Compact SIW Power Divider with CSRRs for WLAN Application

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Abstract— In this paper, the development of compact substrate-integrated-waveguide (SIW) power divider with complimentary-split-ring-resonators (CSRRs) is presented. The proposed SIW power divider is designed to work at S-band frequency for wireless local area network (WLAN) application. Two reversely arranged CSRRs incorporated into the SIW surface are intended to produce filtering effect of power divider useful for suppressing unwanted signals. Some parametric studies upon the physical parameters are carried out through simulation to obtain the compact design of power divider. Based on parametric studies, the proposed SIW power divider with CSRRs is then deployed on a 1.6 mm thick FR4 epoxy dielectric substrate with the size of 40 mm × 30 mm. From the characterization, the proposed SIW power divider shows capability to work at the frequency of 2.4 GHz with the rejection rate more than 20 dB at the stopband area which is suitable for the desired application.

1. INTRODUCTION

Nowadays, wireless communication system with high speed data transfer has been becoming one of the most growth technological developments in communication systems. The development has driven researchers and academicians to undertake numerous techniques in making supporting devices on communication systems to be more effective. Many communication devices including filters, combiners, and dividers are usually arranged by transmission line to satisfy desired specifications [1, 2]. Various manufacturing methods have also been developed in several ways with the emphasize in minimizing the size and enhancing the performance parameters of transmission line-based communication devices.

One of communication devices which hold important role in communication systems is power divider. Basically, it is an equipment with the capability to divide a signal power from a device to be spread out into some other devices. One of the most widely known techniques for designing power divider is the Wilkinson method which have been implemented with some configurations [3–7]. However, as the growth of design and manufacturing technologies in communication systems, recently power divider which is previously designed and realized with large size and complex method can be miniaturized through substrate integrated waveguide (SIW) method. This method allows integration of waveguide into substrate by adding some via-holes on the substrate yielding the reduced cost and size of production. As a result, a power divider with compact size, simple design, and lower loss value could be implemented [8, 9].

Furthermore, the use of power divider is sometimes combined with filtering functionality. Therefore, a resonant approach by involving some resonators to attain the filtering effect can be undertaken. This can be realized, one of methods, by adding Complementary Split Ring Resonators (CSRRs) for bandpass frequency filtering [10, 11]. In addition, the CSRRs which is combined with the SIW method could also improve the performance of power divider, particularly in bandwidth response [11, 12]. By taking those advantages, in this paper, a compact SIW power divider with CSRRs is designed to work at S-band frequency for WLAN application. In the design, two reversely arranged CSRRs are incorporated into the SIW surface to produce filtering effect useful for suppressing unwanted signals. Some parametric studies are carried out to obtain the compact design of power divider which is suitable for the implementation.

2. DESIGN AND SIMULATION

The design of compact SIW power divider with CSRRs is presented in Figure 1. It is expected that the proposed SIW power divider is workable at the S-band frequency suitable for WLAN application. The design uses a 1.6 mm thick FR4 epoxy dielectric substrate with the relative permittivity (ϵ_r) of 4.3 and the loss tangent (δ) 0.02 for the deployment. On the top side of dielectric substrate, a patch with 2 reversely arranged CSRRs with the dimension of 34.27 mm length and 11.6 mm width is positioned on the middle of dielectric substrate and connected to Port#1 as the input port and Port#2 and Port#3 as the output ports. Whilst the bottom side of dielectric substrate is for the groundplane with the dimension similar to the dielectric substrate of 40 mm length and 30 mm width. On its side of patch, there are 9 via holes with the diameter of 1 mm and the separation of 1.4 mm half-surrounding a circular CSRR and connecting the patch and the groundplane. The diameter of outer CSRR is 9 mm with the width of slot of 1.5 mm, whereas the diameter of inner CSRR is 4 mm with the same slot width of 1.5 mm.

