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Efficiency Assessment of AI-Driven Koch Hybrid Fractal Antenna Design for Wireless Body Area Network

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Abstract
Fractal antennas are an essential part of wireless communication technologies including wireless body area networks (WBANs) that have been developed as a result of the radio communication era. Healthcare uses are particularly suitable for wearable communications and fractal antenna (FA), which are composed of inexpensive, flexible textile fabrics. In this paper, we present a unique fractal antenna layout for the Koch hybrid (Koch and meander curve geometries) using a dragonfly swarm-assisted iterative function system (DS-IFS). Moreover, we employ a substrate made of a wearable fabric (cotton, jeans, etc.). The ground layer and the patch were constructed with copper tape. To attain the required efficiency, evaluation of performance is carried out on the horizontal plane of this antenna. A computational framework for fractal shape is created employing the IFS and then adjusted for feed location employing the dragonfly swarm optimization (DSO) method. The outcomes of this study, when assessed against other techniques, verify the efficiency of the suggested approach and reflect notable advancements in antenna performance measurements.

Keywords- Fractal antenna, geometric curves, wireless body area networks (WBANs), dragonfly swarm-assisted iterative function system (DS-IFS), and fabrics

1. Introduction

The design of Koch hybrid fractal antennas for WBAN constitutes the development in the fields of healthcare tracking and wearable technology. WBAN seeks to provide actual-time monitoring of health and treatments by integrating wireless connectivity with healthcare devices to monitor physiological data [1]. The Koch fractal antenna design was particularly appropriate for the WBAN systems in terms of physical, perceptual and dependability. They provide various advantages, including concerning, downsizing, multi-band operations and productivity [2]. The Koch curve is geometrically distinguished due to its self-similar and space-filling qualities, which are the source of the Koch fractal antenna. Regarding the structure of each multiplication, the basic antenna component was duplicated and expanded in geometry to help the antenna obtain a multi-band appearance to encompass important WBAN frequencies [3]. The Koch hybrid fractal design takes minimal space and has the ability to vibrate at several frequencies suitable for WBANs [4]. The antennas constitute to work in the confined space of the human body that constitutes any feasible implantable gadget. Providing support for multiple healthcare sensor networks are always observing biochemical signs, such as temperatures, blood pressure and heartbeat among other signs that depend on capacity [5].

Holding features of Koch hybrid fractal antennas, WBANs might be revolutionary in the sphere of healthcare. The individual courses of treatment following the time information of analytics allow for monitoring patients and timely identification of deviations from health. They help medical practitioners reduce cases of hospitalization, enhance the level of diagnosis, and increase friendly patient outcomes through intervention.

The Koch hybrid fractal antennas found higher-order modeling and optimization [6]. Designers emulate and analyze the antenna's working characteristics like the radiated sequence, resistance match, and productivity by employing electromagnetic models. The signal transmission and distortion throughout the human body, utilizing Koch hybrid fractal antennas for WBAN [7]. Depending on the necessity, it can be useful in making a whole functionality of communicating over the wireless networks of medical instruments and the outside tracking system more reliable and reducing the attenuation of signals caused by the tissues of the body by placing the antenna on the wearable or implants. The analysis and simulation in the design of Koch hybrid fractal antennas for WBAN applications employ advanced modeling methods and simulation tools [8]. The antenna's performance under various operating circumstances using advanced electromagnetic modeling instruments is controlled by factors, such as substrate materials, feed and fractal iteration levels to achieve the required characteristics. Potential difficulties in precisely creating intricate fractal shapes on textile substrates constitute difficulties and possess an impact on durability and reliability. The environmental elements from real world, including fabric deterioration, may affect the antenna's longevity and dependability.
The study's aim is to develop a novel dragonfly swarm-assisted iterative function system (DS-IFS) technique to enhance a unique fractal antenna layout for Koch hybrid (Koch and meander curve geometries).
The following Sections make up the article: Section 2, Literature Review; Section 3, Methodological part; Section 4, Experimental result; and Section 5, Conclusion.

