IEEE Paper Referred

https://ieeexplore.ieee.org/document/7289377

SciHub Link

In this paper there is a lot of trend analysis for gain and bandwidth with reference to electrical height, may be we can try for the improvements…

https://ieeexplore.ieee.org/document/8359339

In this paper there used a gain enhancing method by substrate I think we may look the this and thick any way to increase gain……—---

https://sci-hub.hkvisa.net/https://ieeexplore.ieee.org/document/8675254

In this paper there are different designing of patch antenna so we can try a different design.

https://sci-hub.hkvisa.net/10.1109/TAP.2018.2820733

The usage of metamaterial structure affecting the gain and SAR …

https://ieeexplore.ieee.org/document/9316279

The paper implements different patch antenna so that the SAR and other params are altered.

https://ieeexplore.ieee.org/document/9263312

Meaderline antenna is proposed and the discussion on gain is not there and Bandwidth is discussed..

https://doi.org/10.1109/LAWP.2020.3019462

BW of antenna can be increased by manipulating DGS without changing the size of antenna.

https://doi.org/10.1109/APUSNCURSINRSM.2019.8888646

Foldable antenna shows increase in resonance frequency ,size of antenna also reduced

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WHAT ARE FLEXIBLE ANTENNAS

https://www.mdpi.com/2072-666X/11/9/847/htm

The demand for wearable devices, military applications, health monitoring systems, communication devices, and global positioning systems (GPS)

Recent innovations in engineered materials have been leveraged to augment the field of flexible electronics.

Flexible electronic devices are often lightweight, portable, less expensive, environment friendly, and disposable. The flexible electronics market is expected to reach 40.37 billion in revenue by 2023. Flexible electronic systems require the integration of flexible antennas operating in specific frequency bands to provide wireless connectivity, which is a necessity in today's information-oriented society.

Mechanically foldable antenna structures are typically used to modify their electromagnetic (EM) properties by reconfiguring their shape [1]-[3]. These antenna designs are recently emerging as highly promising for applications that require reconfigurable performance, including military, space, and other wireless communication systems [4]. By contrast, there exist wireless applications where antennas are unavoidably prone to folding, yet their EM performance should remain ideally uninterrupted (e.g., wearables)

https://sci-hub.se/https://ieeexplore.ieee.org/document/8888646

Flexible Antennas: A Review Sharadindu Gopal Kirtania 1 , Alan Wesley Elger 1 , Md. Rabiul Hasan 1 , Anna Wisniewska 1 , Karthik Sekhar 2 , Tutku Karacolak 1 and Praveen Kumar Sekhar 1,

Miniaturized and flexible energy storage and self powered wireless components.

Desirable features

Low cost requirements to produce billions in quantity, disposable in some cases

Flexible lightweight compact mechanically robust efficient desirable radiation characteristics

Applications

Biomedical monitoring, WLAN (wireless local-area network (WLAN) is **a group of colocated computers or other devices that form a network based on radio transmissions rather than wired connections**. A Wi-Fi network is a type of WLAN), beam switching detection system, wearable head imaging systems, RF energy harvesting, wearable glasses, UWB (What is UWB used for?

Ultra-wideband (UWB) is a radio-based communication technology for **short-range use and fast and stable transmission of data**.), etc

The markets for flexible wireless devices are rapidly increasing partly due to the demands in wearable and implantable devices for health-monitoring systems and daily-life wireless devices (e.g., cell phones, laptop computers, etc.). For this reason, the need for flexible printed antennas has increased in recent years, especially for biomedical applications [10,11].

A review of flexible perovskite oxide ferroelectric films and their application - ScienceDirect

Internet of Things: Architectures, Protocols, and Applications (hindawi.com)

Specifically, flexible antennas are a major component in the implementation of in vivo monitoring of vital signs, regulation of organ functions, neural interfaces, continuous gait analysis, intracranial sensors, drug delivery systems, and countless other functions [12,13].

164382.pdf (gla.ac.uk)

(PDF) Flexible Electronics: The Next Ubiquitous Platform (researchgate.net)

To integrate the devices onto the human body characterized by curvilinear surfaces and dynamically changing motions, the device must be conformal and physically flexible or even stretchable. Because the bending stiffness of a thin film structure that characterizes its resistance against bending deformation roughly scales with the cubic of its thickness thinning down, the thickness of the structure represents an effective means to enable flexible/bendable antennas. Apart from biomedical applications, there is shared interest between Federal agencies, industry, and academia in developing a flexible antenna for extreme conditions. Federal agencies' applications for high-temperature flexible devices include: the new gas-cooled nuclear reactor (high-temperature H2 safety monitors) and strict automotive emissions control requirements (tailpipe sensors) from the Department of Energy (DOE); requirement of flexible antennas and antenna radomes with extreme thermal shock resistance for missile applications and high-temperature substrates for hypersonic antennas for the Department of Defense (DoD); communication solution for beyond-line-of-sight communications on small- to medium-scale unmanned aircraft systems (UAS) for the National Aeronautics and Space Administration (NASA); and Wireless Physiological and Environmental Monitoring (WiPEM) system requirement (for first responders) from the Department of Homeland Security (DHS).

