Implementation of Minkowski Fractal Geometry Antenna Design for Multiband Application

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* Corresponding Author: Ankit Kumar Manuscript Received: Manuscript Accepted:

Abstract

This paper manages scaling down and tuning of wearable electro-textile antennas by the utilization of Minkowski fractal geometries and tuning holes. It is a challenging task today to explore body mounted antenna system for various monitoring applications. The increasing interest in wearable product such as medical devices, health monitoring, sport wear and military domains promises to replace wired-communication networks in the near future in which antennas play a paramount role. By varying the size of slot present in the Minkowski fractal geometries we can change the resonant frequency as per requirement. Previous work done using the same geometry increases the complexity as number of iterations increases only up to 2nd iteration. The use of tuning holes for the development of WLAN/WiBro and GSM 1900 antennas has been demonstrated for the first time in this research work. These designs result in good impedance and radiation characteristics of antennas. Wearable electro-textile patch antenna is designed by using Minkowski fractal geometries with tuning hole for 0th, 1st, 2nd and proposed iterations (3rd iteration). Different electro-textile materials used for wearable electronics (like polyester fabric) are considered for the substrate (or dielectric medium) configuration of Micro-strip antennas. Three highly efficient and flexible antennas, built using three different conductive fabrics and an insulating polyester fabric are evaluated and results reported in this paper by simulation in CST software. Also hardware implemented of the same antenna and results were measured for Minskowki fractal geometry with tuning holes for Aluminum material and its results were compared with simulated software results. The hardware designed antenna can be used for WiBro/WLAN and GSM 1900 applications. In the essential outline these antennas are intended for WLAN applications and hence specifically tuned by tuning holes designed over the patch. The Flectron antenna provides a gain of 6.89 dB with an impedance bandwidth of 82 MHz whereas, the Zelt antenna offers a gain of 7.96 dB and an impedance bandwidth of 55 MHz the Aluminum antenna offers a gain of 7.94 dB and an impedance bandwidth of 53 MHz, by applying Minkowski fractal geometry to the antennas, miniaturization is achieved. In its first iteration, antenna designs are optimized and tuned to WiBro band and in the second iteration antennas are further miniaturized in order to make them suitable for GSM 1900 applications. In these two bands, the gain and efficiency of these Flectron, Zelt and Aluminum antennas confirm to their respective wireless standards. The simulation studies reveal that Zelt antenna yields better results compared to Flectron and Aluminum antenna for proposed (3rd iteration). Also the impact of different iterations is also considered to make them suitable for GSM 1900 applications. Thus, in this analysis, the performance and limitations of these designs in accordance with their separate operating environment are also compared. The tuning holes yields better results contrasted with normal antenna.

Keywords: Minokowski Geometry, Zelt Antenna, Flectron Antenna, Fabrication, CST, Micro-strip Antenna

1. ***INTRODUCTION***

Improvement of wearable Micro-strip antennas has quickly enlarged within the recent past, as Micro-strip style is easy to any form. Antenna properties like reduced size, straightforward creation; mechanical ability and ease square measure crucial wants to set up antennas for wearable applications. The concept of making reduced antennas by applying cutting down procedure utilizing geometry was already tested technique. The pattern components turn out "fractal loading" and allow the formation of smaller sized antennas for a given frequency of operation. Commonly 50-75% shrinkage is possible by utilizing a pattern configuration whereas maintaining the performance [1-2].

Fractal associate degree antennas likewise offer varied alternative benefits like they'll be astonishingly very little for applications obliging an put in antenna, for clear substrate materials it's attainable to style nearly unbearable larger scale structure, it conjointly has lowers price and enhances desirability. The target of this paper is to check, analyze style and describe wearable pattern antennas capable of operating with trendy wireless standards. varied structures of fractals are tested so as to realize a comparison between them and therefore the parameters like radiation patterns, come back loss, BW, SWR curves, input resistance are wont to compare these antennas.

Other objective is to form associate degree antenna capable to work consistent with the IEEE 802.11 standards (802.11a = 5,235 to 5,350 GHz and 5,725 to 5,875 GHz, 802.11b = 2,412 to 2,472 GHz and 802.11g = 2,412 to 2,472 GHz). The remainder of the paper is organized as follows: second section describes the properties of Hermann Minkowski island pattern and its generation method [3]. The third section presents the antenna style parameters. Then the performance characteristics of all designed antennas are compared in fourth section. Finally the conclusion is drawn on the idea of those results are show in fifth Section.

Communication between humans was 1st by sound from setting out to finish voice. With the will for to some extent additional distance communication came like drums visual strategies signal flags and smoke signals were used. These communication optical devices utilized the sunshine portion of spectrum. It’s been utilized for communication that solely terribly recent in human history that the spectrum outside the visible region through the utilization of radio.

Their search work bestowed here is primarily supposed to investigate geometrical options of fractals that influence the performance of antennas victimization them. Many antenna configurations supported pattern geometries are rumored in recent years [1] – [4]. These are low profile antennas with moderate gain and may be created operative at multiple frequency bands and thus are multi-functional. During this work the multi-band (multifunctional) side of antenna styles are explored any with special stress on distinguishing pattern properties that impact antenna multi-band characteristics.

Antennas with reduced size are obtained victimization David Hilbert curve geometry. Furthermore, style equations for these antennas are obtained in terms of its geometrical parameters like pattern dimension. Antenna properties have conjointly been connected to pattern dimension of the geometry. to get foundations for the understanding of the behavior of such antennas, the character of pattern geometries is explained 1st, before presenting the standing of literature on antennas victimization such geometries.

In Today’s world, so as to face the technological development, men got to sustain with the evolution. This evolution ends up in the event of cellular devices. This mentioned several new areas of investigation; the one with main interest for this paper is that the analysis of antennas with pattern geometries.

