PROPOSAL FOR COMMUNICATIONS THROUGH THE PLASMA SHEATH FOR VESSELS WITH HYPERSONIC SPEEDS AND TRACKING VESSELS AT HYPERSONIC SPEEDS.

DR. THEODORE R ANDERSON

CEO, HALEAKALA R&D INC
tedanderson@haleakala-research.com

7 Martin Road, Brookfield, MA 01506, USA

30 MAY 2022

WWW.HALEAKALA-RESEARCH.COM

518 409 1010

I. Radio Communication with Hypersonic Aerial Vehicle by Treating the Plasma Sheath as an Antenna.

References [1-6] and supplementary material in section 18.8 [6] of cover this topic. The idea here is to use the plasma sheath as a leaky wave plasma antenna (Figures 1 and 2) and not try to drive electromagnetic waves at communication frequencies through the plasma with more power. In this approach we are working with the plasma sheath instead of against it. At the present time there is no data yet.

A fast surface wave traveling near the speed of light on the outside of a plasma sheath couples readily to free space. Fast (Vp>c) and slow surface waves (Vp<<c) are launched by a conventional antenna on the inside of the sheath between the plasma and metal vehicle.

Fast surface waves propagate in low loss waveguide fashion. Slow surface waves are absorbed by the plasma.

Due to the finite conductivity of a relatively thin sheath then it is possible for a fast surface wave field to couple through and radiate by the process of antenna leaking.

It may take many wavelengths for the wave to leak through, depending on the plasma conductivity and thickness.

The plasma sheath becomes a leaky wave plasma antenna. This approach is not to eliminate the plasma sheath (very difficult) but optimize the sheath to use it as a leaky wave plasma antenna.

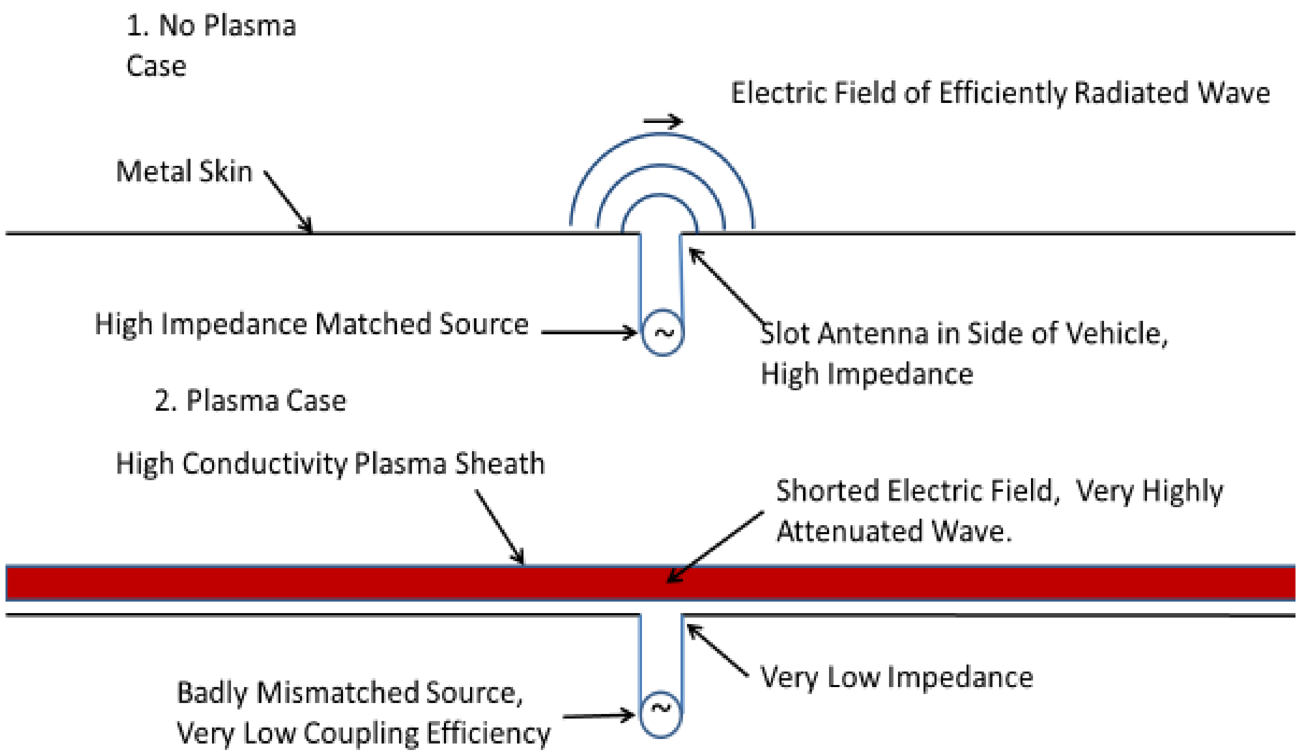


Figure 1. This is a schematic of the region near the metal skin with and without the plasma sheath.

