A NEW DESIGN METHOD FOR A DUAL BAND BRANCH LINE HYBRID COUPLER

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ABSTRACT

This paper presents the design of a dual band branch line hybrid coupler(BLHC) with different power division ratios at two bands. In the proposed design, transmission lines of the BLHC are transformed to π-type equivalent circuits which represent different impedances and λ/4 electrical length at two frequency bands. In order to verify the proposed method, a dual band coupler with different power division ratios is designed for 0.9 GHz and 2 GHz applications. The desired power division ratios are 1:1 and 1:3 at the two operating frequency bands. The measured results show excellent performance with an insertion loss of less than 0.33 dB, a return loss of less than −18.07 dB, and good isolation characteristics.

KEY WORDS: Dual band, branch line hybrid coupler, impedance, open stub.

INTRODUCTION

Information and communication systems have always mattered in agriculture as well. Ever since people started growing crops, raising livestock or caught fish, they have sought information from one another for everyone's benefit. Using simple communication tools, such as storytelling, wisdoms of the village elders have passed on generations after generations, with continuous knowledge addition from the community in each stage. By using mobile phone technology, there have been diverse types of innovations taking place in the agriculture sector, which include commodity and stock market price information and analysis, meteorological data collection, advisory services to farmers for agricultural extension, early warning systems for disaster prevention and control, financial services, traceability of agricultural products, agricultural statistical data gathering, etc. It is are predicted that the availability of broadband Internet, 3G and 4G connectivity will soon be available in rural areas. The prices of smart phones are decreasing and they are becoming affordable. Technology therefore is not considered a major constraint although its adoption and adaptation to local needs are [1].

Development of the modern wireless communication systems with various frequency standards is accompanied by the active usage of multiband microwave devices. As a directional coupler is one of the base components of Radio Frequency (RF) parts of these systems and can be used in structure of amplifiers, mixers, phase shifters and other devices, therefore in recent years much attention is given to new schemes for the couplers, operating at two arbitrary frequency bands. In the case of widely used branch-line couplers, a lot of dual-band schemes are proposed in the literature. In the majority of reports the structures of relatively simple two-branch-line couplers are considered, two-section topology (tri-branch-line construction) has been used with the object of bandwidth broadening. Among all variety of the offered options of a dual band two-branch-line coupler realization one can note the next main approaches. It may be the usage of right/left handed met material transmission lines [2]–[3], the usage of stretched segments of line [4] or meander lines [5] for branches implementing, the usage of scheme in which all ports are extended through a transmission line section [6].

Branch line hybrid couplers are very often used for RF and microwave system. Dividers consist of one input port, two output ports and isolation port [4]-[5]. The Branch line hybrid coupler which is satisfied with all ports matched with isolation between the output ports is the most typical divider among them. As shown in Fig. I, the branch line hybrid coupler consists vertical line with impedance Z_a, horizontal line with impedance Z_b and quarter wave length of transmission line. Equations for calculating impedance and electrical length of a transmission lines are found easily in standard literatures [7]-[9].

Recently, a lot of work has been presented demonstrating multiband operation with one component [10]-[14].

Therefore, this paper presents a dual-band branch line hybrid coupler with different power division ratios at two bands. The organisation of the remaining part of this paper is as follows: Section II describes the theories and the proposed methodology to optimise the size of the branchline coupler that includes the detailed mathematical calculation and simulation process. Dual-band branch-line hybrid coupler is optimally designed, fabricated and measured. The measured results agreed well with the simulation. Section III and IV discusses the results obtained from this simulation study and the detailed analysis. Lastly, Section V provides the conclusion.

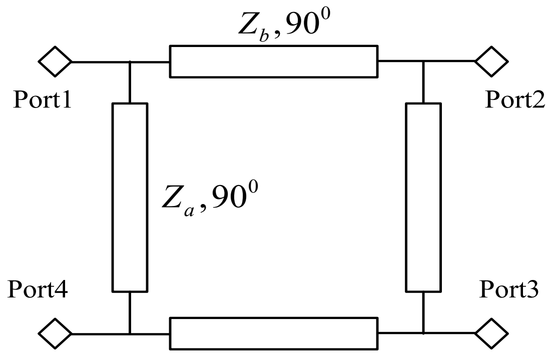


Figure 1. A schematic of a branch-line hybrid coupler.