2. Related works

The wearable antenna was a small and low-profile, designed for WBAN systems involving the body. A flexible substrate made of vinyl polymers are readily accessible at a reasonable cost and was utilized for the design of a triangle patch antenna [9]. The topology of the antenna was created by combining serpentine structures, periodic structures and Koch curve antenna. The results show how Koch fractal geometry constitutes a defective ground plane that may effectively miniaturize dimensions and boost bandwidth. The antennas were distinguished from Koch-type dipoles through the location of the polarity arm's center terminal [10]. The frequency wavelength for various antenna scales varied with the arm's shape. The analysis determined that the pole length of the wire and its dimensions affect the frequency and reflective factor. The antennas running at a specific frequency may be distinguished from one another. The experimental outcome demonstrated that the Koch-type antenna with the same dimension possesses various center node positions.
The article examined how the antenna's frequency characteristic varies as the quantity of recursive component iterations increases [11]. They use HFSS to replicate the versions of the Koch antenna system. The predicted antenna characteristics, including transmission loss and emission sequence, show the relevance of each repetition. The experimental outcome showed that antenna design was necessary to achieve higher bandwidths. The CPW feed-equipped Hybrid Koch antenna was suggested for 5G applications [12]. The prototype's tiny sectional dimension was maintained while achieving ultra-wide resonant through computational design. To increase the FBW of the antenna, the CPW data was integrated into the cooling system cable. The experimental result demonstrated that CPW was designed for a wide range of wireless transmission systems.
They described a larger bandwidth mixed fractal antenna termed as MIMO antenna [13]. The Koch curves were integrated into the entire hexagonal reflecting surface to generate the MIMO antenna. The suggested antenna maintained a higher DG value, complete frequency range and good isolation. The experimental finding demonstrated that the suggested MIMO antenna has FBW to form greater impedance. They examined a novel WHFASR for real systems [14]. Jeans were the selected substrate of textile for WHFASR, with a depth and dimension-dependent constant of dielectric IFS. Utilizing the mathematical tool Koch, antennas were combined to improve performance and minimize the size of the constructed antenna. The result outcome exhibited that the suggested approach produced and tested with a VNA constitutes the real systems.
The creation and design of fractal antennas with increased gain for double and triple bands were showcased. The fractal antenna technique was used to create a multiband capability [15]. The properties of the fractal antenna constitute the patterns of radiation and coefficient of reflection at every repetition. The experimental outcome indicates how the antenna's total size may be used to integrate the WLAN transmission modules.

3. Methodology

A novel dragonfly swarm-assisted iterative function system (DS-IFS) technique was proposed to enhance the unique fractal antenna layout for the Koch hybrid (Koch and meander curve geometries).

3.1 Dragonfly Swarm Optimization (DSO)

The combination of Koch fractal antenna and Dragonfly Swarm Optimization (DSO) improves the WBAN functions by using the inherent similarity of fractal patterns to optimize antenna characteristics. The intelligent search-optimization method is also known as DSO. The dragonflies behave both dynamically and statically. A static swarm was a little group of dragonflies that forages for food in a limited area. Flies constitute a way that was typified by sudden and quick shifts in flight routes. Conversely, a massive swarm of flies migrates from one location to another, and keeps moving in the same direction over a considerable distance known as a swarm. The swarm of dragonflies was comparable to an optimization issue. Hence, the phase of exploitation was characterized by the static behavior of the swarm, while the phase of exploitation was characterized by dynamic behavior. Five characteristics of dragonflies are given in order to construct the model for representing the movements of the cluster flies: segregation, symmetry, cohesiveness, meals and adversary. Where Alg_j, Af_j, Sep_j, Eej and Coh_j are used to represent alignment, food, separation, enemy and cohesion characteristics of each dragonfly cluster.

Within the specified locality, the distance among neighboring is required to optimize the area of search and prevent collisions. The individuals on a cluster with m neighbors, was represented by j. Equation (1) may be used to determine the separation of individual clusters. The outcome is displayed below, where w represents the current location and w_l represents the location of l_{th} neighboring.

$$Sep_j = \sum_{l=1}^{m}(w - w_l) \quad (1)$$

Equation (2) utilizes the integration term to match a person's velocity with others in the same area. The l_{th} nearby velocity was denoted by U_l.

$$Alg_j = \frac{\sum_{l=1}^{m}(U_l)}{m} \quad (2)$$

Every cluster individual has an inclination to go toward the mass center of nearby DFs. Equation (3) determines the cohesiveness property.

$$Coh_j = \frac{\sum_{l=1}^{m}(U_l)}{m} \quad (3)$$

Given that food was necessary for survival, all cluster individuals possess a tendency to migrate in that direction. Equation (4) used to obtain the location of food.

