Optimization of UWB Array Antenna for Bio-Medical Applications Using Cuckoo Search Algorithm

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Abstract

A four-element microstrip antenna array is designed in which the array is made using Wilkinson power dividers and four identical patch antenna elements. The elements of the designed array are perfectly developed to get a constant gain and have a compact size against the frequency. Using the microstrip technology equipment a prototype can be built to enhance the directivity, return loss and also its return loss and radiation pattern. The antenna array that is put forth here comprises of two major parts which are the array of the antennas and also its power network. In many of the important applications like biomedical, communication and also radio frequency applications the power divider plays a crucial role. Power dividers also function as the power networks of the array of antennas. An equal division power divider is generally required to synthesize the radiation pattern. Here a very new design for a power splitter having the same square sector of four ports and also its application is also presented. Techniques like insertion and also insertion fitting techniques were employed to adjust or alter the phase and amplitude of the signals that are exiting each branch of the power divider. The impedances of the branches are adjusted according to the required power ratio by using the pairing techniques. Electromagnetic Solvers which are based on MOM used in the design process. The parameters using which the power divider is made up of is the dielectric constant Er=4.3,loss tangent of 0.02 and height of 1.6mm.Along with the design of the ultra wide band antenna is also designed. Finally some of the optimization techniques such as the fly flight algorithm, cuckoo search algorithm, spring cuckoo algorithm for reducing mutual coupling and improving antenna parameters such as return loss, gain pattern, directivity and radiation. The experimental measurements are made using the network vector analyzer. A good agreement was found between the measurements and the results of the simulation.

Keywords: Rectangular Patch, Antenna array, Wilkinson power divider, UWB Antenna, UWB Array, optimization techniques.

1. Introduction

1.1 UWB

Ultra-wide band (UWB) technology is an ideal candidate for low-power, low-cost, high-speed, short-range wireless communication systems [3]. According to the Report and Order of the Federal Communications Commission (FCC) of 2002 for unlicensed uses of UWB devices within the frequency band 3.1-10.6GHz [5]. The UWB signal is defined as a signal having a fractional bandwidth greater than 20% of the center frequency. The ultra wide bandwidth of the system makes the design of the antenna a new challenge. This is due to the fact that fading and multipath interference become more evident than in the narrow band system [6]. To overcome this phenomenon, smart antennas use antenna arrays as one of the possible solutions, a multi-objective optimization for the set of UWB antennas in the indoor environment [4].

1.2 Array Antenna

The antennas can be classified as a single element or array antennas [12]. The antennas of a single element can be omnidirectional or directional. Directional antennas have a maximum gain for the addresses of the user and less in others [14]. Antenna arrays can be classified as in-phase matrices or adaptive arrays [7]. A phased array antenna system uses a matrix of omnidirectional or simple directional element antennas and combines the signal induced in the antennas to form a array output [16].

1.3 Wilkinson Power Divider

Power dividers are critical segments of a few microwave and millimeter wave circuits and furthermore an integral part of the antenna array power supply network [8]. They are basically power dividers as they divide the power, from input to the output ports, into required ratio and the same circuits can also be used as power combiners when used in reverse direction [9]. They play a vital role in various RF and communication applications such as in building wireless communication systems, power amplifiers, transmission line fault testing ratio measurements, test equipment’s and also in signal processing applications [15]. Resistive Type, T-Junctions and Wilkinson Power Dividers are conventional three types of available power dividers [19]. Resistive type and T-junction type are the smallest preferred power dividers due to the reason that a poor isolation is observed between the output ports in comparison with Wilkinson power divider. If matched at all ports, is almost lossless and gives high isolation between output ports, however, if any mismatch occurs,
The reflected power is dissipated through the isolation resistor [20]. This makes Wilkinson power divider is a perfect choice for power division [21].