•

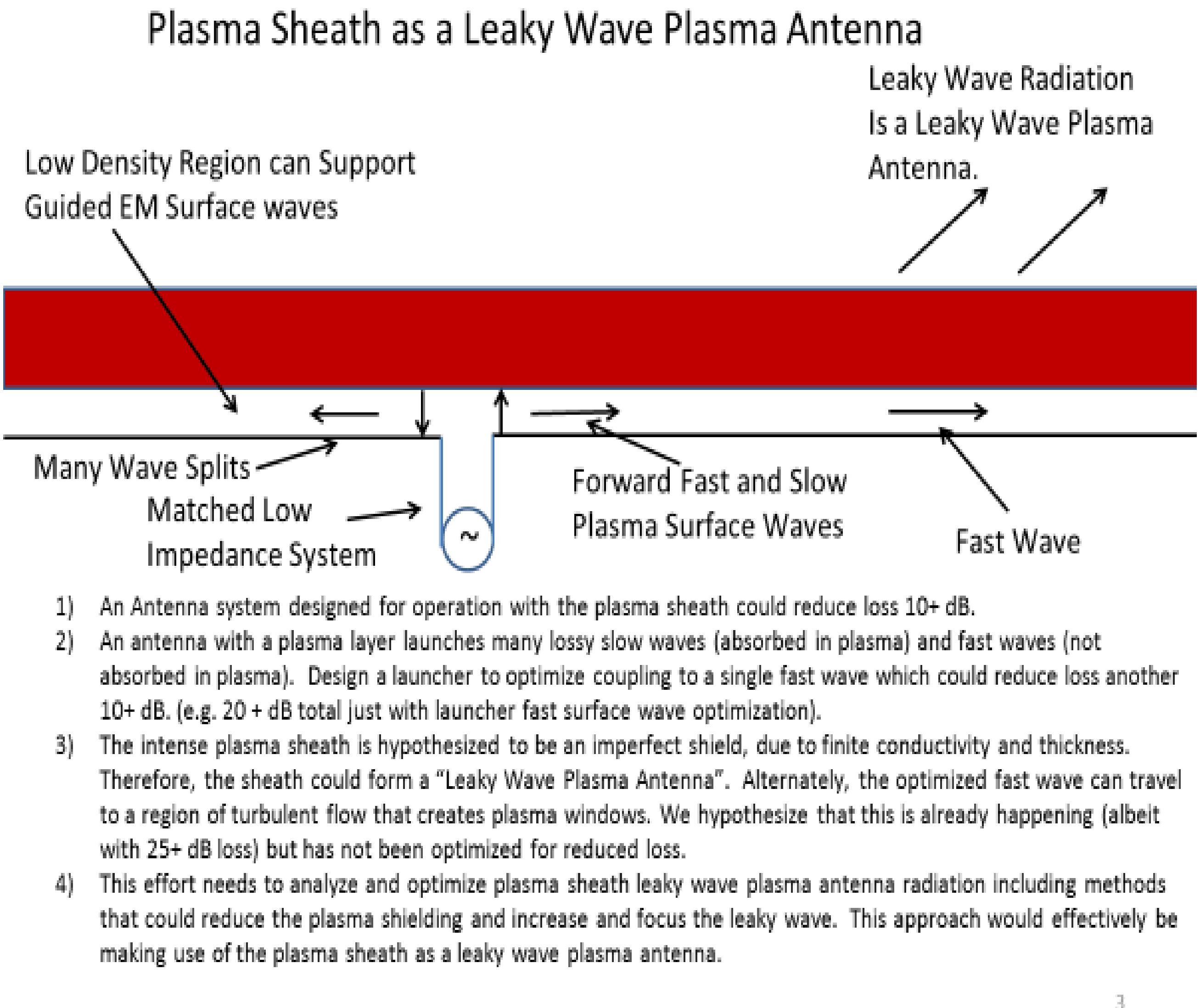


Figure 2. The design and physics for using the plasma sheath as a leaky wave plasma antenna to communicate through the plasma sheath.

STATEMENT OF WORK.

Radio Communication with Hypersonic Aerial Vehicle by Treating the Plasma Sheath as an Antenna

Phase I.

- **Using simulations, theoretical analysis, and experiments to study the wave launching of a slot antenna inside a plasma sheath.**
- **Determine sources of loss:**
  - **from impedance mismatching,**
  - **slow wave coupling,**
  - **fast wave launching loss,**
  - **loss thru plasma.**

Phase II.

- **Use simulations, analysis, and basic experiments to demonstrate principles of slow and fast surface wave couplings.**
- **Use simulations, analysis, and basic experiments to determine input impedance and matching of the antenna in the plasma sheath.**
- **We will simulate, analyze, and measure the fast wave coupling in the plasma sheath.**
- **Guided by standard antenna techniques we will simulate, analyze, and measure radiation resistance and radiation efficiency of the antenna in the plasma sheath to the inside fast surface wave.**
- **Optimize a single fast surface wave.**

Phase III

- **Continue to reduce those losses found in Phase 1 and 2 by tailoring the system and plasma sheath.**
- **Using simulations, analysis, and basic experiments we will study the fast surface wave coupling to the outside and how plasma density and thickness tradeoffs can increase the leaking and radiation.**
- **We will determine if we can reduce (not eliminate) the plasma frequency and/or thickness and increase the leaking with aerodynamic tailoring, charged plates, modest material injection, and modest magnets.**
- **Using simulations and basic experiments we will determine if our techniques can reduce the losses down to low enough levels at 1-6 GHz that will allow communications through the plasma sheath.**

References

[1] Chadwick, K. M., D. W. Boyer, and S. S. Andre, “Plasma and Flowfield Induced Effects on Hypervelocity Reentry Vehicles for L-Band Irradiation at Near Broadside Aspect Angles.” in 27th AIAA Plasmadynamics and Lasers Conference, New Orleans, LA, June

1996, https://arc.aiaa.org/doi/10.2514/6.1996-2322.

[2] Norris, G., "Plasma Puzzle: Radio Frequency-Blocking Sheath Presents a Hurdle to Hypersonic Flight," Aviation Week & Space Technology, March 2009, p. 58.

[3] Blottner, F. G., "Viscous Shock Layer at the Stagnation Point with Nonequilibrium Air Chemistry," AIAA Journal, Vol. 7, No. 12, December 1969, pp. 2281–2288, https://arc.aiaa.org/doi/abs/10.2514/3.5528?journalCode=aiaaj.

[4] Hartunian, R. A., et al., "Implication and Mitigation of Radio Frequency Blackout During Reentry of Reusable Launch Vehicles," in AIAA Atmospheric Flight Mechanics Conference, Hilton Head, South Carolina, August 20–23, 2007.

II. Steering and Focusing Antenna Beams to Track Hypersonic Speeds Using the Physics of Refraction of EM Waves Through a Plasma

