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Program

T1.1: Tutorial 1 - Practical Applications of Asymptotic Techniques in Electromagnetics....N/A

The asymptotic techniques have been widely used for solving electromagnetic problems when the electrical size of the scenario is large in comparison to the wavelength. These techniques are applied to problems such as the analysis of on-board antennas, computation of the RCS, antenna design or the study of the propagation in mobile communications. However, the accuracy of these techniques is related to the fidelity of the geometrical modeling compared to the real scenario. There are two options. The first option is a simplification of this modeling using canonical structures to simplify the geometrical treatment associated with these techniques. The disadvantage of this option is a loss of accuracy in the results. The second option is an exact modeling of the scenario in order to obtain results that are as accurate as possible. In this case, the price to pay is the computational cost associated with the solution of the problem. This tutorial attempts to show how this second modelling option can be applied to obtain very accurate results; combining the electromagnetic techniques with some geometrical techniques enables the solution of realistic and complex problems with a reasonable amount of computational resources.With this aim, the tutorial presents the application of high frequency or asymptotic techniques to the analysis of complex electromagnetic problems. By complex problems we refer to those that are completely arbitrary in shape. A suitable geometrical modeling of the problem is then needed. This modeling is performed by means of parametric surfaces called NURBS (Non Uniform Rational B-Splines) that are commonly used in the world of Computer Aided Graphic Design for aeronautical and architectural applications. A description of this modeling is included in the tutorial. The main objective of the tutorial is the application of the asymptotic techniques to the analysis of problems modeled by these kind of surfaces. Two techniques are described: the Uniform Theory of Diffraction (UTD) and the Physical Optics (PO). The basic theory of both techniques is explained but with special focus on their applicability to objects modeled by NURBS. A section is also dedicated to the so-called ray-tracing acceleration techniques which are very important for addressing complex problems with a reduced computational cost. The application of these techniques to both UTD and PO are included in the tutorial.

T2.1: Tutorial 2 - Measurements as Field Sources in Computational Electromagnetics with Application in Antenna Placement Analysis and EMC....N/A

The source reconstruction, or equivalent source method, provides an accurate near-field representation of any radiating device in terms of equivalent electric and magnetic currents. The equivalent currents can be determined from measured near- or far-field data through a post-processing step involving the solution of an integral equation. The equivalent currents constitute an accurate 3D electromagnetic model, maintaining near and far field properties of the measured device. A newly created link, enable the import of such models into several commercial computational electromagnetic (CEM) solvers in the form of a near-field Huygens box.The tutorial cover the application of the link to the computational analysis of antenna placement on large structures, and electromagnetic compatibility (EMC) using commercially available near-field measurement systems, post-processing, and CEM tools. Application examples are discussed in detail:1. Antenna placements on larger complex structures,2. Pre-compliance emission analysis of a printed circuit board (PCB). Experimental validations of the computational processes are shown from measurement results.The tutorial covers the following topics:1. Introduction to the equivalent source/current method - Near Field measurement techniques - Equivalent source/

current processing of near field data2. Huygens Box link to computational tools and validation scenarios3. Source antenna measurement and post-processing issues - "Free space" antenna source - Flush mounted antenna applications4. Application examples - Radiation of flush mounted small antenna in complex scenario - Emission analysis PCB board in realistic scenarios (EMC)5. Discussion, Next Steps and Conclusion

T3.1: Tutorial 5 - Stepped Plane Wave Simulation for some common antenna problems using exising simulation software....N/A

Traditional antenna simulations use active source or sources together with other structures and the solution finds the far or near electromagnetic (EM) field distributions. In some cases, it is useful to perform the inverse operation, which treats the antenna as a passive structure being excited by an external, controlled EM field. In far-field cases, the external controlled EM field used is a plane wave. This tutorial will demonstrate how this method can be applied using some existing EM simulation tools. Examples will include some common antenna problems, solved for comparison both in the ‘traditional' method and the stepped external field method. Where time permits, some examples will be done as live simulations.

