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PLASMA ANTENNAS

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ABSTRACT

Plasma antennas refer to a wide variety of antenna concepts that incorporate some use of an ionized medium. This study summarizes the essential theory behind the operation of plasma antennas based on a survey of patents and technical publications. Plasma Antenna is a new captivating concept which could very well be the future of high-frequency, high-speed wireless communications. Using Plasma antennas, it is possible to transmit focused radio waves that would quickly dissipate using the conventional antennas. A plasma antenna is a type of radio antenna currently in development in which plasma is used, replacing the metal elements of a traditional antenna. Plasma antennas can be used for both transmission and reception. Although plasma antennas have solely been implemented in recent years, the concept is not new. A patent for an antenna using the idea was granted to J Hettinger in 1919.

KEYWORDS: Plasma, Wi-Fi, Beam-Focusing, Silicon Chip, Electron Cloud, Emitting Element, Passive State, Conductivity, Antenna Detectability, Metal Reflector, Cylindrical Monopole, Maxwell Curl Equations, Boltzmann Equation, Electron Distribution Function (EDF)

INTRODUCTION

Copy of first plasma antenna.

Figure 1

Transmission and reception of electromagnetic waves has become an integral part of the current day civilization. Antenna is a necessary device for this process. It is an electrical transducer that transmits or receives electromagnetic waves. In other words, antenna is defined as an electrical conductor of a specific length that radiates radio-waves generated by a transmitter and collects these waves at the receiver.

Figure 2

Antennas are used in systems such as wireless LAN (local area networks), cell phones, radar, radio and television broadcasting, point-to-point radio communication, and spacecraft communication. Antennas are generally used in air and outer space, although they can also be employed underwater or through soils and rocks.

Growing need for increase in speed of communication network along with data handling capacity are the major forces helping to explore new vistas of transmission and reception. With the wireless technologies moving from 2G to 3G, 4G, 5G, then on, the real advantage of upgrading the Wi-Fi networks is to get them to run faster. Wi-Fi can manage 54 megabits of data per second (54mbps). The fancied Wi-Fi using Plasma antenna technology would handle up to 7 gigabits per second (7Gbps). Thus we could download a TV show in a few seconds. Advances in antenna technology are expected to play a great role in the desired speed and capacity handling capabilities of communication networks.

FUNDAMENTAL PLASMA THEORY

The different states of matter generally found on earth are solid, liquid and gas. In 1879, an English physicist, Sir William Crookes, acknowledged a fourth state of matter, which is now known as Plasma.

Figure 3

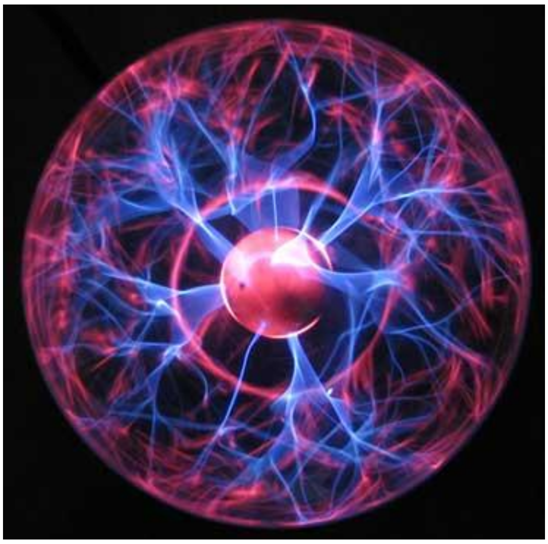

Figure 4

Plasma is by far the most common form of matter. Plasma in the stars and in the questionable space between them makes up over 99 per cent of the visible universe and possibly most of what is not visible. Concerning antenna technology, plasmas are conductive assemblies of charged and neutral particles and fields that exhibit collective effects. Plasmas carry electrical currents and generate magnetic fields. In a plasma antenna, the customary metal-conducting components of a conventional antenna are replaced by plasma. These are antennas operating in the radio frequency that use plasma as the guiding medium for electromagnetic radiation. The plasma antennas are basically a cluster of thousands of diodes on a silicon chip that produces a tiny cloud of electrons when charged. These tiny, dense electron clouds can reflect high-frequency waves like mirrors. This is done by focusing the beams by selectively activating specific diodes. The ‘beam-forming’ capability could allow ultra-fast transmission of high data loads-like those needed to flawlessly stream a TV show to an untethered tablet. This creates an attractive alternative for the next generation of super-charged wireless transmitters. Several types of plasma antennas can be built, including dipole, loop and reflector antennas. In Plasma antennas, the plasma with electric conductivity serves as an emitting element.

