Alternate Background Coils Study

Part I: Code Development

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Why An Optimization Code for Background Coils?

- Existing Conventional TF coils provide a 1/R field of which Saddles must buck out a large part of
  - For c82, computed normal field errors at plasma boundary from TF alone are 50% max and 15% avg
  - Saddle coils require 23 MA-m of conductor vs 86 MA-m of TF (existing TF are even taller than needed)
  - TF field alone on c82 plasma introduces high m-modes in B•n
- Alternate background configurations may provide a significant portion of the helical field.
  - Provide a better initial match to plasma
- Provides a tool which we know “what’s in there”

Structure of Background Coil Optimization Code

- Code built around NAG routine E04UCE which minimizes a target or object function using a sequential quadratic programming (SQP) method, subject to constraints:
  - simple bounds on variables
  - linear/nonlinear constraint equations.
- Variables are parameters representing coil
- Target function built of Physics and Engineering Objectives
- Same NAG routine also used by Extended NESCOIL and ONSET Codes

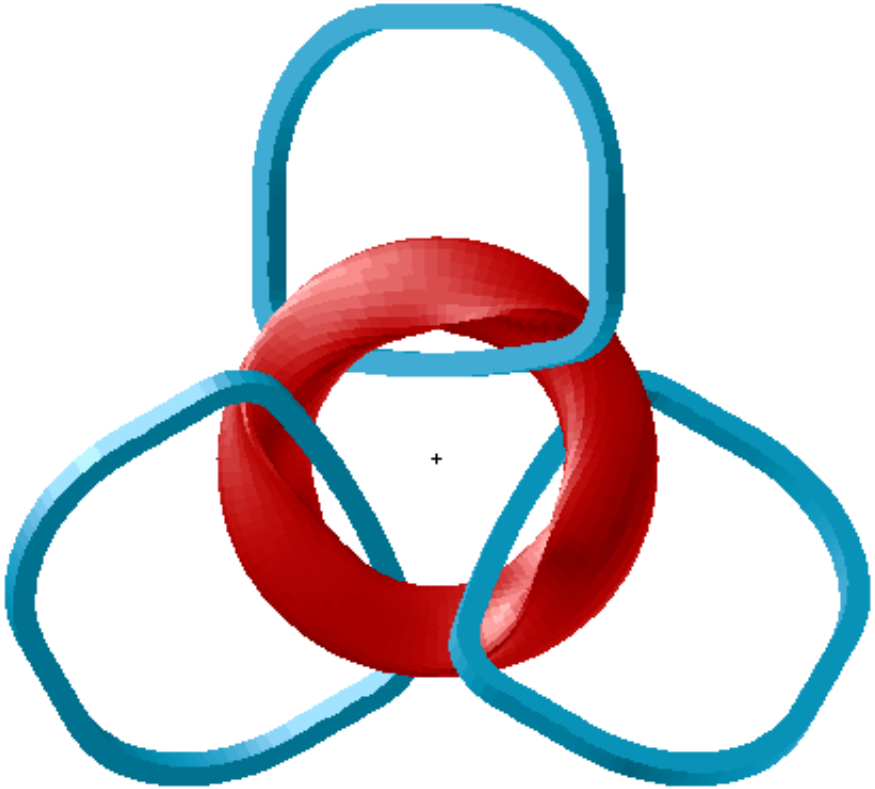
Background Coil Types

- Tilted Planar TF
  - Conventional TF
  - Interlocked TF
    (Links major axis)
- PF
  - Circular
  - Wavy PF
- Modular
  - Tilted Planar &Circular
  - Tilted Planar
  - Non Planar

- Current Sheet (NESCOIL)
  - Fixed Surface
  - Variable or Fixed Ipol* & Itor* allowing for cross topology searches
- 1/R Field
  - Variable Ipol
- Helical
  - Fixed Surface
  - Variable Modulation