1.4 Optimization

Most design optimization problems in engineering are often highly non-linear, and involve many different design variables under complex constraints. These constraints can be written as simple limits, such as the ranges of material properties, or as non-linear relationships that include maximum voltage, maximum deflection, minimum load capacity, and geometric configuration. Such non-linearity often results in a multimodal response landscape. Subsequently, local search algorithms such as hill climbing and Nelder-Mead downhill simplex are not suitable, only global algorithms should be used to obtain optimal solutions (Deb 1995, Arora 1989, Yang 2005, Yang 2008). Modern metaheuristic algorithms have been developed with the aim of carrying out a global search, the typical examples are genetic algorithms (Goldberg 1989), particle swarm optimization (PSO) (Kennedy and Eberhard 1995, Kennedy et al 2001). The effectiveness of metaheuristic algorithms can be attributed to the fact that they mimic the best characteristics of nature, especially the selection of the most appropriate in biological systems that have evolved by natural selection over millions of years. Two important characteristics of metaheuristics are intensification and diversification (Blum and Roli 2003, Gazi and Passino 2004, Yang 2009). The intensification is intended to find the best current solutions and select the best candidates or solutions, while diversification ensures that the algorithm can explore the search space more efficiently, often by randomization. Recently, a new metaheuristic search algorithm, called Cuckoo Search (CS), has been developed by Yang and Deb (2009). Preliminary studies show that it is very promising and could overcome existing algorithms, such as PSO. In this document, we will study CS and validate it against the test functions, including the stochastic test functions. Then, we will apply it to solve design optimization problems in engineering. Finally, we will discuss the unique characteristics of Cuckoo Search and propose topics for future studies.

1.5 Cuckoo Search

To describe the search for the cuckoo more clearly, let's briefly review the interesting breed behavior of certain cuckoo species.

1.5.1 Cuckoo Breeding Behavior

Cuckoo are fascinating birds, not just due to the lovely sounds they make, yet in addition due to their repagation strategy. A few animal varieties, for example, the ani and Guira cuccoos, lay their eggs in common homes, in spite of the fact that they can wipe out the eggs of others to build the likelihood of bringing forth of their own eggs (Payne et al 2005). A good number of species are dedicated to the parasitism of forced breeding when they lay their eggs in the nests of other host birds (often other species). There are three basic types of brood parasitism: parasitism of intraspecific breeding, cooperative reproduction and nest capture. Some host birds may have direct conflict with intrusive cuckoos [11]. On the off chance that a host winged creature finds that the eggs are not his property, he will toss these outsider eggs or basically leave his home and construct another home elsewhere. Some cuckoo species, for example, the parasitic rearing Tapera of the New World have developed such that female parasites are regularly extremely had practical experience in emulating the shading and example of the eggs of a couple of picked have. The permittivity of a substance is usually given comparative to that of free space which is known as relative permittivity or dielectric constant $\varepsilon_r$. Here we use FR-4 with $\varepsilon_r = 4.3$, $\delta = 0.025$ species (Payne et al 2005). This decreases the probability of their eggs being relinquished and along these lines expands their reproductivity. What's more, the egg-laying time of a few animal types is additionally shocking. Parasitic cuckoo regularly pick a home where the host feathered creature has quite recently laid its own eggs. As a rule, the cuckoo eggs bring forth somewhat sooner than their host eggs. Once the main cuckoo is brooded, the principal natural move to be made is to remove the host's eggs by indiscriminately driving the eggs out of the home, which builds the segment of the cuckoo chicken's sustenance given by its host feathered creature (Payne et al 2005). Concentrates additionally demonstrate that an adorable chick can likewise mirror the call of host chicks to access all the more sustaining open doors [2].

