# Draft White Paper Plasma Antennas for Advanced Drone Based Ground Penetrating Radar

**Dr. Ted Anderson**

## Table of Contents.

# Plasma Antennas for Advanced Drone Based Ground Penetrating Radar

## I. Summary of the Plasma Antenna GPR Technology.

This white paper explores novel concepts for the potential use of plasma antennas for Ground Penetrating Radar (GPR) for use in medium sized drones and other unmanned aerial platforms (e.g. aerostats). The application targeted is the use of GPR for the discovery, and monitoring, of tunnels along the US southern border, but other applications are obvious (e.g. search and rescue, police, military). While many GPR systems are in use they generally lack the speed, depth, resolution, and broad area coverage that is desired for effective border security. Most GPR systems are mounted on vehicles that keep the system close to the ground (e.g. within a few meters or even near ground contact) but require scanning raster style to paint a subterranean image of an area. This takes an enormous amount of time, and physical labor, on the order of an hour per acre. Small drone GPR systems are available that fly close to the ground (e.g. a few meters), and while this speeds up the scanning considerably, it is still very slow and unsuitable for developed areas. High altitude low frequency Synthetic Radar (SAR) GPR systems exist and have been flown in larger manned aircraft, and such a system might be adapted to work for this application but likely will require higher frequency (e.g. UHF/0.3-3GHz) and close to ground operation (e.g. 100 meters) to attain the resolution at the depth needed (e.g. a ~0.7 m wide by 2 m high tunnel up to 30 m depth) and maintain a safe clearance over dwellings and obstacles, but this is not a desired solution requiring several highly skilled personnel to operate one expensive aircraft, where a fleet of perhaps a dozen or more might be required to adequately monitor the US southern border, and could be dangerous with respect to accidents and hostile actions. What is desired is an unmanned system that covers a large geographical area in a short time, at a safe altitude, automated, relays back the information to home base in real time, inexpensive, and simple to operate with minimal training.

The plasma antenna has attributes that can make it highly desirable for aerial platforms. The plasma antenna can have relatively high gain, directivity, and low sidelobes in a compact size, compared to conventional antennas [1 ]. This gives the plasma antenna an improved operating altitude, depth, and resolution over low gain antennas such as the dipole in common use. It can sweep focused UHF (0.3-3 GHz) beams at extremely high speed, e.g. 10’s of degrees per microsecond. This can be used to scan transversely via electronics at high speed covering large areas rapidly and could enable a form of 3-dimensional SAR without having to fly a grid [4]. It has very low sidelobe levels due to its much reduced diffraction effects at plasma boundaries. This gives the potential for greatly reduced electromagnetic interference (EMI) to the GPR system, both unintentional EMI from external sources and intentional jamming signals and EMP sources, and greatly reduced EMI to external systems as well as greatly reduced unauthorized detection of signals (i.e. stealth). It also permits multiple antennas with high isolation to be deployed on a single platform, such as for transmitting and receiving simultaneously, for enhanced operating altitude, depth and resolution with SAR and triangulation techniques, and reduced clutter. For security and military applications it has stealth, low sidelobes makes it harder to detect and jam, the plasma components have a very low radar cross section (RCS) even in its “on” state as typical aircraft searching radar frequencies above the plasma frequency of the antenna pass through the plasma with little reflection.

One small disadvantage of the plasma antenna is that it is a vacuum electron device (VED) requiring high vacuum compatible materials and sealing techniques. Fragile glass tubes first come to mind, that are convenient for laboratory experiments and educational demonstrations, but this application will utilize the materials and manufacturing techniques of making very rugged microwave tubes including the use of high temperature ceramics and hard brazed seals. This can make the plasma antenna as rugged as needed to easily withstand the physical and thermal abuse of any platform. A disadvantage of the plasma antenna is that it requires a power source to energize the plasma tubes. It has been found that the power can be substantially reduced by fast pulsing the plasma [1] at low duty and operating in the afterglow. The relaxation time can be fast (e.g. a microsecond) or slow (milliseconds) depending on the type of gas, pressure, and cross sectional geometry of the tubes. The frequency of deep ground penetrating radars is typically less than 1 GHz. The power to establish a plasma frequency of 1 GHz is very low even utilizing continuous excitation. The plasma frequency required depends on the type of plasma antenna. For plasma antennas operating in the conduction mode (i.e. like a high conductivity metal) to form antenna elements and reflectors, the plasma frequency must be equal or higher than the rf frequency. For steering and focusing antenna beams for operating in the transparent refraction mode (e.g. lenses and focusing) the plasma frequency can be substantially less than the operating frequency. In one experiment [1] an estimated 3 GHz plasma intensely focused a 44 GHz rf signal with several wavelengths thickness. Consider that an ordinary small fluorescent bulb (of a few Watts driver power) has a typical plasma frequency of ~ 3 GHz. A 1 GHz plasma tube will require substantially less power even in continuous excitation mode. (Plasma tubes must be excited with zero average/DC current or ion acoustic instability can arise, resulting in uneven and unstable plasma, and electrode sputtering with short life will occur—alternating polarity pulse or square wave AC excitation solves both problems). A refraction antenna requires precision control of the local plasma densities for accurate phase front control. A conduction antenna requires much less plasma density control as the primary requirement is that the plasma frequency be at or above the operating frequency. This enables relatively easy low duty pulse excitation to reduce the plasma power as the plasma could be excited to e.g. ~2 GHz peak and allowed to relax to ~1 GHz, which for heavy gases puts pulse excitation in the 0.1-1 uSec pulsewidth per 1 mSec range. For light fast gases (with very fast steering response, e.g. a few microsec to change/sweep the rf beam 180 degrees) might require on the order of 10 nSec excitation per 1 uSec range. A properly designed 1 GHz array is not expected to require more than a few Watts of excitation power. Self-excitation of the plasma (and loss of control of the plasma density) can occur at very high rf power but at the power levels of the anticipated GPR (sub Watt to a few kWatts) we don't anticipate a problem. For refraction mode for steering and focusing antenna beams we need a plasma frequency of the order of 1/2 the rf frequency, an easy requirement for a 1 GHz antenna, but the plasma needs to be a significant thickness compared to a wavelength to keep plasma reflection low (where high transparency is desired). E.g. order of 1 wavelength for the large refraction (e.g. 45 degrees) required to make a focusing lens. This can add substantial size to the antennas at <3 GHz, but a small addition to size >10 GHz. Therefore, at high frequency >10 GHz we are persuaded in the direction of refraction/lensing mode antennas and at low frequency < 3 GHz in the direction of conduction/reflection mode antennas, but overlap occurs of course. This does not rule out hybrid mode plasma antennas as refraction effects can enhance the performance of conduction mode antennas. In the plasma antenna an element can operate in both conductive and refractive modes by changing the plasma density. This may be applicable to our circular window antenna to further enhance gain without any increase in size.

Considering the advantages and disadvantages of the various types of plasma antennas, we are proposing a windowing type antenna for drone based GPR in which a dipole (or similar) metal antenna is surrounded by high conductivity plasma tubes that form a circular resonator, as in Figure 1. A calculation of resonances is shown in Figure 2 and radiation patterns are shown in Fig 3. As we are only interested in radiation directed toward the ground for GPR then the top half of the resonator can be metal for a beam that can steer nearly +/-90 degrees downward as shown in Fig 4. This metal half is placed inside the lower surface of the wing. The axis is in the direction of travel. Electronics and wiring would be inside the wing except for connections to the ends of plasma tubes that could be high impedance circuits to eliminate rf coupling. Such high angle steering not only provides transverse beam sweeping as the craft moves forward, but would permit steep turns allowing a winged drone to circle and scan a small target area. For continuous monitoring of a specific target (e.g. activity in the tunnel) a heliostat platform could be ideal. SAR GPR has been used on a large airship [6]

Our initial prototype GPR plasma antenna would be a single window antenna at a single frequency of ~1 GHz. The electronics of a single antenna GPR drone such as the Cobra [2] that operates at several frequencies up to 800 MHz could be obtained for an installation test on a wheeled vehicle (such as a small ATV) to compare the response to the supplied dipole antenna, preferably on the same type of soil as at the southern border. In this quick test we expect some enhancement in depth and resolution due to the increased gain and directivity over the supplied dipole antenna. This very simple, very low power (unlicensed), GPR system would not take full advantage of the plasma antenna. The driver electronics would not be as nearly compact or efficient as could be made with a dedicated development, and we may use commercially available equipment such as a square wave AC supply. As there is no antenna scanning or SAR capability with the Cobra system, we will simplify the plasma antenna to being fixed directional (though the window could be manually switched for side looking tests), and not supply an electronic control system for scanning. This task will take an estimated 6 months. A logical follow on task (6 mo.) could be to develop a multiband antenna using the multiple resonances of the window antenna on the same platform.

We envision that the next phase (one year) would be to incorporate SAR [4] into a similar ground based low power platform. Compact efficient flyable drivers with electronic sweep control would also be developed in parallel. Hardened tubes and rugged antenna assemblies, suitable for flying, would also be developed.

To take maximum advantage of the plasma antenna with its gain, directivity, low sidelobe, multi-frequency, and sweeping capabilities will require a dedicated design multi-antenna SAR system [5] at higher rf power (hundreds of Watts peak to a few kW peak pulse) on a specialized platform, such as a larger GPS controlled winged drone feeding back the information in real time to home base (possibly via satellite).