The main downside of common antennas is that they solely operate at one or 2 frequencies, limiting the quantity of bands that instrumentality is capable of supporting. Another issue is that the size of a typical antenna. Owing to the terribly strict area that a French telephone has, putting in place over one antenna is extremely tough. To assist these issues, the utilization of pattern formed antennas is being studied.

2. RELATED WORK

This paper [5] introduces for the first time a novel flexible magnetic composite material for RF identification (RFID) and wearable RF antennas. First, one conformal RFID tag working at 480 MHz is designed and fabricated as a benchmarking prototype and the miniaturization concept is verified. Then, the impact of the material is thoroughly investigated using a hybrid method involving electromagnetic and statistical tools. Two separate statistical experiments are performed, one for the analysis of the impact of the relative permittivity and permeability of the proposed material and the other for the evaluation of the impact of the dielectric and magnetic loss on the antenna performance. Finally, the effect of the bending of the antenna is investigated, both on the -parameters and on the radiation pattern. The successful implementation of the flexible magnetic composite material enables the significant miniaturization of RF passives and antennas in UHF frequency bands, especially when conformal modules that can be easily fine-tuned are required in critical biomedical and pharmaceutical applications.

In this paper [6], we analyze the performance of novel wearable multiple-input–multiple-output (MIMO) systems, which consist of multiple electro-textile wearable antennas distributed at different locations on human clothing. For wearable applications, a semi directional radiation pattern of the wearable patch antenna is preferred over an omni directional radiation of conventional dipole antennas to avoid unnecessary radiation exposure to the human body and radiation losses. Additionally, the spatial distribution of the antennas is not constrained as a typical handheld unit. Through theoretical modeling and simulation, the wearable MIMO system is shown to demonstrate a significantly higher channel capacity than a conventional system on a handheld platform (e.g., a compact dipole array or a single dipole), due to enhanced spatial diversity and antenna pattern diversity. The unique effects of antenna directivity and location on the MIMO system capacity are investigated in terms of antenna correlation and effective gain under different wireless channel models. The advantage of a wearable system over a conventional system was further confirmed by detailed physical modeling through the combination of full-wave electromagnetic and ray-tracing simulations. Finally, complex channel response matrices were measured to characterize the performance of a body-worn MIMO system in comparison with a reference full-size dipole antenna. The 319% improvement in 10% outage capacity for the body-worn system over the reference system made of a full-size dipole antenna is consistent with the 288% improvement projected by theoretical modeling and the average 300% improvement found in the physical simulation of two typical indoor scenarios.

The design of the first wearable active receiving textile antenna in the 2.45 GHz ISM band is addressed for use in personal area networks [7]. The integrated low-noise amplifier is realized on a hybrid textile substrate and positioned directly underneath a wearable patch antenna.

The antenna and low-noise amplifier are designed by means of circuit/full wave co-optimization techniques within a novel multi-platform simulation setup to account for all the losses induced by using textile materials. A good agreement between simulations and measurements is obtained. An available gain of about 12 dB, on top of the passive antenna gain of about 5 dBi, and a noise figure of about 1.3 dB are realized. The effect of the human body on the active antenna performance is investigated by means of on-body measurements.

This paper [8] discusses the design of a broadband Dielectric Resonator Antenna (DRA) tailored and modified appropriately for implementation as a textile wearable antenna in Body Area Networks (BAN). DRA addresses the issues of small size, wide bandwidth and low conductive loss in particular. Due to its vital credentials, DRA serves well to be a choice as a wearable antenna for on-body communication system. The proposed design is simulated in CST Microwave Studio (CST MWS). The prototype is a textile-based construction offering a wide impedance bandwidth. Detailed tests and measurements carried out using a full-body phantom are reported in this paper.

A fully fabric triangular shaped Micro strip patch antenna is proposed for Wireless Broadband (WiBro) communication systems operating in the frequency range of 2.3 GHz to 2.4 GHz with 2.34 GHz as center frequency [9]. Three highly efficient and flexible antennas, built using three different conductive fabrics and an insulating polyester fabric are evaluated and results reported in this paper. To the best of authors' knowledge, this is the rest attempt.

This work [10] investigates the design of a flexible Minkowski fractal antenna. Two potential materials are included for examination - conductive copper tape and ShieldIt conductive textile. Both are designed and simulated to achieve a satisfactory resonance at the Very High Frequency (VHF) band for Land Mobile Radio (LMR) application through proper structure segmentation and iteration. Optimization concludes that the antenna is suitably fed using an L-shaped folded ground plane, with a Minkowski radiator of the third iteration (n3). The better performing material, i.e. conductive copper tape, is used to fabricate an antenna. It is observed through measurements that the wearable antenna reaches a gain of larger than 0 dB and an efficiency of 48 %, with a size of less than 0.5 m.

3. PROBLEM IDENTIFICATION

In order to transmit to receive data in communication system, it is necessary to have compact system, Transmission and reception system requires transmitting or receiving antenna to transmit/receive information. There are different factors which govern antenna selection. These are size, weight, complexity, bandwidth, gain and applications. One of best antenna that can optimize all parameter is micro-strip antenna. This antenna is having small size and less weight but suffer from disadvantage like low bandwidth, high return loss and loss gain and efficiency. In order to use micro strip antenna for different WSN application, different techniques have to be applied which are slot antenna, fractal antenna, use of met material, electron band gap structures, use of DGS. Advantage of using slot configuration is that characteristics of antenna improved in term of gain and return loss. By applying DGS, only bandwidth of antenna increased, hence in order to increase bandwidth of antenna and multiband characteristics, fractal antenna would be required. There are different fractal geometries that are used. Minkowski fractal geometry had been used to make ring shape patch antenna for dual band application.

