Notch band optimization of planar Ultra Wide Band antenna using GA

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Abstract

The paper presents the optimization of the notch band in an Ultra Wide Band (UWB) serrated monopole antenna using a modified Genetic Algorithm approach. The results are compared with that of a similar antenna where the slot is designed using conventional approach. The algorithm is found to be highly efficient in terms of computation time and slot area.

1. Introduction

Ultra Wide Band (UWB) antennas are capable of high data transmission rates and can be used in communication applications such as RFID devices, sensor networks, radar and location tracking requiring small size and non dispersive properties. Its commercial usage of frequency band from 3.1GHz to 10.6GHz was approved by the Federal Communications Commission (FCC) in 2002. UWB antennas should reject interference with existing wireless networking technologies such as IEEE802.11a in the U.S. (5.15-5.35GHz, 5.725-5.825GHz) and HIPERLAN/2 in Europe (5.15-5.35GHz, 5.47-5.725GHz) [1]. This is important because UWB transmitters should not cause any electromagnetic interference on nearby wireless LAN systems. Therefore, UWB antennas with notched characteristics in WLAN frequency band are desired. The ability to provide this function can relax the requirements imposed upon the filtering electronics within the wireless device.

2. The planar UWB antenna

The geometry of the planar Ultra Wide Band antenna chosen for notch band optimization is shown in Fig. 1. The antenna operates from 3.5GHz to 12GHz [2]. The monopole has a staircase edge, with a mirror image geometry on the ground plane with an offset of 2mm along y-direction. This geometry increases the edge dimensions and provides improved bandwidth due to multiple resonances as explained in [2].The antenna radiates with good return loss in the W-LAN frequency (5.1GHz to 5.82GHz). To avoid this interference, a notch band at these frequencies is desired. The paper deals with the optimization of the slot in the antenna to achieve the above desired radiation characteristics.

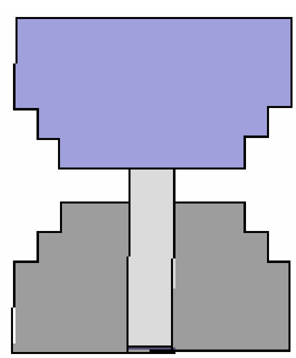

Fig. 1 UWB antenna chosen for optimization of notch

3. Genetic Algorithm Optimization

Genetic algorithm is an effective tool for optimizing the antenna design to achieve required radiation characteristics of antenna. In order to overcome the inherent slow convergence feature of conventional approach in selection /crossover, a novel approach to population generation is adopted. The optimization is done in two phases. The first phase locates the region of slot structure which will satisfy the notch band frequency. This is done in contrary to conventional GA which gives randomly and disorderly distributed array of small slots. The second phase optimizes the slot dimension.

3.1 First Phase

A 1cm x 1cm square region symmetrical about the feed is chosen as search area and is divided into 20 x 20 matrix region, with each square of size 0.5mm x 0.5mm. To obtain a well connected slot structure, initial population comprises of 10 chromosomes - 5 containing random slots and 5 containing connected slots at random locations. The antenna characteristics is simulated using ANSOFT HFSS. A '1' is represented by presence of metal and a '0' is represented by absence of metal. The operating bandwidth and presence or absence of notch determine the cost. The cost function is formulated giving importance to band limits (3&12 GHz). Patterns not satisfying band requirements are assigned the maximum cost (12); where 12 >> required BW (12-3GHz) + required notch BW (5.825-5.1GHz)]. For all other cases,the cost function = [9 - Bandwidth] + [Notch bandwidth]. The first generation results reveal the effect of perturbed edges on ultra wide band performance. Random matrix patterns give only 20% - 34% bandwidth, while connected slot patterns give ultra wideband characteristics. Introduction of connected slot patterns can delay convergence. So, modifications are incorporated to conventional crossing and selection procedures to reduce convergence time.

3.2 Improved Genetic Algorithm for faster convergence

3.2.1 Combined Row and Column crossing:

Genetic algorithm allows two types of crossing in matrix chromosomes. They are Row and Column crossing with respect to the cross over point. Conventionally, either of these is followed through out the iterations. In this paper, an alteration is made to this procedure. Same parents are made to cross, row wise and column wise with respect to a random cross over point. The new generation consists of both, row cross over and column cross over offsprings in addition to their parents. This approach increases the diversity of new generation resulting in increased search efficiency. Two point crossing is performed to get maximum benefit of crossing.

3.2.2 Modified Tournament Selection

Tournament Selection has proved to be effective in electromagnetic field applications [3]. But Tournament Selection results in multiple selection of a parent, leading to slow convergence. This makes the next generation highly inferior in terms of diversity. Thus the convergence heavily depends on mutation. Preferred mutation rate is 0.05-0.08%. Rate of mutation adopted in this paper is 0.07%. Crossing is avoided if multiple selection of a parent occurs. Tournament selection is performed until the selected generation comprises of dissimilar parents with maximum occurrence fixed as 2. The modified tournament selection is then followed by crossing. The presence of minimum cost patterns along with other dissimilar parents is thus assured. This modification ensures diversity and helps in faster convergence. Five parents are selected using 'modified tournament selection' and they are made to cross, column wise and row wise to yield five children each. Thus the second generation will contain fifteen patterns (five parents+10 off springs). Cost of all fifteen off springs is calculated and third generation parents are selected. Iterations are thus continued. Simulation results indicate that the required notch band is obtained when the slots are located in the vicinity of the feed point region. The slots near the top and bottom are also found to produce an adverse effect.