METHODOLOGY

Pi-type equivalent circuit

It is known that the majority of branch line hybrid couplers have the structure with one or two planes of symmetry. When the branch line coupler in Figure 1 is determined power coupling ratio between the two outputs, impedance of each line is calculated by the following formula:

$$k^2 = \frac{P_3}{P_2}\left(\frac{P_{cp}}{P_{dp}}\right) \quad (1)$$

$$cp: coupled\ port, dp: direct\ port$$

$$Z_a = \frac{Z_0}{\sqrt{k^2}} \quad (2)$$

$$Z_b = \frac{Z_0}{\sqrt{1+k^2}} \quad (3)$$

Figure 2 (a). shows a transmission line with line impedance Z_0 and electrical length θ. It is represented by the π-type equivalent circuit composed of shunt stubs and a series line as shown in Figure 2(b). The impedance or admittance values of equivalent circuit elements are calculated by equations (4) and (5).

$$Z_e = \frac{Z_0 \sin\theta}{\sin\theta_e} \quad (4)$$

$$Y_{in} = j\frac{\cos\theta_e}{Z_e \sin\theta_e} \quad (5)$$

In this case, electrical length of the line has to obey the following condition to get the same property at two angular frequencies ω_1, ω_2 respectively.

$$\ell = \frac{\upsilon_p \pi}{\omega_1 + \omega_2} \quad (6)$$

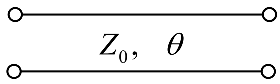
$$\theta_e = \frac{360 \cdot \ell}{\lambda} \quad (7)$$

$$\upsilon_p : velocity\ of\ the\ wave$$

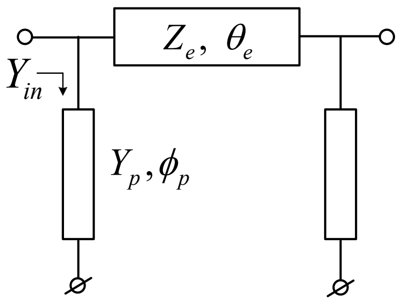
$$\lambda : wavelength\ at\ \omega_1$$

Shunt susceptances should to be minus value at a higher frequency band by using the above equation. It can be realized by using a shunt stub line. Equations for electrical length and impedance of the stub line are shown as bellow.

$$Y_{in,\omega_1} = Y_p \tan\phi_p$$
$$Y_{in,\omega_2} = Y_p \tan\phi_p \quad (8)$$



(a) Transmission line



(b) π-type equivalent circuit

Figure 2. Equivalent circuit of a transmission line.

Design of a dual-band branch line hybrid coupler
To obtain wide band performance with branch line hybrid coupler, it should be 1 section branch line hybrid coupler as shown in Figure 1.
Each component values are summarized in Table 1. The 1 section structure as shown in Figure 1 can be transformed to the proposed dual-band scheme by using (1)-(8). All impedances and electrical lengths of Figure 3 can be computed, and the values are listed on Table 2.

Table 1

Specifications of the dual-band BLHC

Parameters	f_1	f_2
Center frequency [GHz]	0.9	2
Division ratio	1:1	1:3
Input/output impedance (Z_0)	50	50
Vertical line impedance (Z_a)	50	28.86
Horizontal line impedance (Z_b)	35.35	25

Table 2

Each value of the dual-band BLHC

Impedance [Ω]		Electrical length [deg]	
Z_{ea}	54.48	θ_{ea}	66.60
Z_{eb}	39.86	θ_{eb}	63.36
Z_t	54.14	$\emptyset_t$	48.15