1.5.2 Levy Flights

In nature, animals seek food in a random or quasi-random way, animals seek food randomly or quasi-randomly. In general, the feeding route of an animal is, electively, a random walk because the next movement is based on the current location / status and the probability of transition to the next location. The direction you choose depends explicitly on a probability that can be modeled mathematically. For example, several studies have shown that the behavior of many animals and insects has demonstrated the typical characteristics of Levy flights (Brown et al 2007, Reynolds and Frye 2007, Pavlyukevich 2007). A recent study by Reynolds and Frye (2007) shows that fruit flies or Drosophila melanogaster explore their landscape using a series of straight flight paths punctuated by a sudden turn of 900 degrees, leading to an intermittent search pattern without Levy-flight style scales. Studies on human behavior, such as the hunter-gatherer search patterns Ju / hoansi, also show the typical characteristic of Levy flights. Even light can be related to Levy's flights (Barthelemy et al 2007). Subsequently, this behavior has been applied to optimization and optimal search, and preliminary results show its promising capacity (Shlesinger 2006, Pavlyukevich 2007).

1.5.3 Cuckoo Search Idealized Rules

To simplify when describing our new cuckoo search (Yang and Deb 2009), we now use the following three idealized rules:

- Each cuckoo lays one egg at a time, and dumps it in a randomly chosen nest;
- The best nests with high quality of eggs (solutions) will carry over to the next generations;
- The number of available host nests is fixed, and a host can discover an alien egg with a probability $p \in [0, 1]$. In this case, the host bird can either throw the egg away or abandon the nest so as to build a completely new nest in anew location.

In Section II, our system description is presented. Several numerical results are included in Section III. Finally, the conclusion is drawn in section IV.

2. Antenna Design

2.1 Substrate Design

<table>
<thead>
<tr>
<th>Materials used</th>
<th>Dielectric constant</th>
<th>Thickness (mm)</th>
<th>Loss tangent</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR-4</td>
<td>4.3</td>
<td>1.6</td>
<td>0.025</td>
</tr>
</tbody>
</table>

is used as antenna substrate. Selection of material for designing the antenna is unique in this paper. Whereas FR-4 is the primary Insulating backbone upon which the huge majority of rigid printed circuitboards (PCBs) are produced.
In this work, first considering the Basic U slot CPW antenna is as shown in fig.1 and their dimensions are included in Table 2. The designing and simulations are carried out in MOM based CST Microwave Studio. With the substrate material properties are shown in Table 1 and the radiating element used is copper and Results are discussed in section III.

![Fig.1: Proposed U-slot antenna](image1)

![Fig. 2: Prototype of Proposed U-Slot antenna](image2)

![Fig.3: Testing Arrangement of Proposed U-Slot](image3)

<table>
<thead>
<tr>
<th>Table 2: Dimensions of the U slot antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimension</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>L</td>
</tr>
<tr>
<td>W</td>
</tr>
<tr>
<td>W₁</td>
</tr>
<tr>
<td>L₁</td>
</tr>
<tr>
<td>L₂</td>
</tr>
<tr>
<td>L₃</td>
</tr>
<tr>
<td>W₂</td>
</tr>
<tr>
<td>Wₚ₁</td>
</tr>
<tr>
<td>g₁</td>
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<tr>
<td>g₂</td>
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<tr>
<td>L₄</td>
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<tr>
<td>L₂</td>
</tr>
<tr>
<td>L₄</td>
</tr>
<tr>
<td>Wₚ₁</td>
</tr>
<tr>
<td>H</td>
</tr>
</tbody>
</table>

2.2 1X2 Array Antenna Implementation

The main purpose of implementation of array is to enhance the Gain, Directivity and radiation pattern for achieving of these three parameters we will implement 1X2 proposed array antenna shown in Fig.4. Length and width of array antenna is 50X25X1.6mm², FR-4 with εᵣ =4.3, δ=0.025 is used as antenna substrate and results are discussed in section III.

![Fig.4: 1X2 proposed array antenna](image4)

2.3 1X4 Array Antenna Implementation

Here we implement 1X4 Array Antenna of size is 100X25X1.6mm² FR-4 with εᵣ =4.3, δ=0.025 is used as antenna substrate shown in fig 5 and results are discussed in section III.