References:

[1] Plasma Antennas, by Theodore Anderson, Artech House, 2011

[2] http://www.radarteam.se/

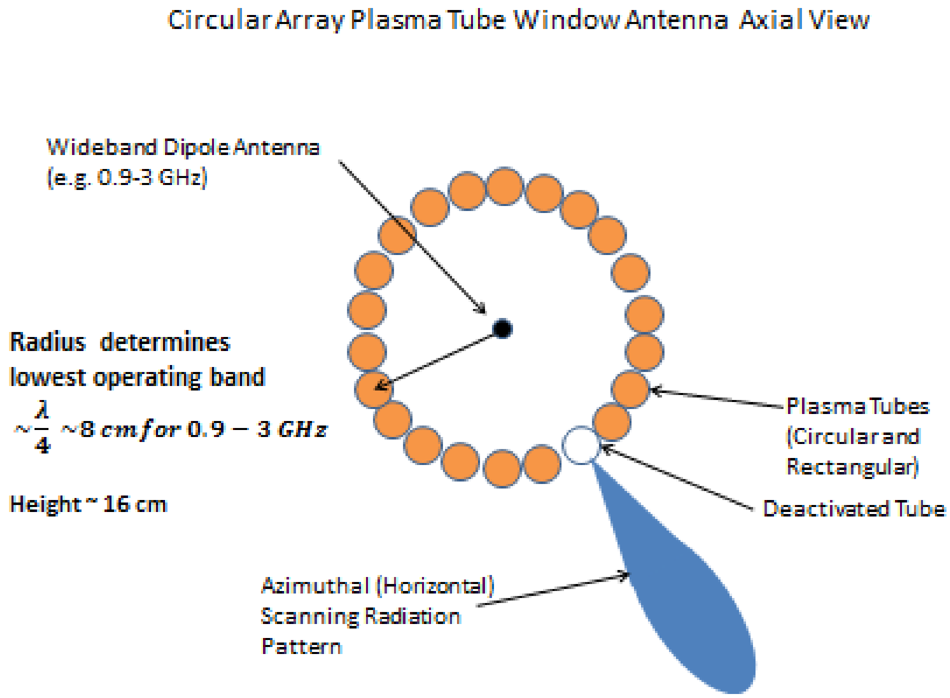
[3] Imaging Study for Small Unmanned Aerial Vehicle (UAV)-Mounted Ground-Penetrating Radar: Part I – Methodology and Analytic Formulation by Traian Dogaru, ARL-TR-8654, Mar 2019

Draft White Paper: Plasma Antennas for Advanced Drone Based Ground Penetrating Radar.
[4] Autonomous Airborne 3D SAR Imaging System for Subsurface Sensing: UWB-GPR on Board a UAV for Landmine and IED Detection, Maria Garcia-Fernande, Yuri Alvarez-Lopez and Fernando Las Heras, Remote Sensing, Oct 2019

[5] A numerical model for a GPR device with two receiving antennas, https://ieeexplore.ieee.org/document/7996035

[6] The Mineseeker Airship: 'Supporting the U.N.', Elizabeth A. Cramer, Journal of Conventional Weapons Destruction, Apr 2001.

## II. Schematics of the Plasma Antenna GPR Technology.




S

Figure 1. Circular plasma tube window antenna.

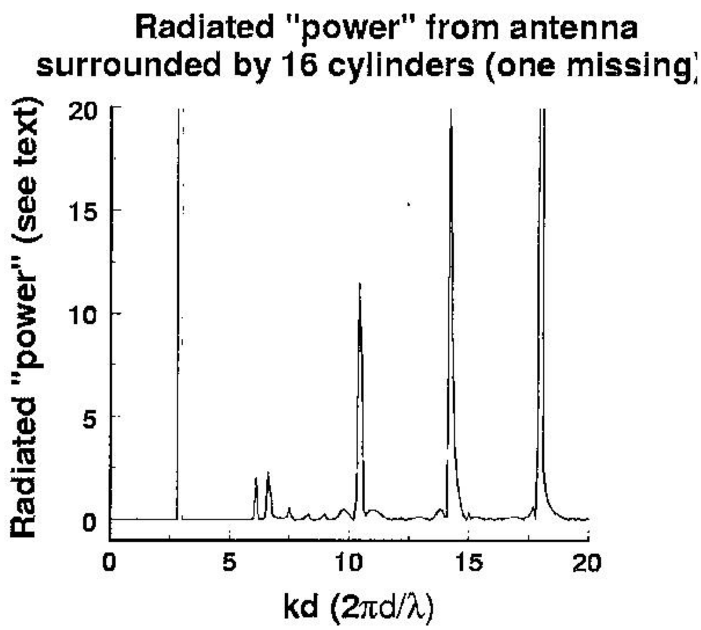


Figure 2. Resonances of the window plasma antenna.

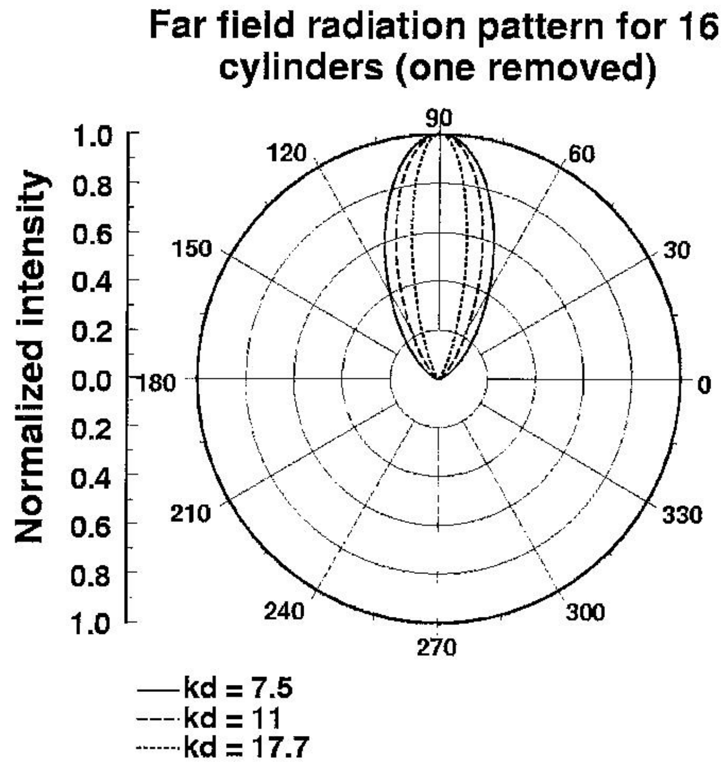



Figure 3. Radiation patterns for the circular window plasma antenna.

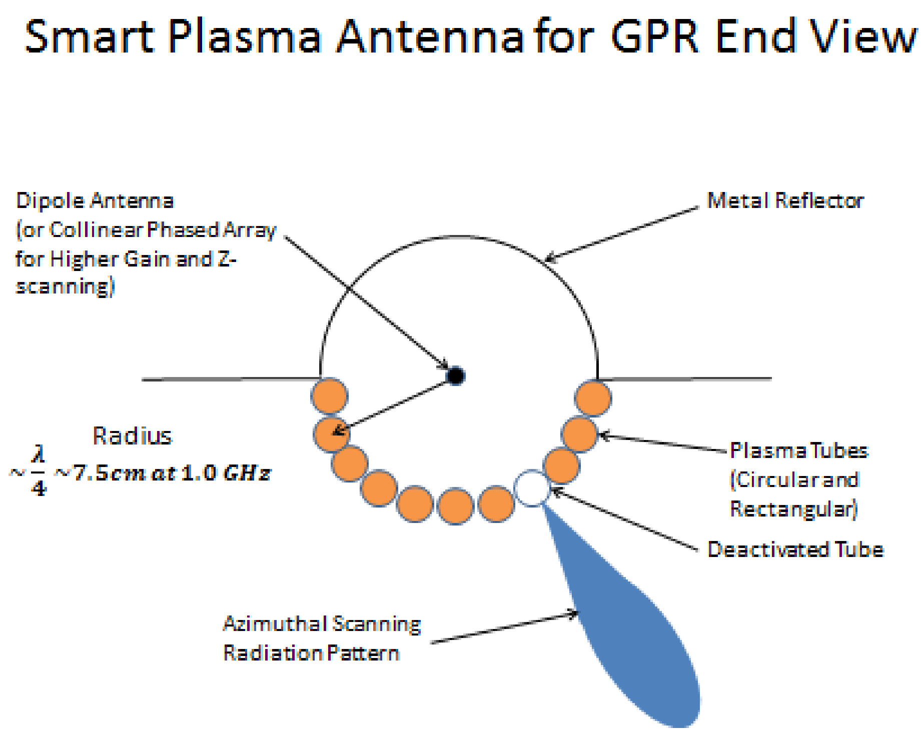


Figure 4. Downward radiating half circular plasma tube window antenna for aerial GPR platforms.