T1.2: Tutorial 4 - Towards Energy-Efficient Hyper-Dense Wireless Networks with Trillions of Devices....N/A

The information and communication technology (ICT) data traffic is expected to increase 1,000 fold by 2020. This increasing demand is quickly draining the scarce radio resources and will eventually affect our nations' economy. This strongly motivates the need for intensive research on the next generation of wireless networks. Beyond conventional cellular data, machine-to machine (M2M) and device to device (D2D) communication will be responsible for a big portion of the wireless traffic in the next few years. This will, in turn, further strain existing wireless infrastructure and require novel designs. According to recent forecasts, there will be 12.5 billion inter-connected machine-type devices worldwide by the year 2020, up from 1.3 billion in 2012. For coping with such traffic growth, it is well known that the major technique for meeting a much needed 1000x capacity improvement will be a byproduct of massive network densification. The idea is to introduce heterogeneous networks (HetNets) having new, additional nodes, such as small cellbase stations, deployed within local-area range and making the network closer to the end-users. The integration of macro/micro/pico/small cell base stations (SBSs) with disparate cell sizes and capabilities, has already been approved as a working item in LTE-advanced and 5G. Such hyper-dense and heterogeneous networks (HDHNs) can significantly improve spatial frequency reuse and coverage, thus meeting the wireless capacity crunch. For example, it is envisioned that a viral and hyper-dense deployment of low-cost small cells in the near future, with 200-300 small cells per typical macro cell coverage, approaching one-to-one ratio with the number of UEs. Such HDHNs are characterized by two unique features: a) massive number of devices and b) highly dynamic environment. How to manage, operate, and optimize such hyper-dense, dynamic networks, in an energy-efficient and sustainable manner, is an important research challenge that has recently received significant research interest from both academia and industry. The main goal of this tutorial is to introduce different aspects of designing HDHNs with advanced capabilities while focusing on spectral-efficiency (SE) and energy-efficiency (EE). In particular, we will introduce a plethora of techniques that include stochastic geometry, fuzzy logic, and game-theory that are necessary for deploying and operating large-scale, self-organizing HDHNs that can be used to support various communication systems with seamless mobility.

T2.2: Tutorial 3 - OTA testing of Wireless Devices in RIMP and Random-LOS: Preparing for 5G Wireless Systems....N/A

The reverberation chamber has through the last fifteen years been used to emulate a rich isotropic multipath (RIMP) environment, and it has successfully demonstrated its ability to test Over-The-Air (OTA) performance of multiport antennas and active wireless devices. The latter include e.g., handsets, laptops and small base stations. The measured throughputs of practical 4G LTE devices with MIMO and OFDM capabilities have been shown to be in excellent agreement with basic theoretical algorithms. Now is the time to use this concept to provide a complete characterization of the OTA performance to cover all real-life environments. This is naturally done by introducing the pure LOS (Line-Of-Sight) as a complementing limiting edge environment, and by taking into account the statistics of the randomness introduced by users. The latter plays a major role in pure LOS that thereby rather becomes a random LOS environment. The two limiting environments are linked together through a pragmatic real-life hypothesis, and work has started to test this by simulations.It will be shown that the fundamental characterizing quantity becomes the probability of detection of single or multiple bit streams (for diversity and multiplexing cases, respectively) over an ensemble of users. This probability of detection becomes equal to a relative throughput in a multipath environment, readily seen through the simple threshold receiver model representing an ideal digital receiver.The new approach represents a way to optimize the wireless networks by taking the statistics of users into account. This will be particularly important for the next Fifth Generation (5G) wireless systems, which will extend to higher frequencies at which the Random-LOS gets increased relevance and thereby importance too. The Random-LOS OTA testing is already in 4G very relevant for automotive applications, and the tutorial will show the first verification of automotive Random-LOS experimental OTA test setups.

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S5.2.1: Keynote 1 - Antenna and Wireless Technologies for Safeguading Australia....N/A

Antenna technology is critical for defence and national security. Chief Defence Scientist Dr Alex Zelinsky outlines cutting edge defence applications of smart antenna technology for surveillance, communications, electronic warfare and direction finding. The proliferation of broadband wireless communication technology poses new challenges that require antennas to adapt to changing operating conditions. DST Group has a long history of radar research and is continuing to find innovative applications in collaboration with international partners and Australian industry and universities. The presentation reflects on the traits of an ideal antenna and what's possible in the near future.

