VERY COMPACT REVERSIBLE WILKINSON POWER DIVIDER FOR L BAND, S BAND AND UWB APPLICATIONS

[1]HARDYAL SINGH, [2]RUCHI

[1,2]Deptt. Of ECE, Desh Bhagat University, Mandi Gobindgarh-147301
E-mail: herrysekhon863@gmail.com

Abstract- In this paper we have suggested a very compact reversible equal power divider by using rectangular rings. The rectangular rings of different impedances on microstrip line are proposed in this design. In the proposed design 3 dB powers splitting from one input port to two output ports is achieved. We obtain good impedance matching at all the three ports and also excellent isolation between two output ports are achieved over L band (1-2 GHz), S band (2-4 GHz) and UWB(3.1-10.6 GHz) range. The simulated return loss is -61.56 dB at 9.2 GHz design frequency. The average insertion loss and group delay are around 3 dB and 0.13ns respectively. The proposed design is very compact that is size reduction of 95% as compared to conventional design is achieved. The design is reversible and simple. Etching a slot on the section of power divider enhances bandwidth and reduced return loss up to -61.56 dB at 9.2 GHz. The proposed design was simulated using CST- Microwave Studio. With adjusted parameters the proposed antenna exhibits a broad impedance bandwidth and good isolation between output ports.

Keywords- Wilkinson Power divider, Ultra Wide Band, L-band, S-band, Compact, Impedance Matching, Port

I. INTRODUCTION

Power dividers called as power splitters and when used in reverse it acts as the power combiner a vital role in various RF and communication application [1]. It is a passive device which is used in the field of radio technology which requires power to be distributed among different paths. The easiest way to approach this method can be done by using a power splitter/divider. Basically power dividers are reciprocal devices that are they can also be used to combine power from output ports into the input port [2]. A power divider for RF power division and combinations is basic passive component and applied to many millimeter-wave systems and needed in various microwave applications. UWB systems are having main features such as low cost, low complexity and very high data rate for short ranges. So, UWB is a short distance radio communication technology that operates over 3.1-10.6 GHz frequency spectrum. However, the narrow bandwidth provided is a serious problem for UWB systems. The L band and S band operates over 1-2 GHz, 2-4 GHz band respectively. There are various applications in these frequency bands like mobile services, satellite navigation, telecommunication, amateur radio, astronomy, digital audio broadcasting, satellite communication, amateur television and many more. The two main categories of power dividers are reactive and resistive and each can be suited for its own specific applications. Wilkinson Power Divider (WPD) belongs to reactive power divider in which it has some special properties such as lossless network, high isolation between output ports and low insertion and isolation loss [3, 4].It has a single input port and more than one output port. But the main advantage of divider is that all ports are theoretically matched and output ports are isolated from one another [5]. It is usual, but not mandatory, for the transmission from the input port to be identical to all output ports. It can be designed with different transmission line sections such as s strip line, coaxial, microstrip, airstrip and lumped element circuit topographies to realize its designs. Three-port networks cannot be reciprocal and matched without being lossy [6, 7]. The solution to this, in the Wilkinson Power Divider, is to add a resistor between the two outputs. This resistor absorbs energy if there is a mismatch between the outputs. One of the biggest drawbacks of the Wilkinson Power Divider is that it has a quite narrow bandwidth which is a serious barrier for UWB application. Among them, the UWB devices have attracted great interest in industrial communities [8].

In the past years, a large number of Wilkinson Power Dividers have been studied and reported in the literatures [1-16]. A new technique for suppressing multi-spurious pass bands of microstrip Wilkinson power divider by means of multi-band defected ground structure (DGS) has been proposed in [9]. A circularly symmetric power divider has been presented in [10] which split a signal into n equi phase equi amplitude parts where n can be odd or even. The power divider provides isolation between output terminals and approximately matched terminal impedances over about a 20 percent band. In [11], a novel microstrip power divider with capacitor loading has been proposed in which the whole size of new structure has been reduced to 47% of conventional Wilkinson power divider. A novel approach to the design of an Ultra- Wideband power divider was proposed in [12]. In order to achieve the ultra-wideband performance, the divider is established by introducing rectangular rings of different impedances on microstrip line due to which good insertion loss has been achieved. Also, the circuit integration is enhanced because of the special placement of the isolation elements. A new family of planar Wilkinson-type power dividers with multi-band operation has been proposed in [13]. In [14], a modified two-way microstrip Wilkinson power divider with the total dimensions reduced by 50% compared with the conventional circuit was presented.