3.3 Second Phase

To further reduce the iteration time and intensify the search, so as to avoid local minimum, the search area is confined to 6mm x 5.75mm, 0.25mm above the bottom edge. Edge distortion at the bottom is thus avoided, maintaining the proximity to the feed line. The search area is divided into 24 x 23 squares each having a size of 0.25mm x 0.25mm, creating a new set of initial population. As in the first phase, initial population is a mixture of random and connected slot matrices. None of these patterns distort the basic antenna edges, ensuring wide band characteristics. Hence in the second phase, cost function is based more on notch properties than wide band width. Cost function is thus formulated as, Cost= $|x\text{-}x1| + |y\text{-}y1| + 12\,z$

Where, x =desired starting frequency in GHz of the simulated notch band, x1=5.1(desired starting frequency of notch band); y=0.72GHz (desired bandwidth of notch), y1 is the bandwidth of simulated notch band, z = 1; if notch is absent & z = 0; if notch is present. The selection and cross over adopted in first phase is used in second phase also.

4. Results and discussion

In the fourth generation of the second phase, the pattern shown in Fig.2 satisfies the requirement of notch at 5.1-5.82GHz, as illustrated by the return loss characteristics in Fig.3. The transmission characteristics is shown in Fig.4. The pattern has a well connected inverted ‘u’ slot and nine randomly located slots. The total number of slots is 79; each having an area of 0.25mm x 0.25mm- total slot area is 4.93 mm^2.

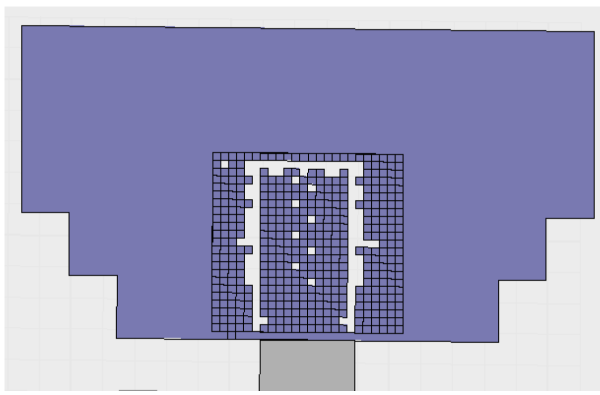

Fig.2 GA optimized slot pattern

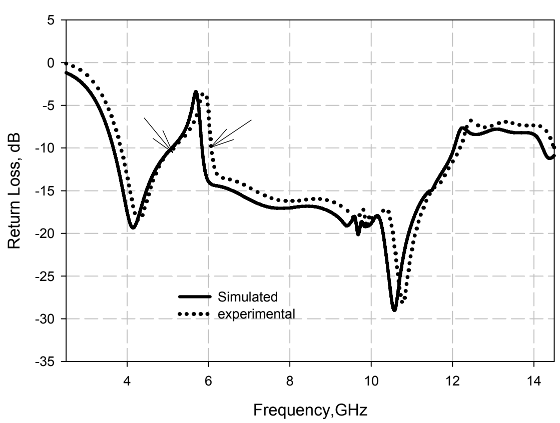

Fig.3. Return loss characteristics of optimized pattern

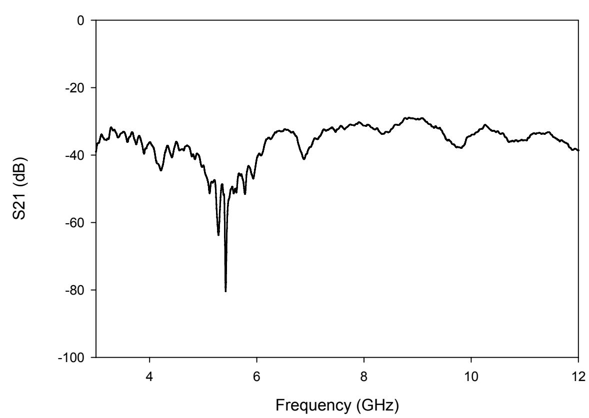

Fig.4. Transmission characteristics of optimized antenna

To achieve the same radiation characteristics, umpteen iterations are required in conventional method, resulting in a slot area of 17mm^2. On the other hand, the novel method proposed in this paper leads to faster convergence in just eight generations.

The importance of random slots is studied and tabulated in Table1.

Table.1 Analysis of optimized pattern

	BW of the Antenna GHz	BW of notch GHz
Pattern without Random slots (only the basic 'inverted U')	3.65-12.1	5.21-6.35
'U'+2 random slots	3.67-12.27	5.18-6.19
'U'+3 slots	3.65-12.2	5.35-6.35
'U'+4slots	3.67-12.1	5.32-6.3
'U'+ above 4slots+2 slots not in The original pattern.	3.62-12.24	5.18-6.19 Second notch At10.6 with small Band width
'U'+8 slots	3.62-12.1	5.27-6.38

The significance of the scattered slots is validated by analyzing several other patterns as well. It can be concluded that all slots are important in meeting the requirement. Results confirm that the number of 'scattered' slots and their location have a direct impact on bandwidth and resonant frequency of the notch.

5. References

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