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OPTIMIZATION OF MEANDER LINE ANTENNA USING ACO TECHNIQUE

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***Abstract*— Meander Line Antenna is small size, low cost, light weight and higher efficiency antenna. Ant colony optimization (ACO) is one of the most recent techniques for approximate optimization. The inspiring source of the ACO algorithms is real ant colonies. ACO is inspired by ants' foraging behavior. In this work ant colony system algorithm is used to optimize the antenna. Meander line antenna is designed using HFSS tool and MATLAB is used to implement ACO algorithm. The structure of antenna is optimized. ACO is best adaptable technique for optimization of Meander Line Antenna.**

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I. INTRODUCTION

Antenna plays a significant part in communication system. Therefore, an increasingly number of technicians begin to do the some research and development of antenna. However, with rapid development of communication industry, the requirement of antenna will be achieved with high quality. Nowadays, there are different kinds of antennas in market such as dipole antenna, patch antenna, loop antenna, meander-line antenna and so on. In order to meet demand of developing communication equipment the research of antennas focuses on some particular aspect, for instance, how to reduce size of antennas while maintaining higher radiation efficiency.

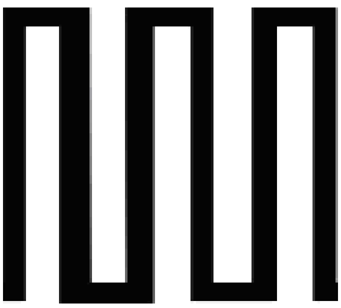

Figure 1 Basic structure of meander line antenna [1]

Now a day's due to rapid changes in the wireless communication technologies, there is tremendous increase in the data rate and at same time reduction in the antenna size and weight is demanded. There are varieties of techniques to reduce the size of microstrip antennas: use of high permittivity substrates, shorting pins, and meander line. Inserting suitable slots in radiating patch is also a common technique in reducing the dimensions of patch antenna. The slots introduce parasitic capacitances which tend to reduce the resonant frequency of the antenna .For wireless communications applications such as USB Dongle, radio frequency identification tags, Bluetooth headset, Mobile phone Meander line antenna is convincing solution. Meander line antenna is one type of the micro strip antennas. The meander line antenna was proposed by Rashed and Tai for reduce the resonant length. Meandering the patch increases path over which the surface current flows and that eventually results in lowering of resonant frequency than the straight wire antenna of same dimensions. The electrical small antenna defines as the largest dimension of the antenna is no more than one-tenth of a wavelength. Meander antenna is electrically small antenna .The design of meander line antenna is a set of the horizontal and vertical lines. Combination of horizontal and vertical lines forms turns. If number of turns increases efficiency increases. In case of meander line if meander spacing is increase resonant frequency decreases. At the same meander separation increase resonant frequency decreases [1].

Optimization problems are of the high importance both for the industrial world as well as for scientific world. Examples of the practical optimization problems include train scheduling, time tabling, shape optimization, telecommunication network design, or problems from computational biology. Optimization techniques becoming popular with antenna designers as computer processing power increasing. This gives the designers the luxury to commit the time elsewhere while the optimization routine finds the solution. There is no generally applicable analytic design methodology for meander line antennas. So there is a need for computational methods for design optimization. Ant colony optimization is one of the optimization technique based on approximation. Ant colony optimization (ACO) takes inspiration from the foraging behavior of some real ant species. These ants deposit pheromone on the ground in order to mark some favorable path that should be followed by other members of the colony. Ant colony optimization exploits a similar mechanism for solving optimization problem.

II. DESIGN OF ANTENNA

The meander line antenna is designed using HFSS tool. It is used to simulate each antenna model including S11 reflection coefficients, radiation pattern, radiation efficiency and Voltage Standing Wave Ratio for studying characteristic parameter of antenna, the antenna designs, and measure results.

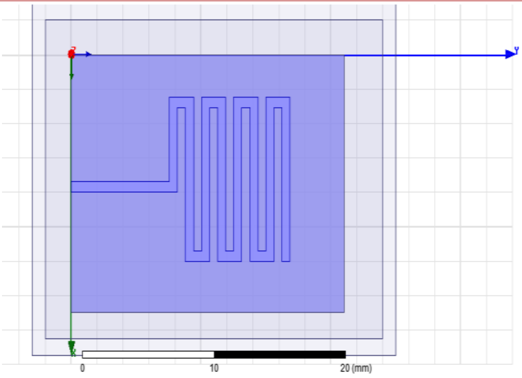

Figure 2 Geometry of antenna

The MLA is created using meander line and shaped ground as shown in figure 2, is created on rectangular Roger RO3210(tm) substrate. The height of substrate is 2.5 mm with relative permittivity 10.2 and substrate size is 22mm×16mm. Ground size is 22mm × 16mm. Number of meander lines are 8 and width of line is 0.62mm and length of each segment is 10 mm.