Introduction

Refraction of electromagnetic waves and particles through a plasma has been studied by a number of researchers. In 1967, Hug et al [1] measured the index of refraction in an argon plasma. These results are very useful for plasma antennas since argon has been the gas of choice for plasma antennas due to the abundance and low cost. Atmospheric air plasma antennas have been patented and a useful application of this is a paper by Mathuthu et al [2] on the index of refraction, plasma frequency, and phase velocity in a laser induced air plasma. Specifically the patents by Anderson [3,4] are laser induced air plasma antennas. ELF plasma antennas designed and conceptualized by Anderson [5] can be laser induced air plasma antennas The effect of magnetic fields on plasma antennas have been theoretically simulated by Melazzi et al [6] and the effect on refraction through a plasma has been studied by Mesfin et al [7]. Useful for measuring refraction of plasma in plasma antennas, Tallents did research on measuring refraction in a plasma. The physics of refraction in a plasma is dependent on plasma density and plasma frequency. Experiments that connect refraction through a plasma as a function of plasma density have been done by Petrov[8]. Gekelman et al [9] did plasma experiments on the complex index of refraction. Given the connection of plasma to metamaterials as shown by S.Sakai et al [10], excellent work on negative refraction was done by Zhan et al [11].
Both steering and focusing of antenna beams can be done by electromagnetic waves (or more appropriately called for this book antenna beams) through a plasma. Anderson [12] has a patent on steering and focusing antenna beams by refraction through a plasma. Essentially steering and focusing are one and the same. Focusing is just steering inward on two sides of plasma when an antenna beam passes through it. Plasma lenses have been used to focus laser beams and particle beams. Focusing of a high powered laser beam by a plasma was done by Habibi et al [13]. An excellent paper authored by Gordon et al [14] covers optical plasma lenses. Gushenets et al [15] and Katsouleas et al[16] used plasma lenses to focus electron beams. Linardakis et al [17] were the first to use the physics of refraction of antenna beams passing through a plasma to steer antenna beams. Electronic phased arrays using an array of metal antennas have significant insertion losses and mutual coupling that the physics of refraction of antenna beams passing through the plasma may overcome.

Basic Physics of Refraction Theory of Electromagnetic Waves Propagating Through a Plasma.

The phase speed of electromagnetic waves in a plasma is given by:

$$v_p = \frac{c}{\sqrt{1-\omega_p^2/\omega^2}}, \qquad (1)$$

Where the plasma frequency is given by:

$$\omega_p = \sqrt{\frac{n_e\, e^2}{\epsilon_0\, m_e}} \qquad (2)$$

In this paper we are experimenting in the region where the antenna frequency is greater than the plasma frequency:

$$\omega > \omega_p \qquad (3)$$

In this region refraction and not reflection takes place.

The phase speed of electromagnetic waves in a plasma is greater than in free space. The greater the density of the plasma, the greater the phase speed. Since the plasma density can be reconfigured, the steering and focusing of antenna beams by the physics of refraction through a plasma is reconfigurable [18,19]. The amount of refraction through a plasma depends on the path length through a plasma and the change in plasma density over that path length [18,19]. This physical process can also be considered as a plasma lens [18,19].

Refraction in a plasma depends on:

1. Plasma density
2. Path length
3. Gradient of plasma density
4. Wavelength

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 is covered in [18,19]. This 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.

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. Rapid changes in the plasma density account for rapid steering of electromagnetic waves through a plasma and this can be faster than steering an antenna beam by phased array technology and phase shifters and fast enough to track objects moving at hypersonic speeds. Antenna beam steering by refraction through a plasma 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 an above hypersonic speed tangential velocity of the antenna beam. The phase speed of electromagnetic waves in a plasma can exceed the speed of light as explained in [18,19]. 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.

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. This creates doubling of the steering and focusing effect by refraction through the plasma of the antenna beam.

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.

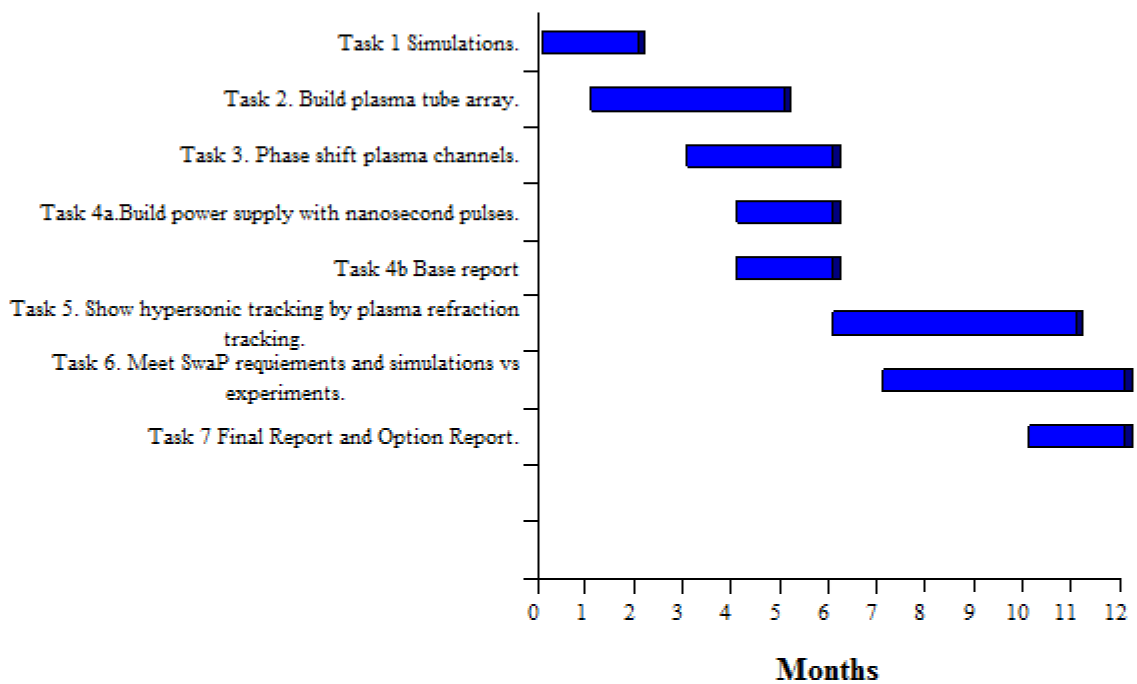
Broadband wave matching techniques, such as dielectric cones on the array of tubes or plate containing plasma, and RF absorber on the edges, could make this plasma system with or without a reflector virtually invisible. By comparison a conventional phased array using metal elements has a very high radar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

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

STATEMENT OF WORK.

Steering and Focusing Antenna Beams to Track Hypersonic Speeds Using the Physics of Refraction of EM Waves Through a Plasma

HALEAKALA
R&D, INC.
GANTT CHART STATEMENT OF WORK



tedanderson@haleakala-research.com,

References

1. W. F. Hug, D. Evans, R. S. Tankin, and A. B. Cambel, *Measured Index of Refraction for Argon Plasma*, Phys. Rev. 162, 117 – Published 5 October 1967.

2. M. Mathuthu , R. Raseleka, A.Forbes , Nicholas West, *Radial Variation of Refractive Index, Plasma Frequency and Phase Velocity in Laser Induced Air Plasma*, Published in: IEEE Transactions on Plasma Science (Volume: 34 , Issue: 6 , Dec. 2006) Page(s): 2554 – 2560

3. T. Anderson, *Laser driven plasma antenna utilizing laser modified Maxwellian relaxation.* Patent number 6,650,297, issued November 18, 2003.