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Applications of Flexible Antennas under Different Frequency Bands

DIFFERENT MATERIALS USED …….

1.A compact wideband flexible implantable slot antenna ......

https://ieeexplore.ieee.org/document/8359339

a.implantable antenna is designed using thin and biocompatible substrate-superstrate layers to
achieve human body insulation as well as flexibility
b.To improve the antenna gain, a metamaterial (MTM) array with epsilon very large (EVL) behavior has been introduced on the superstrate of the implantable antenna
These ring slots with the outer radius R1 and R2 respectively, are fabricated on a 10 mm × 10 mm Kapton polyimide substrate with dielectric constant (εr) 2.91 and loss tangent 0.005. A superstrate layer of Rogers 6010 having high dielectric constant 10.2 and loss tangent 0.0023 is placed over the antenna. High dielectric value of the superstrate material decouples the antenna from the absorbing, lossy surrounding as well as stabilizes the effective permittivity fluctuations around the antenna [18]. Both these substrate and superstrate materials are chosen based on impedance matching, minimum reflection and biocompatibility
Result -an antenna gain enhancement technique is discussed using MTM loaded superstrate. This technique ensures no additional dielectric structure is required and allows the pre-existing antenna superstrate to be used for metamaterial designing. Thus this technique makes the MTM loaded antenna configuration compact and fully implantable. It has also been observed that due to the inclusion of MTM superstrate, the SAR value of the antenna doesn't change significantly.

2.A Compact, Low-Profile Fractal Antenna for Wearable On-Body WBAN Applications
https://sci-hub.hkvisa.net/https://ieeexplore.ieee.org/document/8675254
The proposed triangular patch antenna is designed using low-cost widely available vinyl polymer-based flexible substrate
analysis shows that extremely small frequency detuning is caused by various bending radii which makes our structure highly conformal and good candidate for body-worn devices

3.Investigation of SAR Reduction Using Flexible Antenna with Metamaterial Structure in Wireless Body Area Network
https://sci-hub.hkvisa.net/10.1109/TAP.2018.2820733
, which makes the antPolyimide substanceenna thin and bendable, is used as the substrate for the antenna,he antenna gain is increased by 9.3 dB and 5.37 dB, and the radiation efficiency is increased by 48.4% and 35.7%, at 2.45 and 5.8 GHz, respectively. In addition, the specific absorption rate (SAR) is decreased by more than 70%

4.A Method to Realize Robust Flexible Electronically Tunable AntennasusingPolymer-Embedded Conductive Fabric
https://doi.org/10.1109/TAP.2017.2772036
Conductive fabric is used to form the conducting parts of the antenna on a PDMS substrate.

t. The tests demonstrated that lumped components and other antenna parts remained intact and in working order even under extreme bending (to a bending radius of 28 mm) and after washing, thus maintaining the overall antenna performance including good frequency reconfigurability from 2.3 to 2.68 GHz

For realization of the antenna conductive parts, i.e., the ground plane and patches, we used NCS95R-CR, a nylon ripstop fabric coated with nickel, copper, silver and a waterresistant layer, which is readily available from Marktek Inc. Its nominal thickness is 0.13 mm and it has a very low sheet resistance of less than 0.01 Ω/sq. As the substrate and the complete encapsulation of the fabric antenna, PDMS was chosen over other textile or flexible polymer materials due to the desirable properties of PDMS such as water resistance, thermal and chemical stability, transparency, and most importantly an extremely low Young's modulus, which means high flexibility [11], [27]

5.Realization of 3D Flexible Antennas using Liquid Metal and Additive Printing Technologies
https://sci-hub.hkvisa.net/10.1109/LAWP.2016.2615568
combination of three different materials: (a) the Galinstan liquid metal [14], which is used to realize the radiating element, (b) the Ninjaflex flexible plastic used to realize, through a 3D FDM printing process, the dielectric substrate encapsulating the liquid metal, and (3) the electro-textile copper constituting the antenna ground plane.
The obtained experimental results confirm the possibility of realizing flexible miniature antennas with good impedance matching and fair total efficiency. These performance are maintained when the antenna is bent and placed over a human body phantom.