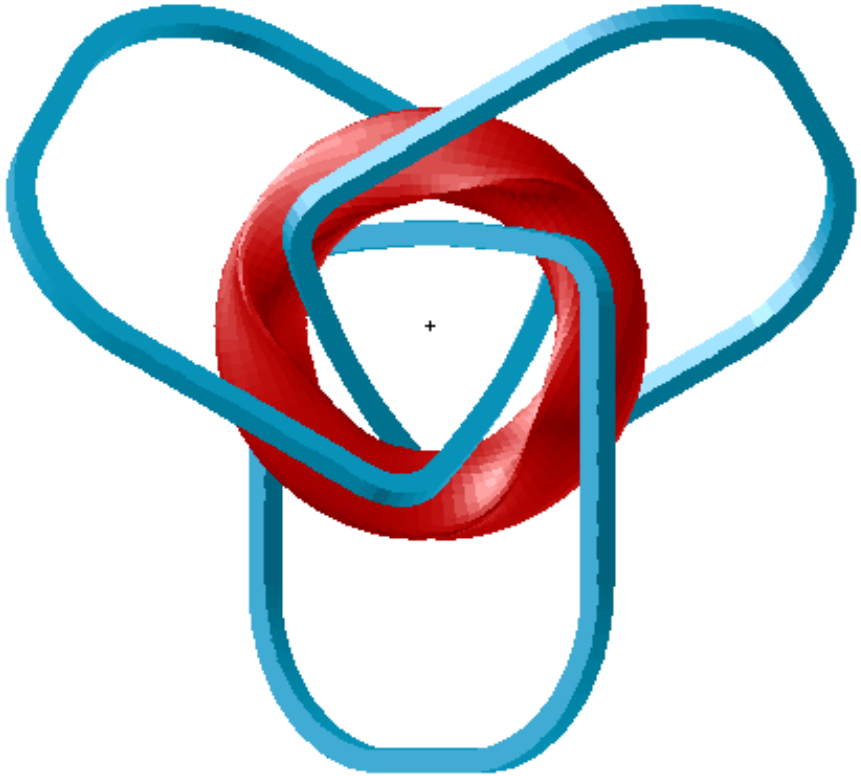
*Not all Combinations result in realizable coils

