Various Antenna Structures Performance Analysis based Fuzzy Logic Functions

Antenna Performance Analysis Based FLF

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***Abstract*—The antenna is a critical component of the communication system. The antenna is used in wireless communication for signal transmission and reception over long distances. There are numerous sorts of antennas, such as wire antennas, traveling wave antennas, reflector antennas, microstrip antennas, and so on. The application of antennas is determined by the antenna's attributes as well as the frequency range of operation. As a result, it is vital to understand the behavior of antennas over a wide range of operations and select the optimum antenna for the application. The performance parameters of the antenna determines its efficiency. VSWR, Return Loss, Directivity, Bandwidth, and more parameters are available. As a result, one of the primary areas of focus is antenna analysis. In this study, we simulate various antenna types and derive performance parameters such as return loss, directivity, and so on. MATLAB will be used to simulate the antenna at various frequencies. When all of the parameters are taken into account, the analysis becomes quite tough. In this case of ambiguity, we use fuzzy logic to calculate the antenna's performance index. A variety of antenna parameters will be fed into the fuzzy inference system, which will make a judgment based on a set of rules. The crisp numbers are turned into fuzzy values using the fuzzification process, then evaluated and defuzzied to obtain the antenna's performance index. The fuzzy inference system will be developed in MATLAB, and the overall system will be modeled in Simulink.**

***Keywords*—Antenna; antenna element; function; fuzzy logic function; fuzzy inference system; Matlab; Simulink**

I. Introduction

A radiated element is a type of electrical equipment that converts electric power into radio waves, allowing the signal to be transmitted over open space. It also converts incoming radio signals to electrical impulses. As a result, in the field of wireless communication systems, the antenna is extremely significant. Several things influence antenna selection. The frequency of operation [1], as well as the application, are two of these criteria. The antenna's performance is determined by numerous criteria such as return loss, reflection coefficient, and voltage standing wave ratio. In this research, multiple antenna topologies are modeled for performance characteristics for different frequencies using MATLAB's antenna [2] toolbox. These parameters are fed into the fuzzy inference system, which analyzes the antenna's performance while taking all of the parameters into account. The fuzzy inference system is created using a rule set drawn from antenna experts' knowledge. Using fuzzy rules, the crisp values are fuzzified [3] and assessed for performance, while the linguistic values are defuzzified to crisp values. The proposed fuzzy inference method is used to analyze the antenna's performance. Simulink is used to model the system, and the performance of the antennas at various frequencies is assessed, as well as the performance variation of the antennas regarding frequency, is plotted. This study addresses the construction of a system that uses fuzzy logic to examine the performance of antenna configurations. The antenna structures are simulated in this step using the MATLAB antenna design toolkit, and the performance parameters are extracted. These collected parameters are fed into the analyzer, which determines the antenna's performance. Lotfi A. Zadeh published a study on fuzzy logic in 1964. Zadeh continued to develop the fuzzy set theory between 1965 and 1975. Fuzzy logic arose as a result of the challenges experienced by standard mathematical techniques in constructing and evaluating complicated systems. The performance study of the antenna structure is particularly complex because the parameters that determine performance must be considered and studied at the same time. The fuzzy inference system described in this paper was designed to avoid this complexity [4]. The first research team considers the use of fuzzy logic in educational institutions. It discusses how fuzzy logic can be used to analyze student performance. The marks earned by pupils are fed into the fuzzy inference system, which evaluates the student's performance. The rectangular microstrip antenna [5] was modeled and simulated. It also provided a method for integrating Matlab into Visual Basic. Matlab is a great tool for designing and simulating antenna structures of all types. The tool provides a detailed explanation of the performance parameters of the designed antenna. [6] Proposes utilizing Matlab to construct and analyze a parabolic reflector. [7] examines the analysis of E-plane and H-plane normalized patterns. Analysis of the parabolic reflector, such as f/D, gain, and radiation patterns, was performed, and the appropriate results were provided. A second study team considers faculty performance evaluation in educational institutions. In this research, we propose the creation of a fuzzy inference system to evaluate the antenna's performance. MATLAB is used to simulate the many types of antennas [8] describes the modeling of a rectangular microstrip antenna using Matlab and Visual Basic. [9]. Shows a Matlab simulation of an NxN antenna array, with the antenna array factor indicated for each person. It demonstrates the effect of increasing the directivity of the