6.Dual-Band Elliptical Planar Conductive Polymer Antenna Printed on a Flexible Substrate
https://sci-hub.hkvisa.net/10.1109/TAP.2015.2479643

an organic antenna using multiwall CNTs doped-PANI is proposed. The substrate selected is kapton because it offers desirable mechanical properties (flexible, conformal, and lightweight) allowing the development of mechanically flexible planar antennas with potentially complex geometries. It has been demonstrated that the flexibility of both, the kapton substrate and the doped conductive polymer, gives the possibility of building crumpled antennas with good performance evaluated in simulations and measurements
One of the main interests of this kind of antennas is the possibility to integrate them in future flexible electronic devices that operate in multiple frequency bands and in body-worn electronics thanks to crumpling possibilities without impairing mechanical and electrical properties.

7.A Transparent and Flexible Polymer-Fabric Tissue UWB Antenna for Future Wireless Networks
https://sci-hub.hkvisa.net/10.1109/lawp.2016.2633790

wideband (UWB) antenna that uses a transparent conductive fabric tissue on a polydimethylsiloxane (PDMS) substrate is presented in this letter. The fabric tissue is integrated onto the PDMS having a thickness of 2 mm to produce an efficient UWB antenna These results denote that the antenna can perform well under bending conditions. Table II shows the measured efficiency and gain respectively in flat and curved situations; these indicate a high value of efficiency at lower spectrum while the value slightly dicreases at higher frequencies because of conductive and dilectric loss increase at such frequencies; and the gain showed satisfactory values when antenna is flat, further proving the stable performance. The gain exhibit a noticeable change when the antenna is bent.

8.Compact, Flexible, and Transparent Antennas Based on Embedded Metallic Mesh for Wearable Devices in 5G Wireless Network
https://sci-hub.hkvisa.net/10.1109/TAP.2020.3035911
and flexible 5G multipleinput multiple-output (MIMO) and millimeter wave (mmW) array antennas with Ni-based embedded metallic mesh (EMM) nanotechnology are presented for the next-generation wireless communication in emerging application
s. The EMM has the advantages of high conductivity, superior transparency, and mechanical stability.
antenna based on the EMM exhibits superior transparency of 93%, optimal radiation efficiency up to 85%, isolation above 20 dB, envelope correlation coefficient (ECC) under 0.005, and operation in 5G n79 band (4.4–5 GHz). The measured results are in good agreement with the simulated results. In addition, transparent and flexible 5G mmW arrays with a maximum gain of 9.6 dBi and a scanning angle of approximately ±75◦ are demonstrated in the 26 and 28 GHz bands

9.Permittivity-Customizable Ceramic-Doped Silicone Substrates Shaped with 3D-Printed Molds to Design Flexible and Conformal Antennas
https://sci-hub.se/https://doi.org/10.1109/TAP.2020.2969748
is based on the synthesis of compounds of silicone and powders of ceramic materials, such as Alumina and Barium Titanate, which are shaped through specifically designed 3D-printed molds.
all the obtained results demonstrate that the proposed approach provides a possible alternative for realizing 3D, customized, and robust antennas whenever the electromagnetic/mechanical performance of conventional 3D-printing materials are not satisfactory.

10.An overview of Electromagnetic Band-Gap Integrated Wearable Antennas
https://sci-hub.se/https://doi.org/10.1109/ACCESS.2020.2982965

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Ideal Parameters of Flexible Antennas for WBAN

- The substrate material used in flexible antenna needs to possess minimal dielectric loss, low relative permittivity, low coefficient of thermal expansion, and high thermal conductivity.
- The antenna should be operated at Ultra high frequencies of 1.5 - 5 GHz range. But **Federal Communications Commission(FCC)** has opened an unlicensed frequency band around 60GHz, given the smaller wavelength and the higher free space attenuations at such frequencies, it is easier to confine the signal around human body.
- On Body Communication desire wide beam or omnidirectional radiations in the plane parallel to human body surface to provide maximum coverage over the body.
- According to IEEE 95.1 and International Commission on Non-Ionizing Radiation Protection(ICNIRP) the Specific Absorption Rate(SAR) for On Body Antennas is 1.6W/kg for any 1g of tissue and 2W/kg for any 10g of tissue.
- According to IEEE 802.15.6 Standard the Maximum Data Rate should be in range of 0.0919 - 0.4857 Mbps
- The Gain for the WBAN antenna can range from 2.24 - 7.53dB however when the antenna come in contact with Human Body this gain value decreases as Human body is a lossy medium, when loss added to the substrate loss no matter what substrate you are using, the body tissue helps in impedance matching, the lossy body is a good absorber so gain decreases.
- The Reflection Coefficient for the WBAN antenna can be in between -8dB and -30dB.
- The VSWR for the most of Antenna Applications should be less than 2.
- A Return Loss of 20dB is considered quite good for the Antenna Application