4. PROPOSED METHODOLOGY

On the basis of various literature studied, following objective has been proposed.

- Design and simulation of fractal micro-strip patch antenna with coaxial feeding technique using CST and HFSS for the minimization of return losses.
- Optimization of antenna parameter for bandwidth, gain and return loss by the use of fractal configurations and its testing through CST and HFSS.
- Effect of changing feed point of coaxial feed.
- Effect of changing substrate.
- Effect of changing feed.
- Effect of changing substrate thickness.

There are different steps that have been followed in order to achieve the objective of dissertation.

- Fractal antenna dimensions calculated before design using HFSS or CST software.
- Design, simulation and analysis are carried out using simulation software.
- Application of different iterations of fractal geometry so as to obtain wideband characteristics.

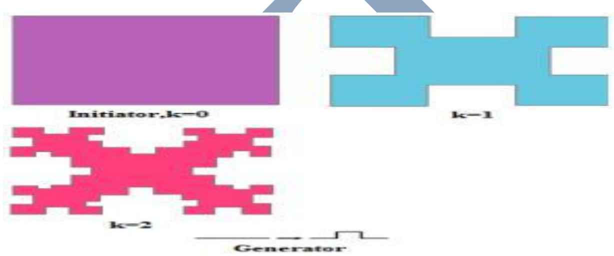

Figure 1: Proposed Fractal Geometry

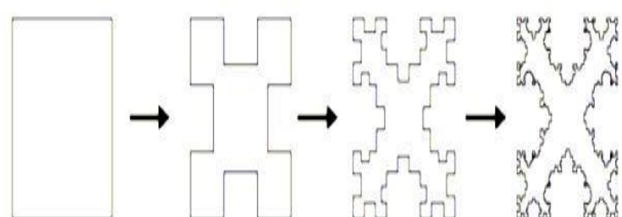

Figure 2: Formation of Minkowski island fractal at different iterations

Certain fractals can be constructed using iterations; this procedure is normally called Iterated Function Systems (IFS). Fractals are made up from the sum up of copies from itself, each copy smaller than the previous iteration. IFS works by applying a series of affine transformations w to an elementary shape a through many iterations. The affine transformation w, compromising rotation, scaling and translation, is given by:

$$W(x) = Ax + t = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix}$$

The matrix A is given by:

$$A = \begin{bmatrix} (^1/_s)\cos(\theta) & -(^1/_s)\sin(\theta) \\ (^1/_s)\sin(\theta) & (^1/_s)\cos(\theta) \end{bmatrix}$$

Where: x1, x2 are coordinates of a point x r is the scale factor
θ is the rotation angle
t is the translation factor
s is the scaling factor

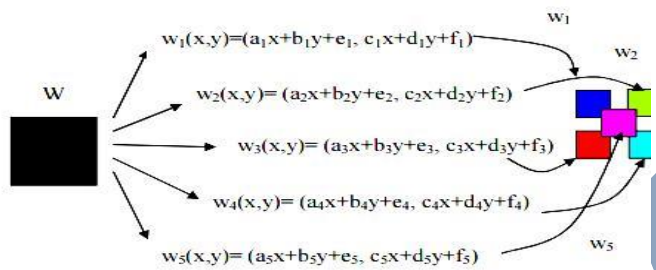

Figure 3: Generation of Minkowski fractal geometry

The iterative procedure is continued to get the successive stages of Minkowski fractal patch antenna is shown in Figure 3. The starting geometry of the Minkowski fractal antenna is the initiator square patch, and the successive iterations of fractal antenna is obtained by replacing each of the four straight sides of the starting structure with the generator with indentation as shown in the Figure 4. The indentation width S can vary from 0 to 1.

Table 1: IFS Transformation coefficients for the Minkowski fractal geometry

w_i	a_i	b_i	c_i	d_i	e_i	f_i
w_1	1/3	0	1/3	0	0	0
w_2	1/3	0	1/3	0	1/6	0
w_3	1/3	0	1/3	0	0	1/6
w_4	1/3	0	1/3	0	1/6	1/6
w_5	1/3	0	1/3	0	1/3	1/3

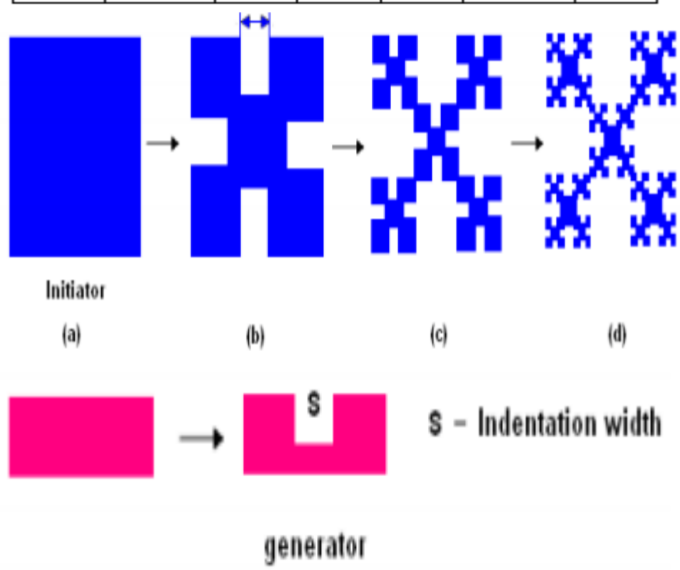

Figure 4: Generation of Minkowski fractal patch antenna (a) Initiator patch (b) First iterated Minkowski fractal patch (c) Second iterated Minkowski fractal patch (d) Third iterated Minkowski fractal patch.

