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A wideband antenna array with novel 3dB branch-line power dividers as feeding network.

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I. Introduction

Wideband antenna arrays are essential components in ultrawide band (UWB) wireless systems. Such arrays can be implemented with wideband antenna elements and power dividers to form the feeding network [1].

Several power dividers have been developed in waveguide and printed circuits [2]. Printed circuits can be based on microstrip or coplanar characteristics, of which the most common are: Wilkinson power dividers [3], t-junctions, and couplers with a loaded port such as branch-line [4], coupled-lines and Lange [5].

T-junctions are the only ones that can be implemented by traditional 2D photolithography since they do not require loads, resistive components nor bond wires. However, they present a low matching at the ports and narrow bandwidths (BW). In [6] the 13% BW divider forms a feeding network for a four patch antenna array, and in [7] a BW of only 11% is achieved. In Abbosh [8]-[9] t-junctions have been modified to improve their matching characteristics and implemented in multilayer structures .Their reported BW is about 80% at –8dB input rejection. Another two-layer structure is shown in Billakowski [10], where a divider with 100% BW for an input return loss below -12 dB, was designed.

Wilkinson dividers improve the matching characteristics of t-junctions because they eliminate the reflection at the ports by inserting a resistor between the branches of the divider. In [11-13] Wilkinson dividers with bandwidths of up to 100% are reported however, fabrication techniques become complicated as surface mount resistors are required.

Directional couplers can also be used as power dividing networks [4]. Three branch line couplers are described in [14-16], where stubs are added at the ports to increase the BW. However, a load is still needed at the isolated port for good matching. Their BW is of up to 50% for a return loss below -10 dB. An elaborated process to modify ground plane is required as it is proposed by Tang [17] and Ho [18], where a BW of 40% is achieved.

Wideband 3dB coupled line couplers have been reported in [19-20] using multilayer micromachined fabrication techniques. By connecting several directional couplers in tandem [21], bandwidth enhancement can be obtained. In references [22-23] a BW up to about 150% is obtained. However, for all cases, one port has to be matched to a load and bond wires or multilayer fabrication processes must be used.

Lange couplers [5], which offer very wide band characteristic responses, can be found in [24-25]. Chua [24], has reported two Lange couplers with BWs of about 40%. Nevertheless, bond wires are required and the isolated ports must be loaded for good matching. In [25], a 41% BW PCB Lange divider design is described, where via holes are used instead of bond wires.

In this paper we introduce a novel type of wide bandwidth branch-line power divider that does not require surface mount resistors, loads at the ports nor bond wires and hence it can be manufactured using traditional 2D photolithography. The circuit is implemented in microstrip technology and its BW is about 40% with a rejection below -14 dB. This divider is implemented on a corporate feeding network, which feeds a two and four antenna array. The design procedures along with simulated and experimental results of the whole network are presented.

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II. Design procedure of the novel branch-line 3dB power divider

To start the design, two conventional microstrip 8.3dB couplers were designed at 22GHz and cascaded. The substrate used was Duroid 5880 with ε_r= 2.2 and thickness h= 0.381 mm. Then these 2 couplers were merged to form a 3 branch structure and stubs were added at the ports to increase the BW following [26]. It was observed that by removing the 50Ω load of the isolated port and by optimizing the widths of the λ/2 matching stubs a 3-port power divider with excellent matching was obtained. The final circuit of the 3-port branch line divider is shown in Fig.2a, and the simulated responses with [27] in Fig.1. As it can be seen a 50% power split is achieved at the center frequency. The BW is about 40% for +/- 0.5dB coupling unbalance and a return loss lower than -14dB The phase difference at the output ports is almost less than 9 degrees throughout the band. Power losses are at about 0.5dB at the center frequency.

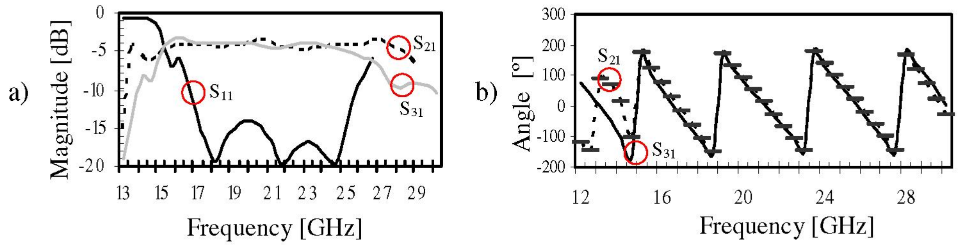

Fig.1. Simulated results: a) Magnitude and b) Phase.

Two corporate feed networks have been designed using the branch line power dividers. The first one consists of one power divider feeding a Two-Vivaldi antenna array, see Fig.2c. And the second one has 3 dividers and Four-Vivaldis as shown in Fig.2d. The Vivaldi antennas were designed at the center frequency following the procedure exposed in [28]. A single Vivaldi is shown in Fig.2b.