![Fig.5: 1X4 proposed antenna Array](image5)
2.4 Design Procedure for Proposed for Proposed Power Divider

Fig. 6 demonstrates the schematic diagram of the conventional two-section Wilkinson power divider with adjusted port. For better coupling and impedance coordinating, as can be found in Fig. 4. The proposed WB power divider is simulated with electromagnetic solvers in view of MOM. The sizes of a power splitter with moderately great execution were resolved. The insulation resistance $R = 100\Omega$. Fundamentally, here the structure depends on the variable band microstrip technique. What's more, to enhance the large bandwidth utilizing the variable-width innovation appeared in Fig.7, the width and length of the substrate is appeared. The power divider WB has simulated and measured the substrate FR-4 with a dielectric constant $\varepsilon_r = 4.4$ and a thickness of 1.6mm and the insulating resistance $R = 100\Omega$ has been utilized. And every one of the measurements are appeared in TABLE3.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Dimension</th>
<th>Calculated Value (Millimetres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$L_1$</td>
<td>4.3</td>
</tr>
<tr>
<td>2</td>
<td>$L_2$</td>
<td>6</td>
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<td>$L_4$</td>
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<tr>
<td>5</td>
<td>$L_5$</td>
<td>11.42</td>
</tr>
<tr>
<td>6</td>
<td>$L_6$</td>
<td>10.3</td>
</tr>
<tr>
<td>7</td>
<td>$W$</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>$g_1$</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>$g_2$</td>
<td>0.7</td>
</tr>
<tr>
<td>10</td>
<td>$g_3$</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 3: Dimensions of the Proposed 1X2 Power Divider

![Fig. 6: Schematic diagram of 1X2 Wilkinson power divider](image)

![Fig. 7: Layout of Proposed 1X2 WB Power Divider (Dimension is 11.42 mmx10.3 mm)](image)

2.5 Structure of Proposed Four-Way Wilkinson Power Divider

The implementation of 1X4 power is also same as 1X2 power divider only difference is arms are attached at the port2 and port3 of the 1X2 proposed power divider then 1X4 proposed power divider is established in Fig8 and Dimensions are shown in Table4 and results are discussed in section III.

![Fig. 8: Basic 1X2 Wilkinson power divider](image)

![Fig. 9: Fabricated Structure of Proposed WB Power](image)

![Fig. 10: Testing arrangement of proposed1X2 power Divider on FR4 material](image)
Fig. 11: Basic 1X4 Wilkinson power divider

Fig. 12: Layout of Proposed 1X4 WB Power Divider (Dimension 32.9mm × 22.55mm)

Fig. 13: Fabricated Structure of Proposed 1X4 WB Power Divider (Dimension is 32.9 mm×22.55 mm)

Table 4: Dimensions of the Proposed 1X4 Power Divider

<table>
<thead>
<tr>
<th>S.No</th>
<th>Dimension</th>
<th>Calculated Value (Millimetres)</th>
</tr>
</thead>
<tbody>
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<td>3</td>
<td>W3</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>W4</td>
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</tr>
<tr>
<td>5</td>
<td>W5</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>W6</td>
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<tr>
<td>7</td>
<td>L1</td>
<td>6</td>
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<td>8</td>
<td>L2</td>
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<tr>
<td>9</td>
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<td>32.9</td>
</tr>
<tr>
<td>11</td>
<td>g1</td>
<td>0.2</td>
</tr>
<tr>
<td>12</td>
<td>R</td>
<td>100Ω</td>
</tr>
</tbody>
</table>

2.6 Array Implementation Using 1X2 Power Divider

Here attaching two U-slot antennas to the power divider port2 and power divider port3 for equal power division whenever we are adding the antenna to the power divider then the parameter like Directivity, Gain, Radiation pattern and Return loss results are fallen down so we move for optimization for better results and results are discussed in section III.

