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Massive Antenna Array design with Reduced VSWR and Increased Gain for Broadband Application

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Abstract : *Antenna array is significant to achieve high gain and directivity. 22-Element planar phased array is designed in this paper to increase gain. The existed methodology to design broadband planar phased array like current sheet array technique has drawbacks of high VSWR and low gain. Impedance matching is also a challenging constraint with respect to array. In this paper, we attempted to solve all these problems and to increase gain over a frequency range of 4 – 20 GHz. The design is implemented with the help of printed dipole antenna. This antenna has two arms and these two arms are placed on both sides of the substrate. This design reduces the complexity when compared to the existed Balun design. The simulation results also show that, the gain of designed planar phased array is considerably high and VSWR is actively low over a frequency range of 4 – 20GHz. This antenna is suggested in scanning applications and the applications which need constant gain over prescribed bandwidth. The proposed design is also extendable with antenna elements with infinite array.*

Keywords: *Antenna array, Printed Dipole Antenna, VSWR, Coaxial cable, Antenna Gain*

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I. Introduction

The Antenna array is one of the emerging areas to achieve high gain and to control complex applications. These phased arrays are very useful in scanning applications with rapid scan rate; usually it is required in RADAR based system [1]. It is a single multi function installation which can replace the several sensor installations. The durability and reliability of sensors depends on many characteristics, they may change according to situations. Hence, it is not recommendable to use multiple sensors to function single complex system [12]. The proposed broadband phased array concept will provide solution and it is low complex installation [11]. The phased array technology can be implemented in two types. They are

1. Micro-strip patch antenna
2. Vivaldi antenna

These two set-up's has their own drawbacks. They are

1. Micro strip patch antenna cannot handle larger bandwidth. It can function only for low bandwidth applications. In general, rapid scan rate applications need larger bandwidth and hence it is not suggested to implement in real scenario [3,4].
2. Coplanar antennas exhibit high gain and directivity. These two factors are very important to design antenna for high complexity circumstances. But, Vivaldi antenna is not co-planar [11,12].

To resolve this problem, active research started in this field. One of the notable contributions from Harris is highly commended for handling certain circumstances. He introduced Current Sheet Array (CSA) technology to wide range of frequency bands [2,7]. He concluded that, the Voltage Standing Wave Ratio (VSWR) is better in the frequency band of 2-18 GHz. Each dipole antenna has a feed element which can be placed at the centre of dipole and has two legs which extends outward till defined length. By maintaining some space place adjacent antenna whose adjacent legs are also extends outwards to free space. Now, place proper impedance matching material between these two antennas [5, 9]. This process is applicable for all antennas which are in array. Feeding of all these antennas with single cable is possible by implementing Balun structure. This design is very difficult when the space between the adjacent antennas is very small. This paper will give you detailed outlook on method to form broadband array for closely spaced elements instead of existed Balun design. In this analysis, we used array with 22 elements which are linear and are in phase [6, 7]. The results shown that, the value of VSWR is less than 3 in the frequency band of 4-20 GHz. This shows much improvement when compared to CSA implementation. In this paper, we used printed Dipole Antenna with two arms and coaxial feeding is used. Coaxial cable has two conductors, namely inner conductor and outer conductor [9].

II. Design setup

The proposed design set up is shown in following figure 1. This antenna has following elements. They are

- Printed Dipole Antenna
- Ground plane
- Dielectric material
- Feeding with co-axial cable.

