

# Prospect of Wearable Antenna

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## ABSTRACT

Usage of wearable materials in the Antenna portion has been seen on the ascent because of the later scaling down of remote gadgets. A wearable Antenna is intended to be a part of the fabric utilized for correspondence purposes, which incorporates following and route, versatile processing and open wellbeing. This writing survey expect to reveal this Antenna technology innovation and gives perusers the foundation of the wearable Antenna that would incorporate about determination of the Antenna, material for the Antenna and examination that must be done to outline appropriate wearable Antenna. Every one of the plans introduced is of the late advancement in wearable innovation.

**Keywords:** wearable antenna, textile antenna, antenna, on body communication

## 1. INTRODUCTION

As of late, body-driven wireless communication turns into a vital piece of fourth era mobile communication system (4G). In supporting the expanding enthusiasm for antennas and engendering research for body correspondence frameworks, the IEEE 802.15 institutionalization bunch has been set up to institutionalize applications planned for on-body, off-body or in-body communication. Body-centric communication has its spot immovably inside the circle of personal area network (PANs) and body area network (BANs). One of the applications – the on-body communications–portray the connection between body mounted device imparting remotely, while off-body correspondence characterizes the radio connection between body worn device and base units or mobile device situated in encompassing environment. At last, in-body communication is correspondence between remote medicinal inserts and on body hubs [1].

One of the overwhelming examination subjects in Antenna for body-driven interchanges is wearable, fabric-based Antennas. Regularly, wearable antenna prerequisites for all present day application require light weight, ease, just about support free and no establishment. There are number of specific occupation portions that apply body driven correspondence frameworks, for example, paramedics, fire contenders, and military. Moreover, wearable Antenna likewise can be connected for youths, the matured, and competitors with the end goal of observing.

Outlining textile antenna requires the information on electromagnetic properties, for example, permittivity, and misfortune digression of the material. Conductive material, for example, Zelt, Flectron and unadulterated copper polyester fabric fabrics are routinely utilized as the emanating component while non-conductive material, for example, silk, felt and downy are utilized as substrates. Electromagnetic properties for these materials are not promptly accessible. Measurement of the electromagnetic properties of different material substrate done in [2] utilizing a transmission/reflection waveguide technique. Essential permittivity and misfortune digression quality were incorporated into the reproduction.

This work expects to present late sorts of Antenna and different contemplations that must be explored, including appropriate material determination, creation techniques and investigation required for a wearable Antenna design.

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## 2. TYPES OF WEARABLE ANTENNA

### 2.1. Conventional Wearable Designs

Customary Antenna outlines which incorporate planar dipoles, monopoles, planar Inverted F Antennas (PIFAs), and microstrip patches were utilized as a part of late research for wearable Antennas design. Microstrip Antennas are planar and these can be made onto a printed circuit board (PCB). This made them a pragmatic antenna sort because of their minimal effort, and facilitates for creation. In [3], Salonen investigated the planar inverted F Antenna (PIFA) outline as a wearable antenna that proposed to be set on the sleeve of cloth. PIFAs resemble quarter wave monopole antennas, which collapsed structure is parallel with the ground plane, as appeared in Figure 1.

Figure 2 demonstrates one conceivable area arrangement of the antenna, on the sleeve of dress. The impact of the antenna's ground plane to the heading of the most grounded radiation was additionally appeared. The ground plane makes a shield for human so the radiation won't transmit towards human body. IN other words, the ground plane worked as a reflector for radiation. Utilizing the same antenna design idea, the outline of a wearable flexible planar inverted F Antenna (Flex PIFA) for Bluetooth worked framework was presented in [4]. The Antenna was intended to be connected on a human arm and utilized flexible substrate material with 0.236 mm thickness, a dielectric steady of 3.29, and a loss tangent of 0.0004.

Antenna's prerequisites that impact the Antenna choice in [5] are low profile, worked in the frequency range of 100 MHz – 500 MHz, omni-directional scope in the azimuth plane, produces wideband return loss and has a vertical or round polarization. For a wearable antenna Omni-directional radiation pattern is required, in which it will be reasonable for cell phones and shrewd garments. Other than that, omni-directional radiation pattern ought to be intended to have negligible/no side i.e. we can say, which can hurt the human body.