4. T. Anderson, *Plasma antenna with electro-optical modulator*, Patent number 6,087,993, issued July 11, 2000.

5. T. Anderson, *ELF Plasma Antenna*, NUWC-NPT Technical Memorandum 972159, 30 September 1997, Approved for public release; distribution is unlimited.

6. D. Melazzi, V. Lancellotti, P. De Carlo, M. Manente, D. Pavarin, T. Anderson, *Numerical Investigation into the Performance of Two Reconfigurable Gaseous Plasma Antennas*, EuCAP 2014 Conference Proceedings.

7. Belayneh Mesfin, V. N. Mal'nev, E. V. Martysh, and Yu. G. Rapoport, *Waves and negative refraction in magnetized plasma with ferrite grains*, Physics of Plasmas 17, 112109 (2010).

8. V. G. Petrov, *Influence of refraction on plasma density measurements*, Plasma Physics Reports, April 2006, Volume 32, Issue 4, pp 311–316.

9. W. Gekelman et al, *Using plasma experiments to illustrate a complex index of refraction,* Am. J. Phys., Vol. 79, No. 9, September 2011.

10. S.Sakai,;K. Tachibana, *Plasmas as metamaterials: a review;* IOP Publishing Plasma Sources Science And Technology, Plasma Sources Sci. Technol. 21 (2012) 013001.

11. Y. Zhan and B. Guo, *Negative refraction in a rotational plasma metamaterial,* Published 9 November 2018 • © 2018 Hefei Institutes of Physical Science, Chinese Academy of Sciences and IOP Publishing, Plasma Science and Technology, Volume 21, Number 1.

12. T. Anderson, *Plasma Devices for Steering and Focusing Antenna Beams*; U.S. Patent Issue Number: 8,384,602, Issued February 26, 2013.

13. M. Habibi and M. Davoodianidalik, *Self-Focusing of High-Power Laser Beam through Plasma*, Open access peer-reviewed chapter, October 3rd 2018.

14. D. F. Gordon, A. B. Stamm, B. Hafizi, L. A. Johnson, D. Kaganovich, R. F. Hubbard, A. S. Richardson, and D. Zhigunov, *Ideal form of optical plasma lenses,* Physics of Plasmas 25, 063101 (2018).

15. V. I. Gushenets et al., *Electrostatic Plasma Lens Focusing of an Intense Electron Beam in an Electron Source With a Vacuum Arc Plasma Cathode*, IEEE Transactions on Plasma Science, vol. 41, no. 8, pp. 2171-2176, Aug. 2013.

16. J. J. Su, T. Katsouleas, J. M. Dawson, and R. Fedele, *Plasma lenses for focusing particle beams*, Phys. Rev. A 41, 3321 – Published 1 March 1990.

17. P. Linardakis, G. Borg and N. Martin, *Plasma-based lens for microwave beam steering,* Electronics Letters, 13th April 2006 Vol. 42 No. 8.

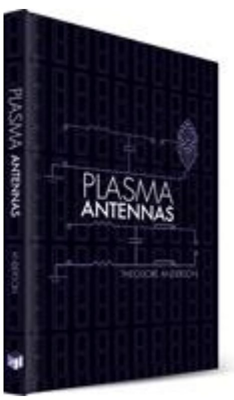
18. Anderson, T. R. “Plasma Antennas Second Edition”, Chapter 13, Artech House, 2020.

19. Anderson, T. R. “Plasma Antennas Second Edition”, Section 18.8 supplementary material, Artech House, 2020.

The Second Edition of my book titled "Plasma Antennas":

Plasma Antennas, Second Edition, Theodore Anderson, Copyright: 2020 Artech House, ISBN: 9781630817503

My original book titled "Plasma Antennas":



Plasma Antennas
Theodore Anderson, Haleakala Research and Development, Inc.

ISBN 978-1-60807-143-2

Copyright 2011, Artech House.

Book Chapter
Frontiers in Antennas: Next Generation Design & Engineering, chapter 10; Plasma Antennas, Theodore R. Anderson, McGraw -Hill, Frank Gross editor. ISBN 0071637931 / 9780071637930

Resume of Dr. Theodore (Ted) R. Anderson

Security Clearance (possibly not current) DOD and DOE
Citizenship United States
O***ffice address: 7 Martin Road, Brookfield, MA 01506-1762***

Phones: office and cell: 518-409-1010 Fax: 508 867 3918
e-mail: tedanderson@haleakala-research.com; websites: www.haleakala-research.com

Highest degree **PhD in physics** from New York University in 1986.
To verify and/or buy my PhD thesis go to: http://disexpress.umi.com/dxweb and type in: **TURBULENT WALL PRESSURE FLUCTUATIONS IN TERMS OF SPECTRAL DENSITIES CALCULATED FROM DISCRETE AND CONTINUOUS ORR-SOMMERFELD EIGENFUNCTIONS (ECKHAUS, TOLLMIEN-SCHLICTING)**
by *Anderson, Theodore Robert*, **New York University**, 1986, 173 pages; You can also type in: UMI Publication Number 8706713

CURRENT STATUS.

I am founder, Chief Executive Officer, principal investigator, and Chief Technology Officer of *Haleakala Research and Development Inc.(* www.ionizedgasantennas.com) 2002-present. I have won 9 phase 1 SBIR (Small Business Innovative Research) contracts and 2 phase 2 SBIR contracts with the US Air Force, US Army, US Navy, and US Marine Corp. This amounted to over 2 million dollars in R&D funds. Scientific American published an article on my technology and company in the February 2008 issue on page 22. The Air Force wrote a success story on my company and technology which appeared on the Air Force website. See my website for all the details: www.ionizedgasantennas.com.

I AM CURRENTLY WORKING ON A FAR-UVC TECHNOLOGY TO KILL COVID-19 AND OTHER VIRUSES WITHOUT HARMING HUMANS. I TREAT THE FAR-UVC DEVICE AS A PLASMA ANTENNA IN THE FAR-UVC SPECTRUM.

RECENT PATENTS:

Magnetic Resonance Imaging and Positron Emission Tomography Work.

Theodore Anderson, *MRI Device with Plasma Conductor*

:

Appl. No.:	**15/531645**
Filed:	**June 15, 2016**
PCT Filed:	**June 15, 2016**
PCT NO:	**PCT/US2016/037568**

Allowed is US June 2019; filed internationally.

