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Design of Compact Rat Race Coupler for WLAN Receivers

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***Abstract*— Rat Race Coupler is simply a 3 dB coupler that can be an alternative to a Magic Tee. They are mainly used to combine or split the signals with almost no loss. In this paper Rat race Coupler operating at a frequency of 2.4 GHz is designed using the Advanced Design System software (ADS).It is used for WLAN receiver applications. The rat race is simulated and the results shows better insertion loss (3.5dB) and isolation loss (33 dB) at the designed frequency.**

***Keywords*— Rat Race Coupler, Magic Tee, WLAN receiver.**

I. Introduction

With rapid advancement in wireless communication systems and other microwave systems, these systems are being miniaturized. This leads to the compact and handheld devices and systems. This compactness is dependent on the compactness and miniaturization of components and devices. The couplers are basically power dividers/ combiners with equal or unequal power division and with or without phase shift. Branch line couplers [1, 2], power dividers [3-7] and hybrid ring couplers [8, 9] are the some of the power dividing/ combining devices. The rat-race coupler is one of basic building blocks used in RF and microwave circuits. The rat-race coupler is transmission line based device in which output appearing at a particular port depends on the phase of the signals arriving at that port following different paths. Accordingly this can be designed and implemented in wave guide as magic Tee. In micro strip line, strip line and co-planar wave guide, it is implemented as 3dB hybrid coupler. In these designs, the implementation is easier where the characteristics impedance of the line can be changed by changing the widths of the corresponding lines. The rat-race coupler design based on the micro strip line is very popular. In micro strip line configuration, other phasing techniques are used to reduce the size of the coupler [11-13]. The various coupler designs [14] are compared for their performances with respect to form factors of these couplers.

In micro strip design, the ground plane is an integral part of the system and hence less portability. For realization of these couplers we require to use a ring of one and half wave length circumference and hence it occupies less area. More over the ports of the coupler are located along the periphery and they cannot be put in line. For compactness if the micro strip line is meandered then the line loss increases.

II. THEORY

The Rat-race coupler is a 4-port device [10] which can be used as a power divider or power combiner. The phase of output for some port combination may be 0° or 180° depending upon the input- output combinations. The schematic and symbol of 180 deg. hybrid is shown in Fig. 1(a, b). Depending upon the input- output combinations the hybrid can be used as

(a) In -phase power splitter
(b) Out-of phase power splitter and
(c) Power combiner

When port 1 is used as an input port this signal is equally divided in two pats travelling clockwise and anti-clockwise respectively with respect to port 1. The distance travelled by signal travelling in clockwise direction from port1 to port 2 is $5\lambda/4$ and the distance travelled by other half signal following anti clockwise direction is $\lambda/4$. Path difference modes, between these two signals is λ. Outputs at this port are in phase. Similarly the outputs will be in phase at port 3 by similar reason.

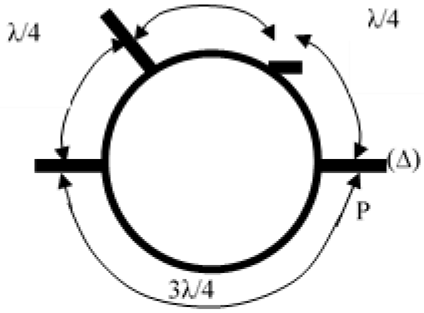

Fig.1 Schematic of RRC

The scattering matrix for the ideal 3 dB 180◦ hybrid thus has the following form:

$$S = \frac{-j}{\sqrt{2}} \begin{vmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{vmatrix}$$

III DESIGN & ANALYSIS

Rat-race (ring hybrid) is one of the oldest and simplest designs for the fabrication of a 180° hybrid. As shown in Figure 2, it is a ring shape making of transmission lines which compose of three λ/4 line sections and one 3λ/4 line section. The port impedances are all 50. The quarter-wave length sections along to the circumference operate as a transformer which transforms the 50 loads on two output ports to 100 each at the isolation port.

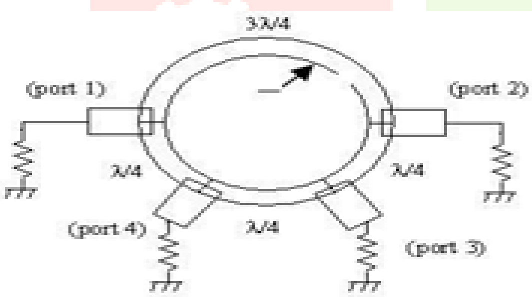

Fig. 2Top view of Microstrip Rat Race Hybrid

The ring characteristic impedance is 50√2 . By constructing the ring hybrid based on the above specifications, the ports are all matched and the power form the source is split equally between two output ports.