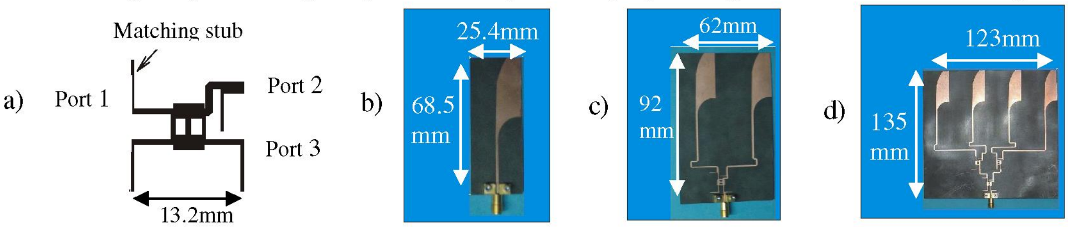

Fig.2. a) The implemented divider, b) Vivaldi Antenna, c) Two-Vivaldi array, d) Four-Vivaldi array.

III. Simulated and Experimental results

The simulated antenna using [29] and its measured S_{11} parameter are shown in Fig.3. Both responses show good correlation having a BW of 40% for S_{11} better than about –8dB. The measured and simulated responses of the return loss of the two and four antenna arrays are shown in Fig.4a, and Fig.4b, respectively. As it can be seen, the simulated and experimental responses show very good agreement. BW is 50% for S_{11} below -8dB for the 2 antenna array. And a BW about is 50% for S_{11} lower than -10dB for the 4 antenna array.

The simulated radiation patterns for both arrays are shown in Fig.5a and Fig.5b. As it can be observed the first sidelobe is -3dB and -10dB below the main lobe, respectively for the E plane at the center frequency. The –3dB beamwidths are 48° and 60°, for the E plane and H plane, respectively for the 2-antenna array. For the 4 antenna array the beamwidths are 40° and 59° for the E and H planes.

IV. Conclusions

A new type of wide band corporate feeding network using a novel type of 3 dB branch line power divider was presented. This divider can be manufactured using traditional photolithography as it does not require any surface mounted components, multilayer structures nor 50Ω loads at the ports as compared to traditional couplers. Two antenna arrays with their respective feeding network were successfully implemented and their simulated and experimental results show good agreement.

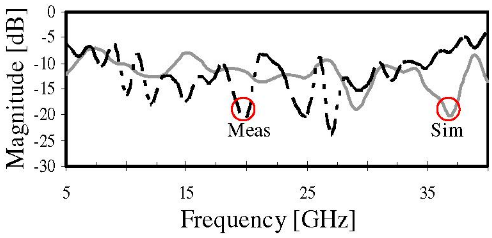

Fig.3 Measured and simulated S11 response for a Vivaldi antenna.

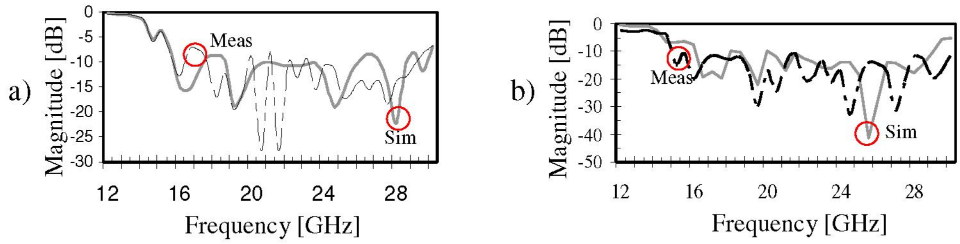

Fig.4. Measured and simulated S11 response for: a) Two-antenna array, b) Four-antenna array.

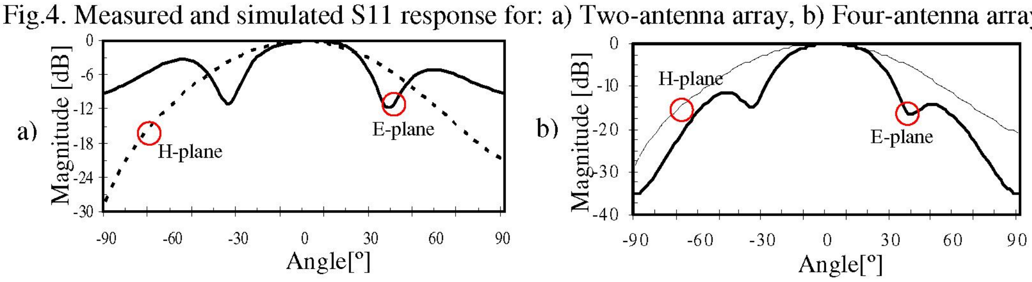

Fig.5. Simulated radiation pattern of: a) Two-antenna array, b) Four-antenna array.

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