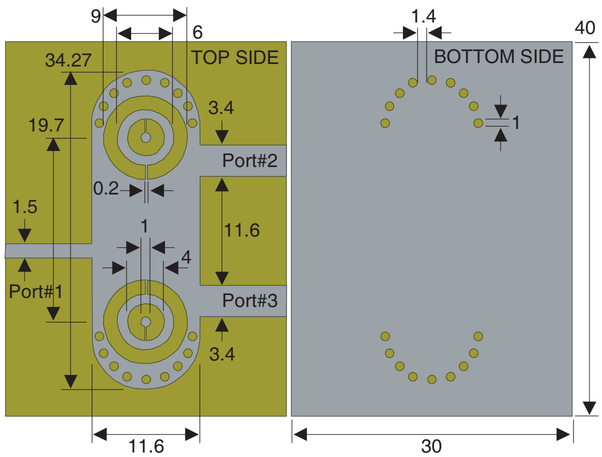

Figure 1: Design of compact SIW power divider with 2 reversely arranged CSRRs (unit in mm).

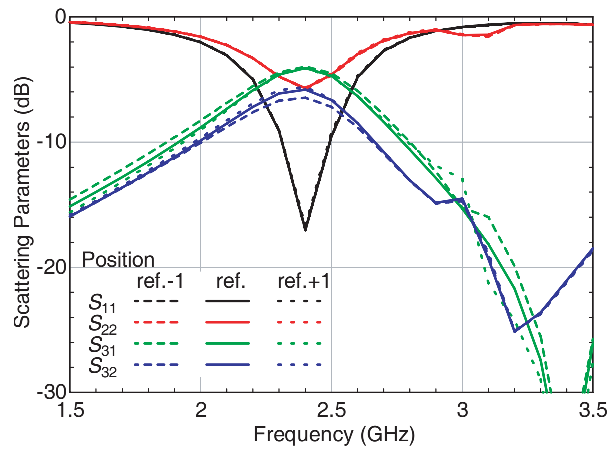

Figure 2: Simulated result of SIW power divider with varied position of Port#1.

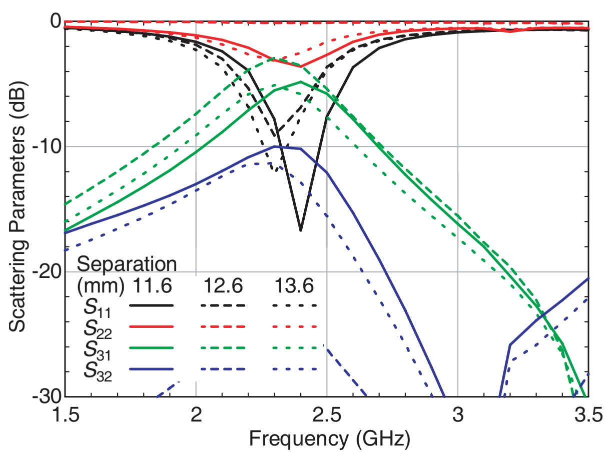

Figure 3: Simulated result of SIW power divider with varied separation between Port#2 and Port#3.

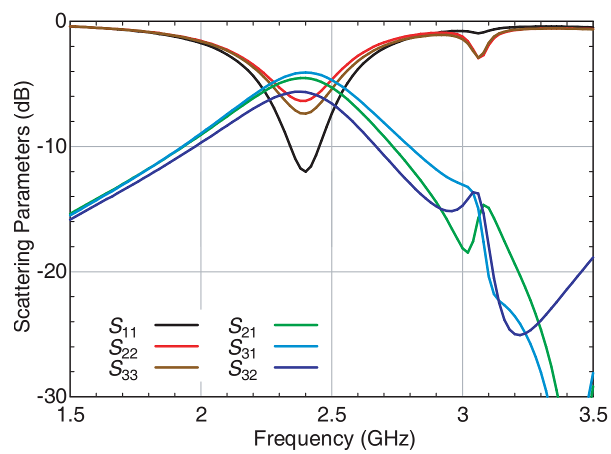

Figure 4: Simulated result of SIW power divider as optimum design for realization.

