International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-5, March 2020

Recent Trends in Bio-Medical Textile Antennas

Regidi Suneetha, P V Sridevi

Abstract: *It is aimed to provide an insight on microstrip patch antenna in biomedical applications, the challenges and to discuss the procedure in the way they are dealt so far, in the literature. Microstrip patch antenna gained considerable scientific interest because of its integration with textiles, body mounted applications and medical implants. The ease of integration, confirmability, planar structure, miniaturization, patient safety and biocompatibility make pondering conclusion of intriguing mathematical and experimental paradigm. Simulation tools like HFSS, CST Microwave Studio etc., are being used and the antenna is fabricated after getting satisfactory results. The fabricated antenna is tested under various bio-medical, environmental and mechanical stress and strain conditions. The challenges along with some remedial solution are being discussed with envision to achieve painless, uncomplicated, trustworthy diagnosis and treatment.*

Keywords *: Biocompatibility, Electromagnetic (EM) Waves, Miniaturization, RF Shielding, Specific Absorption Rate (SAR), Wearability.*

I. INTRODUCTION

Great research is going on since 1950s in the field of Electromagnetic (EM) Waves leading to great results in various fields of communication, medicine etc., and various papers are being published on microstrip antenna. Antenna is a device which is used to transmit and receive radio signals or EM waves which travel with speed of light. Microstrip antenna is a concept which came into light in the year 1954, "The first symposium on microwave strip circuits" which was held on Oct 11and 12, 1954 at Tufts College, Boston. But it was practically came into existence during late 1970s after that extensive research is being done.

Wide research is going on biomedical antennas since late 1980s and it attracted serious attention of the antenna community during early years of 2000. There are hundreds of papers published in conferences, journals, magazines of research articles in archival journals. There were also several review articles, and few books available, [2–8].

Two frequency bands: MICS-Medical Implant Communications Service (402-405 MHz) and ISM-Industrial Scientific and Medical (2.4-2.47GHz) among the frequency bands which were regulated by the US Federal Communication Commission.

Revised Manuscript Received on March 30, 2020.
* Correspondence Author
Regidi Suneetha*, ECE Department, Andhra University College of Engineering(A), Andhra University, Visakhapatnam, India. Email: rsuneetha@rocketmail.com
Prof P V Sridevi*, ECE Department, Andhra University College of Engineering(A), Andhra University, Visakhapatnam, India. Email: pvsridevi1965@gmail.com

II. BIO-MEDICAL ANTENNAS

Bio-Medical antennas can be used for

(A) Information transmission.

Antennas play key role in information transmission right from very small antennas of pill size to very big antennas of room size. Miniatured [18-20] antennas of very small size antennas are supposed to provide various advantages like easy to swallow and operability, within the body without external connections, and they can also be surgically implanted to monitor specific body functions externally. The life cycles of various plants and animals are being studied from various on board satellites. Furthermore, birds and animals are equipped with small transmitters in order to monitor their activities, to avoid battery usage for wireless transmission of power, magnetic coupling is being implemented.

(B) Diagnosis

Ultra-wideband range (UWB) (3.1-10.6 GHz) biomedical radar systems are mostly preferred for monitoring physiological signatures, diagnostic inspection etc., Clinical diagnostic applications like ECG, EEG measurements require geometrically small antennas.

(C)Treatment.

In vivo and in vitro medical examinations [19] and treatments can be done using radiated heat from antennas for various diseases like tumors, cancers etc.,

The human body is non-homogenous in nature and due to different electrical properties, certain antenna parameters like resonant frequency, radiation efficiency and radiation pattern will vary. Materials play prominent role in designing the body implantable antennas.

Biocompatible insulation plays vital role and is a must to provide insulation from short circuit since the human body is highly conductive in nature and also needs protection from oxidation effects. Due to the biocompatible insulation the overall radiation efficiency of the antenna may get reduced, the transition of the EM wave between source and the human body model reduces the coupling of the high near field terms of the EM radiation in the surrounding living tissue. Thus, while designing implantable antennas for biomedical application an improvement in the radiation efficiency without any adverse effect on the human body is to be considered. The effect of radiation to the other organs can be reduced due to the ground plane while the normal-mode helical or dipole antennas do not have this advantage. This property is common for all planar antennas, which have a ground plane.

