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IN THE UNITED STATES DISTRICT COURT

DISTRICT OF UTAH, CENTRAL DIVISION

nCAP LICENSING, LLC, nCAP TELECOMMUNICATIONS, LLC, nCAP MEDICAL, LLC, Plaintiffs, vs. APPLE, INC., Defendant.	**SECOND AMENDED COMPLAINT** Case No.: 2:17-cv-00905 Judge: Robert J. Shelby Magistrate Judge: Brooke C. Wells **JURY TRIAL DEMANDED**

Plaintiffs nCAP Licensing, LLC, nCAP Telecommunications, LLC and nCAP Medical, LLC (collectively referred to as "nCAP") hereby complain against Defendant Apple, Inc. as follows:

OVERVIEW

After significant research and development efforts, nCAP, a small Utah-based business, developed an antenna system and antenna enhancer designed to fill an unmet need for a covert antenna system which could be easily deployed in non-traditional locations like battlefields or disaster sites. Originally tested by American combat forces, nCAP's antenna systems are currently in use or testing by the Department of Defense ("DoD"), National Aeronautics and Space Administration ("NASA"), police and firefighting forces, and medical technology companies. nCAP was initially granted U.S. Patent No. 9,088,071 for its antenna enhancer invention, and subsequently was granted a continuation application which issued as U.S. Patent No. 9,954,276.

Unlike the DoD, NASA, and other lawful users of nCAP's technology—who have utilized nCAP's antenna enhancer invention and paid fair value for nCAP's marketed products—Apple has sought the benefits of nCAP's groundbreaking technology without any corresponding costs. Apple knew of nCAP's technology before using it. Apple was repeatedly exposed to the groundbreaking technology at various Department of Defense events. nCAP also sought to enter into licensing discussions with Apple on multiple occasions, yet all requests were ignored. In fact, instead of engaging in licensing discussions, an employee of Apple telephoned nCAP pretending to be a girl who wanted to acquire some of nCAP's patented antenna enhancer "for a boyfriend"—presumably to secretly acquire and reverse engineer nCAP's enhancer product in the wake of negative publicity concerning "Antennagate" and the poor performance of Apple's antennas in the iPhone 4. Although that attempt at corporate espionage ultimately failed, Apple eventually discovered how to create a material that uses nCAP's patented technology. Apple knew nCAP's technology was both groundbreaking and patent pending, but Apple began including a material utilizing nCAP's patented technology without permission or even approaching nCAP about a license. Plaintiffs nCAP Licensing, LLC, nCAP Telecommunications, LLC, and nCAP Medical, LLC (collectively "nCAP") file this lawsuit to force Apple to stop this unlawful use of nCAP's technology.

THE PARTIES

1. Plaintiff nCAP Licensing, LLC is a Delaware corporation organized and existing under the laws of the State of Delaware, and maintains its principal place of business in Heber City, Utah. Plaintiff nCAP Telecommunications, LLC is a Delaware corporation organized and existing under the laws of the State of Delaware, and maintains its principal place of business in Heber City, Utah. Plaintiff nCAP Medical, LLC is a Delaware corporation organized and existing under the laws of the State of Delaware, and maintains its principal place of business in Heber City, Utah. The Plaintiffs maintain websites at http://www.nCAP.com/, http://nCAPlicensing.com, http://nCAPtelecom.com/, and http://nCAPmedical.com/.

2. Defendant Apple is a California corporation with its principal place of business at 1 Infinite Loop, Cupertino, California 95014. Apple has designated The Corporation Trust Company, Corporation Trust Center, 1209 Orange Street, Wilmington, Delaware 19801 as its agent for service of process.

JURISDICTION AND VENUE

3. This action includes a claim of patent infringement arising under the patent laws of the United States, 35 U.S.C. §§ 1 *et seq*. This Court has jurisdiction over this action pursuant to 28 U.S.C. §§ 1331 and 1338(a).

4. This Court has personal jurisdiction over Apple. Apple conducts business and has committed acts of patent infringement and has induced acts of patent infringement by others in this district and has contributed to patent infringement by others in this district, the State of Utah, and elsewhere in the United States. Apple also has affirmatively availed itself of the benefits of this district by filing answers and counterclaims in patent litigation in Utah. Specifically, Apple answered and filed counterclaims in *Leaper Footwear v. Nike et al,* Cause No. 2-07-cv-00740, and settled before answering in *Driessen et al v. Starbucks et al.*, Case No. 2:2008cv00126.

5. Apple also participated in the Utah Tech Tour in September of 2016, with Apple CEO Tim Cook speaking along with Senator Orrin Hatch as the headliners of the conference.

6. Apple owns and operates three Apple stores in Utah in Farmington, Murray, and Salt Lake City. Apple sells its products at the Apple stores, including a plurality of products which infringe upon the patent owned by nCAP.

7. Apple furthermore subjected itself to this Court's jurisdiction when a representative of Apple telephoned nCAP attempting to acquire samples of the subject technology.

8. Venue is proper in this district pursuant to 28 U.S.C. §§ 1391(b), 1391(c) and 1400(b) because, among other things, Defendant is subject to personal jurisdiction in this district, has multiple regular and established places of business in this judicial district, certain of the acts complained of herein, including acts of infringement, occurred in this judicial district.

PATENTS-IN-SUIT

9. On July 21, 2015, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 9,088,071 (the "'071 patent") entitled "TECHNIQUES FOR

CONDUCTIVE PARTICLE BASED MATERIAL USED FOR AT LEAST ONE OF PROPOGATION, EMISSION AND ABSORPTION OF ELECTROMAGNETIC RADIATION."

10. A copy of the '071 patent is attached as Exhibit A, and incorporated by reference.

11. On April 24, 2018, the United States Patent and Trademark Office duly and legally issued U.S. Patent No. 9,954,276 (the "'276 patent") entitled "TECHNIQUES FOR CONDUCTIVE PARTICLE BASED MATERIAL USED FOR AT LEAST ONE OF PROPOGATION, EMISSION AND ABSORPTION OF ELECTROMAGNETIC RADIATION."

12. A copy of the '276 patent is attached as Exhibit B, and incorporated by reference.

13. nCAP owns all rights, title, and interest in and to the '071 and the '276 patents (collectively the "patents-in-suit") and possesses all rights of recovery.

FACTUAL ALLEGATIONS

14. On or about April 17, 2010, nCAP's predecessor in interest was originally incorporated in Utah as ChamTech Technologies, Inc. (ChamTech) d/b/a ChamTech Operations Enterprise. On or about November 8, 2013, nCAP Holdings, LLC was formed in Delaware. ChamTech assigned its interests in the patent to nCAP Holdings, LLC on or about October 1, 2014. nCAP Holdings LLC subsequently assigned its interests in the patent to nCAP Licensing, LLC (a wholly owned subsidiary of nCAP Holdings, LLC.), both Delaware corporations. Throughout this complaint, "nCAP" will be used to refer to ChamTech and the various nCAP entities, regardless of time period.

15. In 2009, nCAP's CEO, Anthony Sutera ("Sutera"), was operating FreeLinc

Technologies Inc. ("FreeLinc"), a research and development company focused on improving two-way radio communications using near-field magnetic induction technology. FreeLinc was developing multiple uses for its near-field magnetic induction technology, including in public safety, healthcare, consumer products, commercial, and military applications. FreeLinc worked on improving radio communications for the military generally, but also provided solutions for the Defense Intelligence Agency (DIA). During the course of their interactions, Sutera learned that DIA was interested in using FreeLinc's near-field magnetic induction technology to create an antenna which could be "hidden in plain sight."

16. Sutera was unconvinced that FreeLinc's near-field magnetic induction technology was the solution to DIA's problems. Sutera and others formed nCAP, believing that there were larger commercial needs related to DIA's stated problem. Specifically, nCAP's mission focused on providing portable, easily established communications in non-traditional locations. nCAP sought to develop an effective antenna for remote, impoverished, and disaster-stricken or otherwise difficult locations.

17. nCAP initially began to develop a "spray-on" antenna to reduce the amount of equipment that was required to establish communications in isolated or devastated terrain or to establish temporary or permanent command centers, hospitals, or garrisons. The result of nCAP's research and development was the creation of a material ("the Material"), which is one embodiment of the antenna enhancer of the patent in suit, which is formed by suspending conductive nano-particles in a substrate so that the particles are close but not touching (and thus not conductive), but close enough to create micro-capacitances which resulted in previously unobserved RF and electromagnetic (EM) properties

18. nCAP tested the patented invention's performance as both an antenna enhancer and an antenna, and determined that it outperformed any conventional antennas. Independent testing indicated that both the received and transmitted signal strength of a test cell phone was increased. Because of this improved signal strength, the average battery usage of a test cell phone was also significantly reduced.

Figure 1. Early application of the patented antenna enhancer on an iPad. This iPad was modified as part of the CENTCOM contract.

19. Apple released the iPhone 4 in July of 2010. In a series of events later dubbed "Antennagate," the iPhone 4 was plagued with antenna reception and transmission problems. Although Apple attempted to alleviate the issue by sending consumers free protective phone cases designed to alleviate some of the reception and transmission issues, these events nevertheless caused a public relations backlash, likely leading Apple to continue seeking ways to improve antenna reception on its products.

20. nCAP filed its first provisional application No. 61/416,093 relating to the antenna/antenna enhancer applications of the Material on November 22, 2010. The application published on June 14, 2012.

21. Around the time nCAP filed its provisional patent application and before the

application was publicly available nCAP began participating in quarterly military experimentation events at Camp Roberts, California with CENTCOM, SOCOM, PACOM, NPS (Naval Post Graduate School), dozens of DoD and other government agencies, and various other government contractors on a DoD-owned base. These experimentation events began on or about November of 2010 and continued through December of 2012.

22. nCAP began explaining the operation of its patent pending antenna enhancer and antenna systems to DoD employees at these military experimentation events. The DoD military events were an opportunity for various participants such as nCAP to demonstrate their new innovations. Because of their participation at DoD events, discussing secret and top secret projects, event attendees were privy to discussions of the enablement of nCAP's patent pending antenna enhancer *before those details were publicly available* because nCAP's patent application had not yet published.

23. None of the specific composition and enablement information nCAP disclosed was publicly available yet, since nCAP's patent application had not yet published. For example, nCAP described its patent pending antenna enhancer to Apple and other attendees as nano-particles coated in "funky" stuff. The nano-particles should be "close but not touching", nCAP told Apple and the other attendees. nano-particlenCAP also described some of the electromagnetic properties it had observed between the nano-particles, such as micro-capacitances of the nano-particles.

24. Apple attended at least one of these demonstrations where enablement, composition, and "know-how" details were disclosed. An Apple employee also met with Rhett Spencer, the CTO of nCAP, during the course of the demonstrations.

25. The military experimentation events were held at a remote military installation with poor cellular reception. Because of that poor reception, several contractors were unable to showcase their various products and applications. At the request of various military personnel and the contractors in attendance, nCAP applied its patented invention to numerous RF-enabled devices such as cellular telephones and radios, which solved the problems caused by the poor reception of those devices at the remote military installation.

26. nCAP and the other attendees were introduced to each other at the beginning of each day of exercises. nCAP routinely went to the exercises performed by other entities and observed those exercises. During the exercises, and after the exercises were complete, nCAP would offer to modify the devices of the participants by applying nCAP's patented antenna enhancer to their cellular devices, and encourage them to perform the exercise again and compare the results of the unmodified versus the modified cellular devices. Each time, the participants' results were better after their devices were modified with nCAP's patented antenna enhancer.

27. nCAP would modify the cellular devices of other participants by applying to the cellular device an adhesive strip coated in nCAP's patent pending antenna enhancer. Apple was present when nCAP made modifications to various cellular devices. When it modified the cellular devices, nCAP demonstrated how to best place the patent pending antenna enhancer element so as to most improve the cellular signal. Apple learned of how to most effectively apply nCAP's patent pending antenna enhancer

28. Apple was aware that the application of nCAP's patent pending antenna enhancer resulted in a marked improvement in cellular communication. At the conclusion of each day,

participants would again meet to discuss the results from that day's exercises. At each conclusory meeting, the participants whose cellular devices were modified by nCAP raved to their fellow participants, including Apple, that nCAP's patented antenna enhancer improved the performance of their cellular devices and consequently their exercises were better.

29. Apple was present on multiple occasions when nCAP modified the cellular devices of attendees, during experiments where nCAP's patented antenna enhancer improved the performance of the attendees' cellular devices, and when the attendees exclaimed over the improved performance because of the nCAP antenna enhancer.

30. At each event where Apple and nCAP were both present, Apple had access to multiple samples of nCAP's patented antenna enhancer and/or nCAP's patented antenna system. Apple also had the opportunity to witness how best to apply the patent pending antenna enhancer to cellular devices it had designed and manufactured.

31. While its patent was pending but before it had published, nCAP further explained its patent pending antenna enhancer and antenna systems to the other attendees in various documents and white papers. nCAP provided the DoD with copies of its white papers describing the composition of its patent pending antenna enhancer. These papers were shared amongst participants.

32. Apple was aware that nCAP's technology was the subject of a pending patent application. Although the demonstrations occurred both before publication of the patent application and before the '071 or '276 patent issued, nCAP's spray cans that held the spray-on antenna material were marked initially with "Patent Pending". Subsequently, U.S. Patent No.

9,088,071 was added to all of nCAP's products (*see*, *e.g.*, Figures 2 through 5).

33. nCAp added U. S. Patent No. 9,954,276 to its products after the issuance of that patent on April 24, 2018.

Figure 2. nCAP's Spray-On Antenna

Figure 3. nCAP Antenna

Figure 4. nCAP's Spray-On Antenna System

Figure 5. Various Sizes of Antennas Invented, Manufactured and Sold by nCAP

34. nCAP further participated in the Trident Spectre Naval Special Warfare exercises in Fort Story Virginia, on or about April 28, 2011 through May 12, 2011. nCAP was involved in dozens of experiments utilizing the patented invention. At Trident Spectre, nCAP was exposed to another small company that built, equipped and flew specialized aircraft, Broadbay Group. Ray Fitzgerald ("Fitzgerald"), of Broadbay Group, was interested in brokering a deal between nCAP (then ChamTech) and Apple. Fitzgerald circulated a non-disclosure agreement from Apple Inc, but nothing resulted from these initial discussions.

35. Late in 2011 an early investor in nCAP attempted to begin negotiations with Apple Inc. The investor reached out to Shervin Pishevar ("Pishevar") a venture capitalist out of San Francisco. In December of 2011, Pishevar wrote an introductory email for nCAP to Erik Lammerding ("Lammerding") of Apple at his Apple email address. Pishevar introduced nCAP to Lammerding, noting that nCAP had "…revolutionary new technology. World changing stuff."

36. Lammerding responded, "If you have a moment, give me a shout out on my mobile on Monday." And he sent his cellular telephone number.

37. nCAP did not hear from Apple regarding their technology.

38. On or about February 8, 2012, nCAP's CEO Anthony Sutera demonstrated the properties of the patented invention at a Google "Solve for X" conference. Sutera's appearance is available at: https://www.youtube.com/watch?v=4efE_gO9lFo. Sutera's presentation disclosed that there was a patent pending on nCAP's Material. In the course of the presentation, Sutera displayed a modified Apple cellular device. Sutera's display of Apple's cellular device reflected where the patent pending antenna enhancer should be applied.

39. On February 8, 2012 The Wall Street Journal published an article about Sutera's appearance at the Google Solve for X Conference. The article asked "Where was this stuff when the iPhone 4 came out?"

40. The Wall Street Journal article went on to note that "The company has already patented critical aspects of its technology and begun to sell to government customers…" (emphasis added).

41. Shortly after the Google presentation and the Wall Street Journal article, on or around February 22, 2012, nCAP's then General Counsel, Kristin Vazquez, received a phone call which showed up on Caller ID as "Apple Inc". The caller identified herself as a random female seeking a sample of the patented invention because "her boyfriend wanted it." After hanging up, Vazquez called the unidentified caller back using *69. The party answering the telephone identified herself as a member of the office of the head of Mobile Devices for Apple Inc.

42. The Caller ID, showing "Apple Inc." was photographed during the call with the unnamed female (inserted herein, and incorporated by reference):

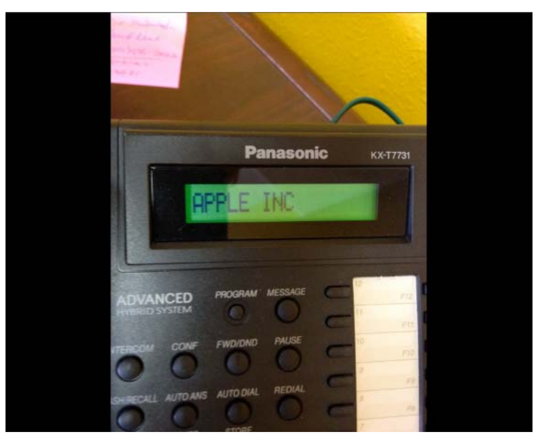


Figure 6. Photograph of telephone illustrating the call from Apple, Inc. after the Google Solve for X conference.

43. On or about May 1st, 2012 the United States Central Command ("CENTCOM"), a part of the Department of Defense ("DoD"), approached nCAP regarding the research and development of radio frequency ("RF") technologies. CENTCOM sought improvements or solutions to various known problems in the RF field. Specifically, CENTCOM was seeking to resolve issues with near field interference and power requirements that required multiple antennas, larger antennas, and larger power sources than was convenient for deployment with armed forces, who frequently must travel on foot in hostile foreign territories. nCAP signed a contract with the Defense Acquisition Regulatory Council ("DARC") governing the research and development of RF technologies. As part of its contract with CENTCOM, nCAP added its antenna enhancer to cellular-enabled tablets and other cellular devices. The goal of nCAP's work was to increase the range of cellular communications, and also improve battery life of the modified cellular devices.

44. nCAP, as a participant in the events hosted by the Department of Defense fall within 48 C.F.R. 27.402 which recognizes contractors' rights in data and copyrights. Since it is recognized that contractors may "have proprietary interests in data" and that agencies shall "protect proprietary data from unauthorized use and disclosure," nCAP had a reasonable expectation that its participation in the Government program would not damage nCAP's "legitimate proprietary interests" in the patented invention.

45. On or about February 17, 2014, nCAP received a request from third-party vendor ("Case Vendor"), a manufacturer of protective cases for cellular phones. Case Vendor explained to nCAP that it wanted to augment its protective cases to provide a signal boosting case. nCAP

CTO Rhett Spencer ("Spencer") made a site visit to Case Vendor and began testing application of the patented invention to the Case Vendor products.

46. During the testing, nCAP discovered that applying the patented invention to Case Vendor's Samsung product line improved signal strength, but it had no effect on Case Vendor's Apple's tested product line (the iPhone 5s). This result was baffling as an nCAP representative, Spencer, had already achieved improved signal strength on the iPhone 5.

47. Mystified by the ineffectiveness of the patented invention on the iPhone 5s, nCAP representatives disassembled an iPhone 5s to discern any issues. nCAP then discovered that a gold substance, which was not present in prior iPhone versions, had been applied to the antenna component of the iPhone 5s (See Figure 3, showing the gold substance applied to an Apple product).

Figure 7. Gold substance discovered on antennas of Apple's products. The antennas have been peeled back.

48. nCAP examined the gold material and evaluated its properties. Upon evaluation, nCAP discovered that Apple's gold material had the same EM and RF properties as well as the same characteristics when examined by a scanning electron microscope and spectroscopy as one embodiment of nCAP's patented invention.

49. The figures below illustrate, with two different magnifications, nCAP's Material as compared to the gold material found in the Apple products. nCAP original discovered Apple's material in an iPhone 5s. nCAP has since observed this gold material in all the examined antenna-incorporating Apple products that have been sold since the 5s's release (i.e., iPhone 5s, iPhone 5c, iPhone 6, iPhone 6s, iPhone 6 Plus, iPhone 6s Plus, iPhone 7, iPhone 7 Plus, iPhone SE, iPad 4th Generation, iPad 5th Generation, iPad 6th Generation, iPad 7th Generation, iPad mini, iPad mini 2, iPad mini 3, iPad Air, iPad Air 2, iPad Pro, iPod Touch 5th and 6th generations, Apple Watch Original, Apple Watch Sport, Apple Watch Edition Series 1 and 2, Apple Watch Series 1 and 2 (including Hermes, Nike and other special editions), iMac, iMac with Retina 4k display, iMac with Retina 5k display, MacBook Air, MacBook Pro, MacBook Pro with Retina display, MacPro, Mac mini , Magic Mouse 2, Apple TV (4th generation), Apple Pencil, Apple AirPods, HomePod, and any further releases, later models or other products which are not colorably different). Below are examples from the iPhone 6, 7, and Apple Watch. Each photo reflects irregular wafers as well as more spherical micro-particles.

50. While color differences appear, these are due to changed lighting conditions at the time of photograph, not any relevant difference in the Material.)

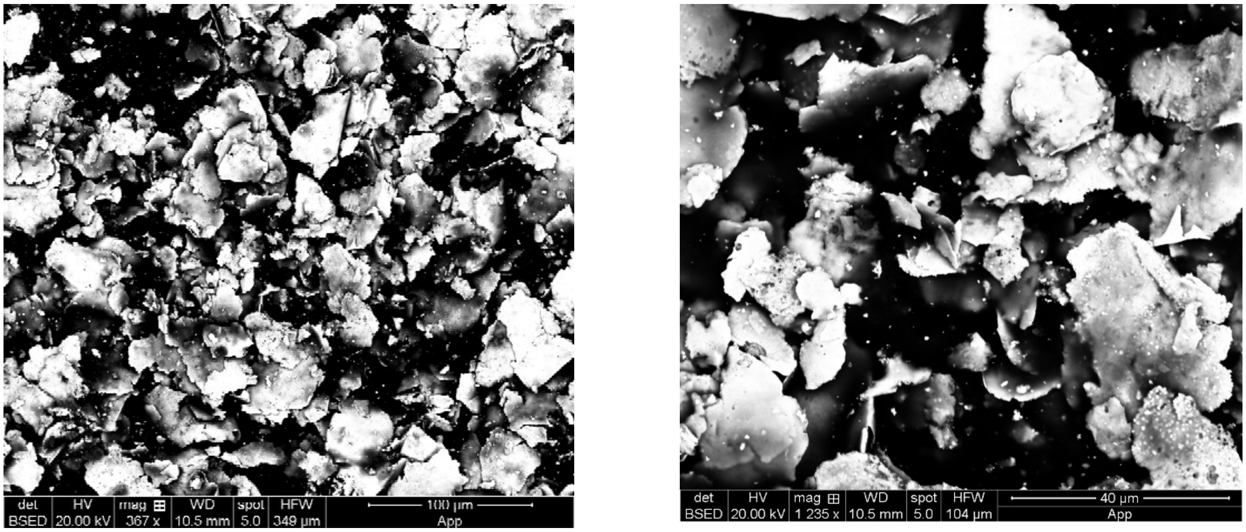


Figure 8. Sample of nCAP's Material, one embodiment of the patented invention.

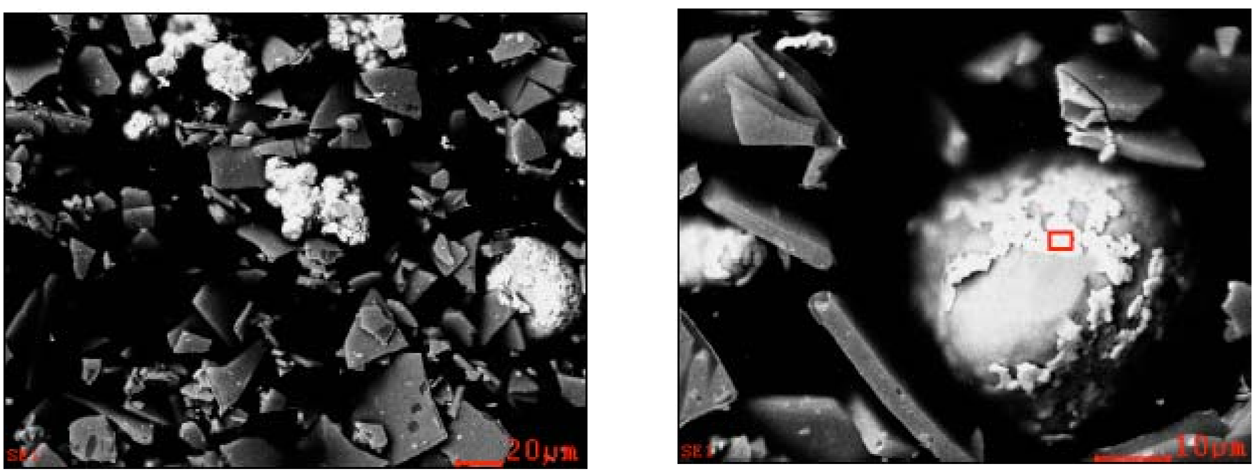


Figure 9. Sample of Apple's infringing material from the iPhone 5s

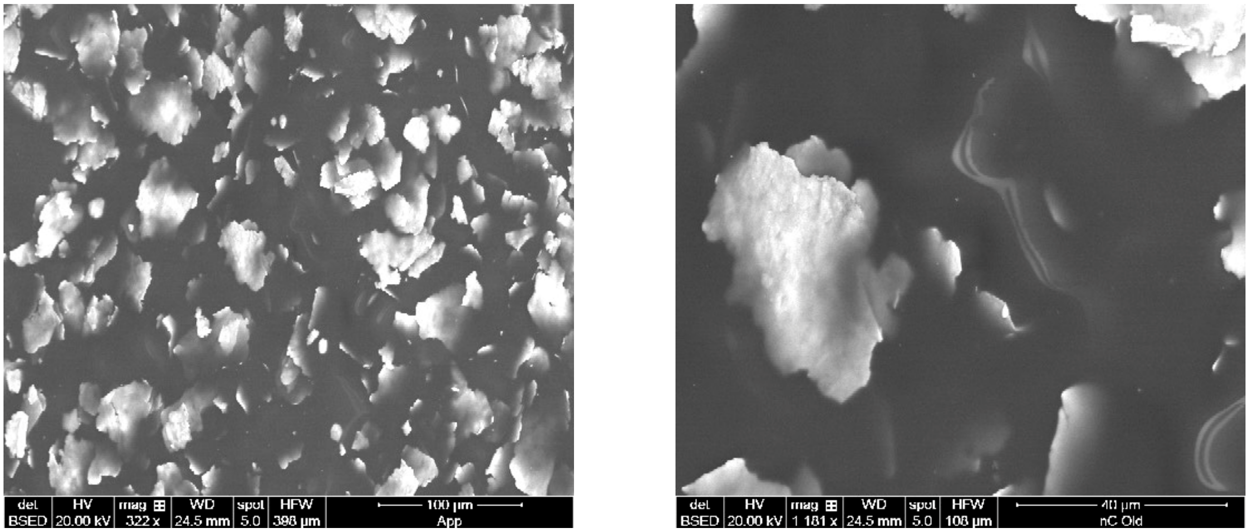


Figure 10. Sample of Apple's infringing material from the iPhone 6.