$$Af_j = w_{food} - w \quad (4)$$

When faced with an opponent, a cluster of people usually disperses. Equation (5) used to determine the enemy's position.

$$Ee_j = w_f + w \quad (5)$$

Combining all five qualities has an impact on the cluster. Equation (6) indicates the updated location of each individual, which was determined byΔw_j.

$$w_j = w_j + \Delta w_j \quad (6)$$

$$\Delta w_j = \omega \Delta w_j + \left(b.Sep_j + c.Alg_j + d.Coh_j + e.Af_j + f.Ee_j\right) \quad (7)$$

Here w represents the inertial factor. a, b, and c are separation, alignment and cohesion weights, respectively, here e stands for the adversary factor and d represents the food factor. Where Alg_j, Af_j, Sep_j, Ee_j and Coh_j are used to represent alignment, food, separation, enemy and cohesion characteristics of each dragonfly cluster. By utilizing various parameter factors, it was possible to achieve variety in the exploratory and exploitative behaviors. Figure 1 illustrates the flow chart of DSO.

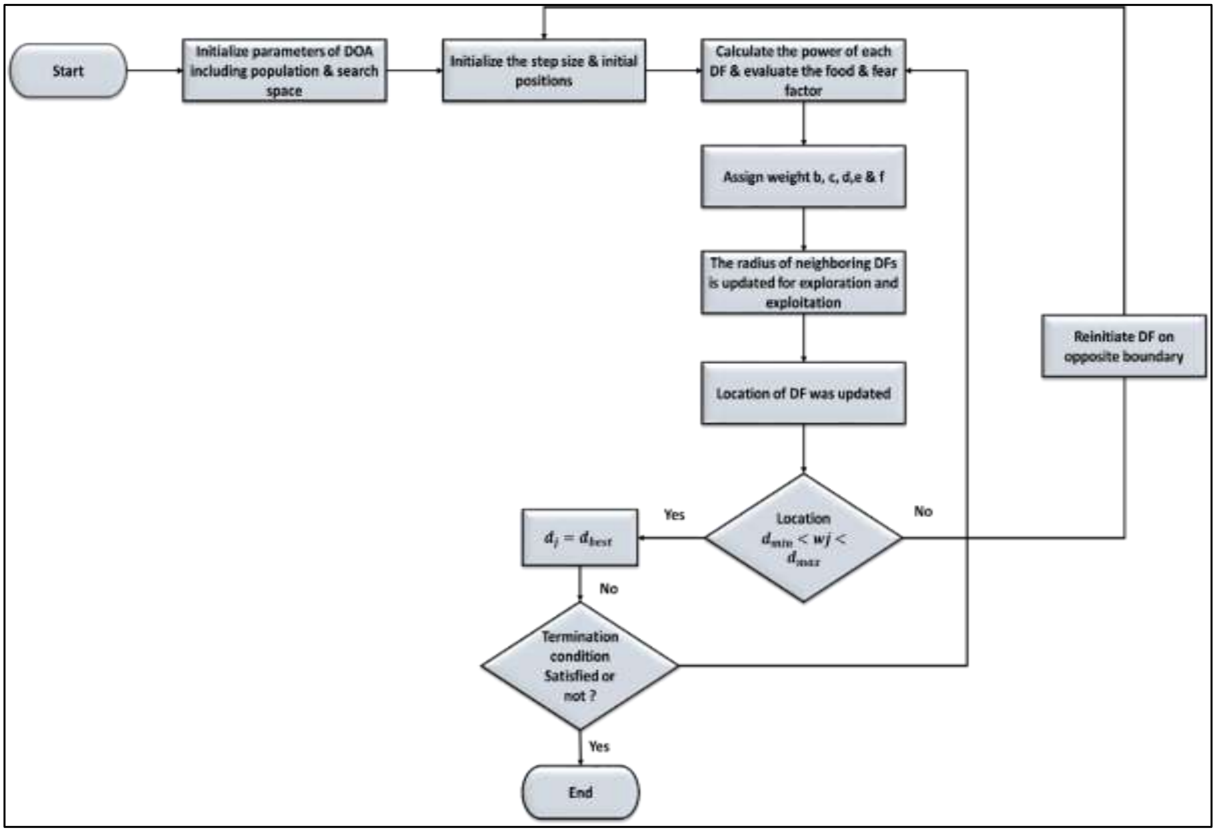

Figure (1): DSO flow chart

3.2 Iterative Function System (IFS)

The Iterative Function System (IFS) is integrated with the Koch fractal antenna for obtaining the use of recursive methods to build antenna structures. For the purpose of creating fractal antennas, the IFS were extremely useful. The user can suggest recursion and identical fractal structures with the aid of IFS. The following formula describes the terms of IFS [18].

$$w\begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \tag{8}$$

Where a, b, c and d illustrate the orientation and scalability of variables. There are specific change in x and y axes.

