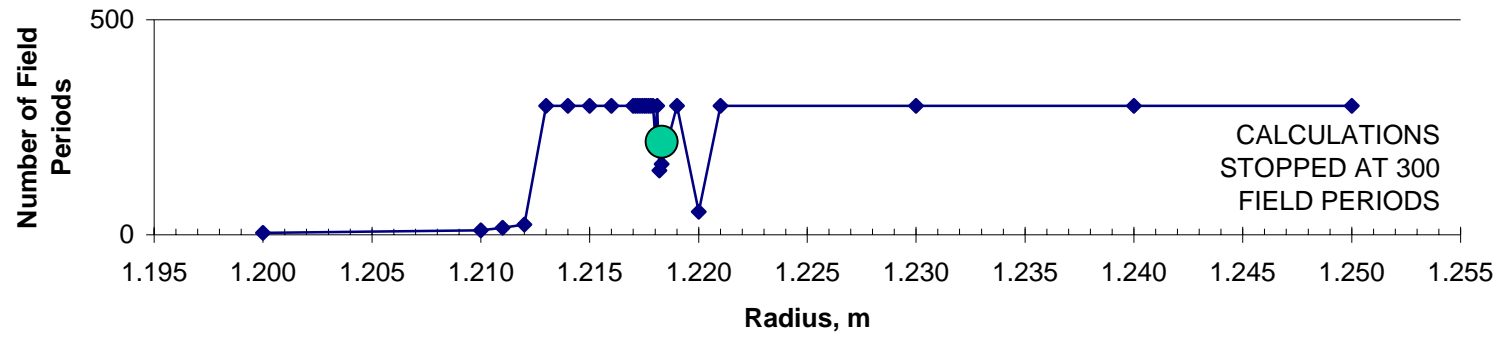
Length of Field Lines Before Lost



Length of Field Lines Before Lost

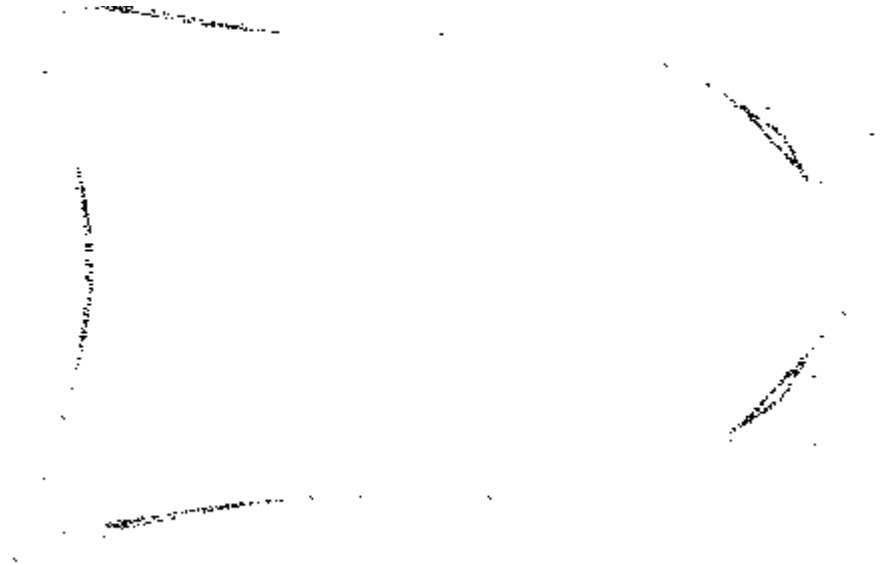
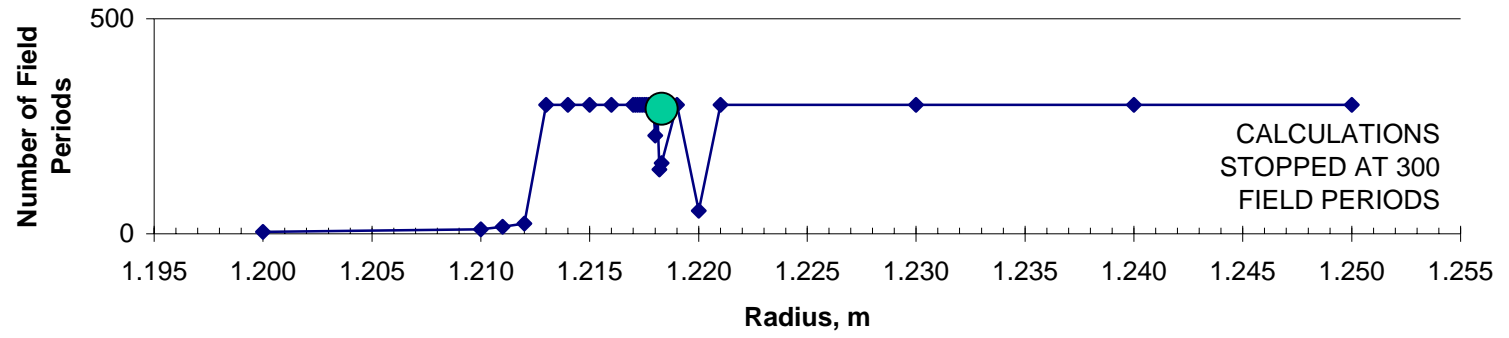


