Haleakala Research and Development, Inc.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

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Antenna Systems 2015

Plasma Antenna Patents Relevant to RFID and Owned by Dr. Theodore Anderson

1. Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas. Patent No. 6,870,517.

2. Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas. Patent No. 7,342,549.

3. Reconfigurable scanner and RFID system using the scanner, Patent No. 6,922,173

4. Near-field plasma reader, Patent No. 6,700,544. .

5. Tunable plasma frequency devices, Patent No. 7,292,191.

6. Tunable plasma frequency devices, Patent No. 7,453,403.

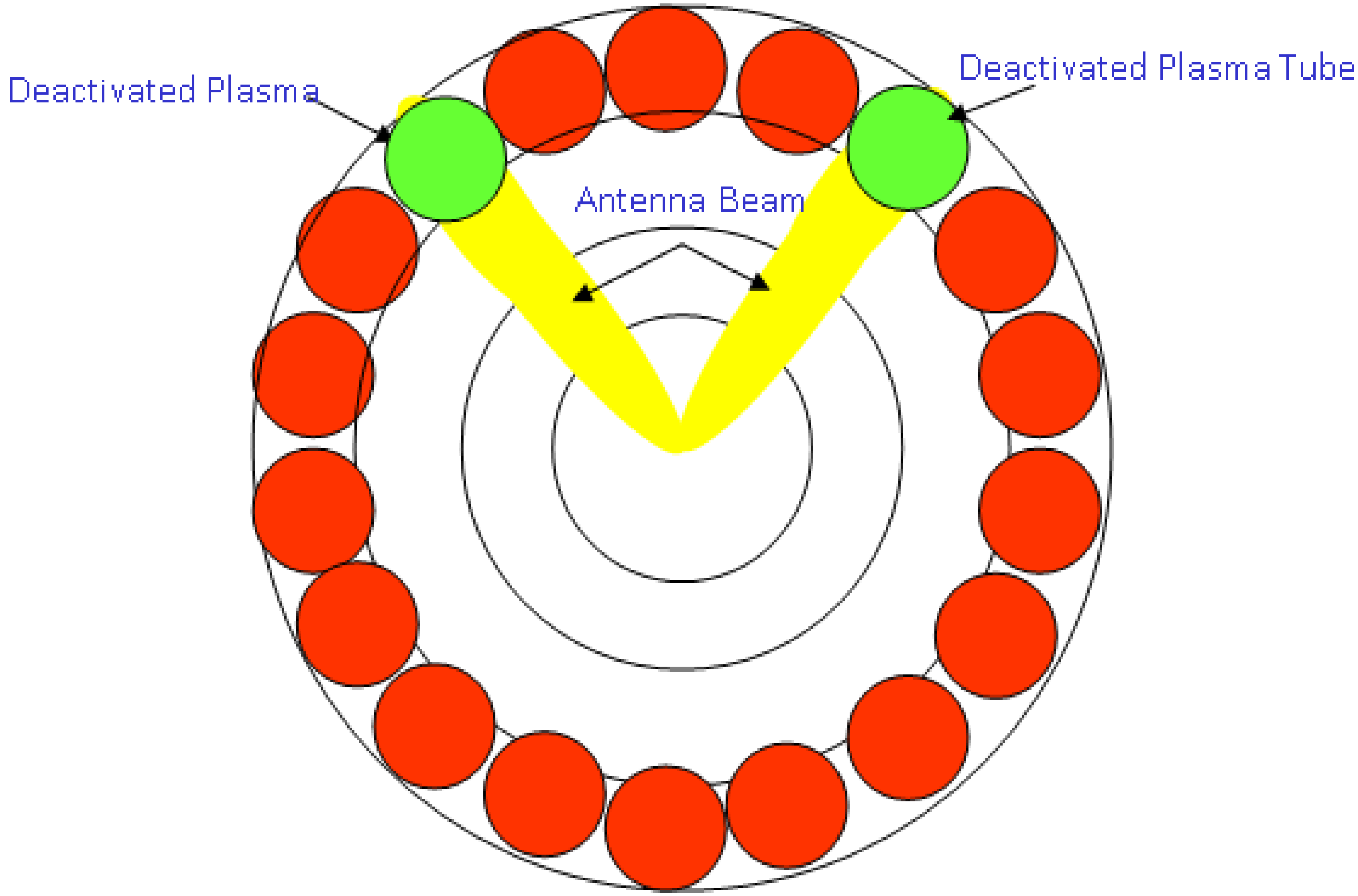
7. High SNR plasma antenna. Patent No. 8,077,094.

