The Millimeter-Wave Low-Loss Suspended Microstrip Power Divider/Combiner Design

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***Abstract*—**Design of a suspended microstrip Wilkinson power divider/combiner is proposed to work at mm-wave regime with very low insertion loss. Numerical and experimental results validate the design method.

Keywords—Mm-wave; Wilkinson power divider/combiner

I. Introduction

The wireless systems for the upcoming fifth generation (5G) cellular network, proposing mesh-like connectivity by using millimeter wave (mm-Wave) spectrum, show promised feature for supporting multi-Gbps throughput due to the available of wide-bandwidth [1]-[2]. This demand is the driving force towards the rapid research and development of the mm-Wave technologies. The newly freed mm-Wave spectrum includes 3.85 GHz of licensed band from 27.5 to 28.25 and 37 to 40 GHz as well as 7 GHz of unlicensed spectrum from 64 to 71 GHz. However, in millimeter wave region, the design of using electromagnetic circuit elements is known as a very tough subject to achieve due to very sensitivity in fabrication requirement and high insertion loss in wave propagation. The sensitivity on fabrication resulting in slight misalignments on parameters in the order of 0.1 millimeter change the characteristic of the circuit element and cause unexpected consequence. This study aims to design a mm-wave Wilkinson power divider/combiner with k-connector interface for 5G millimeter wave applications. The challenges are as follows:

1) For coaxial-to-microstrip launch, fabrication of these structures and fixing the connectors may require very careful handling. The fringing fields over launch region on Panel Launch Coaxial Line feed has capacitive input impedance resulting in distortion of the poor matching performance. Although, there are many techniques [3]-[4] can be used to improve the VSWR performance, they are not practical because of the need of special process and narrow-band design in natural.
2) The conventional Wilkinson circuit must be placed very close to each other, to be connected to the 100 Ω resistor. This layout raises the undesirable mutual coupling between the output arms [5] to introduce the poor isolation.
3) With the considered characteristics of the dielectric substrate and operating frequency, dielectric losses are the major source of loss, and it is significantly larger than radiation and ohmic losses [6]

With employing the suspended microstrip line guided structure, the mm-Wave Wilkinson power divider/combiner design is proposed in this paper to overcome the above-mentioned problems. The numerical and measured results of the proposed design approach will be introduced detail, showing very loss insertion loss (less than 0.5dB) over the frequencies of interest. Finally, a brief conclusion is made

II. Design and Results

Figure 1.a illustrates the proposed design of the mm-Wave Wilkinson power divider/combiner, including (1) the top cover, (2) the Duroid RT5880 substrate ($\varepsilon r = 2.2$; h = 15 mils), and (3) the mechanical base to fix both the PCB substrate and k connectors.

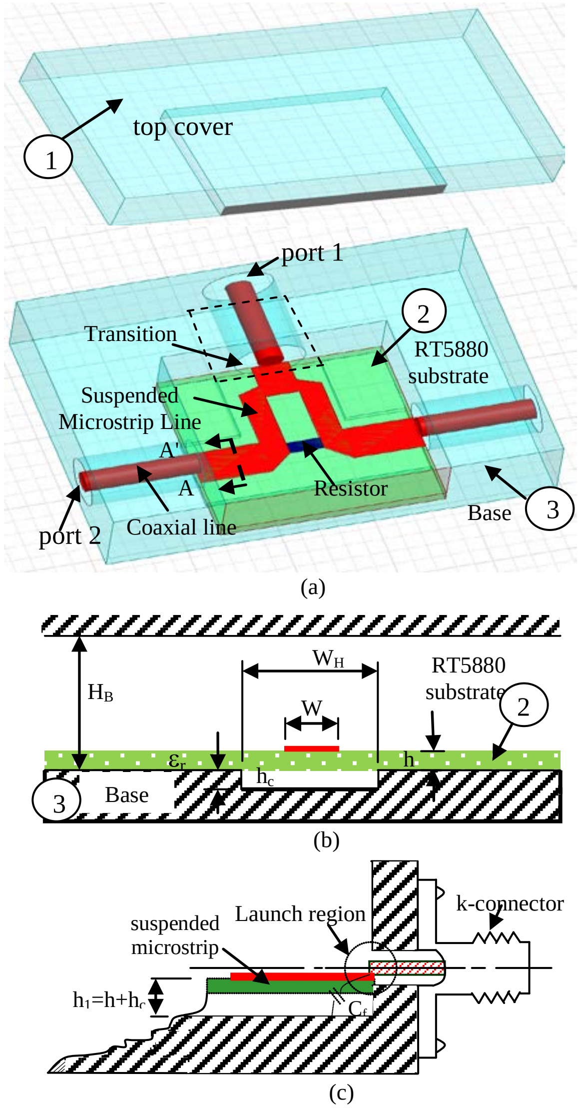


Fig.1 (a)The layout of the mm-Wave Wilkinson power divider/combiner design.; (b) A-A' cross-sectional view of (a); the guided structure of the suspended microstrip line; (c) The cross-section view of the panel launch coaxial line feed.