In this paper we have designed a reversible power divider by using rectangular rings of different impedances on microstrip line that fit within Wilkinson power divider. In order to achieve the wide bandwidth over L-band**,** S-band and ultra wide band the divider is established by using these rectangular rings and etching a slot on widest rectangular section of divider. In the design results indicate that proposed power divider has wide bandwidth, very compact size, reversible structure, good impedance matching, low insertion loss and reduced group delay within operating band.

The size reduction of 95% as compared to conventional power divider is obtained in this proposed power divider. It can be noted that such a design can be utilized to UWB active power combining system. Clearly, this type of microstrip planner UWB power divider is different approach than waveguide based power dividers.

II. STRUCTURE AND DESIGN

Fig.1 shows basic structure of traditional two-section Wilkinson power divider with matched port. The proposed power divider is simulated by using CST-Microwave Studio. In this design rectangular rings of different impedances on microstrip line and isolator resistor are used. [10]. The power divider is fabricated on Rogers 5880 substrate with dielectric constant of 9 and thickness of 0.8 mm and isolator resistor R=100 ohm enhances the isolation between output ports and used to avoid mismatch between output ports.

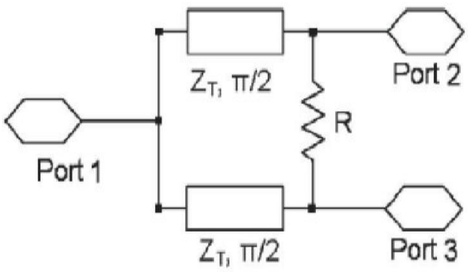

Fig.1. Top View of Proposed Power Divider

In order to reduce the size of power divider we have used stepped impedance technique. The size is reduced to 95% as compared to conventional design. By introducing a slot of 1mm x 0.2 mm we obtain a wide impedance bandwidth covering entire L band, S band, ultra wideband and return loss less than -60 dB at 9.2 GHz is achieved. Along with very compact size, wide bandwidth and simple design the proposed power divider has reversible structure that is front and back side of divider are exactly similar which is very big advantage of proposed design.