V SIMULATION RESULTS

Simulated Results of Zelt Material for All Iteration

3 dB Beam width H-Field and E-Field Result of second Iteration for Zelt Material

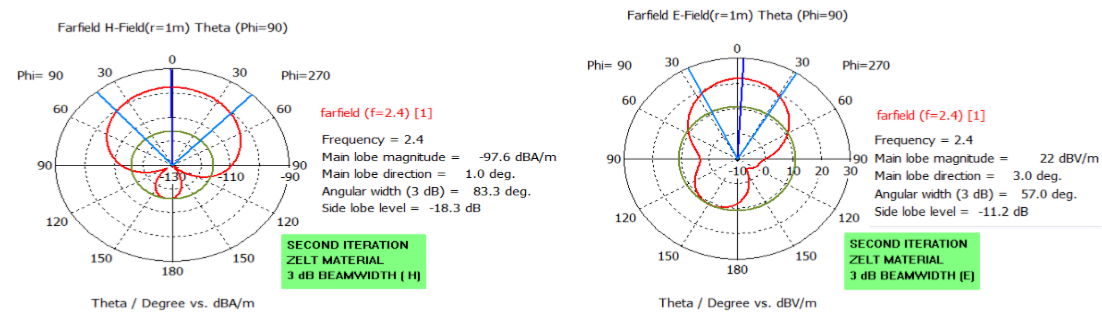

Figure 5: 3 dB Beam Width H-Field and E-Field Result of second Iteration for Zelt Material Gain Result of second Iteration for Zelt Material

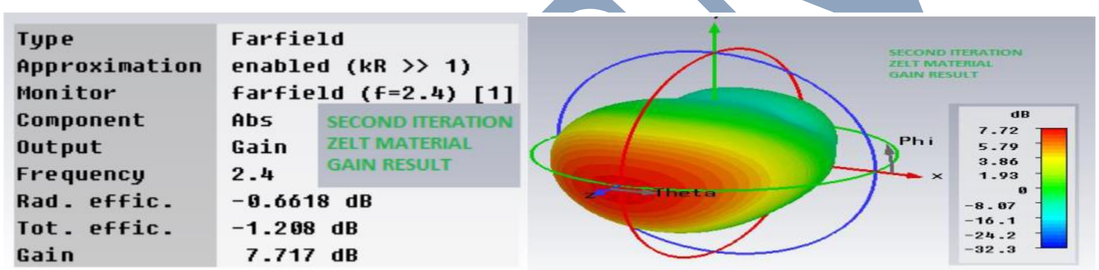

Figure 6: Gain Result of second Iteration for Zelt Material Directivity Result of second Iteration for Zelt Material

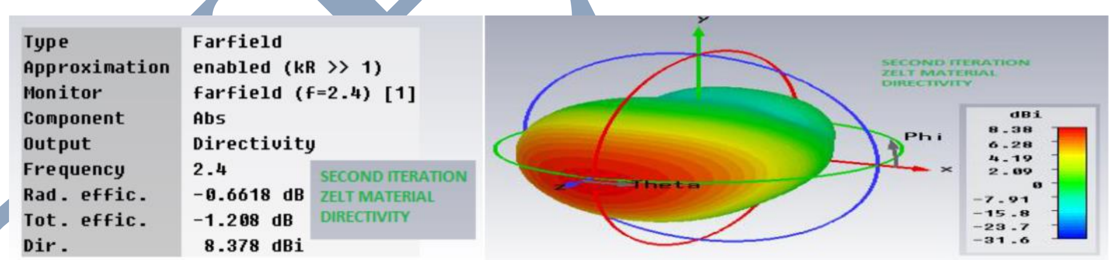

Figure 7: Directivity Result of second Iteration for Zelt Material VSWR Result of second Iteration for Zelt Material

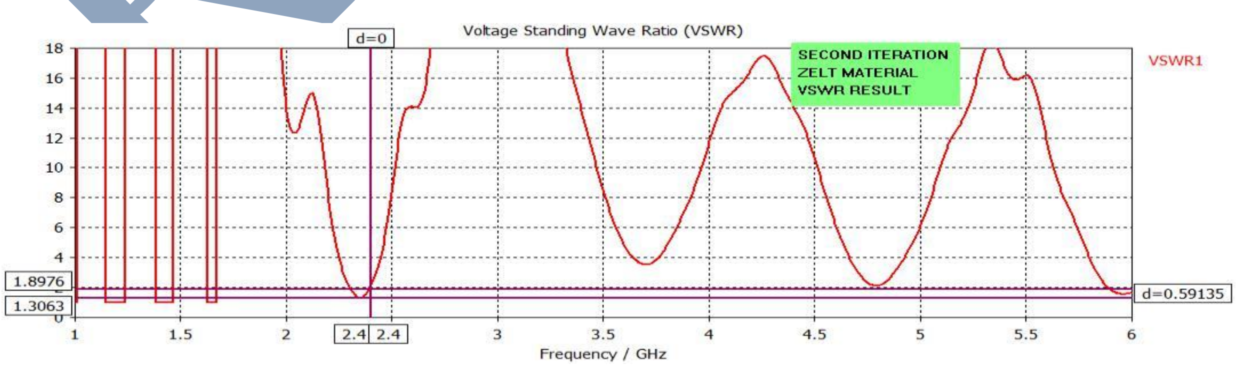

Figure 8: VSWR Result of second Iteration for Zelt Material Total Efficiency Result of second Iteration for Zelt Material

