Elliptically Bended Hybrid Ring Coupler

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Abstract – In this paper, a size reduced elliptically bended hybrid ring coupler is proposed with better directivity, isolation factor, coupling factor, better impedance matching and undesired signal suppression for wideband applications. The proposed elliptically bended compact hybrid coupler is desired to operate at 1.8 GHz providing wide bandwidth, better return loss, and isolation with less insertion loss where a novel gradual impedance bending technique is implemented to suppress unwanted signals.

Keywords – Coupling factor, Gradual impedance bending, Hybrid coupler, Signal suppression, Wide bandwidth.

1. Introduction
RADIO frequency applications require variety of couplers for power combination and division at different ranges. The challenges faced by these directional couplers are that the power is to be coupled with better directivity, isolation factor, coupling factor and better unwanted signal suppression. The 180° Hybrid Coupler is a 4-port structure which is used to equally divide an input signal with a phase shift of 180° between the two ports or to combine two input signals that are 180° phase apart. 180° Hybrid couplers generally consist of one centre ring with circumference 1.5 times the wavelength which is six times that of quarter wavelength. Each port is separated by a quarter wavelength that is 90° apart.

The objective of this design is to have a broadband directional coupler that can act as a power combiner suitable for radio frequency applications. Also, different broadband applications like Bluetooth, GSM require directional couplers for power combination and division. The existing broadband directional couplers have shown effective results as they operate at high frequency ranges. Also, power combiners at high frequency ranges have shown optimized results in suppressing the noise signals. The proposed broadband directional coupler can operate in the range of 1.8GHz GSM band and suitable for radio frequency applications with better power coupling and performance characteristics.

2. Design
Figure 1(a) shows the usual hybrid ring coupler with 50 Ω termination impedance and 70.7 Ω line impedance. These couplers though simple requires large area about 7cm*7cm for resonant frequency of 1.8GHz. Also unwanted higher frequency signals are present while implementing this design. To avoid these drawbacks, we go for elliptically bended hybrid coupler which is shown in Figure 1(b). It provides compactness and also provides effective signal suppression of higher frequency components. The elliptical bended line has impedance value of 1.2Z₀=60 Ω which is less than 70.7 Ω line impedance. For easy implementation of structure, the elliptical bend is done at λg/16 at both port ends. From the centre cut line the line is bended more than λg/8 which provides moon-shaped structure.

Fig. 1: (a) Hybrid coupler structure (b) Elliptically bended structure.

Couplers are the essential component for power...
transmission or reception which can act as power divider, combiner, amplifier, mixer and phase shifter [1]. Compact couplers are already proposed along the with filtering characteristics [2]-[5] and folding of lines shows effective results in [6]. Combining the benefits of both we achieved compact structure along with suppression characteristics throughout the desired band.

3. Results

The magnitude characteristics of usual hybrid ring coupler with port 4 as feed at a center frequency of 1.8 GHz is shown in Figure 2(a). $|S_{44}|$ below 10 dB line gives return loss >25 dB. The insertion loss of $|S_{24}|$ & $|S_{34}|$ are almost less than 1dB and isolation $|S_{14}|$ is > 40dB. But we can note the unwanted higher frequency repetition at nf0 frequencies for this design.

![Fig. 2: Coupler characteristics (a) Actual structure characteristics (b) Elliptically bended structure characteristics.](image)

The magnitude characteristics of elliptically bended ring coupler with port 4 as feed at a center frequency of 1.8 GHz is shown in Figure 2(b). The return loss $|S_{44}|$ is >30 dB. The insertion loss of $|S_{24}|$ & $|S_{34}|$ are maintained as less than 1dB and isolation $|S_{14}|$ is > 40dB as like usual one. The advantage of going for this design is higher frequency components are suppressed in a wide manner which can be visibly seen in Figure 2(b).

![Fig. 3: Signal suppression at higher frequencies.](image)

Figure 3 shows the effective signal suppression more than 30dB for a wide band of frequency range from 2GHz to 11GHz. Thus, the modified design is best suitable for wide band radio frequency applications.

The results of actual hybrid ring structure are compared with results of elliptically bended structure in Table I. The overall area requirement is decreased nearly 40% because of the elliptically bended structure. For the center frequency around 1.8GHz, the new structure provides good impedance matching as the impedance value does not exceed $60\,\Omega$. Suppression of unwanted signals is the additional benefit of elliptically bended structure.

![Table 1: Hybrid Ring Coupler Vs Elliptically Bended Coupler](image)

|                  | Circuit Area (%) | Return loss (dB) | Insertion loss (dB) | 3-dB Bandwidth (%) | Impedance (Ω) |
|------------------|------------------|------------------|--------------------|--------------------|--------------|
| Hybrid Ring      | 100              | >25 / >35        | <1                 | >25                | 50 / 70.7     |
| Elliptically Bended Ring | 61             | >30 / >35        | <1                 | >25                | 50 / 60       |

4. Conclusion

In this work, a novel gradual impedance bending technique is implemented to suppress unwanted signals more than 30dB with better results such as return loss greater than 30 dB, insertion loss less than 1dB, isolation more than 40dB, and 3-dB coupling bandwidth more than 25%. With no compromise in results the designed structure is desired to perform well for wideband radio frequency applications.
References

[1]. D. M. Pozar, Microwave Engineering, 4th ed. Hoboken, NJ, USA: Wiley, 2012.

[2]. Z. Xu, J. Xu, and C. Qian, “A Novel Dual-Mode Microstrip Ring Coupler for Low-Cost Balanced Frequency Doubler Application,” IEEE Trans. Microw. Theory Tech., vol. 66, no. 7, pp. 3270–3276, Jul. 2018.

[3]. P. Mondal, A. Chakrabarty, and Y. C. Chiou, “Design of miniaturized branch-line and rat-race hybrid couplers with harmonics suppression,” IET Microw. Antennas Propag., vol. 3, no. 1, pp. 109–116, Jan. 2009.

[4]. K.-X. Wang, X. Y. Zhang, S. Y. Zheng, and Q. Xue, “Compact filtering rat-race hybrid with wide stopband,” IEEE Trans. Microw. Theory Tech., vol. 63, no. 8, pp. 2550–2560, Aug. 2015.

[5]. J.-T. Kuo and C.-Y. Tsai, “Periodic stepped-impedance ring resonator (PSIRR) filter with a miniaturized area and desirable upper stopband characteristics,” IEEE Trans. Microw. Theory Tech., vol. 54, no. 3, pp. 1107–1112, Mar. 2006.

[6]. R. K. Settaluri, G. Sundberg, A. Weisshaar, and V. K. Tripathi, “Compact folded line rat-race hybrid couplers,” IEEE Microw. Guided Wave Lett., vol. 10, no. 2, pp. 61–63, Feb. 2000.