SPACE-BASED TECHNOLOGIES

Background

Space is a frontier that offers a whole new world of discovery and innovation; it is full of untapped potential in both the private and public sectors. Successful cooperation between government entities and private companies has created a continuously growing industry. The emerging industry opens the door to inventions and research in satellites, antennas, navigation systems, imaging, communications, and more. Researchers at the University of New Mexico have lead innovation in space-related technologies as highlighted through the featured inventions.

Market Opportunity

According to Markets and Markets, "North America is witnessing a huge surge of demand from education, government, and defense sectors to survey the surface of the Earth for various purposes. This has resulted in North America being a global leader in the Earth observation and remote sensing segment." The Satellite Industry Association valued the global space industry was worth $271 billion in 2019 and expects a rise of investments and support from both government entities and the private sector. In concurrence, Frost & Sullivan expects "demand for satellite-based services across co-connectivity and situational awareness domains [to] experience [continuous] growth." The market for space-related technologies is healthy and open to innovation.

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TECHNOLOGY BREAKTHROUGH

Antennas

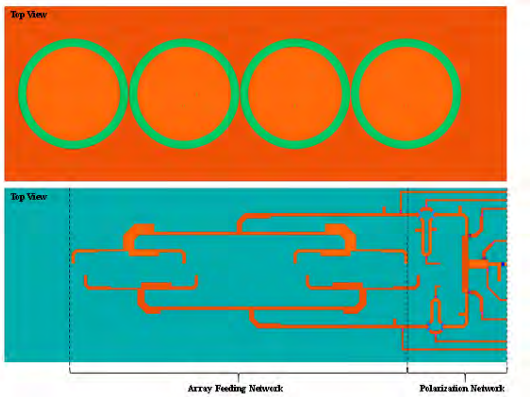
Feeding Network for Reconfigurable Antenna Polarization (Ref. 2020-119)

Researchers at the University of New Mexico and BlueCom Systems and Consulting LLC have developed a low cost, low profile and low power method to achieve reconfigurable polarizations in antennas. The method achieves low loss N reconfigurable polarizations, due to the combination of an orthogonal mode supporting antenna with a reconfigurable power divider. The overall design cost effectively composes a single port driven antenna system with the desired number of reconfigurable polarizations. Enhanced polarization capabilities provide a significant improvement on the necessary telecommunication characteristics needed for adequate connectivity and reliability. In addition, fabrication ease, inexpensive production, and low power consumption enable this technology to overcome the limitations presented by currently available antenna arrays.

Benefits:

- Inexpensive and easy to fabricate
- Offers less interference and better signal to noise ratio
- Requires low power consumption
- Provides diverse polarizations with a single main feeding port
- Applicable to single or array antennas

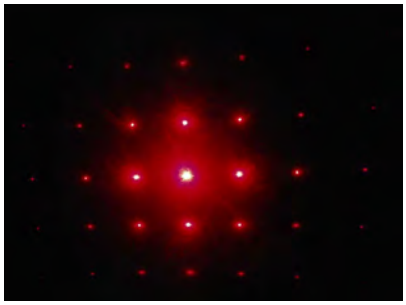
Intellectual Property:
Filed Provisional Patent 63/211,430



Six-polarization reconfigurable array antenna

Laser-based Technique for the Parallel Writing of Metal Formed Antenna Arrays (Ref. 2020-118)

Researchers at the University of New Mexico have developed the following novel approaches critical for the development of laser formed antenna arrays: 1) use of customized diffraction optics to create patterns for parallel writing of arrays, and 2) high precision robotic arms to achieve the movement required for such antennas. The combination of these two technologies creates a technique for parallel writing of metal formed antenna arrays using lasers. The use of optical elements such as diffraction gratings in combination with specific optical techniques can allow for the realization of an array of laser spots to form a single high-power laser which in turn will allow for the writing of hundreds of antennas on a metal sheet simultaneously. The ability to form high-performance antennas with lasers not only allows for the scaling of the process to simultaneously fabricate a large array of such antennas but could also lead to the realization of low- cost phased antenna arrays.