### 2.2. Textile Antenna Designs

The work in [6], asserted to be the first textile antenna with circular polarization. Circular polarization is expected to guarantee that the antenna is reliable in applications where the wearer is mobile. As a consequence of this dynamism, the introduction of the body changes persistently. A circular polarization wave emanates vitality in both the plane horizontal plane and vertical planes and all planes in the middle of [7] so however the body introduction changes, the Antenna still can get signals. Substrate utilized as a part of the configuration is polyimide spacer fabric with 6 mm thickness and has a permittivity of 1.5. A conductive material – a nickel plated woven material – was utilized as the antenna patch and the ground plane. The conductive material utilized has sheet resistance of under  $1\Omega/\text{square}$  to keep losses at a minimum. So as to interface the textile antenna with the SMA connector, a  $50\ \Omega$  impedance line was manufactured on a printed circuit board (PCB). Development of the textile is appeared in Figure 3.

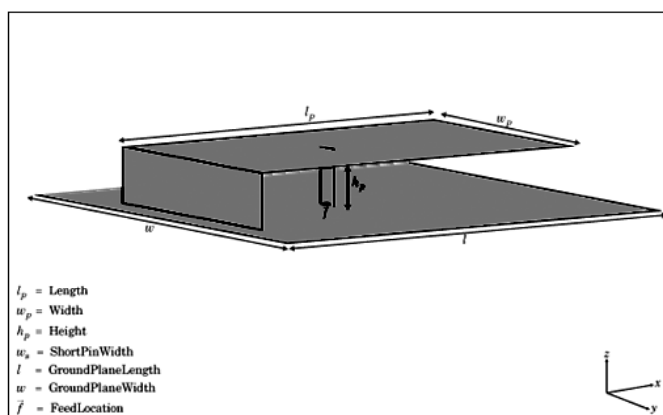


Figure 1: Construction of the PIFA

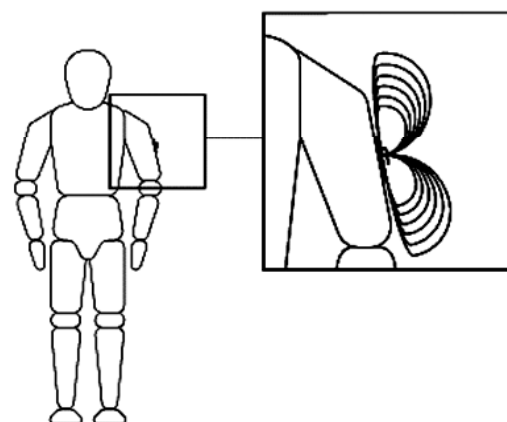


Figure 2: Possible placement of the PIFA antenna

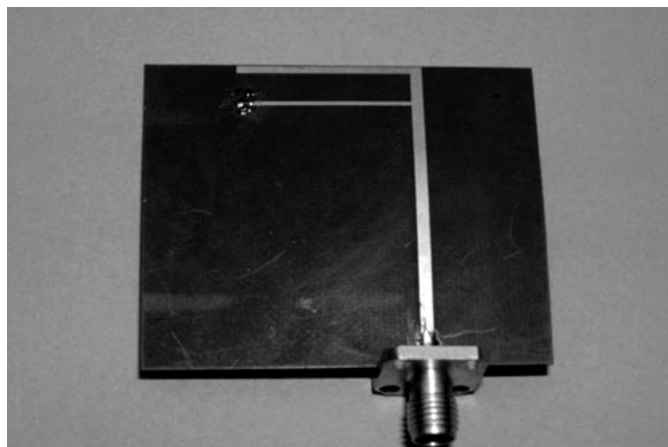


Figure 3: 50  $\Omega$  impedance line antenna with the SMA connector

A textile Antenna for defensive apparel in [8] was additionally planned with circular polarization to enhance gathering in the genuine application. The outline delivered a circular polarization by putting the feed point of the patch, subsequently energizing the two orthogonally polarized TM<sub>01</sub> and TM<sub>10</sub> modes.