Here e and f constitute the transformation and shifts controlled by factors.

The following list consists of 28 transformation matrices, $w1$ through $w28$ for iteration:

$$W1 = \begin{bmatrix} \frac{1}{12} & 0 \\ 0 & \frac{1}{12} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} \quad W2 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1}{12} \\ 0 \end{bmatrix}$$

$$W3 = \begin{bmatrix} 0 & \frac{-0.455}{12} \\ \frac{0.455}{12} & 0 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.33}{12} \\ \frac{0.33}{12} \end{bmatrix} \quad W4 = \begin{bmatrix} \frac{0.284}{12} & 0 \\ 0 & \frac{0.284}{12} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.33}{12} \\ \frac{0.788}{12} \end{bmatrix}$$

$$W5 = \begin{bmatrix} 0 & \frac{-0.455}{12} \\ \frac{0.455}{12} & 0 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.61}{12} \\ \frac{0.788}{12} \end{bmatrix} \quad W6 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.61}{12} \\ \frac{0.33}{12} \end{bmatrix}$$

$$W7 = \begin{bmatrix} \frac{1}{12} & 0 \\ 0 & \frac{1}{12} \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{2}{12} \\ 0 \end{bmatrix} \quad W8 = \begin{bmatrix} 0 & \frac{-1}{12} \\ \frac{1}{12} & 0 \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{3}{12} \\ 0 \end{bmatrix}$$

$$W9 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{3}{12} \\ \frac{1}{12} \end{bmatrix} \quad W10 = \begin{bmatrix} \frac{-0.455}{12} & 0 \\ 0 & \frac{-0.455}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{2.66}{12} \\ \frac{1.33}{12} \end{bmatrix}$$

$$W11 = \begin{bmatrix} 0 & \frac{-0.284}{12} \\ \frac{0.284}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{2.21}{12} \\ \frac{1.33}{12} \end{bmatrix} \quad W12 = \begin{bmatrix} \frac{0.455}{12} & 0 \\ 0 & \frac{0.455}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{2.21}{12} \\ \frac{1.61}{12} \end{bmatrix}$$

$$W13 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{2.66}{12} \\ \frac{1.61}{12} \end{bmatrix} \quad W14 = \begin{bmatrix} 0 & \frac{-1}{12} \\ \frac{1}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{3}{12} \\ \frac{2}{12} \end{bmatrix}$$

$$W15 = \begin{bmatrix} \frac{-1}{12} & 0 \\ 0 & \frac{-1}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{3}{12} \\ \frac{3}{12} \end{bmatrix} \quad W16 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{2}{12} \\ \frac{3}{12} \end{bmatrix}$$

$$W17 = \begin{bmatrix} 0 & \frac{-0.455}{12} \\ \frac{0.455}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.66}{12} \\ \frac{2.66}{12} \end{bmatrix} \quad W18 = \begin{bmatrix} \frac{-0.284}{12} & 0 \\ 0 & \frac{-0.284}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.66}{12} \\ \frac{2.21}{12} \end{bmatrix}$$

$$W19 = \begin{bmatrix} 0 & \frac{-0.455}{12} \\ \frac{0.455}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.382}{12} \\ \frac{2.21}{12} \end{bmatrix} \quad W20 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1.382}{12} \\ \frac{2.66}{12} \end{bmatrix}$$

$$W21 = \begin{bmatrix} \frac{-1}{12} & 0 \\ 0 & \frac{-1}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{1}{12} \\ \frac{3}{12} \end{bmatrix} \quad W22 = \begin{bmatrix} 0 & \frac{-1}{12} \\ \frac{1}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{3}{12} \end{bmatrix}$$