III. OPTIMIZATION PROTOCOL

Ants use environment as a medium of communication. They exchange information indirectly by the depositing pheromones, all detailing the status of their "work". The information exchanged has local scope, only an ant located where pheromones were left has a notion of them. This system is called "Stigmergy" and occurs in many social animal societies (it has been studied in the case of the construction of pillars in the nests of termites). The mechanism to solve a problem too complex to be addressed by single ants is a good example of a self-organized system. This system is based on positive feedback (the deposit of pheromone attracts other ants that will strengthen it themselves) and negative (dissipation of the route by evaporation prevents the system from thrashing). Theoretically, if the quantity of pheromone remained the same over time on all edges, no route would be chosen. However, because of feedback, a slight variation on an edge will be amplified and thus allow the choice of an edge. The algorithm will move from an unstable state in which no edge is stronger than another, to a stable state where the route is composed of the strongest edges [10].

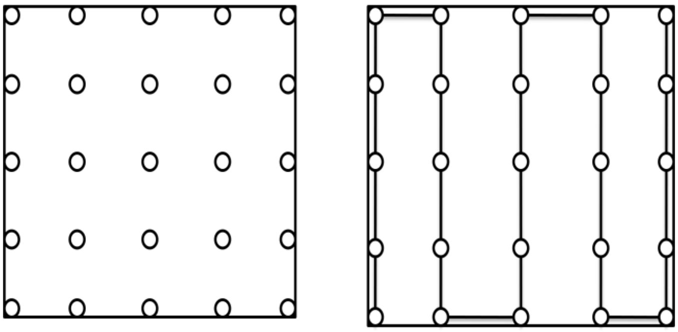

Figure 3 (a) defines the grid and its numbering system on a 5 × 5 grid.

(b) Shows a feasible meander line antenna

The Ant Colony System Algorithm

ACO is modeled on the foraging behavior of Argentine ants. The seminal work by Dorigo showed that this behavior could be used to solve discrete optimization problems. ACO is in fact a collection of meta-heuristic techniques, one of which is the ant colony system. It is shown to have good performance and is robust enough to be applied across a range of combinatorial optimization problems. ACS can best be described with the TSP metaphor as it is a well understood optimization problem and, as previously shown, a close relation to the problem dealt with in this paper. Consider a TSP with N cities. Cities i and j are separated by distance d (i, j). Place m ants randomly on these cities (m « N). In discrete time steps, all ants select their next city then simultaneously move to their next city. Ants deposit a substance known as pheromone to communicate with the colony about the utility (goodness) of the edges. Denote the accumulated strength of pheromone on edge (i, j) by τ (i, j). At the commencement of each time step, Equations 1 and 2 are used to select the next city s for ant k currently at city r. Equation 1 is a greedy selection technique that will choose the city that has the best combination of short distance and large pheromone levels. Using the first branch of Equation 1 exclusively will lead to sub-optimal solutions due to its greediness. Therefore, there is a probability that Equation 2 will be used to select the next closest city instead. This equation generates a probability and then roulette wheel selection is used to generate s. These two equations collectively are called the pseudo-proportional rule: s is given by Equation 1 if q $\leq q_0$, otherwise it is defined by Equation 2.

$$s = arg\ max_{u \in J_{k(r)}} \{\tau(r,u)[\eta(r,u)]^{\beta}\} \qquad (1)$$

$$s = R\left(\frac{\tau(r,s)[\eta(r,s)]^{\beta}}{\sum_{u \in J_{k(r)}} \tau(r,u)[\eta(r,u)]^{\beta}}\right) \quad if\ s \in \qquad (2)$$

0 otherwise

where η(r, u) = d(r, u), R is the roulette wheel selection function, q_0 is a parameter bounded between 0 and 1. Values of q_0 close to 1 correspond to a greedy search, whereas values close to 0 represent a random search. Each ant maintains a memory of its pervious steps. In the case of both TSP and meander lines, ant k can only select available values from Jk(r) where r is the current city or grid point respectively. To maintain the restriction of unique visitation, ant k is prohibited from selecting a city which it has already visited. The cities which have not yet been visited by ant k are indexed by$J_{k(r)}$. It is typical that the parameter β is negative so that shorter edges are favoured. The use of τ(r, s) ensures preference is given to edges that are well traversed (i.e., have a high pheromone level).