Length of Field Lines Before Lost

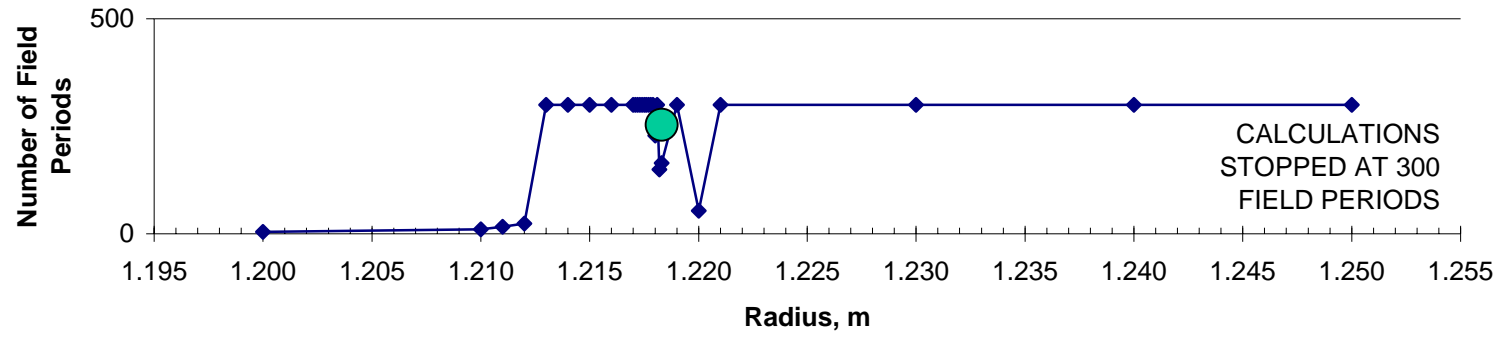


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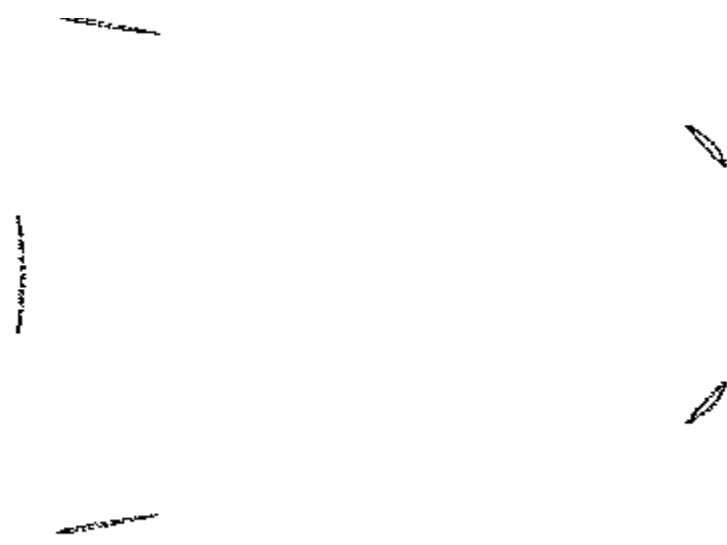
