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Design an Ultra- Wideband Modified Wilkinson Power Divider Fed-by Balanced Antipodal Vivaldi Antenna Array for Imaging Applications

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Abstract: ***In this paper, design of compactand modified geometrical structure of 1-to-4 way ultra-wideband Wilkinson power divider used as a feeding network for 4-element of balanced antipodal Vivaldi antenna (BAVA) array has introduced. The proposed Wilkinson power divider has been designed and printed on low-cost Epoxy laminate substrate FR4 along with the thickness of 1.6mm and relative permittivity of ε_r =4.3 respectively. The transformation of power divider network which are based on bent corners as a replacement of sharp corners or edges used for the decrement in unintended radiation and employing a single radial stub on each branch to encounter the antenna-specifications. Further some adjustments in the dimension of stubs matching in order to increase the reflection of the power divider network. The design presents the model of a power divider and maintains an equal power splitting at different ports with practical insertion loss and conventional return loss below -10dB. The reasonable impedance matching has achieved at every single port with acceptable isolation performance values over the (3-to-10 GHz) frequency range. The divider as well as antenna elements design and its optimization are practicable via computer simulation technology (CST) simulation software. The experimental results are revealed to encounter the array-specifications under ultra-wideband frequency range..***

Keywords: UWB; BAVA and CST.

I.INTRODUCTION

Power Splitter or Divider is considered as a significant component especially in microwave circuit design as well as interconnected subsystems. It is extensively used in power amplifiers, mixers and phase shifters. At this time the power divider strongly considers as a significant component mainly in an ultra-wide band application [1] and antenna array related system feeding network [2-5].

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The design model of Wilkinson power divider is very popular due to its narrow bandwidth and particularly used in UWB antenna array application [6], [7]. For the further advancement in frequency bandwidth and expansion in channel frequency a general design of power divider with some modification in basic geometrical shape has been developed [8-10].

The following parameters like return loss, isolation, insertion loss, group delay and bandwidth achieved from divider network has necessary for the configuration of any power divider and the mentioned parameters generally used to evaluate the specific performance in many satellite and radar communication application system [11], [12].

Currently, the most focused type of power divide named Wilkinson [13] is an optimal selection of several researchers. It is typically used in feeding network of antenna array system because of its simple geometrical structure, low insertion losses and compacted in size. Although, the isolation circuit is associated with output ports and it also offers electrical separation but cannot physical isolation to the circuit.

A novel conceptual idea of power divider network has been introduced in 2010 [14]. The isolation components has positioned among the $\lambda/4$ transmission lines by arbitrary phase angle understudy of 90^0 while in conventional Wilkinson power divider to enhance physical separation as well as electrical isolation instantly. The geometrical configuration of divider network has been published in [15].

In this study the design approach of modified Wilkinson power divider linked with 4-element of balanced antipodal Vivaldi antenna (BAVA) [16], [17] has been introduced. The paper is discussing a practical technique of Wilkinson power divider along with structural alteration by consuming conventional power splitter for feeding network [18-20]. This research based on two different stages of 1-to-2 way Wilkinson power dividers along with 3GHz to 10GHz range of frequency. The material Epoxy laminate (FR4) using total-thickness of 1.6 mm with permittivity ofε_r= 4.3 is used for print development. For the expansion in performance parameters a number of modifications have been ended in an actual design. The placement of curved corners instead of pointed edges is used for the decrement in unintended as well as non-uniform radiation by the feeding-network [21], [22].An additional alteration has been made in the stubs length. Further four element of BAVA connected with modified power divider are exposed to observe the antenna array specification.

The impedance matching-bandwidth of the projected Wilkinson power divider covers the well-definedUWB frequency range. The CSTMWS simulation software is considered for authenticate the outcomes [23].

II.CONVENTIONAL DESIGN

Two parallel uncoupled quarter wavelength transmission-lines have been used for the formation of conventional Wilkinson power divider. The characteristic impedance of all uncoupled lines is $\sqrt{2}Z_0$ and matched with the input port of divider. For the better isolation of divider a shunt resistor $2Z_0$ would be associated among the output ends of the port. The basic structural configuration of 1 to 2 sections power divider is represented in Figure 1(a) and Figure 1(b) correspondingly [14].