There by, the radiation to the human body is reduced because of the ground plane needed by the antenna which in turn reduces back radiation. The antennas in a free space environment do not show a good 50 ohm matching characteristic. It is noticed that due to high conductivity of various types of fluids inside the human body, wherever the antennas are located, the resonant characteristics are very similar. In low profile UWB PIFA (Planar Inverted F-Antenna) antenna, increase in the width of radiating patch or feed plate increases the bandwidth. Further increase in the distance of shorting plate from feed plate increases the resonant frequency as well as bandwidth. For maximum bandwidth both the radiating patch as well as feed plate should be placed near to the ground plane edge.

III. SPECIFIC ABSORPTION RATE (SAR)

When human body is exposed to the electromagnetic field, its natural tendency is to absorb the radiated energy. The rate at which RF energy is absorbed, is measured in terms, of power absorbed per mass of tissue that is in watts per kilogram. As human body is constituted of different tissues such as skin, blood, bone, muscle etc., the values of density, conductivity and dielectric differ with respect to the tissue. The high level of SAR means high level of radiation absorption which may lead to many health issues such as headache, insomnia and severe problems like cancers. Usually SAR is measured in SAR_{1g} and SAR_{10g} for mass averaging of 1g and 10g respectively.

$$SAR = P / \rho = \sigma E^2 /2\rho = J^2 /2\rho\sigma$$

Here, P is the power loss density within the human tissue, ρ is the tissue density, σ is the tissue conductivity, E is the Electric field strength, J is the current density. Australian Communication Authority Standard, Federal Communication Commission SAR limit is given as 2W/Kg in 10g of tissue, 1.6W/Kg in 1g of tissue.

Methods to decrease SAR value.

1) Positioning of RF Shields 2) Separating antenna from human body using Reflectors. 3) Using Metamaterials.

Due to the increasing demand and usage of wireless communication at higher and microwave frequencies. Base stations and WiFi access points are generating invisible electric and magnetic forces of radiation leading to electromagnetic pollution and interferences. This electromagnetic pollution may lead to small general health issues to severe health issues like fetal abnormalities in girls exposed to even low level of microwave radiations leading to genetic abnormalities affecting future generations. So it is required to use RF Shields and reflectors to decrease the effects of radiation on human body.

The author[24] choose a soft and skin friendly fabric, which is made of natural material 70% bamboo and 30% silver as shielding textile material. Using the above material vests were designed for pregnant women to completely cover the abdomen to protect the fetus from the electromagnetic radiations. It is observed from reflectivity measurement that for frequency range of 0.7 GHz-3 GHz fabric attenuation is 17.08 dB and fabric attenuation along with aluminum foil is 20.5, but it is not practically possible to use aluminum foil in the vests, only fabric is used as shield and in the place curtains both the fabric along with aluminum foil is used to get more shielding from radiation.

IV. TEXTILE ANTENNAS

(A) Relative Permittivity and thickness of the textile fabric.

S. Sankaralingam[8,9] have determined the dielectric constant of 6 different fabrics using technique based on resonance method of microstrip patch radiator to obtain dielectric constant of fabric, with advantages of good accuracy, simple sample preparation and fast measurement speed. They concluded that the textiles generally have low dielectric constant which are pretty much useful for the flexible textile antennas. These textile microstrip patch antennas may replace microstrip patch antennas on PCB for various applications especially bio medical applications due to the ease of drapability and flexibility during human body movements.[1]

Conductive threads are inserted into fabrics by means of weaving. Weaving styles of the textile conductive threads can be of two types 1) Plain weaving or Plain foil thread style 2) Twilled weaving or Twisted foil thread style.

[2] When conducting threads are used to create transmission lines in antennas, performance characteristics vary with respect to the type of conducting thread which is being used. It is stated by the author that by stitching using higher density and by stitching using procedure parallel to the transmission lines improved conductivity. It is also stated that the current flow direction is more in single thread to that of thread to thread in traverse direction.

Performance differ between conducting threads and conductivity improves by stitching along the length of the transmission line with increased density, the author suggests that the current prefers single thread than transverse movement from thread to thread, also stated that the conduction can be improved by preprocessing the thread. The author used plain thread.