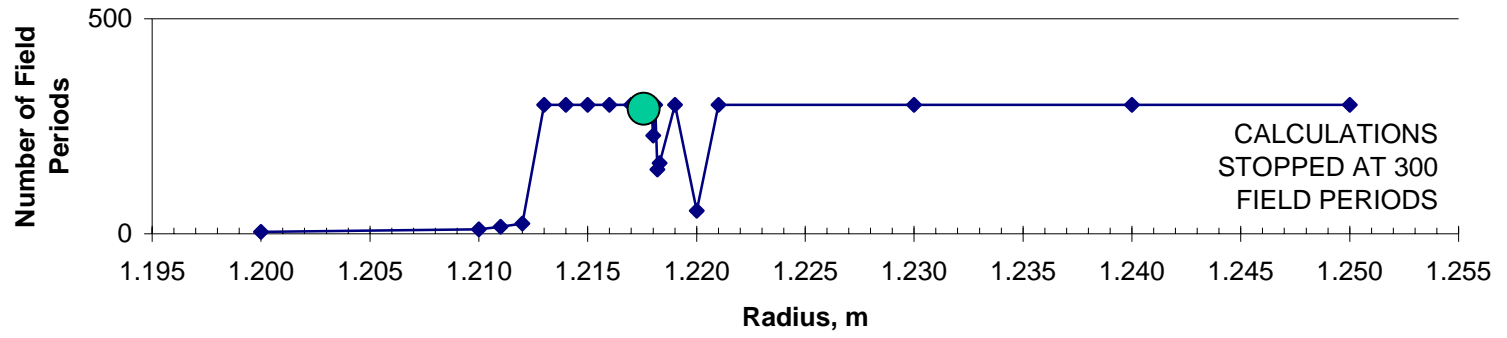
Length of Field Lines Before Lost



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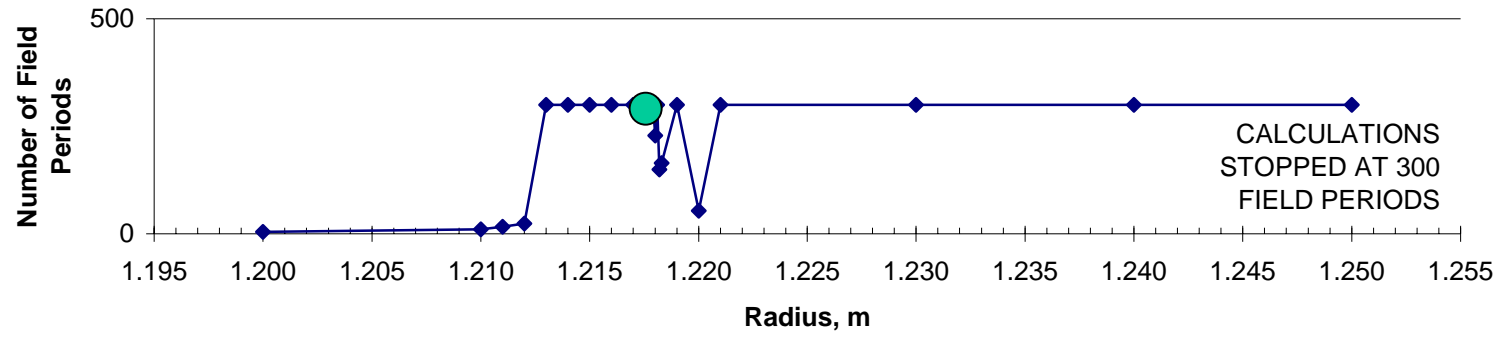