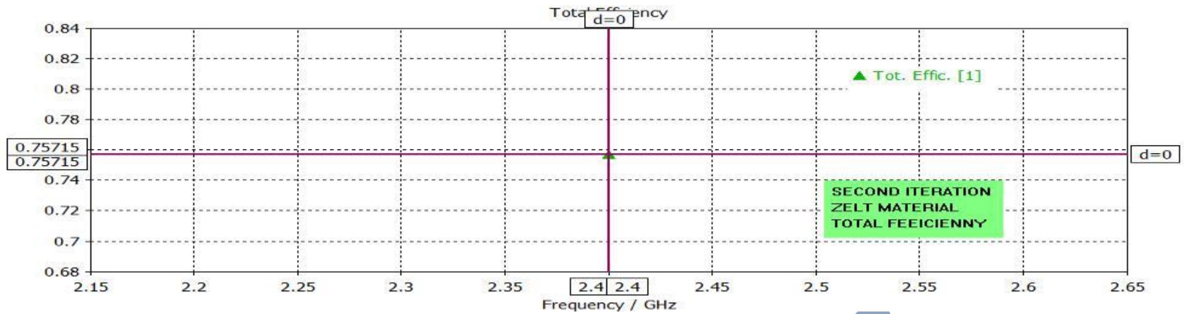

Figure 9: Total Efficiency Result of second Iteration for Zelt Material Radiation Efficiency Result of second Iteration for Zelt Material

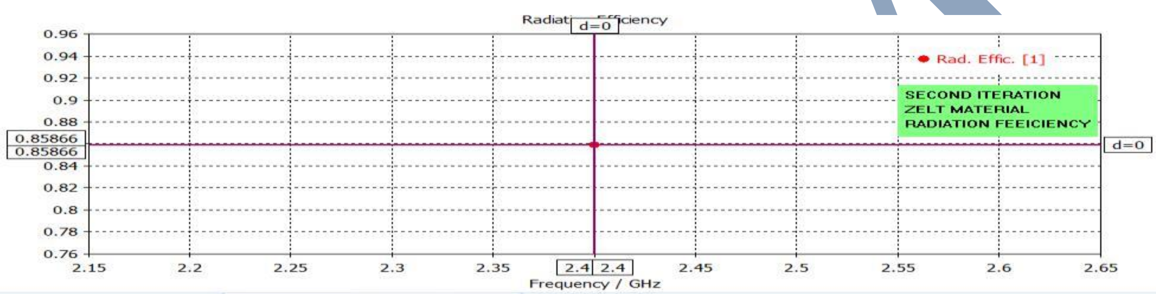

Figure 10: Radiation Efficiency Result of second Iteration for Zelt Material Admittance Result and Impedance Result of second Iteration for Zelt Material

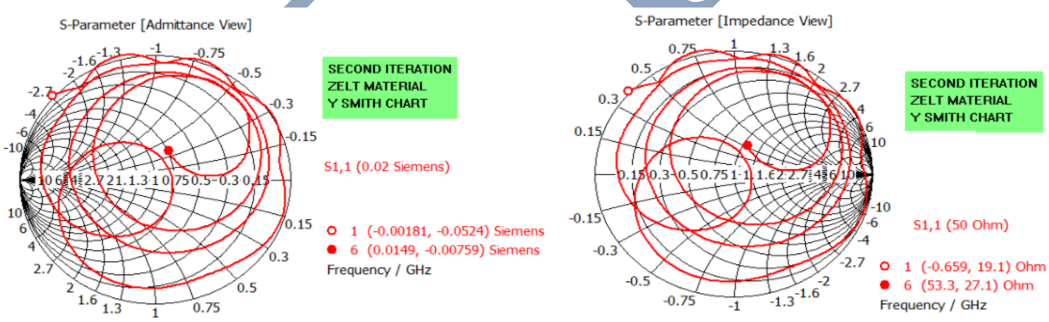

Figure 11: Admittance Result and Impedance Result of second Iteration for Zelt Material Return loss Result of second Iteration for Zelt Material

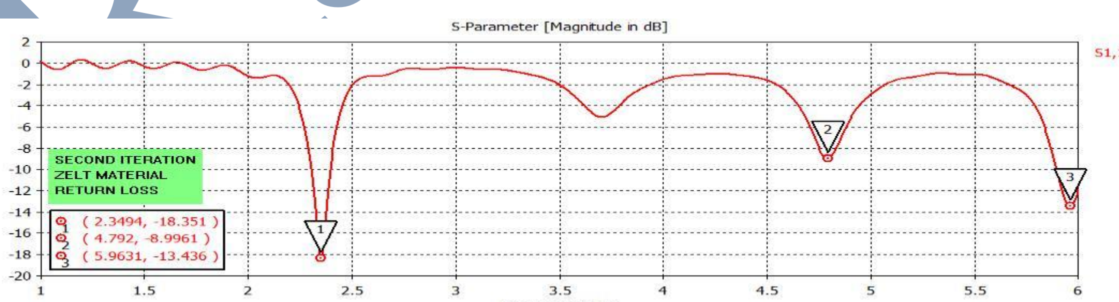

Figure 12: Return loss Result of second Iteration for Zelt Material Simulated Result of Flectron Material for All Iteration Admittance Result and Impedance Result of second Iteration for Flectron Material

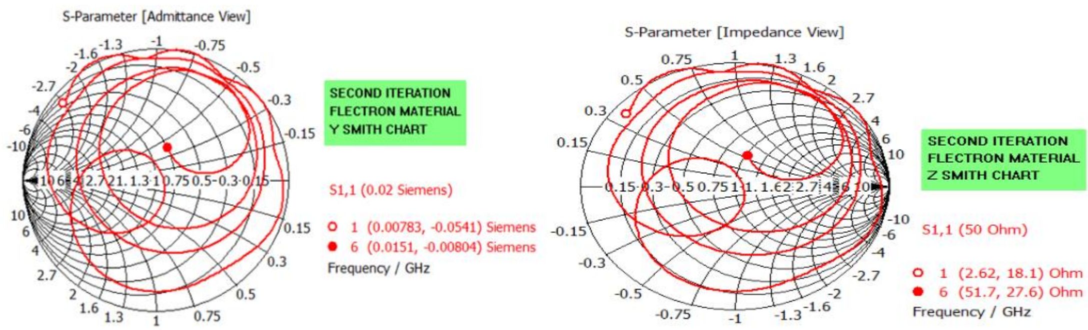

Figure 13: Admittance Result and Impedance Result of second Iteration for Flectron Material