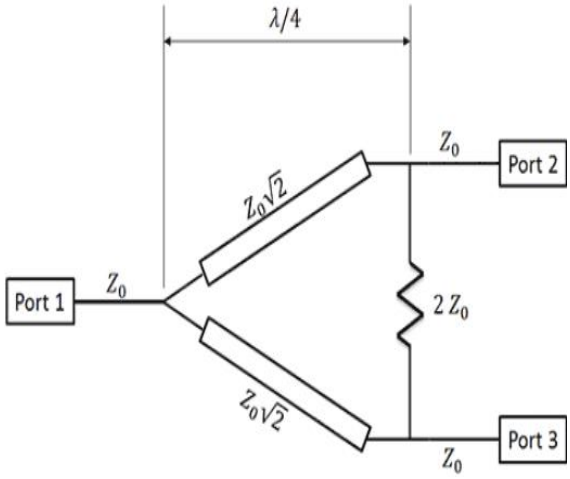

Fig. 1(a)Equally-Split 2-way Wilkinson Power Divider

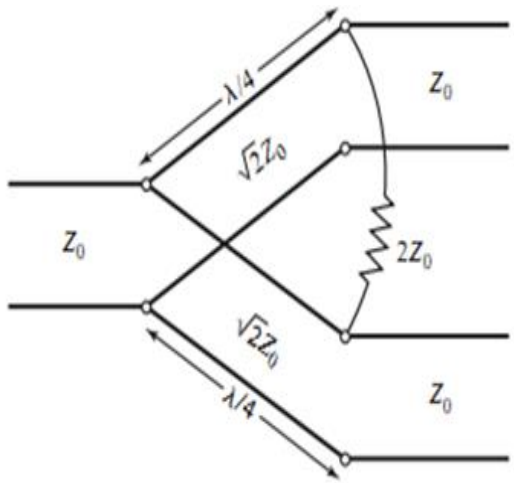

Fig. 1(b)Equivalent Circuit of Conventional Power Divider Network

The dimensional analysis of Wilkinson power divider can be find by the following general expression (1)-(5) [24].

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r+1}{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23 + \frac{0.1}{\varepsilon_r}\right) \quad (1)$$

$$\frac{W}{d} = \frac{8e^A}{e^{2A}-2} \quad (2)$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{d}{W_1}\right)}}\right] \quad (3)$$

$$\lambda_g = \frac{c}{f_0\sqrt{\varepsilon_{eff}}} \quad (4)$$

$$l = \frac{\lambda_g}{4} \quad (5)$$

The concept of N-way divider is formally used for improvement in the number of output ports as signify in Figure 2. The elementary circuitry of mentioned power-divider can be coordinated at all network ports and corresponding port is matched with isolation among all network ports.

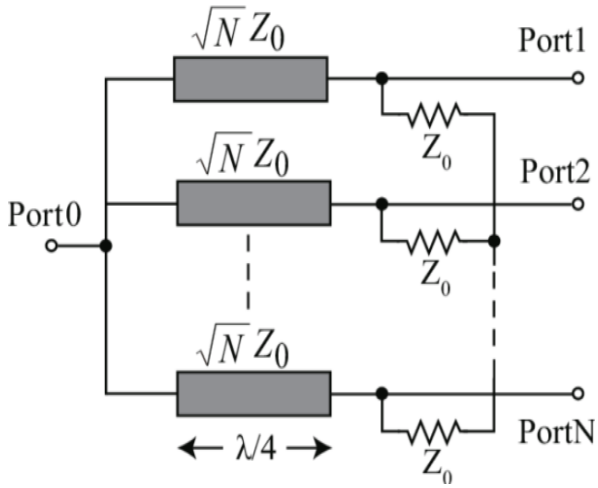

Fig. 2 N-Way Power Divider for Equal Power Split

III.PROPOSED DESIGN OF 4-WAY WILKINSON POWER DIVIDER

A recommended scheme of 1-to-4 way Modified Wilkinson power divider is represented in Figure 3. The matching-impedance of both ports like input or output has around 50Ω. The first transmission line has characteristic impedance of Z_1=70.7Ω and as well as for the another transmission lines Z_2=100Ω. The separation distance among the output ports are 0.6 λ to avoid grating lobes. The Table-1 has presented the adjusted dimensions of improved Wilkinson power divider and the suggested idea of power divider has been presented [5].

