Increasing Antenna Range using Plasma Lens Focusing

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Increasing Antenna Range by Increasing Directivity

- Friis Transmission Line Equation shows that Range increases as the square root of directivity of the transmitting antenna times the directivity of the receiving antenna.
- Directivity can be increased by plasma lens focusing.

New Range in Terms of Directivity of Sono-buoy Antenna with other Antenna Directivity Fixed.

Of course the new range will increase even more if the directivities of both the transmitting and receiving antenna is increased by plasma lens focusing.

$$NewRange = OldRange\left(\frac{NewDirectivity}{OldDirectivity}\right)^{1/2}$$

$$Directivity = \frac{4p}{BeamSolidAngle}$$

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Beam Solid Angle

$$BeamSolidAngle = q_1 q_2$$

$$q_1 = HalfPowerBeamWidthInOnePlane$$

$$q_2 = HalfPowerBeamWidthInPerpendicularPlane$$

Some Physics of Plasma Transparency and Reflection

- The plasma frequency is proportional to the density of unbound electrons in the plasma or the amount of ionization in the plasma. The plasma frequency sometimes referred to a cutoff frequency is defined as:

$$w_p = \sqrt{\frac{4pn_e e^2}{me}}$$

where n_e is the density of unbound electrons, e is the charge on the

electron, and me is the mass of an electron

- If the incident RF frequency on the plasma is greater than the plasma frequency the EM radiation passes through the plasma and the plasma is transparent.

$$w > w_p$$

- When the opposite is true, plasma acts as a metal, and transmits and receives microwave radiation.

Definition of Plasma Cutoff

- Definition of cutoff: the displacement current and the electron current cancel when electromagnetic waves impinge on a plasma surface. The electromagnetic waves are cutoff from penetrating the plasma
- When the plasma frequency is above cutoff, the electromagnetic waves are reflected from the plasma
  - The EM waves are cutoff from transmission through the plasma.
- When the plasma frequency is below cutoff, the electromagnetic waves pass through the plasma.

Steering and Focusing when the Plasma Density is Below Cutoff.

- Steering and focusing can also be achieved when the Plasma Density is below cutoff.
  - **The speed of electromagnetic waves in a plasma is a function of plasma density.**
- An effective Snells Law causes refraction of electromagnetic waves passing through a plasma of variable density (plasma density varying from container to container containing plasma)
  - **this enables focusing of the electromagnetic waves**
  - **decreases beamwidths**
  - **increases directivity**
  - **increases antenna range**
- The steering and focusing of by the plasma can occur on a time scale of milliseconds.

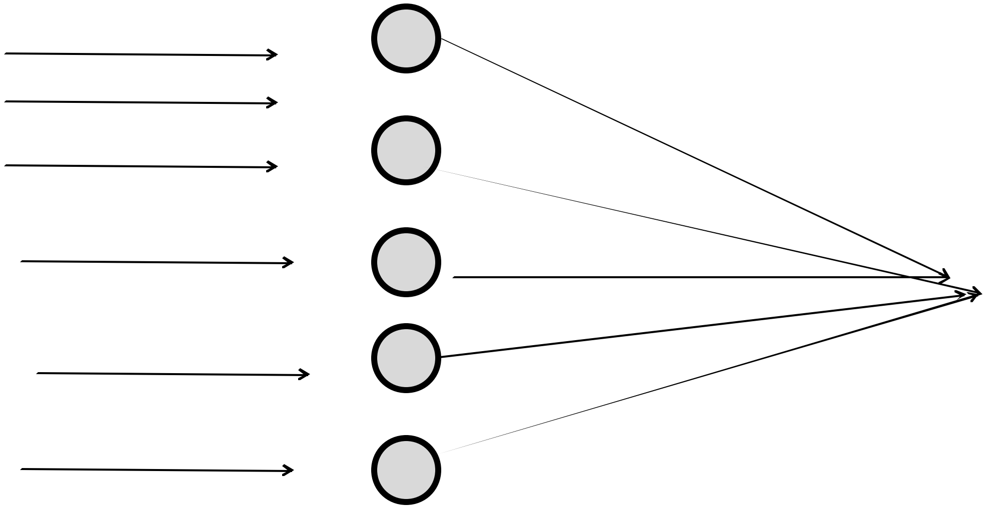
Steering and Focusing when the Plasma Density is Below Cutoff

- Incident RF waves on the left (see next slide) impinge on plasma tubes with different densities but with the plasma densities below cutoff.

- Focusing or steering can be achieved depending on how the plasma densities are varied from tube to tube.

Focusing when the Plasma Density is Below Cutoff.

By increasing the plasma density up and down from the bore site plasma tube we obtain a convergent plasma lens. This increases directivity.