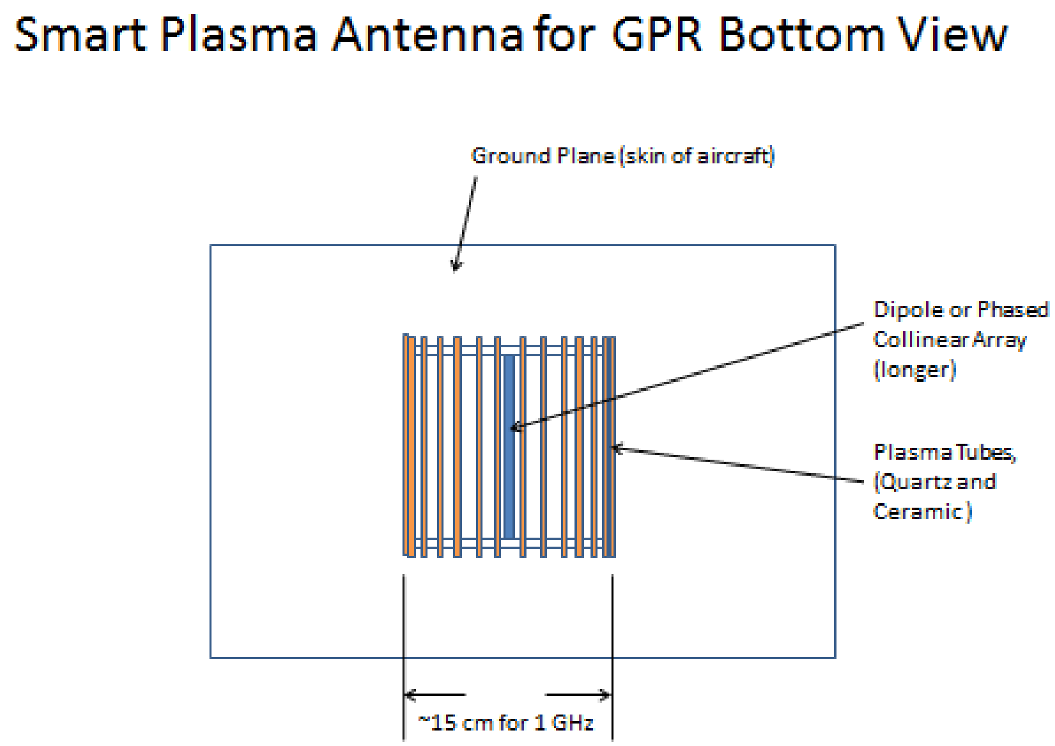
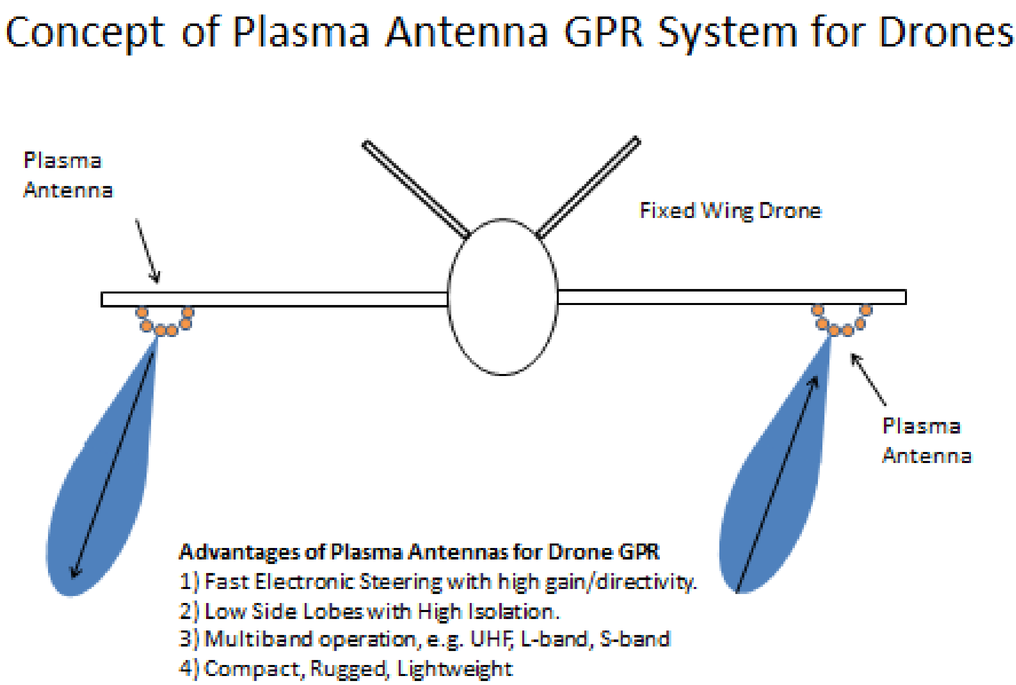
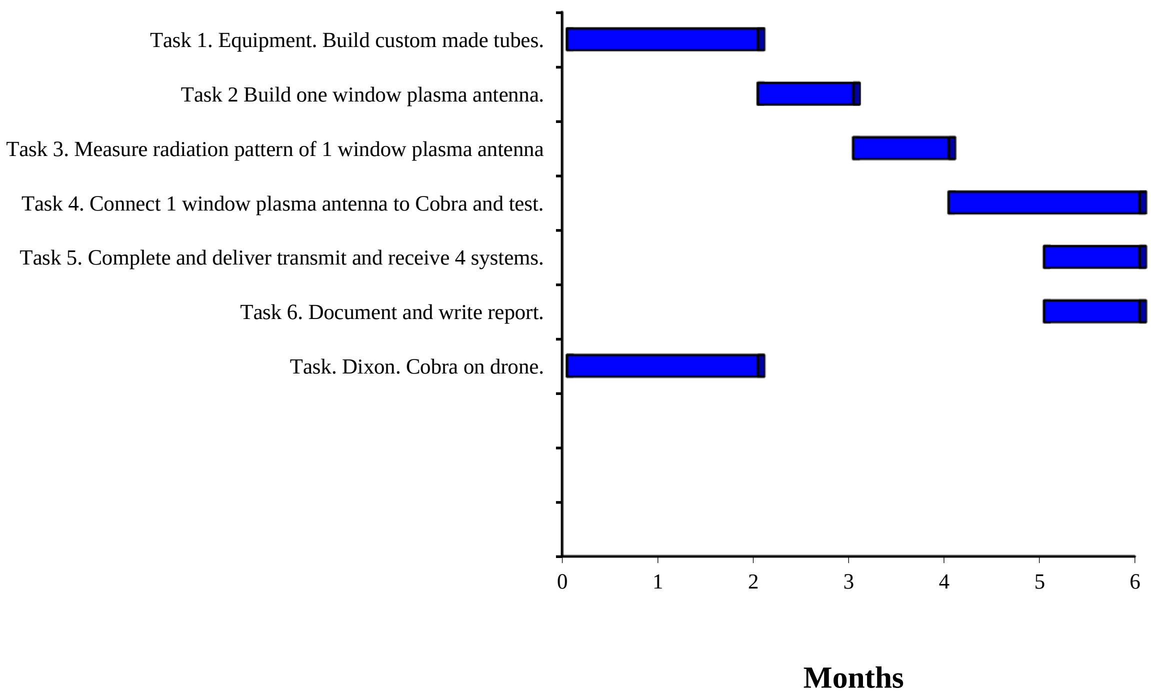



Figure 5. Bottom view of the circular plasma window GPR antenna..


Concept of Plasma Antenna GPR System for Drones
Plasma Antenna
Fixed Wing Drone
Plasma Antenna
Advantages of Plasma Antennas for Drone GPR
1) Fast Electronic Steering with high gain/directivity.
2) Low Side Lobes with High Isolation.
3) Multiband operation, e.g. UHF, L-band, S-band
4) Compact, Rugged, Lightweight

## III. Schedule and Gantt Charts for First Six Months of Development of Plasma Antenna GPR.

[redacted]



# I. Budget (ROM).

## Equipment and materials estimate:

1) Materials for making tubes (ceramic, quartz, kovar, copper, tungsten). $10,000. Even if we have to resort to a glass blower this should cover ~25 tubes for 2-3 arrays.

2) Electronic power supplies and rf parts: $10,000

3) Vacuum pump and parts: $10,000

4) Bakeout oven and parts $2,000

5) Hard brazing of ceramic tubes $5,000

6) Misc parts and materials (e.g. NASA bonding agent, Synfoam, absorber): $5,000

7) Small ceramic cutoff saw $1,000

8) Machine shop fabrications $3,000

7) Cobra (or similar) GPR unit (without drone): $15,000

8) Drone boom fabrication $2,000

9) Sinewave inverter for powering electronics. $1000

10) VNA 0.4-6 GHz 3-port. $5000 with cal kits, etc

11) Spectrum analyzer. $3000 For looking at noise (with LNA) and EMI (.e.g. from our driver)

12) PLC AC 220V to DC 0-1500V 0.5A Adjustable 750W Power Supply Regulator portable. $900.00

In addition a CST (computer simulation technology) code would help (but not necessary) guide our work. Usually this involves licensing fees over a certain period of time.

## Total equipment and parts estimate: $72.9K

## Travel for 3 people (6 months): $ 10K

## Labor for 3 people in Haleakala R&D, Inc (full time and probably more than full time for 6months)

Dr. Theodore Anderson $100 K

Dr. Larry Barnett $90 K

Fred Dyer $70 K

Jeff Peck  $30K.

Mike Kaminski  ?

Total labor: $ 290 K (need quote from Mike Kaminski)

## Total estimated budget for Haleakala R&D, Inc. for first 6 month (Phase I and Phase II)

**$ 372.9 K.**

## IV. Haleakala R&D, Inc. Plasma Antenna Team. Brief Bios of Team and Full Resumes of Dr. Theodore Anderson and Dr. Larry Barnett.

**Brief Bios of Haleakala R&D, Inc engineers.**

1. Dr. Theodore Anderson; Position PI and CEO Haleakala R&D, Inc.

Dr. Theodore R. Anderson (sometimes referred to as Dr. Ted Anderson) is a foremost authority and pioneer on plasma antennas. Dr. Anderson has over 20 issued patents on plasma antennas, plasma frequency selective surfaces, plasma waveguides, and plasma MRI/PET. He has published several peer reviewed journal articles on plasma antennas, and has presented at many conferences with symposium papers on plasma antennas. He founded Haleakala Research and Development, Inc. in 2002 which became a company focused on the plasma antenna technology. His contact information is tedanderson@haleakala-research.com and cell phone 518-409-1010. The Haleakala R&D, Inc webiste is: www.ionizedgasantennas.com

He has published in the areas of plasma antennas, plasma physics, electrodynamics, fluid dynamics, acoustics, hydroacoustics, atomic physics, foundations of quantum mechanics, nuclear engineering, and mathematical scattering theory.

