Review of Seven-Element Ground Skirt Monopole ESPAR Antenna Design From A Genetic Algorithm and the Finite Element Method

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Abstract— **Electronically Steerable Passive Array Radiator Antenna (ESPAR) is a smart antenna that can help to improve the performance and effectiveness of wireless network systems, especially in ad hoc networks. There are several benefits that can be attained by smart antenna, such as better range and coverage, increased capacity, multipath rejection and reduced expense. In this research, the antenna structure was optimized by a genetic algorithm using a finite element based cost function, and maximal main lobe gain in a single azimuth with loading conditions. The result of the simulated gain was 7.3 dBi at 2.4 GHz. However, the experimental gain was recorded as greater than 8 dBi. The antenna was optimized and the error that was noticed between simulated and measured gain was the same in several structures. The average main lobe elevation was reduced in the optimized antenna by 15.3 to just 9.7 above the horizontal. ESPAR presented in the research was accurately optimized with agreement between simulated and measured results.**

Keywords—Adaptive antenna; Finite Element; Genetic algorithm; Parasitic radiator; Passive Array.

I. RESEARCH CONTEXT

Mobile wireless network systems have become a significant area of growth recently. The most important part in this system is the antenna because the efficiency of wireless network systems depends on the performance of the antenna that is used. The ESPAR antenna is one of these antennas that has been developed in order to be used in wireless ad hoc computer network. Seven-element ground skirt monopole ESPAR antenna design was optimized by using a genetic algorithm and finite element method.

The antenna comprised six parasitic elements surrounded by a single feed element. In terms of the configuration of the antenna, a genetic algorithm was utilized with a finite element method based cost function to address the antenna structure optimization.

The genetic optimization concentrated on developing the main lobe horizontal gain of the antenna. The antenna was designed in order to work at 2.248 GHz. However, it was found to be working at 2.4GHz in experimental resonance. Due to the finite ground, the radiation lobe elevation was reduced by using the ground skirt. In order to simulate and optimize the antenna, a High Frequency Structure Simulator was employed with genetic algorithm. The main reason for the optimization was to amplify directional gain in a single azimuth direction. Designing the antenna based on predetermined criteria needs to use computer optimization to obtain automated process.

A dual PIII 850 with 1G random access memory was used in optimization and it took approximately four weeks. In measurement results, the maximum gain of the antenna was 8.08dBi and its front-to-back was 10 dB and front-to-null was recorded at 18 dB. Furthermore, there was agreement between experimental and simulated results except a small error found between simulated and measured gain which was 0.7 dBi. The antenna was successfully optimized and the optimization solution space was very large.

II. LITERATURE REVIEW

Optimization of the ESPAR antenna was the main purpose of the research. Using a genetic algorithm with a finite element was the way to optimize the antenna. Designing the antenna was to work for 2.484 GHz, but experimental resonance was found at 2.4 GHz. On one hand, Schlub et al [1] designed a six element switched parasitic antenna where the resonance frequency was recorded at 1.55 GHz and measured experimentally at 1.56 GHz. There was not a significant different about frequency shifting between both antennas, and the difference between resonance and simulated frequency did not significantly affect on the results.

Using genetic algorithm in order to optimize the ESPAR antenna is commonly used in research. For instance, Mitilineos et al [3] mentioned that in such cases the numerical techniques commonly utilized for optimization and design of ESPAR antennas are not applicable. Therefore, an objective function of the genetic algorithm is involved.

Lu et al [2] designed nine and 17-element DE-ESMB antennas. They concluded that these types of antenna array were quite small as compared to their free space counterparts and the nine and 17-elements were more applicable for mobile terminals. Lu et al [2] developed ESPAR antenna array using numerical modeling techniques and concluded that the ESPAR antenna can produce single or multiple beams in order to increase the capability of wireless access. Security effectiveness can be improved better than the case for the monopole antenna that is used commonly in wireless systems. Furthermore, many new features can be offered by the smart antenna which cannot be achieved by the existing wireless system.

III. Research Methods

The method that was used in the research was quite common for experimental research. It seems to be employed because the appropriate approaches are clear. This kind of approach is used to explore and collect factual information and investigate relationships between simulated results and measured results, it is called a quantitive approach. Analyses of information led to quantified results and then the conclusion is drawn from an evaluation of the results in the light of the theory and literature.

There are many styles of research. One of these styles is the experimental style which is used when numerous variables are available and known. The experimental style consists of eight stages, which are aim, objectives, identify variables, determine sample size, and conduct the experiment, data analysis, conclusion and further research. It is important to complete all stages in order because each stage prepares for the next [4].

In the reviewed research the authors used the experimental style. The research was started with obvious goals, and then the objectives were determined to know what was to be tested and to understand the limits of the scope of the experiment. The variables were clear in the research and were adequate to meet the necessary measurements. In the third and forth section of the research, experiment was executed and conducted accurately. Data was analyzed and compared with simulated results.

Finally, the conclusion was determined by comparing between simulated and measured results and showed a clear picture for the results. Further development of the research was brief and provided little useful information which was enough information for readers to get better suggestion for further work.

IV. Data Collection and Presentation

Data requirement is an early stage of any research and it is considered a good discipline to give preliminary consideration to data that is needed. For any research, the collection of data is the main issue that faces scientists. Collecting specific data and examining such data are important aspect when preparing to strong research [4].

In this reviewed research, authors determined all the data that was needed to address the objectives of the paper. A genetic algorithm, finite element method and many important equations which related to the paper requirements were explained.

The sequence of presenting the paper was appropriate for this kind of research. The introduction gave a clear picture of the research because it consisted of information for the whole research. However, the introduction was quite long. Furthermore, the second part of the research could have been divided into two parts. The first part was best to done with antenna design and the second part antenna configuration, in order to give a clear understanding for readers. In addition, figure 1 which showed dimensions of the antenna was good with all dimensions of the elements. However, there was not a picture of the back of the antenna. Furthermore, the size of the ground skirt was not given in the research and it is important to give such essential details.

V. Conclution

The ESPAR antenna presented in the research was optimized by using algorithm with a finite element method. The optimization was very large, and effected by localized, suboptimal solutions. Therefore, the robust nature of a genetic algorithm was the reason for using the GA for optimization. The GA utilized a FEM based cost function to acquire accurate modeling of the antenna.

Finally, the structure of the physical antenna and loading reactance were correctly optimized. The antenna was optimized with agreement between simulated and measured results.

VI. Avenues For Further Work

Authors suggested that the optimization process could be adapted to more complex optimization. For instance, physical size can be reduced by immersed the antenna in a dielectric medium. Lu [2] mentioned that ESPAR can be improved by using the optimal design which is required and the size of antenna array and antenna performance can be affected by the material of dielectric directly, such as antenna gain, return loss and the radiation pattern.

The nine and 13-elements of this kind of antenna provide a better performance in aspects such as the gain, main lobe and directivity. Two beams simultaneously can be produced by the nine element antenna, separated by 180°. Also four beam directions probably attained at 90° spacing through the azimuth plane. The size was reduced by embedding the switched parasitic array in a homogeneous dielectric material.

VII. References

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