Fig. 15: 1X2 Antenna Array using power divider

2.7 Array Implementation Using 1X4 Power Divider

Here we consider first single power divider port1 as input port at port2 and port3 we connecting another power dividers its look like a shape of inverted T shape at left side power divider at port2 we connecting basic U-slot antenna the same way we connecting at port3, port4, port5 finally it forms as 1X4 antenna array using power divider shown in fig and results are discussed in section III.

Fig. 16: Testing arrangement of proposed 1X2 Antenna Array using power divider
2.8 Fire Fly, Cuckoo, Spring Cuckoo Optimizations

2.8.1 Firefly Optimization on UWBArray Antenna

Many applications took the firefly algorithm as a standard as it is attracted with its features. Some of the demonstrations by Horng et.al confirmed that firefly-based algorithm uses least computation time for digital image compression. This firefly algorithm was also utilized by Banati and Bajaj for the purpose of feature selection and proved that this algorithm gave a better and a consistent performance in the case of time and optimality compared to the other algorithms.

The highly non-linear and all the multimodal design problems can be efficiently solved by the firefly algorithm which was confirmed by Gandomi et.al. The Firefly algorithm was proved to outperform the artificial bee colony which is ABC algorithm when it was applied in the antenna design optimization. Further more it was also proved that this algorithm out performed the PSO algorithm and also obtained the best global results.

The discrete version of the Firefly Algorithm was proved to efficiently solve the NP-hard scheduling problems. The detailed analysis gave a conclusion that the firefly algorithm was efficient compared to a wide range of test problems. All the scheduling and the travelling salesman problems can be easily solve in a promising way using the Firefly algorithm.

2.8.2 Cuckoo Search Optimization on UWBArray Antenna

The description of the new Cuckoo search can be given easily with the three ideal rules:
1) A nest is randomly chosen and the by the cuckoo for dumping its egg laid one at a time.
2) The high quality eggs in the best nests will be carried out to the next generations.
3) The egg that is laid by the cuckoo is found out by the host bird with a probability pa ∈ [0,1] as the number of available host nests are fixed.

According to the above case the hosting bird can either throw the egg far away or construct a new nest. Further more simplifying the last assumption by the approximation of the fraction of the nests can be replaced by the new nests which are randomly chosen. For a maximization problem, the fitness of a solution will be proportional to the value of the objective function. All the other forms of the fitness function are also developed in a similar way to the existing fitness function in all the genetic algorithms. For easy understanding the representations like each of the eggs in those nests will represent a solution and the good cuckoo egg will definitely represent a new solution to the problem.

The Firefly Algorithm

Begin
1) Objective function: \( f(x), x=(x_1,x_2, \ldots, x_n) \);
2) Generate an initial population of fireflies \( x_i=1,2,3, \ldots, n \);
3) Formulate light intensity \( I \) so that it is associated with \( f(x) \)
   (for example, for maximization problems, or simply \( I = f(x) \))
4) Define absorption coefficient \( \gamma \)
While (\( t < \text{MaxGeneration} \))
   for \( i = 1 \to n \) (all \( n \) fireflies)
      for \( j = 1 \to n \) (\( n \) fireflies)
         if (\( I_j > I_i \))
            Evaluate attractiveness with distance \( r \) via;
            move firefly \( i \) towards \( j \);
            Evaluate new solutions and update light intensity;
            end if
        end for
    end for
Post-processing the results and visualization;
end