8. Reconfigurable scanner and RFID. Patent number RE43, 699.

9. Plasma Devices for Steering and Focusing Antenna Beams; U.S. Patent Issue Number: 8,384,602

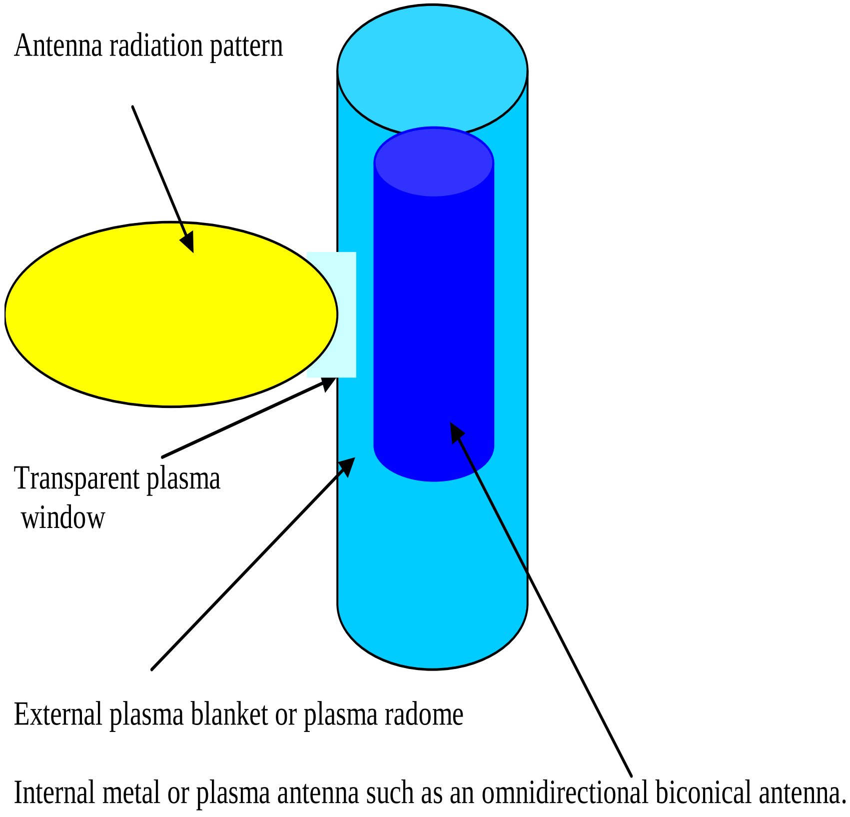
Schematic of a two beam smart plasma antenna RFID reader.

External plasma blanket (in this case in the form of plasma tubes) in red steers and shapes the reader beam and also protects the inside reader antenna from EMI.



Schematic of a smart plasma antenna RFID reader. External plasma blanket steers and shapes the reader beam and also protects the inside reader antenna from EMI.