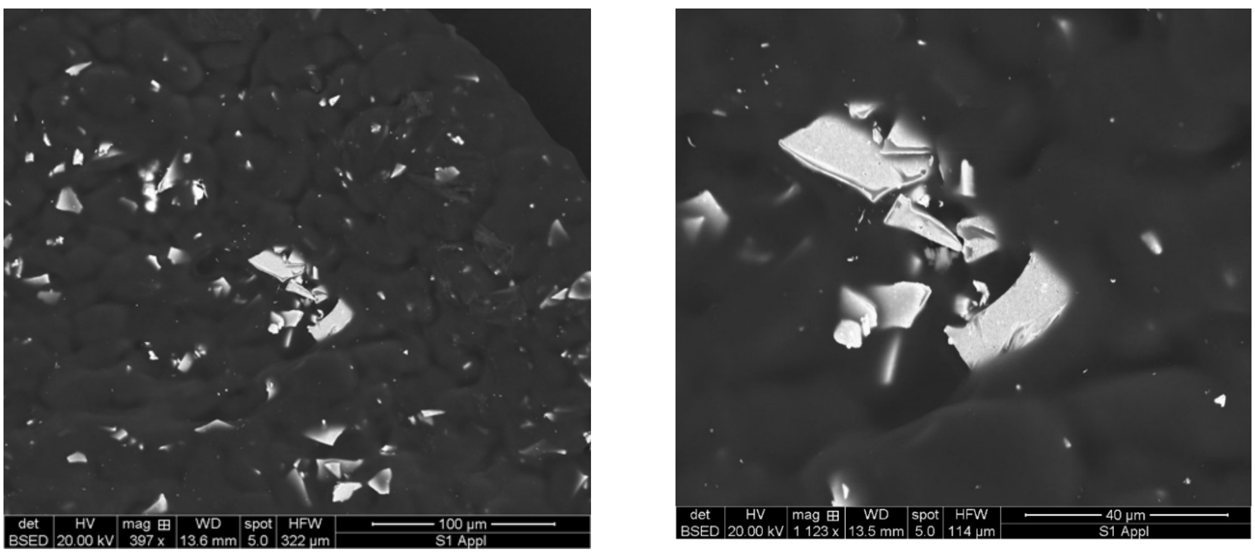


Figure 11. Sample of Apple's infringing material from the Apple Watch.

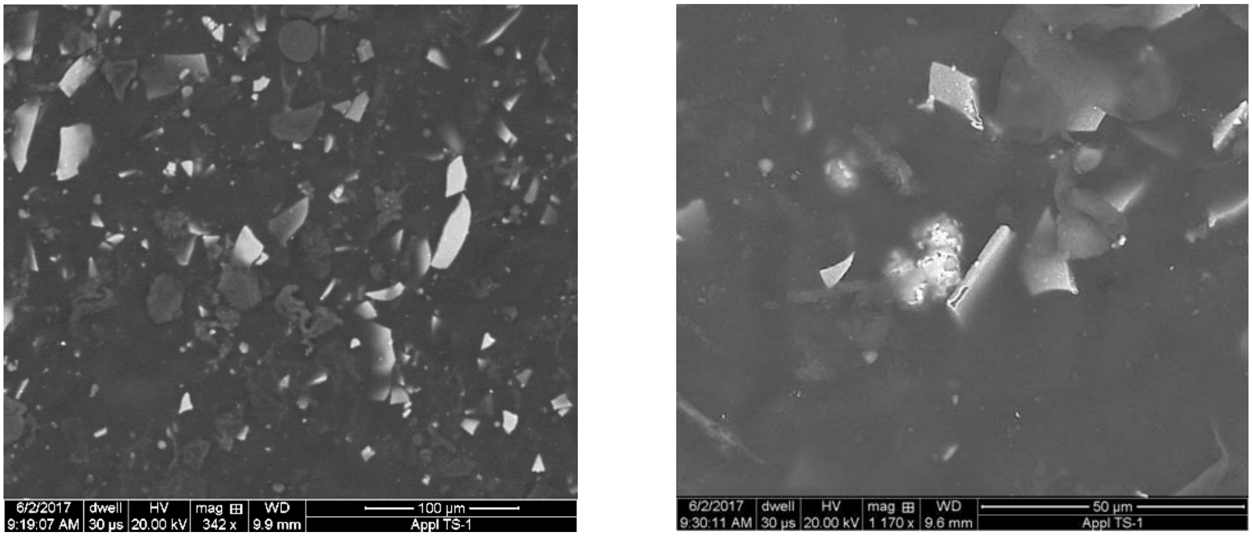


Figure 12. Sample of Apple's infringing material from the Apple i7.

51. To perform its analysis, nCAP extracted the gold substance from the antenna of the Accused Instrumentalities in a clean room. The gold substance was placed on a carbon film stem for imaging on a FEI Quanta 600 scanning electron microscope (SEM) with an energy-dispersive X-ray spectroscopy (EDAX) detector.

52. The spectroscopy identified the presence of pieces or particles of Silica, Nickel, and Silver in Apple's gold substance sample. Specifically, it appeared to include chips of silica as well as multiple "bubbles" of silver-coated nickel as most of the compound.

53. nCAP's Material has similar conductive particles or bubbles made primarily from copper. Copper and Nickel are both conductive materials, resulting in capacitance as described in the specification and claims of the patents-in-suit.

54. This is illustrated by Figures 9 and 10. Figure 9 is a detail photograph of a bubble from the patented invention and the spectroscopy of the interior of the bubble, reflecting a primarily copper interior. Figure 10 is a detail photograph of one of the bubbles from the Apple

material and the corresponding spectroscopy of the interior of the bubble, reflecting a primarily nickel interior.

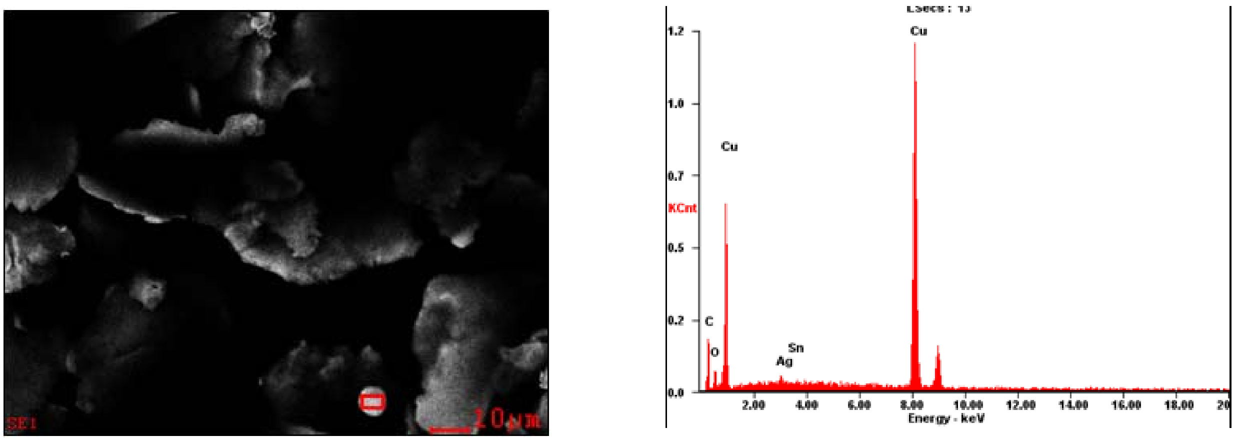


Figure 13. Detail photograph of patented invention and spectroscopy of the bubble reflecting a copper interior.

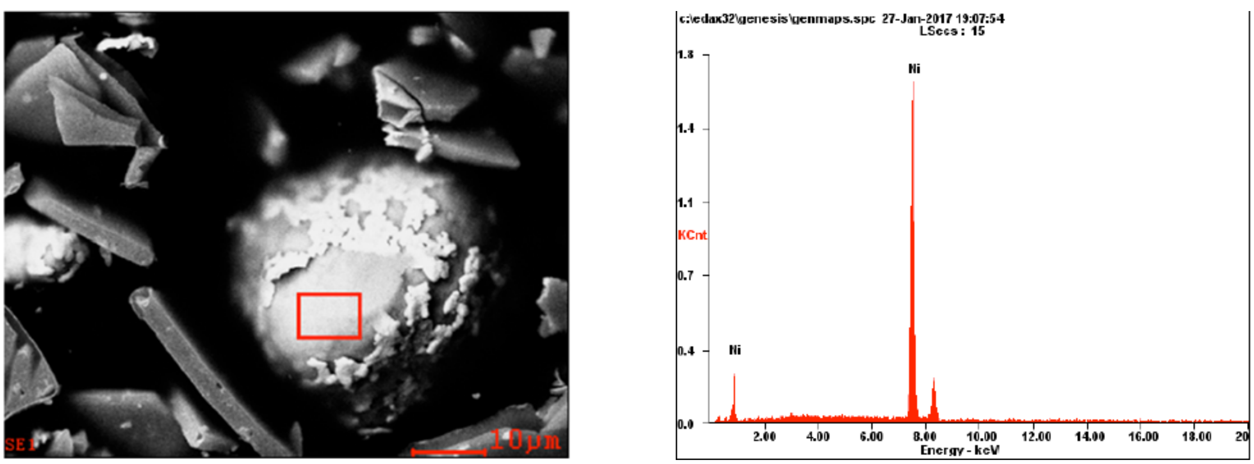


Figure 14. Close up photograph of one of the bubbles in the gold substance from the Accusd Instrumentalities, and spectroscopy of a portion of the particle.

55. Since developing the patented invention, nCAP has manufactured and sold a variety of products incorporating its Material, one embodiment of the patented invention. nCAP sold a spray-on version of the Material to the military. nCAP also offered classes to the

military on how to appropriately apply the spray-on version of the Material as the patented antenna system or antenna enhancer in the field.

56. nCAP also continues to manufacture antennas which embody the patented invention, using its Material. Currently, nCAP sells primarily to the military and to police units. It is also working to develop an underwater communications system, leveraging the Material as an antenna enhancer.

57. In addition to its use of the Material as an antenna enhancer (as described in the patents-in-suit), nCAP is also exploring applications of the Material in biotechnology and energy spaces.

58. Apple has committed and continues to commit acts of infringement under 35 U.S.C. § 271 (i) with many versions of numerous Apple's hardware products with antennas, including but not limited to, for example, iPhone 5s, iPhone 5c, iPhone 6, iPhone 6s, iPhone 6 Plus, iPhone 6s Plus, iPhone 7, iPhone 7 Plus, iPhone SE, iPad 4th Generation, iPad 5th Generation, iPad 6th Generation, iPad 7th Generation, iPad mini, iPad mini 2, iPad mini 3, iPad Air, iPad Air 2, iPad Pro, iPod Touch 5th and 6th generations, Apple Watch Original, Apple Watch Sport, Apple Watch Edition Series 1 and 2, Apple Watch Series 1 and 2 (including Hermes, Nike and other special editions), iMac, iMac with Retina 4k display, iMac with Retina 5k display, MacBook Air, MacBook Pro, MacBook Pro with Retina display, MacPro, Mac mini , Magic Mouse 2, Apple TV (4th generation), Apple Pencil, Apple AirPods, HomePod, and any further releases, later models or other products which are not colorably different (the "Accused Instrumentalities").

59. Apple's hardware products with antennas, including but not limited to, for example, iPhone 5s, iPhone 5c, iPhone 6, iPhone 6s, iPhone 6 Plus, iPhone 6s Plus, iPhone 7, iPhone 7 Plus, iPhone SE, iPad 4th Generation, iPad 5th Generation, iPad 6th Generation, iPad 7th Generation, iPad mini, iPad mini 2, iPad mini 3, iPad Air, iPad Air 2, iPad Pro, iPod Touch 5th and 6th generations, Apple Watch Original, Apple Watch Sport, Apple Watch Edition Series 1 and 2, Apple Watch Series 1 and 2 (including Hermes, Nike and other special editions), iMac, iMac with Retina 4k display, iMac with Retina 5k display, MacBook Air, MacBook Pro, MacBook Pro with Retina display, MacPro, Mac mini , Magic Mouse 2, Apple TV (4th generation), Apple Pencil, Apple AirPods, HomePod, and any further releases, later models or other products which are not colorably different and which meet at least one claim of the '071 and '276 patents.

60. Apple does not have any rights to the patents-in-suit.

61. In committing these acts of infringement, Apple knew or should have known that its actions constituted an unjustifiably high risk of infringement of at least one valid and enforceable patent. Because of this unjustifiably high risk, Apple's has committed egregious misconduct warranting enhanced damages.

COUNT ONE: PATENT INFRINGEMENT

62. nCAP incorporates by reference the preceding paragraphs as if fully set forth herein.

63. As described below, Apple has infringed and continues to infringe the patents-in-suit.

64. Apple's Accused Instrumentalities meet the claims of the patents-in-suit.

65. Apple makes, uses, offers to sell, sells and imports Apple's Accused Instrumentalities within the United States or into the United States without authority from Plaintiff.

66. Apple therefore infringes the patents-in-suit under 35 U.S.C. § 271(a).

67. Apple has actual knowledge of the patents-in-suit. For example, nCAP discussed the sale of or license to its intellectual property with Apple as early as 2011 through Broadbay, and again in 2011 through Pishevar.

68. Apple knew or should have known of nCAP's patented invention, one embodiment of which is the Material. Apple was an attendee at one or more events which occurred at military installations or military bases where cans of nCAP's spray-on Material were demonstrated. The cans were marked with "Patent Pending."

69. On information and belief, Apple also viewed the unveiling of nCAP's Material at the Solve for X conference. The presentation during "Solve for X" disclosed that the Material was "patent pending." Further, Apple would have seen the article in the Wall Street Journal which recited that nCAP had "…already patented critical aspects of its technology…"

70. nCAP also marked the antennas that it sold to police and firefighting units with "Patent Pending" and subsequently with the patent number.

71. Apple indirectly infringes the patents-in-suit by inducing infringement by others, such as its suppliers, by, for example, providing design and technical specifications for antennas and antenna enhancers to its suppliers, and requiring its suppliers to meet those specifications. Apple also actively markets to, encourages use by, and instructs consumers, businesses,

distributors, resellers, computer equipment manufacturers, and sales representatives, to use, promote, market, distribute, and/or sell the Accused Instrumentalities.

72. Apple took the above actions intending to cause infringing acts by others.

73. Apple was aware of the patents-in-suit and knew that the others' actions, if taken, would constitute infringement of the patents-in-suit. Alternatively, Apple believed there was a high probability that others would infringe the patents-in-suit but remained willfully blind to the infringing nature of others' actions.

74. Apple therefore infringes the patents-in-suit under 35 U.S.C. § 271(b).

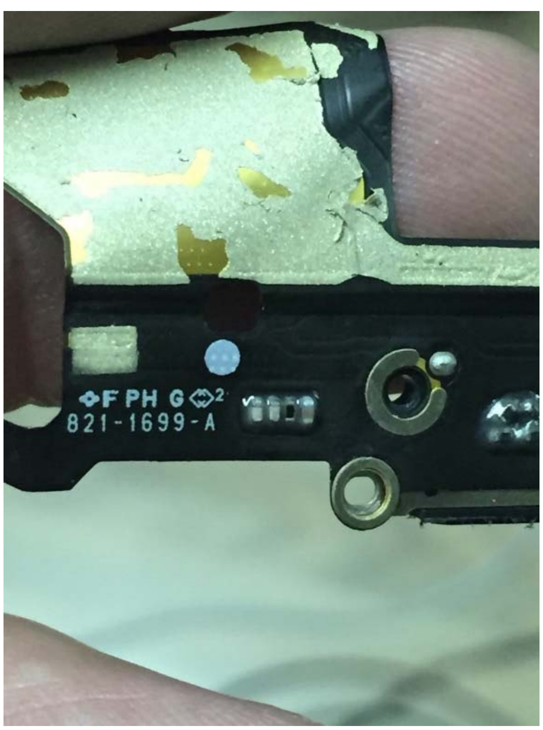
75. In offering to sell and selling the components specified above, Apple has known these components to be especially made or especially adapted for use in an infringement of the patents-in-suit and that these components are not a staple article or commodity of commerce suitable for substantial non-infringing use. Alternatively, Apple subjectively believed there was a high probability that these components to be especially made or especially adapted for use in an infringement of the patents-in-suit and that these components are not a staple article or commodity of commerce suitable for substantial non-infringing use but took deliberate steps to avoid confirming the same. Apple therefore infringes the patents-in-suit under 35 U.S.C. § 271(c).

76. Apple's acts of infringement have caused damage to nCAP. nCAP is entitled to recover from Apple the damages sustained by nCAP as a result of Apple's wrongful acts in an amount adequate to compensate nCAP for Apple's infringement subject to proof at trial. In addition, the infringing acts and practices of Apple have caused, are causing, and, unless such acts and practices are enjoined by the Court, will continue to cause immediate and irreparable

harm to nCAP for which there is no adequate remedy at law, and for which nCAP is entitled to injunctive relief under 35 U.S.C. § 283.

77. Apple has committed and continues to commit acts of infringement under 35 U.S.C. § 271 with the Accused Instrumentalities. In committing these acts of infringement, Apple knew or should have known that its actions constituted an unjustifiably high risk of infringement of a valid and enforceable patent and therefore committed sufficiently egregious conduct to warrant enhanced damages.

78. As an example of Apple's infringement, Apple infringed upon independent claim 12 of the '071 patent. Apple makes, uses, offers to sell, sells and imports an antenna enhancer. The antenna enhancer is observable with the naked eye on all of the Accused Instrumentalities, and is visible as a gold substance (examples from the iPhone 5s, iPhone 6, Apple Watch, and the iPad 4, below):



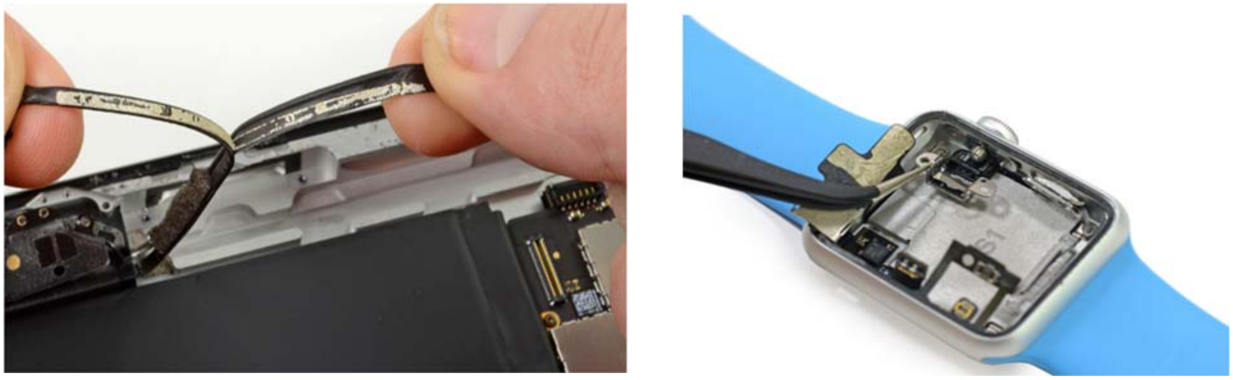


Figure 15. Antenna Enhancer Element

79. The antenna enhancer is comprised of an antenna enhancer element (pictured above) affixed onto the antennas of the device. Apple's antenna enhancer element (gold material) was not present in Apple iPhones or other devices which pre-date the iPhone 5s.

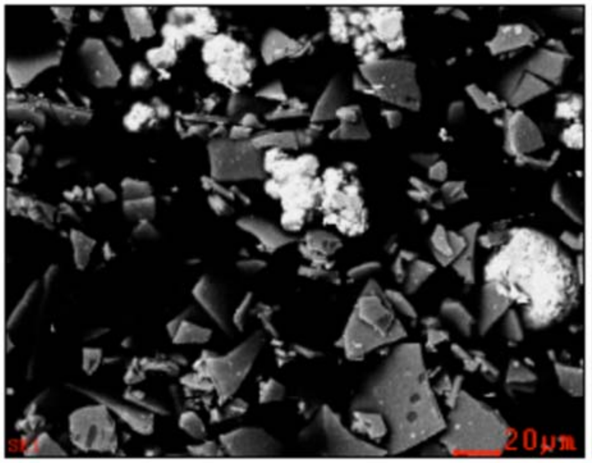


Figure 16. Nano-Particles

80. The Apple's antenna enhancer is formed of a conductive particle based material. Apple's antenna enhancer is formed of nano-particles affixed in a substrate. Spectroscopic analysis of the nano-particles (the lighter colored granules) in the suspect material indicates that they are formed of highly conductive particles, including silver and nickel. This is consistent

with the composition of one embodiment of the patented invention. The patented invention uses, in one embodiment, silver and copper, another conductive material. These nano-particles are affixed in a substrate, similar to the substrate in one embodiment of the patented invention. The substrate is composed of a variety of other materials, including carbon, and other trace elements.

81. As illustrated by the photographs above, Apple's antenna enhancer element is disposed at an area of an inner side of a housing of a wireless device. All the wireless devices released or manufactured after the iPhone 5s was released include Apple's antenna enhancer in the inner side of the housing.

82. The antenna enhancer in each of these wireless devices is least one of an internal radiating or receiving antenna, as an example the Wi-Fi antenna which operates as both a radiating and a receiving antenna.

83. The housing of the wireless device in the Accused Instrumentalities is formed of a conductive material. As an example, iPhone housings are made from aluminum, which is a conductive material. https://www.cnet.com/news/how-its-aluminum-housing-may-be-causing-iphone-5-shortages/. Later models, such as the 7, also have an aluminum housing: http://appleinsider.com/articles/16/09/09/how-apple-achieves-the-high-gloss-jet-black-color-on-the-iphone-7-7-plus. As does the Macbook: http://appleinsider.com/articles/08/10/14/apple_details_new_macbook_manufacturing_process. On information and belief, all of the Accused Instrumentalities include a conductive material as a housing.

84. Further, consistent with claim 12, a non-conductive material is disposed between Apple's antenna enhancer element and the radiating or receiving antenna. Specifically, Apple's antenna systems are housed in a plastic case, which is non-conductive.

85. Apple's conductive particle based material comprises particles dispersed in a binder. As described above, the nano-particles of Apple's material are primarily nickel coated in silver, which are conductive. The conductive nickel/silver nano-particles are dispersed in a binder containing other elements such as carbon, as illustrated by the spectroscopic analysis.

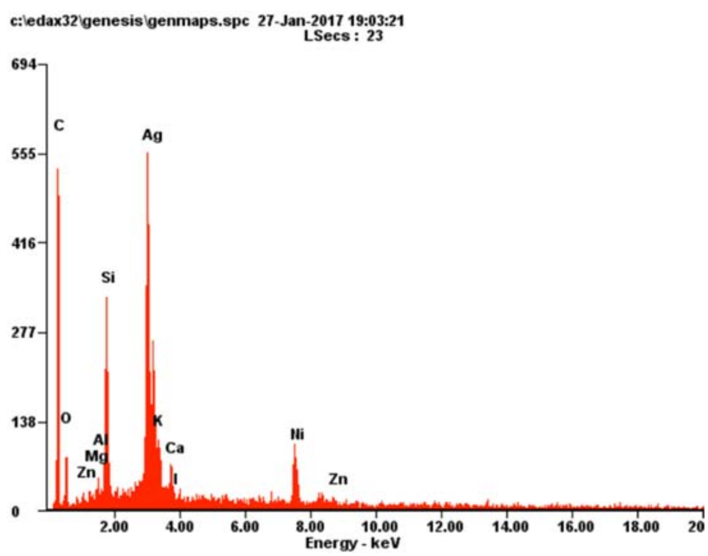


Figure 17. Spectroscopic Analysis

86. The conductive nano-particles in Apple's material are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another. As illustrated above, and here again, the conductive particles (i.e. the more lightly colored nano-particles) are near/adjacent to each other, but they do not touch. The nano-particles in the example below are anywhere from approximately 30 to 60 microns apart.

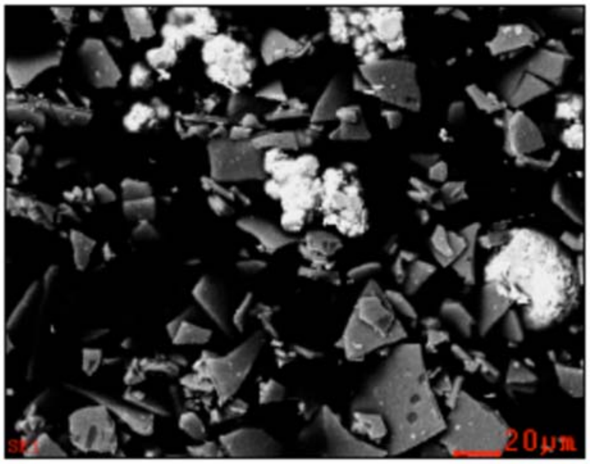


Figure 18. Nano-Particles

87. Apple's infringement of the patents-in-suit has been and continues to be willful.

88. To the extent that Apple releases any new version of the Accused Instrumentalities, such instrumentalities will meet the claims of the patents-in-suit and infringe 35 U.S.C. § 271(a)-(c) in ways analogous to Apple's current infringement described above.

89. As a further example of Apple's infringement, Apple infringed upon independent claim 1 of the '276 patent. Apple makes, uses, offers to sell, sells and imports an antenna system. The antenna system is observable with the naked eye on all of the Accused Instrumentalities, and is visible as a gold substance applied to a conductive substrate (examples from the iPhone 5s, iPhone 6, Apple Watch, and the iPad 4, below):

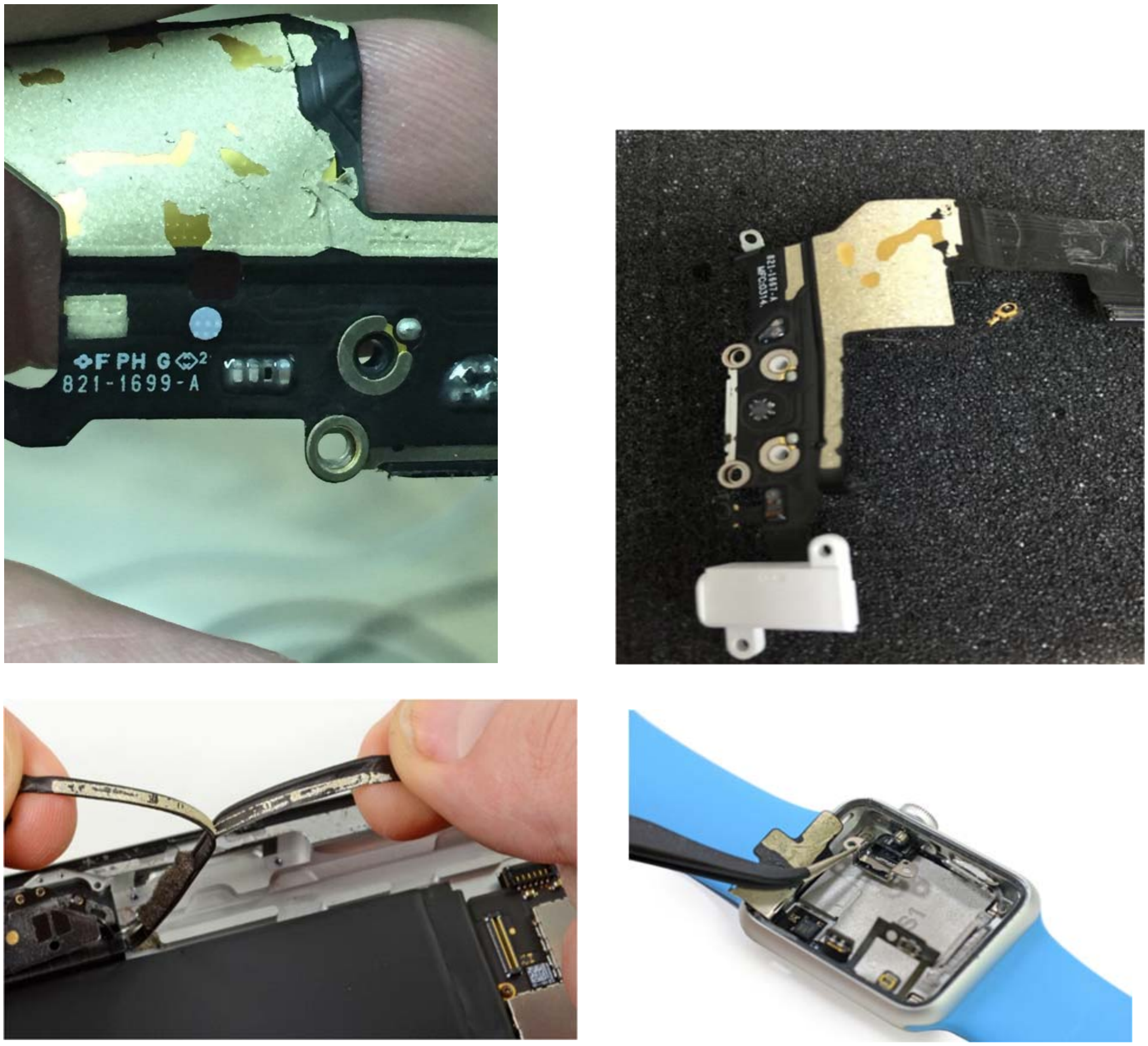


Figure 19. Antenna Enhancer Element

90. The antenna system is comprised of a radiating antenna element (pictured above) affixed onto a conductive substrate. Apple's radiating antenna element (gold material) was not present in Apple iPhones or other devices which pre-date the iPhone 5s.