$$W23 = \begin{bmatrix} \frac{0.472}{12} & \frac{-0.472}{12} \\ \frac{0.472}{12} & \frac{0.472}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{2}{12} \end{bmatrix} \quad W24 = \begin{bmatrix} \frac{0.455}{12} & 0 \\ 0 & \frac{0.455}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{0.33}{12} \\ \frac{1.66}{12} \end{bmatrix}$$

$$W25 = \begin{bmatrix} 0 & \frac{-0.284}{12} \\ \frac{0.284}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{0.78}{12} \\ \frac{1.66}{12} \end{bmatrix} \quad W26 = \begin{bmatrix} \frac{-0.455}{12} & 0 \\ 0 & \frac{-0.455}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{0.78}{12} \\ \frac{1.38}{12} \end{bmatrix}$$

$$W27 = \begin{bmatrix} \frac{-0.472}{12} & \frac{0.472}{12} \\ \frac{-0.472}{12} & \frac{-0.472}{12} \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} \frac{0.33}{12} \\ \frac{1.38}{12} \end{bmatrix} \quad W28 = \begin{bmatrix} 0 & \frac{-1}{12} \\ \frac{1}{12} & 0 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{12} \end{bmatrix}$$

The generating curve for the initial iteration was defined by equation 9.

$$W = W_1 U W_2 U W_3 U W_4 U W_5 U W_6 U W_7 U W_8 U W_9 U W_{10} U W_{11} U W_{12} U W_{13} U W_{14} U W_{15} U W_{16} U W_{17} U W_{18} U W_{19} U W_{20} U W_{21} U W_{22} U W_{23} U W_{24} U W_{25} U W_{26} U W_{27} U W_{28} \quad (9)$$

The generating curve gets longer with each repetition. The lengthening corresponds with the number of iterations as follows.

$$L = h\left(\frac{10}{4}\right)^n \quad (10)$$

The variables n, h and L represent the number of iterations, height and length of the curve.

3.3 Dragonfly Swarm-assisted Iterative Function System (DS-IFS)

For WBAN functions, a hybrid methodology that combines Dragonfly Swarm Optimization (DSO) with Iterative Function System (IFS) and Koch Hybrid Fractal Antenna design takes advantage of each technique to provide an effective and optimized antenna design. DSO efficiently handles large problems by integrating the phases of exploration and utilization, drawing inspiration from the swarming behavior of dragonflies. When DSO and IFS are combined, identical fractal designs are produced through the use of repetitive trends, which improves optimization and offers an adaptable antenna design framework. The identical and broad spectrum characteristics of the Koch fractal antenna are used to create a small, high-performing antenna for WBAN. The hybrid design guarantees a strong, compact antenna with enhanced radiation properties and bandwidth, which was essential for dependable and effective wireless connectivity in body-centric systems. The hybrid approach addresses issues of dimensions, productivity and reliability and presents a viable solution for WBAN applications.

3.4 Design of fractal antenna layout for koch hybrid

The Koch curve and meandering curve are two fractal geometries that are combined in the creation of a fractal antenna layout for the Koch hybrid. The Koch curve was overlaid upon the foundation geometry known as meandering curve. The fractal antenna layout for koch hybrid geometry constitutes the final shape that was created by combining two topologies. The central portion of line segments was replaced with three identically sized segments that were at right angles to one another during the meander curve creation procedure. After obtaining the Koch curve, the two right-angle portions of identical size are used to secure the position of the primary section.

With the help of a denim substrate, the fractal antenna layout for the Koch hybrid was manufactured. Dielectric constant and loss tangent are values of Jean. The ground planes and patches were constructed using copper tape. Equations 11 and 12 illustrate how the model of transmission lines was used to compute the fractal antenna layout for the Koch hybrid patch. To get the required specifications, a partial flaw was produced in the surface plane.

Equation 11 was utilized to compute the dielectric effective constant ϵ_{reff} in the following manner:

$$\epsilon_{reff} = \frac{f_q+1}{2} + \frac{f_q-1}{2\sqrt{1+12\left(\frac{2e_q g\sqrt{\frac{\epsilon_q+1}{2}}}{d}\right)}} \qquad (11)$$

The actual length of the patch was determined by equation 12.

$$K = \frac{d}{2e_q\sqrt{\epsilon_{reff}}} + 2.0412h\frac{(\epsilon_{reff}+0.3)\left(\frac{d}{2e_q g\sqrt{\frac{\epsilon_q+1}{2}}}+0.264\right)}{(\epsilon_{reff}+0.258)\left(\frac{d}{2e_q g\sqrt{\frac{\epsilon_q+1}{2}}}+0.8\right)} \qquad (12)$$

The fractal antenna layout for koch hybrid design in accordance with the number of iterations.