Theodore Anderson, *International Patent: Plasma elements for MRI/PET*

International Application Number PCT/US2016/037568, filed June 15, 2016; <https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2016205326>.

16 out of 21 claims allowed at international patent office in Geneva, Switzerland.

Theodore Anderson, *US Patent: Plasma elements for MRI/PET*

US Application Number 15/183,323,filed, June 15, 2016,

To see published application on the Internet, go to the PTO web site at <http://appft1.uspto.gov/netahtml/PTO/srchnum.html> and enter the Publication Number 2016/0370442 without the slash.

RECENT PUBLICATIONS

Anderson, Theodore, "Beam-Steerable Helical Antenna Using Plasma Reflectors", EuCAP 2022, Madrid Spain.

Anderson, Theodore, "Antenna Beam Focusing and Steering with Refraction Through a Plasma", EuCAP 2019, presentation and conference symposium. March 2019.

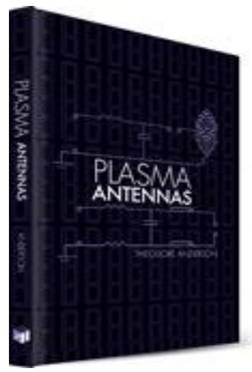
**Anderson, Theodore, "Magnetic Imaging Resolution and Positron Emission Tomography Using Plasma Antennas",
EuCAP 2019, presentation and conference symposium. March 2019.**

Books

The Second Edition of my book titled "Plasma Antennas".
See: https://us.artechhouse.com/Plasma-Antennas-Second-Edition-P2101.aspx

The Second Edition of my book titled "Plasma Antennas":

Plasma Antennas, Second Edition,
Theodore Anderson, Copyright: 2020 Artech House,
ISBN: 9781630817503



My original book titled "Plasma Antennas",
Theodore Anderson, ISBN: ISBN 978-1-60807-143-2
Copyright 2011, Artech House

Book chapters on plasma antennas by Theodore Anderson.

Theodore Anderson, ***Plasma Antennas,*** Open access peer-reviewed chapter, ***Selected Topics in Plasma Physics,*** Submitted: October 21st 2019Reviewed: March 2nd 2020Published: July 14th 2020, DOI:10.5772/intechopen.91944

Theodore R. Anderson, chapter 10; *Plasma Antennas*, *Frontiers in Antennas: Next Generation Design & Engineering*,, McGraw -Hill, Frank Gross editor. ISBN 0071637931 / 9780071637930

Popular Mechanics Article On Haleakala R&D, Inc or Dr. Ted Anderson plasma antennas:

Hambling, D.; *Scientists Control Plasma for Practical Applications*; Popular Mechanics; July 2010; page 18; http://www.popularmechanics.com/technology/engineering/news/scientists-control-plasma-for-practical-applications

Anderson, T., *An Overview of Experimental and Numerical Results on Plasma Antenna Arrays,* EuCAP Conference Proceedings, April 2015.

Anderson, T., *Numerical Investigation into the Performance of Two Reconfigurable Gaseous Plasma Antennas,* EuCAP Conference Proceedings, April 2014.

Anderson, T., *Plasma Antennas Co-site and Parasitic Antenna Interference Reduction Using Plasma Antennas,* AMTA Conference Proceedings, October 2013

Anderson, T., *Plasma Antennas: Theory, Measurements, and Prototypes*, AMTA Conference Proceedings, October 2013

Anderson, T., IEEE APS/URSI 2014 Paper #1547: *Theory, Measurements, and Prototypes of Plasma Antennas,* Conference Proceedings, July 2014.

Anderson, T., IEEE APS/URSI 2014 Paper #1928: *Plasma Frequency Selective Surfaces*, Conference Proceedings, July 2014.

Anderson, T., IEEE APS/URSI 2014 Paper #1538*: Plasma Antenna VSWR and Co-Site and Parasitic Interference Reduction or Elimination*, Conference Proceedings, July 2014.

Anderson, T., *Smart Plasma Antennas,* AMTA Conference Proceedings, October 2014, See: http://amta2014.org/

Anderson, T., *Plasma Antennas: Plasma Satellite and Reflector Antennas*, AMTA Conference Proceedings, October 2014. See: http://amta2014.org/

Anderson, T., *Plasma Antennas: Plasma Frequency Selective Surfaces for Antenna Radomes,*, AMTA Conference Proceedings, October 2014. See: http://amta2014.org/

Presented on plasma antennas at the Antenna Systems Conference in 2008, 2009, 2010, 2011, 2012, 2013, and will present in November 2014. See: http://www.antennasonline.com/conferences/program/conference-sessions/

Recent Conferences with presentations and booths.

1. 2019 IEEE APS/URSI Conference, Atlanta, Georgia July 7 to July 12, 2019.

Booth with prototypes:

I will have booth displaying prototypes for my company Haleakala R&D of my plasma antenna technology at the 2019 IEEE APS Conference in Atlanta July 7 to July 12. See the link and scroll down to Booth 32
https://www.2019apsursi.org/Exhibitors.asp

2. 5 G Antenna Systems Conference September 26, 2019.

Presentation and publication:

Anderson, Theodore; *Antenna Beam Focusing & Steering with Refraction Through a Plasma with Corresponding Circuitry for the Advancement of 5G*
https://antennasonline.com/conference-schedule/

3. IEEE International Symposium on Phased Array Systems and Technology, Waltham, Massachusetts October 15-18, 2019.

Presentations and publications:

Anderson, Theodore; *New Smart Plasma Antenna with Radiation Patterns and VSWR Measurements*

Anderson, Theodore *Antenna Beam Focusing and Steering with Refraction Through a Plasma with Corresponding Circuitry*

EuCAP 2022, Madrid Spain.

