

An Operating Intelligent Plasma Antenna

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Abstract

We have developed and demonstrated a prototype for an intelligent plasma antenna. Circular plasma tubes have been used. Both unwanted background noise and multi-path reception clutter are reduced. A computer de-energizes a plasma tube, causing a lobe of microwave radiation to be emitted. Sequentially de-energizing the plasma tubes causes the radiation lobe to scan in azimuth. When a receiving antenna is detected, the computer ceases scanning, and locks onto the receiving antenna. In addition we have demonstrated the opening of a plasma microwave barrier in microseconds, and the intercepting of microwave radiation independent of polrization in plasma tubes.



Figure 1. Plasma Antenna.

I. Plasma Antenna

A plasma is an ionized gas which, when highly energized, behaves as a conductor. A plasma antenna [1] generates localized concentrations of plasma to form a plasma mirror which deflects an RF beam launched from a central feed located at the focus of the mirror. An ionized region, or solid state plasma, can be generated in silicon using electronically controlled devices (plasma diodes) that are positioned between closely spaced metal surfaces which constrain the beam. One may find in Fig. 1 a demonstration of a plasma antenna. In Fig. 2 a plasma antenna installed in an electrical anechoic chamber and a metal antenna designed to be an identical twin to the plasma antenna have been shown. The microwaves are generated by a line antenna, focused in one dimension by the metal pillbox, and focused in the second dimension by either the plasma antenna or a metal twin [2].

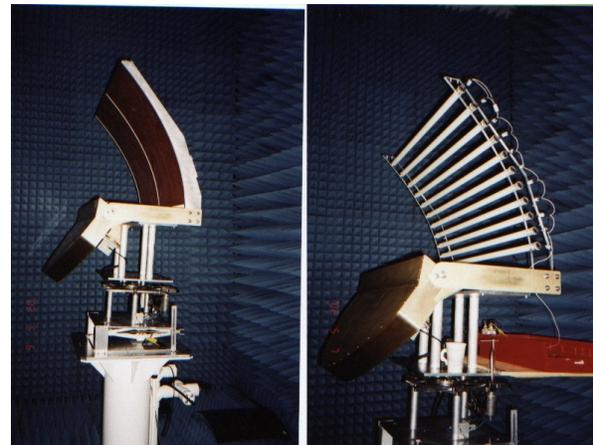


Figure 2. Typical Plasma Antennas. Plasma antenna installed in an electrical anechoic chamber and a metal antenna designed to be an identical twin to the plasma antenna.

II. Intelligent Antenna

Smart antenna is a system of antenna arrays with smart signal processing algorithms. The smart antennas are used to identify the direction of arrival of the signal, to calculate beamforming vectors, to track and locate the antenna beam on the mobile/target. Early smart antennas were designed for governmental use in military applications, which used directed beams to hide transmissions from an enemy. Presently smart antennas

may have many applications including cell phones because they provide greater capacity and performance benefits than standard antennas.

Smart antenna as shown in Fig. 3 are divided two types: 1) switched beam smart antennas that a decision is made as to which beam to access, at any given point in time, based upon the requirements of the system; and 2)

adaptive array smart antennas those allow the antenna to steer the beam to any direction of interest while simultaneously nulling interfering signals.

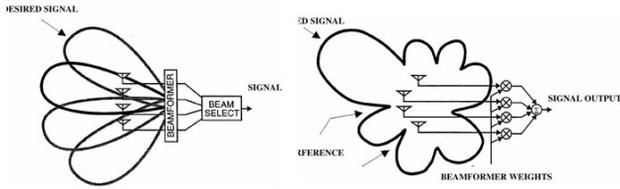


Figure 3. Two types of intelligent antennas: 1) switched beam smart antenna, and 2) adaptive array smart antenna.

In Fig. 4 a radiation pattern [3] is shown that compares plasma antenna (blue dots) and solid reflector (red). In Fig. 5 a plasma antenna is used for receiving radio FM and AM waves to a radio. When we increase the density of plasma in the tube, the antenna works in FM. In the lower density the antenna works in both FM and AM.

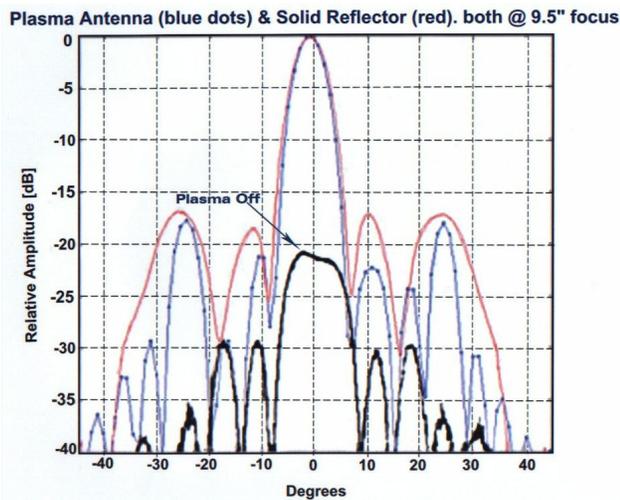


Figure 4. Comparison of radiation pattern in plasma antenna (blue dots) and solid reflector (red).