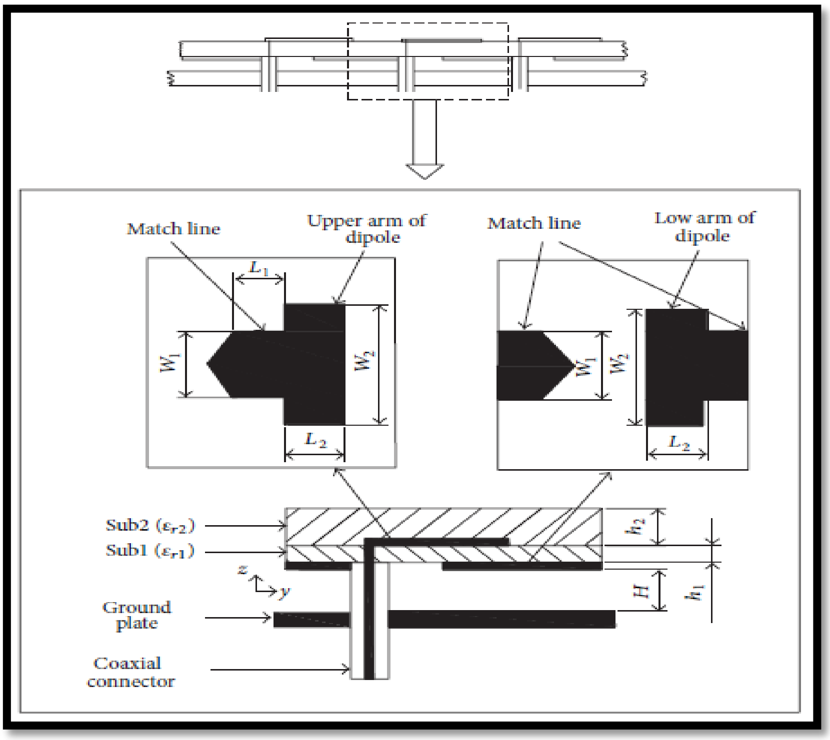


Fig.1. Antenna elements with Infinite array

As shown in figure 1, the antenna should be designed in ground plane configuration with coaxial feeding mechanism. Inner conductor of cable is connected to upper arm and outer conductor is connected to lower arm. This setup eliminates the need to design Balun [10]. Here, we have two substrate layers with

Height of substrates = h1, h2
Effective dielectric constants = Ɛ1, Ɛ2
Matched line size = W_1×L_1
Size of arm of dipole = W_2×L_2
Space between dipole and ground sheet is H

All antennas existed in array setup are attached with flat capacitor, this results greater improvement in impedance bandwidth. This improvement is due to Capacitive-couple effect [6]. This proposed set-up is different from conventional/existing set-up in two different aspects. They are

We reduced the design of Balun by connected inner and outer conductors of the coaxial cable to the Dipole
We used flat capacitors to achieve best coupling instead of Inter-digital capacitors as implemented in [2].

This new set up has series of periodic planar structures with dumped lumped circuit elements. This new set up is surrounded by a dielectric material. For this type of set-up, it is recommendable to use Periodic Moment Method (PMM). Dipole antenna is implemented in array mode and hence we should consider the effect of mutual coupling. This effect of coupling is analyzed with the help of HFSS Simulator. The discontinuity between matched line and substrate 2 will result poor impedance matching which results poor radiation phenomenon. This discontinuity can be replaced by adjusting the size of line / thickness of substrate / adjusting both parameters. The design considerations are given below.

H= Height of the substrate = 6mm
Ɛ1 = Dielectric constant of substrate 1 = 3.35
Ɛ2 = Dielectric constant of substrate 2 = 2.2
h1 = height of the substrate 1 = 1.5 mm
h2 = height of the substrate 1 = 4 mm
Length of centre element in an array = 8.7 mm

This set up will allow beam to scan between -300 to +300 within the operating frequency of 4-20 GHz. The results in following figure 3 shows that, the resultant VSWR characteristics.

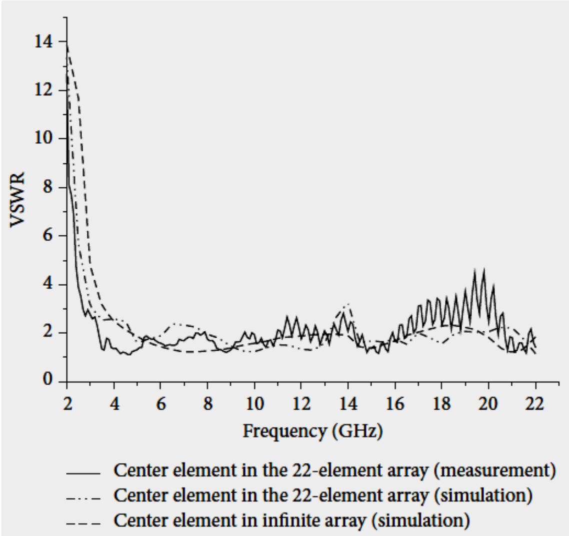


Fig.2. Frequency Vs VSWR

III. Phased array design with 22 elements

The The following figure 3 shows the prototype design of the above discussed method.