4. **Anderson, Theodore, "Beam-Steerable Helical Antenna Using Plasma Reflectors", EuCAP 2022, Madrid Spain.**

GOVERNMENT AND INDUSTRIAL EXPERIENCE

<u>I received my PhD in physics from New York University in 1986. I taught at the University of Connecticut for 12 years and Rensselaer Polytechnic institute for 16 years. I worked on antennas at Naval undersea Warfare Center for 12 years, and I taught antennas and EMI at RPI for several years. I have done extensive antenna testing with network analyzers and Diamond Engineering equipment in various anechoic chambers. I have published more work and have more patents on the plasma antenna than anyone.</u>

Haleakala Research and Development Inc. founder, CEO and president. 2002 to present

Exponent, Inc; Army Land Warrior Technical Supervisor and Coordinator. Exponent press release:
"Exponent, Inc. (Nasdaq: EXPO), is pleased to announce the addition of **Dr. Theodore R. Anderson,** Senior Systems Engineer, to Exponent's Technology Development Practice. Dr. Anderson's focus will be on Exponent's Land Warrior project with the U.S. Army. Dr. Anderson has a strong technical background and a lengthy record of creativity in the areas of electronics design and analysis, particularly in antenna systems, which are critical to the successful development of a Land Warrior system. ***<u>He will supervise the design, analysis, and testing of the electronic components of the Land Warrior system, and its future variants."</u>*** **2000-20002**

Knolls Atomic Power Laboratory May, 1999-December 2000

- worked with the University of Michigan on finite element electromagnetic codes to solve frequency selective surface filtering. in the infrared spectrum.

- I used the electromagnetics code called FSDA_PRISM

Naval Undersea Warfare Center—New London, CT / Newport, RI 1988 – 1999
Electromagnetic compatibility, digital signal processing, antenna research and design. Fluid dynamics, flow noise, acoustics, and hydroacoustics.

- Used ANSOFT, NEC, and various finite difference time domain codes, and project management for submarine electromagnetics
- I program managed this work
- Began to pioneer plasma antenna technology**.**
- Pioneered flow noise and hydroacoustices work for towed arrays and SONAR domes. (see publications section).

Electric Boat, General Dynamics, Groton, CT. 1983 -1988
Worked in CFD, flow noise, hydrocaoustics, and acoustics.

Gibbs and Hill Inc., NY, NY 1980-1983
Worked on and designed commercial nuclear power plants.

TEACHING AND UNIVERSITY POSITIONS.

Rensselaer Polytechnic Institute — Troy, NY.

- I taught radar, antennas, and electromagnetic compatibility in the ECSE Dept. 1999-2015
- I taught at the Rensselaer Polytechnic Institute, Hartford, CT Branch. 1986- 1999.

I taught mechanical and electrical engineering. I taught several antenna and EMC courses, several fluid dynamics courses including CFD.

- **I taught in the RPI Navy Nuclear Program. I taught fusion, reactor physics, Monte Carlo Techniques, shielding, and radioactive waste. 1999-2015.**

Plug Power. I taught in house course at Plug Power in Electromagnetic Compatabilty. 2003.

University of Tennessee, ECE Dept. Research professor. September 2003 to present time.

Union College—Schenectady, NY 1999 – 2001
I taught mathematical methods for engineers and systems engineering

University of Connecticut Mechanical engineering, Ocean Engineering, and EE Departments—Avery Point, CT 1983 – 1995
Taught physical acoustics, underwater sound with signal processing, special topics in acoustics, acoustical oceanography, and mathematical methods for engineers, hydroacoustics, fluid dynamics and astronomy

University of Bridgeport—Bridgeport, CT 1990 – 1999

- I taught mechanical, aeronautical, and management engineering

- I taught project management, quality control, quantitative methods, heat transfer, gas turbines, turbomachinery

Uniphase Telecommunications Products—Bloomfield, CT 1997

- I taught opto-electronics (on-site)

University of New Haven—New Haven, CT 1983 – 1988

- I taught electrical and mechanical engineering

Hunter College—NYC, NY 1980 – 1983

- I taught general physics and astronomy

Cooper Union School of Engineering—New York, NY. 1980

- I taught electronic circuits

OPTICS BACKGROUND.

1. **I modeled the t-matrix for electron-atom scattering in a laser field.**

2. **I taught optoelectronics at RPI, Hartford, CT. I used texts:**

    a. **Principles of Quantum Electronics by Dietrich Marcuse (Jul 1980)**

    b. **Optical Electronics in Modern Communications (Oxford Series in Electrical and Computer Engineering) by Amnon Yariv (Mar 13, 1997).**

    c. **Quantum Electronics by Amnon Yariv (Jan 17, 1989)**

3. **I taught fiber optics at RPI, Hartford, CT. I used texts:**

   a. **Theory of Dielectric Optical Waveguides (Quantum electronics--principles and applications) by Dietrich Marcuse (Apr 10, 1974).**

   b. **Light Transmission Optics (Van Nostrand Reinhold electrical/computer science and engineering series)** by Dietrich Marcuse (Aug 1982**).**

   c. **Principles of Optical Fiber Measurements by Dietrich Marcuse (Jul 28, 1981).**

   d. **Fiber-Optic Communication Systems (Wiley Series in Microwave and Optical Engineering) by Govind P. Agrawal (Oct 19, 2010)**

4. **I taught courses on lasers at RPI, Hartford, CT.**

   a. **Laser Fundamentals by William T. Silfvast (Jan 12, 2004)**

   b. **Laser Physics by Murray Sargent III, Marlan O. Scully and Willis E. Jr." Lamb (Jan 22, 1978)**

EDUCATION

PhD, Physics, New York University, New York, NY
(electrodynamics, opto-electronics, atomic physics and fluid dynamics) 1986

MS, Applied Science, New York University 1983

MS, Physics, New York University 1979

Studied engineering at Columbia University, New York City, 1979-1981

Studied Mathematical Physics at the Department de Physique Theorique, Universite de Geneve, Geneva, Switzerland.

PATENTS BY DR. TED ANDERSON

ISSUED PATENTS (Several of my patents have appeared in the Antennas and Propagation Magazine.)

1	6,710,746	Antenna having reconfigurable length
2	6,700,544	Near-field plasma reader
3	6,674,970	Plasma antenna with two-fluid ionization current
4	6,657,594	Plasma antenna system and method
5	6,650,297	Laser driven plasma antenna utilizing laser modified maxwellian

relaxation
6 6,624,719 Reconfigurable electromagnetic waveguide
7 6,512,496 Expandible antenna
8 6,369,763 Reconfigurable plasma antenna
9 6,169,520 Plasma antenna with currents generated by opposed photon beams
10 6,118,407 Horizontal plasma antenna using plasma drift currents
11 6,087,993 Plasma antenna with electro-optical modulator
12 6,087,992 Acoustically driven plasma antenna
13 6,046,705 Standing wave plasma antenna with plasma reflector
14 5,963,169 Multiple tube plasma antenna
15. 6,876,330 Reconfigurable antennas
16. 6,870,517 Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas
17. 6,842,146 Plasma filter antenna system
18. 7,342,549. Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas.
19. 6,922,173. Reconfigurable scanner and RFID system using the scanner
20. 6,700,544. Near-field plasma reader
21. 6,870,517. Configurable arrays for steerable antennas and wireless network incorporating the steerable antennas
22.. 7,292,191. Tunable plasma frequency devices
23. 7,453,403. Tunable plasma frequency devices.
24. 8,077,094 Plasma device with low thermal noise

Recently Issued patents.