In gas plasma antenna, the concept is to use plasma discharge tubes as the antenna elements. When the tubes are energized, these transform into conductors, and can send and receive radio signals. When de-energised, these relapse into non-conducting components and do not reflect prying radio signals. The fact that the emitting element is formed over the interval required for the emission of an electromagnetic pulse is a vital advantage of plasma antennas. In the absence of plasma in the discharge tube, such a device does not exhibit electric conductivity. It remains passive. A plasma stream flowing from a jet into the surrounding space, the plasma trace of a body moving at an ultrasonic velocity in the atmosphere, and optional plasma objects have been studied as possible antenna elements. These solid-state plasma antennas use beam-forming technology and the same manufacturing process that is currently used for silicon chips. That makes it sufficiently small to fit into smart phones.

Higher frequencies mean shorter wavelengths and hence antennas which are smaller in size. The antenna actually becomes cheaper with the smaller size because it needs less silicon. There is a gas plasma alternative however it’s not solid state, thus it is bigger and contains moving parts. This makes it more of an issue to manufacture. That makes way for solid-state plasma antenna to be used for next generation Wi-Gig (was announced in December 2009) that can reach up to 7Gigabits per second bandwidth over frequencies upto 60 GHz.

Figure 5

DEVELOPMENT PROGRESS

Primary investigations were associated with the feasibility of plasma antennas as low-radar cross-section radiating elements and thus further development and future commercialization of this technology. The plasma antenna R&D project has advanced to develop a new antenna solution that minimizes antenna- detectability by radar at the first instance. But since then an investigation of the greater technical issues of existing antenna systems has revealed areas where plasma antennas might be functional. A noteworthy progress has been made in developing plasma antennas. Presently, plasma antennas have been working in the region of 1 to 10 GHz. Field trials have shown that an energized plasma reflector is essentially as effective as a metal reflector. On the other hand, when de-energized, the reflected signal falls by over 20 dB. Yet a few technicalities associated with plasma antennas like increase in the operation plasma density without overloading the plasma discharge tubes, reduction of the power required and the plasma noise caused by the ionizing power supply, etc, have to be introspected in order to make them the practical technologies for wireless communication in near future.

The future of high-frequency, high-speed wireless communications could very well be plasma antennas capable of transmitting focused radio waves that would quickly dissipate using conventional antennas. Thus, plasma antennas might be able to revolutionize not just high-speed wireless communications but also radar arrays and directed energy weapons. The promising hope is that plasma antennas will be on-the-shelf in the upcoming years. The bad news is that some military powers can use it to create a more advanced version of its existing pain beam.

STRUCTURE OF THE PLASMA ANTENNA

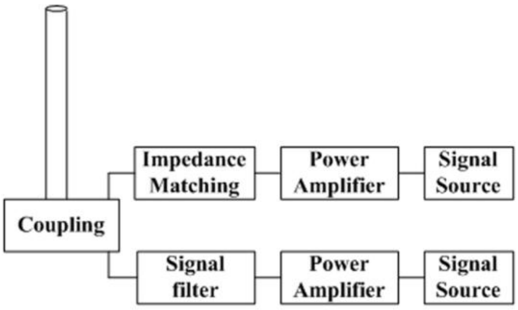

Figure 6: The Structure of Monopole Cylindrical Plasma Antenna Excited by Surface Wave

The plasma antenna system consists of two parts, one is the excited power circuit part and the other is the transmitting signal circuit part. The two circuits are made up of signal source, power amplifier, filter, and impedance matching part, etc. as shown in figure. The measurement of the plasma antenna in near field and far field can adopt the measure methods of the metal antenna with modifying in the measure equipments and environment.