2. Dr. Larry Barnett; Position Principal Engineer.

Larry R. Barnett obtained the BSEE in 1972 from Tennessee Technological University, MSEE in 1975 from the University of Tennessee Space Institute, and the Ph.D. with major in EE and minor in Physics in 1978 from the University of Tennessee. He began his professional association at the Naval Research Laboratory in Washington, DC in the Plasma Physics Division, at first as a National Research Council Associate and then as a Research Physicist until 1983. From 1983 to 1990 he was a Research Assistant Professor and then Research Associate Professor in the Electrical Engineering department of the University of Utah. In 1989 he began independent research, development, and consulting dba Mountain Technology. He was located in Colorado from 1989 to 1994 and in 1995 he relocated to Normandy, Tennessee. He has had, since 1988, and continues extensive collaboration with National Tsing Hua and National Taiwan Universities in Taiwan and has consulted and contracted development projects with several research oriented facilities in Taiwan including the Synchrotron Radiation Research Center (SRRC) and the Electronic Research Service Organization (ERSO). He has recently subcontracted with the University of California Davis Dept. of applied Science on high power W-band gyrotwt's, gyrotrons, klystrons, and twt's. He has had consulting associations with other groups including NASA Lewis Research.

3. Jeff Peck; Position Engineer.

Jeff Peck's experience relative to plasma antenna development:

Implemented hardware for an earlier generation of Haleakala steerable plasma antennas:

- High voltage generation
- Fast switched current controlled pulsing
- Control of which and when tubes would be activated
- Oversaw the mechanical development of the housing
- Did the assembly and test of several systems

Experience at General Electric with antennas, beam forming/steering and RF/microwave systems for airborne military applications will be invaluable. Having done numerous commercial developments from concept to implementation and low volume production, gives insight into how things should be implemented in order to achieve a working end-goal.

4. Francis F. Dyer; Position Engineer.

1710 Stone St.

Tazewell, TN 37879

Electrical Engineer with 40 years of experience in:

- Plasma and vacuum technology
- High voltage systems up to 100kV.
- Medical device design and manufacturing.
- Robotics system repair and maintenance for medical device manufacturing.
- More than 20 journal articles.
- Two patents.
- R&D 100 Award

# Full resumes of Dr. Theodore Anderson and Dr. Larry Barnett.

## 1. 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.ionizedgasantennas.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.

## 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, "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**

**Theodore R. Anderson, *Plasma Antennas Second Edition*, publication date under contract. Due for publication: June 2020.**

**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**

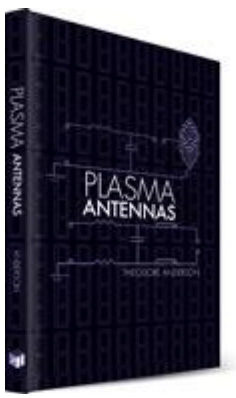
**http://www.barnesandnoble.com/w/plasma-antennas-theodore-anderson/1100484810?ean=9781608071432&itm=2&usri=plasma%2bantennas#CustomerReviews**

**Books**

**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

## 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/**

# Upcoming 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***

## GOVERNMENT AND INDUSTRIAL EXPERIENCE

***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.***

**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. ***He will supervise the design, analysis, and testing of the electronic components of the Land Warrior system, and its future variants."*** **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. 1999-2005
- I taught at the Rensselaer Polytechnic Institute, Hartford, CT Branch. 1986- 1999.

Draft White Paper: Plasma Antennas for Advanced Drone Based Ground Penetrating Radar.

**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. 1999-2006.**

**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.

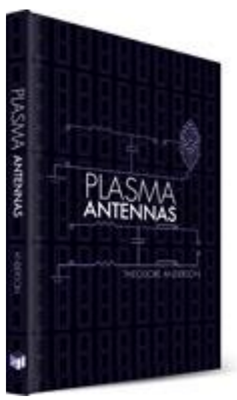
21. Anderson, T., Control of Electromagnetic Interference from Arc and Electron Beam Welding by Controlling the Physical Parameters in Arc or Electron Beam: Theoretical Model, 2000 IEEE Symposium Record, Volume 2, pages 695-698, ISBN 0-7803-5677-2
22. Anderson, T, and James Raynolds, Frequency Selective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

**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

## 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.

## SOME 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
2. 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
3. Dr. Larry Cohen, Naval Research Laboratory; lawrence.cohen@nrl.navy.mil; 202-404-7726, cell (240) 217-0504, send2larry@msn.com
4. Fred Dyer, CEO Industrial Instruments, phone 757 817 6207, freddyer66@gmail.com
5. Kevin Shoemaker, CEO Shoemaker Labs, phone 321 446 2961, shoemakerlabs@gmail.com
6. Francis Parche, Principal Engineer Harris Corporation, 321 727 4023, fparsche@harris.com
7. Professor Frank Bohlen. Marine Sciences Institute—University of Connecticut, (860) 405-9176

**More references on request.**

## 2. Dr. Larry R. Barnett

Resume

Larry R. Barnett obtained the BSEE in 1972 from Tennessee Technological University, MSEE in 1975 from the University of Tennessee Space Institute, and the Ph.D. with major in EE and minor in Physics in 1978 from the University of Tennessee. He began his professional association at the Naval Research Laboratory in Washington, DC in the Plasma Physics Division, at first as a National Research Council Associate and then as a Research Physicist until 1983. From 1983 to 1990 he was a Research Assistant Professor and then Research Associate Professor in the Electrical Engineering department of the University of Utah. In 1989 he began independent research, development, and consulting dba Mountain Technology. He was located in Colorado from 1989 to 1994 and in 1995 he relocated to Normandy, Tennessee. He has had, since 1988, and continues extensive collaboration with National Tsing Hua and National Taiwan Universities in Taiwan and has consulted and contracted development projects with several research oriented facilities in Taiwan including the Synchrotron Radiation Research Center (SRRC) and the Electronic Research Service Organization (ERSO). He has recently subcontracted with the University of California Davis Dept. of applied Science on high power W-band gyrotwt's, gyrotrons, klystrons, and twt's. He has had consulting associations with other groups including NASA Lewis Research.
His experiences include klystrons, traveling-wave tubes, gyrotron traveling-wave amplifiers, gyro-monotrons, harmonic gyrotrons, gyro-bwos, gyromagnetrons, peniotrons, free electron lasers, vacuum electronics, cathode and electron gun development, beam analyzers, high power microwave generators and plasma generation, overmoded microwave devices, microwave circuits with waveguide and microstrip, antennas, plasma antennas, conventional electronics and diagnostics, millimeter and submillimeter devices, optics, electron guns, submillimeter O-type bwos, high power transmitters using klystrons and twts, high power rf and microwave transmission lines and waveguides, rf plasma production, plasma antennas, millimeter-wave rf heating and cavities, magnetohydrodynamic plasma power generation, high voltage electronics and power supplies, high power solid state and tube electronics, crowbars and high power switching, pulse power supplies and modulators, microwave

interactions in plasma, multipactor plasma diagnostics, and support systems including vacuum systems, cryogenics, and superconducting magnets. He has approximately 100 publications, many in prestigious journals such as Physical Review Letters, Review of Scientific Instruments, IEEE Electron Devices and Plasma Science, and about 20 patents. His career has been basic physics research and research engineering oriented. His strengths are as a laboratory experimentalist and specialized laboratory equipment designer. He is regarded highly in the scientific community as a laboratory experimentalist "that can make things work". Major projects designed and built dba Mountain Technology include three high power 70 kW CW klystron microwave transmitters for powering the SRRC 1.5 GEV storage ring facility and then upgraded to 100 kW CW, a 150 kV pulse modulator for gyrotron research, a 30 kW 30 kV modulator system for EIO research, an S-band high power waveguide

automatch circuit for an rf plasma chamber, a 50 kW CW 45 kV twt transmitter power supply using solid state IGBT inverter technology, a high speed variable pulse width, 30 kV, 30 kW average power modulator system for general twt, bwo, and magnetron research, and a millimeter wave quasi-optical cavity for RF heating of film materials. He redesigned and rebuild the UC Davis TE01 95 GHz gyrotwt that achieved 140 kW peak with 60 dB gain. He recently participated with the National Taiwan University to build a working wideband tuneable Ka-Band Gyro-BWO. He is also participating in the NTU microwave insect control experiments. He recently supplied four 30 kV magnetron pulse modulators to WavePower Technology in Taiwan and a 100 kV pulse modulator to NTU.
Most recently he was the technical team leader at the Univ. of CA on the Marine Corps W-band high power klystron project for the Joint Non-Lethal Weapons Program (JNLWP) Area Denial Technology (ADT) project in which 56 kW of power has been achieved at 95 GHz, and a 10 kWCW tube was designed. He has received a Marine Corps commendation for this work. He also participated in the DARPA HiFive project and is the co-inventor of the double staggered vane twt interaction circuit that is predicted to produce more than 100 Watts CW with 50 GHz bandwidth centered at 220 GHz with 40 dB gain (and produced ~50 W). He also participated in the scandate cathode development at UCD that has achieved more than 100 A/cm2 emission densities, and has built a beam analyzer that has taken beam density profiles of sheet beams as small as 1000 um by 30 um with <1 um resolution with measured densities up to 450 A/cm2. He is the inventor of a low power normal magnet, the electropermagnet, that can achieve 20+ kG and is currently pursuing designing and building 40 to 100 kWCW 2nd harmonic 94 GHz gyrotrons using the electropermagnet for area denial technology (ADT) purposes, which was funded by a NAVSEA SBIR and expected to be further funded by the Marine Corps ADT project. He made a 94 GHz electropermagnet gyrotron under the SBIR that achieved 30 kW peak pulse power and a subsequent revision at UCD produced 55 kW peak and is predicted to produce 40 kWCW.

