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NOVEL MINIATURIZED WILKINSON POWER DIVIDER FOR 3G MOBILE RECEIVERS

S. Shamsinejad, M. Soleimani, and N. Komjani

Electrical Engineering Department
Iran University of Science and Technology (IUST)
Tehran, Iran

Abstract—This paper reports the miniaturization of a microstrip Wilkinson power divider by substituting the quarter wave transmission lines employed in conventional Wilkinson power dividers with its equal circuit consisting of two stubs and an inductor. Reduction of the device length to 53% its size are reported here. This Wilkinson power divider is designed at 2140 MHz for using in 3G-UMTS receivers. Furthermore, the second harmonic suppression is realized in this configuration and its frequency response is similar to low pass filters because of inductor. Also, the dividing procedure, the reflection coefficient and the isolation are as good as conventional Wilkinson.

1. INTRODUCTION

Power Dividers and combiners play an important role in the design of microwave circuits and their applications are various. So far, quite a lot of power divider/combiner structures with equal or unequal power division have been proposed. In almost all those structures, quarter wavelength long transmission lines are used as the basic building section resulting in a significant circuit size. Consequently, continuous efforts were carried on to reduce the device size while keeping the original performances often by using capacitors [l–4]. Wilkinson power dividers are indispensable components of microwave amplifier and antenna distribution circuits; however conventional power dividers are quite large, especially at C-band where the quarter-wave transmission lines can be several millimeters long [5].

To reduce the size of passive 3 dB microstrip Wilkinson power divider, capacitor version was already proposed, but we require a power divider with extreme loss in higher frequencies especially at second 3G downlink harmonics [6]. In this paper, we use an inductor and two stubs instead of transmission lines, so low pass characteristics are achieved and the Wilkinson power divider is miniaturized by this method.

To fully illustrate this approach, the characteristics of new miniaturized Wilkinson power divider are presented and its dimensions are compared to the conventional one. The characteristics include the calculated reflection and isolation coefficients and insertion loss. Furthermore, the new miniaturized Wilkinson suppresses the second harmonics of downlink frequency band in 3G systems. The downlink center frequency in 3G systems is equal to 2140 MHz which the Wilkinson is designed at it. Therefore, second harmonics around 4280 MHz are suppressed.

2. NOVEL MINIATURIZED WILKINSON POWER DIVIDER DESIGN

In order to reduce the size of the Wilkinson power divider, we use equivalent circuit shown in Figure 1 instead of conventional Wilkinson branches (by ABCD matrix equalizing) [5]. The circuit consists of two stubs, one inductor and the transmission lines between them.

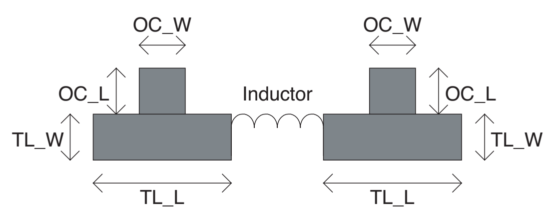

Figure 1. Equivalent circuit for branches of conventional Wilkinson.

This structure must be optimized to equalize the S parameter matrices of the conventional branch and the circuit shown in Figure 1. We use ADS software for optimization purposes. After optimization, final values for the dimensions of the corresponding parts and the part number and the inductance of the inductor are represented in Table 1. The RO3210 is used as substrate.

Now we substitute old branches with new one and achieve the miniaturized Wilkinson power divider shown in Figure 2. Furthermore, conventional Wilkinson power divider includes one resistant placed between its output ports with resistance of $2 \times Z_0 = 100\,\Omega$ ($Z_0 = 50\,\Omega$). The $100\,\Omega$ resistant remains in the previous place [5].

Table 1. Dimensions of novel equivalent circuit shown in Figure 1.