91. The conductive substrate and the radiating antenna element are layered. The conductive substrate is visible, above, as a metallic layer underneath the conductive particle based material.

92. The layers are substantially parallel to each other. The conductive particle based material is applied onto (but it does not encircle) the conductive substrate.

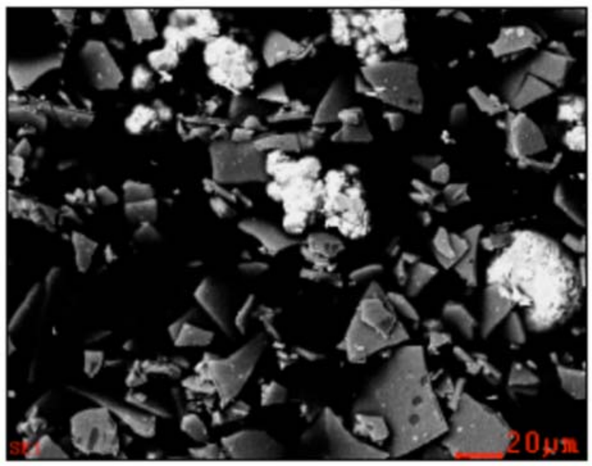


Figure 20. Nano-Particles

93. Apple’s radiating antenna element is formed of a conductive particle based material. Apple’s radiating antenna element is formed of nano-particles dispersed in a binder. Spectroscopic analysis of the nano-particles (the lighter colored granules) in the suspect material indicates that they are formed of highly conductive particles, including silver and nickel. This is consistent with the composition of one embodiment of the patented invention. The patented invention uses, in one embodiment, silver and copper, another conductive material. These nano-particles are affixed in a binder, similar to the substrate in one embodiment of the patented invention. The substrate is composed of a variety of other materials, including carbon, and other trace elements.

94. The radiating antenna element in each of these wireless devices is least one of an internal radiating or receiving antenna, as an example the Wi-Fi antenna which operates as both a radiating and a receiving antenna.

95. Further, consistent with claim 1, the radiating antenna element is applied to a conductive substrate.

96. Apple's conductive particle based material comprises particles dispersed in a binder. As described above, the nano-particles of Apple's material are primarily nickel coated in silver, which are conductive. The conductive nickel/silver nano-particles are dispersed in a binder containing other elements such as carbon, as illustrated by the spectroscopic analysis.

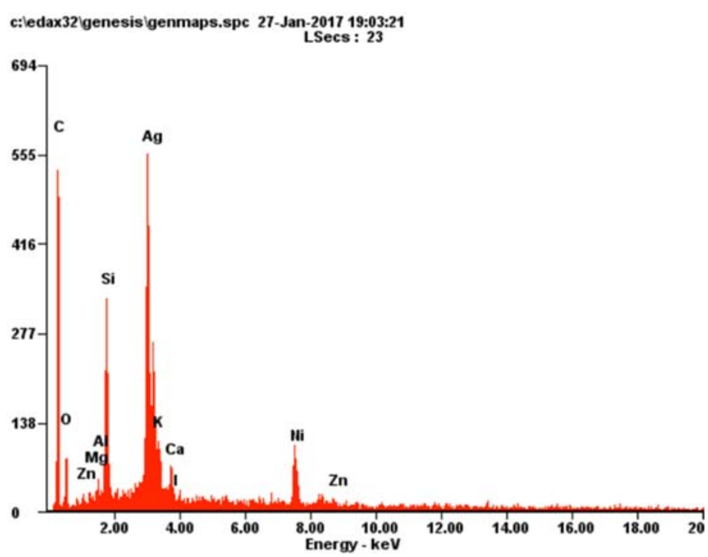


Figure 21. Spectroscopic Analysis

97. The conductive nano-particles in Apple's material are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another. As illustrated above, and here again, the conductive particles (i.e. the more lightly colored nano-

particles) are near/adjacent to each other, but they do not touch. The nano-particles in the example below are anywhere from approximately 30 to 60 microns apart.

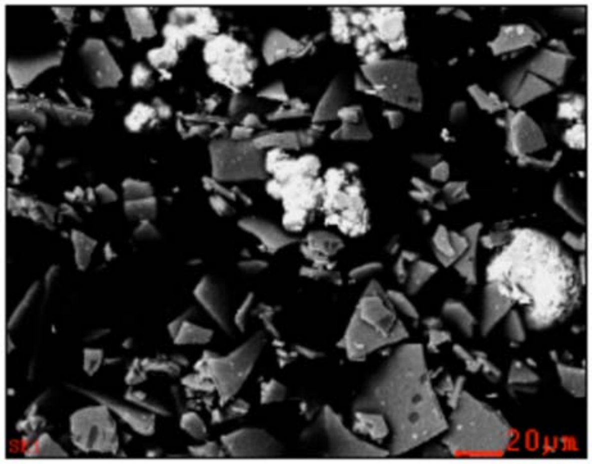


Figure 22. Nano-Particles

98. Apple's infringement of the patents-in-suit has been and continues to be willful.

99. To the extent that Apple releases any new version of the Accused Instrumentalities, such instrumentalities will meet the claims of the patents-in-suit and infringe 35 U.S.C. § 271(a)-(c) in ways analogous to Apple's current infringement described above.

COUNT TWO: VIOLATION OF UTAH UNFAIR COMPETITION ACT

100. nCAP incorporates by reference the preceding paragraphs as if fully set forth herein.

101. As described above, Apple has infringed and continues to infringe the patents-in-suit.

102. As described above, Apple began its efforts to infringe on the '071 and '276 patent before it was issued, and before it was even published or otherwise publicly available.

Apple began its efforts to capitalize on nCAP's know-how and technology as early as 2010 at the time nCAP began participating in DoD events. Before any information was publicly available, Apple began aggregating information disseminated at DoD events regarding nCAP's patent pending antenna enhancer. Apple's early efforts led to the resultant patent infringement by Apple once the '071 and '276 patents were issued.

103. As described above, Apple and nCAP participated in numerous events hosted by the Department of Defense on military installations. These events disclosed secret and top secret projects. These events also occurred before nCAP's patent application was published. In the course of these events, Apple attended meetings and discovered from nCAP information about its patent pending antenna enhancer, including at least the following:

- Where the antenna enhancer should optimally be placed on a cellular device;
- How to confirm optimal placement;
- The composition of the antenna enhancer (coated nano-particles);
- The placement of the nano-particles in the substrate (close but not touching);
- How effective the antenna enhancer was at improving the performance of a cellular device; and
- Possible bases for the functioning of the antenna enhancer (micro-capacitance).

104. At those events, cutting edge technology was demonstrated by the participants, including nCAP and its demonstration of its antenna enhancer and antenna systems. nCAP's material was readily available to Apple at these events. nCAP further disclosed enabling details regarding its patent pending antenna enhancer and antenna systems to participants at the DoD events before those details were published by the patent office. Specifically, nCAP disclosed

that its antenna enhancer included nano-particles, that the nano-particles should be "close but not touching", and that the nano-particles required a specific coating. nCAP additionally disclosed that the antenna enhancer should be applied to a specific location on the cellular devices, adjacent to the cellular antenna itself.

105. nCAP, as a participant in the events hosted by the Department of Defense (DoD) fall within 48 C.F.R. 27.402 which recognizes contractors' rights in data and copyrights. Since it is recognized that contractors may "have proprietary interests in data" and that agencies shall "protect proprietary data from unauthorized use and disclosure," nCAP had a reasonable expectation that its participation in the Government program would not damage nCAP's "legitimate proprietary interests" in its patent pending antenna enhancer and antenna system.

106. Apple's access to these details before the application was published, and at the DoD events where there was an expectation of privacy, provided Apple with a "head start" in duplicating nCAP's results. Apple had information, directly from nCAP, which would not be publicly available for months or even years—until the time the application published in June of 2012.

107. Apple's unfair head start and subsequent infringement not only deprived nCAP of its rights to enter the market first, but devalued nCAP's intellectual property to such a degree *before* the issuance of the patent that nCAP struggled to arrange financing and to launch its businesses. Apple's head start and subsequent infringement made it difficult for nCAP to capitalize on its antenna enhancer and antenna systems once they were patented. Apple's business practices amount to not only to patent infringement, but are unfair because Apple deprived nCAP of its fair shot at establishing its own business capitalizing on its patented

antenna enhancer and antenna systems. It is unfair for Apple to not only infringe on nCAP's patents, but also demolish nCAP's opportunities to establish its own business because of Apple's head start in infringing on the '071 and '276 patents.

108. In addition to Apple's behavior in gleaning information from nCAP at DoD events, Apple proactively attempted to obtain a sample of the patent pending antenna enhancer and antenna systems by telephoning nCAP's offices and requesting a sample. When Apple requested a sample of the antenna enhancer, it did not do so honestly. Instead, a representative from Apple's Head of Mobile Devices office pretended to be a woman looking for a sample of the antenna enhancer for her boyfriend's phone.

109. Before any details of the '071 or '276 patents were publicly available, while Apple was nefariously attempting to get a sample of nCAP's antenna enhancer and while Apple was gleaning as much information as it could from DoD events, Apple was simultaneously declined to engage in business discussions with nCAP.

110. Apple's acts towards nCAP are one example of Apple's ongoing pattern of efficient infringement. "Efficient infringement is a cold-hearted business calculation whereby businesses decide it will be cheaper to steal patented technology than to license it and pay a fair royalty to the innovator." http://www.ipwatchdog.com/2016/10/25/efficient-infringement-arrived-hill/id=74131/ Apple's habitual behaviors with nCAP and other patentees are efficient infringement.

111. Apple repeatedly acts as an efficient infringer. As an example, Apple efficiently infringed on patents assigned to the Wisconsin Alumni Research Foundation (WARF). "Apple not only couldn't be bothered to license the patent; it wouldn't even let WARF in the door to

negotiate. Instead, Apple sent the foundation a link to a page on the Apple website, which says that the company can lay claim to any unsolicited idea." https://www.nytimes.com/2015/10/24/opinion/the-patent-troll-smokescreen.html As in the WARF case, here Apple could not be bothered to attempt to negotiate a business relationship with nCAP.

112. Apple's efficient infringement means that small entities like nCAP never have "the chance to grant an exclusive license to an Apple competitor, which could have hurt Apple while maximizing [their own] financial gain." Instead they have "to resort to expensive litigation to get what [they] should have been able to achieve through less expensive negotiation." Id.

113. Apple has a *pattern* of using its size and enormous political, industrial, and financial influence to bully, squash or otherwise make life difficult for entities like nCAP. Apple is recognized as being part of a technological "Gang of Five" companies which essentially control the immediate past, present, and future of technology. In one commenters opinion, the "oligopoly" of Apple, along with the others in the gang of five "…handicaps independent companies with new ideas." Often Apple will "extend[] its power [] by aping the features of other tech companies' products, and incorporating them into a platform." https://www.theverge.com/2017/3/8/14848642/walt-mossberg-tech-gang-of-five-apple-google-microsoft-amazon-facebook

114. Apple, as one of "the Gang of Five engages in business operations which are the hallmark of efficient infringement…" http://www.ipwatchdog.com/2017/03/17/tech-ruling-class-stifles-innovation-efficient-infringement/id=79391/ Because of the nature of efficient

infringement, not all activities are directed at the same patent holder. Instead, Apple's treatment of each patent holder falls into a pattern of efficient infringement. Because Apple's acts are directed towards multiple different patentees, the individual acts appear to be merely normal competitive behaviors. But when Apple's actions are viewed through the lens of its *pattern* of behavior, it is clear that Apple's habitual unfair acts are, both individually and collectively, efficient infringement.

115. As a further example, although Apple phones rely heavily on Qualcomm's patents and modem chips, Apple has recently sued Qualcomm over its royalty rates. Although a royalty dispute is not, alone, an indicia of an unfair business practice, Apple's suit coincidentally coincides with "regulatory investigations and fines on three continents, including a lawsuit announced [at the same time as Apple's lawsuit] by the U.S. Federal Trade Commission." https://www.bloomberg.com/news/articles/2017-01-23/apple-s-legal-assault-on-qualcomm-is-part-of-phone-margin-grab Apple has further suspended its payments to Qualcomm during the pendency of the suit, even though Apple could not produce its phones without Qualcomm's technology. Apple's behavior in suing Qualcomm, the likelihood that Apple used its political clout to instigate simultaneous regulatory investigations of Qualcomm, and Apple's decision to forgo paying Qualcomm indicate a habitual, unfair pattern of behavior on Apple's part. In that example, it is directed at Qualcomm, but it is a symptom of a larger unfair pattern that Apple has applied to nCAP.

116. Further, Apple even uses the mere suggestion of pulling out of its existing contracts to force the renegotiation the contracts, devalue existing companies and their intellectual property. As an example, Apple asserted it would drastically reduce its contracts

with Imagination Technology, Dialog, and possibly Synaptics. The results were devastating for each. Imagination Technology's stock fell 72 percent, while Dialog and Synaptics fell 36 percent and 12 percent respectively. http://www.ipwatchdog.com/2017/06/20/apple-holding-companies-innovation-hostage/id=84788/; https://www.bloomberg.com/news/articles/2017-11-30/apple-reportedly-making-in-house-power-chips-in-blow-to-dialog

117. As one intellectual property blogger has noted "Imagination, Dialog and any other companies that run afoul of Apple should be ready for a long, drawn-out process, because Apple does not back down from a fight. To be convinced, one must only look at the company's assault on Qualcomm." http://www.ipwatchdog.com/2017/06/20/apple-holding-companies-innovation-hostage/id=84788/

118. In complaining about another patent infringement lawsuit, Apple has stated that the patent holder plaintiff "Smartflash makes no products, has no employees, creates no jobs, has no U.S. presence, and is exploiting our patent system to seek royalties for technology Apple invented." http://www.latimes.com/business/la-fi-apple-patent-verdict-20150226-story.html (quoting Apple's statement). But in this case, Apple's own actions have made it exceedingly difficult for nCAP to make products, hire employees, create jobs, or otherwise leverage its own patents. Apple is creating the conditions under which nCAP struggles to grow.

119. Efficient infringement is an unfair business practice, which Apple has used to materially diminish the value of nCAP's patents. "Efficient infringement is the cause of much distress and agony for innovators struggling to survive. The very existence of widespread efficient infringement, which is nothing more than stealing, absolutely stifles innovation."

http://www.ipwatchdog.com/2017/03/17/tech-ruling-class-stifles-innovation-efficient-infringement/id=79391/

120. Apple's acts, described herein and incorporated by reference, including adopting nCAP's patent pending technology which it only learned of at a DoD event, telephoning nCAP under false pretenses to attempt to obtain a sample of nCAP's patent pending antenna enhancer, and routinely refusing to engage in business negotiations with nCAP regarding its patented technology while infringing on that same patented technology *each* represent an unfair business practice that violates industry standards and is inequitable. Collectively and individually, these acts are indicia of habitual, systemic practices which Apple engages in of devaluing the intellectual property rights of individuals and small or nascent businesses. Apple's habitual unfair practices culminated in Apple's infringement, in this case, of the '071 and '276 patent and the impairment of nCAP's ability to determine its own future and the direction of both its business and its intellectual property rights.

121. Businesses like nCAP often do not have the financial resources available to a large market competitor because of the highly innovative nature of the patented technology. It can be difficult to market and sell what potential buyers might see as "magic." Apple already sees the value in the patented technology. Apple should be prohibited from acting unfairly in business negotiations. nCAP should have the opportunity to access the capital necessary to expand both research and development as well as product manufacturing capabilities, enabling it to manufacture the material (and receive the resulting profits) rather than simply receive royalties on the use of the technology itself. Apple's unfair behavior and subsequent infringement impairs the value of nCAP's patent by depriving nCAP of an ability to use the rights flowing from that

patent to seek all of the profits from manufacturing the material as a first-mover and lawful monopolist. This has stymied nCAP's business development, and slowed nCAP's marketing to other large market competitors.

122. Apple engaged and engages in intentional business acts and practices that are unlawful, unfair or fraudulent and a violation of the Utah Unfair Competition Act. In addition to infringing on nCAP's patented invention, Apple engaged in a pattern of intentional behavior which was unfair and materially diminished the value of nCAP's intellectual property. Utah Code Ann. § 13-5a-102.

123. Apple violated equitable rules of fair play, as well as industry standards, when it leveraged its access to nCAP's antenna enhancer to create its own infringing product. Apple's intentional business practice of aggregating information regarding nCAP's material at DoD events before the information was published by the Patent Office, requesting nCAP's material under false pretenses, refusing to discuss business arrangements regarding the antenna enhancer with nCAP, and utilizing its own infringing antenna enhancer in the Accused Instrumentalities represents a pattern of unfair business practices that include Apple's ultimate infringement on nCAP's '071 and '276 patents and result in a material diminution in the value of nCAP's intellectual property. Apple created its own "head start" in infringing the '071 and '276 patents to its own advantage. In giving itself a head start, Apple also eradicated much of the value of nCAP's intellectual property because nCAP's struggled to get capital to form businesses based upon its own intellectual property.

124. nCAP was denied the value of bringing its patented invention to market, and building businesses around its intellectual property, or selling it to various consumers. Without

Apple's infringement, nCAP would have leveraged its patent to generate more business, such as with Case Vendor, different cellular telephone manufacturers, antenna manufacturers, or by selling the Material to Apple itself. Because of Apple's infringement, nCAP has been unable to capitalize on these potential business opportunities.

125. Because of Apple's unfair competition, nCAP's intellectual property value was diminished because nCAP was forced to forgo business opportunities relating to cellular devices. Specifically, nCAP was unable to continue adapting protective cases with its material since the Accused Instrumentalities already included the infringing antenna enhancers. Consequently, nCAP lost one existing contract with a protective case manufacturer, and lost the ability to pursue other contracts with other case manufacturers.

126. The value of nCAP's intellectual property was further diminished as a result of Apple's infringement because shareholders lost confidence in nCAP's ability to leverage the value of the antenna enhancer. As a result, shareholders attempted to negotiate buybacks, sell their shares, or otherwise were unwilling to continue pursuing business opportunities with nCAP. This resulted in diminished working capital, which made it difficult for nCAP to leverage its intellectual property, consequently decreasing the value of nCAP's intellectual property, overall.

127. nCAP's intellectual property was further diminished by Apple's unfair competition because nCAP was unable to pursue business opportunities with other cellular device manufacturers. Apple's infringement of nCAP's patents resulted in a cloud over the value of the patent, and made it impossible for nCAP to negotiate from a point of strength with other cellular device manufacturers. As an example, other cellular device manufacturers

contacted nCAP regarding its intellectual property, but nCAP was unable to negotiate details for a business agreement because of Apple's infringement and the looming patent litigation.

128. Apple's unfair competition diminished the value of nCAP's intellectual property because nCAP was unable to acquire outside funding. As an example, at least one investment bank would not move forward with nCAP because of Apple's infringement and the uncertainty of nCAP's future in light of required litigation.

129. Not only has nCAP been denied the ability to sell its product, acquire funding, engage in new contracts, or generate business, nCAP is further forced to litigate against Apple in order to realize the value of its patent. This diminishes the value of the patent, since Apple and any other potential licensee can take a wait and see attitude with respect to the value of nCAP's patented technology. Rather than pay fair value before including patented technology in its products, Apple can instead leverage its immense financial resources toward the goal of "efficient" infringement, contending that even in a worst-case scenario it should pay only the same value that it likely should have paid in an arms-length licensing negotiation.

130. Apple's practices in infringing on nCAP's patents-in-suit were unlawful, unfair, or fraudulent and those practices leads to a material diminution in value of the patent. Further, Apple's practices are habitual when examined across multiple patentees in the industry. Apple habitually makes it difficult for innovators, patentees, and small business owners to enter the industry, negotiate with other industry participants, and leverage their own intellectual property. This behavior goes beyond normal competitive measures, is unfair, and violates industry standards and business norms. Because Apple's unfair competition is a pattern of behaviors, targeted at a plurality of individuals or individual entities, it is difficult for any one of Apple's

victims to prevent or stop Apple's unfair competition. Each of Apple's unfair, unethical, and unscrupulous actions against an individual entity are part of this violation of ethical business practices.

131. As a result of Apple's unfair business acts, nCAP has been unable to make business arrangements with one or more potential consumers, such as Case Vendor or Apple itself. Because of Apple's unfair tactics, including its unfair head start, nCap has been injured by being unable to obtain the good will of being the company that provided this technology to the cell phone market. nCAP further lost the opportunity to decide with whom it would engage in business dealings (Apple versus other cellular device manufacturers, case manufacturers, etc.). nCAP also had difficulty accessing funding, recruiting investors, or otherwise building its own business. nCAP has lost its opportunity to market its patented invention exclusively, or to otherwise dictate its own business future. Further, nCAP has lost good will that cannot be compensated through damages or fully obtained through an injunction which is further injuring the company.

DEMAND FOR JURY TRIAL

132. nCAP hereby demands a jury for all issues so triable.

PRAYER FOR RELIEF

Plaintiffs hereby seek the following relief from this Court:

133. A judgment that Apple has directly infringed the patents-in-suit, contributorily infringed the patents-in-suit, and induced the infringement of the patents-in-suit

134. A preliminary and permanent injunction preventing Apple and its officers, directors, agents, servants, employees, attorneys, licensees, successors, and assigns, and those in active concert or participation with any of them, from directly infringing, contributorily infringing, and inducing the infringement of the patents-in-suit;

135. A judgment that Apple's infringement of the patents-in-suit has been willful;

136. A judgment and order requiring Apple to pay Plaintiffs damages under 35 U.S.C. § 284, including supplemental damages for any continuing post-verdict infringement through entry of the final judgment, with an accounting, as needed, and enhanced damages for willful infringement as provided by 35 U.S.C § 284;

137. A ruling that this case be found to be exceptional under 35 U.S.C. § 285, and a judgment awarding to Plaintiffs their attorneys' fees incurred in prosecuting this action;

138. A judgment that Apple violated Utah Code Ann. § 13-5a-102;

139. A judgment and order requiring Apple to pay Plaintiffs damages under Utah Code Ann. § 13-5a-103, including actual damages and costs and attorney fees;

140. A ruling that the circumstances are appropriate and a judgment that Apple pay punitive damages;

141. A judgment and order requiring Apple to pay Plaintiffs the costs of this action (including all disbursements);

142. A judgment and order requiring Apple to pay Plaintiffs pre-judgment and post-judgment interest on the damages awarded;

143. In the event a permanent injunction preventing future acts of infringement is not granted, an order requiring Apple to pay to Plaintiffs an ongoing royalty for its continued infringement with periodic accountings; and

144. Such other and further relief as the Court may deem just and proper.

DATED this 14th day of May, 2018.

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Exhibit A

US009088071B2

(12) **United States Patent**
Spencer et al.

(10) **Patent No.: US 9,088,071 B2**
(45) **Date of Patent: Jul. 21, 2015**

(54) **TECHNIQUES FOR CONDUCTIVE PARTICLE BASED MATERIAL USED FOR AT LEAST ONE OF PROPAGATION, EMISSION AND ABSORPTION OF ELECTROMAGNETIC RADIATION**

(75) Inventors: **Rhett Francis Spencer**, Heber City, UT (US); **Eric Guzman Hernandez**, Tampa, FL (US); **Anthony Joseph Sutera**, Draper, UT (US)

(73) Assignee: **ChamTech Technologies, Incorporated**, Wilmington, DE (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 598 days.

(21) Appl. No.: **13/303,135**

(22) Filed: **Nov. 22, 2011**

(65) **Prior Publication Data**

US 2012/0146855 A1 Jun. 14, 2012

Related U.S. Application Data

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(51) **Int. Cl.**

H01Q 1/38	(2006.01)
H01Q 1/36	(2006.01)
H01Q 17/00	(2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 1/364*** (2013.01); ***H01Q 1/38*** (2013.01); ***H01Q 17/004*** (2013.01); *Y10T 29/49016* (2015.01)

(58) **Field of Classification Search**
USPC .... 343/700 MS, 897, 702
See application file for complete search history.

