Proposed Plasma Antenna System Designs that Track and Attack Objects at Hypersonic Speeds.

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Steering and Focusing Antenna Beams to Track Hypersonic Speeds the Physics of Refraction.
Introduction

- We propose a plasma antenna concept that could have significant advantages for some advanced military applications.
- This concept is refraction of electromagnetic waves in a plasma in which the frequency of the electromagnetic waves is above the plasma frequency for steering and focusing antenna beams.
- The application is using this physics to track objects at hypersonic speeds.
- An array of tubes or plate containing plasma is placed in the antenna beam path, as in front of a conventional feed horn/small array
  - The phase shifting plasma channels focus and steer the antenna beam.
- In this application the operating frequency is above the plasma frequency, where the plasma is:
  - essentially a cold plasma with short relaxation time
  - the electromagnetic waves propagate through the plasma with a plasma frequency dependent phase velocity.
  - this will require high pulses per second (pps) power supply with pulsing (e.g. pps of MHz with nano-sec pulse widths) or direct current.

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Array of tubes or plate containing plasma design.

- The short relaxation time of the plasma in this design permits fast adjustment of phase shift in the plasma channels on the order of 1 to 10 micro-sec.
- Antenna beam steering of the order of 6 to 60 degrees per microsecond would not be unreasonable.
- This is a very high angular speed of the antenna beam which results in a super-hypersonic speed tangential velocity of the antenna beam.
- This means that a plasma refracted radar beam could theoretically sweep the on order of 10E8 to 10E9 m/sec at a range of 1 km, and 10E7 to 10E8 m/sec at a range of 100 m.
  - These are tracking speeds far faster than the fastest hypersonic missiles and bullets.
  - The tangential velocity of the antenna beam can exceed the speed of light in the same way that phase speeds in waveguides and in plasmas exceed the speed of light,
  - Nevertheless the transfer of energy and momentum does not exceed the speed of light.

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Array of tubes or plate containing plasma coupled with flat metal plate reflector design

- Related to the plasma sheet or an array of multiple plasma tubes of small diameter is the plasma plasma sheet or an array of multiple plasma tubes of small diameter coupled with a metal flat plate reflector.
  - in which a plasma sheet or an array of small diameter tubes containing plasma encapsulated in ruggedized material is attached to a flat metal plate reflector.
  - the advantage of this is that the electromagnetic waves refract through the plasma, reflect off of the metal plate, and refract back through the plasma giving a double refraction and twice the steering and focusing effect.
  - The disadvantage is that the metal plate reduces stealth.
    - But flat metal plates have a reduced RCS because of reduced back scattering differential and total cross section if oriented other than perpendicular to the antenna beam.
- A doubling of the total phase shift per thickness of the plasma plate would be achieved.
  - Doubling the steering and focusing effect by refraction through the plasma of the antenna beam.

Stealth and Resistance to Jamming.

- The plasma array of tubes with plasma with or without a reflector is very stealth.
- In the plasma/metal reflector design, a flat metal plate has very low effective radar cross section to adversary radar.
  - flat metal plates have a reduced RCS because of reduced back scattering differential and total cross section if oriented other than perpendicular to the antenna beam
- Whether the plasma is on (ionized state) or off (extinguished state) the array of tubes or plate containing plasma is little more than a flat dielectric plate that would have even lower radar cross section than a flat metal plate.

Stealth and Resistance to Jamming

- Broadband wave matching techniques, such as dielectric cones on the array of tubes or plate containing plasma, and RF absorber on the edges, could make this plasma system with or without a reflector virtually invisible.
- By comparison a conventional phased array using metal elements has a very high radar cross section.

More Compact than a Comparable Metallic Phased Array.

- We anticipate a plasma system using refraction to steer and focus an antenna beam to be more compact than a comparable metallic phased array.
  - *Plasma channels can be packed many per wavelength for:*
    - *Compactness.*
    - low sidelobe control.

Ruggedization

- The plasma refraction system/reflector can be made extremely rugged. Laboratory plasma antennas typically have used glass tubes, which has invited criticism for their fragility.
- While initial beam steering and focusing through refraction in a plasma experiments would likely start out with stacks of rectangular glass tubes and borosilicate or fused quartz plates to contain the plasma.
- The rectangular glass tubes and plates to contain the plasma would be ultimately made of tough ceramic plates.
  - The plates would have the plasma channels ground into them, and the plates sealed together at the edges.
  - Small gaps between the plates would allow equalized gas pressure, single port vacuum and gas processing (prior to pinching off as with microwave tubes), and thermal stress relief.

Ruggedization

- . The plasma/metal reflector would have a plate or array of plasma tubes attached to a flat metal plate which provides higher ruggedization and conduction cooling.
- For even higher ruggedization the front surface of the ceramic plate with lexan glass could be very thick
  - and also overcoated with thick soft radome dielectric material, of several or (even many) cm,
  - and provide very high resistance to bullets, shrapnel, and high pressure shock waves (as from nearby explosions)
    - that would easily disable a conventional antenna.
- Rather than being fragile, the array of tubes or plate containing plasma alone or coupled with flat metal plate reflector design could be more survivable than any fast tracking metal phased array type.

Offensive Hypersonic Capability

using the physics of refraction through plasma

- A plasma or conventional antenna DEW and/or jammer which can scan DEW and/or jamming beams using the physics of refraction of antenna beams through a plasma at hypersonic speeds.
- The DEW and jammer beams are coupled with plasma tracking beams and scan and attack in unison to disable missiles or other objects traveling at hypersonic speeds.
- ***The key is using the physics of refraction through plasma to scan and attack at hypersonic speeds.***

Highly advanced systems

- Highly advanced systems can be visualized as follows:
  - Ground, ship, airborne/space, or missile based antenna beams refracted through plasma systems could operate alone or in conjunction with conventional long range radars as a hybrid system.
- If in conjunction with conventional long range radars as a hybrid system:
  - Slow speed and/or long range targets would be handled by the long range conventional radar.
  - When a hypersonic missile, aircraft, etc. is detected the target would be passed off to one of multiple plasma antenna systems that use antenna beam focusing and steering using the physics of refraction through a plasma
  - or a mechanically positioned (within the tracking aperture) plasma antenna system that uses refraction that assumes the hypersonic close range duty, and/or a such a plasma antenna system using refraction equipped with a anti-missile missile.