1. Purpose of Experiments
Include immediate goal of the experiments, scientific importance and/or programmatic relevance. Refer to any relevant program milestones.

Characterize the antenna performance, impurity characteristics and their dependence on antenna phasing for the magnetic field-aligned antenna. We will also investigate the effect of magnetic pitch angle on antenna performance and impurity characteristics.

2. Background
Discuss Physics Basis of the proposed research. Prior results at Alcator or elsewhere, and any related work being carried out separately.

We have installed the magnetic field-aligned, 4-strap ICRF antenna on the J-port in Alcator C-Mod. The entire antenna is rotated from the horizontal plane by 10° and is intended to be aligned with the total magnetic field for a 1 MA, 5.4 T discharge. The field-aligned antenna is designed to minimize integrated $E_\parallel$ (electric field along a magnetic field line) through symmetry. Toroidal phasing of straps on ICRF antennas has a measurable effect on RF sheath potentials and observed impurity production [1,2]. Typically, ICRF antennas are operated in dipole phasing $[0, \pi, 0, \pi]$ due to the deleterious effects of monopole phasing $[0, 0, 0, 0]$. This is likely because the cancellation of $E_\parallel$ along field lines is greater for dipole phasing than for monopole phasing for antenna structures which are misaligned with the equilibrium magnetic field [3].

Using finite element method and a cold plasma model, four antenna phases were analyzed for the rotated antenna: $[0, \pi, 0, \pi], [0, 0, \pi, \pi], [0, \pi, \pi, 0], [0, 0, 0, 0]$. In each case, the field-aligned antenna had reduced integrated $E_\parallel$ relative to the previous antenna geometry. The reduction in the integrated $E_\parallel$ varies depending on phase, with a minimum reduction of 2-3. However, the most significant reduction occurs for monopole $[0, 0, 0, 0]$ phasing where the integrated $E_\parallel$ nearly vanishes and had the greatest $E_\parallel$ mitigation of all
possible phase configurations for the field-aligned antenna. Although monopole phasing may not provide optimal heating due to a \( k_{||} \) spectrum peaked at \( k_{||}=0 \) [4], we are very interested in the impurity characterization of this toroidal phasing. Since the mitigation is dependent on symmetry, the magnetic field pitch is likely to be important. An investigation of its sensitivity will be useful in analyzing the effectiveness of the rotation. See also Ref. 5-9.

3. Approach
Describe the methodology to be employed; explain the rationale for the choice of parameters, etc. Describe the analysis techniques to be employed in interpreting the data, if applicable. If the approach is standard or otherwise self-evident, this section may be absorbed into the Experimental Plan.

To characterize the rotated J antenna performance, the plasma response to the rotated J antenna will be compared to the plasma response to the D and E antennas within the same discharge. In particular, we are interested in impurity characteristics, SOL density profile modification, plasma potential variation, and SOL transport. We would like to investigate the plasma response dependence on antenna phasing and plasma current. Within each discharge, we will pulse rotated J and D and E antennas for \( \sim 300 \) msec each with 200 msec between RF pulses. To avoid issues with respect to plasma so-called “memory” (for example second H-mode is poorer than the first), we will also vary the order of the antennas. Both L and H-mode plasmas will be utilized since they have significantly different edge SOL, pedestal, and impurity characteristics.

For the initial operation, we will utilize \([0, \pi, 0, \pi]\) and switch to \([0, 0, 0, 0]\) electronically. Since we need to switch the transmission line network to access heating \([0, \pi, \pi, 0]\) and current drive \([0, \pi/2, \pi, 3\pi/2]\) phasing, we will need a separate run day. We will monitor plasma characteristics [stored energy, temperature, radiated power] using available diagnostics. We will use McPherson and CHROMEX spectrometers for global, antenna quadrant and mid-plane impurity views. The SOL reflectometer and GPI will be used to monitor SOL density and transport modifications. We will also use emissive probes at the AB limiter to monitor plasma potential.

