Plasma Antenna Technology

The Technology of the Future

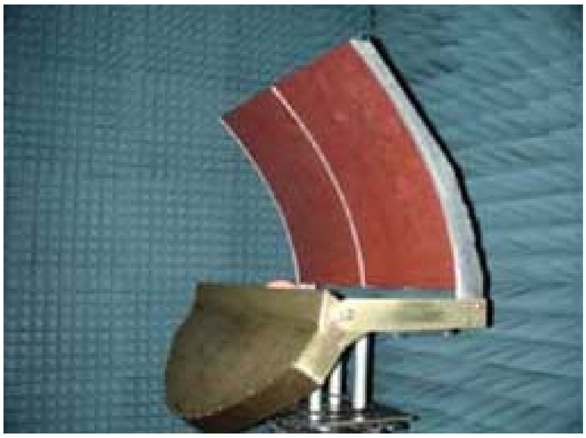
Credit Line:
ASI Technology Corporation

http://www.asiplasma.com/

What is Plasma?

On earth we live upon an island of "ordinary" matter. The different states of matter generally found on earth are solid, liquid, and gas. Sir William Crookes, an English physicist identified a fourth state of matter, now called plasma, in 1879. Plasma is by far the most common form of matter. Plasma in the stars and in the tenuous space between them makes up over 99% of the visible universe and perhaps most of that which is not visible. Important to ASI's technology, plasmas are conductive assemblies of charged and neutral particles and fields that exhibit collective effects. Plasmas carry electrical currents and generate magnetic fields.

Standard Parabolic Reflector



Plasma Antenna Technology

The essence of a plasma antenna is that it is equal to performance of a metal antenna but is lighter. When a plasma antenna is turned off, it is transparent - immune to electronic countermeasures and allowing other adjacent antennas to transmit or receive without interference.

Since the discovery of radio frequency ("RF") transmission, antenna design has been an integral part of virtually every communication and radar application. Technology has advanced to provide unique antenna designs for applications ranging from general broadcast of radio frequency signals for public use to complex weapon systems. In its most common form, an antenna represents a conducting metal surface that is sized to emit radiation at one or more selected frequencies. Antennas must be efficient so the maximum amount of signal strength is expended in the propogated wave and not wasted in antenna reflection.

Plasma antenna technology employs ionized gas enclosed in a tube (or other enclosure) as the conducting element of an antenna. This is a fundamental change from traditional antenna design that generally employs solid metal wires as the conducting element. Ionized gas is an efficient conducting element with a number of important advantages. Since the gas is ionized only for the time of transmission or reception, "ringing" and associated

Plasma Parabolic Reflector

effects of solid wire antenna design are eliminated. The design allows for extremely short pulses, important to many forms of digital communication and radars. The design further provides the opportunity to construct an antenna that can be compact and dynamically reconfigured for frequency, direction, bandwidth, gain and beam width. Plasma antenna technology will enable antennas to be designed that are efficient, low in weight and smaller in size than traditional solid wire antennas.

When gas is electrically charged, or ionized to a plasma state it becomes conductive, allowing radio frequency (RF) signals to be transmitted or received. We employ ionized gas enclosed in a tube as the conducting element of an antenna. When the gas is not ionized, the antenna element ceases to exist. This is a fundamental change from traditional antenna design that generally employs solid metal wires as the conducting element. We believe our plasma antenna offers numerous advantages including stealth for military applications and higher digital performance in commercial applications. We also believe our technology can compete in many metal antenna applications.

Plasma Reflector

Initial studies have concluded that a plasma antenna's performance is equal to a copper wire antenna in every respect. Plasma antennas can be used for any transmission and/or modulation technique: continuous wave (CW), phase modulation, impulse, AM, FM, chirp, spread spectrum or other digital techniques. And the plasma antenna can be used over a large frequency range up to 20GHz and employ a wide variety of gases (for example neon, argon, helium, krypton, mercury vapor and zenon). The same is true as to its value as a receive antenna.

Market Applications of Plasma Technology

Plasma antennas offer distinct advantages and can compete with most metal antenna applications. The plasma antenna's advantages over conventional metal elements are most obvious in military applications where stealth and electronic warfare are primary concerns. Other important military factors are weight, size and the ability to reconfigure. Potential military applications include:

Shipboard/submarine antenna replacements.
· Unmanned air vehicle sensor antennas.
· IFF ("identification friend or foe") land-based vehicle antennas.
· Stealth aircraft antenna replacements.
· Broad band jamming equipment including for spread-spectrum emitters.
· ECM (electronic counter-measure) antennas.
· Phased array element replacements.
· EMI/ECI mitigation
· Detection and tracking of ballistic missiles
· Side and back lobe reduction

Military antenna installations can be quite sophisticated and just the antenna portion of a communications or radar installation on a ship or submarine can cost in the millions of dollars.