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According to the above case the hosting bird can either throw the egg far away or construct a new nest. Further more simplifying the last assumption by the approximation of the fraction of the nests can be replaced by the new nests which are randomly chosen. For a maximization problem, the fitness of a solution will be proportional to the value of the objective function. All the other forms of the fitness function are also developed in a similar way to the existing fitness function in all the genetic algorithms. For easy understanding the representations like each of the eggs in those nests will represent a solution and the good cuckoo egg will definitely represent a new solution to the problem. Finally, the aim is to get a new solution to replace the old not so good solutions in the nests. As this algorithm can be extended by a more complicated case as the nests that are present has more number of eggs representing a different set of solutions. Here the most simplest approach where the assumption is that the nest has only single super egg.
ALGORITHM FOR CUCKOO SEARCH

begin
Objective function f(x), x = (x1, ..., xd)T
Generate initial population of n host nests xi (i = 1, 2, ..., n)
while (t ≤ MaxGeneration) or (stop criterion)
Get a cuckoo randomly by L’evy flights evaluate its quality/finess fi
Choose a nest among n (say, j) randomly if (fj ≥ Fj),
replace j by the new solution;
end
A fraction (pA) of worse nests are abandoned and new ones are built;
Keep the best solutions (or nests with quality solutions);
Rank the solutions and find the current best
end while
Postprocess results and visualization

end

3. Results and Discussions

This section presents all results of U-Slot antenna, Array antenna, power divider and optimization values all are discussed. First we discuss return loss parameter of U-Slot antenna shown if Fig.11(a), return loss value is 57.02dB at a frequency of 8.23GHz, VSWR shown in fig.11(b) the value is 1.2. Directivity shown in fig.11(c), the value is 4.64dBi, gain shown in fig.11(d) the value is 3.96, and finally radiation pattern is shown in fig.11(e). All these values are simulated values. Now we discuss measured values for the u-slot antenna Return loss value is 50.0124 shown in fig.11 (f), VSWRs is 1.32 shown in fig.11 (g)

Now we Discus 1X2 array antenna results in fig.12 (a) shows Return loss of the 1X2 array antenna the value is 37.5233dB, at a frequency of 8.33GHz, VSWR shown in fig.12 (a) value is 1.32. Directivity shown in fig.12 (c), Value is 5.21dBi, Gain is shown in fig.12(d) the value is 4.75dB, finally radiation pattern is shown in fig.12(e). Next we discuss 1X4 array antenna results fig.13(a) shows Return loss of the 1X4 array antenna the value is 59.81dB, VSWR shown in fig.13(b) value is 1.02 , Directivity shown in fig.13(c) Value is 5.61dBi, Gain is shown in fig.13(d) the value is 4.75, finally radiation pattern is shown in fig.13(e)

In Fig. 11(a) S11 parameter of 1X2 power divider is presented. Return loss of the 1X2 power divider achieved -24.668dB at 8.18 GHz wide band of 3 GHz to 10.6 GHz range is presented, and also S21 and S11 are presented at Fig. 11(b) and Fig. 11(c). Next discussion regarding insertion loss or transmission parameter of 1X2 power divider S21 & S11 are presented at figures of Fig. 12(a) to Fig. 12(b).

In Fig. 18(a) to Fig. 18(e) return loss parameters of 1X4 power divider is -36.1725dB at 8.896 GHz band of 2GHz to 10GHz range is presented, for S32 -59.6248dB at 9.946 GHz, for S33 -43.337dB at 9.974 GHz, for S34 -36.4356dB at 9.89 GHz, for S35 -37.91dB at 10.058 GHz are presented. In Fig. 19(a) to Fig. 19(d) Insertion loss of 1X4 power divider is presented. In Fig. 20(a) to Fig. 20(f) Isolation loss parameter is presented. The fabricated results of 1X2, 1X4 power divider of Return loss, Insertion loss, Isolation loss, VSWR are presented in fig.21 to fig.26.

Finally optimization results of firefly, cuckoo search, spring cuckoo search results are shown in fig.29 (a) to fig.30 (d), that parameter are directivity, gain, radiation pattern and return loss parameters are presented, so here main purpose of using optimization is to enhance the antenna parameter. While we observing 1X2, 1X4 array antenna their antenna parameters are increases. While we attaching power divider to the 1X2, 1X4 array antenna results are fall down. To enhance the antenna parameter we go for optimization, using optimization the antenna parameters are enhanced shown in fig.29 (a) to fig.30 (d) and good agreement between simulated and measured results.