Tilted Planar TF



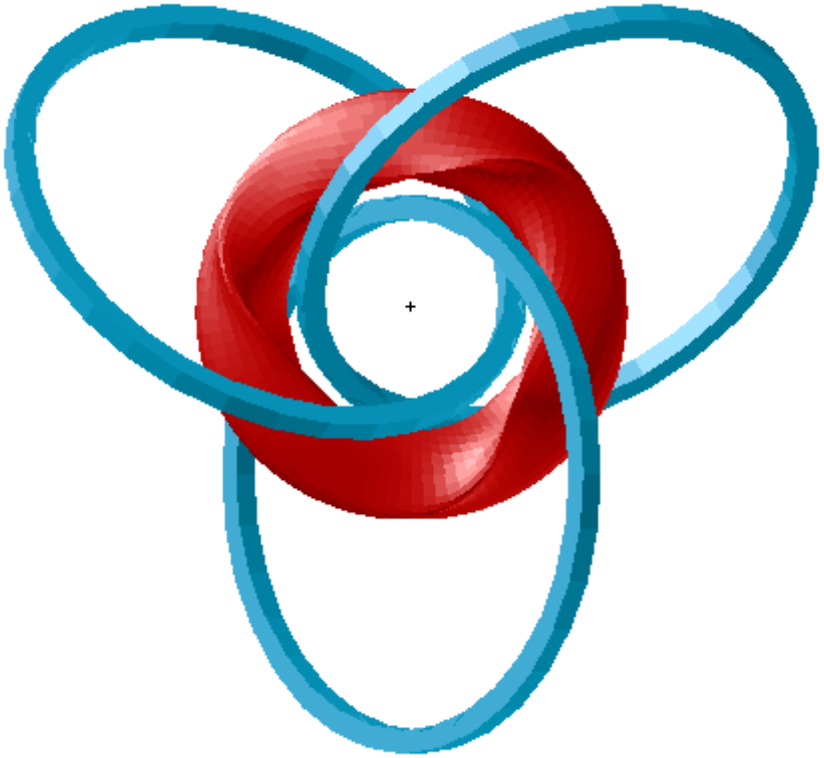
Conventional

Interlocked



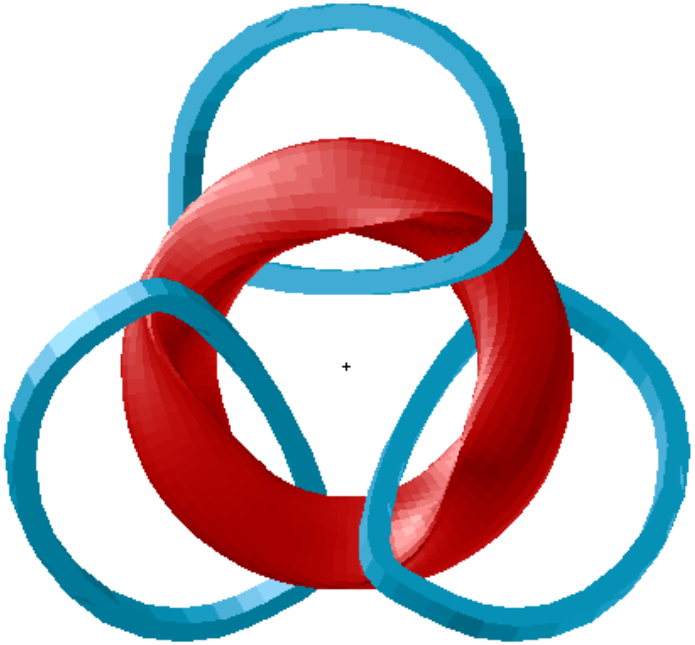
An Interlocked TF is an L=3 Winding

Planar Modular



Tilted Circular & Planar

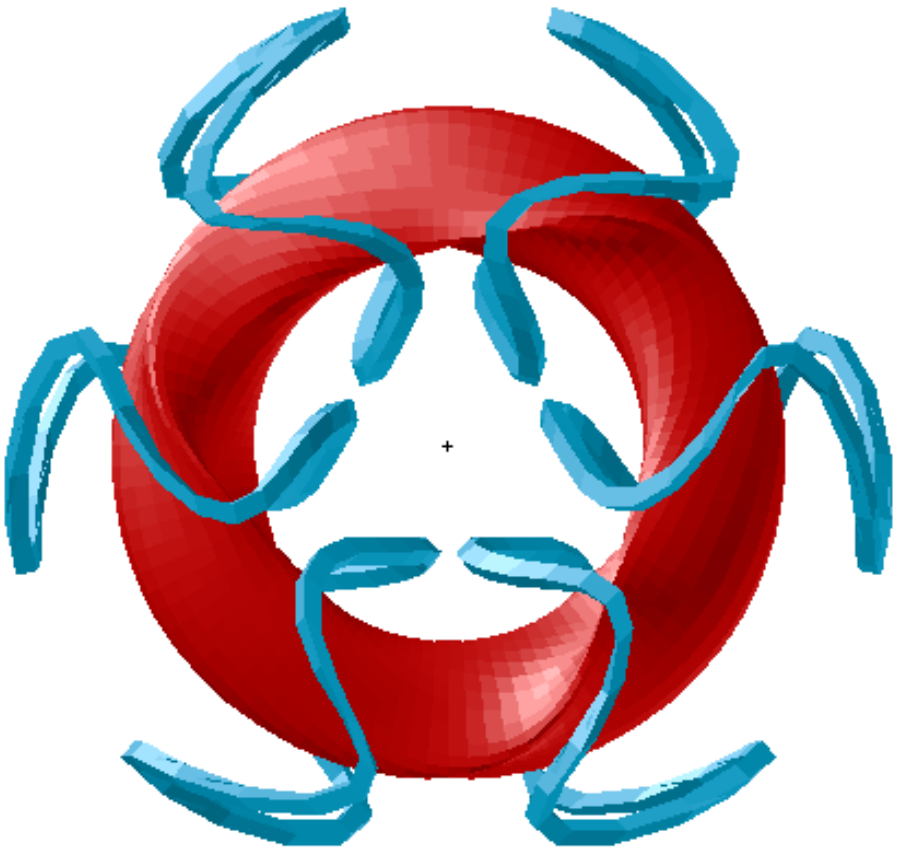
(Shown interlocked)