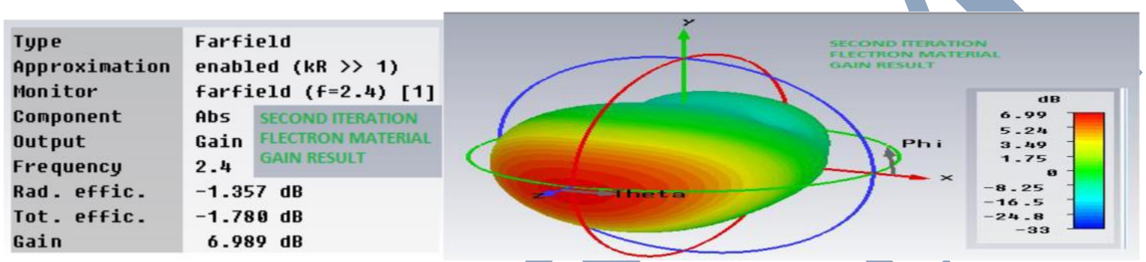

Figure 14: Gain Result of second Iteration for Flectron Material Directivity Result of second Iteration for Flectron Material

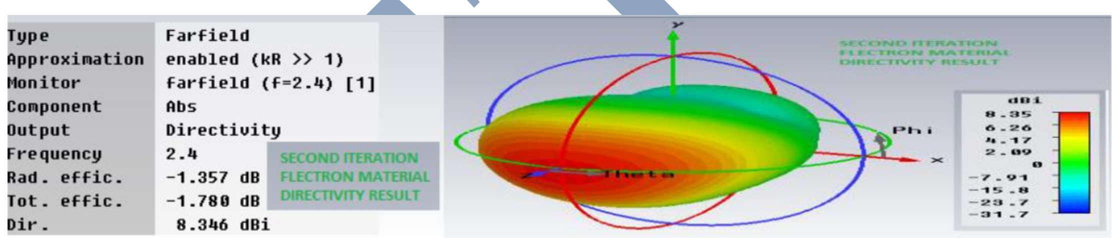

Figure 15: Directivity Result of second Iteration for Flectron Material VSWR Result of second Iteration for Flectron Material

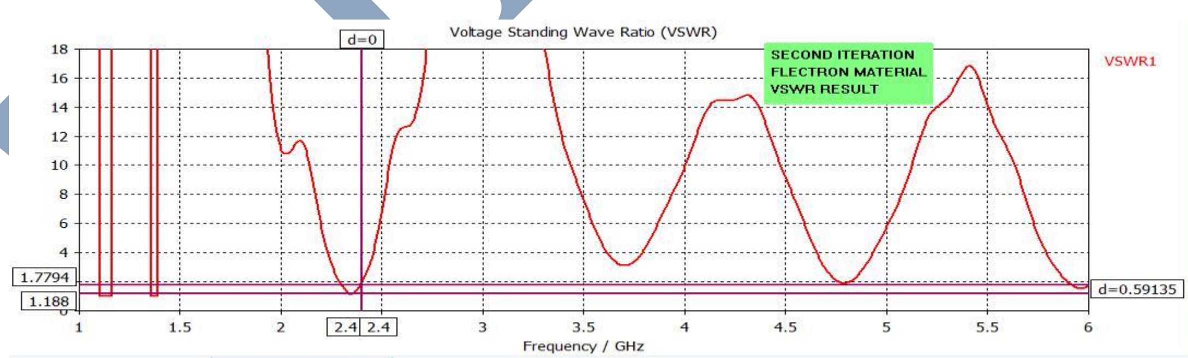

Figure 16: VSWR Result of second Iteration for Flectron Material Total efficiency Result of second Iteration for Flectron Material

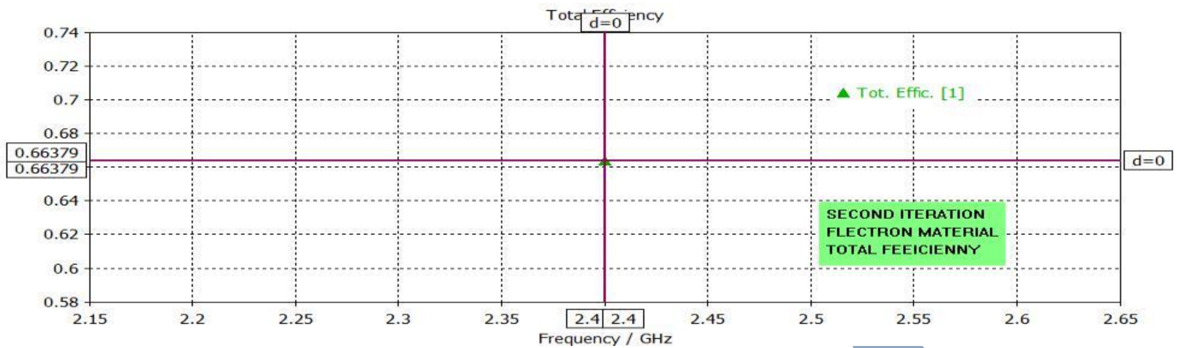

Figure 17: Total efficiency Result of second Iteration for Flectron Material Radiation efficiency Result of second Iteration for Flectron Material

