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Suggested Reference

Hunter, I. W., Montemayor, L., Paster, E. T., Pillai, P., & Ruddy, B. P. (2010, August 13). *WO2012/021300 A1, Conformable antenna using conducting polymers*. United States. Retrieved from <http://patentscope.wipo.int/search/en/WO2012021300>

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(43) International Publication Date
16 February 2012 (16.02.2012)

(10) International Publication Number
WO 2012/021300 A1

(51) International Patent Classification:
H01Q 1/27 (2006.01) *H01B 1/12* (2006.01)
H01Q 1/36 (2006.01)

(21) International Application Number:
PCT/US2011/045743

(22) International Filing Date:
28 July 2011 (28.07.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/373,343 13 August 2010 (13.08.2010) US

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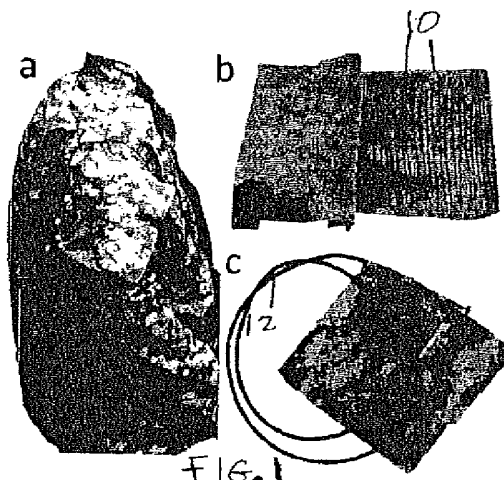
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: CONFORMABLE ANTENNA USING CONDUCTING POLYMERS



(57) Abstract: Antenna including a wire (10) made of a conducting polymer. The wire is sewn into fabric material in a selected pattern. A preferred conducting polymer is polypyrrole. It is also preferred that the wire be encased in a non - conductive, low dielectric plastic.



WO 2012/021300 A1

CONFORMABLE ANTENNA USING CONDUCTING POLYMERS**Priority Information**

The present application claims priority to U.S. Provisional Application Serial No. U.S. 61/373,343, filed on August 13, 2010, which is incorporated herein by reference in its entirety.

Sponsorship Information

This invention was made with government support under Contract No. W911NF-07-D-0004 awarded by the Army Research Office and under Contract No. NBCHC0080001 awarded by the U.S. Department of Interior. The government has certain rights in this invention.

Background of the invention

This invention relates to antennas and more particularly to a conformable antenna made from a conducting polymer.

Soldiers performing dismounted operations in the field use radios that have antennas with a distinct visual signature and thereby become easy targets. Such antennas also tend to snag on other equipment or vegetation creating a hazard and a distraction to an ongoing operation. Therefore, it has become desirable to develop an antenna that can conform to soldiers and be virtually indistinguishable from a soldier's body armor. Traditional antennas are made of materials such as metals that tend to break under repeated cycles of loading and unloading which therefore makes them undesirable for such field operations.

It is therefore an object of the present invention to create patch antennas made from conducting polymers that can easily conform to a soldier's body and can match the performance of existing antennas.

Summary of the Invention

In a first aspect, the invention is an antenna including a wire made of a conducting polymer, the wire sewn into, or adhered onto, fabric material in a selected pattern. In a preferred embodiment, the conducting polymer is polypyrrole (PPy). It is preferred that the wire be encased in a non-conductive, low dielectric plastic. It is also preferred that the fabric material include a hook-and-loop portion for attachment to another object such as an article of clothing. In this embodiment, the antenna further includes a connector for connecting the

wire to a proximal end of a coaxial cable. A distal end of the coaxial cable preferably includes a connector for interface with a radio device.

In another embodiment of this aspect of the invention, the fabric material with the embedded antenna is enclosed in a weather-proof casing. It is also preferred that the proximal end of the coaxial cable be strain relieved within the fabric material.

In yet another aspect, the invention is a method of making a conductive polymer wire including growing a thin film of conductive polymer on a crucible and slicing the polymer in a helical pattern to form a wire with a selected width.

Brief Description of The Drawing

Figs. 1a, 1b, and 1c are perspective views of the antenna disclosed herein sewn into fabric and applied to an article of clothing.