An array of points created from a high-power laser

Benefits:

- Scalable fabrication process results in low-cost, phased antenna arrays development
- Enables an array of laser spots from a single high-power laser
- Simultaneous writing of hundreds of antennas
- Ability to fabricate antennas in parallel

Intellectual Property:
Filed Provisional Patent 63/197,947

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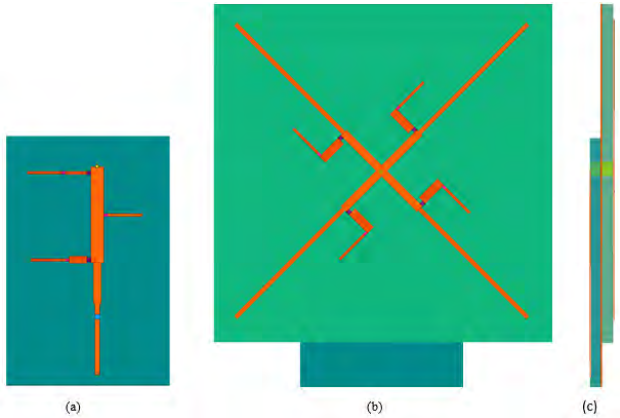
Low Loss Tunable Matching Network for Pattern Reconfigurable Array Antennas (Ref. 2020-103)

Researchers at the University of New Mexico (UNM) have developed a low loss reconfigurable array antenna. The reconfigurable tuning network is used to create an independent radio frequency (RF) switch that maintains stable tuning and highly efficient system. The active elements can be any RF switch type, are able to activate and deactivate RF energy, and can be used to form single RF-port array antennas. Moreover, switches can be implemented to establish a beamforming antenna, eliminating the complexity of transceivers used to control each individual RF. The reconfigurable switching system provides independent multiple beam steering, at any desired frequency, while embracing low-cost and straightforward simplicity characteristics. Moreover, this can be used to approach different reconfigurable antenna models; such as, polarization diverse or a combination of other radiating characteristics.

Benefits:

- Can instantaneously alter its operating behavior (radiation pattern, , space) to adjust in new electromagnetic behavior
- Single-Pole, Variable Throw system
- Applicable at any desired frequency
- Increased efficiency with reduction in power losses
- Cost-effective

Intellectual Property: Filed Utility Patent 17/341,160



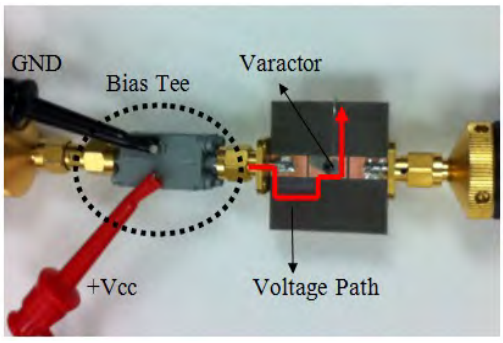
Reconfigurable Tuning Switch Topology
a) Top View b) Side View c) Bottom View

Reconfigurable Filtenna (Ref. 2012-068)

A new reconfiguration technique for frequency tunable antennas has been developed, with the objective of changing the antenna's operating frequency without incorporating active components in the antenna radiating surface. This can be done by integrating a reconfigurable band-pass filter within the feeding line of the antenna. The antenna can tune its frequency based on the filter's operation. This integrated antenna- filter combination, with filtering and radiation performance, is referred to as "filtering antenna" or a filtenna.

Benefits:

- Integrates both the band-pass filter and the antenna within the same antenna substrate, which allows easier, more efficient and more compact integration
- Negative effects of the biasing lines on the antenna behavior are minimized since they no longer reside in the radiating surface of the antenna
- By tuning the operating frequency of the filter, the antenna is able to maintain the same radiation pattern and a constant gain since the antenna surface current distribution are not disrupted.