Prior obtaining the mentioned geometry above, parametric studies upon its physical parameter were extensively performed through simulation. It is noticeable that each part of SIW power divider including the dimension of patch, the width of port, the position and separation between ports, the number and separation of via holes, and the dimension of CSRRs has own impact contributing to the characteristic response indicated in its scattering parameter. Among all physical parameters, the position of Port#1 and the separation between Port#2 and Port#3 has play important things to the characteristic response. Figures 2 and 3 plot the simulated results of proposed SIW power divider for variation of Port#1 position and separation between Port#2 and Port#3, respectively. The results show that the position of Port#1 contributes to the magnitude of scattering parameter, and the separation between Port#2 and Port#3 affects to the frequency shifting of scattering parameter. Meanwhile, Figure 4 depicts the simulated result of proposed SIW power divider with the geometry above as the optimum design to be implemented for the hardware realization. It seems that that the return loss and insertion loss values for Port#1 (S_{11} and S_{21}) at the frequency of 2.4 GHz are 12.001 dB and 4.538 dB, respectively, while the rejection rate at the stopband area, i.e., higher frequency region, achieves more than 20 dB.

3. REALIZATION AND CHARACTERIZATION

Figure 5 shows the prototype of compact SIW power divider with CSRRs realized based on the optimum design. To connect the patch and the ground plane through via holes, a short wire is put in each via hole and soldered both at the patch and the groundplane. Each port is installed a 50 Ω SMA connector for experimental characterization. The measurement setup is carried out using a Vector Network Analyzer to obtain the characteristic responses. During the characterization, unused port of realized SIW power divider is terminated with a 50 Ω load. The measured results in comparison with the simulated ones are plotted in Figure 6.

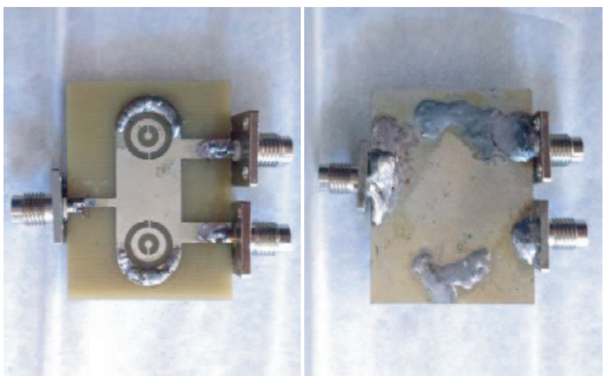

Figure 5: Realized compact SIW power divider with CSRRs; left is top side; right is bottom side.

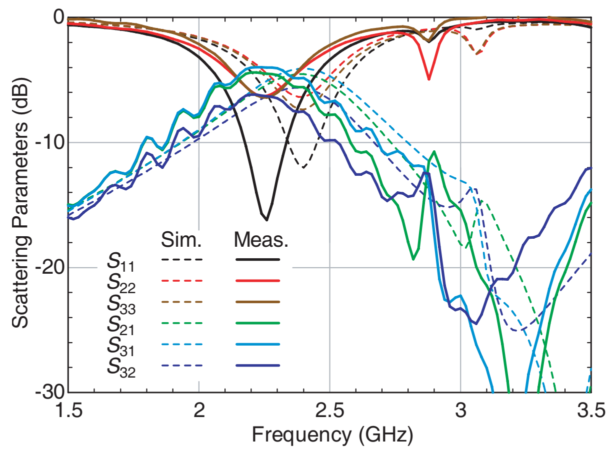

Figure 6: Measured and simulated results of compact SIW power divider with CSRRs.

In general the measured results have same tendency and good agreement qualitatively with the simulated ones. However, there was frequency shifting to the lower frequency region around 140 MHz yielding the working frequency of 2.26 GHz. The measured results of S_{11}, S_{22}, and S_{33} at the frequency of 2.26 GHz were −16.2 dB, −6.281 dB, and −6.415 dB, respectively. This is comparable to the simulated ones which have the values of S_{11}, S_{22}, and S_{33} at the frequency of 2.4 GHz of −12.001 dB, −6.356 dB, and −7.383 dB, respectively. Moreover, the measured S_{21}, S_{31}, and S_{32} at the frequency of 2.26 GHz were −4.493 dB, −3.998 dB, and −6.297 dB, respectively. While the simulated ones were −4.538 dB, −4.087 dB, and −5.661 dB for S_{21}, S_{31}, and S_{32} at the frequency of 2.4 GHz, respectively. The discrepancies between the measured and simulated results indicated by the frequency shifting are probably evoked by the different value of relative permittivity of dielectric substrate in simulation and realization. It shows that the relative permittivity value of dielectric substrate in realization was higher than in the simulation.