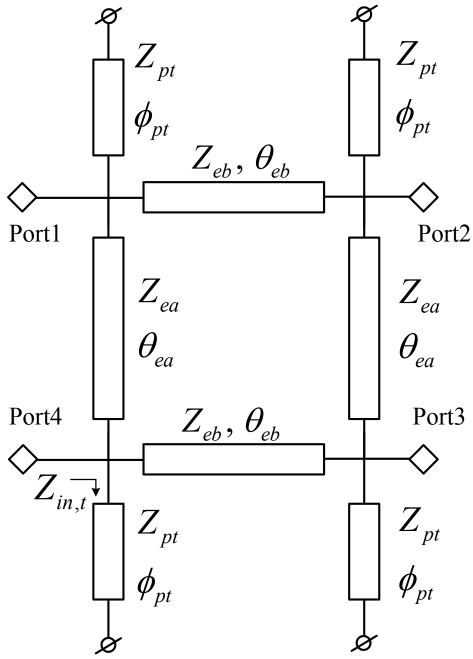


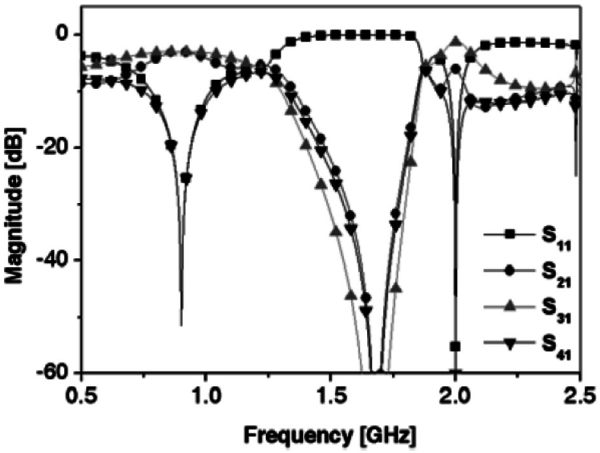
Figure 3. Schematic of a proposed dual band BLHC

Simulation and fabrication

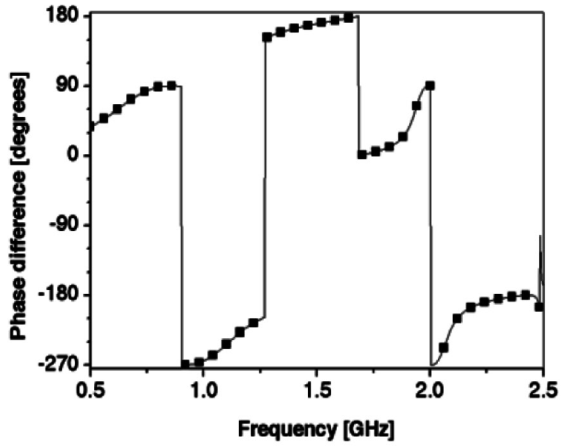
In order to verify the proposed method, a dual-band branch line hybrid coupler has been designed, fabricated and measured.

First of all, the simulation using the information in Table II has been performed, and the results are shown in Figure 4.

Figure 4 (a) shows the size of the signal to be transmitted to each port. The values performances -3.01dB and -3.01dB at 0.9GHz, -6.02dB and -1.28dB at 2GHz ideal ratio of division. Isolation and return loss values have more than -51 dB. Figure 4 (b) shows the phase difference between the two output ports. We can be confirmed a phase difference of 90° at 0.9 GHz and 2 GHz design frequencies.



(a) Insertion, return, and isolation loss



(b) Phase difference between two output ports

Figure 4. Circuit simulation results of the proposed dual band branch line hybrid coupler.