Table. 1 Measurements of Modified1-to-4 Way Wilkinson Power Divider

X	X_1	X_2	X_3	X_4	X_5	X_6
66.3	4.5	5.7	2	5	18.4	17.5
W	W_1	W_2	W_3	W_4	W_5	W_6
100	3.1	5.8	7.8	50.14	2.5	23.86

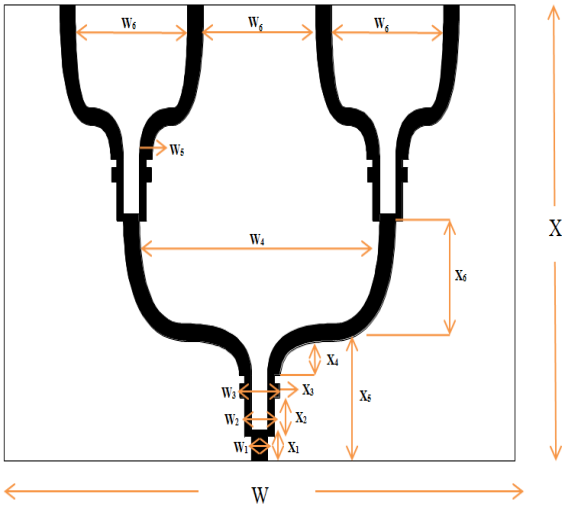

Fig. 3 Schematic Diagram of Proposed-Power Divider

IV.SIMULATION RESULTS OF PROPOSED POWER DIVIDER AND DISCUSSION

The simulation software CST is used for result validation. The proposed power divider has operating under UWB frequency range (3-to-10GHz) and the reasonable outcome has been derived to claim this work novel in research society. The low cost material FR4 has been used in fabrication with a material thickness of 1.6mm. It has constant dielectric value which is ε_r = 4.3 respectively. The layout view of a model on CST has shown in Figure 4.

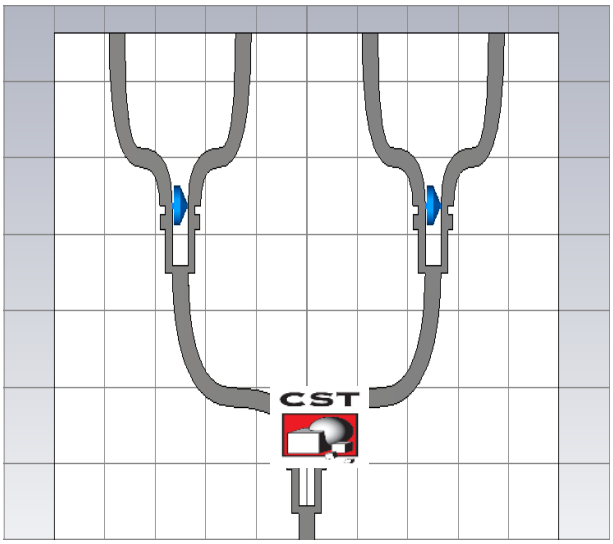

Fig. 4 Schematic Diagram of Proposed Power Divider

4.1 Return Loss

The reflection coefficient of proposed model has been depicted in Figure 5. The satisfactory amount of reflection from input and output port has been received which is better than -10dB at (3-to-10GHz) of frequency range. The standard input impedance matching value of 50Ω has been decided for defined frequency range. The bandwidth of recommended power divider is extended from frequency 3-to-10GHz for ultra-wide band range.

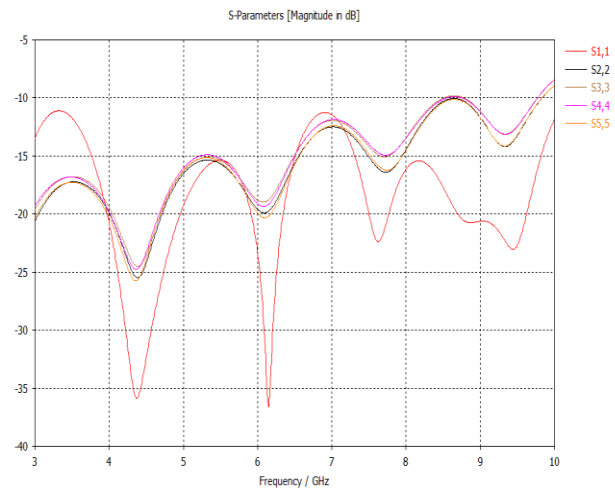

Fig. 5 Reflection-Coefficient of proposed Power Divider (S_{11}, S_{22}, S_{33}, S_{44}, S_{55})

4.2 Insertion loss

The insertion loss S_{21}, S_{31}, S_{41} and S_{51} with respect to S_{11} of proposed divider network has been presented in Figure 6. The maximum insertion loss around -10 dB at (7-to-10 GHz) has been observed, which may be accounted for the separation distance of the output terminals. It has been proved bytheresults, input-power has been shared equally and splits to all output ports. A reasonable performance and low insertion-loss has been observed over the entire UWB frequency range.