Length of Field Lines Before Lost

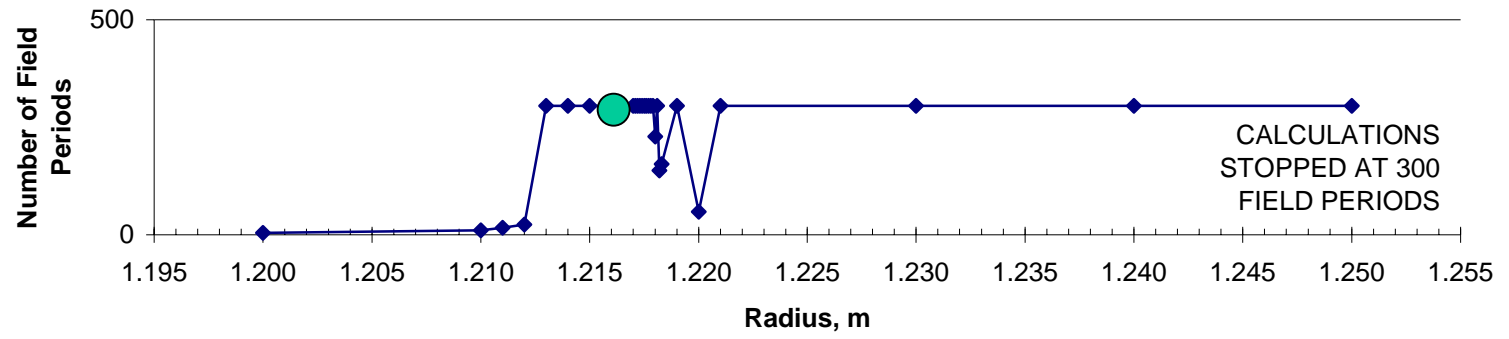


1.2175

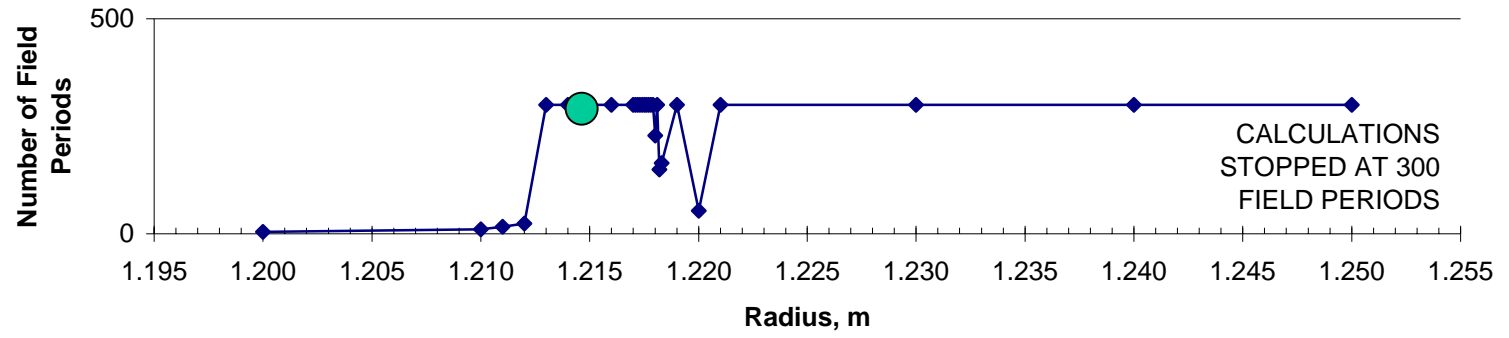
Length of Field Lines Before Lost