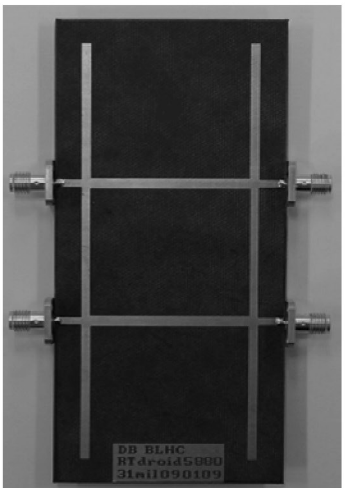
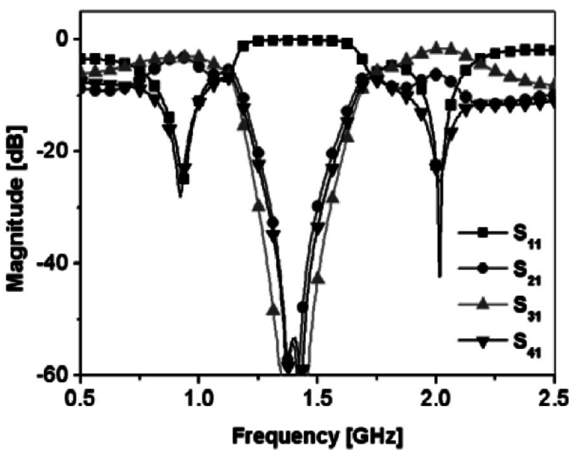
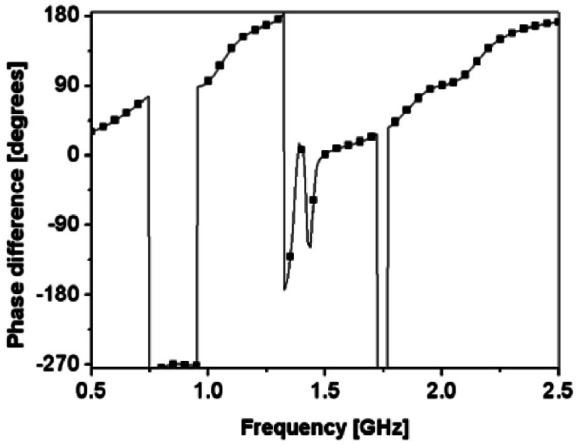


Figure 5. Photograph of the fabricated a dual band BLHC

Figure 5 shows a photograph of the fabricated dualband branch line hybrid coupler. The adopted substrate was RT 5880 with a dielectric constant of 2.2 and a thickness of 31mils.



(a) Insertion, return, and isolation loss



(b) Phase difference between two output ports

Figure 6. Measured results of the fabricated circuit.

RESULTS

Fig.6 present the measured characteristics.The measurement result show that insertion loss had an error of less than 0.33 dB in each -3.34 dB, -3.31 dB at low frequencies, return loss and isolation characteristics are more than -18.07 dB and -21.42 dB. On the other hand, the high frequency show that insertion loss had an error of about 0.49 dB in each -6.34 dB, -1.17 dB, return loss and isolation characteristics are more than -22.55 dB and -22.98 dB.

Figure 6 (b) shows the phase difference between the two output ports. The range error was 90±0.074° at low frequency of 0.9 GHz and 90±0.22° at high frequency of 2 GHz.

DISCUSSION

Hirota's method to reduce the size of a branch-line hybrid coupler is widely adopted in the design of dual-band dividers [15]. In this study, a size reduction of branch-line coupler technique using eight two-step stubs has been reported in. In comparison to conventional hybrid couplers, the reduced size coupler offers lower insertion loss and higher compactness (a significant reduction of 25% in the circuit area). Additional degrees of design choice can be obtained by including shunt open stubs and all these are the reasons for the major reduction in size. The reduced size couplers are potential elements for the growing wireless communications market. Very popular approach in obtaining the dual-band operation of the branch-line coupler is based on the use of stub lines. The structures in which open-circuit or short-circuit stubs are connected to all input ports are proposed in [7]. Further similar dual-band structures with some specialized functions were considered in [8]–[12].

CONCLUSION

A dual-band branch line hybrid coupler with equal split power at two frequencies has been proposed. A new method to calculate the required line impedances and electrical length for both frequencies was adopted in modeling a π-type equivalent circuit for two operating frequency bands. The formulas which satisfy the design conditions were extracted for all impedances (susceptances) and line lengths. In order to verify the proposed method, the dual-band branch line hybrid coupler was designed and measurements were taken, for a O.9GHz cellular system and a 2GHz 3rd generation communication system. The measured power division ratios at two output ports were equal split power at both bands. It is anticipated that the proposed design method can be applicable for dualband operation device with only one component.

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