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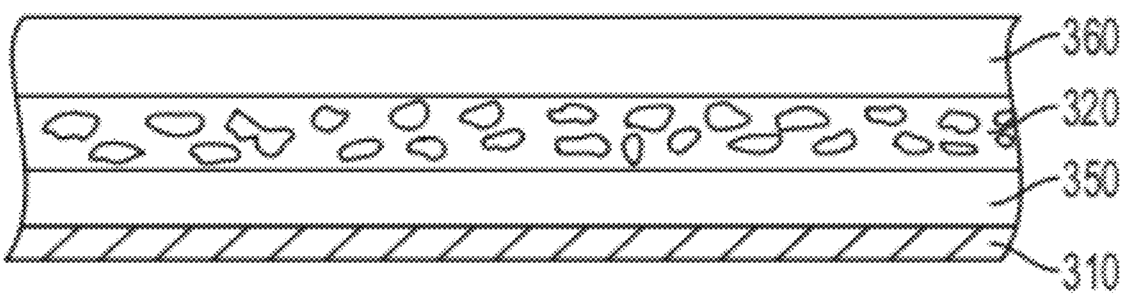
(57) **ABSTRACT**

An antenna system and method for fabricating an antenna are provided. The antenna system includes a substrate and an antenna. The antenna includes a conductive particle based material applied onto the substrate. The conductive particle based material includes conductive particles and a binder. When the conductive particle based material is applied to the substrate, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

15 Claims, 10 Drawing Sheets



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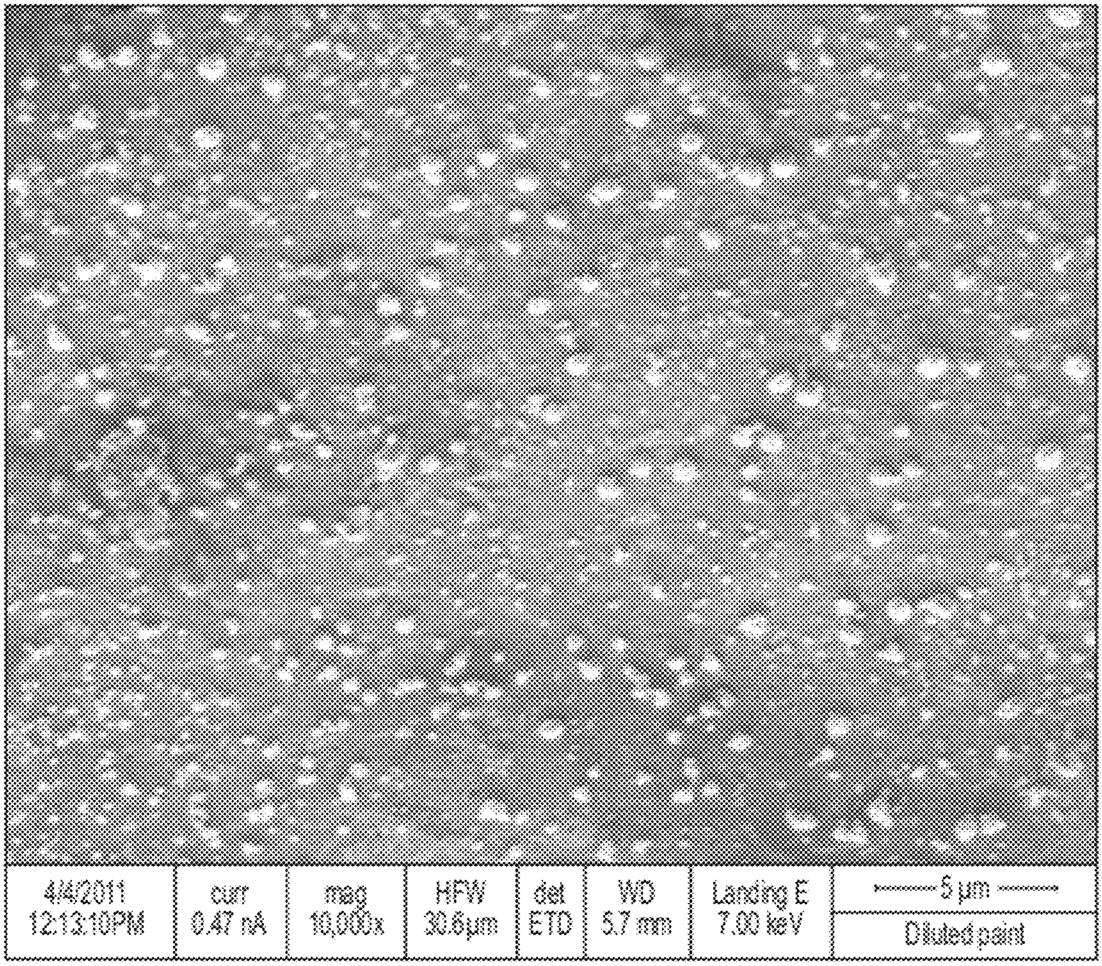
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curr
0.47 nA
mag
10,000x
HFW
30.6µm
det
ETD
WD
5.7 mm
Landing E
7.00 keV
5 µm
Diluted paint

FIG. 1

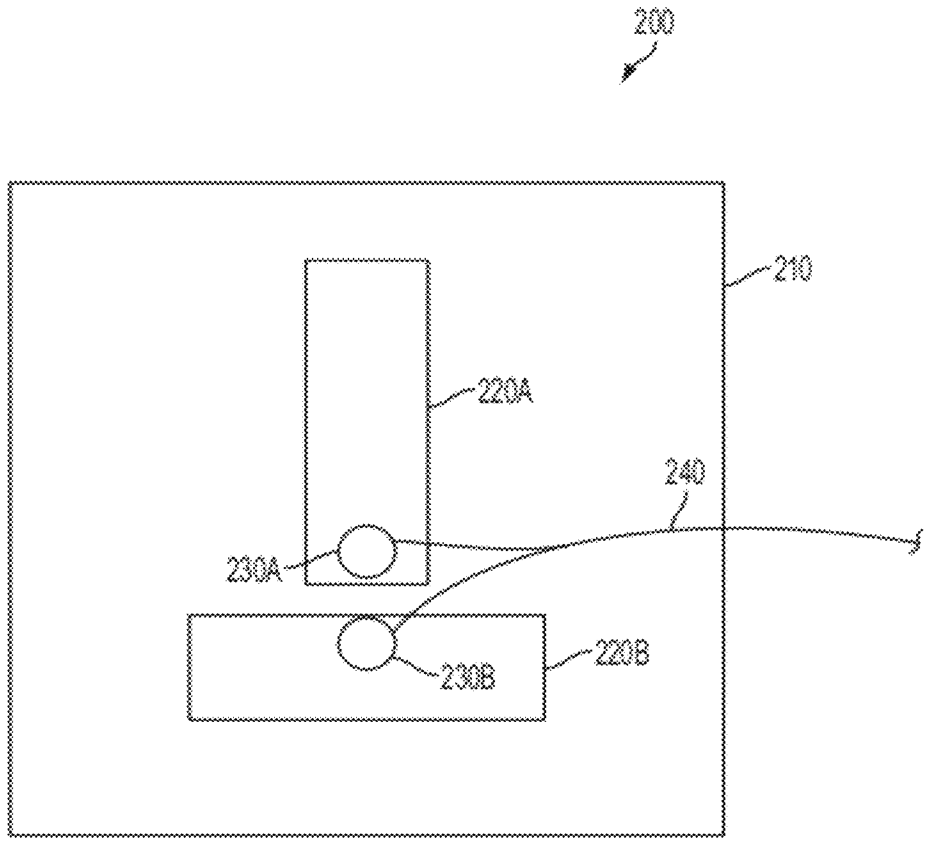

FIG. 2

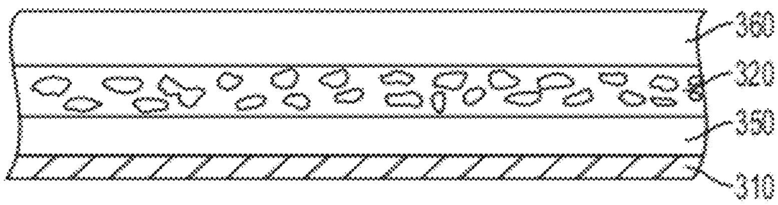

FIG. 3

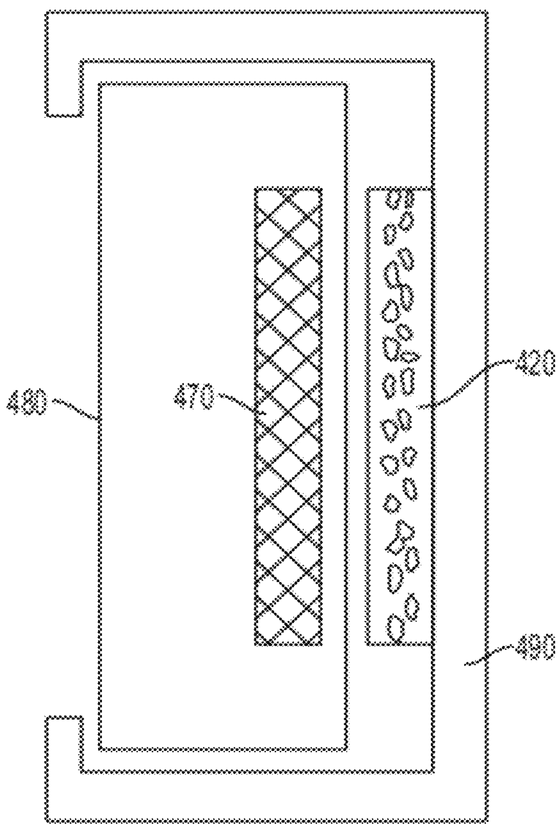

FIG. 4

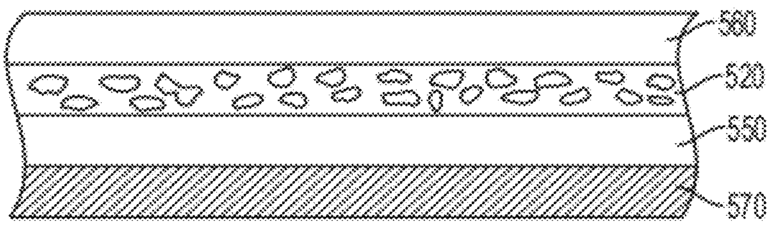

FIG. 5

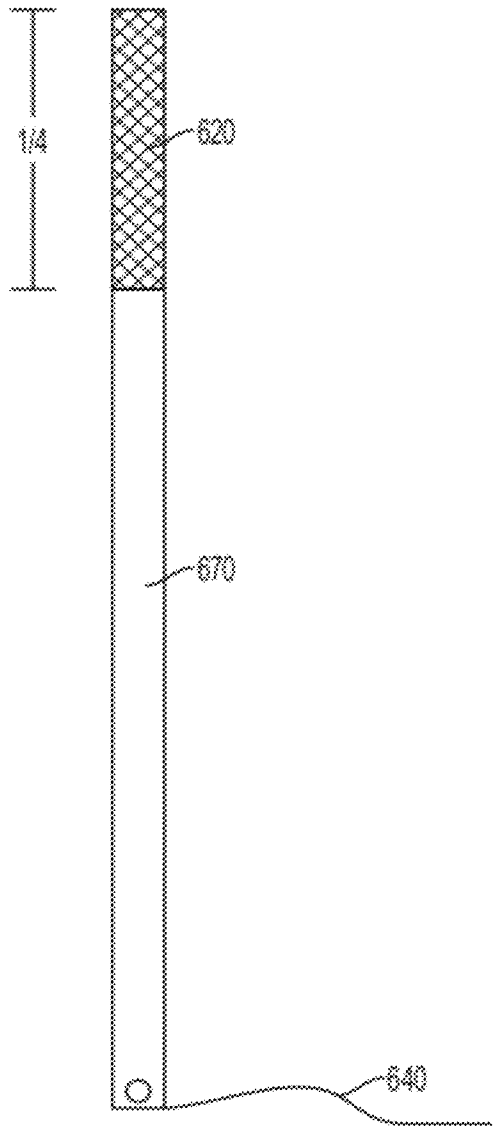

FIG. 6

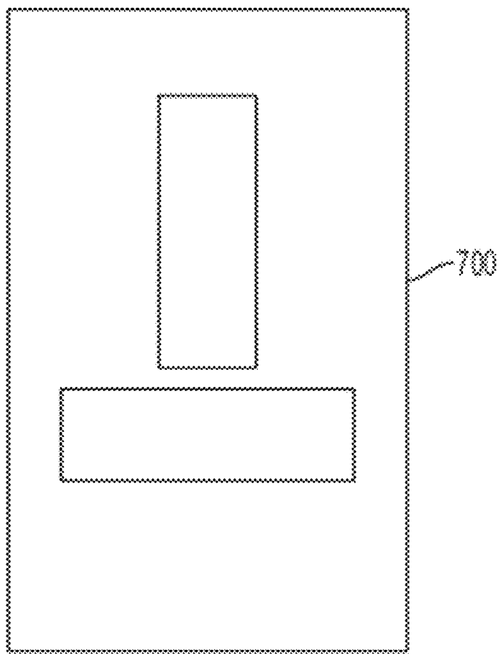

FIG. 7

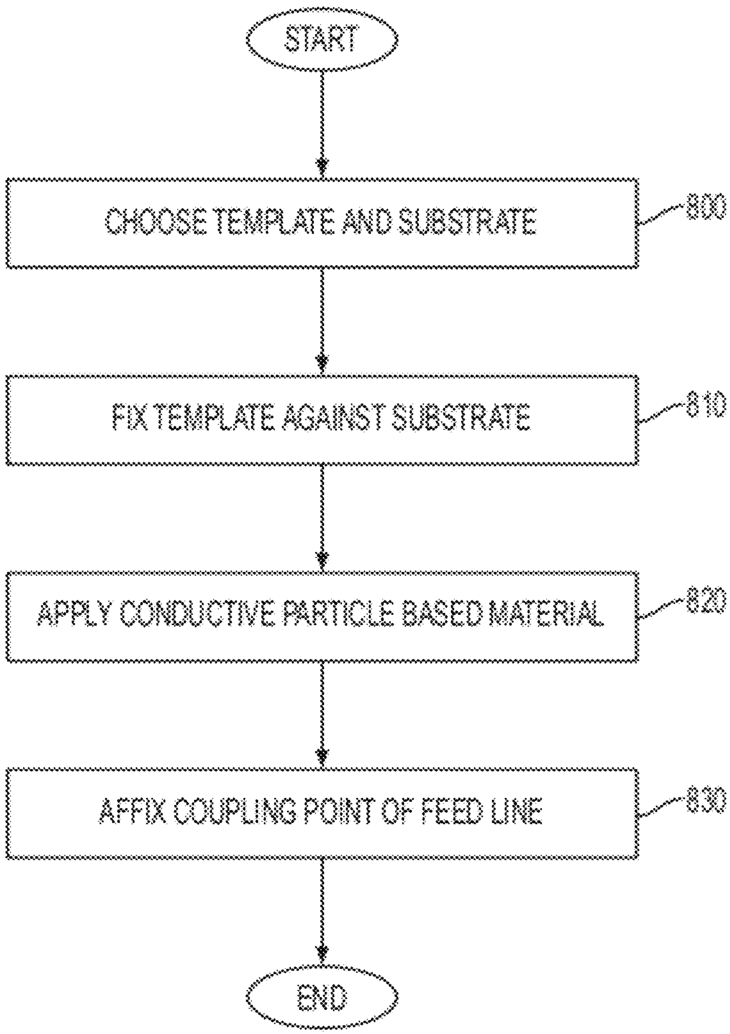
START
CHOOSE TEMPLATE AND SUBSTRATE
800
FIX TEMPLATE AGAINST SUBSTRATE
810
APPLY CONDUCTIVE PARTICLE BASED MATERIAL
820
AFFIX COUPLING POINT OF FEED LINE
830
END

FIG. 8

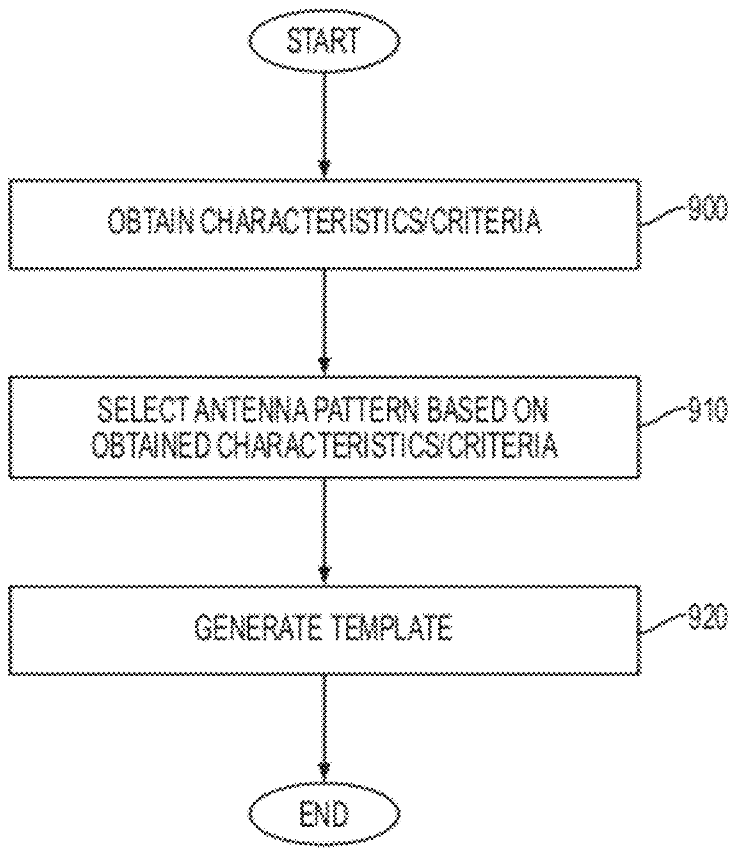
START
OBTAIN CHARACTERISTICS/CRITERIA
900
SELECT ANTENNA PATTERN BASED ON OBTAINED CHARACTERISTICS/CRITERIA
910
GENERATE TEMPLATE
920
END

FIG. 9

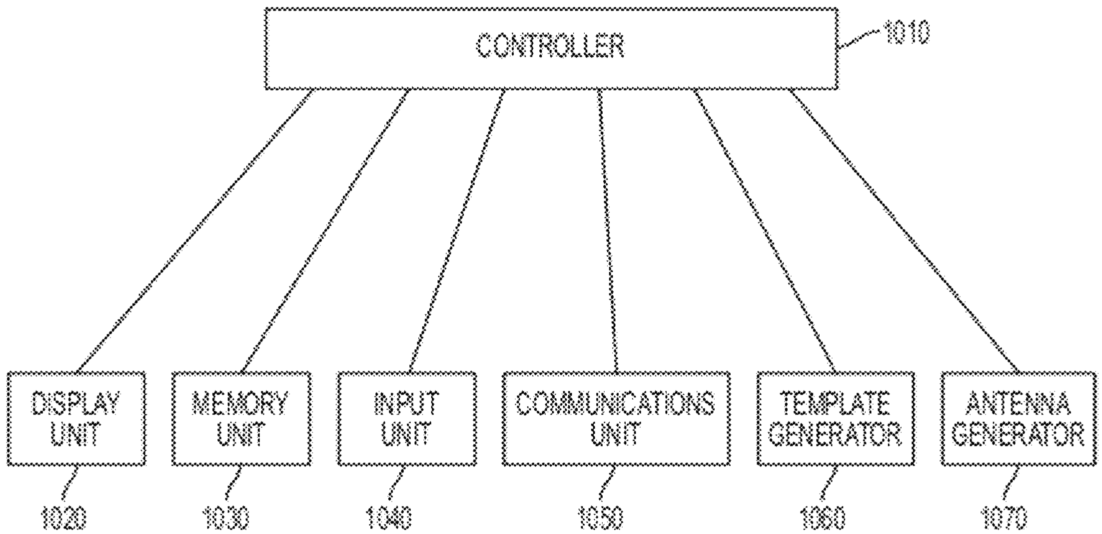
CONTROLLER
1010
DISPLAY UNIT
MEMORY UNIT
INPUT UNIT
COMMUNICATIONS UNIT
TEMPLATE GENERATOR
ANTENNA GENERATOR
1020
1030
1040
1050
1060
1070

FIG. 10

TECHNIQUES FOR CONDUCTIVE PARTICLE BASED MATERIAL USED FOR AT LEAST ONE OF PROPAGATION, EMISSION AND ABSORPTION OF ELECTROMAGNETIC RADIATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §119 (e) of a U.S. provisional patent application filed on Nov. 22, 2010 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/416,093, a U.S. provisional patent application filed on Apr. 8, 2011 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/473,726, a U.S. provisional patent application filed on Apr. 20, 2011 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/477,587, and a U.S. provisional patent application filed on Aug. 2, 2011 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/514,435, the entire disclosure of each of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to techniques for a material used for at least one of propagation, emission and absorption of electromagnetic radiation. More particularly, the present invention relates to techniques for a conductive particle based material used for at least one of propagation, emission and absorption of electromagnetic radiation.

2. Description of the Related Art

A conventional antenna is a device with an arrangement of one or more conductive elements that are used to generate a radiating electromagnetic field in response to an applied alternating voltage and the associated alternating electric current, or can be placed in an electromagnetic field so that the field will induce an alternating current in the antenna and a voltage between its terminals. The conductive elements employed in the conventional antenna are typically fabricated from solid metallic conductors. However, the use of solid metallic conductors is limiting.

Therefore, a need exists for an improved material used for at least one of propagation, emission and absorption of electromagnetic radiation, and implementations of the improved material.

SUMMARY OF THE INVENTION

An aspect of the present invention is to address at least the above-mentioned problems and/or disadvantages and to provide at least the advantages described below. Accordingly, an aspect of the present invention is to provide techniques for a conductive particle based material used for at least one of propagation, emission and absorption of electromagnetic radiation.

In accordance with an aspect of the present invention, an antenna system is provided. The antenna system includes a substrate and an antenna. The antenna includes a conductive particle based material applied onto the substrate. The conductive particle based material includes conductive particles and a binder. When the conductive particle based material is applied to the substrate, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

In accordance with another aspect of the present invention, an antenna enhancer system is provided. The antenna enhancer system includes an antenna and an antenna enhancer. The antenna enhancer includes a conductive particle based material. The antenna enhancer is disposed adjacent to and offset from the antenna. The conductive particle based material comprises conductive particles and a binder. When the conductive particle based material is disposed adjacent to and offset from the antenna, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

In accordance with yet another aspect of the present invention, a method for fabricating a conformable antenna is provided. The method includes selecting a substrate on which to fabricate an antenna, selecting a template corresponding to an antenna design, the template comprising one or more cut out portions, applying a conductive particle based material, through the one or more cutout portions of the template, and onto the substrate to form the antenna, and fixing a coupler of a feed line to the antenna. The conductive particle based material comprises conductive particles and a binder. When the conductive particle based material is applied to the substrate, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

Other aspects, advantages, and salient features of the invention will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses exemplary embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of certain exemplary embodiments of the present invention will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a captured image of a conductive particle based material according to an exemplary embodiment of the present invention;

FIG. **2** illustrates a conductive particle based antenna according to an exemplary embodiment of the present invention;

FIG. **3** illustrates a structure of a conductive particle based antenna according to an exemplary embodiment of the present invention;

FIG. **4** illustrates an implementation of a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention;

FIG. **5** illustrates a structure of a coated conductive particle based antenna enhancer according to an exemplary embodiment of the present invention;

FIG. **6** illustrates an antenna partially coated with a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention;

FIG. **7** illustrates a template used to fabricate a conductive particle based conformable antenna according to an exemplary embodiment of the present invention;

FIG. **8** illustrates a method for fabricating a conductive particle based conformable antenna using a template according to an exemplary embodiment of the present invention;

FIG. **9** illustrates a method for fabricating a conductive particle based conformable antenna using a computerized device according to an exemplary embodiment of the present invention; and

FIG. **10** illustrates a structure of computerized device used for fabricating a conductive particle based conformable antenna according to an exemplary embodiment of the present invention.

Throughout the drawings, like reference numerals will be understood to refer to like parts, components, and structures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of exemplary embodiments of the invention as defined by the claims and their equivalents. It includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope and spirit of the invention. In addition, descriptions of well-known functions and constructions are omitted for clarity and conciseness.

The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used by the inventor to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention are provided for illustration purpose only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

It is to be understood that the singular forms “a,” “an,” and “the” include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to “a component surface” includes reference to one or more of such surfaces.

As used herein, the term “substantially” refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is “substantially” enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of “substantially” is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result.

As used herein, the term “about” is used to provide flexibility to a numerical range endpoint by providing that a given value may be “a little above” or “a little below” the endpoint.

As used herein, the term “antenna” refers to a transducer used to transmit or receive electromagnetic radiation. That is, an antenna converts electromagnetic radiation into electrical signals and vice versa. Electromagnetic radiation is a form of energy that exhibits wave-like behavior as it travels through space. In free space, electromagnetic radiation travels close to the speed of light with very low transmission loss. Electromagnetic radiation is absorbed when propagating through a conducting material. However, when encountering an interface of such a material, the electromagnetic radiation is partially reflected and partially transmitted there-though. Herein, exemplary embodiments of the present invention described below are directed toward techniques that allow for a more efficient interface by reducing the reflections at the interface.

In addition, exemplary embodiments of the present invention described below relate to techniques for a conductive particle based material used for at least one of propagation, emission and absorption of electromagnetic radiation. While the techniques for the conductive particle based material may be described below in various specific implementations, the present invention is not limited to those specific implementations and is similarly applicable to other implementations.

An initial overview of the conductive particle based material is provided below and then specific implementations in which the conductive particle based material is employed are described in detail further below. This initial overview of the conductive particle based material is intended to aid readers in understanding the conductive particle based material that is the basis of various exemplary implementations, but is not intended to identify key features or essential features of those various exemplary implementations, nor is it intended to limit the scope of the claimed subject matter.

Conductive Particle Based Material

In one exemplary embodiment, a conductive particle based material is employed. The conductive particle based material includes at least two constituent components, namely conductive particles and a binder. However, the conductive particle based material may include additional components, such as at least one of graphite, carbon (e.g., carbon black), titanium dioxide, etc.

The conductive particles may be any conductive material, such as silver, copper, nickel, aluminum, steel, metal alloys, carbon nanotubes, any other conductive material, and any combination thereof. For example, in one exemplary embodiment, the conductive particles are silver coated copper. Alternatively, the conductive particles may be a combination of a conductive material and a non-conductive material. For example, the conductive particles may be ceramic magnetic microspheres coated with a conductive material such as any of the conductive materials described above. Furthermore, the composition of each of the conductive particles may vary from one another.

The conductive particles may be any shape from a random non-uniform shape to a geometric structure. The conductive particles may all have the same shape or the conductive particles may vary in shape from one another. For example, in one exemplary embodiment, each of the conductive particles may have a random non-uniform shape that varies from conductive particle to conductive particle.

The conductive particles may range in size from a few nanometers up to a few thousand nanometers. Alternatively, the conductive particles may range in size from about 400 nanometers to 30 micrometers. The conductive particles may be substantially similar in size or may be of various sizes included in the above identified ranges. For example, in one exemplary embodiment, the conductive particles are of various sizes in the range of about 400 nanometers to 30 micrometers. Herein, when a range of sizes of the conductive particles are employed, the distribution of the sizes may be uniform or non-uniform across the range. For example, 75% of the conductive particles may be a larger size within a given range while 25% of the conductive particles are a smaller size.

An effective amount of conductive particles are included relative to the binder so that the conductive particles are dispersed in the binder. The conductive particles may be randomly or orderly dispersed in the binder. The conductive particles may be dispersed at uniform or non-uniform densities. The conductive particles may be dispersed so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another.

The binder is used to substantially fix the conductive particles relative to each other and should be a non-conductive or semi-conductive substance. Any type of conventional or novel binder that meets these criteria may be used. The non-conductive or semi-conductive material of the binder may be chosen to function as a dielectric with a given permittivity.

The conductive particle based material may be formed as a rigid or semi-rigid structure. For example, the conductive particle based material may be a plastic sheet having the conductive particles dispersed therein. The conductive particle based material may be clear or opaque, and may include any shade of color.

In addition, the conductive particle based material may be a liquid, paint, gel, ink or paste that dries or cures. Here, the binder may include distillates, hardening agents, or solvents such as a Volatile Organic Compound (VOC). In this case, the conductive particle based material may be applied to a substrate. Also, when the conductive particle based material is a liquid, paint, gel, ink or paste that dries or cures, the binder may adhere to the substrate. The conductive particle based material may be spayed on, brushed on, rolled on, ink-jet printed, silk screened, etc. onto the substrate. The use of the conductive particle based material that is a liquid, paint, gel, ink or paste that dries or cures is advantageous in that the conductive particle based material may be thinly applied to a substrate and conform to the surface of the substrate. This allows the conductive particle based material to occupy very little space and, in effect, blend into the substrate.

The substrate may be the surface of any conductive, non-conductive or semi-conductive substance. The substrate may be rigid, semi-flexible or flexible. The substrate may be flat, irregularly shaped or geometrically shaped. The substrate may be paper, cloth, plastic, polycarbonate, acrylic, nylon, polyester, rubber, metal such as aluminum, steel and metal alloys, glass, composite materials, fiber reinforced plastics such as fiberglass, polyethylene, polypropylene, textiles, wood, etc.

The substrate may have a coating applied thereto. The coating may be a conductive, non-conductive or semi-conductive substance. The coating may be a paint, gel, ink, paste, tape, etc. The coating may be chosen to function as a dielectric with a given permittivity.

At least one of a protective and concealing (or decorative) coating may be applied over the conductive particle based material once it has been applied to a substrate.

An example of the conductive particle based material is described below with reference to FIG. **1**.

FIG. **1** is a captured image of a conductive particle based material according to an exemplary embodiment of the present invention.

Referring to FIG. **1**, the conductive particle based material includes conductive particles and a binder. The conductive particles are randomly shaped, sized and located. However, conductive particles are dispersed so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another.

Herein, without intending to be limiting, for a conductive particle based material of a given density of conductive particles, the conductive particle based material may be applied at a thickness such that the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another. Herein, without intending to be limiting, it has been observed that a conductive particle based material has a resistance of about 3-17 ohms across any given two points on the surface.

Herein, without intending to be limiting, it has been observed that when the conductive particle based material is formulated such that the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another, the conductive particle based material exhibits properties that enable it to at least one of efficiently propagate electromagnetic radiation, efficiently absorb electromagnetic radiation from space, and efficiently emit electromagnetic radiation into space. Moreover, it has been observed that those properties may be either supplemented or enhanced by including an effective amount of carbon, such as carbon black, in the conductive particle based material. For example, an effective amount of carbon black may be an amount that corresponds to about 1-7% of the conductive particles included in the conductive particle based material.