Electromagnetic band gap (EBG) is a standout amongst the most quickly propelling parts in the field of electromagnetic exploration. Utilizing an EBG structure for the ground plane looks like a flawless attractive conductor. As a result, an electric current can radiate productively close to the EBG ground plane. This idea utilized by Zhu as a part of [9], in planning a double band, body worn antenna. Figure 4 demonstrates the double square double band EBG. Taking into account the  $S_{11}$  estimation result in Figure 5, making the EBG layer at the ground plane enhanced the arrival loss of the antenna to be roughly about the same (at  $-15$  dB) for all the resonant frequencies. It was additionally demonstrated that the surface current of the antenna is balanced, in this way expanding the antenna' productivity.

A textile based antenna in [10] was intended to give a remote short range correspondence in body and individual territory system. It was made totally out of textile. The aperture coupled encouraging component was utilized for the configuration, helped in expanding the data transmission contrasted with other exemplary planar Antenna sustains [11].

### 3. TYPES OF MATERIAL FOR WEARABLE ANTENNAS

A wide range of materials were considered and a summary is provided below [23].

#### 3.1. Conducting Ribbon

This is an industrially accessible item comprising of commonly 3-6 tracks of conductive thread woven into a non-conductive backing strip fabric. The material arrives in a reel so long lengths can be utilized. The

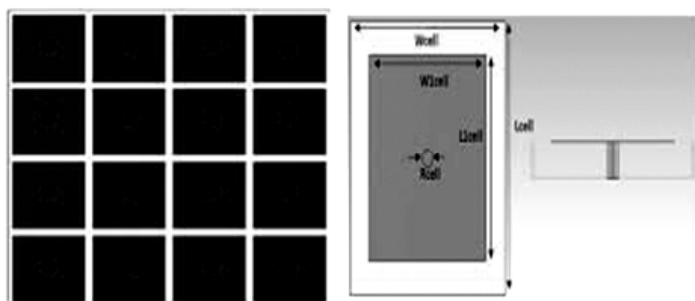


Figure 4: Fabric Substrate Antenna

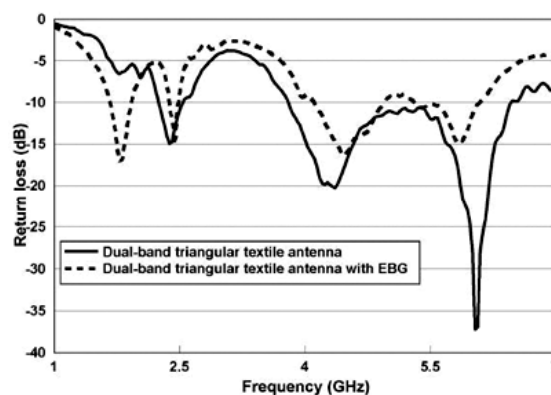


Figure 5:  $S_{11}$  measurement result

material is 15mm wide and to a great degree of flexibility. It was not appropriate for the bowtie as it comes in meager strips. It was additionally not appropriate for the winding as it crimps when bent around corners. It seemed perfect for the broadband dipole. A drawback is that the material can't be solder to so pleat sort connectors were utilized for the antenna terminals and to interface the lumped loads.

### **3.2. Insulated Wire**

Standard flexible insulated wire is a perfect possibility for the broadband wire dipole. This is a restrictive high voltage, multi-strand, single conduit wire with a thick silicone elastic insulating cladding. It is flexible and can be patched to specifically. The wire is easily accessible and can be incorporated into the crease of routine apparel.

### **3.3. Conducting Paint:**

The conductive paint contains a high silver substance to produces a low electrical resistance. The leading paint antenna was low-profile and inconspicuous. The paint couldn't be fastened to so a conducting epoxy was utilized which kept up a solid bond all through the measurements.

### **3.4. Conducting Nylon**

Conducting nylon is accessible from an assortment of producers. The conducting nylon was glue backed and afterward cut into the bowtie and spiral patterns. The pattern was then held fast to the t-shirt. The adhesive framed a solid bond to the t-shirt. The conducting nylon couldn't be patched to so a conducting epoxy was utilized.

### **3.5. Phosphor Bronze Mesh**

Phosphor bronze lattice is commonly utilized for EMC protecting as a part of cloth. This material was again adhesive supported and cut into the spiral and bowtie shapes. The thermal conductivity was sufficient to weld straightforwardly to. It was seen that once collapsed the lattice would hold a curve which made the antenna more prominent when worn as the crimps were obviously unmistakable through the fabric.