Fabricated Prototype

Intellectual Property:
Issued National Patent 9,653,793

Publication:
A Varactor-Based Reconfigurable Filtenna

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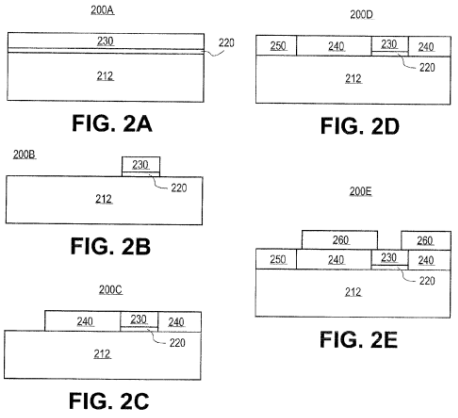
Optically Pumped Reconfigurable Antenna Systems (OPRAs) (Ref. 2009-050)

A new methodology called the "Optically Pumped Reconfigurable Antenna System (OPRAS)" is presented. Unlike other reconfigurable antenna designs, the OPRAS design makes use of intrinsic Gallium Arsenide cells whose doping (and thereby conductivity) can be altered by exposing the cell to laser light of appropriate wavelength. The OPRAS methodology avoids the design complications encountered in existing reconfigurable antenna designs due to crosstalk between bias lines for diode switches or MEMS switches. An added advantage is that by turning off the laser-source, the cells quickly return to their semi-conductive, dielectric, state and thereby reduce the aperture size of the antenna; thus, reducing its Radar Cross Section (RCS), ideal for military/stealth applications.



An exemplary optically pumped reconfigurable antenna sysem (OPRAS) at various stages of fabrication

Benefits:

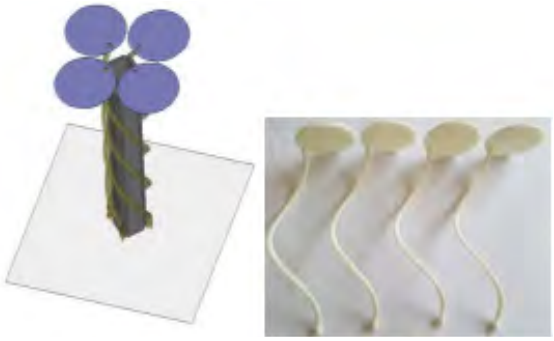
- Reconfigurable corporate feed
- Can be made conformal to any surface
- Optional stealthy ability

Intellectual Property: Issued Utility Patent 8,482,465

Publications: International Symposium (APSURSI), 2010 IEEE Optically Pumped Reconfigurable Antenna Systems (OPRAS); Antennas and Propagation Society

A Modified Quadrifilar Helix Antenna (Ref. 2017-016)

Researchers have developed a new method for creating a quadrifilar helix antenna using 3D printing. This technique provides a way of accurately miniaturizing the length of a quadrifilar helix antenna while maintaining circular polarization. A conical shaped ground plane is also implemented for a more compact structure. This technology shows that 3D printing technology can be used in the area of antenna design in order to facilitate the fabrication of volumetric radiating structures.



The antenna's quadri ilar helix design and components created using 3D printing

Benefits:

- Novel design and method of manufacturing an antenna such as a quadrifilar helix antenna using 3D printing as well as other additive and subtractive manufacturing procedures
- Miniaturizes the length of a quadrifilar helix antenna while preserving good radiation characteristics
- Design allows for lower resonant frequency of the quadrifilar helix antenna without increasing the number of turns and the spacing for each arm
- Antenna gain and radiation efficiency remains acceptable even with miniaturized structure
- Antenna structure can be used for applications that necessitate compactness, acceptable gain and circular polarization such as in small and nano-satellites

Intellectual Property: Issued Utility Patent 10,381,737

Publication: 3D Printed Miniaturized Quadrifilar Helix Antenna

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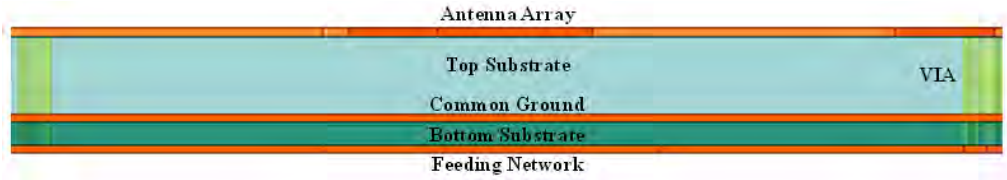
The Achievement of Close to Pure Wideband Circular Polarization in Printed Antenna Arrays (Ref. 2019-066)