Without intending to be limiting, it is believed that when electromagnetic radiation is introduced into the conductive particle based material, electromagnetic radiation may pass from conductive particle to conductive particle via at least one of capacitive and inductive coupling. Here, the binder may function as a dielectric. Thus, it is believed that the conductive particle based material may act as an array of capacitors, which may be at least part of the reason why the conductive particle based material at least one of efficiently propagates electromagnetic radiation, efficiently absorbs electromagnetic radiation from space, and efficiently emits electromagnetic radiation into space.

Alternatively or additionally, and without intending to be limiting, it is believed that the properties that enable the conductive particle based material to at least one of efficiently propagate electromagnetic radiation, efficiently absorb electromagnetic radiation from space, and efficiently emit electromagnetic radiation into space, may be explained by quantum theory at the atomic level.

Herein, without intending to be limiting, it has been observed that the conductive particle based material generates electrical energy when exposed to sunlight.

Herein, without intending to be limiting, it has been observed that the resistance of the conductive particle based material continuously changes over time. Herein, without intending to be limiting, it has been observed that, when energized with a radio signal, the conductive particle based material has infinitely low resistance to that signal.

Herein, while the present disclosure is described in the context of electromagnetic radiation, without intending to be limiting, it is believed that the present invention is equally applicable to bioelectromagnetic energy. Thus, any disclosure herein that refers to electromagnetic radiation equally applies to bioelectromagnetic energy.

Conductive Particle Based Antenna

In one exemplary embodiment, the conductive particle based material is employed to implement a conductive particle based antenna. When used as a conductive particle based antenna, the conductive particle based antenna is fabricated using the conductive particle based material. Here, the conductive particle based material may be formed into a shape that conforms to the desired characteristics of the antenna. For example, the shape and size of the antenna may vary depending on the frequency and/or polarization of the electromagnetic radiation to be communicated. The conductive particle based antenna is at least one of electrically, capacitively, and inductively coupled to at least one of a receiver, a transmitter, and a transceiver at a coupling point of the conductive particle based antenna. The coupling point of the conductive particle based antenna may substantially be an end point of the conductive particle based antenna. The coupling point of the conductive particle based antenna may be coupled to a coupling point of a feed line electrically connected to the receiver, transmitter, or transceiver. When capacitively or inductively coupled, the coupling may occur through a distance that includes an air gap or that has a substance, such as glass, disposed therein.

When a conductive particle based antenna is fabricated using the conductive particle based material, the conductive particle based antenna may exhibit a broad bandwidth self-tuning characteristic by using only a small section of the conductive particle based antenna to emit the electromagnetic radiation into space.

In addition, when the conductive particle based antenna is fabricated using the conductive particle based material, there may be no or little I^2R losses due the small practical size and the majority of the particles not contacting each other. In addition, there may be no or little Radio Frequency (RF) skin effect losses due to the small practical size. Once the signal is coupled to the conductive particle based antenna, the conductive particle based antenna provides little to no resistance to the transmission signal and it is emitted without significant loss into space. The same may happen in reverse for receiving. That is, the received signal may be absorbed and delivered with little to no loss to the coupling device and is then propagated down a feed line to a receiver.

An example of the conductive particle based antenna is described below with reference to FIG. **2**.

FIG. **2** illustrates a conductive particle based antenna according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna **200** shown in FIG. **2** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna **200** of FIG. **2** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **2**, the conductive particle based antenna **200** includes a substrate **210**, a first antenna segment **220**A, a second antenna segment **220**B, a first coupler **230**A, a second coupler **230**B, and a feed line **240**.

The substrate **210** is a rigid flat sheet of a non-conductive material, such as plexiglass. However, any other surface may be chosen as substrate **210**. For example, the surface of a vehicle, the wall of a building, the casing of a wireless device, glass, a tree, cloth, a rock, a plastic sheet, etc., may be chosen as the substrate. When a conductive material is chosen as the substrate **210**, an insulative coating of a non-conductive or semi-conductive material may be applied to the area of the substrate **210** where the conductive particle based antenna **200** is to be applied. Examples of the insulative coating of the non-conductive or semi-conductive material include plastic tape, paper tape, paint, etc. Also, when the substrate **210** is a conductive material, the substrate may be utilized as a ground plane. In addition, a surface preparation coating may be applied to the substrate **210** that allows for better adhesion of the conductive particle based material to the substrate **210**. The insulative coating may serve the same function as the surface preparation coating. Also, the surface preparation coating may be applied beneath or on top of the insulative coating. Furthermore, the surface preparation coating may be used when the insulative coating in not applied.

The first antenna segment **220**A and the second antenna segment **220**B are applied to the substrate **210** according to a desired design. Here, the first antenna segment **220**A is functioning as an active antenna element and the second antenna segment **220**B is functioning as a ground plane. When the substrate **210** is functioning as a ground plane or an earth ground is employed, the second antenna segment **220**B may be omitted. Here, the first antenna segment **220**A and the second antenna segment **220**B are formed using a conductive particle based material formulated as a liquid, paint, gel, ink, or paste that dries or cures. The non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The first coupler **230**A and the second coupler **230**B at least one of electrically, capacitively, and inductively couple to the first antenna segment **220**A and the second antenna segment **220**B, respectively. In addition, the first coupler **230**A and the second coupler **230**B adhere to, or are otherwise in a fixed relationship with, the first antenna segment **220**A and the second antenna segment **220**B. The first coupler **230**A and the second coupler **230**B are electrically connected to respective portions of the feed line **240**.

The feed line **240** is electrically connected to first coupler **230**A and the second coupler **230**B. Also, the feed line **240** is electrically connected to at least one of a receiver, a transmitter, and a transceiver.

An example of a structure of a conductive particle based antenna is described below with reference to FIG. **3**.

FIG. **3** illustrates a structure of a conductive particle based antenna according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna shown in FIG. **3** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna of FIG. **3** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **3**, the conductive particle based antenna includes a substrate **310**, first coating **350**, conductive particle based material coating **320**, and a second coating **360**. One or more of the substrate **310**, the first coating **350**, and the second coating **360** may be omitted. In addition, one or more additional coatings may be utilized.

The substrate **310** may be any surface of any object, regardless of what material(s) the object is constructed of. For example, the surface of a vehicle, the wall of a building, the casing of a wireless device, glass, a tree, cloth, a rock, a plastic sheet, etc., may be chosen as the substrate. When the substrate **310** is a conductive material, the substrate **310** may function as a ground plane.

The first coating **350** is applied on top of the substrate **310**. The first coating **350** may be at least one of an insulative coating and a surface preparation coating. As an insulative coating, the first coating **350** may be a non-conductive or semi-conductive material. Examples of the insulative coating of the non-conductive or semi-conductive material include plastic tape, paper tape, paint, etc. As a surface preparation coating, the first coating **350** may be any material that allows for better adhesion of the conductive particle based material coating **320** to the substrate **310**. The same coating may serve as both the insulative coating and a surface preparation coating. Alternatively, separate insulative and a surface preparation coatings may be utilized either together or individually. The first coating **350** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the first coating **350** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The first coating **350** may be omitted.

The conductive particle based material coating **320** is applied on top of the first coating **350**, if present. Otherwise, the conductive particle based material coating **320** is applied on top of the substrate **310**. Alternatively, the conductive particle based material coating **320** may be an independent structure. The conductive particle based material coating may be formulated using any formulation of the conductive particle based material described herein. For example, the conductive particle based material coating **320** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The second coating **360**, if utilized, is applied on top of the conductive particle based material coating **320**. The second coating **360** may serve to protect and/or conceal the conductive particle based material coating **320**. The second coating **360** may be any material or structure that protects and/or conceals the conductive particle based material coating **320**. The same coating may serve as both the protective coating and the concealment coating. Alternatively, separate protective and concealment coatings may be utilized either together or individually. In one exemplary embodiment, the second coating **360** is formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the second coating **360** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The second coating **360** may be omitted.

Tests were conducted to compare the conductive particle based antenna to a conventional antenna. The conductive particle based antenna was formed using the conductive particle based material whereas the conventional copper antenna was formed using solid copper strips. Both the conductive particle based antenna and the conventional copper antenna were fabricated with the same shape (i.e., the shape shown in FIG. **2**) of the same size so that the effect of the particular structure, if any, is equal to both antennas. A non-conductive plexiglass substrate was used to fix both antennas. The same transmit power and frequency were used for the test. The frequency selected was in the range of about 460 MHz. Testing equipment included a Yeasu FT 7900 Dual band FM transceiver, a Telewave Model 44 Wattmeter, and a FieldFox Model N9912A Portable Network Analyzer operated in SA mode used with a Yeasu Model Rubber Duck Antenna that was located 160 feet from the test antennas. The test data for the conventional copper antenna and the conductive particle based antenna are provided below in Table 1.

TABLE 1

	Conventional Copper Antenna	Conductive Particle Based Antenna
Forward Power	22 watts	41 watts
Reverse Power	12 watts	1 watt
Relative Signal Strength	−35 decibels	−26 decibels

As can be seen in Table 1, the conductive particle based antenna exhibits a significantly higher forward power (i.e., 41 watts) than the forward power of the conventional copper antenna (i.e., 22 watts). This can be explained by the conductive particle based antenna exhibiting a significantly lower reverse power (i.e., 1 watt) than the reverse power of the conventional copper antenna (i.e., 12 watts). Accordingly, the resulting relative signal strength of the conductive particle based antenna is higher (−26 decibels) than the resulting relative signal strength of the conventional copper antenna (−35 decibels).

As can be gleaned from the test, for a given antenna structure, the conductive particle based antenna is more efficient at emitting electromagnetic radiation into space than the conventional copper antenna. Therefore, the conductive particle based antenna has a higher effective gain than the conventional copper antenna. Also, since there is less reverse power, less of the electromagnetic radiation input to the conductive particle based antenna may be converted into heat. Thus, the antenna may operate at a lower temperature for a given input power and therefore may have a higher power rating.

The added gain by using the conductive particle based antenna is well suited to any application in which higher gain and/or lower transmit power for a given antenna structure is desired.

It has been observed that the transmission performance of the conductive particle based antenna varies depending on the type of amplifier used to drive the antenna. For example, the transmitter used in the Yeasu FT 7900 Dual band FM transceiver in the above test is a class C amplifier. When a linear class A amplifier is employed, the transmission performance of the conductive particle based antenna is reduced and approaches that of the conventional copper antenna. Thus, the performance of the conductive particle based antenna is greater when used with an amplifier that operates for less than the entire input cycle, such as the class C amplifier. While a class C amplifier is referred to herein for convenience in explanation, the use of any amplifier that operates for less than the entire input cycle is equally applicable.

Herein, power constrained devices typically employ a class C amplifier in order to take advantage of their efficiency so as to conserve power. Similarly, the use of the conductive particle based antenna in power constrained devices that employ a class C amplifier takes advantage of the efficiency of the conductive particle based antenna so as to further conserve power. The power conservation gained by the power constrained devices by using the conductive particle based antenna may allow for longer operational times and/or smaller power source (e.g., batteries) (and thereby smaller devices and/or a lower cost).

Conductive Particle Based Antenna Enhancer

In one exemplary embodiment, the conductive particle based material is employed to implement a conductive particle based antenna enhancer. When used as a conductive particle based antenna enhancer, the conductive particle based antenna enhancer is fabricated using the conductive particle based material. Here, the conductive particle based antenna enhancer is disposed in an adjacent offset relationship to a conventional antenna with a non-conductive or semiconductive material disposed there between. Alternatively or additionally, an air gap between the conventional antenna and the conductive particle based antenna enhancer may be employed. Here, the conventional antenna is electrically coupled to at least one of a receiver, a transmitter, and a transceiver.

In this configuration, the conductive particle based antenna enhancer is at least one of capacitively and inductively coupled to the conventional antenna. Herein, the electromagnetic radiation that is capacitively and inductively coupled from the conventional antenna to the conductive particle based antenna enhancer is efficiently radiated into space by the conductive particle based antenna enhancer.

The conductive particle based antenna enhancer may be fabricated and positioned so as to be adjacent and offset from the conventional antenna. For example, the conductive particle based antenna enhancer may be added or built into a structure that places it in an adjacent and offset relationship to the conventional antenna.

For example, the structure may create an air gap between the conventional antenna and a surface onto which the conductive particle based material is applied. The structure may be constructed of a nonconductive material. Alternatively, the structure may be constructed of a conductive material and at least partially coated with a nonconductive material. If the structure is constructed of a conductive material, the conductive particle based material may be applied on top of the nonconductive material coating the structure. Herein, the conductive particle based material may be applied to a side of the structure closest to the conventional antenna or a side of the structure furthest from the conventional antenna. The conductive particle based material may be coated with a layer of the nonconductive material or another material. Examples of the structure include a housing of a device (e.g., a housing of a wireless device), an enclosure placed over the existing antenna, and a case placed over a housing of a device (e.g., a protective cover for a wireless device). The conductive particle based material is at least one of capacitively and inductively coupled to the conventional antenna and thereby increases the performance of the conventional antenna. Here, the thickness the nonconductive material and/or air gap directly affects the performance gain of the conductive particle based antenna enhancer and if the nonconductive thickness and/or air gap is too large, performance may decrease. The thickness of the air gap and/or nonconductive material is very small in relationship to the wavelength of the frequency the conventional antenna is designed for. In a specific example of the exemplary implementation described above, a conventional bumper case for an iPhone, which is manufactured by Apple, may have the conductive particle based material applied to a portion thereof that is adjacent to the antenna of the iPhone (the surface that is concealed when the iPhone is installed therein). Here, the conductive particle based material may have a layer of nonconductive material applied on top.

Another example of an implementation of a conductive particle based antenna enhancer is described below with reference to FIG. **4**.

FIG. **4** illustrates an implementation of a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna shown in FIG. **4** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna enhancer of FIG. **4** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **4**, a wireless device **480** and a protective cover **490** are shown. The wireless device **480** includes an internal antenna **470**. The protective cover **490** includes a conductive particle based antenna enhancer **420** that is disposed so as to be adjacent to the internal antenna **470** when the wireless device **480** is disposed in the protective cover **490**.

While the conductive particle based antenna enhancer **420** is shown to correspond to the size of the internal antenna **470**, the conductive particle based antenna enhancer **420** may be smaller or larger than the internal antenna **470**. In addition, while the conductive particle based antenna enhancer **420** is shown as being disposed immediately adjacent to the internal antenna, the conductive particle based antenna enhancer **420** may be disposed at a different location on the protective cover **490**.

While the conductive particle based antenna enhancer **420** is shown as being applied to an inner surface of the protective cover **490**, the conductive particle based antenna enhancer **420** may be applied to an outer surface of, or may be disposed within, the protective cover **490**. When the conductive particle based antenna enhancer **420** is disposed within the protective cover **490**, the material used to construct the protective cover **490** may serve as the binder for the conductive particle based material. When, the conductive particle based antenna enhancer **420** is disposed at an inner or outer surface of the conductive particle based material, one or more of an insulative coating, a surface preparation coating, a protective coating, and a concealment coating may be used. In addition, the conductive particle based antenna enhancer **420** may be formed as an independent structure (with or without a substrate) that is fixed to the protective cover **490**.

The conductive particle based antenna enhancer may be added to an existing conventional antenna or may be added at the time the conventional antenna is fabricated.

In one exemplary embodiment, the conductive particle based antenna enhancer is used to coat a conventional antenna that has been coated with a non-conductive material. The coating of the non-conductive material may be implemented as a liquid, paint, gel, ink, or paste that dries or cures. Herein, the non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. Alternatively, the coating of the non-conductive material may be a film or tape that is applied to the conventional antenna. Layers of other materials may be disposed between the conventional antenna and the non-conductive material and/or between the non-conductive material and the conductive particle based material. Here, depending on the configuration, the conductive particle based material may be coated with a layer of the nonconductive material and/or another material. Here, the thickness the non-conductive material may directly affect the performance gain of the conductive particle based material and if the thickness of the non-conductive material is too large, performance may decrease. The thickness of the non-conductive material is very small in relationship to the wavelength of the frequency the conventional antenna is designed for.

An example of a structure of a coated conductive particle based antenna enhancer is described below with reference to FIG. **5**.

FIG. **5** illustrates a structure of a coated conductive particle based antenna enhancer according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna shown in FIG. **5** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna of FIG. **5** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **5**, the coated conductive particle based antenna includes a conventional antenna **570**, a first coating **550**, a conductive particle based material coating **520**, and a second coating **560**. One or more of the first coating **550**, and a second coating **560** may be omitted. In addition, one or more additional coatings may be utilized.

The conventional antenna **570** may be any surface of any conventional antenna, which in this example, is assumed to be constructed of a conductive material such as metal.

The first coating **550** is applied on top of the conventional antenna **570**. The first coating **550** may be at least one of an insulative coating and a surface preparation coating. As an insulative coating, the first coating **550** may be a non-conductive or semi-conductive material. Examples of the insulative coating of the non-conductive or semi-conductive material include plastic tape, paper tape, paint, etc. As a surface preparation coating, the first coating **550** may be any material that allows for better adhesion of the conductive particle based material coating **520** to the conventional antenna **570**. The same coating may serve as both the insulative coating and a surface preparation coating. Alternatively, separate insulative and a surface preparation coatings may be utilized either together or individually. The first coating **550** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the first coating **550** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The first coating **550** may be omitted.

The conductive particle based material coating **520** is applied on top of the first coating **550**, if present. Otherwise, the conductive particle based material coating **520** is applied on top of the conventional antenna **570**. The conductive particle based material coating may be formulated using any formulation of the conductive particle based material described herein. For example, the conductive particle based material coating **520** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The second coating **560**, if utilized, is applied on top of the conductive particle based material coating **520**. The second coating **560** may serve to protect and/or conceal the conductive particle based material coating **520**. The second coating **560** may be any material or structure that protects and/or conceals the conductive particle based material coating **520**. The same coating may serve as both the protective coating and the concealment coating. Alternatively, separate protective and concealment coatings may be utilized either together or individually. In one exemplary embodiment, the second coating **560** is formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the second coating **560** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The second coating **560** may be omitted.

The conductive particle based antenna enhancer may be fabricated and positioned so as to be adjacent and offset from all or a portion of the conventional antenna. For example, the conductive particle based antenna enhancer may be fabricated and positioned so as to be adjacent to a portion of the conventional antenna corresponding to half or a quarter of the desired wavelength.

An example of an antenna partially coated with a conductive particle based antenna enhancer is described below with reference to FIG. **6**.

FIG. **6** illustrates an antenna partially coated with a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention. The particular structure of the antenna partially coated with the conductive particle based antenna enhancer shown in FIG. **6** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna of FIG. **6** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **6**, an antenna **670** that is connected to a feed line **640** is shown. The antenna **670** is partially coated with a conductive particle based antenna enhancer **620**. As can be seen, the conductive particle based antenna enhancer **620** coats about a quarter of the antenna **670**.

Tests were conducted to compare a conventional copper antenna to the conventional copper antenna with the conductive particle based antenna enhancer. In particular, the same equipment and testing conditions as the test described above with respect to the conductive particle based antenna were performed. Here, insulative tape was applied to the entirety of the conventional copper antenna and the conductive particle based material was then applied onto the insulative tape.

The test data for the conventional copper antenna and the conventional copper antenna that has been enhanced with the conductive particle based antenna enhancer are provided below in Table 2.

TABLE 2

	Conventional Copper Antenna	Conventional Copper Antenna with Conductive Particle Based Antenna Enhancer
Forward Power	22 watts	28 watts
Reverse Power	12 watts	10 watts
Relative Signal Strength	−35 decibels	−27 decibels

As can be seen in Table 2, the conventional copper antenna with the conductive particle based antenna enhancer exhibits a significantly higher forward power (i.e., 28 watts) than the forward power of the conventional copper antenna alone (i.e., 22 watts). This can be explained by the conventional copper antenna with the conductive particle based antenna enhancer exhibiting a significantly lower reverse power (i.e., 10 watts) than the reverse power of the conventional copper antenna alone (i.e., 12 watts). Accordingly, the resulting relative signal strength of the conventional copper antenna with the conductive particle based antenna enhancer is higher (−27 decibels) than the resulting relative signal strength of the conventional copper antenna (−35 decibels).

As can be gleaned from the above identified test, the conventional copper antenna with the conductive particle based antenna enhancer is more efficient at emitting electromagnetic signals into space than the conventional copper antenna alone. Therefore, the conventional copper antenna with the conductive particle based antenna enhancer has a higher effective gain than the conventional copper antenna alone. Also, since there is less reverse power, less of the electromagnetic radiation input to the conventional copper antenna with the conductive particle based antenna enhancer will be converted into heat. Thus, the conventional copper antenna with the conductive particle based antenna enhancer may operate at a lower temperature for a given input power and therefore may have a higher power rating.

Accordingly, the conductive particle based material may be used to enhance a conventional antenna.

Conductive Particle Based Transmission Line

The conductive particle based material may be used to form a conductive particle based transmission line. To implement a conductive particle based transmission line, a transmission line is formed in any of the various ways described herein for forming an object using the conductive particle based material. Herein, at least some of the properties that enable the conductive particle based material to efficiently radiate electromagnetic radiation into space allow the conductive particle based material to efficiently radiate electromagnetic radiation down the transmission line formed using the conductive particle based material. The use of the conductive particle based material as a transmission line is beneficial due to its lower resistance and heat generation.

Conductive Particle Based Electromagnetic Radiation Harvester

The conductive particle based material may be used as an electromagnetic radiation harvester. The high efficiencies of the conductive particle based material in at least one of propagating and absorbing electromagnetic radiation make it ideally suited for use in collecting electromagnetic radiation. While such collected electromagnetic radiation may be electromagnetic radiation that was transmitted with the intention of being harvested by the electromagnetic radiation harvester, the collected electromagnetic radiation may be background electromagnetic radiation. Herein, the electromagnetic radiation harvester may be coupled to a receiver that collects the energy absorbed by the electromagnetic radiation harvester.

The electromagnetic radiation harvester is formed in any of the various ways described herein for forming an object using the conductive particle based material.

Conductive Particle Based Conformable Antenna

The conductive particle based material may be used to construct a conductive particle based conformable antenna. The benefit of the conductive particle based conformable antenna may be easily appreciated when considered in the context of an exemplary use case, which is described below.

According to the exemplary use case, the conductive particle based conformable antenna may use used in a military setting. The Special Operations community has a major logistical and safety issue when it comes to communications in the theater. The US Department of Defense (DoD) has rapidly expanded its communications capabilities within the radio spectrum. In the past, two way radios in a variety of form factors where used for conventional Push-To-Talk (PTT) communications. The use of these systems has now evolved into a true "Digital Battlefield" consisting of a multitude of communications platforms. Vast arrays of data networks came into reality. The scope of radios used today varies widely from conventional voice to Satellite, mesh networks, to Unmanned Aerial Vehicles (UAVs) and unattended ground sensors.

The reason this wide variety of systems is mentioned is to give an understanding of why the conductive particle based conformable antenna may be beneficial to the mission of soldiers. Every RF device utilized by the military operates on a wide range of frequencies and a different type of transmission (Amplitude Modulation (AM), Frequency Modulation (FM), Satcom, Single Side band, etc.).

However, conventional antenna systems are designed and tuned for a limited range of frequencies and are generally designed to work with only one of the hundreds of types of radio devices on the market. The other major downsides to these conventional antenna systems are the logistics of getting them into battle. They are heavy, bulky, expensive, and difficult to transport. Accordingly, there is a need to address the shortcomings of the conventional antenna systems.

The conductive particle based conformable antenna addresses the shortcomings of the conventional antenna systems by being operable with any and all of the radios currently deployed and being developed. As opposed to being an antenna of fixed form, the conductive particle based conformable antenna may instead be constructed on an as needed basis.

For example, the conductive particle based conformable antenna may be constructed on site using the conductive particle based material. In this case, the conductive particle based material is a liquid, paint, gel, ink or paste that dries or cures. Herein, the conductive particle based conformable antenna may be applied to a substrate. In particular, the conductive particle based material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The conductive particle based conformable antenna may be designed based on typical antenna design, theory, and formulas. The antenna design may be generated in advance or at the time the antenna is needed based on desired characteristics.

The conductive particle based material is applied to the substrate to form the conductive particle based conformable antenna based on the desired antenna design.

The substrate may be any surface of any material, such as acrylic, ABS, structural foams, solvent sensitive materials such as polycarbonate and polystyrene, and non-porous surfaces including primed wallboard, wood and clean metals, etc.

When the substrate is a conducting material, a non-conductive or semi-conductive coating may first be applied to the substrate. In this case, the conducting material may serve as a ground plane. When the substrate is a non-conducting material, a ground plane can be accomplished by using the earth's natural ground. Alternatively, the ground plane can be accomplished by fabricating an independent ground plane.

Once the antenna is fabricated, a feed line is coupled to the conductive particle based conformable antenna and an RF communications device. The conductive particle based conformable antenna is at least one of electrically, capacitively, and inductively coupled to a coupling point of the feed line. The conductive particle based conformable antenna may be coupled to the coupling point of the feed line at an end point of the conductive particle based conformable antenna. When capacitively or inductively coupled, the coupling may occur through a distance that includes an air gap or a substance, such as glass.

To fabricate the conductive particle based conformable antenna, a template of the desired antenna design may be used. The template may be a sheet formed of any rigid or semi-rigid material in which the desired design of the antenna is cut out.

An example of a template used to fabricate a conductive particle based conformable antenna is described below with reference to FIG. **7**.

FIG. **7** illustrates a template used to fabricate a conductive particle based conformable antenna according to an exemplary embodiment of the present invention.

Referring to FIG. **7**, a template **700** is shown. The template **700** may be any material that may be used to form a template or stencil. For example, the template **700** may be a sheet formed of a rigid or semi-rigid material. The cut out of the template **700** may be at least one of a positive and a negative of a desired design of an antenna. The template **700** may be an image displayed on a surface showing where conductive particle based material should or should not be applied. The template **700** may be an image displayed on a display or in a guide book that shows a desired design of an antenna. Herein, the template **700** shown in FIG. **7** corresponds to the antenna design shown in FIG. **2**.

Examples of various cutout designs for the template **700** are found in U.S. Design patent application Ser. No. 29/390,425, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,427, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,432, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,435, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,436, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,438, filed on Apr. 25, 2011, and entitled "ANTENNA"; and U.S. Design patent application Ser. No. 29/390,442, filed on Apr. 25, 2011, and entitled "ANTENNA", the entire disclosure of each of which is hereby incorporated by reference.

An exemplary method for fabricating a conductive particle based conformable antenna using a template is described below with reference to FIG. **8**.

FIG. **8** illustrates a method for fabricating a conductive particle based conformable antenna using a template according to an exemplary embodiment of the present invention. Herein, the conductive particle based material used to fabricate the conductive particle based conformable antenna is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **8**, a template and substrate is chosen in step **800**. In step **810**, the chosen template may be fixed against the chosen substrate. In step **820**, the conductive particle based material may then be applied on the template such that the conductive particle based material passes through at least one cut out portion of the template so as to be applied to the corresponding portion of the substrate. The conductive particle based material may be applied until its particle density reaches a certain threshold. This may be determined by measuring the resistance of the material across the length of the antenna (or antenna segment). Here, the threshold may correspond to a predefined resistance or range of resistances (e.g., 11-15 ohms).

The template may then be removed leaving the conductive particle based material to dry or cure on the chosen substrate according to the desired design. In step **830**, one or more coupling points of a feed line may be affixed to the conductive particle based conformable antenna. Herein, step **830** may be omitted. In addition, additional steps may be included, such as applying at least one of an insulative coating, a surface preparation coating, a protective coating, and a concealment coating. Any or all of this fabrication technique may be automated, as will be described below.

While a conductive particle based conformable antenna is described herein, any disclosure related to a conductive particle based conformable antenna is equally applicable to a conductive particle based conformable antenna enhancer.