The plasma is created by the RF excitation power. Electromagnetic power is coupled into the antenna through RF coils. The inductive magnetic field presents axial distribution and the inductive electric field presents radial distribution around the plasma antenna. The inductive magnetic field presents axial reverse symmetric distribution.

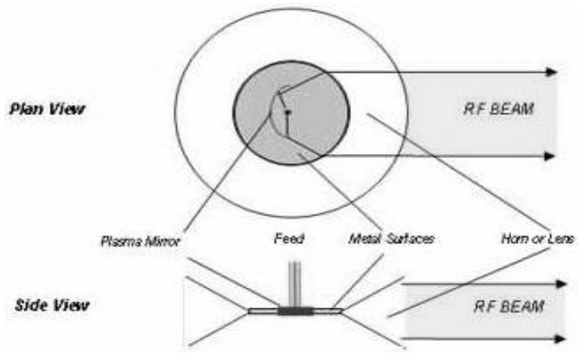

Figure 7

As the state of plasma antenna is determined by power and frequency of the excitation electromagnetic field, and the gas pressure and composition of discharged gas and other parameters are also the influence factors of plasma antenna. In addition, in order to describe the interaction mechanism between the electromagnetic field and the plasma, it is necessary to understand how plasma changes with the work conditions which are adopted in the paper.

The plasma phenomenon can be kinetically modeled with equations including the Maxwell curl equations and the Boltzmann equation. The Boltzmann equation can illustrate the time, space, and velocity evolution of the electron distribution function (EDF), which is expressed as $f(t, r, v)$ where t is the time, r is the location ,v is the velocity of particle. The description of the EDF is the key point to define plasma state, all the macroscopic quantities involved in the problem such as electron density and plasma conductivity etc, can be analyzed with some analytical manipulation from the EDF.

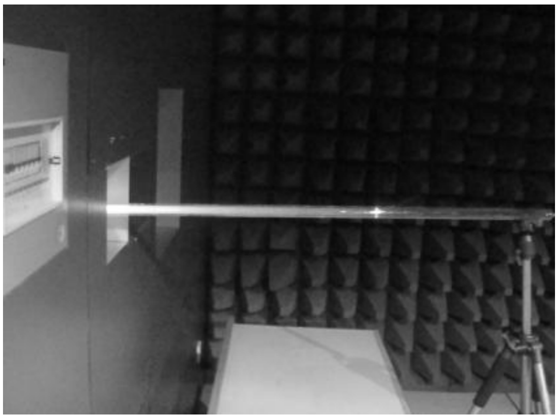

Figure 8: Uniform Distribution in Axial Direction of the Plasma Antenna

WHY USE A PLASMA ANTENNA?

- The plasma antenna can be made to appear and disappear in milliseconds.
- The plasma antenna has an adjustable high-frequency cutoff. It is capable of transmitting and receiving low frequency signals while not communicating with high frequency signals.
- Under special circumstances, plasma antenna can be made operational in microseconds.
- The plasma antenna under special circumstances has less thermal noise than a metal antenna.
- Other applications include plasma lenses and plasma prisms

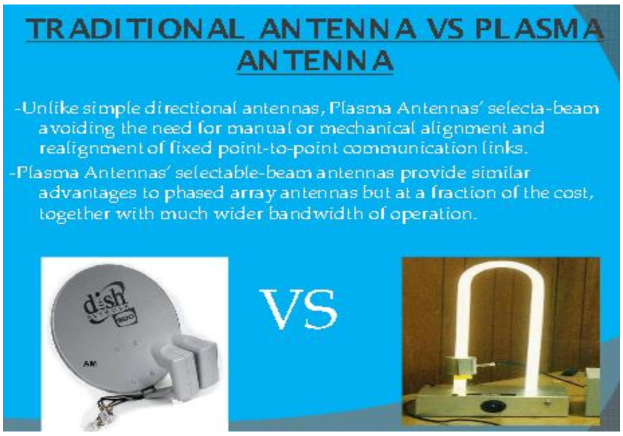

Figure 9

ADVANTAGES

- It is an important advantage that plasma antennas are much lighter than conventional antennas. Based on a set of patented beam-forming technologies, these highly efficient electronically-steerable antennas are extremely lightweight and compact.
- Plasma antennas are free from mechanical parts, thus making them maintenance-free. They are ideally suited for a wide range of wireless communications and sensing applications.
- Plasma antennas have a number of potential reconfigurable advantages for antenna design. When one plasma antenna is de-energised, the antenna goes back to being a dielectric tube. A second antenna can transmit through it. This allows using several massive antennas stacked over each other instead of several small antennas placed next to each other. This results in higher sensitivity and directivity.