Plasma antenna technology has commercial applications in telemetry, broad-band communications, ground penetrating radar, navigation, weather radar, wind shear detection and collision avoidance, high-speed data (for example Internet) communication spread spectrum communication, and cellular radiation protection.

Unique Characteristics of a Plasma Antenna

One fundamental distinguishing feature of a plasma antenna is that the gas ionizing process can manipulate resistance. When deionized, the gas has infinite resistance and does not interact with RF radiation. When deionized the gas antenna will not backscatter radar waves (providing stealth) and will not absorb high-power microwave radiation (reducing the effect of electronic warfare countermeasures).

A second fundamental distinguishing feature is that after sending a pulse the plasma antenna can be deionized, eliminating the ringing associated with traditional metal elements. Ringing and the associated noise of a metal antenna can severely limit capabilities in high frequency short pulse transmissions. In these applications, metal antennas are often accompanied by sophisticated computer signal processing. By reducing ringing and noise, we believe our plasma antenna provides increased accuracy and reduces computer signal processing requirements. These advantages are important in cutting edge applications for impulse radar and high-speed digital communications.

Based on the results of development to date, plasma antenna technology has the following additional attributes:

No antenna ringing provides an improved signal to noise ratio and reduces multipath signal distortion.
· Reduced radar cross section provides stealth due to the non-metallic elements.
· Changes in the ion density can result in instantaneous changes in bandwidth over wide dynamic ranges.
· After the gas is ionized, the plasma antenna has virtually no noise floor.
· While in operation, a plasma antenna with a low ionization level can be decoupled from an adjacent high-frequency transmitter.
· A circular scan can be performed electronically with no moving parts at a higher speed than traditional mechanical antenna structures.
· It has been mathematically illustrated that by selecting the gases and changing ion density that the electrical aperture (or apparent footprint) of a plasma antenna can be made to perform on par with a metal counterpart having a larger physical size.
· Our plasma antenna can transmit and receive from the same aperture provided the frequencies are widely separated.
· Plasma resonance, impedance and electron charge density are all dynamically reconfigurable. Ionized gas antenna elements can be constructed and configured into an array that is dynamically reconfigurable for frequency, beamwidth, power, gain, polarization and directionality - on the fly.
· A single dynamic antenna structure can use time multiplexing so that many RF subsystems can share one antenna resource reducing the number and size of antenna structures.

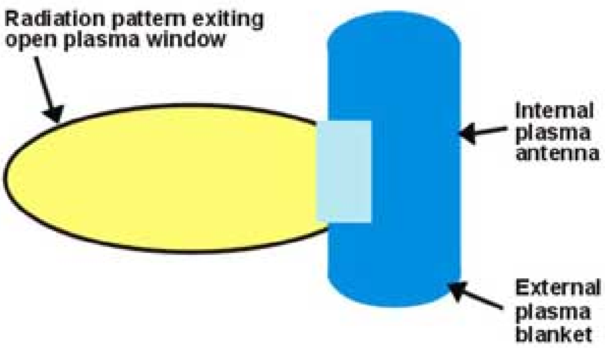
Sponsored Work

To date, plasma antenna technology has been studied and characterized by ASI Technology Corporation revealing favorable attributes in connection with antenna applications. Government sponsored work has included:

• ONR contract N66001-97-M-1153 May 1997 - The major objective of this program was to determine the noise levels associated with the use of gas plasma as a conductor for a transmitting and receiving antenna. Both laboratory and field-test measurements were conducted.

• ONR contract N00014-98-C-0045 November 1997 - The major objective of this effort was to characterize the GP antenna for conductivity, ionization breakdowns, upper frequency limits, excitation and relaxation times, ignition mechanisms, temperatures and thermionic noise emissions and compare these results to a reference folded copper wire monopole. The measured radiation patterns of the plasma antenna compared very well with copper wire antennas.

• MDA Phase I SBIR Contract DASG60-01-P-0063 May 2001 - This six month work (expanded for an additional three months by MDA) focused on using plasma rather than solid metal as the current medium for an antenna. We illustrated the use of controllable apertures (open plasma windows) for far field antenna radiation. Experiments verified our plasma windowing concept.