Figs. 2a and 2b are polar graphs of degrees compared to realized gain dBi for 250MHz and 500MHz of a conformal antenna made from the conducting polymer polypyrrole.

Description of the preferred embodiment

Conducting polymers are electrically conducting materials that have high electrical conductivities ($\sim 10^4$ S/m) and are extremely lightweight and flexible. Wires synthesized from such conducting polymers have a wide range of applications that can include smart textiles, neural probes, polymer based actuators, sensors and antennas. Electrochemically deposited thin films of polypyrrole (PPy) are an attractive conducting polymer due to their robust mechanical properties and high electrical conductivity. Disclosed herein is a novel polymer based patch antenna that can easily be adapted to conform to a soldier's body and we have conducted preliminary tests to assess the feasibility of the use of such polymer wires as an antenna.

Polypyrrole films cannot be synthesized as long wires using traditional electrospinning or wet spinning techniques. The inventors herein have developed a novel approach to manufacture wires of polypyrrole up to four meters long and having a cross section of $20\mu\text{m} \times 1000\mu\text{m}$. We have grown polypyrrole on a crucible and used a tool that slices the film in a helical pattern by running a sharp blade over the polypyrrole film on the crucible. It is preferred that the blade be simultaneously slid along its length such that a fresh cutting edge is continuously presented at the point of contact with the crucible. We have

produced polypyrrole microwires with widths as small as a few micrometers and lengths ranging from tens of millimeters to meters.

In one example, a strip of polypyrrole 4 meters in length was cut using the technique described above. The polypyrrole wire was then encased in a non-conductive, low dielectric plastic in order to protect it. A suitable plastic material is Mylar, polyvinyl chloride, polyvinylidene chloride, low density polyethylene, poly (p-xylylene) and derivatives (parylene). The resulting material was then sewn into a camouflage material.

With reference now to Fig. 1, polypyrrole wire 10 is sewn back-and-forth into camouflage material as shown in Fig. 1b. The polymer wire 10 was then connected to a coaxial cable 12 as shown in Fig. 1c using a custom built connector that was also sewn into the fabric. The other end of the coaxial cable 12 was connected to a BNC connector. It is preferred that the connecting wire be strain relieved within the fabric itself to provide additional robustness. As shown in Fig. 1a, the patch antenna including the polypyrrole wire 10 may be attached to the shoulder of a uniform using hook-and-loop material such as Velcro.

We conducted a preliminary analysis to assess the effectiveness of the polymer material as an antenna. Figs. 2a and 2b show a plot of 250 and 500MHz gain of a helically wound PPy strip relative to a black base. We observed a -10dBi attenuation at those frequencies for the PPy strip in that geometry. We also tested the antenna using commercially available radios and were able to demonstrate transmission and reception over a 1.7 mile radius within an urban environment.

The antenna disclosed herein is light in weight (250mg), flexible and conformable. The antenna can be embedded into uniforms, equipment or structured armor. The polypyrrole material may be grown in batches of 30 feet by 0.04 inches. Robotic instrumentation may be used for wire slicing and removal. It is also preferred that vacuum sealing be used to make the antenna waterproof. Those of ordinary skill in the art will recognize that impedance matching between the antenna and existing radios to improve efficiency may be provided.

The antenna disclosed herein provides weight reduction by a factor of 500 and volume reduction by a factor of 15 or greater when compared with a standard, 1 meter whip antenna of approximately 300 grams. The antenna disclosed herein may be conformable to any geometry.