Education Summary:

1972 BSEE, Tennessee Technological University

1975 MSEE, University of Tennessee Space Institute

1978 Ph.D. Major in EE and Minor in Physics, University of Tennessee Knoxville

Professional Associations:

National Taiwan University, Taiwan, Dept of Physics, collaborator, 2011-2015
University of California, Dept of Applied Science, Consultant/ Subcontractor, 2001-2014.
National Tsing Hua University, Taiwan, Dept of Physics, Consultant, 1988-2010.
Synchrotron Radiation Research Center, Taiwan, Contractor and Consultant, 1991-2002
Electronic Research Service Organization, Taiwan, Consultant and Contractor, 1999-2001.
University of Utah, Dept. of Electrical Engr., Research Associate Professor, 1983 to 1990.
NASA Lewis Research Center, Consultant, 1990-1991.
Naval Research Laboratory, Plasma Science Division, Research Physicist, 1980-1983. BK Dynamics, Senior Engineer, 1979-1980.
National Research Council Associate at the Naval Research Laboratory, 1978 to 1979. Georgia Technological Research Institute, Atlanta, GA., Consultant, 1991

Experience Summary:

Plasma antennas and noise measurements
MHD Plasma Power Generation
Intermodulation of Microwaves in Plasma
Multipactor and RF Breakdown Plasmas
Cyclotron Masers in Magnetic and Electrostatic Fields
Gyrotron Traveling-Wave Amplifiers
Gyrotron Oscillators
Gyromagnetrons Peniotrons
Free Electron Lasers
Vacuum Electronics and Devices Construction
Crowbars and gas switch tube circuits
Overmoded Microwave Devices
High Power Microwave Transmitters
High Power MMW Klystrons
High Power MMW TWTs
Submillimeter O-Type Backward-Wave Oscillators
Magnetrons
Antennas and Couplers
High Power Microwave Transmission Lines and Waveguides
High Voltage Electronics, Modulators, Vacuum Tubes, and Pulse Power Supplies RF Plasma Production
Millimeter-Wave and Submillimeter-Wave Devices and Optics

Electron Guns
High Power Solid State Electronics
Conventional Electronics and Diagnostics
Microwave and RF Circuits with Waveguide and Microstrip. Semiconductor
Microwave and RF Electronics
Support Systems: Vacuum, Cryogenic, and Superconducting Magnets

Publications

1. L. R. Barnett and I. Alexeff, "A Cyclotron Maser Using a Spatially Nonlinear Electrostatic Field", *IEDM Technical Digest*, 168 (1979).
2. L. R. Barnett, K. R. Chu, J. M. Baird, V. L. Granatstein and A. T. Drobot, "Gain, Saturation, and Bandwidth Measurements of the NRL Gyrotron Traveling Wave Amplifier," *IEDM Tech. Dig*. 164 (1979).
3. Alexeff, Igor; Barnett, Larry R.; Barrero, Alejandro; Akingbehin, Kiumi, "Landau Growth for Students Part I: Initial Valuie Problem", Plasma Science, IEEE Transactions on, 1976, Volume: 4, Issue: 1, Pages: 24 - 24
4. L. R. Barnett, J. M. Baird, Y. Y. Lau, K. R. Chu, and V. L. Granatstein, "A High Gain Single Stage Gyrotron Traveling Wave Amplifier," *IEEE-IEDM Tech. Dig.* 314 (1980).
5. L. R. Barnett, J. M. Baird, A. W. Fliflet, V. L. Granatstein, "Circular-Electric Mode Waveguide Couplers and Junctions for Use in Gyrotron Traveling-Wave Amplifiers", *IEEE Trans. Microwave Theory and Techniques*, vol. 28, 1477 (1980).
6. A. W. Fliflet, L. R. Barnett, J. Mark Baird, "Mode Coupling and Power Transfer in a Coaxial Sector Wave-Guide with a Sector Angle Taper", *IEEE Trans. Microwave Theory and Techniques*, MTT-28. 1482, (1980).
7. W. M. Black, W. M. Bollen, R. Tobin, R. K. Parker, L. R. Barnett, and G. Farney, "A High-Power Magnetron for Air Breakdown Studies", *IEDM Technical Digest*, 180 (1980).
8. Y. Y. Lau, K. R. Chu, L. R. Barnett, V. L. Granatstein, "Gyrotron Traveling Wave Amplifier: I. Analysis of Oscillations," *Int. J. Infrared and Millimeter Waves*, vol. 2, 373 (1981).
9. Y. Y. Lau, K. R. Chu, L. R. Barnett, and V. L. Granatstein, "Gyrotron Traveling-Wave Amplifier: II. Effects of Velocity Spread and Wall Resistivity," *Int. J. Infrared and Millimeter Waves*, vol. 2, 395 (1981).
10. K. R. Chu, Y. Y. Lau, L. R. Barnett, and V. L. Granatstein, "Theory of a Wideband Distributed Gyrotron Traveling Wave Amplifier," *IEEE Tran. Electron Devices*, vol. 28, 866 (1981).
11. L. R. Barnett, Y. Y. Lau, K. R. Chu, V. L. Granatstein, "An Experimental Wideband Gyrotron Travelling Wave Amplifier," *IEEE Trans. Electron Devices*, vol. 28, 872 (1981).
12. V. L. Granatstein, M. E. Read, and L. R. Barnett, "Gyrotrons: Using Relativistic Electronics to Produce High-Power, High Efficiency, Millimeter-Wave Sources", *IEEE Transactions on Nuclear Science*, (1981).

13. Y. Y. Lau, J. M. Baird, L. R. Barnett, K. R. Chu, and V. L. Granatstein, "Cyclotron Maser Instability as a Resonant Limit of Space Charge Wave", *International Journal of Electronics*, vol.51, 331 (1981).
14. Y. Y. Lau, L. R. Barnett, and V. L. Granatstein, "Gyrotron Traveling-Wave Amplifier: IV. Analysis of Launching Loss", *International Journal of Infrared and Millimeter Waves*, vol. 3, 45 (1982).
15. Y. Y. Lau and L. R. Barnett, "A Low Magnetic Field Gyrotron-Gyromagnetron", *International Journal of Electronics*, vol. 51, 693 (1982).
16. Y. Y. Lau and L. R. Barnett, "Theory of Low Magnetic Field Gyrotron-Gyromagnetron", *International Journal of Infrared and Millimeter Waves*, vol. 3, 619 (1982).
17. Y. Y. Lau and L. R. Barnett, "A Note on Gyrotron Traveling-Wave Amplifiers Using Rectangular Waveguides", *IEEE Transactions on Electron Devices*, vol. 30, 908 (1983).
18. L. R. Barnett, Y. Y. Lau, K. R. Chu, C. R. Kyler, and V. L. Granatstein, "A Wideband Fundamental Mode Millimeter Gyrotron TWA Experiment", *IEDM Technical Digest*, 375, (1982).
19. L. R. Barnett, D. Dialetis, Y. Y. Lau, and K. R. Chu, "Tapered Interaction Gyro-TWA Experiments," *IEDM Tech. Digest*, 280 (1983).
20. Y. Y. Lau, L. R. Barnett, J. M. Baird, "An Active Circulator Gyrotron of the Reflection Type", *IEEE Transactions on Electron Devices*, vol. 30. (1983).
21. S. H. Gold, D. L. Hardesty, A. K. Kinkaid, L. R. Barnett, and V. L. Granatstein, "High-Gain 35 GHZ Free Electron Laser-Amplifier Experiment", *Physical Review Lette*rs, vol. 51, 1218 (1984).
22. V. L. Granatstein, M. Read, and L. R. Barnett, “Measured Performance of Gyrotron Oscillators and Amplifiers,” in Infrared and Millimeter Waves, vol. 5, edited by K. J. Button (Academic, New York), 267-304 (1984).
23. L. R. Barnett, J. M. Baird, U. A. Shrivastava, and R. W. Grow, "Fourth Harmonic Gyromagnetron Development", *IEDM Technical Digest*, (1984).
24. L. R. Barnett, J. M. Baird, R. W. Grow, "Submillimeter-Wave BWO'S", *IEDM Technical Digest*, 365, (1985).
25. L. R. Barnett, J. M. Baird, R. W. Grow, and S. G. Holmes, "Backward-Wave Oscillators for Frequencies Above 600 GHz", *Tenth International Conference on Infrared and Millimeter Waves*, 125, (1985).
26. P. S. Rha, L. R. Barnett, J. M. Baird, and R. W. Grow, "Self-Consistent Large Signal Theory and Simulation of High Harmonic Gyrotron and Peniotron Oscillators Operation in a Magnetron-Type Cavity", *IEDM Technical Digest*, 535, (1985).
27. U. A. Shrivastava, R. W. Grow, P. S. Rha, J. M. Baird, and L. R. Barnett, "Threshold Power Calculations for the Gyrotron and Peniotron Oscillator Operating at the Harmonic Frequencies Using Coaxial Electron Beam-Circuit Configurations", *International Journal of Electronics*, vol. 61, 33 (1986).
28. J. M. Burke, Czarnaski, Fisher, Ganguly, Fliflet, Manheimer, and Barnett, Twelfth, "85 GHz TE13 Phase-Locked Gyroklystron Oscillator Experiment", *International Conference on Infrared and Millimeter Waves*, IEEE 87CH2490-1, p. 148 (1987).
29. J. M. Baird, L. R. Barnett, R. W. Grow, "Harmonic Auto-Resonant Peniotron (HARP) Interactions", *IEDM Technical Digest*, (1987).