[22,23] They used 3 different conductive materials, a flexible adhesive copper tape, an adhesive conductive fabric, and a conductive thread for evaluating the effects of bending. Flexible adhesive copper sheet with thickness 0.035 mm and conductivity of 5.8e7 S/m, adhesive Conductive Fabrics of ADFORS Saint-Gobain a non-woven fabric, with surface resistivity of 0.04 Ω/sq, is preferred because it has no fraying problems, and a conductive sewing thread of resistivity≤0.0025 Ω/sq, with diameter of 0.2 mm are being used by the authors. SMA coaxial connector is soldered via tin for the first two and via conductive epoxy for the third. Cutting plotter is adopted for shaping conductive parts for first two and cross-stitch embroidery is employed to realize conductive path for the third. However for integrating antenna into clothing the third prototype, conductive sewing thread is mostly suitable, is the conclusion made by the author based on the obtained measurements, for without and with bending conditions applied on the textile antennas.

Table 1

Table showing data of simulated and measured output for three different Conductive textile materials.

S N o	Material	Thickness	Conductivity	Result	Frequency (GHz)	S_{11}(dB)
1	Copper tape	0.035 mm	5.8e7 S/m	Simulated	2.55	27
				Measured	2.56	13
2	Conductive fabric	0.110 mm	2.27e5 S/m	Simulated	2.54	40
				Measured	2.45-2.55	19
3	Conductive thread	0.200 mm	2e6 S/m	Simulated	2.525	29
				Measured	2.21	22

The author insisted that encapsulation with thermoplastic polymer film, protected PCB from the mechanical stresses even after 50 washing cycles [13]. Smart textile can use the latex-based barrier for rigid electronic components like LEDs and ECG monitoring devices. The author concluded that the washability can be better by any of the above approaches or by combined approach.

In order to study the bending effects on the regular textile antenna, here two hallow dielectric cylinders of radius 35mm and 55mm are considered [26], when bending is through length (L) wise and width (W) wise individually, then it can be concluded that the resonant frequency is effected in both the cases independent of the radius of the cylinder and the effect is more in length wise bending compared to the width wise bending.

B) RFID TAGS (radio-frequency identification)

It is quiet necessary for an antenna to endure environmental stresses like harsh weather conditions, continuous washing and mechanical stresses like stretching, and in this paper author used [21] Graphene conductive material because of its mechanical and electrical properties, as it can be integrated easily with fabric materials. Deposition of graphene tag over the IC strap is done, thereby avoiding the usage of conductive glue and attaining wireless measurements without epoxy-glued ICs. The author achieved, for 850–900MHz, 5.2 meters of peak read ranges, however when high humid condition is considered the peak read range is 4.4m for epoxy-glued and 4.7m for printed antenna-IC interconnections. So, from the above measurements the author had supported the use of printed RFID joints. It is also observed that the moisture content affects the loss tangent and dielectric constant of the substrate, fabric thereby peak read ranges. In an another case [25] silver ink is used on a 100% fabric of cotton. Epoxy coating, silicone rubber and regular textile glue are used as protective coating materials after attaching the ICs. 10 meters good read ranges is obtained for all three different coating materials. When these tags were washed in a house hold washing machine for 15 times, all the three tags showed good performance even after washing, textile glue is more protective compared to three.

C) Miniaturization

Can be achieved by the usage of 1) High permittivity substrate 2) Increasing the length of the effective current flow path on the radiating patch. 3) Addition of shorting pins 4) Patch Stacking

Low profile planar inverted-F antenna (PIFA) takes the shape of tie pin which serves dual purpose and the advantage of antenna invisibility[15], gives the advantages of size reduction, increase in directivity and gain, reduction in radiation affect to the human body due to the presence of ground plane.

1^{st} and 2^{nd} iterations of Minkowski fractal geometry[20] are being used in order to attain miniaturization on Zeit and Flectron textiles. Here zeroth iteration is suitable for WLAN applications, 1^{st} iteration for WiBro and 2^{nd} iterations for GSM1900. The two textiles performance characteristics obtained are good. Zeit offers gain, impedance bandwidth of 7.4 dB, 104 MHz. Flectron offers gain, impedance bandwidth of 6.54 dB, 132 MHz. Zeit outperformed Flectron antenna because of its higher electrical conductivity and low conductor loss.

V. STANDARD TESTING METHODS

The electromagnetic solvers Ansoft *HFSS* uses Finite-Element (FE) Method and Finite-Difference Time-Domain (FDTD) Method for antenna design simulation software.