4. CONCLUSION

The development of compact SIW power divider with CSRRs for WLAN application has been presented. The proposed SIW power divider has been realized using a 1.6 mm thick FR4 epoxy dielectric substrate with the dimension of 40 mm × 30 mm. It has been found that each part has own contribution to the performance and the characteristic response of SIW power divider. It has also been shown that the combination of CSRRs and SIW method could reduce the required dimension as well as improve the performance of power divider. In spite of discrepancies occurred in the measured characteristics responses, the proposed SIW power divider with CSRRs has shown acceptable performances at S-band frequency. In addition, further investigations to enhance the performance of SIW power divider particularly in woking bandwidth response are currently still in progress where the result will be reported later.

REFERENCES

1. Freeman, J. C., *Fundamentals of Microwave Transmission Lines*, 1st Edition, Wiley-Interscience, 1996.
2. Iniewski, K., *Wireless Technologies: Circuits, Systems, and Devices*, 1st Edition, CRC Press, 2007.
3. Wilkinson, E. J., "An N-way hybrid power divider," *IRE Trans. Microw. Theory Techn.*, Vol. 8, No. 1, 116–118, Jan. 1960.
4. Tang, X. and K. Mouthaan, "Analysis and design of compact twoway Wilkinson power dividers using coupled lines," *Proceedings of Asia Pacific Microwave Conference (APMC)*, 1319–1322, Singapore, Dec. 2009.
5. Pribawa, N. A. and A. Munir, "Wilkinson topology-based 1 : 6 power divider for L-band frequency application," *Proceedings of 7th International Conference on Telecommunication Systems, Services and Applications (TSSA)*, 215–217, Bali, Indonesia, Oct. 2012.
6. Okada, Y., T. Kawai, and A. Enokihara, "Design method of unequal Wilkinson power divider using LC-ladder circuits for multi-way power dividers," *Proceedings of Asia-Pacific Microwave Conference (APMC)*, 1–4, New Delhi, India, Dec. 2016.
7. Munir, A., E. Bharata, and Edwar, "Cohn topology-based 1 : 8 power divider for S-band array antenna feeding network," *Proceedings of International Conference on Control, Electronics, Renewable Energy and Communications (ICCREC)*, 84–87, Yogyakarta, Indonesia, Sep. 2017.
8. Yang, N., C. Caloz, and K. Wu, "Substrate integrated waveguide power divider based on multimode interference imaging," *Proceedings of IEEE MTT-S International Microwave Symposium Digest*, 883–886, Atlanta, USA, Jun. 2008.
9. Kiris, O., V. Akan, M. Gokten, and L. Kuzu, "Three-way substrate integrated waveguide (SIW) power divider design," *Proceedings of IEEE/ACES International Conference on Wireless Information Technology and Systems (ICWITS) and Applied Computational Electromagnetics (ACES)*, 1–2, Honolulu, USA, Mar. 2016.
10. Zhang, Q.-L., W.-Y. Yin, S. He, and L.-S. Wu, "Compact substrate integrated waveguide (SIW) bandpass filter with complementary split-ring resonators (CSRRs)," *IEEE Microw. Wireless Compon. Lett.*, Vol. 20, No. 8, 426–428, Aug. 2010.
11. Danaeian, M., A.-R. Moznebi, K. Afrooz, and H. Hakimi, "Miniaturised equal/unequal SIW power divider with bandpass response loaded by CSRRs," *Electron. Lett.*, Vol. 52, No. 22, 1864–1866, Oct. 2016.
12. Choudhary, D. K. and R. K. Chaudhary, "A compact SIW based filtering power divider with improved selectivity using CSRR," *Proceedings of Progress In Electromagnetics Research Symposium — Fall (PIERS — Fall)*, 1334–1337, Singapore, Nov. 19–22, 2017.