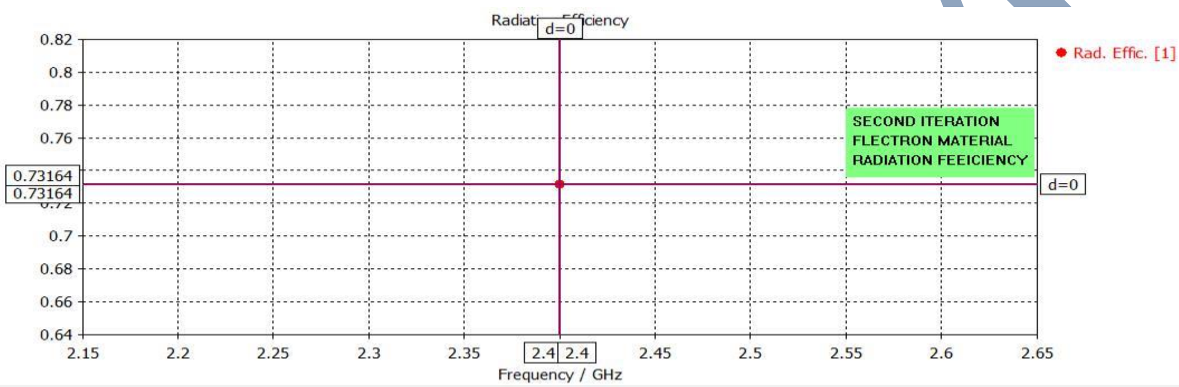

Figure 18: Radiation efficiency Result of second Iteration for Flectron Material Return loss Result of second Iteration for Flectron Material

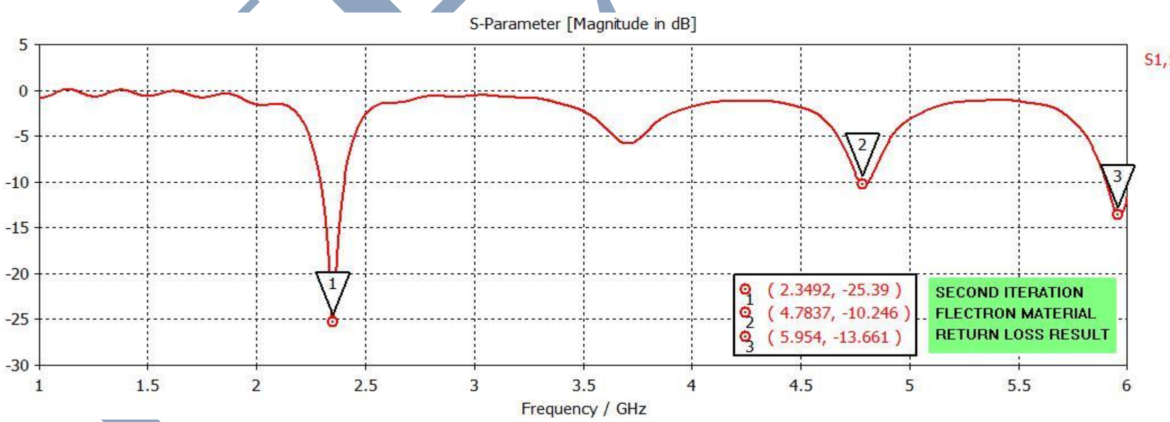

Figure 19: Return loss Result of second Iteration for Flectron Material

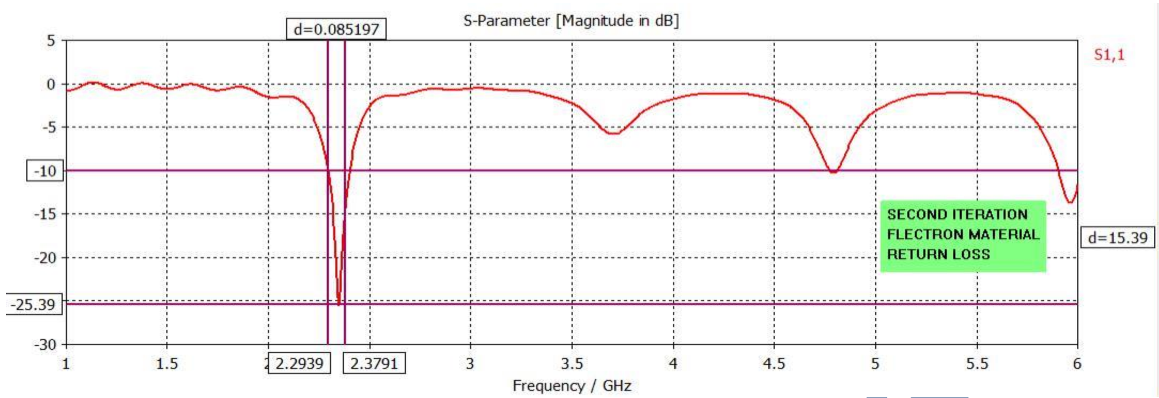

Figure 20: Return loss Result of second Iteration for Flectron Material Result Comparison of Base Paper and Proposed Method for Zelt Material

Table 1: Result Comparison of Base Paper and Proposed Method for Zelt Material

Name of Material	Iteration No.	Resonate Frequency	Return loss	VSWR	Gain	Directivity (dBi)	Antenna Efficiency (%)	Radiation Efficiency (%)	3 dB Beam Width (E)	3 db Beam Width (H)	Band width
Measured result (Zelt)	0th	2.54	-20.02	1.306	7.85	7.82	54.93	100	60.6^0	98.6^0	107
	1st	2.344	-48.9	2.038	7.7	8.52	82.5	82.9	58^0	44.4^0	93
	2nd	2.349	-18.33	1.282	7.72	8.38	75.7	85.9	57^0	83.3^0	90
Base paper Result (zelt)	0th	2.45	-22	Not Measured	7.4	8.6	76	Not Measured	73	62	104
	1st	2.36	-24		6.97	8.4	72.1		75	62.5	100
	2nd	1.91	-23		4.55	7.7	45.1		77.7	55.96	34

The above table compares the results of previous work done with proposed design for Zelt material both use for simulation of Minkowski fractal geometry using tuning holes.