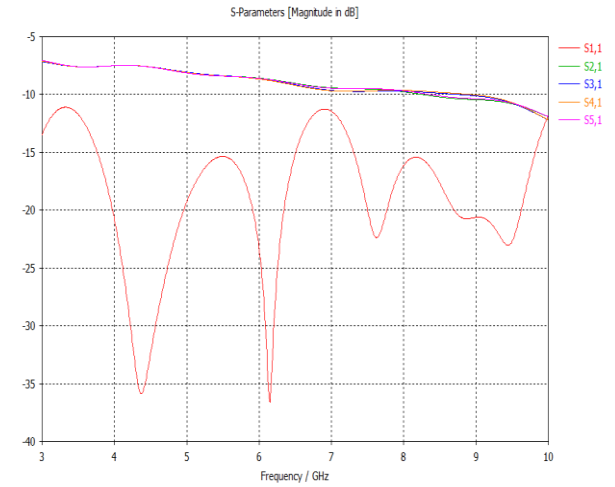

Fig. 6Insertion Loss of Proposed Power Divider (S_{11}, S_{21}, S_{31}, S_{41}, S_{51})

4.3 Isolation

The Isolation result of recommended power divider has shown in Figure 7. The graph represents all output ports have received equal amount of power from the input port. The isolation between all ports has less than -10 dB and offering excellent presentation at UWB frequency range.

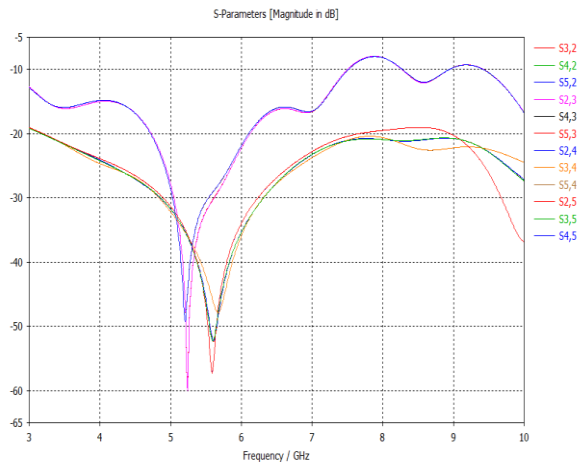

Fig. 7 Isolation of Proposed Power Divider (S_{32}, S_{42}, S_{52}, S_{23}, S_{43}, S_{53}, S_{24}, S_{34}, S_{54}, S_{25}, S_{35}, S_{45})

4.4 Voltage Standing Wave Ratio (VSWR)

VSWR of proposed divider has depicted in Figure 8. According to standard and for better performance the value of ratio should be less than 2. However, it can notice that the VSWR is little high at 9.8-to-10 GHz frequency range, which may be accounted for the inappropriate selection of separation distance between the ports. The simulation result has been shown a very good agreement and proposed UWB model has considered as an excellent power splitter for antenna based array feeding network.