3.a U-Slot Antenna Results

3.1 Return loss
3.2 VSWR

3.3 Directivity

3.4 Gain

3.5 Radiation pattern

3.6 Return loss

3.7 VSWR

3.8 Return loss
3.9 VSWR

Fig. 12 (a): Return loss parameter of 1X2 proposed antenna

3.10 Directivity

Fig. 12 (b): VSWR parameter of 1X2 Proposed antenna

3.11 Gain

Fig. 12 (c): Directivity parameter of 1X2 proposed antenna

3.12 Radiation Pattern

Fig. 12 (e): Radiation Parameter of 1X2 proposed antenna

3.13 Return loss

Fig. 12 (d): Gain Parameter of 1X2 proposed antenna

3.14 VSWR

Fig. 13 (a): Return loss parameter of 1X4 proposed antenna

3.15 Directivity

Fig. 13 (b): VSWR parameter of 1X4 proposed antenna
3.16 Gain

Fig. 13(c): Directivity parameter of 1X4 proposed antenna

Fig. 13(d): Gain parameter of 1X4 proposed antenna

3.17 Radiation Pattern

Fig. 13(e): Return loss parameter of 1X4 proposed antenna

3.18 Return Loss of Proposed 1X2 Power Divider $S_{11}$

3.19 Insertion Loss or Transmission Parameter Of proposed 1X2 power divider $S_{21}$

Fig. 14(a): Return loss ($S_{11}$) parameter Performance of proposed 1X2 power divider

Fig. 14(b): Return loss ($S_{22}$) parameter performance of proposed 1X2 power divider

Fig. 14(c): Return loss ($S_{33}$) parameter performance of proposed 1X2 power divider
3. F. Basic 1X4 Wilkinson Power Divider Results

3.22 Return Loss of 1X4 Power Divider

**S11**

Fig. 18(a): Return loss (S11) parameter performance of proposed 1X4 power divider

**S22**

Fig. 18(b): Return loss (S22) parameter Performance of proposed 1X4 power divider

**S33**

Fig. 18(c): Return loss (S33) parameter performance of proposed 1X4 power divider

**S44**

Fig. 18(d): Return loss (S44) parameter Performance of proposed 1X4 power divider

**S55**

Fig. 18(e): Return loss (S55) parameter performance of Proposed 1X4 power divider
3.23 Insertion loss of proposed 1X4 power divider

\[ S_{21} \]

Fig. 19(a): Insertion loss \((S_{21})\) parameter performance of proposed 1X4 power divider

\[ S_{31} \]

Fig. 19(b): Insertion loss \((S_{31})\) parameter performance of proposed 1X4 power divider

\[ S_{41} \]

Fig. 19(c): Insertion loss \((S_{41})\) parameter performance of proposed 1X4 power divider

\[ S_{51} \]

Fig. 19(d): Insertion loss \((S_{51})\) parameter performance of proposed 1X4 power divider

3.24 Isolation Loss of Proposed 1X4 Power Divider

\[ S_{23} \]

Fig. 20(a): Isolation loss \((S_{23})\) parameter performance of proposed 1X4 power divider

\[ S_{24} \]

Fig. 20(b): Isolation loss \((S_{24})\) parameter performance of proposed 1X4 power divider

\[ S_{25} \]

Fig. 20(c): Isolation loss \((S_{25})\) parameter performance of proposed 1X4 power divider

\[ S_{34} \]

Fig. 20(d): Isolation loss \((S_{34})\) parameter performance of proposed 1X4 power divider
3. G. Validation of Proposed 1X2 Power Divider Parameters

3.25 Return Loss Parameter

3.26 Insertion Loss Parameter

3.27 Isolation Loss Parameter

3. H. Validation of Proposed 1X4 Power Divider Parameters

3.28 Return Loss Parameter

3.29 Insertion Loss Parameter

3.30 Isolation Loss Parameter
3. I Array Implementation Using 1X2 Power Divider Results

3.31 Return loss

![Return loss parameter of 1X2 proposed antenna](image)