3.5 Dataset

3.5.1 Feed Location

Initially, we collected a dataset of 70 samples. To acquire all data, MATLAB software was used. The CFR provided the collection of samples in the MATLAB program. CFR may be accessed easily with the MATLAB program. The technique aids in establishing the functional connection that yields the greatest fit for the received data set among the acknowledged reality and specified value of parameters. The research establishes a link across the corresponding frequency of resonance and feed location using curve-fitting approach.

4. Experimental Results

VNA is used to evaluate and manufacture the antennas. Both measurements and simulations are made for the execution characteristics. The suggested antenna's specifications for performance are described.

The resonance frequencies are assigned at S (1, 1) values. Using the VNA, the suggested DS-IFS was constructed and its performance characteristics were examined experimentally. The contrast between the simulated and experimentally analyzed S (1, 1) parameters is clearly shown. Figure 2 represents the experimental simulation of S (1, 1) feed point of DS-IFS.

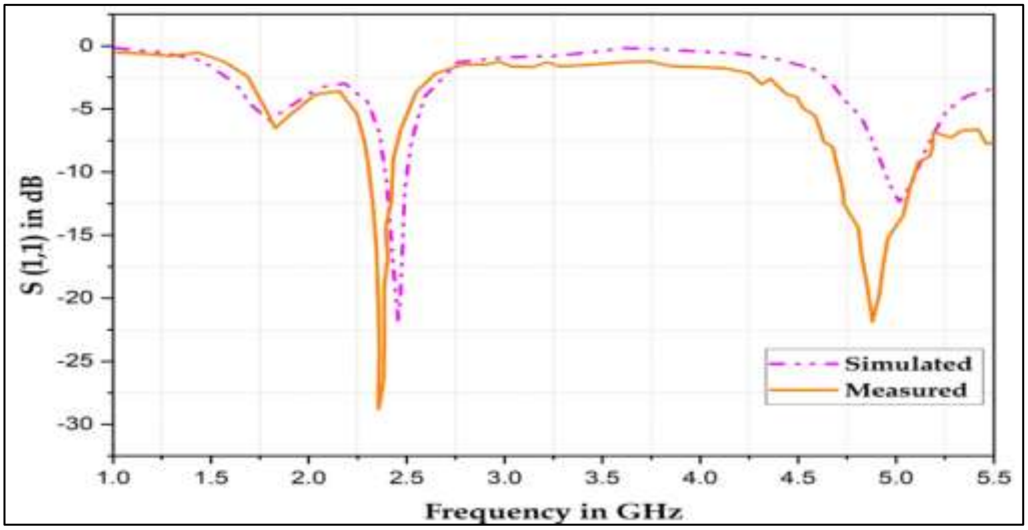

Figure (2): S (1, 1) feed point of DS-IFS experimental simulation.

The anticipated DS-IFS's frequency curve vs radiation efficiency is displayed in Figure 3, showing an efficiency around 85%.

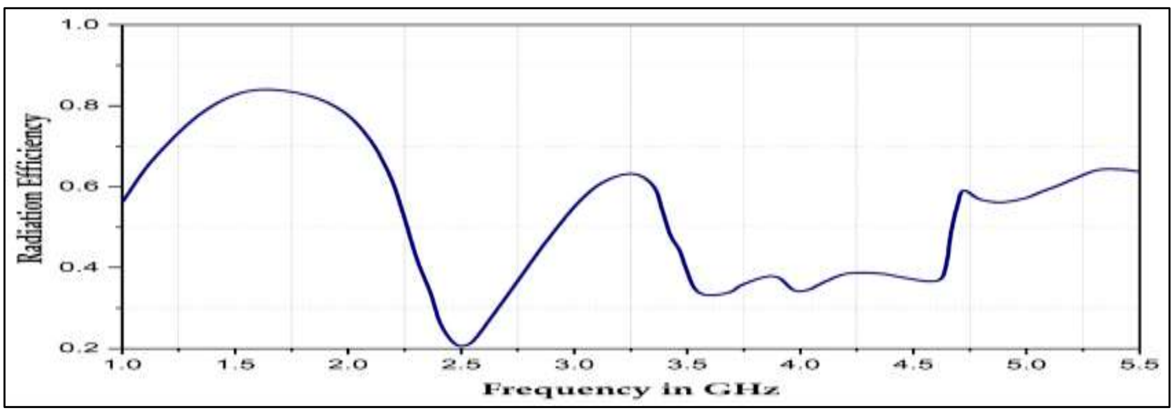

Figure (3): Radiation efficiency of DS-IFS.