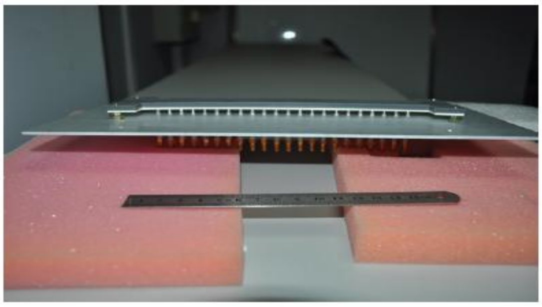
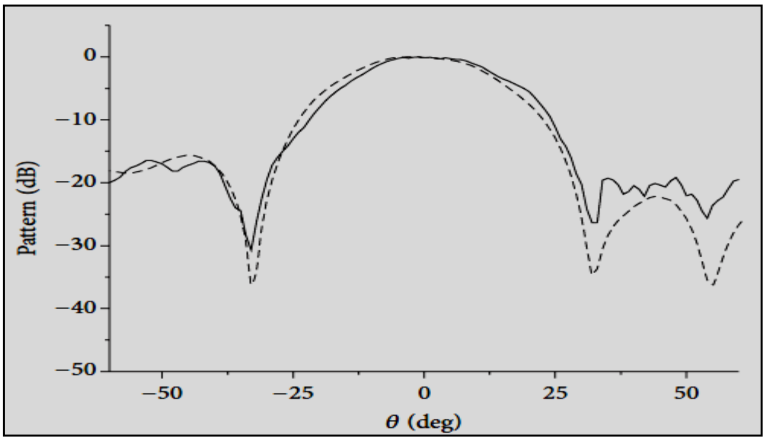
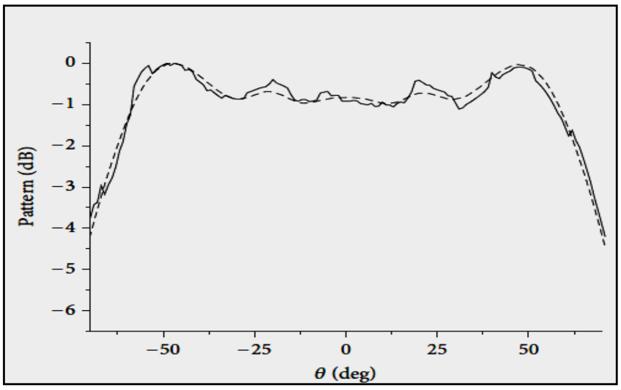


Fig.3. Designed antenna with linear array

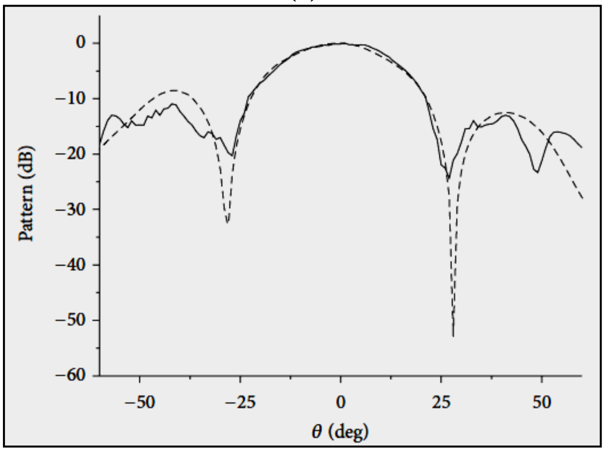
These 22 antennas are linearly arranged with spacing between them is 8.7 mm. This set up follows the type of broadband phased array. All antennas are fed with equal magnitude and are in same phase. From results, it is clear that the resultant VSWR is less than 3 for the band of frequencies 4-20 GHz. We also came to find that the matching characteristics of the centre antenna in an linear array can be analysed very easily than the conventional procedure. This simple set up to decreased the complexity of the system in construction and also the requirements of matching devices. The layer construction should be with minimal errors to get best performance. Improper fabrication and design error will reduce the efficiency of the antenna [8]. To analyse the characteristics of radiation, 8-way power divider is designed and operated under the frequency range of 8 GHz – 9 GHz. This resultant radiation of the 8 element centre antenna is shown in figure 4.