- When a plasma element is not energized it is difficult to detect it by radar. Even when it is energized, it is not affected by the transmissions above the plasma frequency, which falls within the microwave region.
- Plasma elements can be energized and de-energised in seconds. This prevents signal degradation and results in good quality transmission.
- When a particular plasma element is not energized, nearby elements remain unaffected by its radiation.
- High frequency radio waves that would ideally dissipate quickly if beamed by conventional arrays, can be focused by plasma antennas.
- Plasma antennas boost wireless speeds. Such antennas could facilitate next-generation Wi-Fi that allows super-fast wireless data transfers.
- Solid-state plasma antennas deliver gigabit-bandwidth, and high frequency plasma antenna could hold the key for economically viable superfast wireless networking.
- Plasma antennas may additionally be used to create low-cost radar arrays that could be mounted on cars to assist them navigate in low-visibility conditions, or used to make more focused, directed and lighter energy weapons.
- Plasma antennas have developed an innovative range of selectable multi-beam antennas that meet the demands in today’s defense, wireless communication and security markets.

LIMITATIONS

- The current hardware uses a wider range of frequencies so it’s impractically massive to be used for mobile environments.
- Plasma antennas are expensive and hard to manufacture.
- High-frequency signals mean that antennas operating at higher frequencies couldn’t penetrate walls like standard Wi-Fi, so signals ought to be reflected throughout the buildings.
- Using plasma antennas, it is possible to theoretically solve some of these issues as these can operate at a wider range of frequencies, but gas antennas are also more complex (and likely more expensive) than their silicon diode counterparts, which are compact enough to suit within a cell phone.
- With plasma antenna technology, there are problems to iron out, but researchers and engineers are optimistic to make this promising technology commercially available in few years.

A prototype plasma antenna.

Figure 10: The Radio Receives Music Only When the Plasma Antenna is on

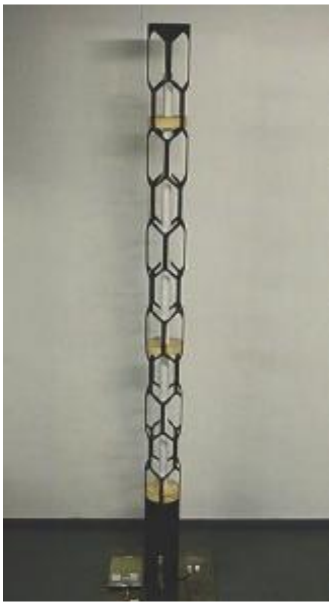

Figure 11: Linear Plasma Antenna Excited at One End by a Surface Wave

CONCLUSIONS

The operational principles of plasma antennas have been known for decades.

The continuing advances in lasers, tubes, signal processing capabilities and solid state electronics have made many of the simpler plasma concepts realizable. Each design generation represents an improvement in performance, reduction in weight and size, and boost in efficiency. In the distant future, plasma-type antennas are possibly the ultimate solution in the hunt for the "ideal" antenna, especially for platforms consisting of non-conducting complex materials. Depending on the function of antenna system, a plasma antenna of any desired shape, size and operational frequency band would be excited at the optimal location on the platform. When the system is not in use the antenna simply disappears, until next required by the system. Plasma antennas could revolutionize high-spreed wireless communications, miniature radar and even energy weapons. Its ability to beam-form high-frequency radio waves into one stream would help deliver wireless content in a snap. Plasma antennas can be made smaller than traditional antennas. The Plasma Silicon Antenna should come to market in a few years. Let's hope so, for the sake of time.

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