4. Resources

4.1 Machine and Plasma Parameters

Give values or range for:

- Toroidal Field: \( \sim 5.2 \) T
- Plasma Current: 0.6-1.2 MA
- Working Gas Species: D2
- Density: \( n_{\text{L4}} \sim 0.4-1.2 \)
- Equilibrium configuration (if possible, refer to database equilibria): likely to utilize discharge developed for commissioning

4.2 Auxiliary Systems

RF Power, pulse length, phasing: up to power limit, dipole phase, monopole, heating, CD
Pellet Injection (species): No
Impurity blow-off injection: Yes
Diagnostic Neutral Beam: allowable
Special gas puffing: GPI, Ninja (He)
Other:

4.3 Diagnostics
List required diagnostics, and any special setup or configuration, e.g. non-standard digitization rate.

Standard diagnostic set plus GPI, SOL reflectometers (C and H), emissive probes, McPherson and Chromex are required. Chromex needs to be monitoring the J antenna, D antenna, and GH limiter views.

5. Experimental Plan
Both sections must be filled in.

5.1 Run sequence Plan
Specify total number of runs required, and any special requirements, such as consecutive days, no Monday runs, extended run period – 10 hours maximum – etc.

We would likely require 2-4 non-consecutive days.

5.2 Shot sequence plan
For each run day, give detailed specification for proposed shot sequence: number of shots at each condition, specific parameters and auxiliary systems requirements, etc. Include contingency plans, if appropriate.

Day 1:

To maintain L-mode, we will utilize an USN discharge from previous RF commissioning run.
Antenna phase will be [0, π, 0, π] unless otherwise specified. Current: 0.9 MA. Density: 0.9 x 10^{20} m^{-2}

1) RF: 300ms D/E, 300ms J, SOL Refl C-port (2 shots)
2) RF: 300ms J, 300ms D/E, SOL Refl H-port (2 shots)
3) GPI, Ninja (Helium) discharges – each antenna fires into separate discharge (4 shots)
   a. D/E antennas – staircase waveform from 0.5-2 MW
   b. Rotated J antenna – staircase waveform from 0.5-2 MW
   c. H-SOL reflectometer utilized for pair of discharges and C-SOL reflectometer utilized for second pair.

Repeat 1-3 for [0, 0, 0, 0] (8 shots)

Day 2:

Repeat 1-3 tests for H-mode (16-shots). If [0,0,0,0] phasing heats poorly, number of discharges will be reduced.
4) Scan Iₚ: [0.6, 0.6, 0.9, 1.2, 1.2] MA (10 discharges)
   RF: 300ms D/E, 300ms J, C-SOL Refl (5 shots)
   RF: 300ms J, 300ms D/E, H-SOL Refl (5 shots)
5) GPI, Ninja (Helium) current scan Iₚ: [0.6, 1.2] MA – each antenna fires into separate discharge (8 shots)
   a. D/E antennas – staircase waveform from 0.5-2 MW
   b. Rotated J antenna – staircase waveform from 0.5-2 MW
   c. H-SOL reflectometer utilized for pair of discharges and C-SOL reflectometer utilized for second pair.

Day 3:

6) Repeat 4-5 for [0, 0, 0, 0] – dependent on data from previous experiments. We could combine [0,0,0,0] in with [0, π, 0, π] (18 discharges)

Day 4:

7) Repeat 4-6 in H-mode (28-shots)

Day 5:

Begin with USN L-mode, 1 sec pulse. Toroidal phasing: [0, π, π, 0]. Current: 0.9 MA. Density: 0.9 x 10^{20} m^{-2}

8) RF: 300ms D/E, 300ms J, SOL Refl C-port (2 shots)
9) RF: 300ms J, 300ms D/E, SOL Refl H-port (2 shots)
10) GPI, Ninja (Helium) discharges – each antenna fires into separate discharge (4 shots)
    a. D/E antennas – staircase waveform from 0.5-2 MW
    b. Rotated J antenna – staircase waveform from 0.5-2 MW
    c. H-SOL reflectometer utilized for pair of discharges and C-SOL reflectometer utilized for second pair.
11) Repeat 1-3 for [0, π/2, π, 3π/2] (8 shots)

Day 6:

12) Repeat previous tests for H-mode (16-shots)

And we rest on the seventh day.

6. Anticipated Results
Discuss possible experimental outcomes and implications. Indicate if the program may be expected to lead to publications, milestone completions, improved operating techniques, etc. Indicate if the experiments are intended to contribute to a joint research effort, or an external database.

Characterize the rotated antenna performance and dependence on phasing and field pitch.

7. References
Include references both to external and internal literature or communications which bear on this proposal. See Section 2.