Fabrication Techniques for Conductive Particle Based Conformable Antenna

In one exemplary embodiment, techniques for constructing a conductive particle based conformable antenna are described. Herein, a computerized device is used to generate a template that is used to construct a conductive particle based conformable antenna.

The computerized device may be any of a desktop computer, a laptop computer, a netbook, a tablet computer, a Personal Data Assistant (PDA), a Smartphone, a portable media device, a specialized mobile device, etc. The computerized device may include one or more of a display, an input unit, a control unit, a printer, memory, a communications unit, and a projection unit.

The conductive particle based conformable antenna that is constructed using the template may be formed using the conductive particle based material that is sprayable, rollable or brushable. The conductive particle based material may be applied directly onto any substrate. The conductive particle based conformable antenna, once fabricated onto a surface, may be painted over with a paint in order to conceal the antenna, provide protection to the antenna, or provide the antenna with desired aesthetics.

According to an exemplary embodiment of the present invention, to create and install an antenna, the computerized device may be used to generate the template. The computerized device may include a graphical user interface that queries a user regarding certain characteristics/criteria or otherwise allows a user to enter certain characteristics/criteria. Based on the input characteristics/criteria, the computerized device generates the template. Herein, the user may input less than all of the characteristics/criteria. In this case, the characteristics/criteria not input by the user may be obtained via a formula, or a local or remote database. In addition, assumed values for the characteristics/criteria not input by the user may be used.

Examples of the characteristics/criteria include one or more of a substrate on which the antenna will be disposed, frequency of operation, aperture or antenna pattern, whether a space saving design is desired, velocity factor, resonant frequency, Q factor, impedance, gain, polarization, efficiency, bandwidth, heat characteristics, type of amplifier, environment, etc. Further, one or more of the characteristics/criteria may include a number of preset options for a given characteristic/criteria. For example, the options for the substrate on which the antenna will be disposed may include one or more of wood, metal, glass, plastic, etc. For another example, the options for the desired antenna pattern include one or more of an omni-directional antenna pattern, a directional antenna pattern, a circular antenna pattern, a phased array antenna pattern, etc.

The computerized device may guide a user in inputting at least one of the one or more the characteristics/criteria and may request additional information from the user.

Based on the input one or more characteristics/criteria, the computerized device determines an antenna pattern using a pattern determination algorithm. The antenna pattern may be a preset antenna pattern or an antenna pattern formed based on an algorithm and the input one or more characteristics/criteria. In addition, the computerized device may determine one or more of a scaling factor of the antenna pattern, dimensions of the antenna pattern or elements of the antenna pattern, grain direction, application notes, etc. Alternatively, or additionally, the characteristics/criteria may not be preset.

The computerized device may determine more than one antenna pattern and may allow a user to select a desired antenna pattern from among the determined more than one antenna pattern.

Once the antenna pattern is determined, as well as one or more of the scaling factor of the antenna pattern, dimensions of the antenna pattern or elements of the antenna pattern, grain direction, application notes, etc., a resulting template may be at least one of displayed on the display of the computerized device, projected onto a surface using the projection unit of the computerized device, and printed using one of an external and an integrated printed. When a projection unit is employed, the computerized device may further include a device that adjusts the scale of the projected template based on at least the distance between the projection unit and the surface on which the antenna is to be constructed. Further, when a projection unit is employed, the computerized device may further include a device that adjusts the location of the projected template so that the projected template remains on the same location of the surface regardless of the movement of the computerized device. The template may then be used to construct the antenna.

Also, the template may correspond to digital data that is stored in a storage device or communicated to another device that applies the antenna material based on the digital data.

In one exemplary embodiment, the computerized device communicates the input characteristics/criteria to a remote computerized device which determines one or more of the antenna pattern, the scaling factor of the antenna pattern, dimensions of the antenna pattern or elements of the antenna pattern, grain direction, application notes, etc., which is then communicated to the computerized device.

In one exemplary embodiment, the antenna patterns may be stored remotely from the computerized device and communicated to the computerized device before or after the antenna pattern is determined. The antenna patterns may be communicated to the computerized device in response to a request by the computerized device or another entity.

An exemplary method for fabricating a conductive particle based conformable antenna using a computerized device is described below with reference to FIG. **9**.

FIG. **9** illustrates a method for fabricating a conductive particle based conformable antenna using a computerized device according to an exemplary embodiment of the present invention.

Referring to FIG. **9**, in step **900**, the characteristics/criteria are obtained by the computerized device as described above. In step **910**, an antenna pattern is selected by the computerized device based on the obtained characteristics/criteria, as described above. In step **920**, a template is generated as described above.

An example of the computerized device described above is described below with reference to FIG. **10**.

FIG. **10** illustrates a structure of computerized device used for fabricating a conductive particle based conformable antenna according to an exemplary embodiment of the present invention.

Referring to FIG. **10**, the computerized device includes a controller **1010**, a display unit **1020**, a memory unit **1030**, an input unit **1040**, a communications unit **1050**, a template generator **1060**, and an antenna generator **1070**. One or more of the components of the computerized device shown in FIG. **10** may be omitted. Also, the functions of one or more of the components of the computerized device shown in FIG. **10** may be performed by a combined component. In addition, additional components may be included with the computerized device.

The controller **1010** controls the overall operations of the computerized device. More specifically, the controller **1010** controls and/or communicates with the display unit **1020**, the memory unit **1030**, the input unit **1040**, the communications unit **1050**, the template generator **1060**, and the antenna generator **1070**. The controller **1010** executes code to have performed or perform any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed by a computerized device. The term “code” may be used herein to represent one or more of executable instructions, operand data, configuration parameters, and other information stored in the memory unit **1030**.

The display unit **1020** is used to display information to a user. The display unit **1020** may be any type of display unit. The display unit **1020** may be integrated with or separate from the computerized device. The display unit **1020** may be integrated with the input unit **1040** to form a touch screen display. The display unit **1020** performs any of the functions/operations/roles explicitly or implicitly described herein as being performed by a display.

The memory unit **1030** may store code that is processed by the controller **1010** to execute any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed by a computerized device. In addition, one or more of other executable instructions, operand data, configuration parameters, and other information may be stored in the memory unit **1030**. Depending on the exact configuration of the computerized device, the memory unit **1030** may be volatile memory (such as Random Access Memory (RAM)), non-volatile memory (e.g., Read Only Memory (ROM), flash memory, etc.) or some combination thereof.

The input unit **1020** is used to enable a user to input information. The input unit **1020** may be any type or combination of input unit, such as a touch screen, keypad, mouse, voice recognition, etc.

The communications unit **1050** transmits and receives data between one or more entities. The communications unit **1050** may include any number of transceivers, receivers, and transmitters of any number of types, such as wired, wireless, etc.

The template generator **1060** may perform any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed when generating a template. For example, the template generator **1060** may be a printer, a cutter, a projector, a display, etc.

The antenna generator **1070** may perform any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed when generating an antenna. For example, the antenna generator **1070** may be a sprayer that sprays the conductive particle based material onto a substrate.

Herein, the functionality described above of the computerized device may result from an application installed on and being executed by the computerized device.

At this point it should be noted that the present exemplary embodiment as described above typically involve the processing of input data and the generation of output data to some extent. This input data processing and output data generation may be implemented in hardware, or software in combination with hardware. For example, specific electronic components may be employed in a mobile device or similar or related circuitry for implementing the functions associated with the exemplary embodiments of the present invention as described above. Alternatively, one or more processors operating in accordance with stored instructions (i.e., code) may implement the functions associated with the exemplary embodiments of the present invention as described above. If such is the case, it is within the scope of the present disclosure that such instructions may be stored on one or more non-transitory processor readable mediums. Examples of the non-transitory processor readable mediums include ROM, RAM, Compact Disc (CD)-ROMs, magnetic tapes, floppy disks, and optical data storage devices. The non-transitory processor readable mediums can also be distributed over network coupled computer systems so that the instructions are stored and executed in a distributed fashion. Also, functional computer programs, instructions, and instruction segments for accomplishing the present invention can be easily construed by programmers skilled in the art to which the present invention pertains.

While the invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. An antenna system comprising:

a substrate; and

a radiating antenna element formed of a conductive particle based material comprising conductive particles dispersed in a binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another,

wherein the substrate is disposed in a first layer and the radiating antenna element is disposed in a second layer that is substantially parallel to the first layer,

wherein the conductive particle based material is applied directly onto, and without encircling, the substrate, and

wherein a portion of the substrate onto which the conductive particle based material is applied directly is non-conductive, and another portion of the substrate onto which the conductive particle based material is applied directly is conductive.

2. The antenna system of claim **1**, wherein the conductive portion of the substrate at least one of electrically, capacitively, and inductively couples to the radiating antenna element, and electrically couples to a feed line.

3. The antenna system of claim **1**, wherein, when a Radio Frequency (RF) signal is input to the radiating antenna element, a reverse power is lower than the reverse power of an identically formed antenna element fabricated from copper.

4. The antenna system of claim **1**, wherein the conductive particles comprise at least one of conductive particles of different non-uniform shapes, conductive particles of various sizes, or conductive particles smaller than 30 micrometers.

5. The antenna system of claim **1**, wherein the conductive particle based material is applied to the substrate as at least one of a liquid, a paint, a gel, an ink and a paste that dries or cures.

6. The antenna system of claim **1**, wherein at least a portion of the non-conductive portion of the substrate is disposed between a conductive material and the radiating antenna element.

7. The antenna system of claim **1**, wherein the substrate comprises a ground plane for the radiating antenna element.

8. The antenna system of claim **1**, further comprising at least one of a protective and concealment coating applied to the radiating antenna element.

9. The antenna system of claim **1**, wherein the radiating antenna element is fed a Radio Frequency (RF) signal amplified by an amplifier that operates for less than an entire input cycle.

10. The antenna system of claim **9**, wherein the amplifier comprises a class C amplifier.

11. The antenna system of claim **1**, wherein the radiating antenna element is also a receiving antenna element.

12. An antenna enhancer comprising:

an antenna enhancer element formed of a conductive particle based material, the antenna enhancer element being disposed at an area of an inner side of a housing of a wireless device that is adjacent to at least one of an internal radiating or receiving antenna,

wherein the housing of a wireless device is formed of a conductive material,

wherein a non-conductive material is disposed between the antenna enhancer element and the at least one of the radiating or receiving antenna, and

wherein the conductive particle based material comprises conductive particles dispersed in a binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

13. The antenna enhancer of claim **12**, wherein the antenna enhancer element and the at least one of the radiating or receiving antenna element are at least one of inductively and capacitively coupled.

14. The antenna enhancer of claim **12**, wherein, when a Radio Frequency (RF) signal is input to the at least one of the radiating or receiving antenna, a reverse power is lower than the reverse power of the at least one of the radiating or receiving antenna element without the antenna enhancer element.

15. The antenna enhancer of claim **12**, wherein the conductive particles comprise at least one of conductive particles of different non-uniform shapes, conductive particles of various sizes, or conductive particles smaller than 30 micrometers.

* * * * *

Exhibit B

US009954276B2

(12) **United States Patent**
Spencer et al.

(10) **Patent No.:** **US 9,954,276 B2**
(45) **Date of Patent:** ***Apr. 24, 2018**

(54) **TECHNIQUES FOR CONDUCTIVE PARTICLE BASED MATERIAL USED FOR AT LEAST ONE OF PROPAGATION, EMISSION AND ABSORPTION OF ELECTROMAGNETIC RADIATION**

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(73) Assignee: **nCap Licensing, LLC**, Heber City, UT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **14/804,018**

(22) Filed: **Jul. 20, 2015**

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Related U.S. Application Data

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(51) **Int. Cl.**
H01Q 1/38 (2006.01)
H01Q 1/52 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01Q 1/526*** (2013.01); ***H01Q 1/24*** (2013.01); ***H01Q 1/364*** (2013.01); ***H01Q 1/38*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC H01Q 1/38; H01Q 1/364; H01Q 1/24; H01Q 17/004
(Continued)

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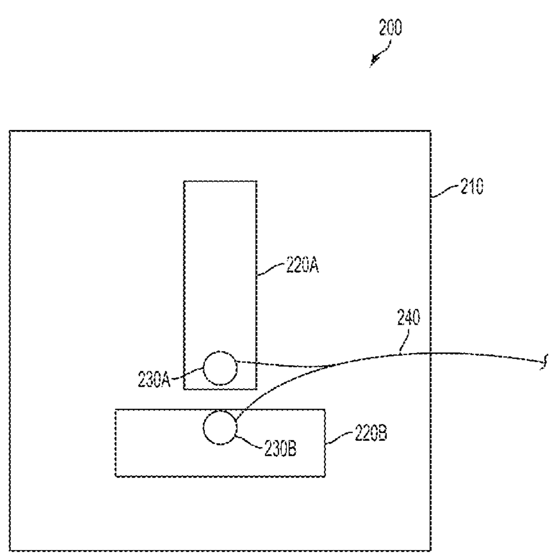
Primary Examiner — Dieu H Duong
(74) *Attorney, Agent, or Firm* — Jefferson IP Law, LLP; Raymond B. Persino

(57) **ABSTRACT**

An antenna system and method for fabricating an antenna are provided. The antenna system includes a substrate and an antenna. The antenna includes a conductive particle based material applied onto the substrate. The conductive particle based material includes conductive particles and a binder. When the conductive particle based material is applied to the substrate, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

11 Claims, 10 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 61/416,093, filed on Nov. 22, 2010, provisional application No. 61/473,726, filed on Apr. 8, 2011, provisional application No. 61/477,587, filed on Apr. 20, 2011, provisional application No. 61/514,435, filed on Aug. 2, 2011.

(51) **Int. Cl.**
H01Q 1/24 (2006.01)
H01Q 1/36 (2006.01)
H01Q 17/00 (2006.01)

(52) **U.S. Cl.**
CPC ***H01Q 17/004*** (2013.01); *Y10T 29/49016* (2015.01)

(58) **Field of Classification Search**
USPC .... 343/700 MS, 702
See application file for complete search history.

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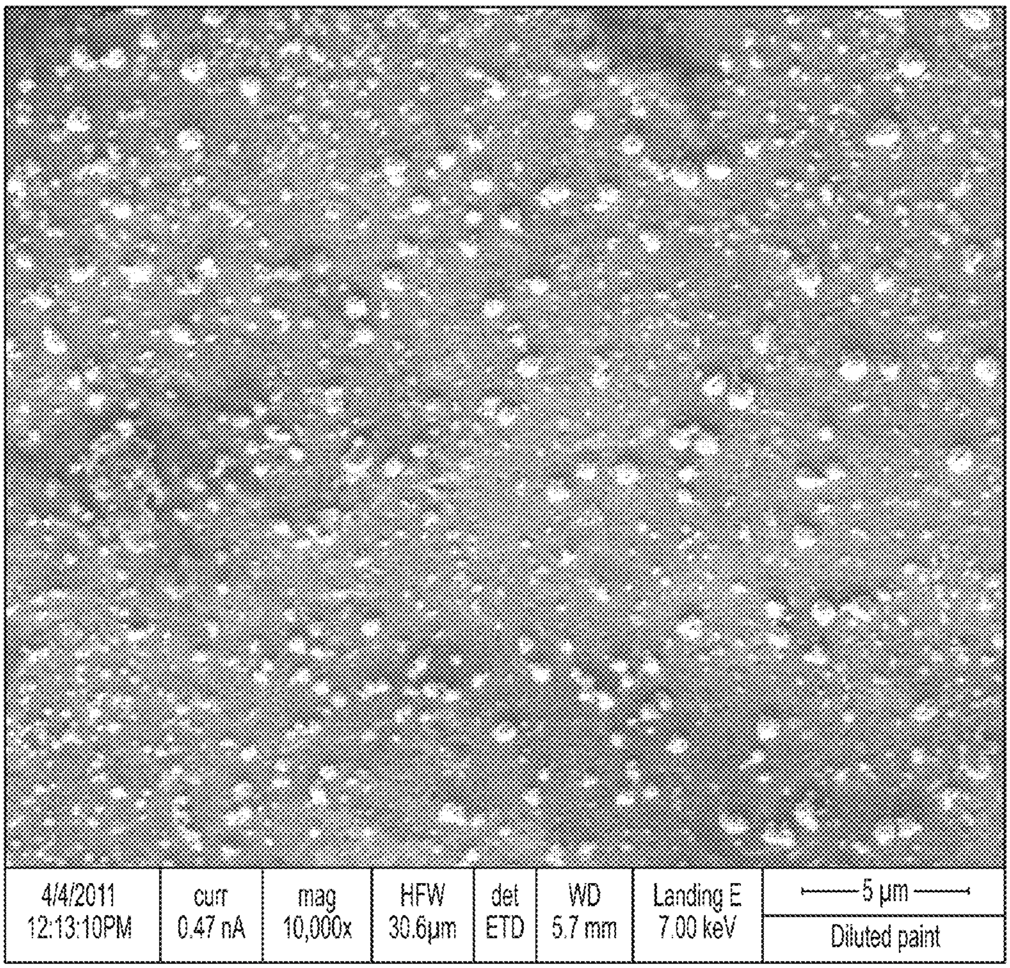
4/4/2011
12:13:10PM
curr
0.47 nA
mag
10,000x
HFW
30.6μm
det
ETD
WD
5.7 mm
Landing E
7.00 keV
5 μm
Diluted paint

FIG. 1

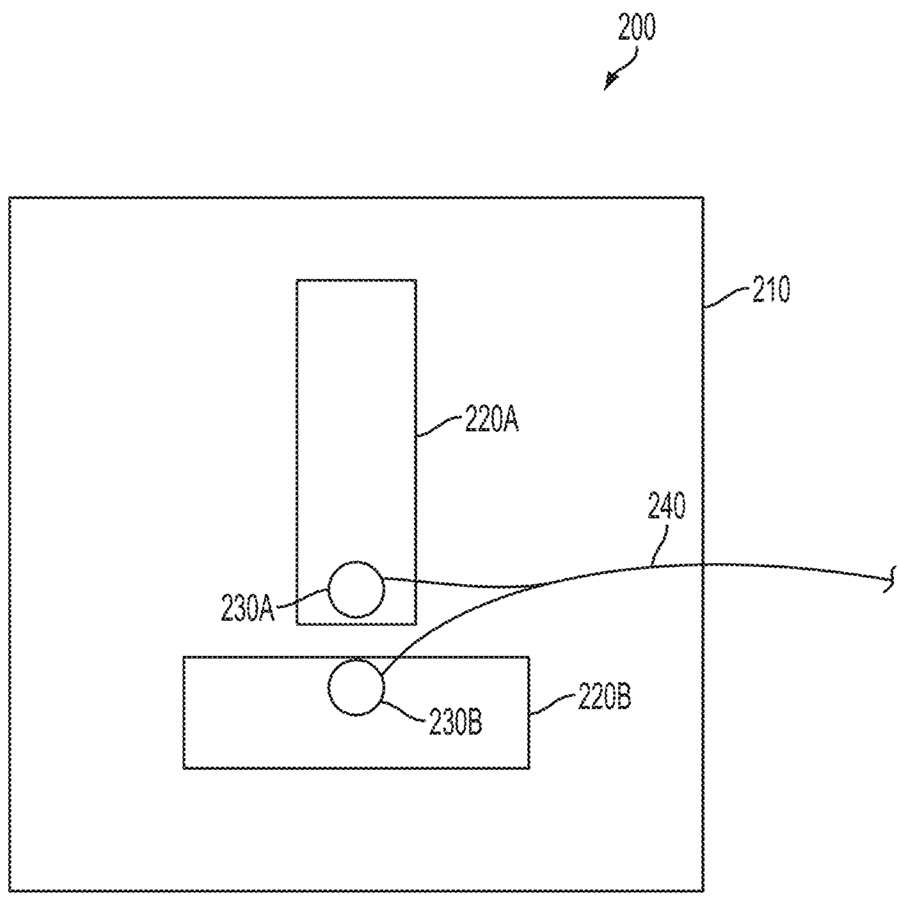

FIG. 2

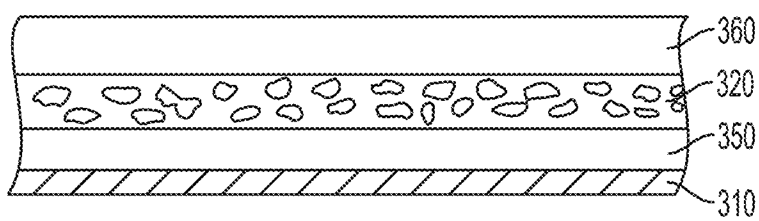

FIG. 3

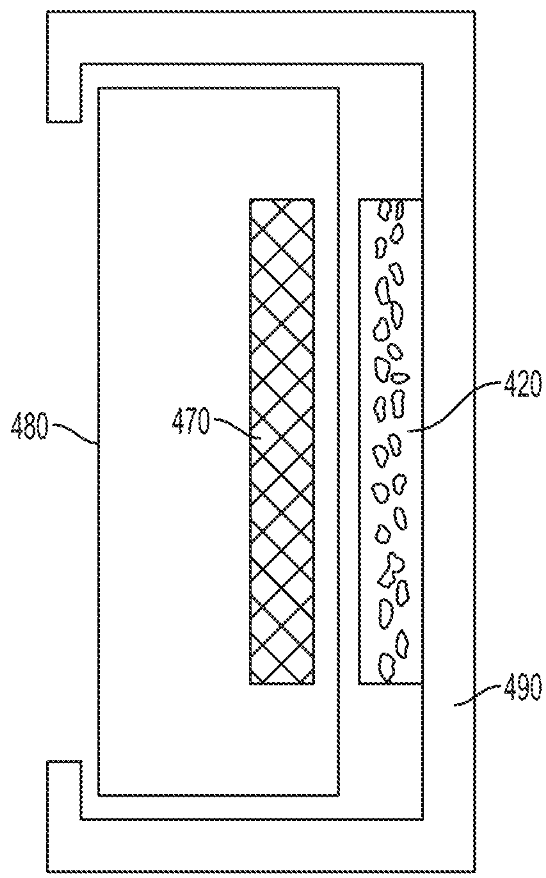

FIG. 4

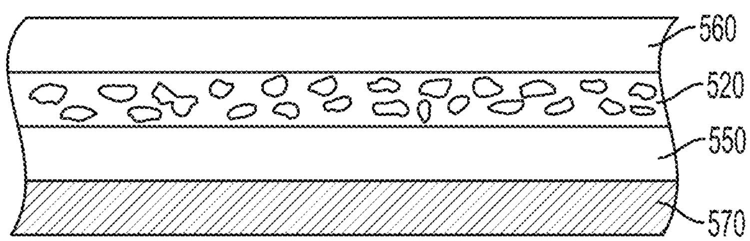

FIG. 5

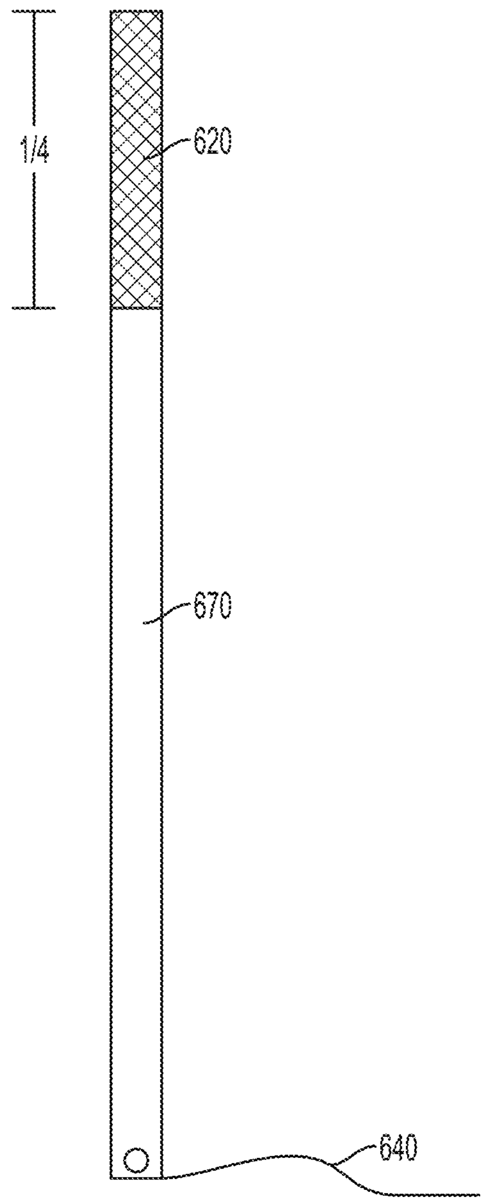

FIG. 6

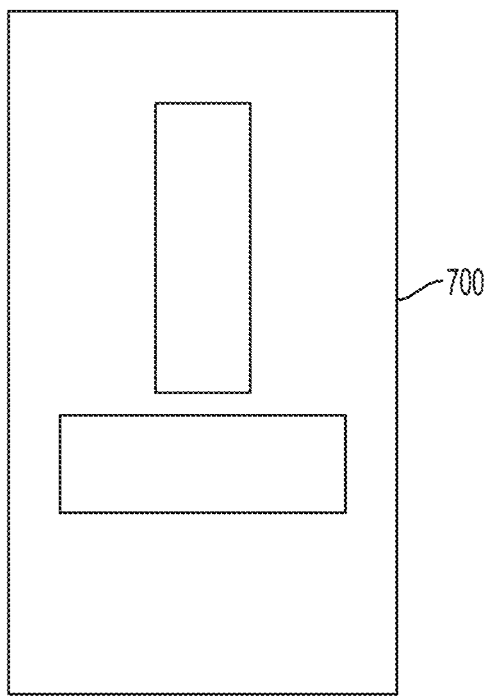

FIG. 7

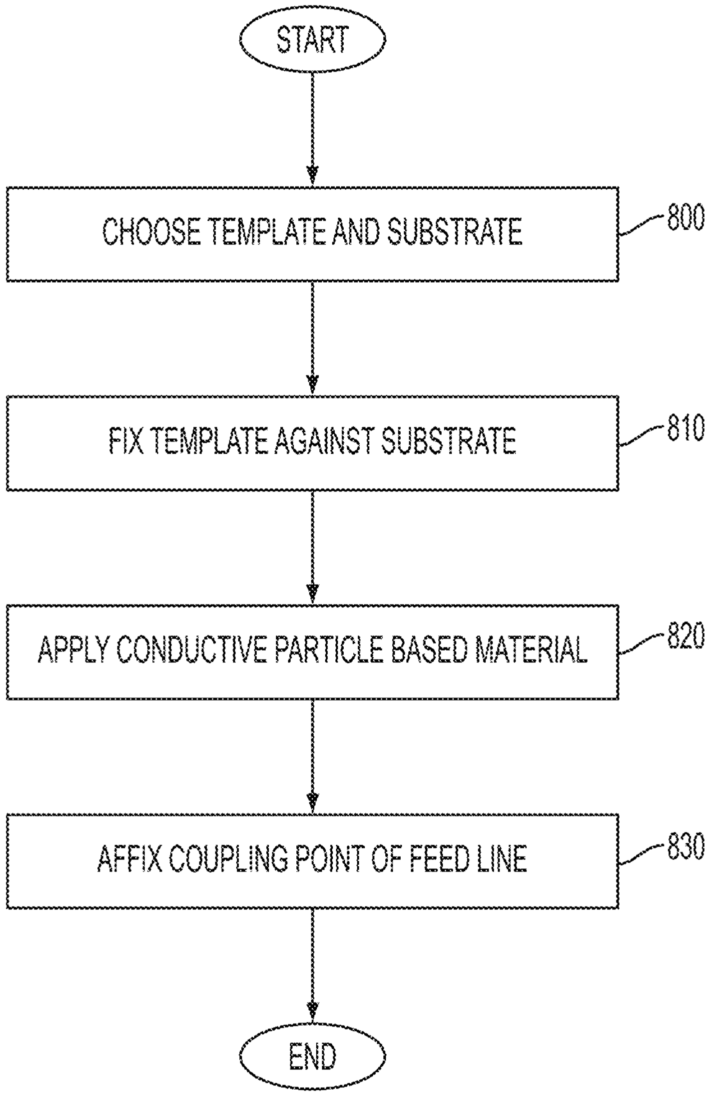
START
CHOOSE TEMPLATE AND SUBSTRATE
800
FIX TEMPLATE AGAINST SUBSTRATE
810
APPLY CONDUCTIVE PARTICLE BASED MATERIAL
820
AFFIX COUPLING POINT OF FEED LINE
830
END