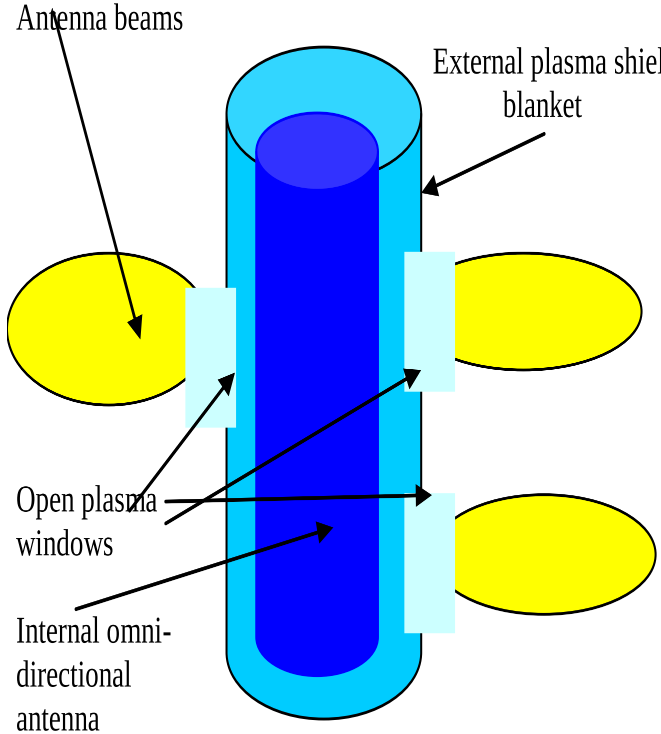
Below is a schematic of a smart plasma antenna RFID reader.



Schematic of a three antenna beam smart plasma antenna RFID reader.

External plasma blanket steers and shapes the reader beam and also protects the inside reader antenna from EMI.

Below is a schematic of a three antenna beam smart plasma antenna RFID reader.



Smart plasma antenna RFID reader with engineer

Ruggedized smart plasma antenna RFID reader

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The smart plasma antenna is based on opening and closing antenna windows to create antenna beam steering.
- It can steer 360 degrees in the azimuthal direction and 180 degrees in the z direction.
- The smart plasma antenna RFID reader can scan and read both passive and active RFID tags.
- Furthermore the smart plasma antenna is very compact compared to a phased array because plasma physics is used to steer and shape the antenna beam.
- The smart plasma antenna can easily fit in a small room where tags are to be read. It meets most SWaP criteria.
- The smart plasma antenna can have an omnidirectional metal antenna along the central axis such as a dipole or biconical antenna and is surrounded by a cylindrical ring of plasma tubes to shape and steer the antenna beam.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The diameter of the smart plasma antenna is approximately one wavelength.
- When one of the plasma tubes has the plasma extinguished, it creates an aperture for the antenna beam. This is an open plasma window.
- The other plasma tubes are on with the plasma not extinguished.
- These plasma tubes with closed plasma windows protect the inside antenna from EMI.
- EMI is reflected from the closed plasma windows of the smart plasma antenna if the plasma density is high enough so that the plasma frequency is greater than the frequencies of the external EMI.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The plasma frequency is proportional to the square root of the unbound electrons and is a measure of the amount of ionization of the plasma.
- If the inside antenna is a plasma antenna then not only is the beamwidth reconfigurable but the bandwidth is reconfigurable with a reconfigurable center line frequency.
- The reconfigurable bandwidth is equal to the difference in plasma frequencies from the inside plasma antenna and the plasma frequency of the outside cylindrical ring of plasma tubes.
- Thus by reconfiguring the relative plasma densities of the inside plasma antenna and the outside ring of plasma tubes, the bandwidth and centerline frequencies get reconfigured.
- This is useful in an RFID reading when some tags need to be read and others ignored through reconfigurable frequency filtering.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The steerable smart plasma antenna comprises has a switchable plasma shield of variably plasma elements for controllably opening a transmission window at selected radial angles positioned at an effective distance to intersect at least the transmission radials for the antenna.

- Preferably, the smart plasma antenna has am omnidirectional in the center and the plasma shield is concentric around the antenna to intersect all transmission radials for the antenna.