Researchers at the University of New Mexico have developed a technique that enables the design of miniaturized, compact antennas that can exhibit broadband close to pure circular polarization. The invention achieves close to pure wideband circular polarization in printed K/Ka-band stacked antenna arrays. The patch antenna elements generate two bands of operation with an elliptical polarization. These elements have minimal separation to create low side lobe levels and highly directional radiation pattern. The elements are divided into groups of four elements and fed using a sequential rotational feeding network that is optimized to change the elliptical polarization of the patches into close to pure circular polarization. The feed network also improves the band of operation of the array and turns it into an ultra-wideband array. High gain and a low axial ratio are exhibited, allowing adequate communication links to be established between the satellite and earth terminal stations. The resulting array can be utilized for satellite or terrestrial communication; as well as satellite to earth communication.

Benefits:

- Highly directional pattern with the lowest side lobe level
- Large operating bandwidth (40% fractional bandwidth)
- Improved bandwidth and circular polarization traits
- Ensures wideband characteristics and high efficiency

Intellectual Property:
Filed National Patent 17/416,462



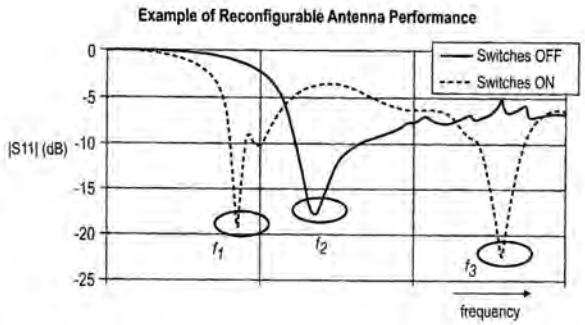
Antenna Layers

Publications:

- A Ka-Band Frequency Reconfigurable Circularly Polarized Antenna Array Using a Ring Resonator
- A K/Ka Band Frequency Reconfigurable Transmit/Receive Antenna Array

Reconfigurable Multifrequency Antenna with RF-MEMS Switches (Ref. 2006-005)

This RF-MEMS reconfigurable multiband antenna is based on a self-similar (fractal) design. Ohmic contact cantilever RF-MEMS switches are integrated with self-similar planar antennas to provide a reconfigurable antenna system that radiates similar patterns over a wide range of frequencies. This multiband antenna is fabricated monolithically on a high-resistivity silicon wafer with the RF-MEMS switches.



Example of Reconfigurable Antenna Performance

Benefits:
This reconfigurable antenna has been fabricated, tested and proven effective and provides the following advantages:

- Enhanced performance compared to conventional multiband antennas
- Radiation of similar patterns at all frequencies
- Very low power requirements/consumption
- Reliability
- Low mass production cost
-

Intellectual Property: Issued Utility Patent 7,589,674

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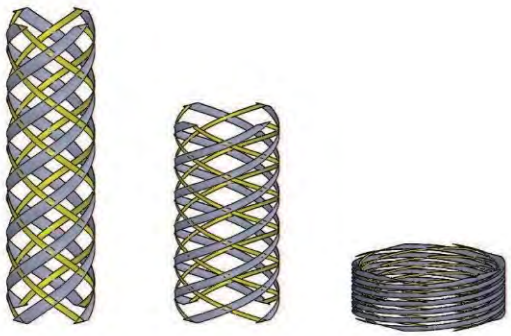
Rapid Design of Deployable Antennas for CubeSats (Ref. 2016-081)

Researchers at the University of New Mexico and California Institute of Technology have developed a novel methodology for the rapid preliminary design of deployable antennas for CubeSats. Coupled electromagnetic and structural design problems are easily addressed by allowing designers to select and compare various antenna topologies against multiple deployment approaches based on desired performance requirements. A graphical representation of antenna performance as a function of geometry using a set of two-dimensional plots eliminates designs which do not meet all requirements, before selecting an optimal solution that will then be modeled.