### **3.6. Conducting Thread**

Conducting thread is appropriate for the spiral antenna however not for the wire dipole or bowtie. A nearby firm with a PC controlled weaving machine was utilized to make a spiral antenna. A glossy silk join was utilized to attempt and guarantee a decent leading way along the arms of the antenna. The balun was associated utilizing conducting epoxy.

### **3.7. Screen Print**

A conspicuous plan to compose a pattern onto a t-shirt is to utilize a conventional screen print method. Conducting ink reasonable for screen printing was obtained and trialed. The printed ink couldn't be fastened to specifically so a conducting epoxy was utilized to associate the balun.

### **3.8. LCP**

Liquid Crystal Polymer (LCP) is an option substrate material to polyimide for the assembling of adaptable PCBs. Normally the substrate and copper foil are secured with an external Kapton layer to give electrical protection and some dampness resistance. To enable simple configuration changes without the necessity for PCB layout and processing, beginning investigations were led on LCP with ½ ounce copper however not covered with Kapton. Segments can be specifically fastened to the LCP material.

### 3.9. Copper coated fabric

There is an assortment of business procedures accessible to coat fabric with copper. The antenna shape is characterized by veiling the fabric and the last item gives a flexible, low resistivity surface which frames a necessary part of the fabric with no extra holding operations. Electrical connection with the copper might be accomplished by binding. The fabric substrate was connected to the article of clothing utilizing iron-on adhesive. The adhesive was plainly unmistakable and made the antenna rather prominent so diverse glue techniques ought to be utilized.

## 4. DESIGNING WEARABLE ANTENNAS

### 4.1. Conductive material

Electro-textiles are conductive fabric built by introducing conductive metal/polymer threads with ordinary fabric. Characteristics of these fabrics, which are wearable, solid and adaptable, made it reasonable to be incorporated into apparel [12]. Ivo Locker in [13] talked about the necessities for conductive fabrics in outlining textile antennas. The conductive material was craved to have a low and stable electrical resistance ( $\leq 1\Omega/\text{Square}$ ) to minimize losses. Flexibility of the material was additionally required so that the Antenna can be disfigured.

Another scientist in [14] utilized an flexible material with the goal that it can be wrapped around an arm as appeared in Figure 6. The material utilized was woven conductive fabric sort, having a  $0.05\Omega/\text{square}$  of surface resistance and 0.125 mm thickness. The material choice is a basic stride when outlining an antenna, keeping in mind the end goal to be powerful and suited for specific applications. The work in [15], which utilized an aramid woven fabric as the material, is fire safe and appropriate for incorporation into flame warrior article of clothing. In [16], a profoundly conductive metalized Nylon fabric was utilized as the conveyor. Its three metalized layers (NI/Cu/Ag) gave high conductivity while the surface resistivity is  $0.03\Omega/\text{square}$ . Other than that, the material likewise gave flexibility and protection against erosion, which will be reasonable when connected in a profoundly destructive environment.



Figure 6: shows the drapability of the wearable antenna

### 4.2. Fabrication method

The creation methods, which will be incompletely controlled by the materials utilized as a part of outlining a textile antenna, is likewise another vital thought, in characterizing and deciding the general expense of the configuration. This is on account of various materials utilized as a part of the antenna design requires diverse manufacture strategies. The work in [17] investigated distinctive creation techniques did to manufacture the same measurement of microstrip patch antenna. The utilization of copper tape was

distinguished as the most straightforward method, as it can specifically be connected to the substrates, and has no additional creation procedure.

Other than that, a more adaptable manufacture strategy was to utilize a conductive spray technique, which can be connected to any textile material [17]. The spray, which is a blend of copper with gasses under pressure, can be utilized to get a conductive layer on the textile surfaces presented to the spray. Figure 7 demonstrates the microstrip patch created utilizing copper tape, woven copper thread and conductive spray.