<table>
<tr><th>Parts</th><th>Dimension</th><th>On Figure 1</th><th>Value</th></tr>
<tr><td rowspan="2">Open circuited Stubs</td><td>Length</td><td>OC_L</td><td>1 mm</td></tr>
<tr><td>Width</td><td>OC_W</td><td>1 mm</td></tr>
<tr><td rowspan="2">Transmission Lines</td><td>Length</td><td>TL_L</td><td>3 mm</td></tr>
<tr><td>Width</td><td>TL_W</td><td>0.8 mm</td></tr>
<tr><td rowspan="2">Inductor</td><td rowspan="2">Inductance</td><td>Part Number</td><td rowspan="2">3.9 nH</td></tr>
<tr><td>AVX L08053R9DEW</td></tr>
</table>

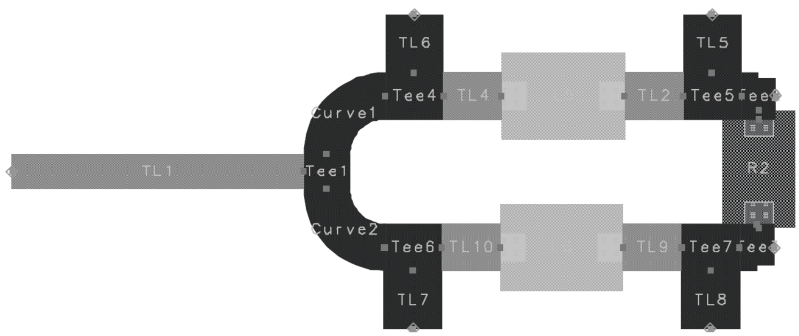

Figure 2. Layout of novel miniaturized Wilkinson power divider.

3. MINIATURIZED WILKINSON POWER DIVIDER ANALYSIS

Now, the Wilkinson is analyzed by ADS in order to calculate its S parameters at 3G downlink frequency band. They are depicted in Figure 3–Figure 7 vs frequency.

3.1. Isolation Factor

If we assign the input to port 1 and outputs to ports 2 and 3, then S_{23} and S_{32} is the isolation factor with the same values due to the symmetry. The isolation factor vs frequency is depicted in Figure 3 at 3G downlink frequency band. The isolation equal to -20.2 dB at the center frequency of 2140 MHz has been reported.

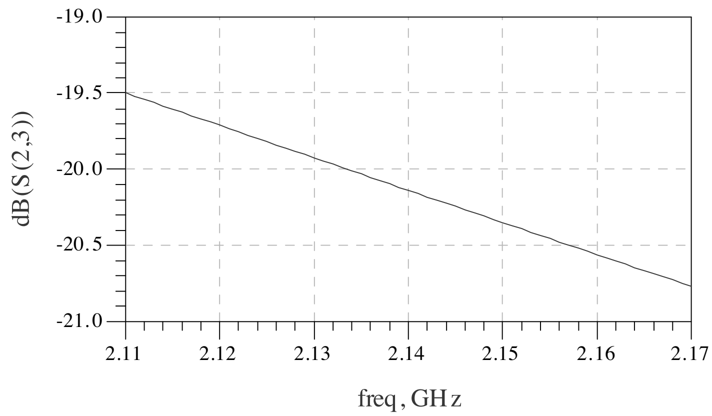

Figure 3. Isolation factor.

3.2. Reflection Coefficient

Corresponding to the previous port assigning, the reflection coefficients are S_{11} (for the input), S_{22} and S_{33} (for the output with the same values due to symmetry). The output and the input reflection coefficients at 3G downlink frequency band are depicted in Figure 4 and Figure 5, respectively. Reflection equal to $-18.45\,\text{dB}$ for the input port and $-28.75\,\text{dB}$ for the output port at the center frequency of 2140 MHz has been reported.