In fig. 1.a, the A-A' cross-sectional view of the guided structure used in the printed Wilkinson power divider/combiner design is the suspended microstrip line as shown in Fig. 1.b, in which the microstrip line printed on Duroid RT5880 substrate along with a slot onto the mechanic base is presented in this design. The width of microstrip line is W. The width and thickness of the cavity slot are W_H and hc, respectively. Consequently, the thickness is increased from h to h_1 (h_1=h+hc) and the effective dielectric constant would be decreased by incorporating air cavity beneath the mcirostrip line. Fig. 2 plots the numerical results by using *Ansoft HFSS* simulator, showing the insertion loss less than 0.5 dB and return loss better than 10 dB over the frequencies of interest.

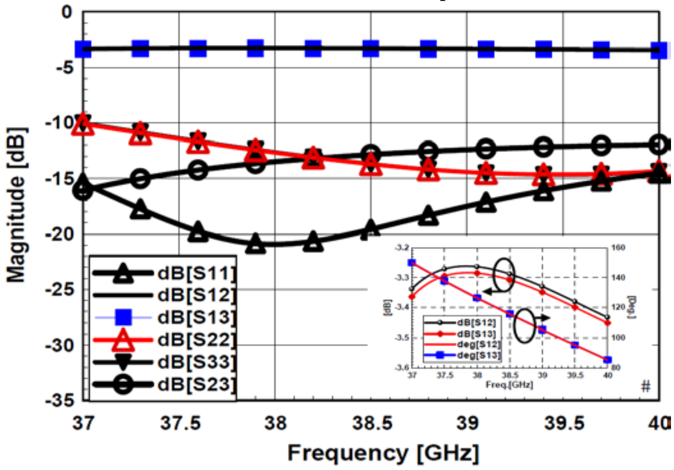
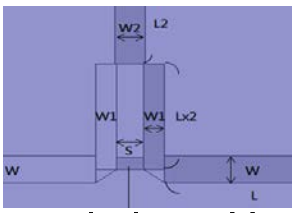


Fig. 2 The simulated results using *Ansoft HFSS EM Simulator; h=0.381 mm;* h_c*=0.2mm;* W_H*=2.4mm;and* H_B*=10mm.*

The photos of the experimental study are plotted in Fig3. Two-port S-parameters were measured using the Rohde & Schwarz ZVA40 vector network analyzer. The measured results are depicted in fig. 4, showing the magnitude of the S_{21}/S_{31} is about -3.3/-3.2 dB and the isolation (S_{23}) is better than 10 dB over the frequencies region from 37.5 to 40 GHz. The performance of the input impedance illustrated by the magnitude of the $S_{11}/S_{22}/S_{33}$ in dB are slightly higher the -10 dB which can be attributed by the manufacture and soldering tolerance when assembling all parts together.



Dimension	Size
W2	0.45mm
W1	0.3mm
W	0.45mm
Lx2	1.8mm
S	0.4mm
L2	1.3mm
L	2.28mm

Fig. 3 The photos and dimensions of the experimental study.

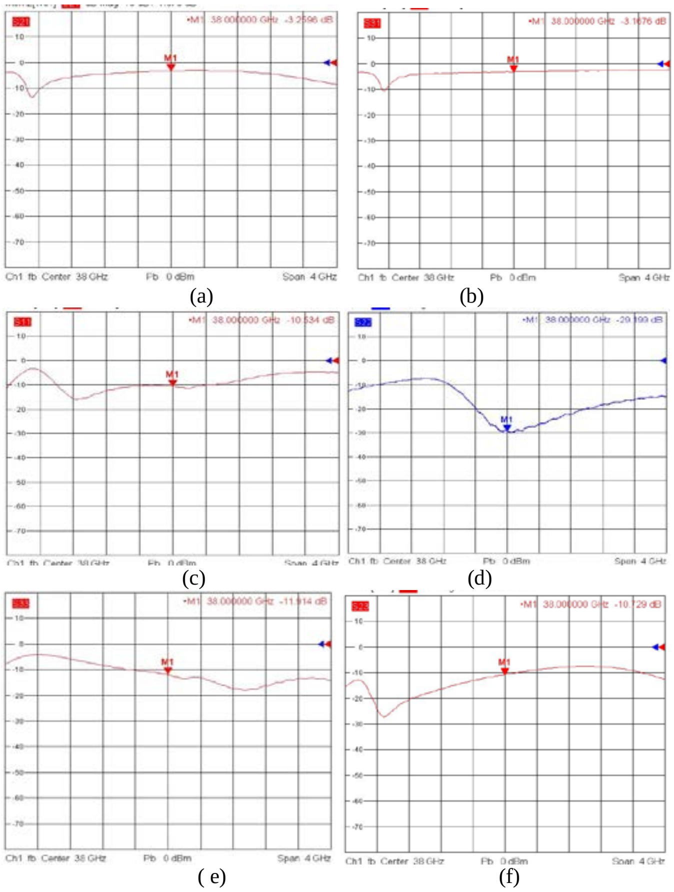


Fig. 4 The simulated results of the experimental study (Fig. 3);Measured magnitude of (a)S_{21}; (b) S_{31}; S_{11}; (d) S_{22}; (e S_{33}; (f) S_{23} in dB.

III. Conclusion

The first-pass design of the suspended microstrip Wilkinson power divider/combiner is validated numerically and experimentally to show that capability of showing very low insertion at mm-wave regime.

References

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