- The plasma shield may also include switchable plasma elements for controlling an elevation angle of the transmission lobe passing through the window, so that the antenna is steerable on two axes.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The electromagnetic shield is formed by a cylindrical annular ring of switched variable plasma elements.
- In one design, the shield is a ring of plasma tubes extending parallel with the omnidirectional antenna.
- When the variable plasma elements are non-conducting or at low density in the case of plasma, so that the plasma frequency is lower than the incident transceived frequencies, or if the plasma elements are off and form a transmission window.
- The omnidirectional antenna can be a conventional metal dipole or other configuration antenna, a plasma antenna or an optical wavelength transmitter.
- Plasma antennas include nested plasma antennas and even stacked plasma arrays of the same type used to form the shield.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The transmission window is formed by either turning off power to the appropriate electromagnetic shield elements, or otherwise making the desired shield elements transparent to the transmitting antenna, such as by reducing plasma density below the threshhold needed to block transmission of an incident signal frequency.
- The shield elements are preferably rapidly switchable, so that the radial transmission direction of the antenna can be changed within microseconds, or faster by Perot-Etalon effects.
- The shield elements are selected for use with antennas broadcasting on a broad range of frequencies.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- An alternate design of the shield utilizes a cylindrical array of switchable variable plasma elements to provide more selective control over where openings in the shield are formed.
- The cylindrical annular shield with the array surrounds an antenna. The elements forming the array are arranged in multiple rows and columns on a substrate.
- The substrate can be a planar sheet rolled into a cylinder shape.
- The variable plasma elements can be either switchable regions surrounding air or other dielectrics in fixed gaps or slots, so that the effective size of the fixed slots can be changed rapidly, or the elements can be formed as linear conductors, rectangles, stars, crosses or other geometric shapes of plasma tubes, photonic bandgap crystals or solid state semiconductors on the substrate.
- The substrate is preferably a dielectric, but may also be made from a conductive metal.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- A more complex shield for the antenna has one or more stacked layers, with each layer being a switchable array of variable plasma elements.
- The layers are spaced within one wavelength of adjacent layers to ensure proper function.
- Each switchable array in the stack can be a filter, a polarizer or a phase shifter, a deflector, or a propagating antenna.
- The layers are combined to produce a particular effect, such as producing a steerable antenna transmitting only polarized signals in specific frequency bands.
- Layers of annular rings, for example, can be stacked at distances corresponding to wavenumber times distance from the central antenna which correspond to transmission peaks for particular frequencies.
- By stacking several frequency-selective layers, a multi-frequency antenna is produced which is controllable to selectively transmit and/or receive each frequency along a particular radial of the smart plasma antenna.