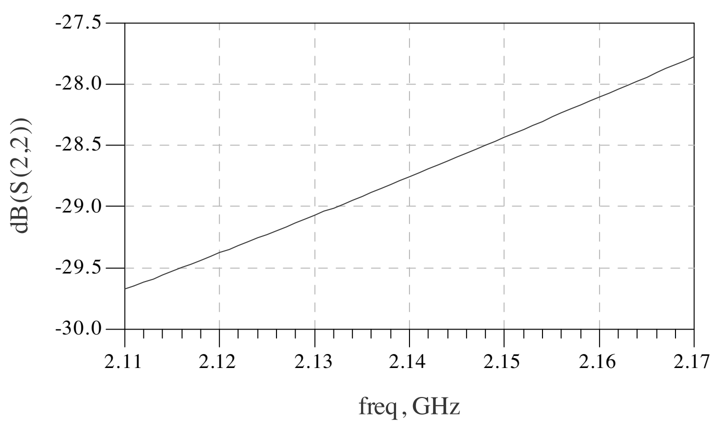

Figure 4. Output reflection coefficient.

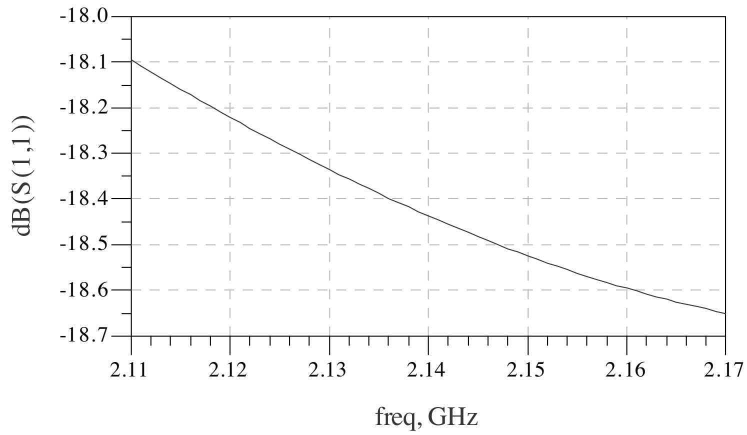

Figure 5. Input reflection coefficient.

3.3. Coupling Factor

Corresponding to the previous port assigning, coupling factors are S_{21} and S_{31} with the same values due to the symmetry. The coupling factor is depicted at 3G downlink frequency band and wide frequency band in Figure 6 and Figure 7, respectively. The coupling factor equal to -3.2954 dB at the center frequency of 2140 MHz has been reported. This value is approximately constant at the desired band, but it is considerably reduced at higher frequencies. It is equal to -17.5 dB

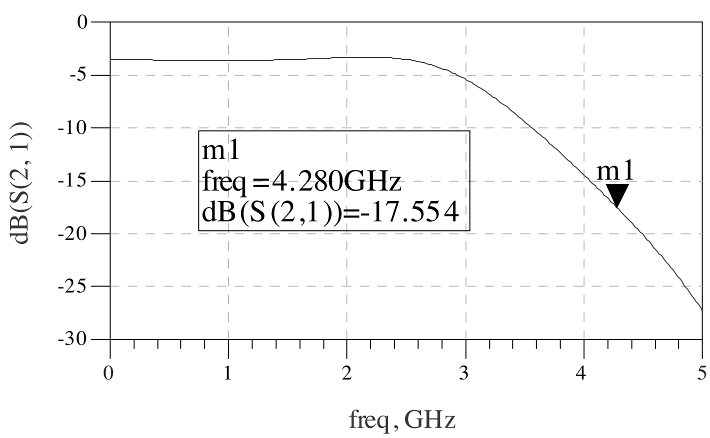

Figure 6. Coupling factor at wide frequency band.

at the second harmonic frequency of 4280 MHz which means that the novel Wilkinson power divider suppresses any signal at all frequencies equal and higher than this. But the coupling factor is approximately constant at lower frequency.