As in natural ant systems, the pattern of pheromone values is constantly evolving to reflect the collective intelligence and memory of the colony. However, unlike real ants these changes do not occur continuously. Instead, two separate update phases are used. They are referred to as local and global pheromone updating. The pheromone level on the selected edge is updated according to the local updating rule in Equation 3.

$$\tau(r, s) \leftarrow (1 - \rho) \cdot \tau(r, s) + \tau_0 \qquad (3)$$

Where:

P is the local pheromone decay parameter, $0 < \rho < 1$ and

τ_0 is the initial amount of pheromone deposited on each of the edges.

Global updating of the pheromone takes place once all ants have constructed a solution. Edges that compose the best solution (so far) are rewarded with an increase in their pheromone level while the pheromone on the other edges is evaporated (decreased). This is expressed in Equation 4.

$$\tau(r, s) \leftarrow (1 - \gamma) \cdot \tau(r, s) + \gamma \cdot \Delta\tau(r, s) \qquad (4)$$

$$\Delta\tau(r,s) \leftarrow \begin{cases} \frac{1}{L} \text{ if } (r,s) \text{is edge within best solution} \\ 0 \qquad\qquad\qquad\qquad \text{otherwise} \end{cases} \quad (5)$$

Where:

$\Delta\tau(r, s)$ is used to reinforce the pheromone on the edges of the best solution (see Equation 5),

L is the length of the best (shortest) tour to date and

γ is the global pheromone decay parameter, $0 < \gamma < 1$ [6]

ACO is used to optimize the meander line structure of antenna. ACO construct best route for meander line. Different structures are computed on different grid sizes ranging from 5×5 to10×10, and efficiency of these structures also observed. Number of structure increases exponentially with increase in grid points. The ACO algorithm is implemented in Matlab. After number of iterations best path is found for meander line, with the increase in grid size, number of iterations also increases to find a best optimal structure. Each run permitted 1000 iterations.

Grid Size	Optimized length of meander line	Total no of structure computed	Efficiency
5×5	25.4 mm	235	98.7%
6×6	36mm	748	98.1%
7×7	49.4mm	3845	97.4%
8×8	65.2mm	6783	96.8%
9×9	81.4mm	10801	95.9%
10×10	104.1mm	10977	94.8%

Table 4.1 optimized values

As shown in the table smaller grid sizes have more efficiency. Optimized structure of meander line is selected to get optimized results of bandwidth, gain and VSWR. So 5×5 grid size is used for optimization of antenna, because best structure on this grid size is found, which has improved efficiency.

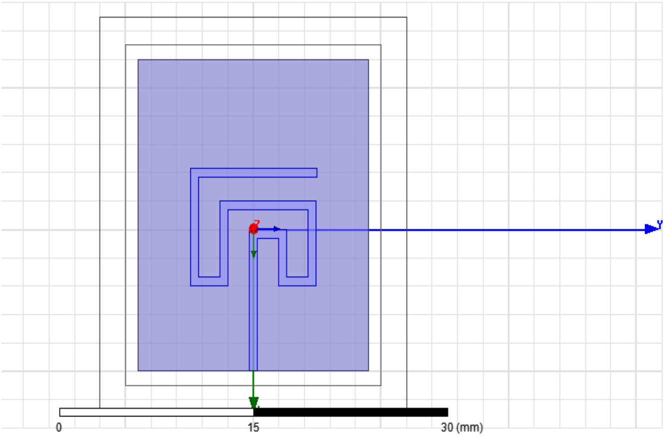

Figure 4 Geometry of antenna optimized with ACO

IV. RESULTS AND DISSCUSION

After optimization with ACO optimized structure of meander line is obtained with different grid sizes. A new antenna is designed from one of the selected structures. So 5×5 grid size optimized structure is used and find optimal solution for bandwidth, gain, VSWR and impedance of antenna. The optimized bandwidth of antenna is 1100 MHZ, and antenna operates from 9.7 to 10.8 GHZ. Return loss of optimized antenna is -34db and antenna has bidirectional pattern.