30. Barnett, L.R.; Grow, R.W.; Baird, J.M., "Backward-wave oscillators for the frequency range from 600 GHz to 1800 GHz", Electron Devices Meeting, 1988. IEDM '88. Technical Digest., International, 1988, Pages: 858 - 861
31. L. R. Barnett, L. H. Chang, H. Y. Chen, K. R. Chu, W. K. Lau and C. C. Tu, "Absolute Instability Competition and Suppression in a Millimeter-Wave Gyrotron Traveling-Wave Amplifier", *Phys. Rev. Lett*. vol. 63, 1062 (1989).
32. K. R. Chu, L. R. Barnett, W. L. Lau, L. H. Chang, and H. Y. Chen, "A Wide-Band Millimeter-Wave Gyrotron Traveling-Wave Amplifier Experiment", *IEEE Trans. Electron Devices*, vol. 37, 1557 (1990).
33. Barnett, L.R.; Stankiewicz, N.; Heinen, V.O.; Dayton, J.A., "Submillimeter backward-wave oscillator", Electron Devices Meeting, 1990. IEDM '90. Technical Digest., International, 1990, Page: 901
34. K. R. Chu, L. R. Barnett, W. K. Lau, L. H. Chang, and C. S. Kou, "Recent Development in Millimeter Wave Gyro-TWT Research at NTHU", invited paper, *IEDM Tech. Dig.*, 699 (1990).
35. K. R. Chu, L. R. Barnett, W. K. Lau, L. H. Chang, A. T. Lin, and C. C. Lin, "Nonlinear Dynamics of the Gyrotron Traveling Wave Amplifier", invited paper, *Phys. Fluids* B3, 2403 (1991).
36. C. S. Kou, S. H. Chen, L. R. Barnett, H. Y. Chen, and K. R. Chu, "Experiments Study of an Injection Locked Gyrotron Backwave Wave Oscillator", *Phys. Rev. Lett*. Vol. 70, 924 (1993).
37. K. R. Chu, L. R. Barnett, H. Y. Chen, S. H. Chen, Ch. Wang, Y. S. Yeh, Y. C. Tsai, T. T. Yang, and T. Y. Dawn, "Stabilization of Absolute Instabilities in the Gyrotron Travelling Wave Amplifier", *Phys. Rev. Lett*. vol. 74, 1103 (1995).
38. Ch. Wang, Y. S. Yeh, T. T. Yang, H. Y. Chen, S. H. Chen, Y. C. Tsai, L. R. Barnett, and K. R. Chu, "A Mechanically Tunable Magnetron Injection Gun", *Rev. Sci. Instru*. 68, vol. 3031 (1997).
39. K. R. Chu, H. Y. Chen, C. L. Hung, T. H. Chang, L. R. Barnett, S. H. Chen, and T. T. Yang, "An Ultra High Gain Gyrotron Traveling Wave Amplifier", *Phys. Rev. Lett.* Vol. 81, 4760 (1998).
40. T. H. Chang, L. R. Barnett, K. R. Chu, F. Tai, and C. L. Hsu, "Dual-function Circular Polarization Converter for Microwave / Plasma Processing Systems", *Rev. Sci. Instru.* vol. 70, 1530(1999).
41. K. R. Chu, H. Y. Chen, C. L. Hung, T. H. Chang, L. R. Barnett, S. H. Chen, T. T. Yang, and D. Dialetis, "Theory and Experiment of Ultrahigh Gain Gyrotron Traveling Wave Amplifier", invited paper, *IEEE Trans. Plasma. Sci*. vol. 27, 391 (1999).
42. T. H. Chang, S. H. Chen, L. R. Barnett, and K. R. Chu, "Characterization of Stationary and Non-stationary Behavior of Gyrotron Backward Wave Oscillator", *Phys. Rev. Lett*. Vol. 87, 064802 (2001).
43. McDermott, D.B.; Song, H.H.; Hirata, Y.; Lin, A.T.; Barnett, L.R.; Chang, T.H.; Hsin-Lu Hsu; Marandos, P.S.; Lee, J.S.; Kwo Ray Chu; Luhmann, N.C., Jr., "Design of a W-band TE01 mode gyrotron traveling-wave amplifier with high power and broad-band capabilities", Plasma Science, IEEE Transactions on, 2002, Volume: 30, Issue: 3, Pages: 894 - 902

44. Song, H.H.; Barnett, L.R.; McDermott, D.B.; Hirata, Y.; Hsu, H.L.; Marandos, P.S.; Lee, J.S.; Chang, T.H.; Chu, K.R.; Luhmann, N.C., Jr.,"W-Band heavily loaded TE01 gyrotron traveling wave amplifier", Vacuum Electronics, 2003 4th IEEE International Conference on, 2003, Pages: 348 - 349
45. H. H. Song, D. B. McDermott, Y. Hirata, L. R. Barnett, C. W. Domier, H. L. Hsu, T. H. Chang, W. C. Tsai, K. R. Chu, and N. C. Luhmann, Jr., "Theory and Experiment of a 94 GHz Gyrotron Traveling-Wave Amplifier," Phys. Plasmas 11, 2935 (2004).
46. Barnett, L.R.; Tsai, W.C.; Hsu, H.L.; Luhmann, N.C., Jr.; Chiu, C.C.; Pao, K.F.; Chu, K.R. 140 kW W-Band TE01Ultra High Gain Gyro-TWT Amplifier"' Vacuum Electronics Conference, 2006 held Jointly with 2006 IEEE International Vacuum Electron Sources., IEEE International, 2006, Pages: 461 - 462
47. Barnett, L.R.; Luhmann, N.C., Jr.; Chiu, C.C.; Chu, K.R.; Ying Chu Yan, "Advances in W-Band TE01 Gyro-TWT Amplifier Design", Vacuum Electronics Conference, 2007. IVEC '07. IEEE International, Pages: 1 – 2.
48. Barnett, L.R., Luhmann, N.C., Jr.; Johnson, M.; Chiu, C.C.; Chu, K.R., "An Experimental Investigation of High Emission Density Cathodes for High Power Gyrotron Amplifiers", Plasma Science, 2007. ICOPS 2007. IEEE 34th International Conf , 2007, Pages: 417 - 417
49. Young-Min Shin and Larry R. Barnett, "Intense Wideband Terahertz Amplification Using Phase-Shifted Periodic Electron-Plasmon Coupling," Appl. Phys. Lett. 92, 091501 (2008).
50. Young-Min Shin, Larry R. Barnett, and Neville C. Luhmann Jr., "Strongly confined plasmonic wave propagation through an ultra-wideband staggered double grating waveguide," Appl. Phys. Lett. 93, 221503 (2008).
51. C. C. Chiu, K. F. Pao, Y. C. Yan, and K. R. Chu, L. R. Barnett and N. C. Luhmann, Jr. "Nonlinearly Driven Oscillations in the Gyrotron Traveling-Wave Amplifier," Phys. Plasmas 15, 123109 (2008).
52. Young-Min Shin; Barnett, L.R. Phase-shifted double vane circuit (Barnett-Shin TWT) for ultra-wideband millimeter and submillimeter wave generation", Vacuum Electronics Conference, 2008. IVEC 2008. IEEE International, 2008, Pages: 54 - 55,
53. L. R. Barnett, N. C. Luhmann Jr., C. C. Chiu, and K. R. Chu, "Relativistic Performance Analysis of an Advanced High-Current-Density Magnetron Injection Gun, " Phys. Plasmas 16, 093111(2009).
54. C. C. Chiu, C. Y. Tsai, and S. H. Kao, K. R. Chu, L. R. Barnett and N. C. Luhmann, Jr., "Study of a High-Order-Mode Gyrotron Traveling-Wave Amplifier," Phys. Plasmas 17, 113104(2010).
55. Young-Min Shin, Barnett, L.R.; Jinfeng Zhao; Gamzina, D.; Luhmann, N.C. "MEMS-integrated 0.22THz TWT amplifier using an ultra-wide plasmonic band structure", IRMMW-THz 34, 1 (2009).
56. Young-Min Shin, Larry R. Barnett, Diana Gamzina, Neville C. Luhmann Jr., Mark Field, and Robert Borwick, "Terahertz vacuum electronic circuits fabricated by UV lithographic molding and deep reactive ion etching,", Appl. Phys. Lett. 95 (2009).
57. Young-Min Shin, Larry R. Barnett, and Neville C. Luhmann Jr., "Quasi-Optical Output Cavity Design for a 50kW Multi-Cavity W-Band Sheet Beam Klystron," IEEE Trans. Elec. Dev. 56(12), 3196 (2009).
58. Young-Min Shin; Barnett, L.R.; Luhmann, N.C., "Numerical and experimental design study

of quasi-optical multi-gap output cavity for W-band sheet beam klystron (WSBK)", Vacuum Electronics Conference, 2009. IVEC '09. IEEE International, 2009 pp 530 – 532.