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beam array factor of the antenna array with an increase in antenna elements, as well as analyzing the effect of increasing the antenna elements on the array factor.[10]-[11]-[12]-[13] cover the design and improvement of antenna element performance. The design of many antennas is known in the literature. [14] describes the design of a square patch antenna. A stacked square patch slotted broadband microstrip antenna is described in another paper [15].

II. Fuzzy Logic

Nowadays, fuzzy control is considered an important tool for control, in addition, it is used for helping developers to solve several problems such as designing switched dynamic output for continuous-time. A new type of dynamic output feedback controllers, namely, switched dynamic parallel distributed compensation controllers, is proposed, which are switched by basing on the values of membership functions. For guaranteeing stabilities, and maintaining parameters values, we propose, for the various antenna structures, abased fuzzy logic functions solution to be used for performance analysis. In practice, type-2 fuzzy logic was initially introduced by Zadeh [16]. The presented technique has been proved to be very interesting especially in complex problems which are treating real-world noisy applications [17]. We know that during system development steps, Type-2 Fuzzy Logic (T2FL) defines the same lexicon of the classical type-1 FL as membership functions, rules, norms operations, fuzzification, inference, and defuzzification [18], but those terms have unlike definitions to picture them. The big differentiation between Type-1 and Type-2 FL consists essentially in kind of fuzzy sets and in the output processor step which precedes the defuzzification bloc; the type-1 MFs are certain and crisp, whereas these type-2 are themselves fuzzy; they are represented by a bounded region limited by two MFs, were corresponding to each primary MF (which is in [0, 1]), a secondary MF is used to the primary one. With regard to the output processor, in type1 FLSs it is represented just by the known defuzzification process (center of sets…), however, in type-2 FLSs it consists of two components: Type reduction and defuzzification; type reduction makes a reduction from a type-2 fuzzy output sets to type-1 sets and then these reduced sets will be defuzzified to obtain the final crisp outputs. Zadeh pioneered fuzzy logic in the 1960s and 1970s. Fuzzy logic incorporates human knowledge with operational algorithms. The computer may be programmed to work in the same way that the human mind does. Traditional logic and set theory are all about whether something is true or false, white or black, zero or one. Fuzzy logic, on the other hand, accepts all conceivable values.

A. Fuzzy Sets

The fuzzy set notion is simply an extension of the classical set concept. When compared to the classical set, the fuzzy set is substantially larger. The classical set has only a few membership options, such as true or false, '0' or '1'.

B. Fuzzification and Defuzzification

The values must be linguistic in order to be applied to the fuzzy inference system. The degree of membership in the fuzzy set is used to represent these linguistic values. Fuzzification refers to the process of transforming these crisp linguistic values into fuzzy linguistic values. The technique of producing quantitative outcomes is known as defuzzification. The fuzzy inference system will generate a fuzzy result that will be represented in terms of the degree of membership of fuzzy sets. Defuzzification assigns explicit real values to the membership degrees of fuzzy sets.

III. Implementation

In this article, several antenna topologies are simulated for different frequency ranges using the MATLAB antenna processing tool. With this collection of characteristics, analyzing the performance of the antenna becomes a tiresome task. At this point of uncertainty, the fuzzy logic idea [19] is used to examine the performance of the antennas while taking into account all of the characteristics. The antennas [20] are simulated for frequency ranges ranging from 1MHz to 10MHz, and the performance characteristics are assessed with a fuzzy inference algorithm to provide a performance index. The derived performance index is displayed versus frequency