- The directivity, efficiency and gain of proposed design are fond higher as compare to previous work.
- This implies that antenna resonant frequency has been reduced considerably with each successive iteration without changing the overall antenna dimensions and thereby miniaturization is achieved.

Table 2 Result Comparison of Base Paper and Proposed Method for Flectron Material

Name of Material	Iteration No.	Resonate Frequency	Return loss	VSWR	Gain	Directivity (dBi)	Antenna Efficiency (%)	Radiation Efficiency (%)	3 dB Beam Width (E)	3 db Beam Width (H)	Band width
Flectr	0th	2.535	-17.27	1.306	7.05	7.80	51.11	84.26	60.4^0	94.7^0	112

on	1st	2.4	-25.35	1.069	7.05	8.47	71.8	72.16	57.8^0	44.8^0	103
	2nd	2.338	-25.39	1.12	6.98	8.34	66.37	73.16	85.4^0	56.7^0	107
Flectr	0th	2.455	Not Measure	Not Measur	6.45	6.45	61.66	Not Measur	73	62	132
on	1st	2.347			5.8	8.3	55.96		75	62.5	100
Base Paper	2nd	1.873	d	ed	2.7	7.6	32.36	ed	77.7	68.6	50

The above table compares the results of previous work done with proposed design for Flectron material both use for simulation of Minkowski fractal geometry using tuning holes.

- The directivity, efficiency and gain of proposed design are fond higher as compare to previous work.
- This implies that antenna resonant frequency has been reduced considerably with each successive iteration without changing the overall antenna dimensions and thereby miniaturization is achieved.

4. CONCLUSION

Wearable electro-textile patch antenna is meant by mistreatment mathematician shape geometries with standardization hole for 0th, first and planned iterations. Three electro-textile wearable antennas mistreatment Flectron and Zelt materials are designed. The planned antenna shows a big size reduction compared to the standard Micro-strip patch antenna. These antenna structures are compatible for wearable applications too as they're made mistreatment solely light-weight weight and versatile textiles. Absolutely cloth rectangular formed Micro-strip patch antenna is planned for Wireless native space network (WLAN) and Wireless Broadband (WiBro) communication systems in operation within the frequency vary of two.3 GHz to 2.49 gigahertz with a pair of.34 gigahertz as center frequency and a couple of.3 GHz to 2.4 gigahertz with a pair of.4 gigahertz as center frequency severally.

The development of an oblong Micro-strip textile antenna for LAN band is delineate during this paper, a trial has been created to develop Micro-strip patch associate degree antennas with rectangular pure mathematics using totally different semi conductive materials and an insulating polyester cloth Simulations and measurements are disbursed over the frequency vary of one.0 GHz to 6.0 gigahertz for all 3 antennas developed.

The simulated resonant frequency in every case of those antennas is a pair of.34 GHz. The simulated resonant frequencies of Zelt and Flectron antenna for planned iteration ar a pair of.335 gigahertz and a couple of.339 GHz. The simulated values of electrical resistance information measure of those antennas ar fifty five Mc and eighty two Mc.

Considering the simulated values of resonant frequencies for all 2 totally different materials antenna a wonderful agreement is found between knowledge obtained with standard time machine and measure. There's an ideal match between simulated resonant frequencies for all 2 totally different materials antenna.

In this paper, a foreseeable rectangular Micro-strip patch antenna has been with success designed having a central frequency of two.4GHz. The utmost radiation potency achieved with the planned style is ninety five.3% of Zelt material. Come back loss magnitude of fourteen.32 dB is obtained with seven.96 dB gain just in case of 00 part distinction of phased array signals in conjunction with radial asymmetry of eight.17dBi. However, the performance degrades at the upper part angles of the phased array parts.

Radiation potency is additionally improved as compared with several strategies wont to improve antenna performance giving highest potency for Zelt material at planned iteration. This could be one amongst the solutions for reducing radiation impact within the fourth generation mobile and portable computer applications. The results show that the designed antenna provides offers smart performance characteristics all told the four frequency bands. Wireless Micro-strip patch antenna was designed and simulated its results with standard time computer code mistreatment mathematician geometry.

During this style we have a tendency to mix 2 totally different materials like Flectron and Zelt for that the primary iterations of mathematician shape geometries are applied on the sides of a sq. patch, and standardization holes are fashioned on its surface. We have a tendency to additionally applied standardization holes pure mathematics for more sweetening of gain, information measure and potency. The planned shape Micro-strip antenna consist dimension thirty eight metric linear unit, length 48.4 metric linear unit and height a pair of.85 mm. Here polyester material with one.44 material constant and Flectron and Zelt conductor use for planning antenna.

Here Aperture Couple Feed Technique is employed for feeding purpose it's a slender information measure and moderate spurious radiation. It consists of 2 totally different substrates separated by a ground plane. Below the lower substrate, there's a Micro-strip feed line whose energy is coupled to the patch through a slot on the bottom plane separating 2 substrates. Simulation results shows this antenna resonant at 5 resonance frequencies and canopy UWB, WIMAX, WIFI, ISM/WLAN/Bluetooth, Hiper-Lan2 band means that it really multiband antenna. Testing result additionally shows over -10 dB negative measured worth for RL parameter in the slightest degree four resonant frequencies that cowl 1-6 gigahertz communication band.

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