59. Gamzina, D.; Spear, A.G.; Barnett, L.R.; Luhmann, N.C., "Terahertz sheet beam gun analyzer", Vacuum Electronics Conference (IVEC), 2010 IEEE International, 2010, Pages: 99 - 100.
60. Jian-Xun Wang, Larry R. Barnett, Stanley Humphries, Neville C. Luhmann, Jr., Young-Min Shin, "Electron Beam Transport Analysis of W-Band Sheet Beam Klystron (WSBK)," Phys. Plasmas 17, 043111 (2010).
61. Jinfeng Zhao; Na Li; Ji Li; Barnett, L.; Banducci, M.; Gamzina, D.; Luhmann, N.C., Jr. High current density and long life nanocomposite scandate dispenser cathode fabrication', Vacuum Electronics Conference (IVEC), 2010 IEEE International, 2010, Pages: 425 - 426
62. Young-Min Shin, Diana Gamzina, Larry R. Barnett, and Neville C. Luhmann Jr. "UV Lithography and Molding Fabrication of Ultra-Thick Micrometallic Structure using a KMPR Photoresist ", IEEE J. Microelec. Micro. Sys. 19 (3), pp. 683 - 698 (June 2010).
63. Young-Min Shin, Jenfeng Zhao, Larry R. Barnett, and Neville C. Luhmann Jr., "Investigation of terahertz sheet beam traveling wave tube amplifier with nanocomposite cathode," Phys. Plasmas 17, 123105 (2010).
64. Field, M.; Borwick, R.; Mehrotra, V.; Brar, B.; Jinfeng Zhao; Young-Min Shin; Gamzina, D.; Spear, A.; Baig, A.; Barnett, L.; Luhmann, N.; Kimura, T.; Atkinson, J.; Grant, T.; Goren, Y.; Pershing, D.E.,'220 GHz 50 W sheet beam travelling wave tube amplifier', Vacuum Electronics Conference (IVEC), 2010 IEEE International, 2010, Pages: 21 – 22.
65. Wen-Ching Tsai; Domier, C.W.; Barnett, L.R.; Luhmann, N.C., "Design and test of a high efficiency energy recovery pulse modulator", Vacuum Electronics Conference (IVEC), 2010 IEEE International 2010, Pages: 493 - 494
66. Young-Min Shin, Larry R. Barnett, and Neville C. Luhmann Jr., "Particle-In-Cell Simulation Analysis of a Multicavity W-Band Sheet Beam Klystron", IEEE Trans. Elec. Dev. 58 (1), 251 (Jan., 2011).
67. Young-Min Shin, Anisullah Baig, Larry R. Barnett, Neville C. Luhmann Jr., John Pasour, and Paul Larsen, "Modeling Investigation of an Ultra Wideband THz Sheet Beam Traveling Wave Tube (SBTWT) Amplifier Circuit", IEEE Trans. Elec. Dev. 58 (9), 3213 (Sept., 2011).
68. Jinfeng Zhao; Gamzina, D.; Baig, A.; Barnett, L.; Jianxun Wang; Luhmann, N.C., Jr., "Scandate dispenser cathode for 220 GHz 50W sheet beam travelling wave tube amplifier", Infrared, Millimeter and Terahertz Waves (IRMMW-THz), 2011 36th International Conference on, 2011, Pages: 1 - 2
69. Young-Min Shin, Anisullah Baig, Larry R. Barnett, Wen-Ching Tsai, and Neville C. Luhmann Jr., "System design analysis of 0.22 THz sheet beam traveling wave tube (TWT) amplifier", IEEE Trans. Elec. Dev. 59, 234 (2012.
70. Young-Min Shin, Anisullah Baig, Robert Barchfeld, Diana Gamzina, Larry R. Barnett, and Neville C. Luhmann Jr, "Experimental study of multichromatic terahertz wave propagation through planar micro-channels", Appl. Phys. Lett. 100 (15), 154103 (2012).
71. Anisullah Baig, Diana Gamzina, Jinfeng Zhao, Youngmin Shin, Robert Barchfeld, Larry R. Barnett, Calvin Domier, and Neville Luhmann Jr. "MEMS Vacuum Electronics" in

Encyclopedia of Nanotechnology, Springer, New York, NY, pp 1359 – 1543 (2012).

72. Anisullah Baig, L. R. Barnett, D. Gamzina and J. N. C. Luhmann, "MEMS compatible sever for 220 Ghz ultra wide band twta: Design and particle-in-cell analysis", Progress In Electromagnetics Research Letters, vol.41, pp. 135-148 2013.
73. Zongjun Shi, Diana Gamzina, Larry R. Barnett, Anisullah Baig, and Neville C. Luhmann, Jr.,Fellow, IEEE. “3D Simulations and Design of Multistage Depressed Collectors for Sheet Beam Millimeter Wave Vacuum Electron Devices” IEEE Transaction in Electron Devices Vol 60, Issue 9, 2013.
74. Anisullah Baig, Diana Gamzina, Robert Barchfeld, Calvin Domier, Larry R. Barnett, and Neville Luhmann Jr. “0.22 THz Wideband Sheet Electron Beam Traveling Wave Tube Amplifier: Cold Test Measurements and Beam Wave Interaction Analysis”, AIP Physics of Plasmas 19, 093110 (2012).
75. Youngmin Shin, Anisullah Baig, Larry R. Barnett, WenChing Tsai, Neville C. Luhmann, “System Design Analysis of a 0.22 THz Sheet Beam Traveling-Wave Tube Amplifier”, IEEE Transactions on Electron Devices, Vol. 59, No. 1, Jan 2012.
76. Anisullah Baig, Youngmin Shin, Larry R. Barnett, Diana Gamzina, Robert Barchfeld, Calvin Domier, Jianxun Wang, “Design, Fabrication and RF testing of Near-THz Sheet Beam TWTA” (Invited Paper), International Journal on Terahertz Science and Technology, Vol 4, No. 4, Dec 2011.
77. Youngmin Shin, Anisullah Baig, Larry R. Barnett, Neville C. Luhmann Jr., Fellow IEEE, John Pasour, and Paul Larsen., “Modeling Investigation of an Ultra Wideband Terahertz Sheet Beam Traveling-Wave Tube Amplifier Circuit”, IEEE Transactions on Electron Devices(IEEE-TED), Vol. 58, No. 9, September 2011.
78. Jinfeng Zhao, Na Li, Ji Li, Diana Gamzina, Anisullah Baig, Robert Barchfeld, Larry Barnett, Subhash Risbud, and Neville C. Luhmann Jr., “Scandia-added Tungsten Dispenser Cathode Fabrication of THz Vacuum Integrated Power Amplifiers” (Invited Paper), International Journal on Terahertz Science and Technology, Vol 4, No. 4, Dec 2011.
79. Y.M. Shin, Diana Gamzina, Larry R. Barnett, Frank Yaghmaie, Anisullah Baig and Neville C. Luhmann, Jr., “UV lithography and Molding Fabrication of Ultra-thick Micrometallic structures using a KMPR Photoresist,” IEEE Journal of Micro-electromechanical Systems (MEMS), VOL. 19, NO. 3, June 2010.
80. Mark Field, Zachary Griffith, Adam Young, C. Hillman, B. Brar, D. Gamzina, R. Barchfield, J. Zhao, A. Spear, Anisullah Baig, C. Domier, L. Barnett, N. C. Luhmann, T. Kimura, J. Atkinson, T. Grant, Y. Goren, T. Reed, M. Rodwell, “Development of 220 GHz, 50 W Sheet Beam Traveling Wave Tube Amplifier (TWTA)”, IEEE International Vacuum Electronics Conference (IVEC), Monterey, USA, 22 – 24 April, 2014.
81. Anisullah Baig, Diana Gamzina, Larry R. Barnett, Calvin Domier and Neville C. Luhmann. Jr. “233 GHz Ultra-Wide Band TWTA: PPM Integrated Sheet Electron Beam Transport and PIC analysis”. IEEE IRMMW-THz Conference, Mainz on Rhine, Germany Sept 1–6, 2013.
82. Anisullah Baig, Diana Gamzina, Robert Barchfeld, Larry R. Barnett, and Neville C. Luhmann, Jr. “Millimeter Wave Band TWTA Compatible with Nano-CNC Fabrication”, IEEE Pulsed Power & Plasma Science Conference – PPPS 2013, San Francisco, USA, June 16 – 21, 2013.
83. Anisullah Baig, Diana Gamzina, Robert Barchfeld, Jinfeng Zhao, Calvin Domier,

Alexander Spear, Larry R. Barnett, and Neville C. Luhmann Jr. “220 GHz Ultra Wide band TWTA: Nano CNC Fabrication and RF testing”, IEEE IVEC May 21–23, Paris, France, 2013.