S5.2.2: Keynote 2 - Recent Medical Applications of Antennas....N/A

In recent years, various types of medical and healthcare applications of antennas have widely been investigated and reported. Typical recent applications include:(1) Information / Wireless power transmission: - Wearable or Implantable vital data sensor / monitor - Wireless telemedicine / Mobile health system - Wireless capsule endoscopy(2) Diagnosis: - High intensity MRI (Magnetic Resonance Imaging) - Microwave CT (Computed Tomography) for cancer detection - Wireless sleep monitor / ECG (electrocardiogram) monitor(3) Treatment: - Thermal therapy (hyperthermia, ablation, etc) - Wireless brain stimulator - Surgical device (coagulation device, microwave knife, etc)In this presentation, some practical medical applications of antennas which have been studied in our laboratory are introduced. Firstly, a wearable dual-mode antenna for vital data monitoring systems is presented. A key technology for the antenna is body-centric wireless communications. Secondly, an X-band antenna for a microwave sleep monitor is demonstrated with human-body phantom experiments. A "dynamic" phantom played an important role for the study. Thirdly, after a brief description of thermal therapy and microwave heating, a coaxial-slot antenna and an array applicator composed of several coaxial-slot antennas for minimally invasive microwave thermal therapy are overviewed. A few results of actual clinical trials by use of coaxial-slot antennas are demonstrated from a technical point of view. Then, as a new therapeutic application of coaxial-slot antennas, intracavitary hyperthermia for bile duct carcinoma is briefly

introduced. Finally, a few different types of surgical devices using high power microwave energy, including a new coagulation device which can detect the complete coagulation, are introduced. Heating characteristics of such microwave surgical devices are evaluated by numerical calculation as well as some experiments using phantoms, meat and animals.

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S5.6.1: Keynote 3 - The Mesmerizing Evolution of Reflector Antennas in Diverse Applications: A Passage from the Ancient Past to the Renaissance and the Present....N/A

A casual Internet search yields over one million web sites associated with the phrase "reflector antenna". This author was so fascinated by a typical reflector antenna shape that when he designed the winning IEEE Antennas and Propagation Society Logo he used a rendition of a reflector antenna in the logo artwork. This logo design now appears on thousands of publication materials related to the IEEE antenna publications, symposia flyers and books, etc. This depiction of an antenna is the most recognized form of any antenna by the general public. Throughout the history of mankind, the reflector antenna has seen a wide range of applications since among other antenna configurations it provides the highest gain, widest bandwidth, and best angular resolutions at the lowest costs. Simply stating, the primary role of a reflector antenna is to confine or radiate most of the electromagnetic energy over its aperture into a focal plane in receive mode or radiate to the far fields for communication or energy transfer in transmit mode. Typical reflector antennas use conic sections, the parabola, ellipse, hyperbola, and sphere, to either focus or efficiently radiate electromagnetic waves. Reflector antennas are typically categorized according to radiation pattern type, reflector surface type, and feed type. Pencil-beam reflectors are the most popular and are commonly used in point-to-point microwave communications and telemetry, since they yield the maximum gain and typically their beam directions are fixed at the time of antenna installation. In satellite communication systems, the uplink pencil-beam is typically steered by moving the reflector, or steering over a limited range using the feed. Recent generations of satellite reflectors have produced other popular types of radiation pattern classifications: contour (shaped) beams and multiple beams. These applications require reflectors with improved off-axis beam characteristics and non-standard conical shapes. Demand for high performance large reflector antennas for space applications have necessitated the development of various deployable concepts, such as, mesh and inflatable designs. Radio astronomy and deep space communications have also resulted into fascinating reflector antenna developments and engineering. In this keynote talk, the development of reflector antennas, from the ancient past to the Renaissance to the present, is reviewed in a concise and novel fashion, along with inferences to present and future developments. The material presented in this overview talk is the summarized version of many journal and conference papers and book chapters co-authored by the author and his contributions to the original designs of many currently functioning communications, remote sensing, and radar antenna systems.