Analysts in [18], then again, built an E-shaped patch antenna utilizing copper tape as the conducting elements, and felt fabric as the substrate. The copper tape was sliced by measurement of the E-shaped patch antenna and mounted on the felt fabric. Producing procedure of the textile UWB antenna utilizing high conductive metalized Nylon as a part of [19] was troublesome and must be done circumspectly. Measurement of the antenna must be held while being joined to the substrate utilizing cement that not influences the electrical properties of the material. A SMA jack was associated with the material antenna utilizing conductive two segment paste

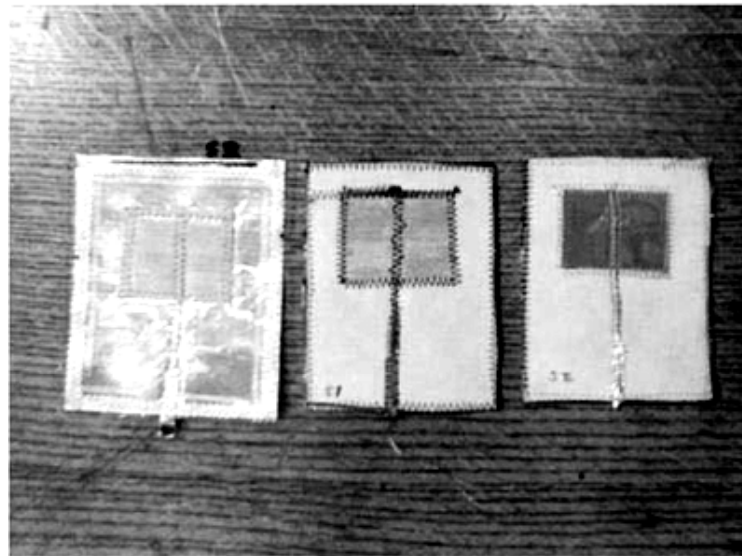


Figure 7: Fabricated textile patch antennas. From left to right; applying copper tape, woven copper thread and conductive spray

## 5. ANALYSIS REQUIRED FOR WEARABLE ANTENNAS

For the most part, the estimations required for ordinary antenna design are return loss, radiation pattern, gain and efficiency. Notwithstanding, conventional planar antenna are flattered, which makes it pointless to research its bending characteristics. Despite what might be expected, a wearable antenna requires different variables to be taken into cautious thought to ensure the execution of the antenna in a body-worn connection. This section will incorporate different estimations that must be completed in looking at a wearable antenna design.

### 5.1. SAR modeling

Open concern in regards to the wellbeing impacts of radiation and lawful prerequisites around the globe have asked specialists and scientists to dependably consider the measure of force consumed by the human body. Subsequently, specific absorption rate (SAR) by remote gadgets has been characterized. The two most regularly utilized SAR breaking point are those of IEEE [20] 1.6W/kg for any 1g of tissue, and ICNIRP (International Commission on Non-Ionizing Radiation Protection [21]) 2W/kg for any 10g of

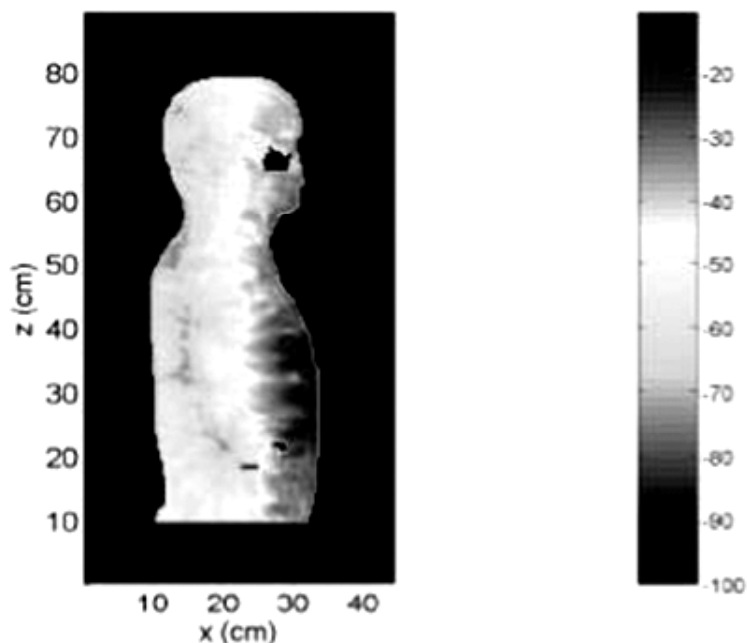


Figure 8: Computed SAR distributions at 2.2 GHz

tissue. In [22], a torso model built from CT and MRI picture of genuine human body was utilized in the SAR demonstrating. The model was utilized to contemplate the antenna execution when the antenna set was on the upper part of the human body. Figure 8 is a case of simulated SAR circulation at 2.2 GHz. From the simulated result, the SAR distribution was given for 1 Watt conveyed power and the colour bar demonstrated relative SAR value in dBi.