IV. Simulation Results and Discussions

A. Antenna Design and Simulation

Antennas are constructed and simulated in Matlab using the antenna design toolbox. We primarily built and simulated five antenna structures: a bow-tie antenna, a monopole antenna, a dipole antenna, an inverted f antenna, and a helix antenna. The simulation yields parameters such as directivity, VSWR, and reflection coefficients, which determine the antenna's performance. The concentration of radiation in a specific direction is measured by directivity. It specifies the antenna's directionality. Efficiency affects both directivity and gain. Patterns can be used to simply determine directivity. The ratio of maximal radiation intensity to average radiation intensity is defined as directivity. The return loss is another key aspect that influences performance. It is a parameter that reflects how much power is lost. As a result, it is a critical element in determining antenna performance. The simulation's VSWR and reflection coefficients are retrieved and used for further processing.

B. Development of Fuzzy Inference System

- The If and Then set of rules is used to create a fuzzy inference system. The regulations are determined based on professional guidance, taking into account all factors of antenna performance.
- The fuzzy system's output is the linguistic value, which must be translated back to crisp value. Defuzzification is the name given to this type of conversion. Defuzzification strategies include the max membership concept, the centroid method, the weighted average method, the mean max method, the center of sum, the center of the biggest area, and the first (or last) of maxima. The centroid approach is utilized for defuzzification in this article. The centroid approach is also known as the center of gravity method.
- The fuzzy logic toolbox is used to create the fuzzy decision system. Performance characteristics such as VSWR, reflection coefficient, return loss, and directivity is fed into the system. Fuzzification is a

process that converts crisp input values to fuzzy language variables.

- The core of the membership function for the given fuzzy set A is defined as that region of the universe characterized by complete and full membership in A. This means that the core consists of those universe elements x such that A (x) = 1. The set of fuzzy linguistic variables is referred to as the fuzzy set A. Triangular membership functions are studied in this study.

C. Parameters of Performance

During the simulation step performance parameters of the antenna are determined and the performance variation value parameters are presented in Table (I) to the Table (V), for bow-tie antenna, a dipole antenna Table (II), inverted f antenna Table (III), a monopole antenna Table (IV), and helix antenna respectively. We simulated the antennas in the frequencies range from 1 Mhz to 10 Mhz.

We presented values in Table (I). In practice, the obtained performance index parameters are optimized due to the fuzzy inference system, we analyze d using the fuzzy rules and the performance index is obtained. Table VI gives the variation of the performance index of various antennas at different frequencies.

These performance parameters are input to the fuzzy inference system and analyzed efficiently by using the fuzzy rules. We storge, at a different frequency, performance index variation of various antennas in the Table (VI). We present a plot of performance index variation in Fig. 7. We need a reasonable separation range than a semantic obfuscation technique. At level 3, semantic obfuscation technique separation range came to 40.6 km, which is a high accomplishment regarding area protection, yet utility of administration is debased, while at that level enhanced semantic obfuscation technique accomplished balance between area protection and administration utility, see Table I.

TABLE I. PERFORMANCE PARAMETERS OF BOW TIE ANTENNA

Reflection Coefficient	0	0	0	-9e-9	-2.2e-8	-4.7e-8 -	8.8e-8	-1.5e-7	-2.4e-7	-3.6e-7
Return Loss	0	0	3e-9	9.4e-9	2.3e-8	4.8e-8	8.8e-8	1.5e-7	2.4e-7	3.7e-7
Directivity	18.7	-24.7	-28.2	-30.7	-32.7	-34.2	-35.6	-36.7	-37.8	-38.7
VSWR	4.7e11	3e10	5.8e9	1.85e9	7.55e8	3.64e8	1.97e8	1.15e8	7.19e7	4.7e7

TABLE II. PERFORMANCE PARAMETERS OF DIPOLE ANTENNA

Reflection Coefficient	-4.5e-8	-7.2e-7	-3.7e-6 -	-1.2e-5	-2.8e-5	-5.9e-5	-1.1e-4	-1.8e-4	-3e-4	-4.6e-4
Return Loss	4.5e-8	7.2e-7	3.7e-6	1.2e-5	2.8e-5	5.9e-5	1.1e-4	1.8e-4	3e-4	4.6e-4
Directivity	-18.2	-22.9	-24.9	-26	-26.5	-26.9	-27.2	-31.4	-31.7	-31.9
VSWR	3.6e8	2.4e7	4.75e6	1.5e6	9.1e4	2.9e5	1.5e5	9.1e4	5.7e4	3.7e4