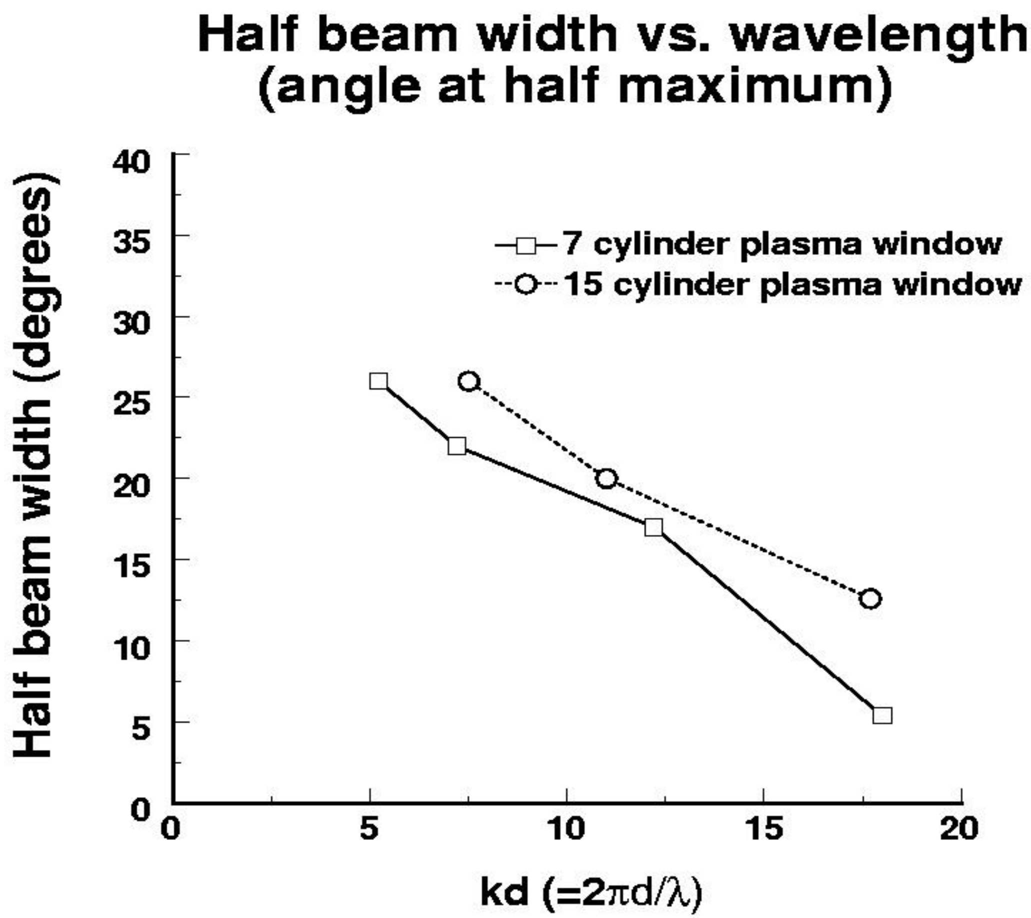
Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- In a further design of the smart plasma antenna, the scanner can be used to track a particular RFID ID tag when one or both are moving, without physical re-orientation of the smart plasma antenna scanner.
- A central unit can be stationary or mobile and has a scanner with one of the two antenna configurations described which is controllable to scan along a specified radial from the scanner.
- The central unit includes circuits for determining when a connection is made between the scanner and RFID ID tag and maintaining the connection while they move relative to each other.
- Once a connection is made, the electromagnetic plasma shield of the unit steerable plasma smart antenna is activated to produce only a transmission window and radiation lobe along the radial axis needed to maintain the connection with the central unit.
- The steerable smart plasma antenna shield on the central and each connected unit is adjusted to compensate for their relative movement while maintaining the connections.

Smart Plasma Antenna as an RFID Reader with Built-in Protection against EMI

- The inactive plasma element is excitable to an active state by an incident received signal.
- The plasma is energized and permits the RFID ID tag to generate a detectable return signal with date or interference in response to the incident signal.
- The incident signal may be a scanning signal or other energizing signal.
- The plasma in the plasma element may be maintained in a weakly or weakly partially ionized state by a power source, such as a battery, laser, voltage source, a radiation source or radioactive source in a known manner, so that the plasma is more easily fully energized by the incident signal.

Half power beam-width versus wavelength for a 8 cylinder smart plasma antenna RFID reader with one window and a 16 cylinder smart plasma antenna RFID reader with one plasma window



Conclusions

- Smart plasma antennas are excellent RFID readers:
  - They are compact and lightweight. The basic dimensions are a wavelength in diameter and height for a cylindrical design.
  - They can steer in the azimuthal and vertical directions for a cylindrical design.
  - The center line frequency is reconfigurable
  - The beamwidth and bandwidth are reconfigurable
  - Single antenna lobes or multilobes can be created.
  - Reconfiguration using Fabry-Perot-Etalon Effects can take place in microseconds.
  - The plasma that steers and shapes the reader antenna beam acts as a shield to EMI.