The frequency versus gain curve for the anticipated DS-IFS was displayed in Figure 4. The largest gain in terms of decibels was attained at a frequency of 4.6 GHz, the maximum increase in decibels was attained.

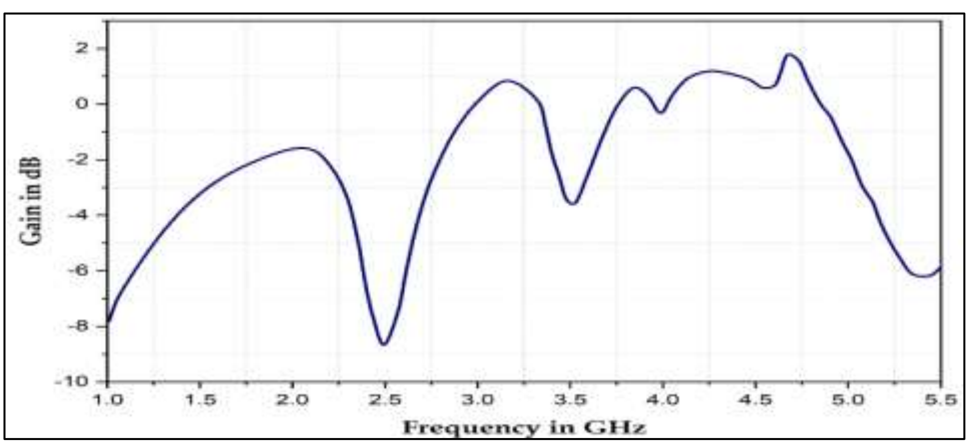

Figure (4): Features of DS-IFS Frequency vs Gain

Choosing the appropriate, accessible substrate substance for a given application is an important issue. In order to meet the mechanical devices and electrical requirements, it should be selected carefully. The suggested DS-IFS was investigated using three textile materials such as polyester, wash cotton, and jeans. The performance parameters were compared among three materials. Figure 5 displays S (1, 1) features analysis of three materials. Compared to other substances, resonance was attained nearer the intended frequency when using jeans as base material, and a higher maximum S (1, 1) dB value was obtained. Table 1 illustrates the performance metrics with various substances.

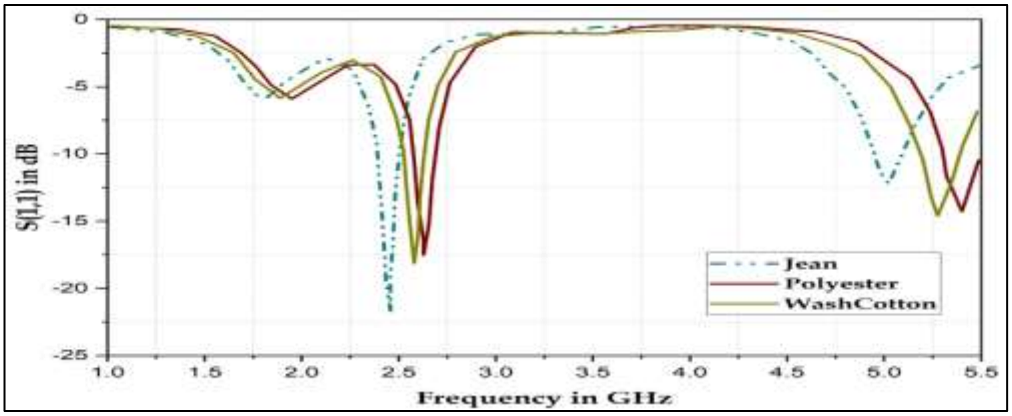

Figure (5): Analysis of DS-IFS three distinct permeable substrates

Table (1): Comparing performance metrics with various substances

Substrate Material	**Jean**	**Wash Cotton**	**Polyester**
Dielectric Constant	1.7	1.51	1.44
Patch Size (mm^2)	45×45	49×54.6	50.2×55.4
Resonant Frequency (GHz)	2.53	2.58	2.63
S(1,1) (dB)	-22.03	-18.70	-17.66
Bandwidth (MHz)	110	110	120

Figure 6 represents the ideal cost vs. iteration count curve for DS-IFS. The number of iterations require to obtain best cost it takes 60th iteration.