CST *Microwave Studio* is also being used for efficient modeling of biomedical antennas.

Electrical Surface Resistivity of Fabrics can be obtained from AATCC Test Method 76-2011.

DC Resistance or Conductance of Moderately Conductive materials can be obtained from ASTM D4496: 2004 Standard Test Method.

Electrical resistance of textile floor coverings can be determined using ISO 10965:2011.

Electrical resistance of light conveyor belts can be determined using ISO 21178:2005.

ASTM D4935 for far-field testing method.

IEC 61967-6 for near-field testing method.

VI. RESULTS

As SAR value is limited to 2W/Kg and 1.6W/Kg in 10g and 1g of tissue, by using aluminium foil along with curtains, the fabric attenuation is decreased by 3.42dB compared to curtains without using aluminium foil, thereby decreasing SAR value for curtains material using 70% bamboo and 30% silver. When conductive textile materials are considered, conductive sewing thread is mostly suitable. Conductivity can be improved by stitching conductive thread in parallel to transmission lines, using single thread and also by preprocessing of conductive thread. Reflection coefficient of conductive thread is 3dB more than conductive fabric and 9dB more than copper tape for (2-3) GHz frequency. When mechanical stresses are considered, the PCB is being protected due to thermoplastic polymer film encapsulation even after 50 wash cycles.

Miniaturization can be achieved by using textile materials with high permittivity substrate, higher electrical conductivity and low conductor loss.

VII. CONCLUSION

Hence it can be concluded that from the fast growing trends of technology, bio medical applications gained considerable amount of scientific interest along with challenges. The integration of textile materials in the fabrication of microstrip patch antennas is achieving solutions to the bio medical applications particularly due to the ease of integration, confirmability, miniaturization, patient safety, biocompatibility and wearability. The invisibility of antenna and miniaturization are pretty much required for specific applications. Bio-Medical antennas can be used for information transmission, diagnosis and treatment. In this paper various methods of decreasing SAR values are mentioned, the usage of skin friendly textile garments with decreasing radiation effects with protective shielding are prescribed. Three types of conductive textile materials are considered and their performances along with the affects of bending and washing with RFID tags on the textile antennas are discussed with practical examples, and it can be concluded that the effect is more in length wise bending compared to the width wise bending. Encapsulation of antenna is preferred as the resonant frequency is effected by the wear and tear and also with the number of wash cycles in cases without encapsulation. Textile glue offered good performance when RFID tags are considered. High electrical conductivity and low conductor loss of the textile material play a very prominent role in attaining miniaturization of the antenna. This field of multidisciplinary textile electromagnetic antennas require rigorous and enormous amount of research in order to achieve optimal performance level.

ACKNOWLEDGMENT

The authors would like to thank Andhra University college of Engineering (A), Andhra University, Visakhapatnam for providing the facilities and Diety, New Delhi for providing the fellowship under Visvesvaraya Ph.D Scheme for doing research.