**Fig. 27 (a):** Return loss parameter of 1X2 proposed antenna

3.32 VSWR

![VSWR parameter of 1X2 proposed antenna](image)

**Fig. 27 (b):** VSWR parameter of 1X2 proposed antenna

3.33 Directivity

![Directivity parameter of 1X2 proposed antenna array](image)

**Fig. 27 (c):** Directivity parameter of 1X2 proposed antenna array

3.34 Gain

![Gain parameter of 1X2 proposed Antenna array](image)

**Fig. 27 (d):** Gain parameter of 1X2 proposed Antenna array

3.35 Radiation Pattern

![Radiation parameter of 1X2 proposed Antenna array](image)

**Fig. 27 (e):** Radiation parameter of 1X2 proposed Antenna array

3. j Array Implementation Using 1X4 Power Divider Results

3.36 Return loss
Fig. 28(a): Return loss parameter of 1X4 proposed Antenna array

3.37 VSWR

Fig. 28(b): VSWR parameter of 1X2 proposed Antenna array

3.38 Directivity

Fig. 28(c): Directivity parameter of 1X2 Proposed Antenna array

3.39 Gain

Fig. 28(d): Gain parameter of 1X2 proposed antenna array

3.40 Radiation Pattern

Fig. 28(e): Radiation parameter of 1X2 proposed Antenna array

3.41 Directivity

Fig. 29(a): Directivity of 1X2 Array antenna with Power divider

3.42 Gain
3.43 Radiation Pattern

Fig. 29 (c): Radiation pattern of 1X2 Array antenna with Power divider

3.44 Return Loss

Fig. 29 (d): Return loss of 1X2 Array antenna with Power divider

3.45 Directivity

Fig. 30 (a): Directivity of 1X4 Array antenna with Power divider

3.46 Gain

Fig. 30 (b): Gain of 1X2 Array antenna with Power divider

3.47 Radiation Pattern

Fig. 30 (c): Radiation pattern of 1X2 Array antenna with Power divider

3.48 Return Loss

Fig. 30 (d): Return loss of 1X4 Array antenna with Power divider
4. Conclusion

In this paper a proposed CPW fed co-planner UWB antenna and their array system is introduced. The planned antenna array structure consists of two main parts, the antenna array, and its feeding network. A novel design for the Wilkinson power divider (the feeding network) is introduced to provide equal power division between output ports. The prototype or the power divider and the antenna array is dine using thin film technology and photolithographic technique. A 1X2 and 1X4 power divider has been designed at UWB band frequency range that depends on the Wilkinson topology. This topology has two phases: the primary stage is a 1X2 power divider and the 1X4 power divider in the second stage has been deployed in the FR4 substrate. The 1X2 and 1X4 power divider have been designed, fabricated and simulated with parameter insertion loss, return loss and isolation loss are presented. Insertion loss of 1X2 power divider is below -3.5 dB and 1X4 power divider is below -7 dB for a frequency range of 3.1-10.6 GHz, return loss of 1X2 power divider is -24.668 dB at a frequency of 8.1849 GHz is achieved, and 1X4 power divider is -36.1725 dB at a frequency of 8.896 GHz is achieved, isolation less than -15.3434 dB at a frequency of 7.986 GHz for 1X2 power divider and -19.3127dB at a frequency of 6.474 GHz for 1X4 power divider is achieved. The simulation of the system is performed using both MOM based CST Microwave Studio and MATLAB. Here using firefly algorithm, cuckoo search algorithm, spring cuckoo search algorithm are used, in this three algorithms spring cuckoo give better results among three algorithms. The experimental measurements are done using the vector network analyzer. Finally all the simulated and measured outcomes coincide with the measured results.

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References:


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