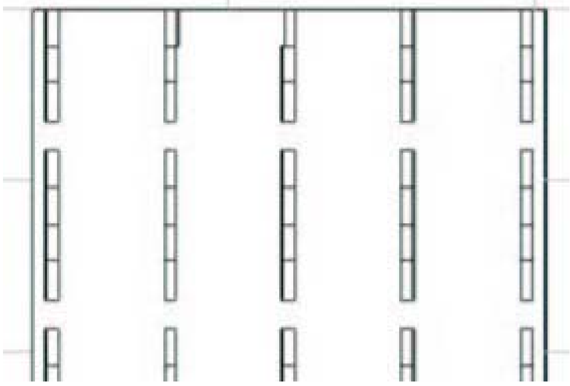


• MDA Phase II SBIR Contract DASG60-02-C-0055 April 2002 - This 24 month contract is focusing on developing a feasibility prototype high power antenna based on our windowing concept and to design and develop a high power phased array using plasma phase shifters to steer the beam. Malibu Research Associates is our subcontractor on this project.

• MDA Phase I SBIR Contract DASG60-02-P-0033 April 2002 - This 6 month contract focused on using plasma as a replacement for metal in a frequency selective surface (FSS) used to filter electromagnetic waves. A tunable FSS can absorb frequencies above the resonant frequency and reflect those above to reduce radar vulnerability to countermeasures. Plasma is an excellent shield and filter for antenna systems.

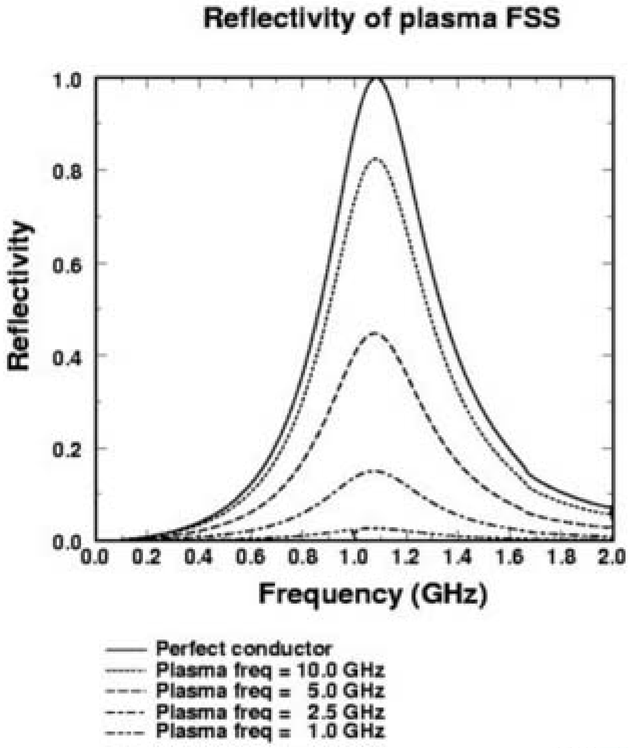
Tunable Plasma Frequency Selective Surfaces for Shielding Radar Systems

Schematic representation of an FSS dipole array



This sketch illustrates a finite section of an FSS dipole array. The array elements are the vertically aligned rectangular regions. The horizontal lines on the rectangles indicate the way in which the elements are broken up into segments for the purpose of defining current modes.

Plot of ASI's theoretical model



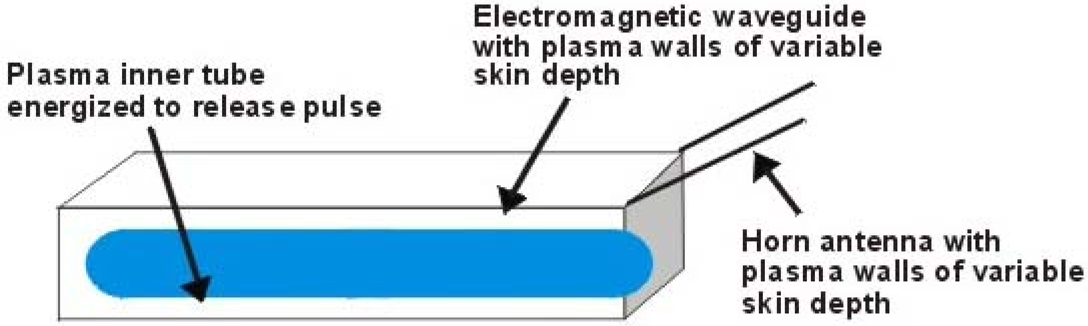
This theoretical plot is of the plasma FSS array illustrated above. Each dipole element is assumed to be in length, in diameter. The vertical separation is taken to be while the lateral separation is taken to be The plot has the curves for the perfectly conducting case (high plasma frequency and density) along with those for several values of the plasma frequency, which depends on plasma density. A well-defined reflectivity resonance exists at 1GHz. This result indicates that appreciable reflection occurs only for plasma frequencies above 2.5GHz. The results illustrate the essence of the plasma FSS: a highly reflective band stop filter can be achieved which can be switched on and off simply by controlling the properties of the plasma.