S5.6.2: Keynote 4 - Antennas and Quasi-optics For Space Terahertz Instrumentation....N/A

This paper will give an overview of some of the antennas and quasioptical components that are used in space instruments. Herschel and Planck observatories will be used as an example to demonstrate the hurdles that had to be overcome. Several Earth observation instruments and astronomical missions which use millimetre and submillimetre wavebands, have been developed or are being planned by ESA. These instruments have many commonalities in their design and construction techniques. One of the issues that the above missions have in common is that they require state-of-the-art technology to achieve their ambitious goals; the highest resolution, the highest sensitivity, the highest frequency of operation. Although technology is advancing at a rapid pace in this frequency range, the requirements for these instruments go well beyond those of related existing (sub)millimetre wave instruments. This has resulted

in the need for new antenna configurations and in the refinement of existing configurations and technologies for top performance. Furthermore, it has to be recognized that there are also no standards or calibration reference sources in this field which complicates the procedures to verify the RF performance under flight conditions. Antenna performance is a critical aspect in millimetre-wave and submillimetre-wave limb sounding, since it determines the resolution and accuracy with which the concentration profiles of atmospheric species can be retrieved. Antenna performance is also a critical aspect of millimetre-wave and submillimetre-wave astronomical missions. For pointed observatories, which seek to map point-like or not very extended objects, the emphasis is then on beam efficiency and the control of main beam shapes. For survey missions, the level of far side lobes also becomes very important and in some cases (such as PLANCK) this exerts a critical influence on the success of the mission. The paper will discuss a range of THz applications and will present the antenna, their feed assemblies and quasi-optical components and systems that are utilised for the frequency region. It will also highlight the procedure that had to be adopted in order to verify RF performance under flight conditions. ESA's Herschel and Planck observatories will be used as an example to highlight some of the hurdles that had to be overcome for verification of flight-performance.. Some scientific results that have been obtained from the recent missions will also be shown. Upcoming mission will be discussed.

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S1.10.1 - Invited: Broadband 3D metamaterial carpet cloak....N/A

We propose and demonstrate ultra-broadband three dimensional carpet cloaking for full polarization. Based on rigorous nonlinear transformation optics, we obtain a group of inhomogeneous constitute parameters. A non-resonant metamaterial, which exhibits broadband magnetic and electric anisotropy with little dispersion, is used as a main building block in the cloak design. Nearly perfect cloaking performance is confirmed over a broad bandwidth with frequency scanning measurement. In particular, the experimental result shows that phase is well preserved by the cloak.

S4.10.1 - Invited: Enhancing the sports experience: Electromagnetics for Fun, Profit & Audience Engagement....N/A

A majority of Australians, regardless of age, ethnic background or wealth, get seriously interested in elite sport during major international events (the Olympic Games, World Championships, Test series, Grand Slams, etc) through to developmental child activities in very early years. Sophisticated wireless systems and other electronics are now in the affordable mass consumer market through smart phone apps or fashionable sports bands. Griffith University's SABEL Laboratories in the Engineering School continue to develop electronic systems for sports performance monitoring based on low cost, wearable technologies. Player activity, player position, player physiology and player fatigue are of great interest to the viewing public and the coaching staff as well as the athletes themselves. There is much to be gained from this new technology. This talk presents an overview of radio communications and sensing systems used in training and competition and the benefits of technologies to a sports obsessed public.

S5.10.1 - Invited: Reconfigurable Magneto-electric Dipole Antennas....N/A

With the rapid development of wireless communications in the past decades, various new antenna techniques are investigated to meet the requirements of fast developing wireless communication systems. By adapting the operating frequency or the radiation characteristics, reconfigurable antennas can cope with the changing system requirements or environmental conditions. Therefore, reconfigurable antennas can significantly improve the efficiency of spectrum usage and also provide additional levels of functionality for the systems.Various antenna structures have been utilized for the design of reconfigurable antennas, such as patch antennas, slot antennas, monopole and dipole antennas, etc. However, only a few of these designs can achieve good unidirectional radiation fulfilling the requirements of antennas for some fixed infrastructures, such as base stations. Recently, a new class of wideband antennas designated as the magneto-electric dipoles was proposed. These antennas were designed based on the complementary antenna concept. The basic structure consists of a planar electric dipole and a shorted quarter-wave patch antenna. These novel antenna elements have many attractive features, including wide impedance bandwidth, low cross polarization, low back radiation, nearly identical radiations in the two principal planes, stable radiation pattern, and constant antenna gain over the operating frequency range. Considering their excellent performances, the magneto-electric dipole antennas are very competitive candidates for reconfigurable unidirectional antennas. In this talk, the latest development of the reconfigurable magneto-electric dipole antennas will be presented, including frequency reconfigurable and beamwidth reconfigurable designs.