References

1. Flexible Antennas: A Review Sharadindu Gopal Kirtania 1 , Alan Wesley Elger 1 , Md. Rabiul Hasan 1 , Anna Wisniewska 1 , Karthik Sekhar 2 , Tutku Karacolak 1 and Praveen Kumar Sekhar 1
2. https://www.slideshare.net/AbhilashPV5/wearable-textile-antenna-144633922
3. IEEE 802.15.6 Standard
4. https://www.researchgate.net/figure/Reflection-coefficient-for-three-antenna-configurations_fig7_342099122

For Final Year Project Presentation 2(b/w 28 th and 30th November)(as per academic calender)

ShortListed Journal Papers for Designing Approach

- https://ieeexplore.ieee.org/document/7289377

  SciHub Link
- https://ieeexplore.ieee.org/document/9263312

  SciHub Link
- https://ieeexplore.ieee.org/document/7299292

  SciHub Link
- https://ieeexplore.ieee.org/document/7929394

  SciHub Link
- https://ieeexplore.ieee.org/document/8630967

  SciHub Link
- https://ieeexplore.ieee.org/document/8359339

  SciHub Link

Selected Journal Paper for Designing

- https://ieeexplore.ieee.org/document/9263312

  SciHub Link

Introduction to Microstrip Patch Antenna(timestamp-20:20))

CST_Design_Tutorial

Start the designing of basic Microstrip Patch Antenna

Substrate Material : Paper

Patch and Ground Plane Material : Copper

Parameters for designing

⇒ Patch

Width(W) = 48.58263 mm

Length(L) = 39.5 mm

Thickness(t) = 0.035 mm

⇒ Feed Line

Width(Wf) = 4.7788049746335 mm

Length(Lf) = 22.393485804682 mm

Thickness(tf) = t = 0.035 mm

Electrical Length of Feed = 90 Degree

Impedance(Zo) = 50 ohm

⇒ Substrate : Paper

Width(Ws) = W+6h mm

Length(Ls) = L+6h+18 mm

Thickness(h) =1.6 mm

Dielectric Constant(ε_r) = 2.31

⇒ Calculators Used

https://www.emtalk.com/mscalc.php

https://www.everythingrf.com/rf-calculators/microstrip-patch-antenna-calculator

Frequency for simulation : 1.5 - 3.5 GHz

Resonance Frequency : 2.4

Results with above parameters:

Parameter	Achieved Value
S11	-4.1026dB
Gain	6.49dBi

⇒Parameters and Design Updation to get better results:

Alter the feed line, make it two, you can cut the existing one,

Two feed lines

Feed line 1:

Width = Wf

Length = Lf/2

Feed Line 2:

Width = Wf/2

Length = Lf/2

Feed line 2 should start above the feed line 1

The below results are with two feed lines

Res. F (GHZ)	W (mm)	L (mm)	Wf (mm)	Lf (mm)	Ws (mm)	Ls (mm)	t (mm)	h (mm)	Gain (dBi)	S11 (dB)
2.4	48.58263	39.5	4.778804974633 5	22.39348580468 2	W+6h	L+6h+18	0.035	1.6	6.65	-7.5098
2.4	48.58263	39.5	3	18	“	“	0.035	1.6	6.68	-10.263
2.4	“	39.2	2	9	“	L+6h+6	0.035	1.6	6.08	-15.669055

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Questions asked on 29 NOV presentation-

1.why paper used as substrate,why not jeans as the antenna is for wearable purpose ;what happens when jeans are used as substrate?

2.why microstrip line used for feeding ;why not use coaxial cable?

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<u>For Final Year Project Re-Presentation(on 04th January, 2023)</u>

Task is to design an antenna using a jean substrate and to achieve optimal s11 value followed by optimal gain value.