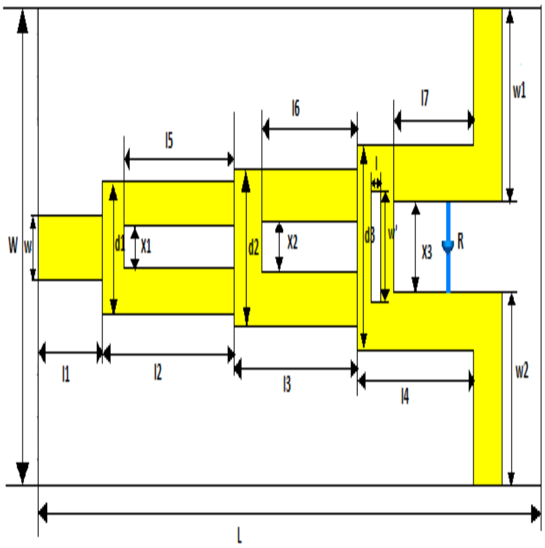

Fig.2. Top View of Proposed Power Divider

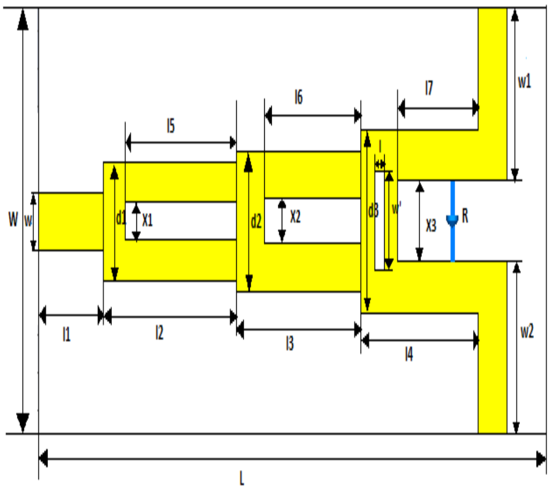

Fig.3. Back side View of Proposed Power Divider

Fig. 2 shows the proposed 2-way power divider (that is N=2). For a design frequency of 9.8 GHz and ports impedance of 50 ohm, the proposed design area is 15 x 5.6 mm. Another advantage of using rectangular shaped divider is that all output ports are designed together. The resistance is fixed for upper and output lines which give good isolation and matching. By etching a slot on the widest section of power divider we obtain wide bandwidth over L band, S band and ultra wideband and also return loss decays around 9.2 GHz to value of -61.56dB. The proposed design is reversible that front and back side of power divider is similar. Fig.3. shows the back side of proposed power divider. The reversible structure is a big advantage of the proposed design. By introducing the slot on widest rectangular section we obtain return loss -10 dB over entire UWB range.

The size reduction of 95% is achieved in proposed design. Table-I shows the dimensions of front and back side of proposed power divider.

Table-I

Divider parameter	L	W	l 1	l 2	l 3	l 4
Dimensions in mm	15	5.6	1.65	3.6	3.35	3.18
Divider parameter	l 5	l 6	l 7	w	w 1	w 2
Dimensions in mm	3	2.6	2.95	0.75	2.27	2.27
Divider parameter	x 1	x 2	x 3	d 1	d 2	d 3
Dimensions in mm	0.5	0.6	1.07	2.17	2.59	3.36
Divider parameter	l	w'				
Dimensions in mm	0.2	1				

2.1. Mathematical Analysis

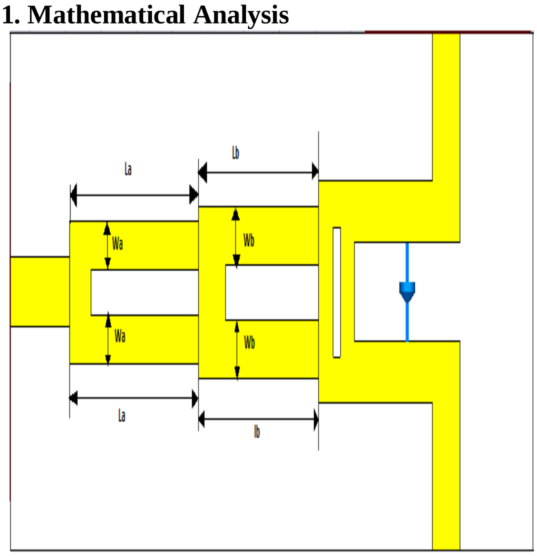

Fig-4: Schematic of UWB Power Divider

A schematic diagram of proposed power divider, which shows an equal power division over an UWB frequency band, is shown in Fig-5.

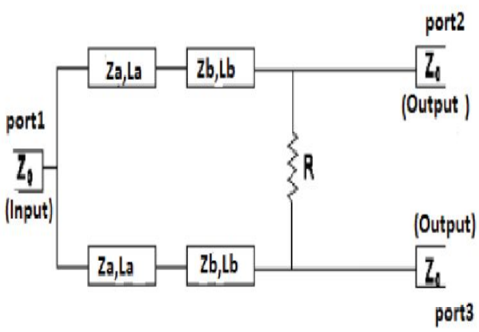

Fig-5: The proposed UWB Wilkinson Power Divider

Each quarter-wave line of a conventional Wilkinson power divider is replaced by two sections of rectangular rings with different characteristic impedance Z_a and Z_b and the physical lengths L_a and L_b, respectively.

(a) Even-mode Analysis

The equivalent circuit of the power divider in the even mode is shown in Fig-6.

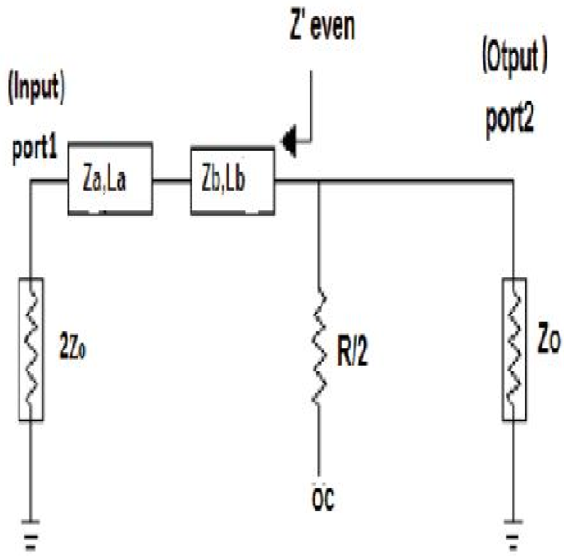

Fig-6: Circuit of the power divider for the even-mode analysis

Since does not current flow through the plane of symmetry, the resistor R can be omitted and the characteristic impedance Z_0 at port 1 is doubled. By introducing the equation in [9], we have