TABLE III. PERFORMANCE PARAMETERS OF INVERTED F ANTENNA

Reflection Coefficient	-1.9e-15	-6e-14 -	5e-13 -	1.7e-12	3.9e-12 -	8.34e-12	-1.5e-11	-2.6e-11	-4.2e-11 -	-6.3e-11
Return Loss	1.9e-15	6e-14	5e-13	1.7e-12	3.9e-12	8.34e-12	1.5e-11	2.6e-11	4.2e-11	6.3e-11
Directivity	1.74	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73	1.73
VSWR	9e15	2.9e14	3.5e13	1.01e13	4.45e12	2e12	1.1e12	6.6e11	4.1e11	2.7e11

TABLE IV. PERFORMANCE PARAMETERS OF MONOPOLE ANTENNA

Reflection Coefficient	-1.37e-8	-2.2e-7	-1.1e-6	-3.5e-6	-8.6e-6	-1.8e-5	-3.36e-5	-5.8e-5	-9.3e-5	-1.4e-4
Return Loss	1.37e-8	2.2e-7	1.1e-6	3.5e-6	8.6e-6	1.8e-5	3.36e-5	5.8e-5	9.3e-5	1.4e-4
Directivity	-18.7	-24.7	-28.1	-30.6	-32.5	-34	-35.2	-36.3	-37.2	-38
VSWR	1.26e9	7.88e7	1.53e7	4.9e6	2e6	9.6e5	5.1e5	3e5	1.8e5	1.2e5

TABLE V. PERFORMANCE PARAMETERS OF HELIX ANTENNA

Reflection Coefficient	-1e-11	-1.6e-10	-8.5e-10	-2.6e-9	-6.5e-9	-1.4e-8	-2.5e-8	-4.3e-8	-6.9e-8	-1.05e-7
Return Loss	1e-11	1.6e-10	8.5e-10	2.6e-9	6.5e-9	1.4e-8	2.5e-8	4.3e-8	1.05e-7	1.05e-7
Directivity	-18.4	-23.8	-26.4	-27.8	-28.7	-29.3	-29.7	-30	-30.2	-30.3
VSWR	1.6e12	1e11	2e10	3.4e9	2.6e9	1.3e9	6.8e8	4e8	2.5e8	1.6e8

TABLE VI. PERFORMANCE INDEXC OF VARIOUS ANTENNA AT DIFFERENT FREQUENCY

Bow Tie	0.43032	0.430105	0.49982	0.4499817	0.4998660	0.499674	0.499878	0.49988	0.49988	0.49988
Invertedf	0.500385	*0.585188*	*0.585288*	0.58529	0.585296	0.585295	0.585295	0.585295	0.585295 0	0.585295
Helix	0.500856	0.4998837	0.499659	0.4996323	0.499804	0.4997788	0.49977	0.499792	0.499802	0.499804
Monopole	0.500042	0.499877	0.499824	0.499814	0.499857	0.49987	0.499878	0.49988	0.49981	0.49969

Fig. 1 depicts the membership function for the input reflection coefficient. The fuzzy set includes the variables more negative(mn), negative(n), and zero(z), as indicated in the picture. Fig. 2 and 3 depict the rule viewer for the given set of inputs. Fig. 4 depicts a surface view of the variation of the performance index with regard to the input parameters.

Fuzzy Surface Viewer Showing the Variation of Performance Index with Respect to Inputs:

The generated fuzzy system is exported to Simulink, and fuzzy modeling is performed, as shown in Fig. 5. Fig. 6 depicts the suggested system's modeling.