<u>⇒Avish’s Work</u>

Reference	**Jean Substrate values**	**Jeans Thickness**
https://www.ijert.org/research/wearable-textile-patch-antenna-using-jeans-as-substrate-at-2.45-ghz-IJERTV3IS050548.pdf	Dielectric constant = 1.6	3.5 mm
https://www.academia.edu/71177364/Novel_Electro_Textile_Patch_Antenna_on_Jeans_Substrate_for_Wearable_Applications	Dielectric constant = 1.75 Loss tangent = 0.085	0.6mm
https://sci-hub.se/https://doi.org/10.1109/SPIN.2018.8474082	permittivity of substrate =1.7	1mm
https://sci-hub.se/https://doi.org/10.1109/APUSNCURSINRSM.2017.8073359	1.Dielectric constant = 1.73 Loss tangent = 0.078 2.Dielectric constant = 1.69 Loss tangent = 0.073 3.Dielectric constant = 1.78 Loss tangent = 0.085	0.6mm
https://ieeexplore.ieee.org/document/9704255	dielectric permittivity of 1.7	—----

Antenna v1.1
Dielectric 1.78
W - 51.92993

L - 43.35791
H -
Ws -120
Ls - 120
Hs-

version	Freq	Ws	Ls	Wp	Lp	Hs	Wf	Lf	W1	L1	Slot with radius at center	Hf	Gain	S11
v	2.417	120	120	52	43	3.5	3	17	0.8	8	n	0.035	3.214	-10.104
v	2.5	‘’	‘’	‘’	‘’	1	‘’	‘’	‘’	‘’	n	‘’	-0.57dBi	-8.65
	2.45	‘’	‘’	‘’	‘’	2	‘’	‘’	‘’	‘’	n	‘’	2.034	-10.95
	2.53	‘’	‘’	‘’	‘’	0.6	‘’	‘’	‘’	‘’	n	‘’	-2.85	-7.47
v6_3	2.43	80	120	52	43	0.6	3.7	20	2	2	5	0.035	-4.007dBi	-15.25
n1	2.44	120	120	70	‘’	‘’	‘’	‘’	‘’	‘’	‘’	‘’	-2.244	-10

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⇒**Sai’s Work**
Substrate is changed from **Paper** to **jeans**
ISM Frequency Band = 2.45GHz

Referred papers for jeans substrate properties for flexible antennas

Research Paper Link	Jeans Substrate Properties	Achieved Parameters
https://ieeexplore.ieee.org/document/8934451	Dielectric Constant(ε_r) = 1.78 Loss Tangent(tanδ) = 0.085 Height(h) = 0.6 mm	S11 = <= -20dB Gain = 2.061dBi SAR = 1.14873 W/kg
https://ieeexplore.ieee.org/document/8275981	Dielectric Constant(ε_r) = 1.7 Loss Tangent(tanδ) = 0.085 Height(h) = 1.5 mm	S11 = <= -31dB Gain = 3.8dBi
http://www.ijiee.org/vol8/687-E315.pdf	Dielectric Constant(ε_r) = 1.68 Loss Tangent(tanδ) = 0.01 Height(h) = 1mm	S11 = <= -30dB

⇒Designing Of Antenna

Substrate Material : Jeans
Patch and Ground Plane Material : Copper

→Parameters for designing

- Patch

    Width(W) = 52 mm

    Length(L) = 45.5 mm

    Thickness(t) = 0.035 mm

- Feed Line

    Width(Wf) = 2.125 mm

    Length(Lf) = 24.38 mm

    Thickness(tf) = t = 0.035 mm

    Electrical Length of Feed = 89.987699251203 ~ 90 Degree

    Impedance(Zo) = 49.994913161355 ~ 50 ohm

- Substrate : Jeans

    Width(Ws) = W+6h mm

Length(Ls) = L+6h+22.6 mm

Thickness(h) = 0.6 mm

Dielectric Constant(ε_r) = 1.78

Loss Tangent(tanδ) = 0.085

→Results

Frequency Range — 1 - 5 GHz

Resonating Frequency - 2.45GHz

Design File(Alphabet)	**W (mm)**	**L (mm)**	**t (mm)**	**Wf (mm)**	**Lf (mm)**	**h (mm)**	**Ws (mm)**	**Ls (mm)**	**S11 peaks (dB)**	**Gain (dBi) (2.45GHz)**
A	52	45.5	0.035	2.125	24.38	0.6	W+6h	L+6h+22.6	-9.479 at 2.3831GHz -16.271424 at 4.94GHz	-4.061
B New slots were Intr..	52	45	"	2	24	"	"	"	-33.394027 at 2.452GHz	-14.3
C slot on GROUND	62	50	"	2.015	23.985	1	"	"	-17.26 at 2.452GHz	3.12

To Enhance the Gain of Antenna

- https://ijneam.unimap.edu.my/images/PDF/IJNEAM%20SPECIAL%20ISSUE%20MEI%202020/Vol_13_SI_Mei2020_211-224.pdf

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Comparision Table **Link**

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