TABLE I. CONVENTIONAL RRC HYBRID OPERATION

EXCITED PORT	OUTPUT PORT	ISOLATED PORT	PHASE DIFFERENCE BETWEEN
1	2,4	3	180◦
2	1,3	4	180◦
3	2,4	1	0◦
4	1,3	2	0◦

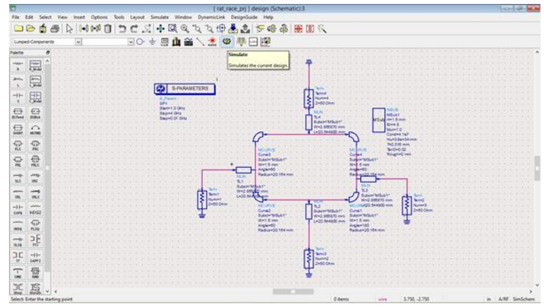

Fig .3 Design Diagram

The parameters like length and width of the transmission line is calculated using the equations of transmission line. A conductor of width w is printed on a substrate of thickness d and relative permittivity εr. These parameters are noticeable in RF circuits design. They relate to the characteristic impedance Z0 and should be calculated carefully. Given that the characteristic impedance Z0 equals to 50, εr equals to 4.8 and d=1.6 mm, the w/d can be calculated.

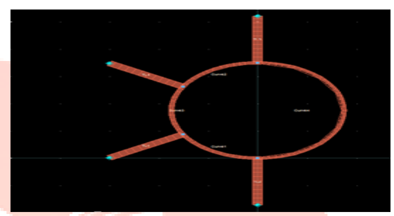

Fig..4 Layout in ADS

The first step in a design is to choose a suitable dielectric substrate of appropriate thickness (h) and loss tangent. A thicker substrate decides being mechanically strong it will increase the radiated power, reduce the conductor loss and improve impedance bandwidth. Here we are using FR-4 substrate. Because a dielectric constant of FR-4 substrate is εr = 4.4 and loss tangent value, $tan\delta$ = 0.02, by increasing the height of the substrate automatically increases the efficiency. Here the height of the substrate is 1 mm.

IV RESULTS & DISCUSSION

The resonating frequency of proposed hybrid coupler is 2.4GHz and the return loss is -35.898 dB and it has an isolation loss of -32.855 dB. This low value of return loss yields higher efficiency in WLAN applications. Figure 5.2 shows the layout of a hybrid coupler on FR4 PCB . The simulated results satisfy the requirements of wireless communication.

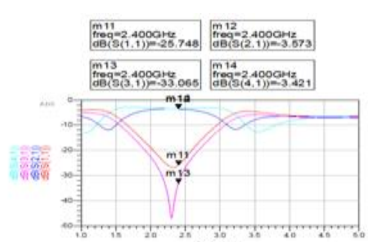

Fig 5.S-Parameters

A.Return Loss:

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber.. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. Return loss is a measure of how well the devices or line are matched. A match is good if the return loss is high. A high return loss is desirable and results in lower insertion loss. It has a better resolution for small values of reflected wave.

TABLE II. RETURN LOSS

S11	S22	S33	S44
-25.748	-26.173	-26.173	-25.748

B.Isolation Loss:

Isolation is the insertion loss in the open path of a switch or between two ports on a passive device. It should be less than -20 dB for good performance

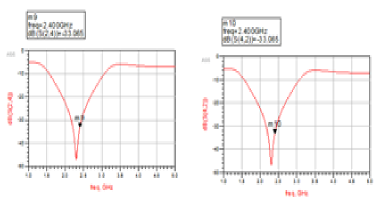

Fig.6 Isolation loss

TABLE III ISOLATION LOSS

S24	S42
-33.065	-33.065

C. Insertion Loss:

For couplers, insertion loss refers to the additional loss above the nominal loss due to splitting. For example, in a 3 dB coupler the insertion loss might be specified as 0.5dB. This implies that for a 0 dB input signal, the two output signals will be approximately -3.5 dB each. The additional losses are caused primarily by reflections, dielectric absorption, radiation effects, and conductor losses.