## 5.2. Measurement with different bending

Estimations for flexible wearable antenna must be finished with various bending position. This is to guarantee the antenna execution, in actuality, applications is up to mark, particularly when the antenna is connected to rounded parts of the body, for example, an arm. In [13],  $S_{11}$  estimations were completed utilizing distinctive bending states of the antenna. The antenna connected around a plastic cylinder was measured to research these bending characteristics. In view of the investigation, the resonance shifted towards the lower frequencies and the bandwidth got to be smaller when bent, independently of the bending direction. The smaller the bending is, the lower the frequency it got to be. Examiners in [10] have likewise discovered comparative estimation patterns while breaking down the bending characteristics.

One of the techniques to defeat this was the antenna must be designed with a wide frequency bandwidth. This is so that if the frequency truly shifted, the antenna will in any case have the capacity to work inside the wanted frequency range. Tanaka in [14] examined this through his measurement report for return loss when the H-plane and E-plane of the antenna were bent. The bending conditions were separated utilizing degrees.  $0^\circ$  showed that the antenna is flattered, while a  $90^\circ$  bending was demonstrated when the H-plane was bent into a V-shape at the bending centre of the microstrip antenna. A  $180^\circ$  bending demonstrated that the antenna was bent into U-shape. Comparative bending conditions likewise apply to the E-plane of the antenna.

## 5.3. On body measurements

Close to remain solitary antenna measurements, where the antenna was measured without presence of human body, onbody estimations must be done also, so as to find out the execution of the antenna at various on-body positions. Positions of wearable antennas will conceivably contrast, contingent upon the use of the antenna.



**Figure 9: Measurement setup for on-body measurement**

Wearable antennas may be intended to be set on the chest, arm, back of the body and so forth. In [17], the created antenna was measured in free space, on human chest and on the human arm. In [15] analysts additionally went similarly as including human body for the estimation. From these past examinations, it was discovered that the antenna put on the back of the body as appeared in Figure 9, is the most stable area that will decrease the change of body orientation thought about different parts, for example, the arm.

## 6. CONCLUSION

From the prospect, it is inferred that there are a few extra viewpoints to be checked when planning a wearable antenna, in contrast with a traditional antenna outline. It demonstrated that there exists a range of potential materials that could be utilized as a part of outlining wearable antennas. SAR investigations, estimations with various antenna bending and on body estimations must be done keeping in mind the end goal to acquire an antenna design that meets the wearable antenna detail. Wearable antennas are promising, and gloat an awesome future close by the advancement of the quickly developing wireless communication technology.

## REFERENCES

- [1] Hall, P. S., and Hao, Y., "Antennas and Propagation for Body Centric Communications", European Conference on Antennas and Propagation (EuCAP), November 2006.
- [2] Zhu, S.Z. and Langley, R., "Dual-band wearable textile antenna on an EBG substrate". IEEE Transactions on Antennas and Propagation, 57 (4). pp. 926-935, 2009.
- [3] P. Salonen, L. Sydanheimo, M. Keskilammi, M. Kivikoski, "A small planar inverted-F antenna for wearable applications". The Wearable Computers, 1999.
- [4] P. Salonen, J. Rantanen, , "A Dual Band and Wide-Band Antenna on Flexible Substrate for Smart Clothing", 27th Annual Conference of the IEEE, Vol.1, 2001.
- [5] J.C.G. Matthew, B. Pirollo, A. Tyler, G. Pettitt, "Body wearable antennas for UHF/VHF", Antennas and Propagation Conference, 2008.
- [6] M. Klemm, I. Locher, G. Troster, "A Novel Circularly Polarized Textile Antenna for Wearable Applications," the Wireless Technology, 2004.
- [7] C.A. Balanis, Antenna Theory: Analysis and Design. 3rd Ed. New York: John Wiley and Sons. Pg.859, 1997.
- [8] C. Hertleer, H. Rogier, L. Van Langenhove, "A Textile Antenna for Protective Clothing". the Antennas and Propagation for Body-Centric Wireless Communications, 2007.
- [9] S. Zhu, R.J. Langley, "Dual Band Body Worn Antenna". The Antennas and Propagation, 2007, EuCAP 2007.