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

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

Issued plasma waveguide patents.

1. 6,812,895 Reconfigurable electromagnetic plasma waveguide used as a phase shifter and a horn antenna
2. 6,624,719 Reconfigurable electromagnetic waveguide

Non-plasma physics patents.

1. Method And Apparatus For Detecting Misaligned Railroad Tracks, filed 4/11/01, serial number 09/832,087
2. Passive Magnetic Field Sensor Using The Barkhausen Effect To Measure Velocity (Angular Or Linear) Of A Moving Body-filed 4/11/00 serial number 09/548387
3. Portable And Lightweight Ramp Structure, issued 3/4/03, US Patent number 6526614

Take note: I presented my smart plasma antenna at the "Booz Allen Hamilton Technology Petting Zoo" in 2007. See: https://www.pressreader.com/usa/the-washington-post/20071224/282415574952689
My point of contact "Booz Allen Technology Petting Zoo" at Booz Allen Hamilton in Mclean, VA was William Barnett.

PUBLICATIONS (Partial List)

1. Anderson, T., Perturbation Model for EMC Sources in the Near Field and Shielded by a Ferromagnetic Material, August, 1997. IEEE EMC Society, Catalog Number 97CH36113. Presented at the International Symposium on Electromagnetic Compatibility, August 1997, Austin, TX.

2. Anderson, T., Iterative Model for EMC Sources in the Near Field and Shielded by Composite Materials, August 1997. IEEE EMC Society, Catalog Number 97CH36113. Presented at the International Symposium on Electromagnetic Compatibility, August 1997, Austin, TX.

3. Anderson, T., and Choo V., The Development of a Large Three-Axis Magnetic Field Susceptibility Test (L-TAMFEST), August 1997. IEEE EMC Society, Catalog Number 97CH36113. Presented at the International Symposium on Electromagnetic Compatibility, August 1997, Austin, TX.

4. Anderson, T., Model for Near Field Electromagnetic Shielding by Cylindrical Shells of Composite Materials, NUWC-NPT Technical Report 10,634, 16 October 1996.

5. Anderson, T., Models for the Near Field Interaction of a Magnetic Field Interaction of a Magnetic Field from Point Sources Representing Transformers and Power Supplies and a Ferromagnetic Cylindrical Shell. IEEE EMC Society. Presented at the Santa Clara Convention Center, August 21, 1996.

6. Anderson, T., The Use of Vector Fields to Model the Physical Blockage from Power Supply, Cable, and Transformer Sources. NUWC-NPT Technical Report 11,091, 18 March 1996.

7. Anderson, T., Turbulent Wall Pressure and Wall Shear Fluctuations Calculated from the Orr-Sommerfeld Equation with Nonlinear Forcing Terms. American Institute of Physics, "Chaotic, Fractal, Nonlinear Signal Processing," AIP Press, Proceedings Number 375, ISBN Number 1-56396-443-0. Presented at the Third Technical Conference on Nonlinear Dynamics (Chaos) and Full Spectrum Processing, July 1995.

8. Anderson, T., Model for Washover of a Buoyant Cylindrical Antenna Towed in Calm and Various Sea States, NUWC-NPT Technical Report 10,753, 23 September 1994.

9. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure Fluctuations, NUWC-NPT Technical Report 10,135, 11 June 1993.

10. Anderson, T., Properties of Continuous Orr-Sommerfeld Waves in a Turbulent Boundary Layer, Bulletin of the American Physical Society, Volume 36, No. 10, November 1991.

11. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure and Wall Shear Fluctuations, Bulletin of the American Physical Society, Volume 35, No. 10, November 1990.

12. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure and Wall Shear Fluctuations, International Union of Theoretical and Applied Mechanics, "Structure of Turbulence and Drag Reduction," A. Gyr (editor), Springer-Verlag ISBN 3-540-50204-1 and ISBN 0-387-50204-1, July 1989.

13. Anderson, T., Wavenumber—Frequency Spectral Densities of Turbulent Wall Pressure Fluctuations, American Society of Mechanical Engineers, Volume 6, "Acoustical Phenomena and Interaction in Shear Flows over Compliant and Vibrating Surfaces," 1988.

14. Anderson, T., Time Domain Modeling and Experimental Verification of the Barkhausen Effect used as a Magnetic Field Sensor. Published and presented at the IEEE EMC Society Meeting, August 1998.

15. Anderson, T., and Javor, E., The Design and Modeling of a Large Helmholtz Coil for Low Frequency Magnetic Field Susceptibility Testing. Published and presented at the IEEE EMC Society Meeting, August 1998.

16. Anderson, T., and Derewainy, C., Electrostatics Discharge Sensitive (ESDS) Equipment Susceptibility to Welding Generated Electromagnetic Fields. Published and presented at the IEEE EMC Society Meeting, August 1998.

17. Anderson, T., Development of a Large Three-Axis DC Magnetic Field Susceptibility Test System, ITEM, the International Journal of EMC, 1998.

18. Anderson, T., ELF Plasma Antenna, NUWC Technical Report Number 10,892, May 1998.

19. Anderson, T., Theory, Design, and Submarine Applications of a Plasma Antenna, NUWC Technical Report Number 10,832, May 1998.

20. Anderson, T., Optimal Design of Helmhotz Coils using Variational Principles. Published and presented at the IEEE EMC Society Meeting, August 1999.