Benefits:

- Rapid design of deployable antennas for CubeSats
- Technology easily addresses coupled electromagnetic and structural design problems of current antennas
- Design tool allows user to compare different antenna types or a single antenna with several different folding schemes
- Methodology has been demonstrated using a relatively small number of antenna types and deployment concepts



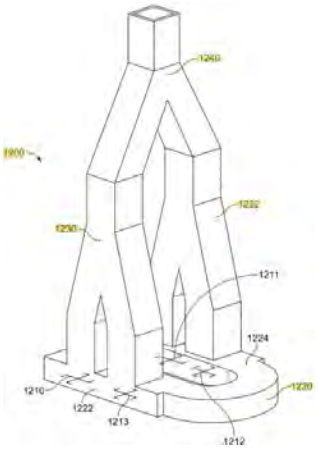
The Antenna's Compressible Design

Intellectual Property:
Issued National Patent 10,733,335

Publication:
Rapid Design of Deployable Antennas for CubeSats: A tool to help designers compare and select antenna topologies

Cross Slot Polarizer (Ref. 2019-057)

Researchers from the University of New Mexico have developed a technique that can create multiple polarization senses for communication systems, right-hand circularly polarized (RHCP) or left-hand circularly polarized (LHCP), by changing the feeding port or linearly polarization by feeding both ports. The design is based on radiating slots in the waveguide that have their radiated powers combined and can create different bands of operation and allow for circular polarization to be generated. Different design parameters can be tuned in order to create a single wider band of operation, or two far apart bands of operation that are narrowband. The design of this polarizer makes it easy to fabricate even with small features for millimeter wave frequencies of operation. This polarizer can be used in a variety of feed applications, such as a conical horn, a pyramidal horn, a lens antenna, or a reflector antenna.



Schematic of a Four-Slot Polarizer Application

Benefits:

- Electromagnetic wave polarization technique
- Used at millimeter wave frequencies
- Simultaneous transmission and reception of different polarization senses
- Easy to fabricate using milling techniques, laser etching, or 3D printing
- Polarizer can be designed to feed any waveguide fed antenna

Intellectual Property: Filed Utility Patent 16/700,745

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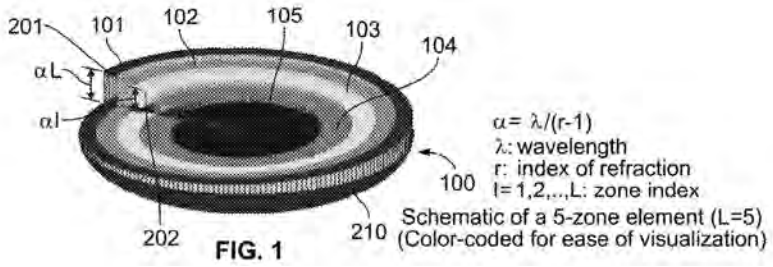
A Rotating Point-Spread Function (PSF) Design for Three-Dimensional Imaging (Ref. 2013-075)

A new technique has been invented that yields a 3D point-spread function with the ability to rotate with changing defocus while still keeping its transverse shape approximately constant over several waves of defocus. This new innovation also offers a broad spatial frequency response with 100% power transmission. This approach may also be generalized for other azimuthally symmetric, monomial phase aberrations.

Benefits:

- Enhanced, highly-sensitive transverse and depth resolution in a snapshot mode
- 3D imaging capabilities of air-to-ground and space-to -space target recognition and remote sensing system
- Generalizes readily for encoding spherical aberration



Schematic of One Embodiment of the Invention

Intellectual Property: Issued Utility 9,350,977; Issued Cont-in-Part 9,823,486

Publications:

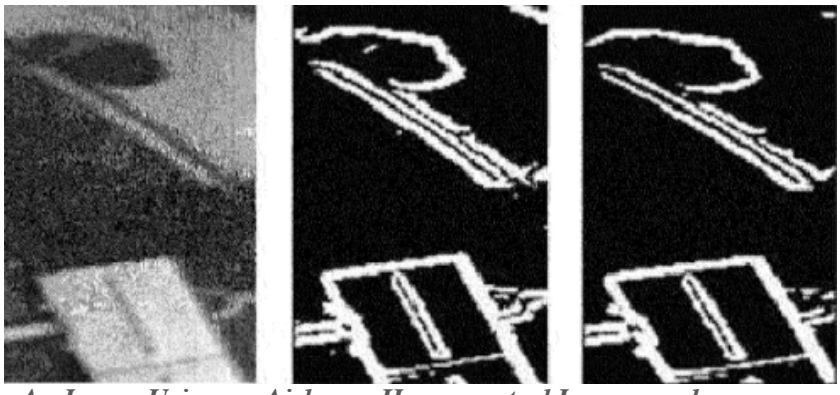
- Rotating point spread function via pupil-phase engineering
- PSF rotation with changing defocus and applications to 3D imaging for space situational awareness

Spectral Ratio Contrast Algorithm For Edge Detection in Spectral Images (Ref. 2010-069)

Researchers from the University of New Mexico have developed a novel joint spatio-spectral algorithm for edge detection of MS and HS images. The algorithm, which is named Spectral Ratio Contrast (SRC), is designed as a dedicated MS/HS edge detection algorithm. The algorithm fuses a given spatial mask with the spectral band ratios from a given edge signature into a non-separable, three-dimensional spatio-spectral mask. This technology also utilizes the concept of the spectral ratio contrast to estimate similarity and discontinuity in a HS/MS image.

Benefits:

- Generates improved edge map useful for HS/MS image segmentation
- Detects isoluminant and weak edges in MS/HS images
- Significant data compression in HS/MS image processing
- Provides great potential for compressive sensing and data acquisition
- Designed from the onset of sensing as a dedicated MS/HS edge detection algorithm
- Estimates similarity and discontinuity in a given HS/MS image rather than measuring the rate of change in the image



An Image Using an Airborne Hyperspectral Imager and Corresponding Images in a Spectral Ratio Contrast Edge Map and in a Multi-Color Gradiet Edge Map

Intellectual Property: Issued Utility Patent 8,649,607

Publications:

- Model-based Edge Detector for Spectral Imagery Using Sparse Spatio-spectral Masks
- Classifier-enhanced algorithm for compressive spatio-spectral edge detection

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Measurement

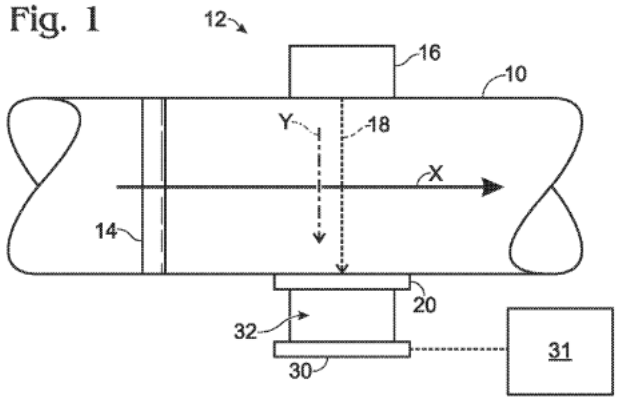
Optical Phase Shift Fluid Flow Velocity Measurement Mechanism (Ref. 2010-062)

Researchers have developed a solid state electro-optical method and apparatus for measuring the velocity of any free stream flow. The mechanism is extremely simple without moving parts. It can be sealed with no secondary pressure outlets or mechanical links where contamination might be an issue, and it can be built in an inexpensive and compact fashion to a high level of redundancy for applications such as space exploration or the primary loop of a nuclear reactor, where field service is impossible or undesirable.

Benefits:

- Can be sealed with no secondary pressure outlets or mechanical links
- Inexpensively and compactly built to a high level of redundancy for many applications
- Applications in space explorations, aerospace measurements, and velocity measurement of fluid flows in any pipe or channel