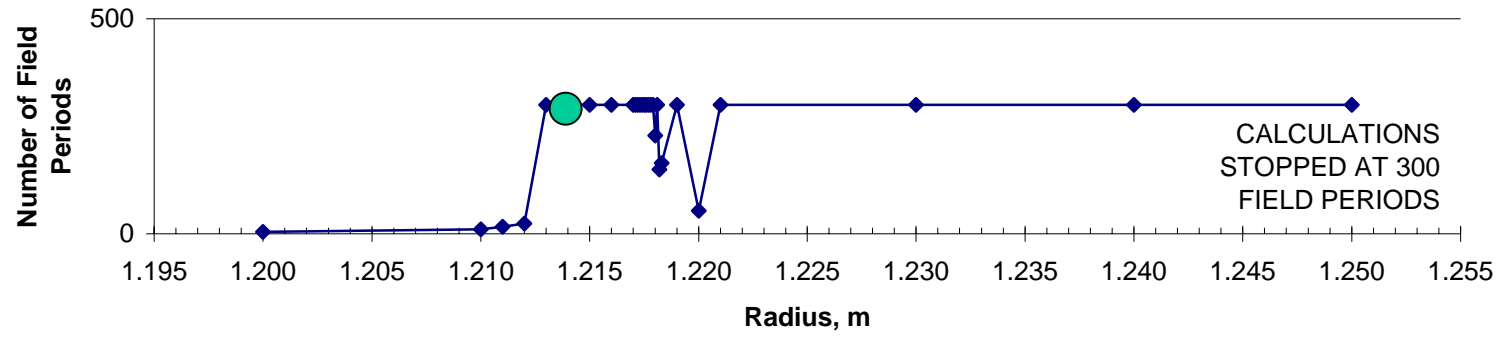
Length of Field Lines Before Lost



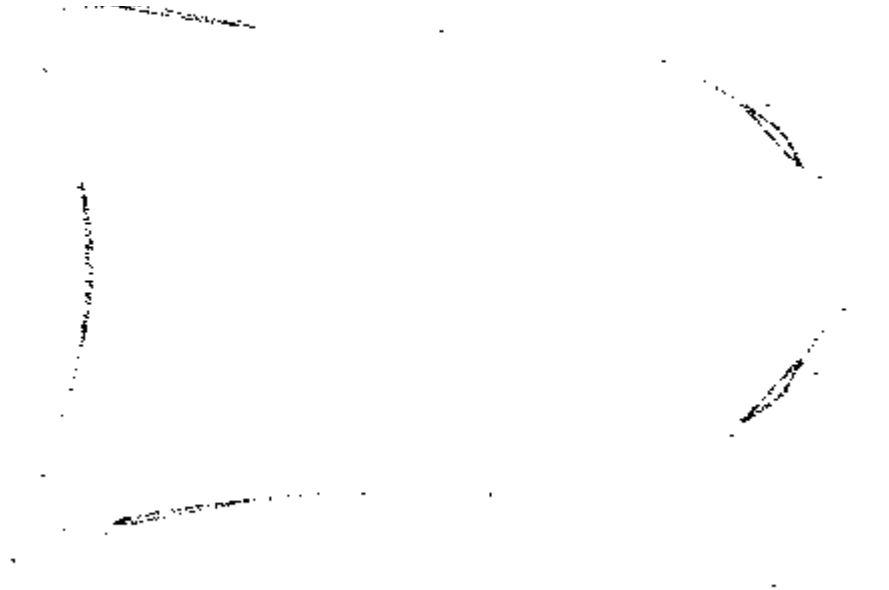
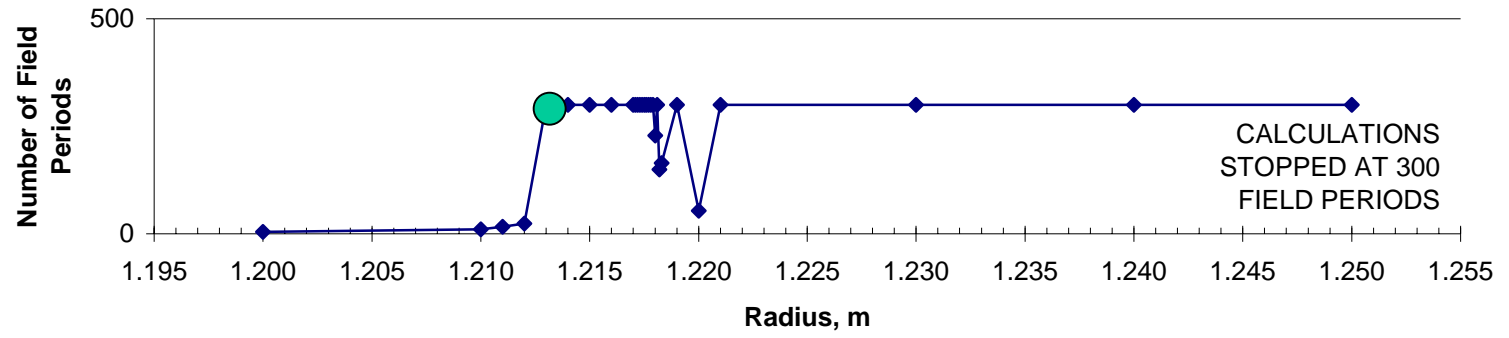
Length of Field Lines Before Lost