FIG. 8

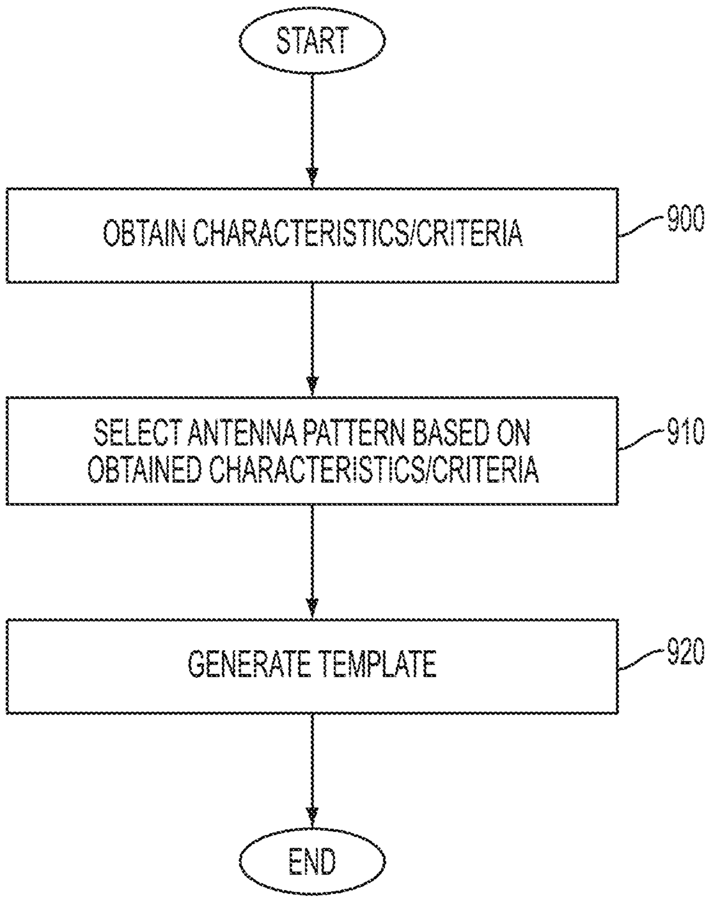
START
OBTAIN CHARACTERISTICS/CRITERIA
900
SELECT ANTENNA PATTERN BASED ON OBTAINED CHARACTERISTICS/CRITERIA
910
GENERATE TEMPLATE
920
END

FIG. 9

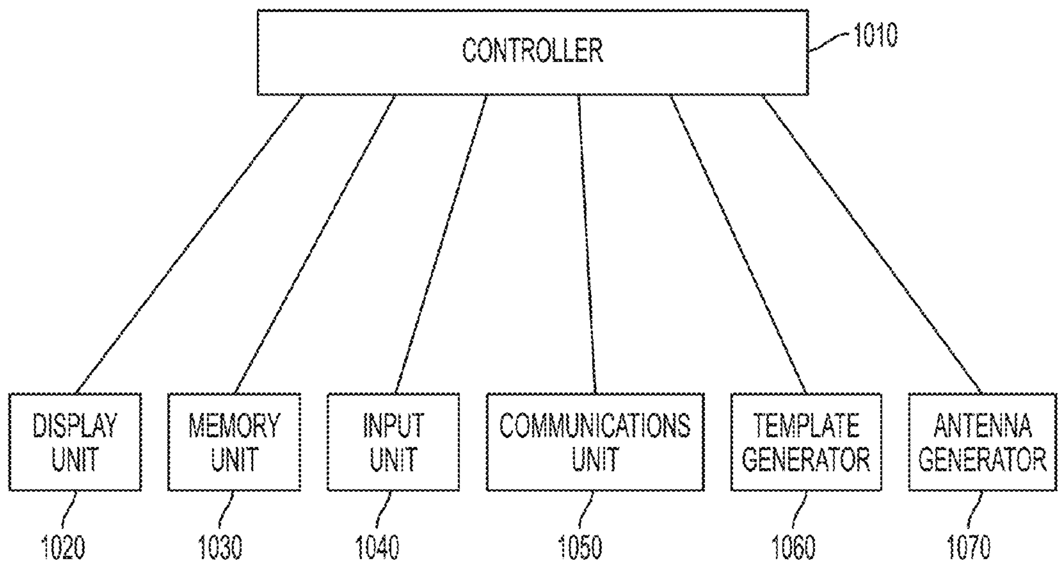
CONTROLLER
1010
DISPLAY UNIT
MEMORY UNIT
INPUT UNIT
COMMUNICATIONS UNIT
TEMPLATE GENERATOR
ANTENNA GENERATOR
1020
1030
1040
1050
1060
1070

FIG. 10

TECHNIQUES FOR CONDUCTIVE PARTICLE BASED MATERIAL USED FOR AT LEAST ONE OF PROPAGATION, EMISSION AND ABSORPTION OF ELECTROMAGNETIC RADIATION

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of a prior application Ser. No. 13/303,135, filed on Nov. 22, 2011, which issued as U.S. Pat. No. 9,088,071 on Jul. 21, 2015, and which claimed the benefit under 35 U.S.C. § 119(e) of a U.S. provisional patent application filed on Nov. 22, 2010 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/416,093, a U.S. provisional patent application filed on Apr. 8, 2011 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/473,726, a U.S. provisional patent application filed on Apr. 20, 2011 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/477,587, and a U.S. provisional patent application filed on Aug. 2, 2011 in the U.S. Patent and Trademark Office and assigned Ser. No. 61/514,435, the entire disclosure of each of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to techniques for a material used for at least one of propagation, emission and absorption of electromagnetic radiation. More particularly, the present invention relates to techniques for a conductive particle based material used for at least one of propagation, emission and absorption of electromagnetic radiation.

2. Description of the Related Art

A conventional antenna is a device with an arrangement of one or more conductive elements that are used to generate a radiating electromagnetic field in response to an applied alternating voltage and the associated alternating electric current, or can be placed in an electromagnetic field so that the field will induce an alternating current in the antenna and a voltage between its terminals. The conductive elements employed in the conventional antenna are typically fabricated from solid metallic conductors. However, the use of solid metallic conductors is limiting.

Therefore, a need exists for an improved material used for at least one of propagation, emission and absorption of electromagnetic radiation, and implementations of the improved material.

SUMMARY OF THE INVENTION

An aspect of the present invention is to address at least the above-mentioned problems and/or disadvantages and to provide at least the advantages described below. Accordingly, an aspect of the present invention is to provide techniques for a conductive particle based material used for at least one of propagation, emission and absorption of electromagnetic radiation.

In accordance with an aspect of the present invention, an antenna system is provided. The antenna system includes a substrate and an antenna. The antenna includes a conductive particle based material applied onto the substrate. The conductive particle based material includes conductive particles and a binder. When the conductive particle based material is applied to the substrate, the conductive particles

are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

In accordance with another aspect of the present invention, an antenna enhancer system is provided. The antenna enhancer system includes an antenna and an antenna enhancer. The antenna enhancer includes a conductive particle based material. The antenna enhancer is disposed adjacent to and offset from the antenna. The conductive particle based material comprises conductive particles and a binder. When the conductive particle based material is disposed adjacent to and offset from the antenna, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

In accordance with yet another aspect of the present invention, a method for fabricating a conformable antenna is provided. The method includes selecting a substrate on which to fabricate an antenna, selecting a template corresponding to an antenna design, the template comprising one or more cut out portions, applying a conductive particle based material, through the one or more cutout portions of the template, and onto the substrate to form the antenna, and fixing a coupler of a feed line to the antenna. The conductive particle based material comprises conductive particles and a binder. When the conductive particle based material is applied to the substrate, the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

In accordance with still another aspect of the present invention, an antenna enhancer is proved. The antenna enhancer includes an antenna enhancer element formed of a conductive particle based material, the antenna enhancer element being disposed adjacent to, offset from, and without encircling, at least one of a radiating or receiving antenna element, wherein the antenna enhancer element is electrically isolated, and wherein the conductive particle based material comprises conductive particles dispersed in a binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another.

In accordance with yet another aspect of the present invention, an antenna enhancer is proved. The antenna system includes a conductive substrate, and a radiating antenna element formed of a conductive particle based material comprising conductive particles dispersed in a binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another, wherein the conductive substrate is disposed in a first layer and the radiating antenna element is disposed in a second layer that is substantially parallel to the first layer, and wherein the conductive particle based material is applied directly onto, and without encircling, the conductive substrate.

Other aspects, advantages, and salient features of the invention will become apparent to those skilled in the art from the following detailed description, which, taken in conjunction with the annexed drawings, discloses exemplary embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects, features, and advantages of certain exemplary embodiments of the present invention will be more apparent from the following description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a captured image of a conductive particle based material according to an exemplary embodiment of the present invention;

FIG. **2** illustrates a conductive particle based antenna according to an exemplary embodiment of the present invention;

FIG. **3** illustrates a structure of a conductive particle based antenna according to an exemplary embodiment of the present invention;

FIG. **4** illustrates an implementation of a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention;

FIG. **5** illustrates a structure of a coated conductive particle based antenna enhancer according to an exemplary embodiment of the present invention;

FIG. **6** illustrates an antenna partially coated with a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention;

FIG. **7** illustrates a template used to fabricate a conductive particle based conformable antenna according to an exemplary embodiment of the present invention;

FIG. **8** illustrates a method for fabricating a conductive particle based conformable antenna using a template according to an exemplary embodiment of the present invention;

FIG. **9** illustrates a method for fabricating a conductive particle based conformable antenna using a computerized device according to an exemplary embodiment of the present invention; and

FIG. **10** illustrates a structure of computerized device used for fabricating a conductive particle based conformable antenna according to an exemplary embodiment of the present invention.

Throughout the drawings, like reference numerals will be understood to refer to like parts, components, and structures.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

The following description with reference to the accompanying drawings is provided to assist in a comprehensive understanding of exemplary embodiments of the invention as defined by the claims and their equivalents. It includes various specific details to assist in that understanding but these are to be regarded as merely exemplary. Accordingly, those of ordinary skill in the art will recognize that various changes and modifications of the embodiments described herein can be made without departing from the scope and spirit of the invention. In addition, descriptions of well-known functions and constructions are omitted for clarity and conciseness.

The terms and words used in the following description and claims are not limited to the bibliographical meanings, but, are merely used by the inventor to enable a clear and consistent understanding of the invention. Accordingly, it should be apparent to those skilled in the art that the following description of exemplary embodiments of the present invention are provided for illustration purpose only and not for the purpose of limiting the invention as defined by the appended claims and their equivalents.

It is to be understood that the singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a component surface" includes reference to one or more of such surfaces.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result.

As used herein, the term "about" is used to provide flexibility to a numerical range endpoint by providing that a given value may be "a little above" or "a little below" the endpoint.

As used herein, the term "antenna" refers to a transducer used to transmit or receive electromagnetic radiation. That is, an antenna converts electromagnetic radiation into electrical signals and vice versa. Electromagnetic radiation is a form of energy that exhibits wave-like behavior as it travels through space. In free space, electromagnetic radiation travels close to the speed of light with very low transmission loss. Electromagnetic radiation is absorbed when propagating through a conducting material. However, when encountering an interface of such a material, the electromagnetic radiation is partially reflected and partially transmitted therethough. Herein, exemplary embodiments of the present invention described below are directed toward techniques that allow for a more efficient interface by reducing the reflections at the interface.

In addition, exemplary embodiments of the present invention described below relate to techniques for a conductive particle based material used for at least one of propagation, emission and absorption of electromagnetic radiation. While the techniques for the conductive particle based material may be described below in various specific implementations, the present invention is not limited to those specific implementations and is similarly applicable to other implementations.

An initial overview of the conductive particle based material is provided below and then specific implementations in which the conductive particle based material is employed are described in detail further below. This initial overview of the conductive particle based material is intended to aid readers in understanding the conductive particle based material that is the basis of various exemplary implementations, but is not intended to identify key features or essential features of those various exemplary implementations, nor is it intended to limit the scope of the claimed subject matter.

Conductive Particle Based Material

In one exemplary embodiment, a conductive particle based material is employed. The conductive particle based material includes at least two constituent components, namely conductive particles and a binder. However, the conductive particle based material may include additional components, such as at least one of graphite, carbon (e.g., carbon black), titanium dioxide, etc.

The conductive particles may be any conductive material, such as silver, copper, nickel, aluminum, steel, metal alloys, carbon nanotubes, any other conductive material, and any combination thereof. For example, in one exemplary embodiment, the conductive particles are silver coated copper. Alternatively, the conductive particles may be a combination of a conductive material and a non-conductive material. For example, the conductive particles may be ceramic magnetic microspheres coated with a conductive material such as any of the conductive materials described above. Furthermore, the composition of each of the conductive particles may vary from one another.

The conductive particles may be any shape from a random non-uniform shape to a geometric structure. The conductive particles may all have the same shape or the conductive particles may vary in shape from one another. For example, in one exemplary embodiment, each of the conductive particles may have a random non-uniform shape that varies from conductive particle to conductive particle.

The conductive particles may range in size from a few nanometers up to a few thousand nanometers. Alternatively, the conductive particles may range in size from about 400 nanometers to 30 micrometers. The conductive particles may be substantially similar in size or may be of various sizes included in the above identified ranges. For example, in one exemplary embodiment, the conductive particles are of various sizes in the range of about 400 nanometers to 30 micrometers. Herein, when a range of sizes of the conductive particles are employed, the distribution of the sizes may be uniform or non-uniform across the range. For example, 75% of the conductive particles may be a larger size within a given range while 25% of the conductive particles are a smaller size.

An effective amount of conductive particles are included relative to the binder so that the conductive particles are dispersed in the binder. The conductive particles may be randomly or orderly dispersed in the binder. The conductive particles may be dispersed at uniform or non-uniform densities. The conductive particles may be dispersed so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another.

The binder is used to substantially fix the conductive particles relative to each other and should be a non-conductive or semi-conductive substance. Any type of conventional or novel binder that meets these criteria may be used. The non-conductive or semi-conductive material of the binder may be chosen to function as a dielectric with a given permittivity.

The conductive particle based material may be formed as a rigid or semi-rigid structure. For example, the conductive particle based material may be a plastic sheet having the conductive particles dispersed therein. The conductive particle based material may be clear or opaque, and may include any shade of color.

In addition, the conductive particle based material may be a liquid, paint, gel, ink or paste that dries or cures. Here, the binder may include distillates, hardening agents, or solvents such as a Volatile Organic Compound (VOC). In this case, the conductive particle based material may be applied to a substrate. Also, when the conductive particle based material is a liquid, paint, gel, ink or paste that dries or cures, the binder may adhere to the substrate. The conductive particle based material may be spayed on, brushed on, rolled on, ink-jet printed, silk screened, etc. onto the substrate. The use of the conductive particle based material that is a liquid, paint, gel, ink or paste that dries or cures is advantageous in that the conductive particle based material may be thinly applied to a substrate and conform to the surface of the substrate. This allows the conductive particle based material to occupy very little space and, in effect, blend into the substrate.

The substrate may be the surface of at least one of a conductive, a non-conductive, or a semi-conductive substance. The substrate may be rigid, semi-flexible or flexible. The substrate may be flat, irregularly shaped or geometrically shaped. The substrate may be paper, cloth, plastic, polycarbonate, acrylic, nylon, polyester, rubber, metal such as aluminum, steel and metal alloys, glass, composite materials, fiber reinforced plastics such as fiberglass, polyethylene, polypropylene, textiles, wood, etc.

The substrate may have a coating applied thereto. The coating may be a conductive, non-conductive or semi-conductive substance. The coating may be a paint, gel, ink, paste, tape, etc. The coating may be chosen to function as a dielectric with a given permittivity.

At least one of a protective and concealing (or decorative) coating may be applied over the conductive particle based material once it has been applied to a substrate.

An example of the conductive particle based material is described below with reference to FIG. **1**.

FIG. **1** is a captured image of a conductive particle based material according to an exemplary embodiment of the present invention.

Referring to FIG. **1**, the conductive particle based material includes conductive particles and a binder. The conductive particles are randomly shaped, sized and located. However, conductive particles are dispersed so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another.

Herein, without intending to be limiting, for a conductive particle based material of a given density of conductive particles, the conductive particle based material may be applied at a thickness such that the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another. Herein, without intending to be limiting, it has been observed that a conductive particle based material has a resistance of about 3-17 ohms across any given two points on the surface.

Herein, without intending to be limiting, it has been observed that when the conductive particle based material is formulated such that the conductive particles are dispersed in the binder so that at least a majority of the conductive particles are closely adjacent to, but do not touch, one another, the conductive particle based material exhibits properties that enable it to at least one of efficiently propagate electromagnetic radiation, efficiently absorb electromagnetic radiation from space, and efficiently emit electromagnetic radiation into space. Moreover, it has been observed that those properties may be either supplemented or enhanced by including an effective amount of carbon, such as carbon black, in the conductive particle based material. For example, an effective amount of carbon black may be an amount that corresponds to about 1-7% of the conductive particles included in the conductive particle based material.

Without intending to be limiting, it is believed that when electromagnetic radiation is introduced into the conductive particle based material, electromagnetic radiation may pass from conductive particle to conductive particle via at least one of capacitive and inductive coupling. Here, the binder may function as a dielectric. Thus, it is believed that the conductive particle based material may act as an array of capacitors, which may be at least part of the reason why the conductive particle based material at least one of efficiently propagates electromagnetic radiation, efficiently absorbs electromagnetic radiation from space, and efficiently emits electromagnetic radiation into space.

Alternatively or additionally, and without intending to be limiting, it is believed that the properties that enable the conductive particle based material to at least one of efficiently propagate electromagnetic radiation, efficiently absorb electromagnetic radiation from space, and efficiently emit electromagnetic radiation into space, may be explained by quantum theory at the atomic level.

Herein, without intending to be limiting, it has been observed that the conductive particle based material generates electrical energy when exposed to sunlight.

Herein, without intending to be limiting, it has been observed that the resistance of the conductive particle based material continuously changes over time. Herein, without intending to be limiting, it has been observed that, when energized with a radio signal, the conductive particle based material has infinitely low resistance to that signal.

Herein, while the present disclosure is described in the context of electromagnetic radiation, without intending to be limiting, it is believed that the present invention is equally applicable to bioelectromagnetic energy. Thus, any disclosure herein that refers to electromagnetic radiation equally applies to bioelectromagnetic energy.

Conductive Particle Based Antenna

In one exemplary embodiment, the conductive particle based material is employed to implement a conductive particle based antenna. When used as a conductive particle based antenna, the conductive particle based antenna is fabricated using the conductive particle based material. Here, the conductive particle based material may be formed into a shape that conforms to the desired characteristics of the antenna. For example, the shape and size of the antenna may vary depending on the frequency and/or polarization of the electromagnetic radiation to be communicated. The conductive particle based antenna is at least one of electrically, capacitively, and inductively coupled to at least one of a receiver, a transmitter, and a transceiver at a coupling point of the conductive particle based antenna. The coupling point of the conductive particle based antenna may substantially be an end point of the conductive particle based antenna. The coupling point of the conductive particle based antenna may be coupled to a coupling point of a feed line electrically connected to the receiver, transmitter, or transceiver. When capacitively or inductively coupled, the coupling may occur through a distance that includes an air gap or that has a substance, such as glass, disposed therein.

When a conductive particle based antenna is fabricated using the conductive particle based material, the conductive particle based antenna may exhibit a broad bandwidth self-tuning characteristic by using only a small section of the conductive particle based antenna to emit the electromagnetic radiation into space.

In addition, when the conductive particle based antenna is fabricated using the conductive particle based material, there may be no or little I^2R losses due the small practical size and the majority of the particles not contacting each other. In addition, there may be no or little Radio Frequency (RF) skin effect losses due to the small practical size. Once the signal is coupled to the conductive particle based antenna, the conductive particle based antenna provides little to no resistance to the transmission signal and it is emitted without significant loss into space. The same may happen in reverse for receiving. That is, the received signal may be absorbed and delivered with little to no loss to the coupling device and is then propagated down a feed line to a receiver.

An example of the conductive particle based antenna is described below with reference to FIG. **2**.

FIG. **2** illustrates a conductive particle based antenna according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna **200** shown in FIG. **2** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the

conductive particle based antenna **200** of FIG. **2** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **2**, the conductive particle based antenna **200** includes a substrate **210**, a first antenna segment **220**A, a second antenna segment **220**B, a first coupler **230**A, a second coupler **230**B, and a feed line **240**.

The substrate **210** is a rigid flat sheet of a non-conductive material, such as plexiglass. However, any other surface may be chosen as substrate **210**. For example, the surface of a vehicle, the wall of a building, the casing of a wireless device, glass, a tree, cloth, a rock, a plastic sheet, etc., may be chosen as the substrate. When a conductive material is chosen as the substrate **210**, an insulative coating of a non-conductive or semi-conductive material may be applied to the area of the substrate **210** where the conductive particle based antenna **200** is to be applied. Examples of the insulative coating of the non-conductive or semi-conductive material include plastic tape, paper tape, paint, etc. Also, when the substrate **210** is a conductive material, the substrate may be utilized as a ground plane. In addition, a surface preparation coating may be applied to the substrate **210** that allows for better adhesion of the conductive particle based material to the substrate **210**. The insulative coating may serve the same function as the surface preparation coating. Also, the surface preparation coating may be applied beneath or on top of the insulative coating. Furthermore, the surface preparation coating may be used when the insulative coating in not applied.

The first antenna segment **220**A and the second antenna segment **220**B are applied to the substrate **210** according to a desired design. Here, the first antenna segment **220**A is functioning as an active antenna element and the second antenna segment **220**B is functioning as a ground plane. When the substrate **210** is functioning as a ground plane or an earth ground is employed, the second antenna segment **220**B may be omitted. Here, the first antenna segment **220**A and the second antenna segment **220**B are formed using a conductive particle based material formulated as a liquid, paint, gel, ink, or paste that dries or cures. The non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The first coupler **230**A and the second coupler **230**B at least one of electrically, capacitively, and inductively couple to the first antenna segment **220**A and the second antenna segment **220**B, respectively. In addition, the first coupler **230**A and the second coupler **230**B adhere to, or are otherwise in a fixed relationship with, the first antenna segment **220**A and the second antenna segment **220**B. The first coupler **230**A and the second coupler **230**B are electrically connected to respective potions of the feed line **240**.

The feed line **240** is electrically connected to first coupler **230**A and the second coupler **230**B. Also, the feed line **240** is electrically connected to at least one of a receiver, a transmitter, and a transceiver.

An example of a structure of a conductive particle based antenna is described below with reference to FIG. **3**.

FIG. **3** illustrates a structure of a conductive particle based antenna according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna shown in FIG. **3** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna of FIG. **3** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **3**, the conductive particle based antenna includes a substrate **310**, first coating **350**, conductive particle based material coating **320**, and a second coating **360**. One or more of the substrate **310**, the first coating **350**, and the second coating **360** may be omitted. In addition, one or more additional coatings may be utilized.

The substrate **310** may be any surface of any object, regardless of what material(s) the object is constructed of. For example, the surface of a vehicle, the wall of a building, the casing of a wireless device, glass, a tree, cloth, a rock, a plastic sheet, etc., may be chosen as the substrate. When the substrate **310** is a conductive material, the substrate **310** may function as a ground plane.

The first coating **350** is applied on top of the substrate **310**. The first coating **350** may be at least one of an insulative coating and a surface preparation coating. As an insulative coating, the first coating **350** may be a non-conductive or semi-conductive material. Examples of the insulative coating of the non-conductive or semi-conductive material include plastic tape, paper tape, paint, etc. As a surface preparation coating, the first coating **350** may be any material that allows for better adhesion of the conductive particle based material coating **320** to the substrate **310**. The same coating may serve as both the insulative coating and a surface preparation coating. Alternatively, separate insulative and a surface preparation coatings may be utilized either together or individually. The first coating **350** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the first coating **350** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The first coating **350** may be omitted.

The conductive particle based material coating **320** is applied on top of the first coating **350**, if present. Otherwise, the conductive particle based material coating **320** is applied on top of the substrate **310**. Alternatively, the conductive particle based material coating **320** may be an independent structure. The conductive particle based material coating may be formulated using any formulation of the conductive particle based material described herein. For example, the conductive particle based material coating **320** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The second coating **360**, if utilized, is applied on top of the conductive particle based material coating **320**. The second coating **360** may serve to protect and/or conceal the conductive particle based material coating **320**. The second coating **360** may be any material or structure that protects and/or conceals the conductive particle based material coating **320**. The same coating may serve as both the protective coating and the concealment coating. Alternatively, separate protective and concealment coatings may be utilized either together or individually. In one exemplary embodiment, the second coating **360** is formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the second coating **360** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The second coating **360** may be omitted.

Tests were conducted to compare the conductive particle based antenna to a conventional antenna. The conductive particle based antenna was formed using the conductive particle based material whereas the conventional copper antenna was formed using solid copper strips. Both the conductive particle based antenna and the conventional copper antenna were fabricated with the same shape (i.e., the shape shown in FIG. **2**) of the same size so that the effect of the particular structure, if any, is equal to both antennas. A

non-conductive plexiglass substrate was used to fix both antennas. The same transmit power and frequency were used for the test. The frequency selected was in the range of about 460 MHz. Testing equipment included a Yeasu FT 7900 Dual band FM transceiver, a Telewave Model 44 Wattmeter, and a FieldFox Model N9912A Portable Network Analyzer operated in SA mode used with a Yeasu Model Rubber Duck Antenna that was located 160 feet from the test antennas. The test data for the conventional copper antenna and the conductive particle based antenna are provided below in Table 1.

TABLE 1

	Conventional Copper Antenna	Conductive Particle Based Antenna
Forward Power	22 watts	41 watts
Reverse Power	12 watts	1 watt
Relative Signal Strength	−35 decibels	−26 decibels

As can be seen in Table 1, the conductive particle based antenna exhibits a significantly higher forward power (i.e., 41 watts) than the forward power of the conventional copper antenna (i.e., 22 watts). This can be explained by the conductive particle based antenna exhibiting a significantly lower reverse power (i.e., 1 watt) than the reverse power of the conventional copper antenna (i.e., 12 watts). Accordingly, the resulting relative signal strength of the conductive particle based antenna is higher (−26 decibels) than the resulting relative signal strength of the conventional copper antenna (−35 decibels).

As can be gleaned from the test, for a given antenna structure, the conductive particle based antenna is more efficient at emitting electromagnetic radiation into space than the conventional copper antenna. Therefore, the conductive particle based antenna has a higher effective gain than the conventional copper antenna. Also, since there is less reverse power, less of the electromagnetic radiation input to the conductive particle based antenna may be converted into heat. Thus, the antenna may operate at a lower temperature for a given input power and therefore may have a higher power rating.

The added gain by using the conductive particle based antenna is well suited to any application in which higher gain and/or lower transmit power for a given antenna structure is desired.

It has been observed that the transmission performance of the conductive particle based antenna varies depending on the type of amplifier used to drive the antenna. For example, the transmitter used in the Yeasu FT 7900 Dual band FM transceiver in the above test is a class C amplifier. When a linear class A amplifier is employed, the transmission performance of the conductive particle based antenna is reduced and approaches that of the conventional copper antenna. Thus, the performance of the conductive particle based antenna is greater when used with an amplifier that operates for less than the entire input cycle, such as the class C amplifier. While a class C amplifier is referred to herein for convenience in explanation, the use of any amplifier that operates for less than the entire input cycle is equally applicable.