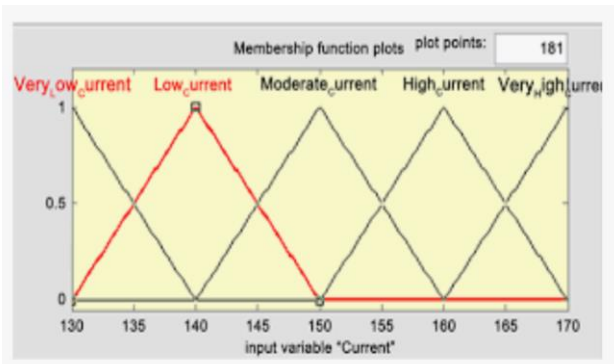

Fig. 1. Membership Function of the Input Variable.

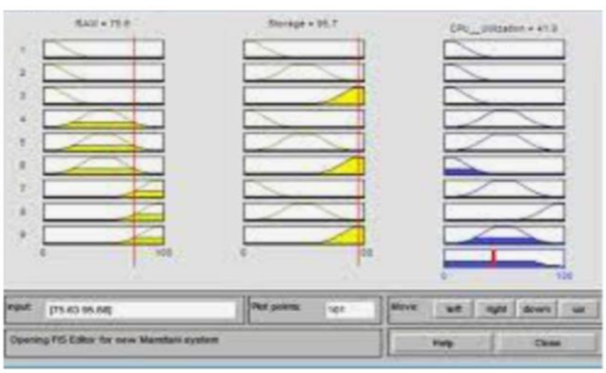

Fig. 2. Fuzzy Rule Viewer for Input VSWr and Directivity of the Input Variable.

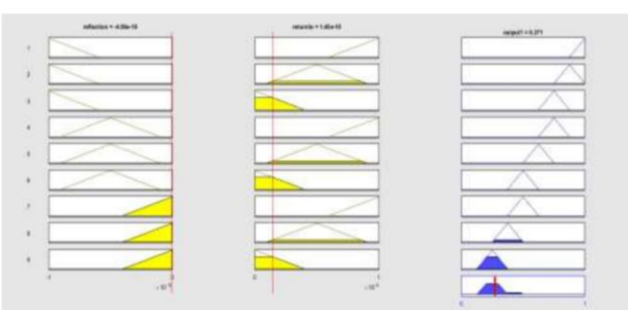

Fig. 3. Fuzzy Rule Viewer for Inputs Reflection Coefficient and Return Loss.

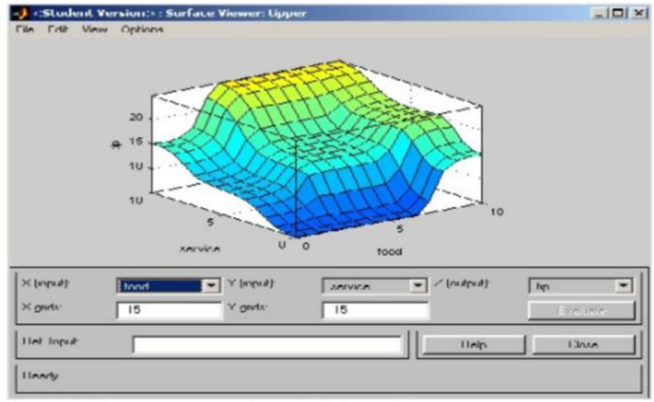

Fig. 4. Fuzzy Surface Viewer showing the Variation of Performance Index with respect to Inputs.