Tilted Planar

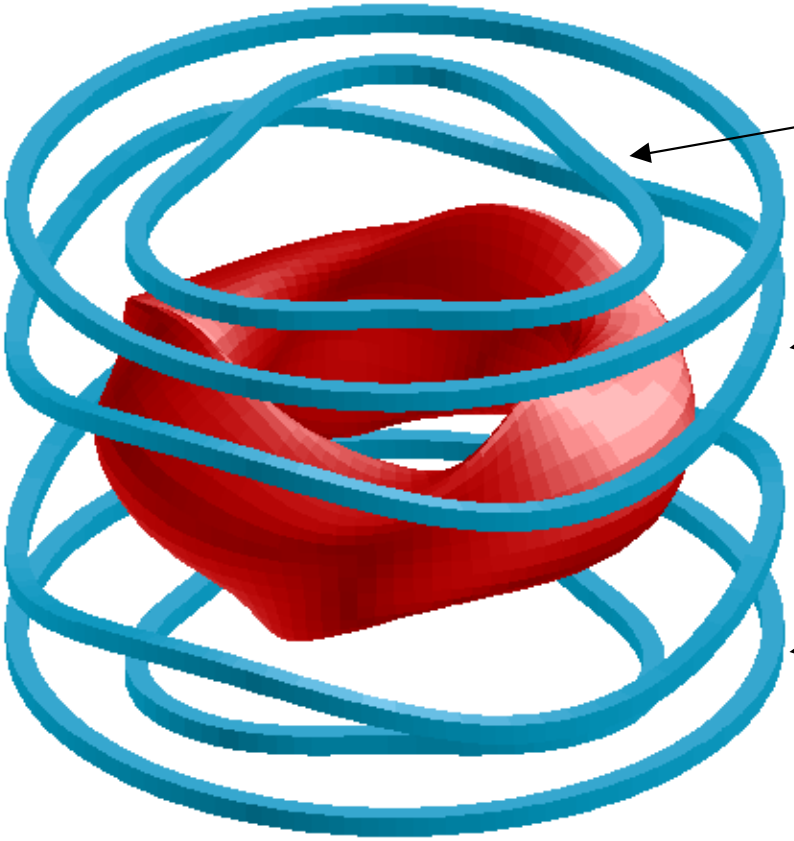
(Non circular)