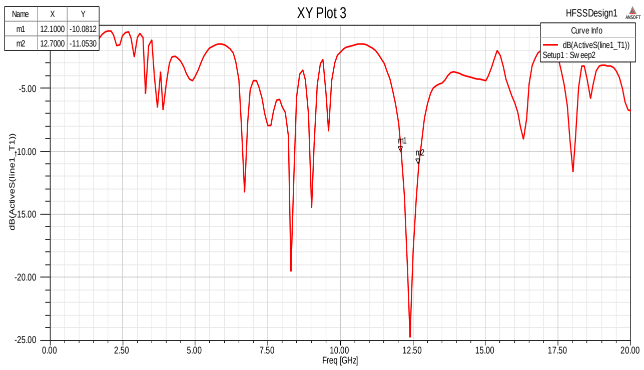

Figure 5 S parameter before optimization

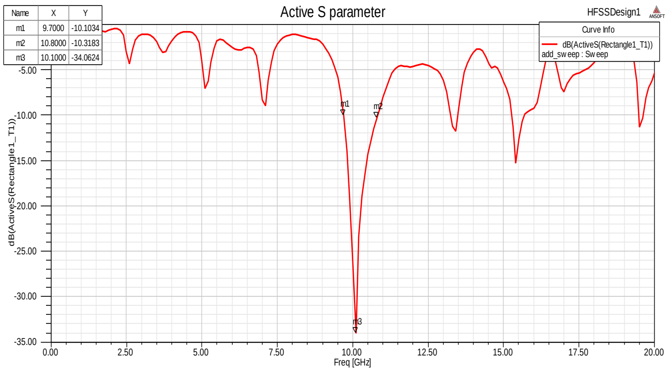

Figure 6 S parameter after optimization

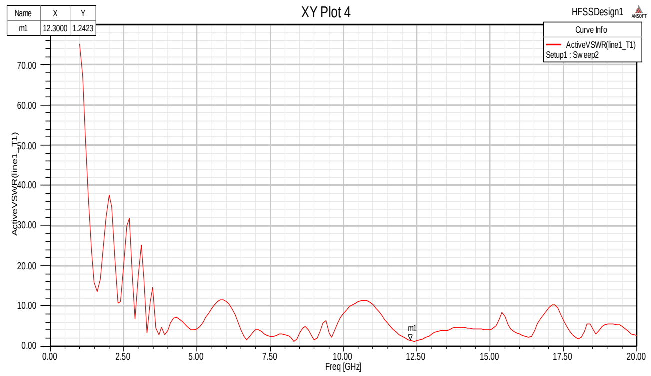

Figure 7 VSWR before optimization

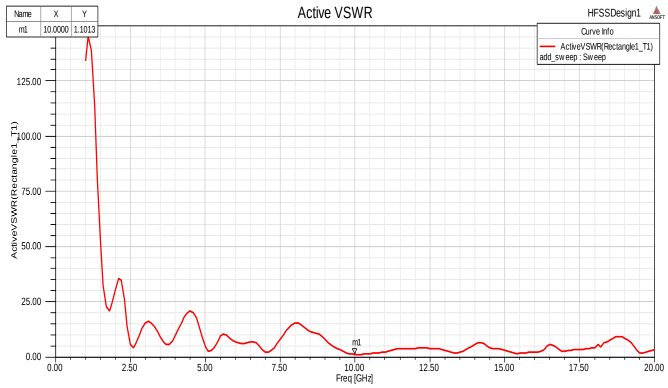

Figure 8 VSWR after optimization

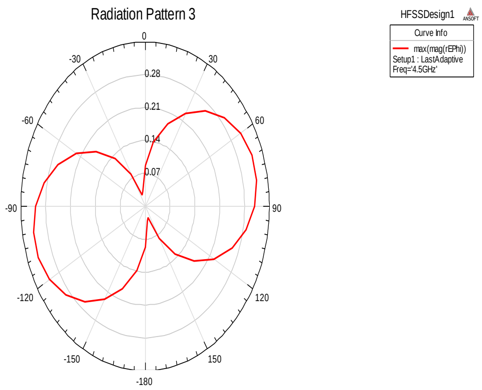

Figure 9 Radiation pattern before optimization

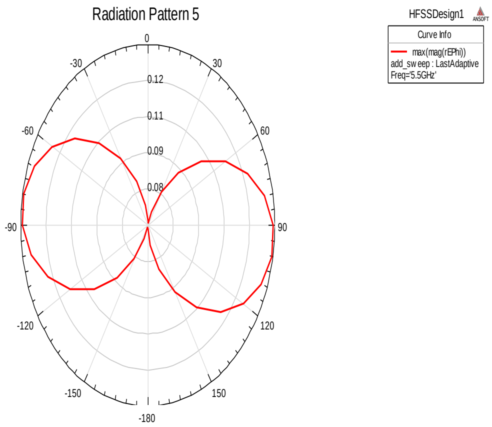

Figure 10 Radiation pattern after optimization

Above figures shows the comparison of results before and after optimization. This shows a comparison of bandwidth, return loss, radiation pattern and VSWR. From this we can conclude the results after optimization are better than before optimization. Antenna’s bandwidth, return loss, VSWR and radiation pattern improved with optimization.

V. CONCLUSIONS

Meander line antenna is one of most exciting types of antenna currently being investigated. It is electrically small antenna. Ant colony optimization technique is mostly used for path optimization problems. It has been proven for suitable for application meander finding problems. It is most suitable technique for optimize meander line path. Using ACO optimized results for meander line antenna are obtained. It improves the S parameter, bandwidth, VSWR of antenna. The optimized antenna can be used in wireless LAN. In future ACO can be used to optimize antenna with large grid sizes with further enhancement in algorithm.

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