S1.10.2 - Invited: Metamaterial-Based Electromagnetic Space, Time and Spacetime Dispersion Engineering....N/A

Everything in our universe occurs in space, time, and spacetime where space and time are interdependent. These concepts are therefore fundamental across all areas of human activities, including history, economy, philosophy, arts and sciences. The author believes systematic endeavours in manipulating waves in space, time and spacetime will bring about considerable opportunities towards the development of tomorrow's electromagnetic science and technology. Manipulation waves in space essentially consists in engineering their spatial frequency (k) spectrum, which may be performed using conventional electromagnetic structures, such as apertures, antennas, lenses, polarizers, photonic crystals, Talbot imagers, optical masks, etc. However, the frontiers of spatial dispersion engineering may

be pushed far beyond the current state of the art, particularly using the novel concept of metasurfaces. The talk will present several innovations in this area, including magnetless nonreciprocal gyrotropy, generalized refraction, multiple wave transformation, multi-refringence, and orbital angular momentum multiplexing. In time, manipulating waves essentially consists in engineering their temporal frequency (?) spectrum, as partly done in ultrafast optics where oscillations are too fast to be handled by digital signal processors, and where real-time chirping and nonlinear materials and devices have therefore to be used instead. Such concepts have been little explored in electromagnetics, and may represent a solution to the exploding demand for faster and more reliable radio if sufficient progress is made. The author developed in his group metamaterial-inspired structures called phasers, which provide specifiable group delay versus frequency responses to perform unprecedented temporal dispersion engineering. The talk will present the related Radio Analog Signal Processing (R-ASP) concept and technology, and demonstrate a number of related applications, such as spectrum sniffing, real-time Fourier analysis, and dispersion code multiple access. Aforementioned concepts typically concern monochromatic spatial dispersion engineering and mono-directional temporal dispersion engineering. Combining the two aspects in simultaneous space and time dispersion engineering, as nature does it in rainbows and humans in holograms, will open up further horizons in electromagnetics processing. The talk will also address this area, first introducing the fundamental concept of temporal to spatial frequency mapping, and next describing a few recent applications, including real-time spectrogram analysis and two-dimensional mapping for the processing of ultrafast waves. Finally, novel concepts in electromagnetic spacetime discontinuities, where space and time are interdependent as in the theories of special and general relativity, will be introduced and discussed as a potential platform for future developments in electrodynamics.

S4.10.2 - Invited: Advanced Phased Arrays and Reflector Antennas for 21st Century Satellite Communication Payloads....N/A

21st century has so far seen several new satellite services such as local-channel broadcast for direct broadcast satellite service (DBS), high capacity K/Ka-band personal communication satellite (PCS) service, hosted payloads, mobile satellite services using very large deployable reflectors, high power hybrid satellites etc. All these satellite services are driven by the operators need to reduce the cost of satellite and pack more capability into the satellite. Antenna sub-system design, mechanical packaging on the spacecraft, and RF performance become very critical for these satellites. This talk will cover recent developments in the areas of antenna systems for FSS, BSS, PCS, & MSS satellite communications. System requirements that drive the antenna designs will be presented initially with brief introduction to satellite communications. Phased array antenna and reflector antenna designs will be covered in this talk.Advanced antenna system designs for contoured beams, multiple beams, and reconfigurable beams will be presented. Contoured beam antennas using dual-gridded reflectors, shaped single reflectors, and shaped Gregorian reflectors will discussed. The figure of merit of these antennas using gain-area-product (GAP) will be addressed. Multiple beam antenna (MBA) concepts and their advantages compared to conventional contoured beams will be introduced. Various designs of the MBA for DBS, PCS, and MSS services will be discussed along with practical examples. Recent advances in feed technology and reflector technology will be addressed and few examples. Advances in multi-band antennas covering multiple bands will be presented. Topics such as antenna designs for high capacity satellites, large deployable mesh reflector designs, low PIM designs, and power handling issues will be included. Introduction to remote sensing antennas with examples will be included in the talk. Advanced high power test methods for the satellite payloads will be addressed. Brief introductions to TT&C antennas, passive inter modulation products (PIM) and multipaction for satellite payloads will be given.