Conventional Modular



Single Modular Coil
With Rotational and
Stellarator Symmetry

Wavy PF



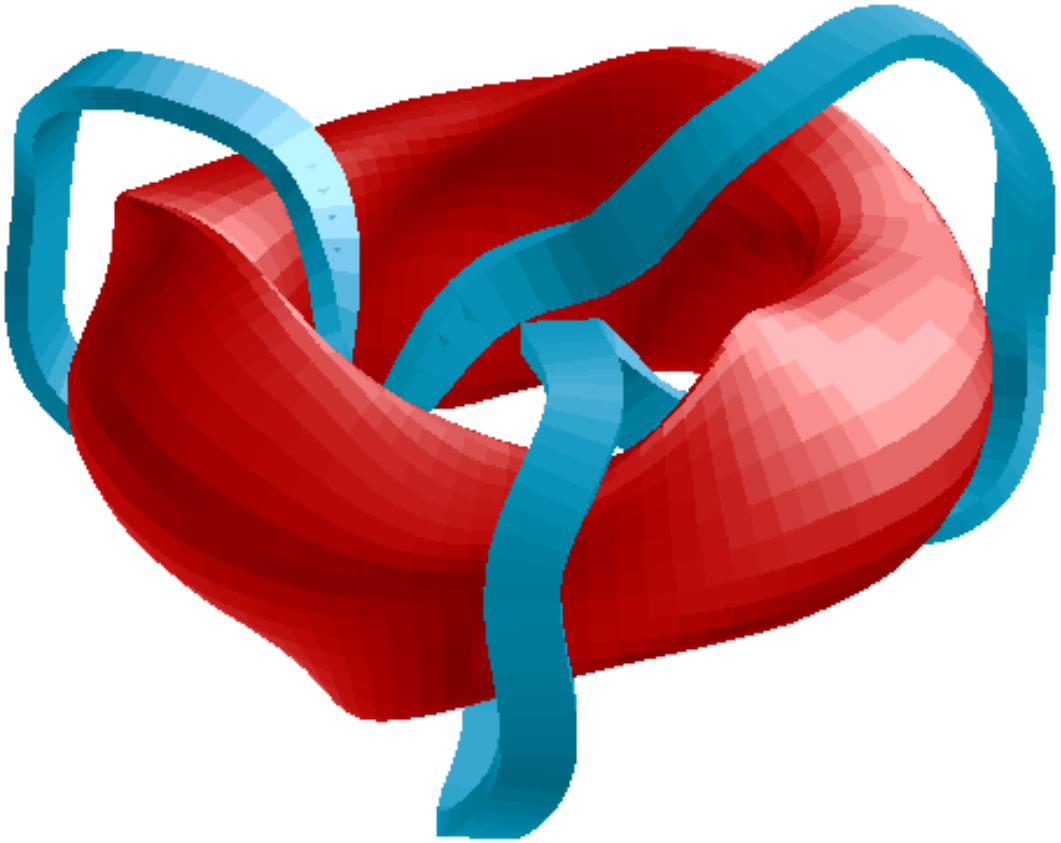
Radial Modulation
(planar coil)

Vertical Modulation
(cylindrical surface)

Conventional PF

Modulation in both R and Z
also supported

Helical



L=1 Torsatron with modulation wound on conformal surface

Background Coil Types Comments

- Allows Mixed Coil Topologies with or without current sheet subject to constraint on total poloidal current

- At present, coil winding surfaces (current sheet, helicals and modulars) are held fixed to speed optimization. Some limited movement is being sought which minimizes the number of optimization variables.

- For Tilted TF and Tilted Planar Modulars, Coils confined to Symmetry planes.

Target Function a Linear Combination of Several Measures

- Max and Mean Field Errors on Plasma Boundary
  - For Background Coils alone or
  - Background Coils with Current Sheet

- Ampere meters of Background Coils
  - Measure of Cost

- Max and Mean Current Density from Current Sheet

- Coil Complexity Measure

Status of Development

- Capabilities presented have been implemented and checked out
  - Minor changes to NESCOIL structure has reduced current sheet solution time from ~ 1 min to < 1 sec for repeated calls
- A systematic study is underway (by Wayne)
  - Feedback is guiding ongoing development
- To date coils from current sheet have been cut using simple uniform contours approach. Sample of results have been passed on to GA code (Buff) to see if even further reductions can be achieved (current density, field errors).

Future Plans

- Incorporate future measures of “goodness of field” coming out of Physics studies into optimizer target function.
- Enhance coil topologies as needed, guided by trade studies
- Vary coil winding surface
- Expand coil representation to multiple filament where needed
- Work with developers of COILOPT code (Lee Berry, et al) for mutual benefit