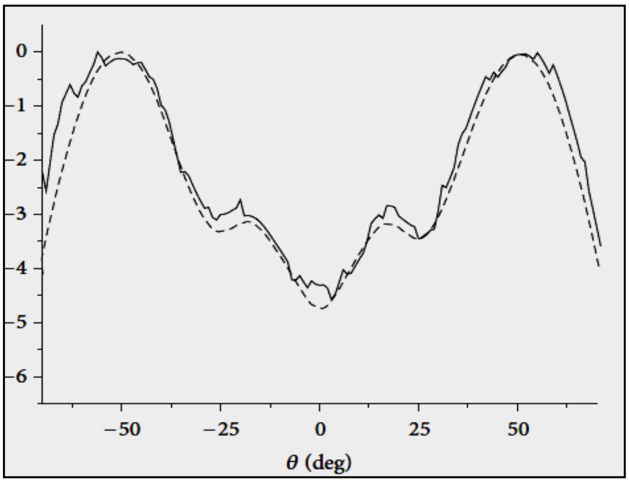
(a)



(b)



(c)



(d)

Fig.4. Simulation of 8-element array

a,b = E,H Plane at 8 GHz
c,d = E,H Plane at 9 GHz

_____________ Theoretical

---------------------- Simulated

From the figure 4, we can observe that at 8 GHz, the relative side lobe level is -16.5 dB and at 9 GHz, the relative side lobe level is -12.5 dB. The following figure 5 shows, gain of 8 element array over a range of frequency 4 – 20 GHz. Due to limit of the power divider, we are showing gain in the range of 8 – 9 GHz. The resultant gain simulation indicates stable in the proposed range of 4 – 20 GHz. From the results, we can conclude that the simulated gain and theoretical gain are equal.

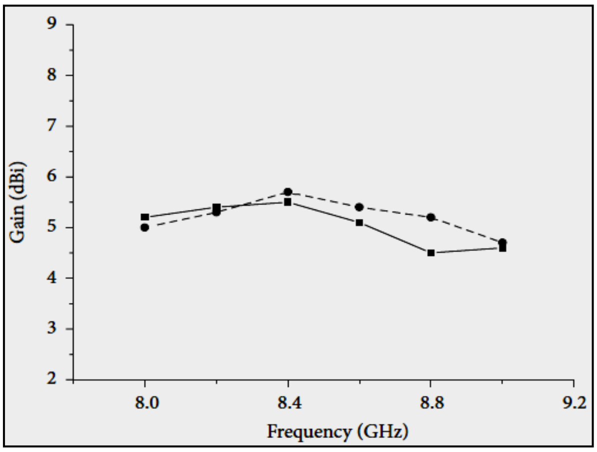


Fig.5. measured Vs Simulated gain over 8 -9 GHz range

IV. Conclusion

This proposed design eliminates the need of complex implementation Balun and replace it with the simple dipole printed antenna. A planar array of 22 elements represented and designed in this paper. The impedance bandwidth of printed dipole antenna was improved by increasing mutual coupling effect. The results shown that, the proposed array design has wide bandwidth. The proposed method reduced VSWR considerably when compared to existed CSA technology. The gain of the dipole antenna with planar phased array shows constant over frequency range of 4 – 20 GHz.

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