• Navy Phase I SBIR Contract N00178-03-C-1013 January 2003 - This contract intends to develop a gas plasma antenna array architecture capable of meeting the broad Navy objectives for future shipboard radar systems. We are proposing a compendium of plasma technologies that could be integrated into existing radar suites or be designed into future revolutionary radars. These technologies are plasma windowing, plasma waveguides, plasma Frequency Selective Surfaces and flat parabolic arrays (FLAPS).

ASI Technology Corporation developed under contract with General Dynamics Electric Boat Division and in conjunction with the Plasma Physics Laboratory at the University of Tennessee, an inflatable plasma antenna. This antenna operatedat 2.4 Ghz and was designed to mount on the mast of an attack submarine. We have also demonstrated prototype plasma waveguides and plasma reflectors to General Dynamics.

Plasma Waveguide with energized tube as a switch acting as a window for a pulse

The following discussion illustrates why there is military and government support for plasma antenna concepts. The gas plasma antenna conducts electron current like a metal and hence can be made into an antenna but with distinct advantages. The following technological concepts are important to plasma antennas:



1. Higher power - Increased power can be achieved in the plasma antenna than in the corresponding metal antenna because of lower Ohmic losses. Plasmas have a much wider range of power capability than metals as evident from low powered plasma in fluorescent bulbs to extremely high-powered plasmas in the Princeton University experimental fusion reactors. In this range, a high-powered plasma antenna is still low powered plasma. Since plasmas do not melt, the plasma antennas can provide heat and fire resistance. The higher achievable power and directivity of the plasma antenna can enhance target discrimination and track ballistic missiles at the S and X band.

2. Enhanced bandwidth - By the use of electrodes or lasers the plasma density can be controlled. The theoretical calculations on the controlled variation of plasma density in space and time suggest that greater bandwidth of the plasma antenna can be achieved than the corresponding metal antenna of the same geometry. This enhanced bandwidth can improve discrimination.

3. EMI/ECI - The plasma antenna is transparent to incoming electromagnetic signals in the low density or turned off mode. This eliminates or diminishes EMI/ECI thereby producing stealth. Several plasma antennas can have their electron densities adjusted so that they can operate in close proximity and one antenna can operate invisible to others. In this physical arrangement mutual side lobe and back lobe clutter is highly reduced and hence jamming and clutter is reduced.

4. Higher efficiency and gain - Radiation efficiency in the plasma antenna is higher due to lower Ohmic losses in the plasma. Standing wave efficiency is higher because phase conjugate matching with the antenna feeds can be achieved by adjusting the plasma density and can be maintained during reconfiguration. Estimates indicate a 20db improvement in antenna efficiency.

5. Reconfiguration and mutifunctionality - The plasma antenna can be reconfigured on the fly by controlled variation of the plasma density in space and time with far more versatility than any arrangement of metal antennas. This reduces the number of required elements reducing size and weight of shipboard antennas. One option is to construct controlled density plasma blankets around plasma antennas thereby creating windows (low-density sections of the blanket) for main lobe transmission or reception and closing windows (high-density regions in the plasma blanket). The plasma windowing effect enhances directivity and gain in a single plasma antenna element so that an array will have less elements than a corresponding metal antenna array. Closing plasma windows where back lobes and side lobes exist eliminates them and reduces jamming and clutter. This sidelobe reduction below 40db enhances directivity and discrimination. In addition, by changing plasma densities, a single antenna can operate at one bandwidth (e.g. communication) while suppressing another bandwidth (e.g. radar).

6. Lower noise - The plasma antenna has a lower collision rate among its charge carriers than a metal antenna and calculations show that this means less noise.

7. Perfect reflector - When the plasma density is high the plasma becomes a loss-less perfect reflector. Hence there exist the possibilities of a wide range of lightweight plasma reflector antennas.