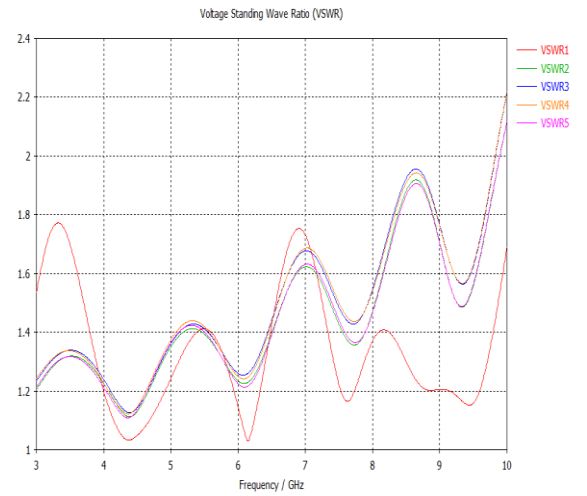

Fig. 8 VSWR of Proposed Power Divider

V.PROPOSED ANTENNA DESIGN FOR ARRAY CONFIGURATION

The proposed geometrical structure and software layout of BAVA antenna element is designed on Rogers RT/Duroid 5880 with a thickness of 1.57mm and permittivity constant of εr= 2.2 respectively, as shown in Figure 9(a) and 9(b). The design contain rectangular slit which equally in size placed on both ends of antenna in order to improve antenna realized gain as well as directivity. The EBG (Electro-magnetic band gap) circular-shape in structure is placed on both antenna arms for bandwidth expansion. The performance parameters of BAVA antenna element will be estimated upon feed lines and radiation flares. The elliptical in shape curves is used for design an antenna element in order to achieve better broad-band features [25]. The optimized dimensions of proposed antenna are mentioned in Table 2.

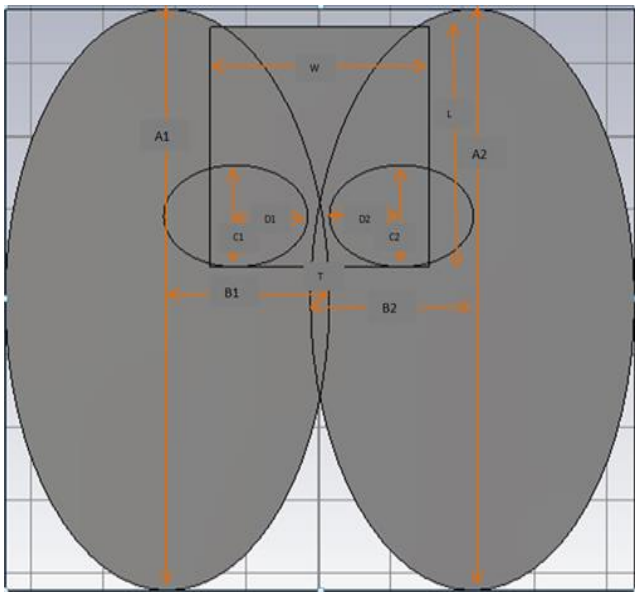

Fig. 9(a)Antenna Geometry

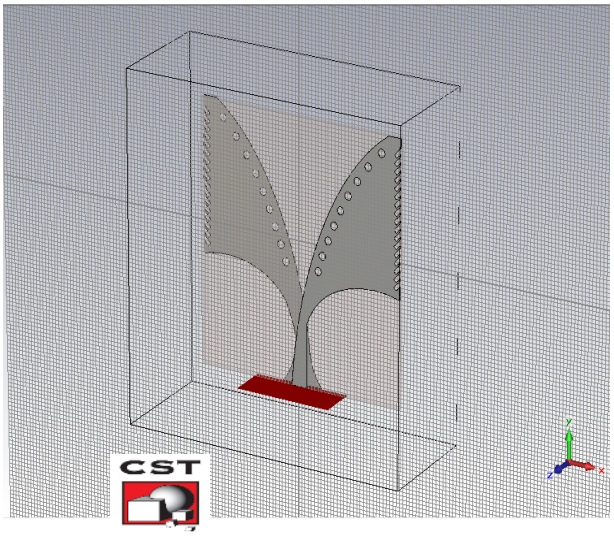

Fig. 9(b)CST layout of Proposed Antenna

Table. 2 Antenna Optimized Dimensions

Parameter	Dimension
W	60.75mm
L	66mm
A1	80mm
B1	22.5mm
A2	80mm
B2	22.5mm
C1	14mm
D1	10mm
C2	14mm
D2	10mm
T(feed width)	4.56mm

SL	1mm
SW	2mm
h	1.5mm
t	0.035mm

The simulated and measured results of proposed antenna are presented in Figure 10. The port of an antenna has provided good impedance-matching bandwidth ($|S_{11}| \leq 10$) as shown in Figure 10.