III. An Operating Intelligent Plasma Antenna

We have used a ring of plasma tubes operating beyond microwave cut-off surrounding a metal transmitting antenna shown in Fig. 6. The plasma tubes are common fluorescent lamps, operating in the cold-cathode mode and wired in series to a high-voltage DC supply. To de-energize a specific tube, it is short-circuited by a high voltage Jennings switch. The individual tubes are de-energized in sequence by a computer, custom designed by Impeccable Instruments. The signal is received on a simple diode detector, and is fed into the computer. When the received signal exceeds a designated adjustable threshold, the computer ceases scanning, and holds this window open. If the received signal subsequently drops below this threshold, the computer recommences the

scanning process. The present scanning rate is about one second per tube.

A computer de-energizes a plasma tube (see Fig. 6), causing a lobe of microwave radiation to be emitted. Sequentially de-energizing the plasma tubes causes the radiation lobe to scan in azimuth. When a receiving antenna is detected, the computer ceases scanning, and locks onto the receiving antenna. When the receiving antenna is disconnected, the computer recommences scanning, looking for another receiving antenna.



Figure 5. A Plasma Antennas connected to a Radio.



Figure 6. Demonstration of a prototype for an intelligent plasma antenna. A ring of plasma tubes operating beyond microwave cut-off surrounds a metal transmitting antenna.

IV. Plasma Microwave Barrier

Plasma barriers are used to protect sensitive microwave apparatus from potentially damaging electronic warfare signals.

Unfortunately, the characteristic decay time of the plasma after power turn-off is typically many milliseconds, so the

opening time of such a barrier generally is predicted also to be many milliseconds (see Fig. 7 and 8). However, we have showed both experimentally and theoretically that we can open such a barrier on a time scale of microseconds. We do this by increasing the plasma density rather than waiting for it to decay. We have two layers of plasma. A standing wave is produced between the two layers that results in microwave transmission, analogous to the transmission found in an optical Fabry-Perot Resonator. The secret lies in the boundary layer behavior of the plasma. Once microwave cut-off occurs, one would expect the plasma behavior to be static.



Figure 7. Fabry-Perot apparatus.

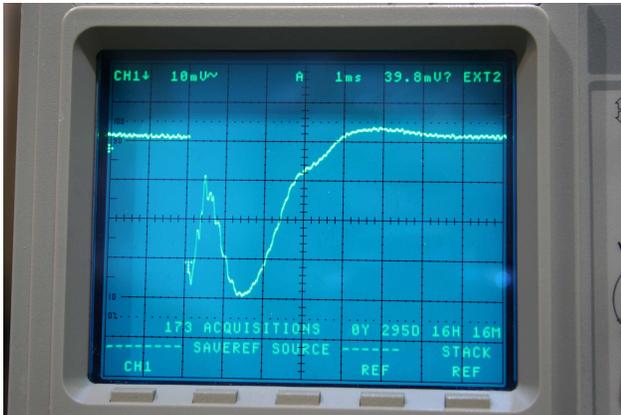


Figure 8. Opening of a plasma microwave barrier in microseconds.

What actually occurs is that at microwave cut-off, the reflection is in phase with the incident wave, in analogy to an open coaxial line. (The electron and displacement currents are equal, but out-of-phase) As the plasma density further increases, the reflection smoothly changes from in-phase to 180 degrees out-of-phase, in analogy to a shorted coaxial line. (The reflection current is much greater than the displacement current.)

Here, $E_r = \left(\frac{1-i\beta}{1+i\beta} \right) E_0$ where E_0 is the incident electric field, E_r is the reflected electric field, and β is

given as $\beta = \sqrt{\left(\frac{\omega_p}{\omega} \right)^2 - 1}$. The consequence of this

phase shift is that, given any kind of a plasma resonator, if the plasma density is raised high enough, the resonance required for the Fabry-Perot effect to take place must occur.

V. Polrization in Plasma Tubes.

We have been designing a plasma shield intended to protect sensitive microwave equipment from intense electronic warfare reflector. The plasma tubes work extremely well in intercepting microwave radiation when the incident wave electric field is parallel to the tubes. However, if the electric field is perpendicular to the tubes, the normally induced plasma current cannot flow, and the plasma effects are not expected to appear. To our surprise, when the plasma tubes were experimentally tested with the electric field perpendicular to the tubes, the plasma tubes not only intercepted the microwave signal, but the observed cut-off with a pulsed plasma lasted about twice as long (see Figs. 9 and 10). The effect appears to be due an electrostatic resonance, and preliminary calculations suggest that a normally ignored term in Maxwell's Equations is responsible.



Figure 9. Attenuation E-field parallel to tubes.

$$\nabla^2 E - \nabla(\nabla \cdot E) = \eta_0 \epsilon_0 \left(\omega_p^2 + \frac{\partial^2 E}{\partial t^2} \right),$$

The term responsible appears to be $\nabla(\nabla \cdot E)$. The frequencies involved are in the range of 2.5 GHz. The plasma tubes used are conventional fluorescent lamps. In

any event, regardless of the theory, the experimental results demonstrated that shielding a sensitive receiving antenna by a layer of parallel plasma tubes is considerably more effective than had been expected.



Figure 10. Attenuation E-field perpendicular to tubes.

VI. Summary

We may summarize our results as: 1) We have produced a computer controlled intelligent plasma antenna. 2) We have demonstrated that plasma windows can open in microseconds. 3) We have demonstrated that plasma windows can open in microseconds. In conclusion, plasma antennas offer many advantages over metal antennas.

Acknowledgments

This work supported by Phase 2 SBIR Grants from the US Army (contract number W15QKN-06-C-0081) and US Air Force (contract number FA9453-06-C-0068).

VII. REFERENCES

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