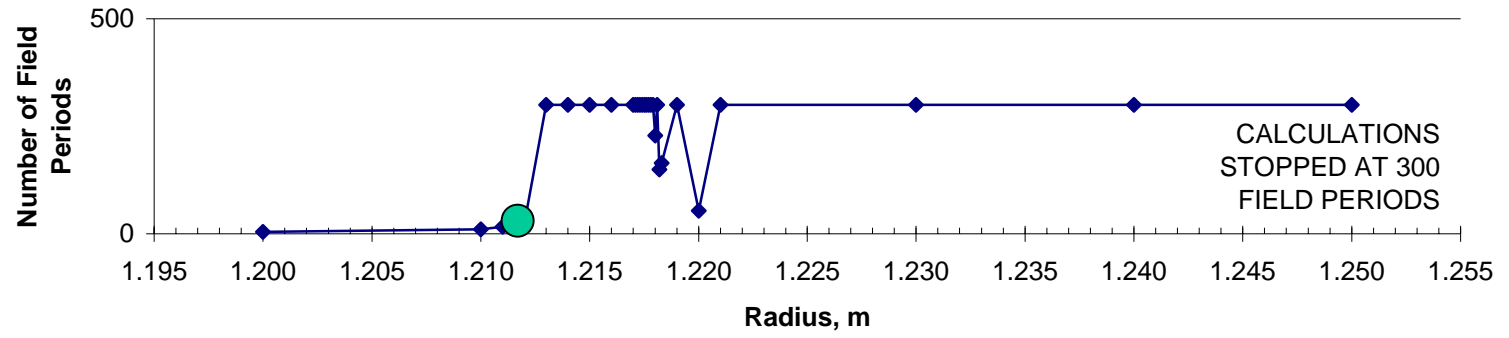
Length of Field Lines Before Lost



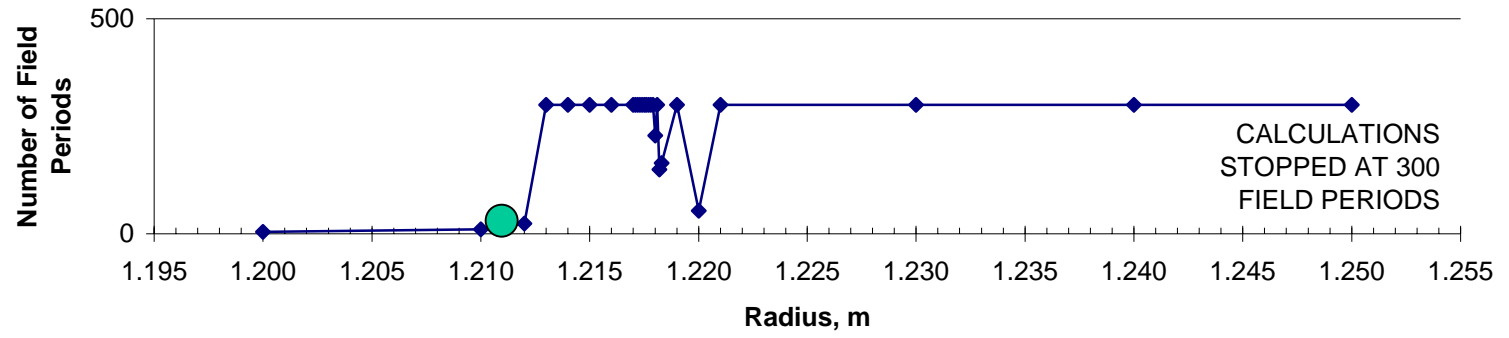
Length of Field Lines Before Lost



Length of Field Lines Before Lost



Length of Field Lines Before Lost



Conclusions (1)

- Results are qualitatively similar to Uragan-3M
 - A well-defined separatrix (the boundary between field lines circulating toroidally and those that do not) appears to exist and is defined by the $\iota=0.6$ ($3/5$) resonant surface
 - Field lines outside the last closed (smooth) magnetic surface are long ($>1\text{km}$) even though stochastic until the $\iota=0.6$ surface is approached
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 - Outside the $\iota=0.6$ surface, field lines quickly stop circulating toroidally (wrapping around the coils?)

Conclusions (2)

- The Project should consider...
 1. Applying the same methodology to characterize the topology of the S3 state (Grossman et al)
 2. Define a stay-out zone that is **OUTSIDE THE LAST SURFACE WITH LONG FIELD LINE LENGTHS** rather than on the basis of a scrape-off layer