$$L_a = L_b = \frac{n\pi}{\beta_1 + \beta_2} \qquad (1)$$

$$Z_b = \sqrt{\frac{Z_0(R_L - Z_0)}{2\alpha} + \sqrt{\left[\frac{Z_0(R_L - Z_0)}{2\alpha}\right]^2 + Z_0^{\,3} R_L}}$$

(2)

$$Z_a = \frac{Z_0 R}{Z_b} \qquad (3)$$

Where R_L is replaced by $2Z_0$ in Fig-3 and

$$\alpha = (\tan(\beta_1 L_a))^2 \qquad (4)$$

$$\beta = \frac{2\pi}{\lambda} \qquad (5)$$

By the formulas, the resonance center frequency is mainly determined by the length of the two sections of rectangular rings L_a and L_b. And the bandwidth Δf is determined by the ratio of Z_a and Z_b.

(b) Odd-mode Analysis

The equivalent circuit of the power divider in the odd mode is shown in Fig-7.

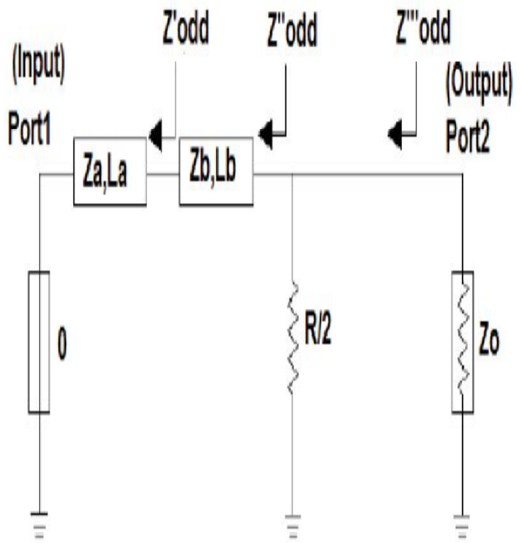

Fig-7: Circuit of the power divider for the odd-mode analysis

The input impedance at port 2 can be calculated as follows:

$$Z'_{odd} = jZa \tan(\beta_1 L_a) \quad (6)$$

$$Z''_{odd} = Zb \frac{Z'_{odd} + jZ_b \tan(\beta_1 L_b)}{Z_b + jZ'_{odd} \tan(\beta_1 L_b)} \quad (7)$$

Where $L_a = L_b$

$$Z'''^{-1}_{odd} = \frac{1}{Z''_{odd}} + \frac{2}{R} \quad (8)$$

For the impedance matching to Z_0, resulting in

$$Z_b - Z_a (\tan(\beta_1 L_a))^2 = 0 \quad (9)$$

$$R = 2Z_0 \quad (10)$$

According to, (1) to (5) and (9) and (10), all the electrical parameters of the proposed Wilkinson circuit are then derived. The power divider has wide bandwidth, good impedance matching and better isolation over L band (1-2 GHz), S band (2-4 GHz) and UWB(3.1-10.6 GHz) range.

III. SIMULATED RESULTS AND DISCUSSION

Fig.8(c) shows simulated return loss of proposed power divider design. It can be seen from the return loss plot that input power has been split equally to two output ports. The isolation is less than -10dB and the performance of proposed design is excellent in terms of return loss over entire L bans, S band and ultra wideband. Fig. 8(a) shows the simulated return loss on proposed power divider. By etching a slot on widest rectangular section of power divider the return loss decays up to -61.56 dB and also return loss become less than -10 dB over entire UWB range.