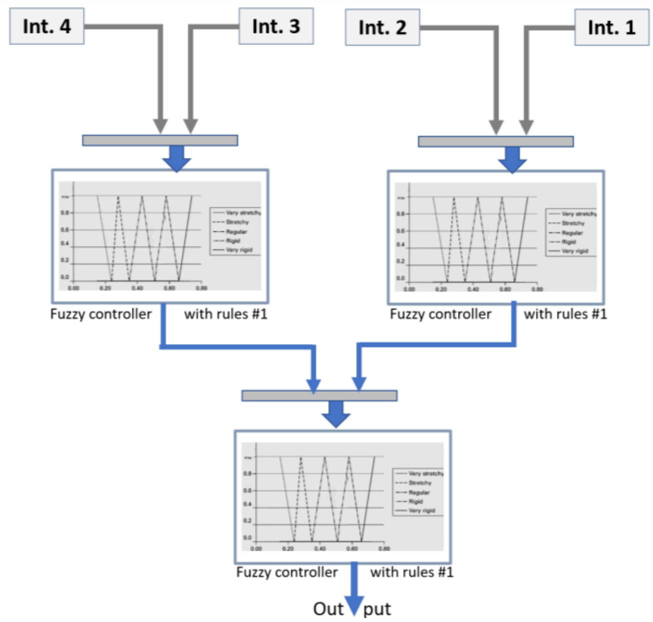

Fig. 5. Simulink Model for Fuzzy.

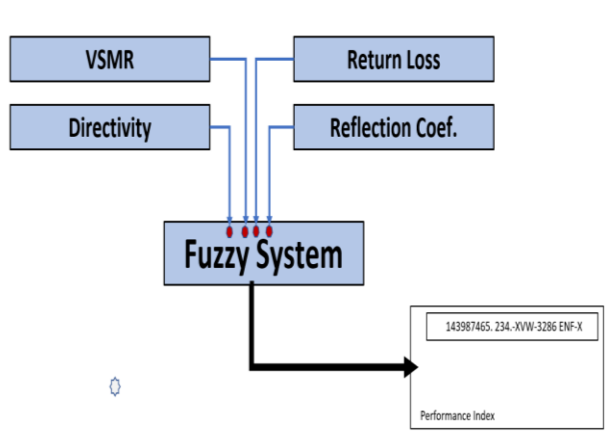

Fig. 6. Proposed System Modeling based on Simulink.

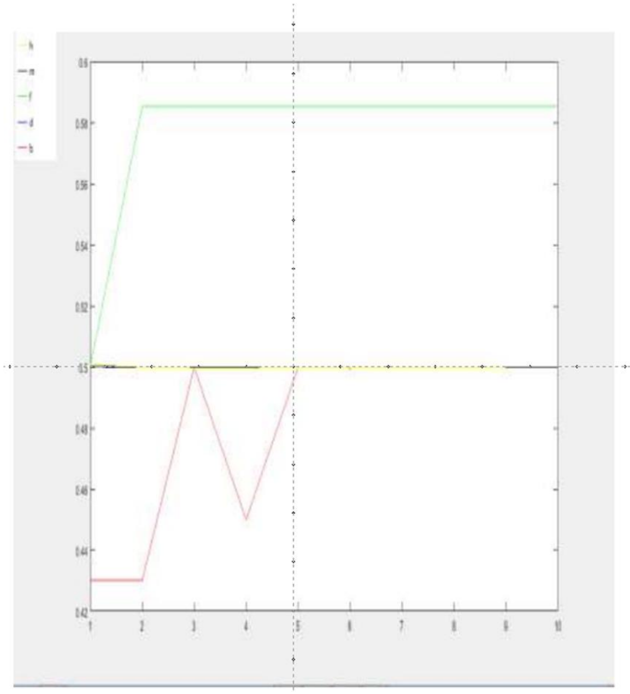

Fig. 7. Performance Index Variation with to Frequency.

Variation is evident when the performance index is plotted against the frequency. Fig. 7 depicts the frequency fluctuation of the performance index.

V. Conclusion

In this research, various antenna topologies are simulated using Matlab, and performance characteristics are retrieved from the simulation results. The antennas are simulated for frequency ranges ranging from 1MHz to 10MHz. Based on fuzzy logic, this research provides a new method for evaluating the performance of an antenna. The traditional mathematical paradigm for decision making cannot be applied to complicated systems such as antenna performance. As a result of this paper, this problem is alleviated, and an exact evaluation of the antenna's performance is possible. The fuzzy system is created, and the proposed system is modeled with Simulink. The constructed system is fed inputs, and the output is observed. The obtained performance index of the antennas is plotted. According to the results of the analysis, the inverted f antenna outperforms the other antennas studied in the frequency range 1MHz to 10MHz.

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