Herein, power constrained devices typically employ a class C amplifier in order to take advantage of their efficiency so as to conserve power. Similarly, the use of the conductive particle based antenna in power constrained devices that employ a class C amplifier takes advantage of the efficiency of the conductive particle based antenna so as to further conserve power. The power conservation gained by the power constrained devices by using the conductive particle based antenna may allow for longer operational times and/or smaller power source (e.g., batteries) (and thereby smaller devices and/or a lower cost).

Conductive Particle Based Antenna Enhancer

In one exemplary embodiment, the conductive particle based material is employed to implement a conductive particle based antenna enhancer. When used as a conductive particle based antenna enhancer, the conductive particle based antenna enhancer is fabricated using the conductive particle based material. Here, the conductive particle based antenna enhancer is disposed in an adjacent offset relationship to a conventional antenna with a non-conductive or semi-conductive material disposed there between. Alternatively or additionally, an air gap between the conventional antenna and the conductive particle based antenna enhancer may be employed. Here, the conventional antenna is electrically coupled to at least one of a receiver, a transmitter, and a transceiver.

In this configuration, the conductive particle based antenna enhancer is at least one of capacitively and inductively coupled to the conventional antenna. Herein, the electromagnetic radiation that is capacitively and inductively coupled from the conventional antenna to the conductive particle based antenna enhancer is efficiently radiated into space by the conductive particle based antenna enhancer.

The conductive particle based antenna enhancer may be fabricated and positioned so as to be adjacent and offset from the conventional antenna. For example, the conductive particle based antenna enhancer may be added or built into a structure that places it in an adjacent and offset relationship to the conventional antenna.

For example, the structure may create an air gap between the conventional antenna and a surface onto which the conductive particle based material is applied. The structure may be constructed of a nonconductive material. Alternatively, the structure may be constructed of a conductive material and at least partially coated with a nonconductive material. If the structure is constructed of a conductive material, the conductive particle based material may be applied on top of the nonconductive material coating the structure. Herein, the conductive particle based material may be applied to a side of the structure closest to the conventional antenna or a side of the structure furthest from the conventional antenna. The conductive particle based material may be coated with a layer of the nonconductive material or another material. Examples of the structure include a housing of a device (e.g., a housing of a wireless device), an enclosure placed over the existing antenna, and a case placed over a housing of a device (e.g., a protective cover for a wireless device). The conductive particle based material is at least one of capacitively and inductively coupled to the conventional antenna and thereby increases the performance of the conventional antenna. Here, the thickness the nonconductive material and/or air gap directly affects the performance gain of the conductive particle based antenna enhancer and if the nonconductive thickness and/or air gap is too large, performance may decrease. The thickness of the air gap and/or nonconductive material is very small in relationship to the wavelength of the frequency the conventional antenna is designed for. In a specific example of the exemplary implementation described above, a conventional bumper case for an iPhone, which is manufactured by Apple, may have the conductive particle based material applied to a portion thereof that is adjacent to the antenna of the iPhone (the surface that is concealed when the iPhone is installed therein). Here, the conductive particle based material may have a layer of nonconductive material applied on top.

Another example of an implementation of a conductive particle based antenna enhancer is described below with reference to FIG. **4**.

FIG. **4** illustrates an implementation of a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna shown in FIG. **4** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna enhancer of FIG. **4** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **4**, a wireless device **480** and a protective cover **490** are shown. The wireless device **480** includes an internal antenna **470**. The protective cover **490** includes a conductive particle based antenna enhancer **420** that is disposed so as to be adjacent to the internal antenna **470** when the wireless device **480** is disposed in the protective cover **490**.

While the conductive particle based antenna enhancer **420** is shown to correspond to the size of the internal antenna **470**, the conductive particle based antenna enhancer **420** may be smaller or larger than the internal antenna **470**. In addition, while the conductive particle based antenna enhancer **420** is shown as being disposed immediately adjacent to the internal antenna, the conductive particle based antenna enhancer **420** may be disposed at a different location on the protective cover **490**.

While the conductive particle based antenna enhancer **420** is shown as being applied to an inner surface of the protective cover **490**, the conductive particle based antenna enhancer **420** may be applied to an outer surface of, or may be disposed within, the protective cover **490**. When the conductive particle based antenna enhancer **420** is disposed within the protective cover **490**, the material used to construct the protective cover **490** may serve as the binder for the conductive particle based material. When, the conductive particle based antenna enhancer **420** is disposed at an inner or outer surface of the conductive particle based material, one or more of an insulative coating, a surface preparation coating, a protective coating, and a concealment coating may be used. In addition, the conductive particle based antenna enhancer **420** may be formed as an independent structure (with or without a substrate) that is fixed to the protective cover **490**.

The conductive particle based antenna enhancer may be added to an existing conventional antenna or may be added at the time the conventional antenna is fabricated.

In one exemplary embodiment, the conductive particle based antenna enhancer is used to coat a conventional antenna that has been coated with a non-conductive material. The coating of the non-conductive material may be implemented as a liquid, paint, gel, ink, or paste that dries or cures. Herein, the non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. Alternatively, the coating of the non-conductive material may be a film or tape that is applied to the conventional antenna. Layers of other materials may be disposed between the conventional antenna and the non-conductive material and/or between the non-conductive material and the conductive particle based material. Here, depending on the configuration, the conductive particle based material may be coated with a layer of the nonconductive material and/or another material. Here, the thickness the non-conductive material may directly affect the performance gain of the conductive particle based material and if the thickness of the non-conductive material is too large, performance may decrease. The thickness of the non-conductive material is very small in relationship to the wavelength of the frequency the conventional antenna is designed for.

An example of a structure of a coated conductive particle based antenna enhancer is described below with reference to FIG. **5**.

FIG. **5** illustrates a structure of a coated conductive particle based antenna enhancer according to an exemplary embodiment of the present invention. The particular structure of the conductive particle based antenna shown in FIG. **5** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna of FIG. **5** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **5**, the coated conductive particle based antenna includes a conventional antenna **570**, a first coating **550**, a conductive particle based material coating **520**, and a second coating **560**. One or more of the first coating **550**, and a second coating **560** may be omitted. In addition, one or more additional coatings may be utilized.

The conventional antenna **570** may be any surface of any conventional antenna, which in this example, is assumed to be constructed of a conductive material such as metal.

The first coating **550** is applied on top of the conventional antenna **570**. The first coating **550** may be at least one of an insulative coating and a surface preparation coating. As an insulative coating, the first coating **550** may be a non-conductive or semi-conductive material. Examples of the insulative coating of the non-conductive or semi-conductive material include plastic tape, paper tape, paint, etc. As a surface preparation coating, the first coating **550** may be any material that allows for better adhesion of the conductive particle based material coating **520** to the conventional antenna **570**. The same coating may serve as both the insulative coating and a surface preparation coating. Alternatively, separate insulative and a surface preparation coatings may be utilized either together or individually. The first coating **550** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the first coating **550** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The first coating **550** may be omitted.

The conductive particle based material coating **520** is applied on top of the first coating **550**, if present. Otherwise, the conductive particle based material coating **520** is applied on top of the conventional antenna **570**. The conductive particle based material coating may be formulated using any formulation of the conductive particle based material described herein. For example, the conductive particle based material coating **520** may be formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the non-conductive material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The second coating **560**, if utilized, is applied on top of the conductive particle based material coating **520**. The second coating **560** may serve to protect and/or conceal the conductive particle based material coating **520**. The second coating **560** may be any material or structure that protects and/or conceals the conductive particle based material coating **520**. The same coating may serve as both the protective coating and the concealment coating. Alternatively, separate protective and concealment coatings may be utilized either together or individually. In one exemplary embodiment, the second coating **560** is formulated as a liquid, paint, gel, ink, or paste that dries or cures. In this case, the second coating **560** may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc. The second coating **560** may be omitted.

The conductive particle based antenna enhancer may be fabricated and positioned so as to be adjacent and offset from all or a portion of the conventional antenna. For example, the conductive particle based antenna enhancer may be fabricated and positioned so as to be adjacent to a portion of the conventional antenna corresponding to half or a quarter of the desired wavelength.

An example of an antenna partially coated with a conductive particle based antenna enhancer is described below with reference to FIG. **6**.

FIG. **6** illustrates an antenna partially coated with a conductive particle based antenna enhancer according to an exemplary embodiment of the present invention. The particular structure of the antenna partially coated with the conductive particle based antenna enhancer shown in FIG. **6** is merely an example used for explanation and is not intended to be limiting. The conductive particle based material used to fabricate the conductive particle based antenna of FIG. **6** is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **6**, an antenna **670** that is connected to a feed line **640** is shown. The antenna **670** is partially coated with a conductive particle based antenna enhancer **620**. As can be seen, the conductive particle based antenna enhancer **620** coats about a quarter of the antenna **670**.

Tests were conducted to compare a conventional copper antenna to the conventional copper antenna with the conductive particle based antenna enhancer. In particular, the same equipment and testing conditions as the test described above with respect to the conductive particle based antenna were performed. Here, insulative tape was applied to the entirety of the conventional copper antenna and the conductive particle based material was then applied onto the insulative tape.

The test data for the conventional copper antenna and the conventional copper antenna that has been enhanced with the conductive particle based antenna enhancer are provided below in Table 2.

TABLE 2

	Conventional Copper Antenna	Conventional Copper Antenna with Conductive Particle Based Antenna Enhancer
Forward Power	22 watts	28 watts
Reverse Power	12 watts	10 watts
Relative Signal Strength	−35 decibels	−27 decibels

As can be seen in Table 2, the conventional copper antenna with the conductive particle based antenna enhancer exhibits a significantly higher forward power (i.e., 28 watts) than the forward power of the conventional copper antenna alone (i.e., 22 watts). This can be explained by the conventional copper antenna with the conductive particle based antenna enhancer exhibiting a significantly lower reverse power (i.e., 10 watts) than the reverse power of the conventional copper antenna alone (i.e., 12 watts). Accordingly, the resulting relative signal strength of the conventional copper antenna with the conductive particle based antenna enhancer is higher (−27 decibels) than the resulting relative signal strength of the conventional copper antenna (−35 decibels).

As can be gleaned from the above identified test, the conventional copper antenna with the conductive particle based antenna enhancer is more efficient at emitting electromagnetic signals into space than the conventional copper antenna alone. Therefore, the conventional copper antenna with the conductive particle based antenna enhancer has a higher effective gain than the conventional copper antenna alone. Also, since there is less reverse power, less of the electromagnetic radiation input to the conventional copper antenna with the conductive particle based antenna enhancer will be converted into heat. Thus, the conventional copper antenna with the conductive particle based antenna enhancer may operate at a lower temperature for a given input power and therefore may have a higher power rating.

Accordingly, the conductive particle based material may be used to enhance a conventional antenna.

Conductive Particle Based Transmission Line

The conductive particle based material may be used to form a conductive particle based transmission line. To implement a conductive particle based transmission line, a transmission line is formed in any of the various ways described herein for forming an object using the conductive particle based material. Herein, at least some of the properties that enable the conductive particle based material to efficiently radiate electromagnetic radiation into space allow the conductive particle based material to efficiently radiate electromagnetic radiation down the transmission line formed using the conductive particle based material. The use of the conductive particle based material as a transmission line is beneficial due to its lower resistance and heat generation.

Conductive Particle Based Electromagnetic Radiation Harvester

The conductive particle based material may be used as an electromagnetic radiation harvester. The high efficiencies of the conductive particle based material in at least one of propagating and absorbing electromagnetic radiation make it ideally suited for use in collecting electromagnetic radiation. While such collected electromagnetic radiation may be electromagnetic radiation that was transmitted with the intention of being harvested by the electromagnetic radiation harvester, the collected electromagnetic radiation may be background electromagnetic radiation. Herein, the electromagnetic radiation harvester may be coupled to a receiver that collects the energy absorbed by the electromagnetic radiation harvester. The electromagnetic radiation harvester is formed in any of the various ways described herein for forming an object using the conductive particle based material.

Conductive Particle Based Conformable Antenna

The conductive particle based material may be used to construct a conductive particle based conformable antenna. The benefit of the conductive particle based conformable antenna may be easily appreciated when considered in the context of an exemplary use case, which is described below.

According to the exemplary use case, the conductive particle based conformable antenna may use used in a military setting. The Special Operations community has a major logistical and safety issue when it comes to communications in the theater. The US Department of Defense (DoD) has rapidly expanded its communications capabilities within the radio spectrum. In the past, two way radios in a variety of form factors where used for conventional Push-To-Talk (PTT) communications. The use of these systems has now evolved into a true "Digital Battlefield" consisting of a multitude of communications platforms. Vast arrays of data networks came into reality. The scope of radios used today varies widely from conventional voice to Satellite, mesh networks, to Unmanned Aerial Vehicles (UAVs) and unattended ground sensors.

The reason this wide variety of systems is mentioned is to give an understanding of why the conductive particle based conformable antenna may be beneficial to the mission of soldiers. Every RF device utilized by the military operates on a wide range of frequencies and a different type of transmission (Amplitude Modulation (AM), Frequency Modulation (FM), Satcom, Single Side band, etc.).

However, conventional antenna systems are designed and tuned for a limited range of frequencies and are generally designed to work with only one of the hundreds of types of radio devices on the market. The other major downsides to these conventional antenna systems are the logistics of getting them into battle. They are heavy, bulky, expensive, and difficult to transport. Accordingly, there is a need to address the shortcomings of the conventional antenna systems.

The conductive particle based conformable antenna addresses the shortcomings of the conventional antenna systems by being operable with any and all of the radios currently deployed and being developed. As opposed to being an antenna of fixed form, the conductive particle based conformable antenna may instead be constructed on an as needed basis.

For example, the conductive particle based conformable antenna may be constructed on site using the conductive particle based material. In this case, the conductive particle based material is a liquid, paint, gel, ink or paste that dries or cures. Herein, the conductive particle based conformable antenna may be applied to a substrate. In particular, the conductive particle based material may be sprayed on, brushed on, rolled on, silk screened, ink jet printed, etc.

The conductive particle based conformable antenna may be designed based on typical antenna design, theory, and formulas. The antenna design may be generated in advance or at the time the antenna is needed based on desired characteristics.

The conductive particle based material is applied to the substrate to form the conductive particle based conformable antenna based on the desired antenna design.

The substrate may be any surface of any material, such as acrylic, ABS, structural foams, solvent sensitive materials such as polycarbonate and polystyrene, and non-porous surfaces including primed wallboard, wood and clean metals, etc.

When the substrate is a conducting material, a non-conductive or semi-conductive coating may first be applied to the substrate. In this case, the conducting material may serve as a ground plane. When the substrate is a non-conducting material, a ground plane can be accomplished by using the earth's natural ground. Alternatively, the ground plane can be accomplished by fabricating an independent ground plane.

Once the antenna is fabricated, a feed line is coupled to the conductive particle based conformable antenna and an RF communications device. The conductive particle based conformable antenna is at least one of electrically, capacitively, and inductively coupled to a coupling point of the feed line. The conductive particle based conformable antenna may be coupled to the coupling point of the feed line at an end point of the conductive particle based conformable antenna. When capacitively or inductively coupled, the coupling may occur through a distance that includes an air gap or a substance, such as glass.

To fabricate the conductive particle based conformable antenna, a template of the desired antenna design may be used. The template may be a sheet formed of any rigid or semi-rigid material in which the desired design of the antenna is cut out.

An example of a template used to fabricate a conductive particle based conformable antenna is described below with reference to FIG. **7**.

FIG. **7** illustrates a template used to fabricate a conductive particle based conformable antenna according to an exemplary embodiment of the present invention.

Referring to FIG. **7**, a template **700** is shown. The template **700** may be any material that may be used to form a template or stencil. For example, the template **700** may be a sheet formed of a rigid or semi-rigid material. The cut out of the template **700** may be at least one of a positive and a negative of a desired design of an antenna. The template **700** may be an image displayed on a surface showing where conductive particle based material should or should not be applied. The template **700** may be an image displayed on a display or in a guide book that shows a desired design of an antenna. Herein, the template **700** shown in FIG. **7** corresponds to the antenna design shown in FIG. **2**.

Examples of various cutout designs for the template **700** are found in U.S. Design patent application Ser. No. 29/390,425, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,427, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,432, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,435, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,436, filed on Apr. 25, 2011, and entitled "ANTENNA"; U.S. Design patent application Ser. No. 29/390,438, filed on Apr. 25, 2011, and entitled "ANTENNA"; and U.S. Design patent application Ser. No. 29/390,442, filed on Apr. 25, 2011, and entitled "ANTENNA", the entire disclosure of each of which is hereby incorporated by reference.

An exemplary method for fabricating a conductive particle based conformable antenna using a template is described below with reference to FIG. **8**.

FIG. **8** illustrates a method for fabricating a conductive particle based conformable antenna using a template according to an exemplary embodiment of the present invention. Herein, the conductive particle based material used to fabricate the conductive particle based conformable antenna is assumed to be formulated as a liquid, paint, gel, ink, or paste that dries or cures.

Referring to FIG. **8**, a template and substrate is chosen in step **800**. In step **810**, the chosen template may be fixed against the chosen substrate. In step **820**, the conductive particle based material may then be applied on the template such that the conductive particle based material passes through at least one cut out portion of the template so as to be applied to the corresponding portion of the substrate. The conductive particle based material may be applied until its particle density reaches a certain threshold. This may be determined by measuring the resistance of the material across the length of the antenna (or antenna segment). Here, the threshold may correspond to a predefined resistance or range of resistances (e.g., 11-15 ohms).

The template may then be removed leaving the conductive particle based material to dry or cure on the chosen substrate according to the desired design. In step **830**, one or more coupling points of a feed line may be affixed to the conductive particle based conformable antenna. Herein, step

830 may be omitted. In addition, additional steps may be included, such as applying at least one of an insulative coating, a surface preparation coating, a protective coating, and a concealment coating. Any or all of this fabrication technique may be automated, as will be described below.

While a conductive particle based conformable antenna is described herein, any disclosure related to a conductive particle based conformable antenna is equally applicable to a conductive particle based conformable antenna enhancer.

Fabrication Techniques for Conductive Particle Based Conformable Antenna

In one exemplary embodiment, techniques for constructing a conductive particle based conformable antenna are described. Herein, a computerized device is used to generate a template that is used to construct a conductive particle based conformable antenna.

The computerized device may be any of a desktop computer, a laptop computer, a netbook, a tablet computer, a Personal Data Assistant (PDA), a Smartphone, a portable media device, a specialized mobile device, etc. The computerized device may include one or more of a display, an input unit, a control unit, a printer, memory, a communications unit, and a projection unit.

The conductive particle based conformable antenna that is constructed using the template may be formed using the conductive particle based material that is sprayable, rollable or brushable. The conductive particle based material may be applied directly onto any substrate. The conductive particle based conformable antenna, once fabricated onto a surface, may be painted over with a paint in order to conceal the antenna, provide protection to the antenna, or provide the antenna with desired aesthetics.

According to an exemplary embodiment of the present invention, to create and install an antenna, the computerized device may be used to generate the template. The computerized device may include a graphical user interface that queries a user regarding certain characteristics/criteria or otherwise allows a user to enter certain characteristics/criteria. Based on the input characteristics/criteria, the computerized device generates the template. Herein, the user may input less than all of the characteristics/criteria. In this case, the characteristics/criteria not input by the user may be obtained via a formula, or a local or remote database. In addition, assumed values for the characteristics/criteria not input by the user may be used.

Examples of the characteristics/criteria include one or more of a substrate on which the antenna will be disposed, frequency of operation, aperture or antenna pattern, whether a space saving design is desired, velocity factor, resonant frequency, Q factor, impedance, gain, polarization, efficiency, bandwidth, heat characteristics, type of amplifier, environment, etc. Further, one or more of the characteristics/criteria may include a number of preset options for a given characteristic/criteria. For example, the options for the substrate on which the antenna will be disposed may include one or more of wood, metal, glass, plastic, etc. For another example, the options for the desired antenna pattern include one or more of an omni-directional antenna pattern, a directional antenna pattern, a circular antenna pattern, a phased array antenna pattern, etc.

The computerized device may guide a user in inputting at least one of the one or more the characteristics/criteria and may request additional information from the user.

Based on the input one or more characteristics/criteria, the computerized device determines an antenna pattern using a pattern determination algorithm. The antenna pattern may be a preset antenna pattern or an antenna pattern formed based on an algorithm and the input one or more characteristics/criteria. In addition, the computerized device may determine one or more of a scaling factor of the antenna pattern, dimensions of the antenna pattern or elements of the antenna pattern, grain direction, application notes, etc. Alternatively, or additionally, the characteristics/criteria may not be preset.

The computerized device may determine more than one antenna pattern and may allow a user to select a desired antenna pattern from among the determined more than one antenna pattern.

Once the antenna pattern is determined, as well as one or more of the scaling factor of the antenna pattern, dimensions of the antenna pattern or elements of the antenna pattern, grain direction, application notes, etc., a resulting template may be at least one of displayed on the display of the computerized device, projected onto a surface using the projection unit of the computerized device, and printed using one of an external and an integrated printed. When a projection unit is employed, the computerized device may further include a device that adjusts the scale of the projected template based on at least the distance between the projection unit and the surface on which the antenna is to be constructed. Further, when a projection unit is employed, the computerized device may further include a device that adjusts the location of the projected template so that the projected template remains on the same location of the surface regardless of the movement of the computerized device. The template may then be used to construct the antenna.

Also, the template may correspond to digital data that is stored in a storage device or communicated to another device that applies the antenna material based on the digital data.

In one exemplary embodiment, the computerized device communicates the input characteristics/criteria to a remote computerized device which determines one or more of the antenna pattern, the scaling factor of the antenna pattern, dimensions of the antenna pattern or elements of the antenna pattern, grain direction, application notes, etc., which is then communicated to the computerized device.

In one exemplary embodiment, the antenna patterns may be stored remotely from the computerized device and communicated to the computerized device before or after the antenna pattern is determined. The antenna patterns may be communicated to the computerized device in response to a request by the computerized device or another entity.

An exemplary method for fabricating a conductive particle based conformable antenna using a computerized device is described below with reference to FIG. **9**.

FIG. **9** illustrates a method for fabricating a conductive particle based conformable antenna using a computerized device according to an exemplary embodiment of the present invention.

Referring to FIG. **9**, in step **900**, the characteristics/criteria are obtained by the computerized device as described above. In step **910**, an antenna pattern is selected by the computerized device based on the obtained characteristics/criteria, as described above. In step **920**, a template is generated as described above.

An example of the computerized device described above is described below with reference to FIG. **10**.

FIG. **10** illustrates a structure of computerized device used for fabricating a conductive particle based conformable antenna according to an exemplary embodiment of the present invention.

Referring to FIG. **10**, the computerized device includes a controller **1010**, a display unit **1020**, a memory unit **1030**, an input unit **1040**, a communications unit **1050**, a template generator **1060**, and an antenna generator **1070**. One or more of the components of the computerized device shown in FIG. **10** may be omitted. Also, the functions of one or more of the components of the computerized device shown in FIG. **10** may be performed by a combined component. In addition, additional components may be included with the computerized device.

The controller **1010** controls the overall operations of the computerized device. More specifically, the controller **1010** controls and/or communicates with the display unit **1020**, the memory unit **1030**, the input unit **1040**, the communications unit **1050**, the template generator **1060**, and the antenna generator **1070**. The controller **1010** executes code to have performed or perform any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed by a computerized device. The term "code" may be used herein to represent one or more of executable instructions, operand data, configuration parameters, and other information stored in the memory unit **1030**.

The display unit **1020** is used to display information to a user. The display unit **1020** may be any type of display unit. The display unit **1020** may be integrated with or separate from the computerized device. The display unit **1020** may be integrated with the input unit **1040** to form a touch screen display. The display unit **1020** performs any of the functions/operations/roles explicitly or implicitly described herein as being performed by a display.

The memory unit **1030** may store code that is processed by the controller **1010** to execute any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed by a computerized device. In addition, one or more of other executable instructions, operand data, configuration parameters, and other information may be stored in the memory unit **1030**. Depending on the exact configuration of the computerized device, the memory unit **1030** may be volatile memory (such as Random Access Memory (RAM)), non-volatile memory (e.g., Read Only Memory (ROM), flash memory, etc.) or some combination thereof.

The input unit **1020** is used to enable a user to input information. The input unit **1020** may be any type or combination of input unit, such as a touch screen, keypad, mouse, voice recognition, etc.

The communications unit **1050** transmits and receives data between one or more entities. The communications unit **1050** may include any number of transceivers, receivers, and transmitters of any number of types, such as wired, wireless, etc.

The template generator **1060** may perform any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed when generating a template. For example, the template generator **1060** may be a printer, a cutter, a projector, a display, etc.

The antenna generator **1070** may perform any of the functions/operations/algorithms/roles explicitly or implicitly described herein as being performed when generating an antenna. For example, the antenna generator **1070** may be a sprayer that sprays the conductive particle based material onto a substrate.

Herein, the functionality described above of the computerized device may result from an application installed on and being executed by the computerized device.

At this point it should be noted that the present exemplary embodiment as described above typically involve the processing of input data and the generation of output data to some extent. This input data processing and output data generation may be implemented in hardware, or software in combination with hardware. For example, specific electronic components may be employed in a mobile device or similar or related circuitry for implementing the functions associated with the exemplary embodiments of the present invention as described above. Alternatively, one or more processors operating in accordance with stored instructions (i.e., code) may implement the functions associated with the exemplary embodiments of the present invention as described above. If such is the case, it is within the scope of the present disclosure that such instructions may be stored on one or more non-transitory processor readable mediums. Examples of the non-transitory processor readable mediums include ROM, RAM, Compact Disc (CD)-ROMs, magnetic tapes, floppy disks, and optical data storage devices. The non-transitory processor readable mediums can also be distributed over network coupled computer systems so that the instructions are stored and executed in a distributed fashion. Also, functional computer programs, instructions, and instruction segments for accomplishing the present invention can be easily construed by programmers skilled in the art to which the present invention pertains.

While the invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims and their equivalents.

What is claimed is:

1. An antenna system comprising:

a conductive substrate; and

a radiating antenna element formed of a conductive particle based material comprising conductive particles dispersed in a binder so that at least a majority of the conductive particles are adjacent to, but do not touch, one another,

wherein the conductive substrate is disposed in a first layer and the radiating antenna element is disposed in a second layer that is substantially parallel to the first layer, and

wherein the conductive particle based material is applied directly onto, and without encircling, the conductive substrate.

2. The antenna system of claim **1**, further comprising a coupler for at least one of electrically, capacitively, and inductively coupling to the radiating antenna element, and for electrically coupling to a feed line.

3. The antenna system of claim **1**, wherein, when a Radio Frequency (RF) signal is input to the radiating antenna element, a reverse power is lower than the reverse power of an identically formed antenna element fabricated from copper.

4. The antenna system of claim **1**, wherein the radiating antenna element is also a receiving antenna element.

5. The antenna system of claim **1**, wherein the conductive particles comprise at least one of conductive particles of different non-uniform shapes, conductive particles of various sizes, or conductive particles smaller than 30 micrometers.

6. The antenna system of claim **1**, wherein the conductive particle based material is applied to the substrate as at least one of a liquid, a paint, a gel, an ink and a paste that dries or cures.

7. The antenna system of claim **1**, further comprising at least one of a protective and concealment coating applied to the radiating antenna element.

8. The antenna system of claim **1**, wherein the radiating antenna element is fed a Radio Frequency (RF) signal amplified by an amplifier that operates for less than an entire input cycle.

9. The antenna system of claim **8**, wherein the amplifier comprises a class C amplifier.

10. The antenna system of claim **1**, wherein at least some of the conductive particles that are adjacent to one another are capacitively coupled to one another.

11. The antenna system of claim **1**, wherein the conductive particle based material has non-ohmic conduction with direct current (DC).

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