Intellectual Property:
Issued Utility Patent US 8,567,259



Side-View Schematic of an Electro-Optical Flow-Meter

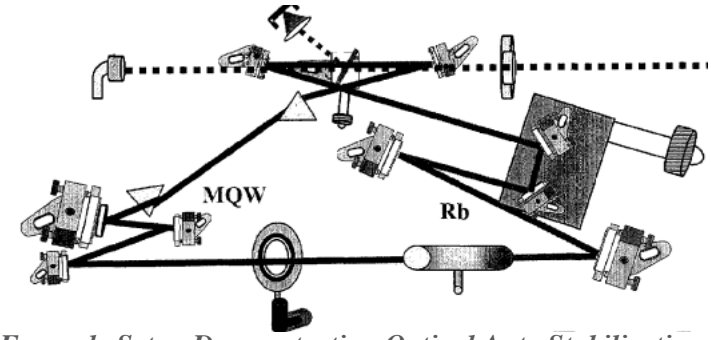
Navigation

Active Bidirectional Mode-Locked Laser for Accurate Measurements in Navigation System of Vehicles (Ref. 2011-013)

A novel mechanism to measure both absolute and relative attitude of a vehicle. This mechanism introduces an Intra-cavity Phase Interferometer (IPI) method using an active bidirectional mode-locked laser that provides both a measurement of all three attitude rotation vectors ("pitch", "yawn", and "row"), and a measurement of the vehicle's position relative to earth using information of its local magnetic field.

Benefits:

- Lightweight with low power consumption
  - High sensitivity inertial and position measurements using a single detection mechanism
- Absence of dead band and associated nonlinearity in the inertial response
- Applications in guidance, navigation and control systems (GNC systems); satellites and satellite navigation



Example Setup Demonstrating Optical Auto Stabilization

Intellectual Property: Issued Utility Patent 9,306,363

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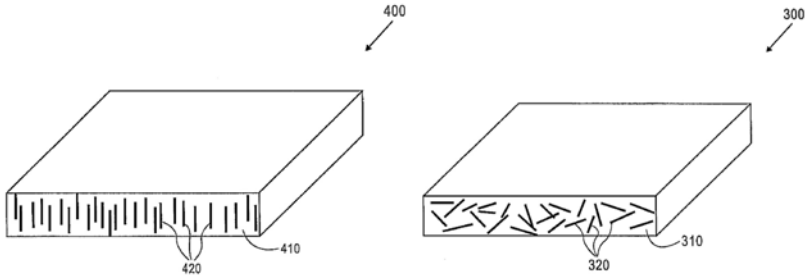
Metal-Carbon Nanotube Composites for Enhanced Thermal Conductivity for Demanding or Critical Applications (Ref. 2006-043)

This technology provides a carbon nanotube composite matrix which improves thermal conductivity and heat dissipation compared to existing commercially available material. Carbon nanotubes can be organized in a random or specific alignment to fit the needs of the application. Because the melting point of carbon nanotubes (> 2000°F) far exceeds traditional metals, the composite provides a material that can withstand higher temperatures and is able to conduct heat at an accelerated rate.

Benefits:
This composite carbon nanotube matrix provides for high performance in vital applications where heat management is imperative. Enhances any application where heat must be quickly dissipated containment, parts, tools, machinery and electronics.

This material provides:
- Increased heat tolerance
- Increased thermal conduction/heat dissipation



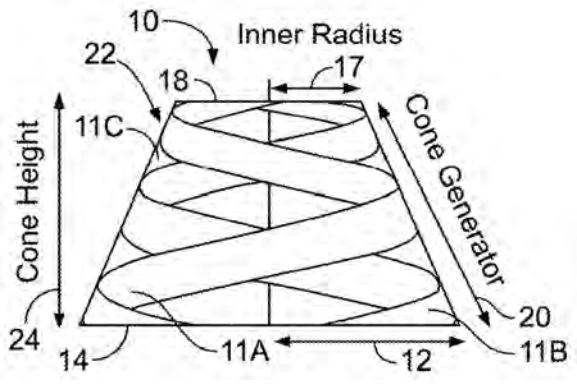
Illustrations of two embodiments of exemplary metal-carbon nanotube composites

Intellectual Property:
Issued Utility Patent 7,998,367

Dual-Matrix Composite Embedded Conductors (Ref. 2015-099)

A deployable high-performance antenna for CubeSats. This new antenna has been designed in a way for it to operate at Ultra High Frequency bands (UHF). The antenna can also be scaled to operate within other frequency spans. In addition, a unique structural concept, using dual-matrix composites, allows the antenna to be packaged into small volumes. The antenna is capable of satisfying size constraints by being compactly folded during launch and deployed successfully once in orbit.