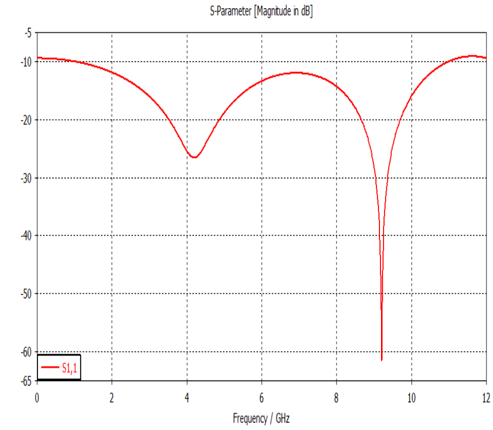

Fig.8(a). Simulated return loss vs. frequency of proposed power divider

Also excellent input port matching is achieved with S11 -61.56 at the design frequency 9.2 GHz as shown in fig. 8(c) and this figure also shows that the transmission parameter S21 and S31 are very close to 3dB at the desired frequency range covering L band, S band and ultrawideband. The small deviation could be due to losses and discontinuities. The design provides excellent approach to design a wideband power divider.

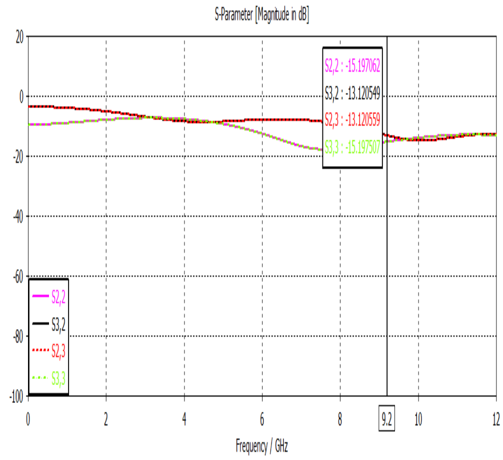

Fig.8(b). Simulated isolation and return loss at output ports

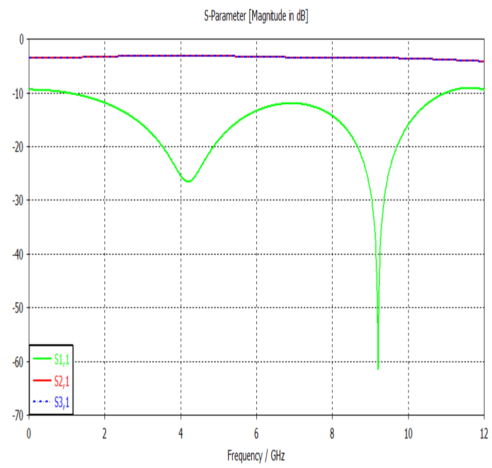

Fig.8(c). Simulated result of proposed power divider

Fig.8 (b) shows the isolation between the 2-way power divider output ports. Good isolation between the output ports S23 at design frequency 9.2 is obtained here. Fig 8(b) shows the output ports matching parameters S22 and S33. The output port matched and achieved return loss less than -10 dB at 9.2 GHz.

Fig.8 (d) shows the group delay within L band, S band and UWB which shows good linearity within these bands. It means the signal reaches from input port to output port at same time. In our proposed design the groups delay also decreases. Here at L band, S band and ultra wideband the total group delay is around 0.13ns with very little variation of about 0.02ns over desired frequency band covering wide bandwidth.

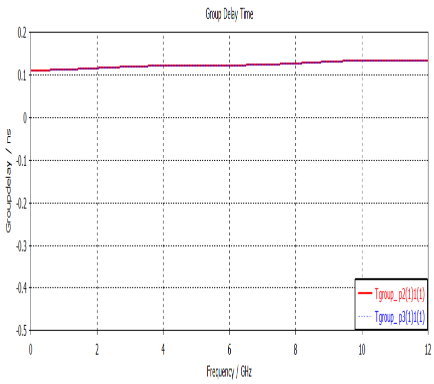

Fig.8(d). Simulated group delay of proposed power divider

The proposed power design structure is very compact that is 95% smaller than conventional power divider. Also the proposed design with reversible and simple structure stands out as a good candidate for many applications. We obtain good impedance matching, good isolation and reduction in return loss by this proposed design.

CONCLUSION

In this paper we have tried to design very compact reversible and simple power divider for L band (1-2 GHz), S band (2-4 GHz) and ultra wideband (3.1-10.6GHz). In order to achieve wide bandwidth rectangular rings of different impedance on microstrip line and etching a slot on widest rectangular section of power divider is suggested. We obtain good isolation and reduced return loss with the proposed design. From the simulated results it can be seen that good power splitting near 3dB, impedance matching and isolation has been obtained. The size reduction up to 95% and reversible structure are big advantages of proposed power divider design. The proposed design occupies 15mm x 5.6 mm area. Simulated results show 3dB power divider works efficiently over wide bandwidth.