Antenna test ranges and software tools required for test and design of 21st century satellite antennas will be presented. Future trends in the satellite antennas will be discussed. At the end of this talk, engineers will be exposed to typical requirements, designs, hardware, software, and test methods for various satellite antennas.

S5.10.2 - Invited: Metamaterial-Inspired Electrically Small Antennas Integrated Into Structural Materials....N/A

An electrically small Egyptian axe dipole antenna has been designed and integrated into a glass fiber reinforced polymer (GFRP), a structural material now commonly found in most mobile platforms. The integration is accomplished by sewing the antenna with conductive threads into the GFRP prepreg and accounting for dimensional variations after curing under high temperature and pressure in an autoclave. The simulated and measured reflection coefficient values and radiated field patterns are in good agreement. These comparisons demonstrate that the antenna is nearly completely matched to the source without any matching circuit and radiates as an electric dipole.

S1.10.3 - Invited: MetaLine, MetaSpiral, and MetaHelical Antennas....N/A

Normally, electromagnetic properties in nature are right-handed. Antennas having this property are designated as natural antennas. On the other hand, antennas having electromagnetic properties that are not found in naturally occurring materials are designated as metamaterial-based antennas (simply referred to as metamaterial antennas). This talk is composed of three chapters and discusses metamaterial-based antennas. Chapter 1 reveals that a metamaterial-based straight line antenna (MetaLine antenna) forms a linearly polarized (LP) beam that scans from the backward direction, through the broadside direction, to the forward direction (BBF scanning) with change in operating frequency. It is also revealed that the MetaLine can realize a circularly polarized (CP) BBF scanning beam. These BBF scanning behaviors cannot be achieved with a corresponding natural straight line antenna having a right-handed property.The metamaterial-based spiral (MetaSpiral) antenna presented in Chapter 2 and the metamaterial-based helical (MetaHelical) antenna presented in Chapter 3 are shown to create a left-handed CP beam across a specific frequency band and a right-handed CP beam across a different frequency band. In other words, each of the MetaSpiral and MetaHelical radiates a counter dual-band CP beam. It should be emphasized that the antenna height for the MetaSpiral is approximately 1/100 of the wavelength at the lowest operating frequency, in contrast to the 1/4 wavelength antenna height of conventional antennas backed by a conducting plate (reflector).

S4.10.3 - Invited: Developing 5G for Mission Critical Machine Communications....N/A

The talk describes a multitenant network and services vision and the most important 5G wireless, wireline and media enabling technologies, leveraging Software Defined Networking (SDN), Network Functions Virtualization (NFV), High Performance (HPC) and Mobile Edge Computing (MEC). Special focus will be plance on Mission Critical Machine Communications (MCC) and the main research challenges to achieve higher speed and lower latency with a high degree of reliability. Conclusions will be drawn on the main standardization activities and roadmap towards the IMT for 2020 and beyond.

S5.10.3 - Invited: Meta-Atom Materials for RF Microwave Substrates Using Additive Manufacturing (3D Printing)....N/A

Metamaterials which are essentially periodic structures with metallic/dielectric and/or magnetic inclusions in a host material, produce truly novel electromagnetic (EM) properties, such as artificial dielectrics and magnetics, lenses etc. These can be in planar form to represent a bespoke RF/microwave substrate, as well as spherical formations for dielectric lenses (e.g. Luneburg) and imaging horn antennas. Placing these novel structures into the complex electronic design world such as multilayer circuits or radiated antennas will open up a new way of designing and manufacturing electronics, aiming towards a single process function from CAD to manufacture. The focus of this paper is on the generic synthesis of metamaterials, by placing these so called meta-atom inclusions in an ordered and systematic manner, analogous to compiling the ‘periodic table' of metamaterials. The inclusions are of the order of microscale dimensions clustered together to form unique patterns. This opens up a plethora of new structures to be formed which do not currently exist. These will not only will aid in improving existing applications but it will break existing boundaries for new applications to be formed. Depending on the ability to make these in small, medium and large scale, the frequencies span from RF/Microware to THz. The impetus of this research is to make a step change in current application of metamaterials and a discernible improvement to the communications link through increasing the capacity for more data improving functionality and productivity. We will present engineered structures with various manufacturing technologies using conventional photolithography and additive manufacturing (3D printing).

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