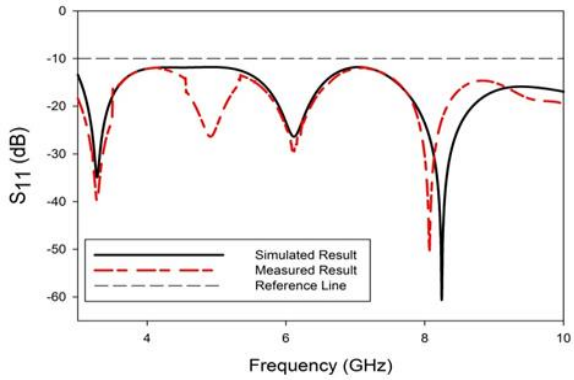

Fig. 10 Return-loss of the Proposed Antenna

VI.EXPERIMENTAL RESULTS OFPROPOSED POWER-DIVIDER FED BY 4-ANTENNA ELEMENTS AND DISCUSSION

An array principle has adopted in order to expand the scanning process of network. The 4-antenna elements of BAVA are fabricated and associated with suggested UWB 4-way modified Wilkinson power divider for the development of antenna array feeding network [26-32]as shown in Figure 11.

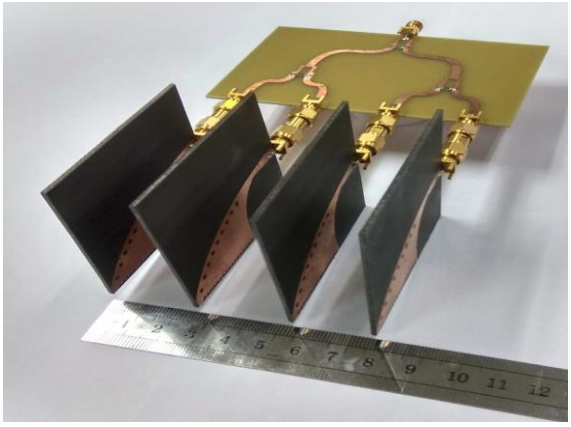

Fig. 11 Fabricated Model of UWB Modified-Wilkinson Power Divider Fed By4-Elements of BAVA Antenna Array

To avoid grating lobes, the separation-distance amoung the antenna elements are preferred to be 0.6 λ, from the center of the UWB range. The VNA reflection coefficient (S_{11})measurementsofproposed antenna array system has been covered the majority of the UWB frequency range as shown in Figure 12, except for averynarrow band from around (8.9-to-9.1 GHz) and (9.5-to-9.8 GHz) where S_{11} is not better than -10dB, which may be accounted for the improper orientation, handmade soldering and SMA connector quality of the antenna elements.

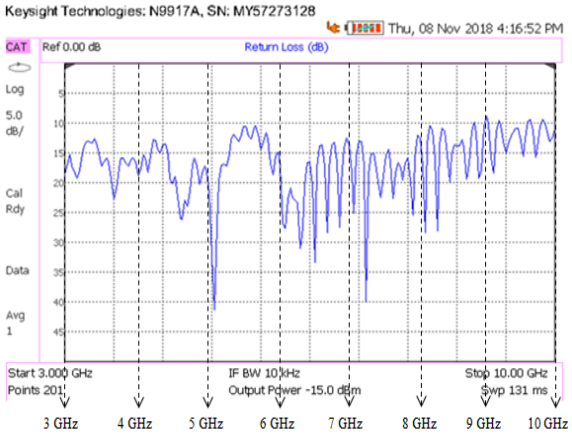

Fig. 12 Measured Reflection Coefficient (S_{11}) of UWB Modified Wilkinson Power Divider Fed 4-Element of BAVA Antenna Array

VII.CONCLUSION

In this research a compact and modified design of UWB Wilkinson power divider has been proposed. In projected structure,thecurved corner has been used as replacement of pointed ends or edges for the decrement in unintended radiation. For the enhancement in performance parameter the length of matching stub has been modified. Now this compact and modified design has been practically tested and verified under frequency range 3-to-10 GHz. The suggested Wilkinson power-divider is producing improved results in a capacity of radiative performance, reduced in structural size and low cost in nature as compared to the traditional 1-to-4 Wilkinson power-divider. The divider model represent the equal power-shared at all output ports with good insertion-loss. It also presented improved isolation and suitable return loss for all output ports which shown improved linearity at UWB frequency range. A stacked of 4-elements of BAVA connected with UWB modified Wilkinson power-divider as a feeding network has been realized in order to meet the design specifications. The recommended power divider is more appropriate to be integrated with array feeding network and UWB imaging applications. Further the uses of different substrate for results improvement will consider in the future work.

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