REFERENCES

[1] T.C. Albuquerque, T.L.V.N. Silva, A.J.R. Serres, R.C.S. Freire, J. Walheim, F. Podevin, F. Burdin, P. Ferrari, T. P. Vuong. “Implementation of Beam-Steering Front-Ends at 2.45 GHz Using Modified Wilkinson Power Dividers, Reflexion Type Phase Shifters and C-Shape Monopole Antennas: First Results” IMOC 2015, pp. 1-5, 3-6 Nov. 2015, Porto de Galinhas.

[2] E.J. Wilkinson, “An N-way hybrid power dividers”, IEEE TransMicrowave Theory Tech., vol. MTT-8, pp. 116-118, 1960.

[3] Jian-Peng wang, Jia Ni, Yong-Xin Guo, Da-Gang Fang “Miniaturized Microstrip Wilkinson Power Divider with Harmonic Suppression” Microwave and wireless components letters, IEEE vol: 19, Issue -7, pp. 440-442, 23 June 2009.

[4] Fallahzadeh, S., Molaei A., Cheldavi, A., “ Microstrip Wilkinson power divider with multi-spurious suppression” MECAP 2010 , 20-22 0ct 2010 cairo.

[5] Ju Wu, En Li, Gao-feng Guo, “Microstrip Power Divider with Capacitive Stubs Loading for Miniaturisation and Harmonic Suppression” ICMTCE-2011, 22-25 May 2011 Beijing.

[6] Hai Hoang Ta and Anh-Vu Pha m “Compact Wilkinson power divider on multilayer organic substrate” IEEE MTT-S 2012, 17-22 June 2012, Montreal, QC, Canada.

[7] T. G. Aboelnaga, E. A. F. Abdallah, “A Very Compact Novel Power Divider for GPR Large Target Detection” EuCAP 2013, pp. 1192-1195, 8-12 April 2013 Gothenburg.

[8] Li-Bin Wan, Ya-Lin Guan, Wei-Long Fu “A novel planar six way power divider” ICNC 2013 , pp. 1510-1514, 23-25 July 2013, Shenyang.

[9] Junsong Ning, Liu Chen, Shirong Bu, and Cheng Zeng, “A New Design of Compact Microstrip Wilkinson Power Dividers” 2014 IEEE International Symposium on Radio-Frequency Integration Technology, pp. 1-3, 27-30 Aug 2014.

[10] Sandeep Kumar, Mithilesh Kumar “Ultra Wide Band Wilkinson Equal Power divider using Rectangular Rings of Different impedance” MedCom 2014, pp. 49-54,7-8 Nov. 2014, Greater Noida.

[11] Mocanu Iulia Andreea, Petrescu Teodor “Dual band Wilkinson power divider with artificial transmission lines for mobile TV services” ISETC 2014, pp. 1-4, 14-15 Nov. 2014, Timisoara.

[12] Raúl Loeches-Sánchez, Dimitra Psychogiou, Dimitrios Peroulis, and Roberto Gómez-García “A Class of Planar Multi-Band Wilkinson-Type Power Divider with Intrinsic Filtering Functionality” RWS, 2015 IEEE, pp. 138-140, 25-28 Jan. 2015, San Diego,CA.

[13] Jin Shi, Jian Wang, Kai Xu, Jian-Xin Chen, and Wei Liu “A Balanced-to-Balanced Power Divider With Wide Bandwidth” IEEE MICROWAVE AND WIRELESS COMPONENTS LETTERS, pp. 573-575, VOL. 25, NO. 9, Sep. 2015.

[14] Chih-Jung Chen, Yin-Drin Su, “A Wide Stopband Low-Pass Wilkinson Power Divider” Proceedings of the 45th European Microwave Conference, 2015 EuMC, pp. 1041-1044, 7-10 Sep. 2015,Paris.

[15] H. P. Phan, T. P. Vuong, T. T. Nguyen, M. H. Luong, Y. Iitsuka, M. H. Hoang “Simple Miniaturized Wilkinson Power Divider Using A Compact Stub Structure” 2015 International Conference on Advanced Technologies for Communications (ATC). IEEE 2015.

★★★