Benefits:
- Vibration tests showed that antenna natural frequencies are significantly higher than environmental forcing frequencies
- Advanced antenna ideal for ultra-high frequency and high-gain performance
- Prototype has been developed and was subjected to structural and electromagnetic testing to verify simulated performance
- Suitable candidate for deployment on top of a 6U CubeSat



Conical Log Spiral Antenna

Intellectual Property:
Issued Utility Patent 10,256,546

Publication:
Dual-Matrix Composite Wideband Antenna Structures for CubeSats

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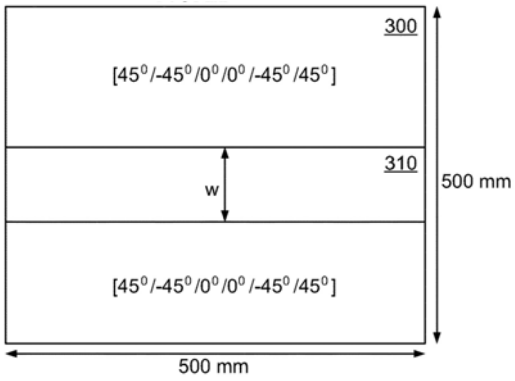
Stiffener Free Lightweight Composite Panels for Civil, Automotive and Aerospace Applications Using Nanomaterials and/or 3D Printing Technology (Ref. 2016-067)

Researchers at the University of New Mexico propose a technology to replacing stiffener plates in composite panels with nanomaterials grown or 3D printed. Researchers have shown that a stiff nanomaterial grown, or 3D printed can allow the same load capacity of the composite panel. This innovation is not limited to only stiffeners plates but can also apply to all load sharing and stiffening elements. Using nanotechnology and/or 3D printing can enable a new generation of structural composites that are light weight and much more versatile for numerous applications.

Benefits:

- Stiffener free composite panels
- Nanomaterials that can be grown or 3D printed
- Not limited to stiffeners plates but to all load sharing and stiffening elements
- Stiffened strips to be as thin as 100 micrometer and its stiffness can be controlled during fabrication
- Technology produces panels that are lighter than the original panel but with the same load carrying capacity
- New generation of structural composites that are light weight and much more versatile for numerous applications
- Enables strong and lightweight composite structures for many civil, automotive, and aerospace applications including airplanes, cars and civil infrastructure



Schematic of the Siffener Free Composite Panel with a Strip of Highly Aligned Nanomaterials

Intellectual Property: Published National Patent US 2020/0009808 A1

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Supporting Technology Transfer and Catalyzing Economic Development at the University of New Mexico

Inventors Featured

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2010-069

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2015-099

Christos G. Christodoulou
2020-119
2020-118
2020-103
2019-066
2019-057
2009-050
2006-005
2012-068
2017-016
2015-099

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2019-057

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2017-016
2015-099

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Company Overview

UNM Rainforest Innovations is a nonprofit corporation formed and owned entirely by the University of New Mexico Board of Regents (UNM). We are a 501(c)(3) non-profit corporation with an independent board of directors. Located at the Lobo Rainforest Building in the heart of the Innovation District in Albuquerque, New Mexico, UNM Rainforest Innovations has proximity to research and development and laboratory facilities and other technology-based companies, many of which are the creation of UNM Rainforest Innovations.

As the technology-transfer and economic-development organization for the University of New Mexico, UNM Rainforest Innovations protects and commercializes technologies developed at the University of New Mexico (UNM) by filing patents and copyrights and transferring the technologies to the marketplace. We connect the business community (companies, entrepreneurs and investors) to these UNM technologies for licensing opportunities and the creation of startup companies.

Visit http://innovations.unm.edu/

Contact Information

UNM Rainforest Innovations is currently exploring commercialization options for these exciting emerging technologies. If you are interested in information about this or other technologies, please contact Alex Roerick, Innovation Manager for Engineering & Physical Sciences, at aroerick@innovations.unm.edu, or (505) 277-0608.

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Supporting Technology Transfer and Catalyzing Economic Development at the University of New Mexico