21. Anderson, T., Control of Electromagnetic Interference from Arc and Electron Beam Welding by Controlling the Physical Parameters in Arc or Electron Beam: Theoretical Model, 2000 IEEE Symposium Record, Volume 2, pages 695-698, ISBN 0-7803-5677-2

22. Anderson, T, and James Raynolds, Frequency Selective Surfaces Used as Infrared Filters, APS meeting, March 2001

23. Anderson, T, and James Raynolds, Losses in Frequency Selective Surfaces, APS meeting, March 2001

24. Anderson, T., Alexeff, I., Reconfigurable Plasma Frequency Selective Surfaces, Submitted to IEEE Transactions on Plasma Science

25. Anderson, T. Antenna Intensity Patterns Through open Plasma Windows, Submitted to IEEE Transactions on Antennas and Propagation
26. Anderson, T, and Alexeff, I., Theory and Experiments of Plasma Antenna Radiation Emitted Through Plasma Apertures or Windows with Suppressed Back and Side Lobes, International Conference on Plasma Science 2002
27. Anderson, T, and Alexeff, I., Storage And Release Of Electromagnetic Waves by Plasma Antennas and Waveguides, 33rd AIAA Plasmadynamics and Lasers Conference 2002
28. Anderson, T. and Alexeff, I., Plasma Frequency Selective Surfaces, International Conference on Plasma Science 2003
29. Anderson, T., Alexeff, I., Reconfigurable Plasma Frequency Selective Surfaces, Submitted to IEEE Transactions on Plasma Science
30. Anderson, T. Antenna Intensity Patterns Through open Plasma Windows, Submitted to IEEE Transactions on Antennas and Propagation
31. Anderson, T. Plasma Frequency Selective Surfaces, 2003 IEEE International Conference on Plasma Science, published in the IEEE Conference Record, IEEE catalog number 03CH37470
32. Anderson, T. , Alexeff, Igor. Theory of Plasma Windowing Antennas, IEEE ICOPS, Baltimore, June 2004
33. Anderson T, Alexeff T, Adavnces in Plasma Antenna Design, in IEEE Int Conf. Plasma Sci., Monterey, CA, Jine 20-23, 2005
34. Anderson, Alexeff, Plasma Antennas I , presented at the SMi 8th annual Stealth Conference, London March 15-16, 2004
35. Anderson, Alexeff, Plasma Antennas II , presented at the SMi 9th annual Stealth Conference, London April 11 -12, 2005
36. Anderson, Alexeff, Plasma Antennas III , presented at the SMi 10th annual Stealth Conference, London April, 2006
37. Anderson, T, Alexeff, I , Plasma Antennas-New Developments, , in IEEE Int Conf. Plasma Sci., Traverse City, Michigan, June, 2006
38. Anderson, T., Alexeff, I., Experimental and Theoretical Results with Plasma Antennas, IEEE Transactions on Plasma Science,. Vol. 34 No. 2, April 2006

39. Anderson, T., Alexeff I., Plasma Frequency selective Surfaces, IEEE Transactions on Plasma Science, Vol. 35, no. 2, p. 407, April 2007.

40. Alexeff I., Anderson, T., Recent results for Plasma antennas, Physics of Plasmas, 15, 057104, (2008)

41. Anderson, T., Alexeff I. Plasma Antenna Windowing: Theoretical and experimental Analysis, IEEE Transactions on Plasma Science, being processed for publication.

42. Anderson, Theodore, "Antenna Beam Focusing and Steering with Refraction Through a Plasma", EuCAP 2019, presentation and conference symposium. March 2019.

43. Anderson, Theodore, "Magnetic Imaging Resolution and Positron Emission Tomography Using Plasma Antennas", EuCAP 2019, presentation and conference symposium. March 2019.

Books

Plasma Antennas, Second Edition

Theodore Anderson

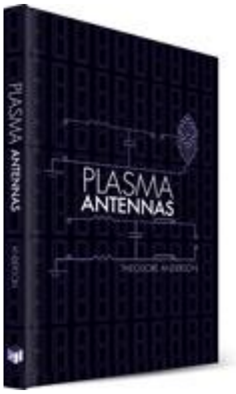
Copyright: 2020
Pages: 350
ISBN: 9781630817503

The Second Edition of my book titled "Plasma Antennas".
See: https://us.artechhouse.com/Plasma-Antennas-Second-Edition-P2101.aspx

Theodore R. Anderson , *Plasma Antennas*, Artech House, ISBN 978-1-60807-143-2; 2011.
http://www.artechhouse.com/Plasma-Antennas/b/2130.aspx

http://www.amazon.com/Plasma-Antennas-Theodore-Anderson/dp/160807143X/ref=sr_1_1?s=books&ie=UTF8&qid=1313592208&sr=1-1

http://www.barnesandnoble.com/w/plasma-antennas-theodore-anderson/1100484810?ean=9781608071432&itm=2&usri=plasma%2bantennas#CustomerReviews



<u>Plasma Antennas</u>
Theodore Anderson, Haleakala Research and Development, Inc.
ISBN 978-1-60807-143-2
Copyright 2011
Book Chapter
Frontiers in Antennas: Next Generation Design & Engineering, chapter 10; Plasma Antennas, Theodore R. Anderson, McGraw -Hill, Frank Gross editor. ISBN 0071637931 / 9780071637930

HOBBIES

Theater enthusiast, amateur playwright, national park buff.. I was a power lifting champion.. I have set several state records in Connecticut in power lifting between 1985 and 1997. I continue to do powerlifting and bodybuilding.

REFERENCES:

1. Professor Alejandra Mercado, professor at the University of Maryland, College Park, Maryland, office phone: (301) 405-3729, cell phone: (301) 233-7212, email: mercado@umd.edu; mercado@ece.umd.edu; alejandra.mercado@gmail.com
4. Professor Mohamed Himdi, IETR (Institut d'Electronique et de Télécommunications de Rennes), UMR CNRS 6164, Université de Rennes 1, Campus de Beaulieu. Bât. 11D, Avenue du Général Leclerc, 35042 RENNES Cedex – FRANCE, Tel : +(33) 2 23 23 67 15, Mobile : +(33) 6 73 60 59 36 email : mohamed.himdi@univ-rennes1.fr
5. Dr. Larry Cohen, Naval Research Laboratory; lawrence.cohen@nrl.navy.mil; 202-404-7726, cell (240) 217-0504, send2larry@msn.com
6. Dr. Fred Dyer, CEO Industrial Instruments, phone 757 817 6207, freddyer66@gmail.com
7. Dr. Kevin Shoemaker, CEO Shoemaker Labs, phone 321 446 2961, shoemakerlabs@gmail.com
8. Dr. Francis Parche, Principal Engineer Harris Corporation, 321 727 4023, fparsche@harris.com
9. Professor Frank Bohlen. Marine Sciences Institute—University of Connecticut, (860) 405-9176

More references on request.