- [10] C. Hertleer, A. Tronquo, H. Rogier, L. Vallozzi, L. Van Langenhove, "Aperture-Coupled Patch Antenna for Integration Into Wearable Textile Systems". *Antennas and Wireless Propagation Letters, IEEE*, 6, 392-395, 2007.
- [11] G. Kumar, K. R. Ray, *Broadband Microstrip Antenna*, Artech House. . pp. 162, 2003.
- [12] H.H. Kuhn, A.D. Child, "Electrically Conducting Textiles," in *Handbook of Conducting Polymers*, T. A. Skotheim, R. L. Elsenbaumer, and J. R. Reynolds, Eds., 2nd ed. New York: Marcel Dekker, 1998, pp. 993–1013.
- [13] I. Locher, M. Klemm, T. Kirstein, G. Troster, "Design and Characterization of Purely Textile Patch Antennas", *Advanced Packaging, IEEE Transactions on*, 29(4), 777-788, 2006.
- [14] M. Tanaka, J. Jae-Hyeuk, "Wearable Microstrip Antenna". *The Antennas and Propagation Society International Symposium*, 2003.
- [15] C. Hertleer, H. Rogier, L. Vallozzi, F. Declercq, "A Textile Antenna based on High-Performance Fabrics". *the Antennas and Propagation*, 2007. *EuCAP 2007*.
- [16] M. Klemm, G. Troster, "Textile UWB antenna for on-body communications". *the Antennas and Propagation*, 2006. *EuCAP 2006*.
- [17] J.G. Santas, A. Alomainy, H. Yang, "Textile Antennas for On- Body Communications: Techniques and Properties". *The Antennas and Propagation*, 2007. *EuCAP 2007*.
- [18] P. Salonen, K. Jaehoon, Y. Rahmat-Samii, "Dual-band E-shaped Patch Wearable Textile Antenna". *the Antennas and Propagation Society International Symposium*, 2005 *IEEE*.
- [19] M. Klemm, G. Troester, "Textile UWB Antennas for Wireless Body Area Networks". *IEEE Transactions on Antennas and Propagation*, Vol. 54, No. 11, November 2006.
- [20] *IEEE Standards for Safety Levels With Request to Human Exposure to Radiofrequency Electromagnetic Fields, 3kHz to 300GHz. IEEE Std. C95.1. 1999.*
- [21] ICNIRP (International Commission on Non-Ionizing Radiation Protection), "Guidelines for limiting exposure to time-varying electric magnetic, and electromagnetic fields (up to 300GHz)," *Health Phys.*, vol. 74, pp. 494-522, 1998.
- [22] Y. Rahmat-Samii, "Wearable and Implantable Antennas in Body-Centric Communications". *the Antennas and Propagation*, 2007. *EuCAP 2007*.
- [23] J. C. G. Matthews, G. Pettitt, "Development of Flexible, Wearable Antennas", *3rd European Conference on Antennas and Propagation*, 2009
- [24] N. H. M. Rais, P. J. Soh, F. Malek, S. Ahmad, N.B.M. Hashim, P.S Hall, "A Review of Wearable Antenna" *Loughborough Antennas & Propagation Conference*, 2009
- [25] Zhi hao jiang, donovan e. Brocker, peter e. Sieber, and douglas h. Werner, "A Compact, Low-Profile Metasurface-Enabled Antenna For Wearable Medical Body-Area Network Devices", *IEEE transactions on antennas and propagation*, vol. 62, no. 8, august 2014.
- [26] Bin Hu, Guo-Ping Gao, Le-Le He, Xiao-Dong Cong, and Jin-Ning Zhao, "Bending and On-Arm Effects on a Wearable Antenna for 2.45 GHz Body Area Network", *IEEE Antennas And Wireless Propagation Letters*, VOL. 15, 2016
- [27] Mai A.R.Osman, M.K.A. Rahim, N.A.Samsuri, Mohammed E. Ali, "Compact and Embroidered Textile Wearable Antenna", *IEEE International RF and Microwave Conference*, 2011.