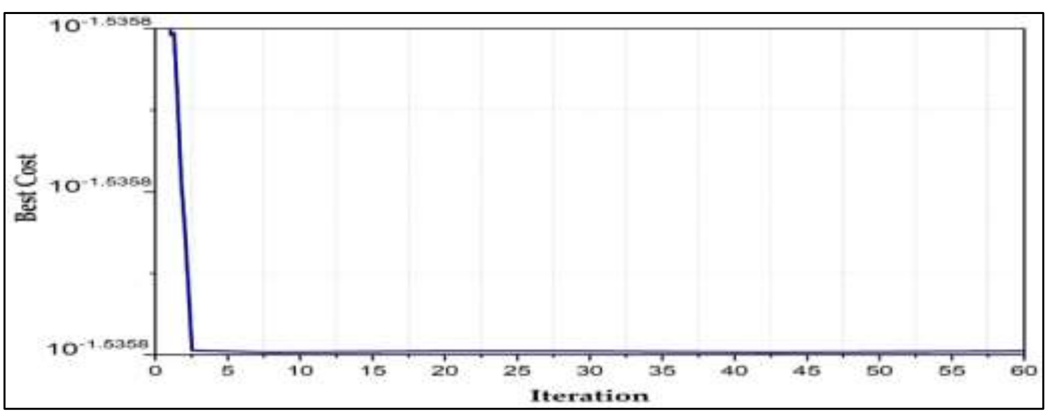

Figure (6): Best Cost Vs Number of iterations

We assess the proposed strategy and calculate its effectiveness using the following indicators: Area (mm^2) and S (1, 1) dB. We also present an efficacy comparison between our proposed strategy and other current approaches. The existing methods include GCSA [16] and WHFASR [17]. Table 2 illustrates the comparison of GCSA, WHFASR and DS-IFS proposed.

Table (2): Comparing GCSA, WHFASR and proposed DS-IFS.

Methods	**Area (mm^2)**	**S (1, 1) dB**
GCSA	1156	-56.02
WHFASR	2600	-22
DS-IFS [proposed]	2895	-58.62

The suggested DS-IFS compared with other existing antennas like GCSA and WHFASR methods. The comparison was conducted among dimensions, S (1, 1). Compared to existing antennas, the suggested antenna is smaller in size. With the exception of reporting antennas, the proposed DS-IFS approach is thin and small. The suggested DS-IFS provides a value for S (1, 1) parameters and complies with all standards. The experimental outcomes demonstrate that the suggested DS-IFS approach is suitable for wireless systems.

5. Conclusion

In this work, we proposed a revolutionary strategy called the dragonfly swarm-assisted iterative function system (DS-IFS) technique to enhance the unique fractal antenna layout for the Koch hybrid (Koch and Meander curve geometries). The IFS and DSO were created and examined. Multi-band functionality is achieved by combining hybrid geometries such as Meandering and Koch curves. To get the frequency of resonance to the design frequency, the ground plane is additionally defective. Additionally, fitting curves were used to maximize the ideal location with DSO. The manufactured object was tested by VNA, and the outcome of the simulation and measurement were compared. The fractal antennas like Koch fractals have a narrow bandwidth. Potential difficulties in precisely creating intricate fractal shapes on textile substrates constitute difficulties and possess an impact on durability and reliability. Environmental elements from the real world, including fabric deterioration, may affect the antenna's longevity and dependability. In future research, multiband or wideband properties might be achieved by creating Koch fractal antennas, which would increase their application and adaptability.

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List of Abbreviations

Abbreviation	**Definition**
WBAN	Wireless Body Area Networks
HFSS	High Frequency Structure Simulator
CPW	Co-Planar Waveguide
FBW	Fractional Bandwidth
MIMO	Multiple Input Multiple Output
WHFASR	Wearable Hybrid Fractal Antenna employing Split Rings
IFS	Iterative Function System
VNA	Vector Network Analyzer
CFR	Curve Fitting Realization