Focused and/or steered Microwaves

Our Smart Plasma Antenna Shown Below Can Do Steering but Can Also be Re-designed to do Beam Focusing and Steering.

Play video of our smart plasma antenna on our website: www.haleakala-research.com

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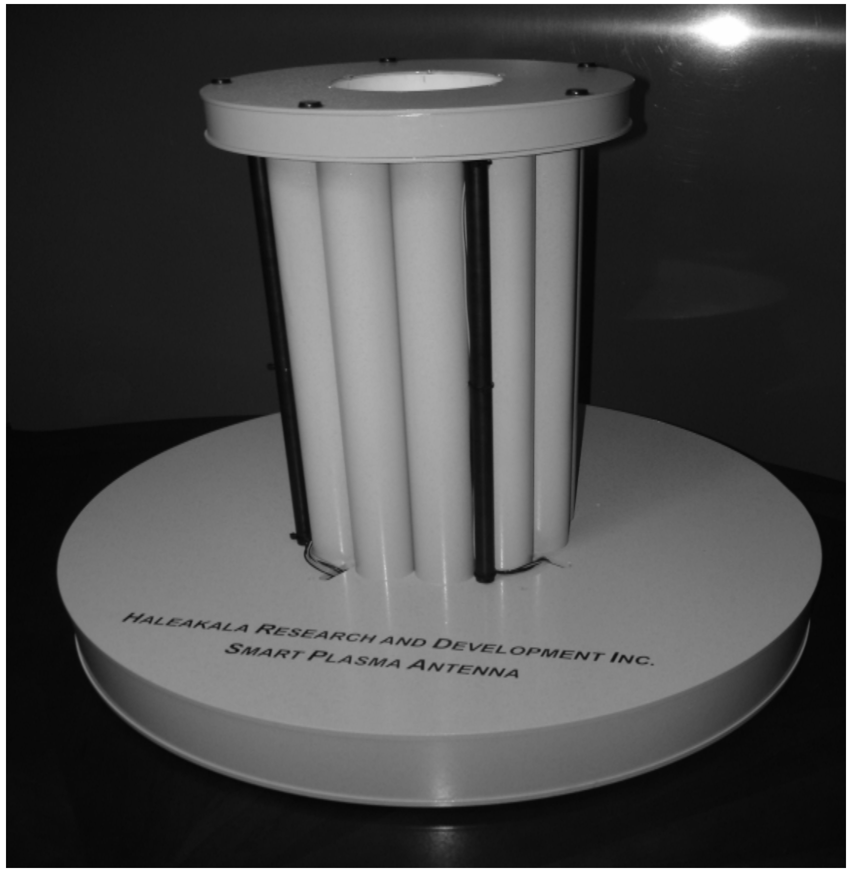
Our Ruggedized Version of Our Smart Plasma Antenna



References for a Plasma Lens

- **Plasma-based lens for microwave beam steering**
  Linardakis, P. Borg, G. Martin, N.
  Res. Sch. of Phys. Sci. & Eng., Australian Nat. Univ., Canberra, ACT, Australia;
  This paper appears in: Electronics Letters
  Publication Date: 13 April 2006
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- **Experimental work done by Dr. Ted Anderson and Professor Igor Alexeff.**

Antenna Range Increases by Decreasing the Beam Widths with Plasma Lens Focusing

- One bank of tubes acts as a convergent plasma lens to decrease the half power beam width q_1
- A perpendicular bank of tubes as a convergent plasma lens to decrease the half power beam width, q_2
- Directivity increases:

$$Directivit\ y = \frac{4p}{q_1 q_2}$$

- Antenna range increases:

$$NewRange = OldRange\left(\frac{NewDirectivity}{OldDirectivity}\right)^{1/2}$$

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Range Increases More When both Transmitting and Receiving Antennas use Plasma Lens Focusing

- The beamwidths of both the transmitting and receiving antennas is decreased by plasma lens focusing
  - The directivities of both the transmitting and receiving antennas is improved by plasma lens focusing.

$$NewRange = OldRange\left(\frac{NewDirectivity_{TransmittingAntenna}\, NewDirectivity_{\mathrm{Re}ceivingAntenna}}{OldDirectivity_{TransmittingAntenna}\, OldDirectivity_{\mathrm{Re}ceivingAntenna}}\right)^{1/2}$$

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Conclusions

- **An electronically steerable and focusing bank of plasma tubes can be made by having plasma densities in the tubes below cutoff but with the plasma densities varying from tube to tube.**
- **Electronic steering and focusing can be made in two dimensions by having two perpendicular banks of tubes.**
  - This can also steer and focus horizontal, vertical, circular, and elliptically polarized signals.
- **Plasma convergent lens focusing**
  - enables focusing of the electromagnetic waves
  - decreases beamwidths
  - increases directivity
  - increases antenna range