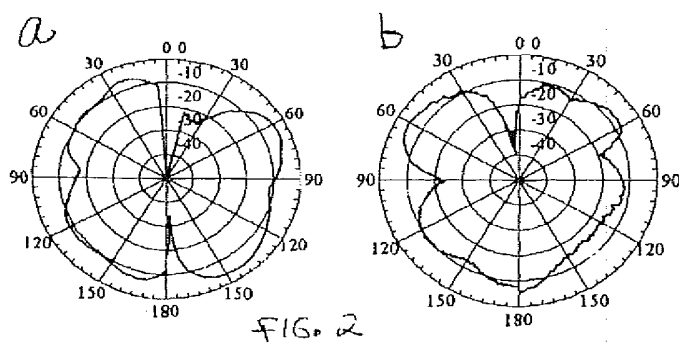
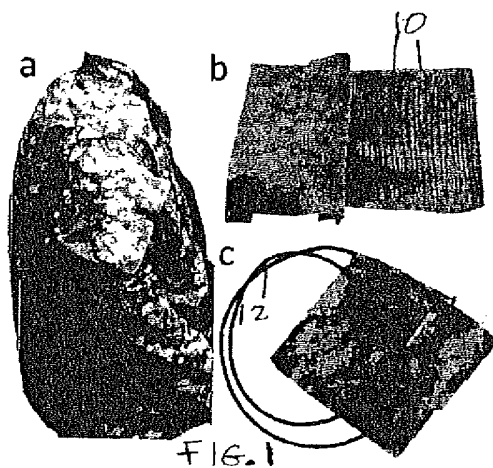
While this disclosure has focused primarily on polypyrrole, it should be recognized that other conductive polymers such as polyaniline, poly (3, 4-ethylenedioxythiophene), polyacetylene, poly (thiophene)s, etc. may be used.

It is recognized that modifications and variations of the invention disclosed herein will be apparent to those of ordinary skill in the art and it is intended that all such modifications and variations be included within the scope of the appended claims.

What is claimed is:

1. Antenna comprising a wire made of a conducting polymer, the wire sewn into fabric material in a selected pattern.
2. The antenna of claim 1 wherein the conducting polymer is polypyrrole.
3. The antenna of claim 1 wherein the wire is encased in a non-conductive, low dielectric plastic.
4. The antenna of claim 1 wherein the fabric material includes a hook-and-loop portion for attachment to another object.
5. The antenna of claim 4 wherein the object is an article of clothing.
6. The antenna of claim 1 further including connecting the wire to a proximal end of a coaxial cable.
7. The antenna of claim 6 wherein a distal end of the coaxial cable includes a connector for interface with a radio device.
8. The antenna of claim 1 wherein the fabric material is enclosed in a weather-proof casing.
9. The antenna of claim 6 wherein the proximal end of the coaxial cable is strain relieved within the fabric material.
10. Method of making a conducting polymer wire comprising:
growing a thin film of conductive polymer on a crucible; and
slicing the polymer in a helical pattern to form a wire with a selected width.

1/1



INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/045743

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01Q1/27 H01Q1/36 H01B1/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01Q H01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2006/125707 A1 (WASCHENKO DONALD P [US]) 15 June 2006 (2006-06-15)	1-8
Y	paragraph [0040]; figures 2a-f paragraph [0059] - paragraph [0062]; figures 4a,b paragraph [0069] paragraph [0030]	9
X	----- WO 2009/005271 A2 (HYPERFLEX CO LTD [KR]; KIM CHEL JIN [KR]) 8 January 2009 (2009-01-08) paragraph [0055] - paragraph [0069]; figures 3-5 paragraph [0083] ----- -/-	1-4,8

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

14 October 2011

Date of mailing of the international search report

19/12/2011

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/045743

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>EP 2 148 388 A1 (NEC CORP [JP]) 27 January 2010 (2010-01-27) paragraph [0043] - paragraph [0044]; figure 15 paragraph [0021] -----</p>	9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/045743

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-9

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-9

Antenna comprising a wire made of a conducting polymer, the wire sewn into fabric material in a selected pattern, further including connecting the wire to a proximal end of a coaxial cable, wherein the proximal end of the coaxial cable is strain relieved within the fabric material.

2. claim: 10

Method of making a conducting polymer wire comprising: growing a thin film of conductive polymer on a crucible; and slicing the polymer in a helical pattern to form a wire with a selected width.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/045743

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006125707 A1	15-06-2006	NONE	

WO 2009005271 A2	08-01-2009	KR 20090002516 A	09-01-2009
		WO 2009005271 A2	08-01-2009

EP 2148388 A1	27-01-2010	EP 2148388 A1	27-01-2010
		JP 4281116 B2	17-06-2009
		JP 2008295019 A	04-12-2008
		US 2010090787 A1	15-04-2010