84. Anisullah Baig, Diana Gamzina, Jinfeng Zhao, Calvin Domier, Larry R Barnett, and Neville C Luhmann. "MM-wave to THz Vacuum Electron Beam Devices. (Invited)" 2012 Asia Pacific Microwave Conference Proceedings, Taiwan (2012): 842-844.
85. Anisullah Baig, Diana Gamzina, Larry R. Barnett, and Neville C. Luhmann Jr., Fellow IEEE., “Simulation Analysis of Nano-CNC fabricated 220 GHz Ultra Wideband TWTA”, IEEE International Vacuum ElectronicsConference, Monterey, CA, pp. 393-394, 2012.
86. Robert Barchfeld, Diana Gamzina, Anisullah Baig, Larry R. Barnett, Neville C. Luhmann Jr., Nano CNC Milling of Two Different Designs of 0.22 THz TWT Circuits, 13th IEEE International Vacuum Electronics Conference (IVEC) and Ninth International Vacuum Electron Sources Conference (IVESC), Monterey, CA, April 24-26, 2012.
87. Jinfeng Zhao, Diana Gamzina, Anisullah Baig, Larry Barnett, and N. C. Luhmann, Jr, Na Li and Ji Li, “Scandate-added Tungsten Dispenser Cathode Fabrication for 220 GHz Sheet Beam Traveling Wave Tube Amplifier”, Proceedings IEEE IVEC pp. 47 - 48, Monterey, CA, 2012.
88. Jinfeng Zhao; Gamzina, D.; Na Li; Ji Li; Spear, A.G.; Barnett, L.; Banducci, M.; Risbud, S.; Luhmann, N.C., “Scandate Dispenser Cathode Fabrication for A High-Aspect-Ratio High-Current-Density Sheet Beam Electron Gun”, Electron Devices, IEEE Transactions on, 2012, Volume: 59, Issue: 6 , Pages: 1792 - 1798
89. Anisullah Baig, Youngmin Shin, Larry R Barnett, Diana Gamzinaand Neville C Luhmann, “Sever design and full model particle-in-cell simulation analysis for a 220 GHz ultra wideband TWTA” IRMMW-THz Proceedings, Texas, USA, pp 1- 2, Oct. 2011.
90. Anisullah Baig, L. R. Barnett, N. C. Luhmann Jr., Y.-M. Shin, “Numerical and Experimental Analysis of THz Sheet Beam Traveling Wave Tube Amplifier (TWTA)”, IEEE International Conference On Plasma Science. Proceedings, ISSN 0730-9244, June 2011.
91. Youngmin-Shin, Jinfeng Zhao, Diana Gamzina, Anisullah Baig, Robert Barchfeld, Alexander Spear, Jain-Xun Wang, Calvin W. Domier, Larry R. Barnett, Neville C. Luhmann Jr., “Microfabricated THz sheet beam vacuum electron devices”, IRMMWTHz Proceedings, Texas, USA, pp 1 – 3, Oct 2011.
92. Jinfeng Zhao, Diana Gamzina, Anisullah Baig, Larry Barnett, Jianxun Wang, N. C. Luhmann. Jr., “Scandate dispenser cathode for 220 GHz 50 W sheet beam traveling wave tube amplifer”, IRMMW – THz Proceedings, Texas, USA, Oct 2011.
93. Robert Barchfeld, Diana Gamzina, Anisullah Baig, Larry R. Barnett, Neville C. Luhmann and Young-Min Shin., "THz sheet beam traveling wave tube amplifier for microwave power module (mpm) application: MEMS-fabrications and characteristic analysis", IEEE International Conference On Plasma Science, pp. 1-1 2011.
94. Anisullah Baig, Jian-Xun Wang, Larry R. Barnett, Neville Luhmann Jr., Young-Min Shin, “Beam Transport Modeling of PPM focused THz Sheet Beam TWT circuit”, IEEE International Vacuum Electronic Conference Proceedings pp. 351 - 352, Feb., 2011.
95. Anisullah Baig,, Diana Gamzina, Micheal Johnson, Calvin W. Domier, Alexander Spear, Larry R.Barnett, Neville C. Luhmann and Young-Min Shin, “Experimental Characterization

of LIGA Fabricated 0.22 THz TWT Circuits" IEEE International Vacuum Electronic Conference Proceedings, pp. 275 – 276, Feb., 2011.

96. Young-Min Shin, L. R. Barnett, Anisullah Baig, N. C. Luhmann, J. Pasour and P. Larsen, "Numerical modeling analysis of 0.22 Thz sheet beam TWT circuit", in Vacuum Electronics Conference (IVEC), 2011 IEEE International, pp. 139-140, 2011.
97. Young-Min Shin, Z. Jinfeng, Anisullah Baig, D. Gamzina, L. R. Barnett and N. C. Luhmann, "Micro-fabricable terahertz sheet beam amplifier integrated with broadband metamaterial circuit", in Communications and Electronics (ICCE), 2010 Third International Conference on, pp. 373-378, 2010.
98. Young-Min Shin, Anisullah Baig, A. Spear, Z. Jinfeng, D. Gamzina, C. W. Domier and N. C. Luhmann, "MEMS fabrications of broadband epsilon negative (eng) metamaterial electronic circuit for 0.22 THz sheet beam TWT application", inInfrared Millimeter and Terahertz Waves (IRMMW-THz), 2010 35th International Conference on, pp. 1-2, 2010.
99. M. Field, R. Borwick, V. Mehrotra, B. Brar, Z. Jinfeng, S. Young-Min, D. Gamzina, A. Spear, A. Baig, L. Barnett, N. Luhmann, T. Kimura, J. Atkinson, T. Grant, Y. Goren and D. E. Pershing, "1.3: 220 GHz 50 W sheet beam travelling wave tube amplifier (TWTA)", in 2010 IEEE International Vacuum Electronics Conference (IVEC), pp. 21-22, 2010.
100. K. R. Chu , L. R. Barnett, W. Y. Chiang, T. H. Chang, K. L. Wu, H. Y. Chang, and S. Y. Cheng, "A Quasi-Optical System for Ultra Rapid Microwave Heating," plenary talk, 7th Int. Conf. on Microwave Materials and Their Applications (June 3-6, 2012, Taipei, Taiwan).
101. W. Y. Chiang, M. H. Wu, K. L. Wu, M. H. Lin, H. H. Teng, Y. F. Tsai, C. C. Ko, E. C. Yang, J. A. Jiang, L. R. Barnett, and K. R. Chu, "A microwave applicator for uniform irradiation by circularly polarized waves in an anechoic chamber" Review of Scientific Instruments 85, 084703 (2014).
102. Barnett, L.R., "A compact normal magnet for high power millimeter-wave gyrotrons: The electropermagnet", Infrared, Millimeter, and Terahertz waves (IRMMW-THz), 2014 39th International Conference, 2014, Pages: 1 - 2
103. M. S. Lin, S. M. Lin, W. Y. Chiang, K. L. Wu, L. R. Barnett, and K. R. Chu, "Effects of Polarization-Charge Shielding in Microwave Heating," Keynote Talk, 16th International Vacuum Electronics Conference (April 27-29, 2015, Beijing, China).
104. M. S. Lin, S. M. Lin, W. Y. Chiang, L. R. Barnett, and K. R. Chu, "Effects of Polarization-Charge Shielding in Microwave Heating," Phys. Plasmas 22, 083302 (2015).
105. N. Lin, L. R. Barnett, and K. R. Chu, "A broadband gyrotron backward-wave oscillator with tapered interaction structure and magnetic field," Phys. of Plasmas (November, 2015).
106. Barnett, L.R., "A normal electropermagnet for high power millimeter-wave gyrotrons", Vacuum Electronics Conference (IVEC), 2015 IEEE International, 2015, Pages: 1 - 2

Patents

1. Cyclotron Maser Using a Nonlinear Electrostatic Field
2. Waveguide Coupler for Gyrotron Traveling-Wave Amplifiers
3. Bametron Microwave Amplifiers and Oscillators
4. Waveguide Coupler Using Three or More Modes
5. Y. Y. Lau, K. R. Chu, V. L. Granatstein and L. R. Barnett, "Wideband Gyrotron Traveling Wave Amplifier," *U.S. Patent* No. 4553875 (1985).

Draft White Paper: Plasma Antennas for Advanced Drone Based Ground Penetrating Radar.

6. L. R. Barnett, Y. Y. Lau, K. R. Chu, and V. L. Granatstein, "Wideband Distributed rf Coupler, *U.S. Patent* No. 4567401 (1986).
7. A low Magnetic Field Gyrotron-Gyromagnetron
8. Active Circulator Gyrotron Traveling-Wave Amplifier
9. Stripline Traveling-Wave Device
10. Harmonic Auto-Resonance Peniotron
11. Noninvasive Vacuum Gauge
12. K. R. Chu, L. R. Barnett, C. Wang, Y. S. Yeh, T. T. Yang, H. Y. Chen, S. H. Chen, Y. C. Tsai, and T. Y. Dawn, “Mechanically Tunable Magnetron Injection Gun”, *U. S. Patent* No. 5814939 (1998).
13. L. R. Barnett, K. R. Chu, T. H. Chang, H. Y. Chang, W. Y. Chiang, C. F. Yu, L. C. Tai, S. Y. Cheng, and C. S. Kou, “Quasi-Optical Material Treatment Apparatus,” US patent no. 9382932 (2008).
14. Larry R. Barnett, “Electro-Permanent Magnet for Power Microwave Tubes”. US Patent no. 7,764,020 (2010).
15. Larry R, Barnett, Young-Min Shin,” Traveling-wave tube 2D slow wave circuit”, US Patent 7952287 (2011).
16. Larry R. Barnett, “Compact Magnet System for a High-Power Millimeter-Wave Gyrotron”, US Patent Pending.

Major Projects as d.b.a. Mountain Technology

1. Three 70 kWCW microwave transmitters using high power klystrons for powering synchrotron storage ring facility, upgraded to 100 kWCW.
2. High power waveguide automatch and circular polarization converter for a plasma etching chamber.
3. 45 kV, 50 kWCW switch mode power supply for TWT transmitter,
4. 150 kV pulse modulator for high voltage gyrotron research.
5. 30 kV 30 kW average power modulator system for EIO research.
6. Gyrotron (cyclotron maser) amplifiers and oscillators (approx. 10 projects).
7. 220 GHz 50 W high gain broadband TWT with high resolution beam analyzer.
8. 95 GHz 56 kW peak sheet beam klystron, 10 kWCW design.
9. 20 kG electropermagnet and electropermagnet gyrotrons.
10. Using microwave power for insect control research.
11. Four 30 kV and one 100kV pulse modulators