REFERENCES

1. C. A. Balanis, Antenna Theory: Analysis and Design, Singapore: Wiley, 1997.
2. Small microstrip patch antenna R. Waterhouse (Department of Communication and Electronic Engineering. Royal Melbourne Institute of Technology, Melbourne, VIC 3000. Australia) Electronics Letters Online No : 19950426.
3. International Journal of Innovative Research in Computer and Communication Engineering Vol. 2, Issue 11, Nov 2014.
4. Muhammad Aamir Afridi Microstrip Patch Antenna − Designing at 2.4 GHz Frequency Biological and Chemical Research, Volume 2015, 128-132 | Science Signpost Publishing.
5. Design and Simulation of Microstrip Patch Array Antenna for Wireless Communication at 2.4GHz. Internationa Journal of Scientific & Engineering Research, Volume 3, Issue 11, November-2012 1 ISSN 2229-5518
6. Elias, N. A., Samsuri, N. A., Rahim, M. K. A., & Othman, N. (2015). Influence of bending of 900MHz textile antenna on specific absorption rate. 2014 IEEE Asia-Pacific Conference on Applied Electromagnetics, APACE2014-Proceeding,261–264 https://doi.org/10.1109/APACE.2014.7043796
7. Soh, P. J., Vandenbosch, G. A. E., Wee, F. H., Van Den Bosch, A., Martinez-Vazquez, M., & Schreurs, D. M. M. P. (2013). Specific Absorption Rate (SAR) evaluation of biomedical telemetry textile antennas. IEEE MTT-S International Microwave Symposium Digest, (c), 1–3.
8. Ingale, T., Ingale, C., Trikolikar, A. A., Rathore, G., & Latane, P. C. (2014). Effect of Different Substrate Material on Performance of H Shaped Patch Antenna. International Journal of Innovative Research in Computer and Communication Engineeri8ng(IJIRCCE), 2(11), 6529–6534.
9. Sankaralingam, S., & Gupta, B. (2010). Determination of dielectric constant of fabric materials and their use as substrates for design and development of antennas for wearable applications. IEEE Transactions on Instrumentation and Measurement, 59(12), 3122–3130.
10. Florencio Díaz, R., Rodríguez Boix, R., Carrasco Yépez, F., Encinar Garcinuño, J., Barba Gea, M., & Pérez Palomino, G. (2014). Broadband reflectarrays made of cells with three coplanar parallel dipoles. Microwave And Optical Technology Letters, 56(3), 748–753.
11. Mehmann, A. (2017). Textile Antennas. (April), 139–159.
12. Salvado, R., Loss, C., Gon, & Pinho, P. (2012). Textile materials for the design of wearable antennas: A survey.Sensors (Switzerland), 12(11), 15841–15857.
13. Tao, X., Koncar, V., Huang, T. H., Shen, C. L., Ko, Y. C., & Jou, G. T. (2017). How to make reliable, washable, and wearable textronic devices. Sensors (Switzerland), 17(4).
14. Gil, I., & Fern, R. (2019). Wearable GPS Patch Antenna on Jeans Fabric. 8–11. https://doi.org/10.1109/PIERS.2016.7734859
15. Salonen, P., Sydänheimo, L., Keskilammi, M., Kivikoski, M., & Box, P. O. (n.d.). A Small Planar Inverted-F Antenna for Wearable Applications.
16. Shawl, R. K. (2007). The Characterization of Conductive Textile Materials Intended for Radio Frequency Applications. 49(3).
17. Chen, X., Ukkonen, L., & Björninen, T. (2016). Passive E-Textile UHF RFID-Based Wireless Strain Sensors. 16(22), 7835–7836.
18. Agneessens, S., Member, S., Lemey, S., Vervust, T., Rogier, H., & Member, S. (2015). Wearable , Small , and Robust : The Circular Quarter-Mode Textile Antenna. IEEE Antennas and Wireless Propagation Letters, 14, 1482–1485.
19. Liu, C., Member, S., Guo, Y., & Member, S. (2015). In Vivo Testing of Circularly Polarized Implantable Antennas in Rats. IEEE Antennas and Wireless Propagation Letters, 14, 783–786.
20. Subramaniam, S., Dhar, S., Patra, K., Gupta, B., Osman, L., Zeouga, K., & Gharsallah, A. (2014). Miniaturization of Wearable Electro-textile Antennas using Minkowski Fractal Geometry. 2014 IEEE Antennas and Propagation Society International Symposium (APSURSI), 309–310.
21. He, H., Akbari, M., Sydänheimo, L., Ukkonen, L., & Virkki, J. (2017). 3D-Printed Graphene Antennas and Interconnections for Textile RFID Tags : Fabrication and Reliability towards Humidity. 2017.
22. Monti, G., Corchia, L., & Tarricone, L. (2013a). Fabrication Techniques for Wearable Antennas. 2013 European Microwave Conference, 1747–1750. https://doi.org/10.23919/EuMC.2013.6687015
23. Monti, G., Corchia, L., & Tarricone, L. (2013b). Fabrication Techniques for Wearable Antennas. 2013 European Radar Conference, 435–438.

AUTHORS PROFILE

Regidi Suneetha presently pursuing full time PhD at Andhra University College of Engineering (A) under Visvesvaraya Phd Scheme is an IEEE member. She received BE, MTech from Andhra University College of Engineering from ECE Department.

Dr P V Sridevi is working as Professor in the Department of ECE, Andhra University College of Engineering (A). She published various articles in reputed National and International journals. Her area of interests include Antennas, VLSI Design, Wireless Communications, Image Processing and Nano Technology.