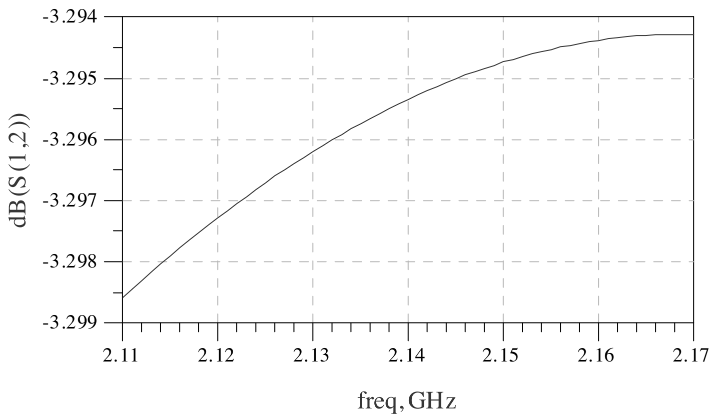

Figure 7. Coupling factor at desired frequency bandwidth.

Therefore, the frequency response of novel Wilkinson is similar to the lowpass filters. This feature makes novel Wilkinson suitable and applicable in receivers integrated GSM and 3G mobile systems.

4. DIMENSIONS COMPARISON

Size reduction at low microwave frequencies has been the main purpose of the novel Wilkinson power divider design. The purpose has been achieved and the comparison between the novel Wilkinson and the conventional one is represented in Table 2. Furthermore, the actual size layout of the novel miniaturized Wilkinson power divider is depicted in Figure 8.

Table 2. Dimensions comparison.

	Conventional	Miniaturized
Length	15.6 mm	8.4 mm
Width	3.2 mm	5.4 mm

The RF input signal must be divided between inphase and quadrature mixers in receivers based on the direct conversion configuration. These mixers are positioned at up and down places; therefore, length reduction of the divider is more important than width reduction due to the available space between the two mixers. Small width dividers are not suitable, while small length dividers are the most effective in circuit size reduction. In order to clarify this concept, the novel Wilkinson application in a 3G direct conversion receiver is shown in Figure 9.

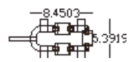

Figure 8. Actual size layout of novel miniaturized Wilkinson.

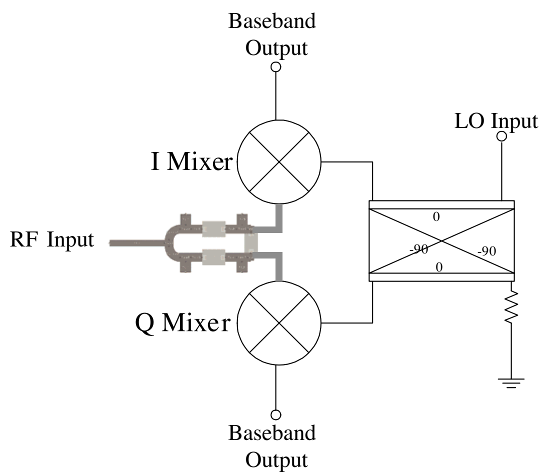

Figure 9. Application of the novel Wilkinson power divider in 3G direct conversion receiver.

5. APPLICATION OF NOVEL WILKINSON IN 3G UMTS MOBILE RECEIVERS

The 3G-UMTS downlink frequency band is expanded from 2110 MHz to 2170 MHz with a center frequency of 2140 MHz, so the novel miniaturized Wilkinson power divider has been designed for this frequency band.

The RF input signal in 3G receivers must be divided between inphase and quadrature mixers. This procedure requires a miniaturized power divider at the above mentioned frequency band.

The novel Wilkinson complies with the 3G requirements and suppresses second harmonics of the 3G downlink frequency around 4280 MHz.

The novel Wilkinson is suitable and applicable in the receivers integrating GSM and 3G technology due to perfect performance at 900 MHz.

6. CONCLUSION

A Novel Miniaturized Wilkinson power divider at 2140 MHz has been developed. Reduction of the device length to 53% its size has been achieved.

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