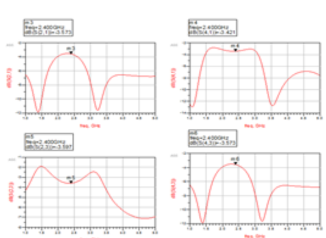

Fig 6.Insertion loss

TABLE IV. INSERTION LOSS

S21	S41	S23	S43
-3.573	-3.421	-3.597	-3.573

V. CONCLUSION

In modern communication industry hybrid couplers are widely used in microwave circuit design. In this paper, 3 dB hybrid coupler was chosen. The hybrid coupler is designed to operate at 2.4 GHz frequency with impedance ($Z0$) is 50 Ω, dielectric constant εr is 4.4 and thickness of dielectric material is 1 mm .The hybrid coupler is successfully simulated. The return and isolation loss obtained is less than -20 dB, the insertion loss obtained is of the range of 0.5 dB, all of which comply with the specified values.

REFERENCES

[1] K.V. Phani Kumar, Rusan Kumar Barik, SS Karthikeyan, "A novel two section branch line coupler employing different transmission Line techniques", AEU International Journal of Electronics and Communications, Vol.70, Issue 5, May 2016, pp.738-742.

[2] Mehrdad Naderi, Hamed Abbasi, "Design of Compact Microstrip Branch Line coupler using Semi- circular rectangular resonators with wide range suppressed harmonics", AEU- International Journal of Electronics and Communications, Vol.84, Feb. 2018, pp.171-176.

[3] Mahdi-Moradian, "Wideband Slot Coupled Power dividers", AEU- International Journal of Electronics and Communications, Vol.82, Dec. 2017, pp.327-333.

[4] Hamed Shahi, Hossein Shamsi, "Compact Wideband Gysel Power dividers with harmonic Suppression and arbitrary power division Ratios", AEU- International Journal of Electronics and Communications, Vol.79,Sep. 2017, pp.16-25.

[5] Xiao Yang, XuChun Zhang, ZhenHeng Liao, "A Novel Planar Four-way Power divider with large dividing ratio", AEU- International Journal of Electronics and Communications, Vol.85, Feb.2018, pp. 1-6.

[6] Ashraf S. Mohra and Majeed A. Alkanhal, " Dual Band Wilkinson Power Dividers Using T-Sections" Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol. 7, No. 2, December 2008, pp-83-90.

[7] Zhen Yang, Weiguo Liu, "A Balanced-to-Single-Ended Wilkinson Power Divider ",Journal of Microwaves, Optoelectronics and Electromagnetic Applications, Vol. 16, No. 3, September 2017, pp-777-784.

[8] Suwan Janin, Keattisak Sripimanwat, Chuwong Phong Charoenpanich, Monai Krairiksh, "A hybrid Ring Coupler Quasi-optical Antenna Mixer", AEU- International Journal of Electronics and Communications, Vol.63, Issue 1,17 Jan. 2009, pp.36-45.

[9] Mohammad Beigizadeh, Rasoul Dehghani, Abdolreza Nabavi, "Analysis and design of lumped element Hybrid International Journal of Electronics and Communications, Coupler using limited quality factor Components", AEU Vol.82, Dec. 2017, pp.312-320.

[10] David M. Pozer, "Microwave engineering" , John Willey and Sons Inc. Publication, third ed., 2005.

[11] Lin-Zong, Jan-Dong,Binshu Wu, Jhih-Min Li, "Hybrid type Rat-Race Coupler designs", APEMC-2015.

[12] Y-C Chiou, J-T Kuo and C-H Chan, "New miniaturized dual band rat-race coupler with microwave C-sections", IEEE MTT-S Int. Microwave Sympo. Dig. 2009, pp.701-704.

[13] Iulia Andreea Mocanu, Teodor Petrescu, " Novel dual band hybrid Rat-Race with CRLH and D-CRLH transmission Lines", Proc. of the Asia Pacific Microwave conference 2011.

[14] He-Xin Xu, Guang- Ming Wang and Ke Lu, "Micro strip Rat-race Couplers", IEEE Microwave magazine, June-2011, pp.117-129.

[15] J. Reed and C.J. Wheeler, "Method of Analysis of Symmetrical Four- Port Networks", IRE trans. On Microwave Theory and Techniques, Vol. MTT-4, pp. 246-252, October 1956.

[16] Spectrum, Elektrotechnik GmbH, "quick Connections, the 99 hand book" 80905, Munich Germany.