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NOVEL ENHANCED AND MINIATURIZED 90° COUPLER FOR 3 G EH MIXERS

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Abstract—This paper reports the miniaturization of a microstrip 90 degree coupler by substituting the quarter wave transmission lines employed in conventional 90 degree coupler with its equal circuits consisting of two oblique stubs and an inductor and capacitors. Reduction of the coupler to 27% its size is reported here. This coupler is designed at 1070 MHz for using in even harmonic mixers of 3 G mobile receivers. Furthermore, the coupler can accurately divide the input signal by two parts with the same power and 90 degree phase difference. Also, the reflection coefficient and the isolation are as good as conventional one and coupling procedure is better than it.

1. INTRODUCTION

Couplers play an important role in the design of microwave circuits and their applications are various. So far, quite a lot of Coupler structures with equal or unequal power division with 90 or 180 degree phase difference 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 [1]. Consequently, continuous efforts were carried on to reduce the device size while increasing the original performances [2–9].

To reduce the size of passive 90° coupler, lumped element version was already proposed but suffers from very narrow-band characteristics and high frequency disability.

90° couplers [1] are indispensable components of microwave amplifier. However, conventional couplers are quite large especially below X-band where the quarter-wave transmission lines can be several millimeters long.

Novel coupler can exactly divide the input signal by two parts have 90° phase difference and the same power. The coupler employs inductors, capacitors and stubs instead of long transmission lines for miniaturizing and enhancing.

To fully illustrate this approach, the characteristics of new miniaturized 90° coupler are presented and its dimensions are compared to the conventional one. The characteristics include the reflection, the coupling and the isolation coefficients. Moreover, the new miniaturized coupler is designed at frequency of 1070 MHz which is half of the downlink center frequency of 3 G-UMTS systems (2140 MHz) [10]. Therefore, the coupler shown in Figure 3, can be used as a splitter for the local oscillator output signal used in 3 G even harmonic mixers. In these structures, the LO operates at 1070 MHz and the output signal must be equally divided between I and Q mixers with 90 degrees phase difference.

2. NOVEL ENHANCED AND MINIATURIZED 90 DEGREE COUPLER DESIGN

In order to reduce the size of 90° branch line coupler, we used the equivalent circuit shown in Figure 1 instead of the vertical branches of the conventional coupler and another one shown in Figure 2 instead of its horizontal transmission lines (by ABCD matrix equalizing) [1]. First circuit consists of two capacitors and one inductor and second one consists of two oblique open circuited stubs and related transmission line.

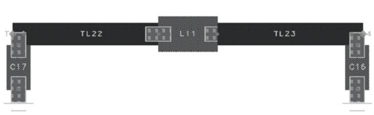

Figure 1. Equivalent circuit for vertical branches.

Figure 2. Equivalent circuit for horizontal transmission lines.

This structure must be optimized to equalize the S parameter matrices of the conventional coupler parts and the circuits shown in Figure 1 and Figure 2. We used ADS software for optimization purposes. After optimization, final values for the length and the width of the corresponding parts and lamped elements are resulted and described in Table 1. The RO3210 is used as substrate.

Now we substitute old lines with new one and achieve the miniaturized 90° coupler shown in Figure 3. Inductors and capacitors part numbers are as following:

Inductor Part Number = NLU201205T-3N0C 3.017 nH
Capacitor Part Number = 06035J4R7AAW 4.7 pF

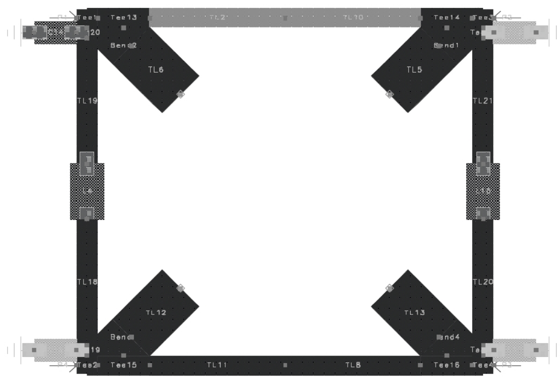

Figure 3. Novel enhanced and miniaturized coupler layout.

Table 1. Values of the novel coupler parts.

Parts	Value
Oblique stubs	Length = 2.544 mm Width = 1.906 mm
Horizontal transmission lines	Length = 13.748 mm Width = 0.700 mm
Vertical transmission lines (between capacitor and inductor)	Length = 5.014 mm Width = 0.768 mm
Inductor	Inductance = 3.017 nH
Capacitor	Capacitance = 4.7 pF

3. THE COUPLER ANALYSIS

Now the coupler is analyzed by ADS in order to calculate its S parameters at the frequency band used in 3 G receiver EH mixers [10].

3.1. Isolation Factor

If we assign inputs to ports 1 and 4 and outputs to ports 2 and 3, then S_{14}, S_{41}, S_{23} and S_{32} are isolation factors with the same values due to the symmetry and the reciprocity characteristics. The isolation factor vs frequency is depicted in Figure 4 at frequency band of 1055 MHz $\sim$ 1085 MHz in order to comply with the local oscillator frequency used in 3 G even harmonic mixer. Isolation equal to -24.2 dB at center frequency of 1070 MHz has been reported.

3.2. Reflection Coefficient

Corresponding to previous port assigning, S_{11}, S_{22}, S_{33} and S_{44} are coupler reflection coefficients with the same value due to the symmetry and the reciprocity characteristics. The reflection factors depicted in Figure 5 at the frequency band of 1055 MHz $\sim$ 1085 MHz in order to comply with the local oscillator frequency used in 3 G even harmonic mixer. Reflection equal to -20.7 dB at center frequency of 1070 MHz has been reported.

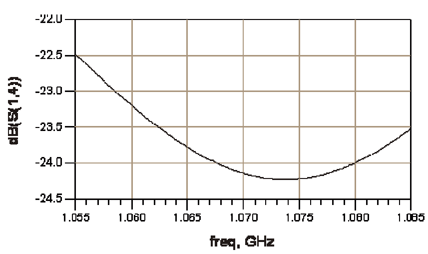

Figure 4. Isolation factor.

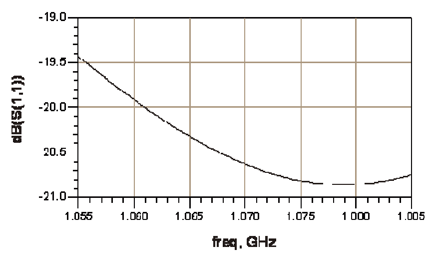

Figure 5. Reflection coefficient.

3.3. Coupling Factor

Corresponding to the previous port assigning, S_{21} and S_{31} are coupling factors with 90° phase difference and equivalent magnitudes for ideal couplers, but their magnitudes is slightly unequal in actual couplers.

Coupling factors are exactly equivalent for the novel coupler which means that the coupler equally divides the input signal. The magnitude and the phase of the coupling factors at desired bandwidth are depicted in Figures 6 and 7 and Figures 8 and 9, respectively. The magnitude of the coupling factor equal to -3.315 dB at center frequency of 1070 MHz has been reported; as it can be seen, this value is approximately constant in the desired frequency band.

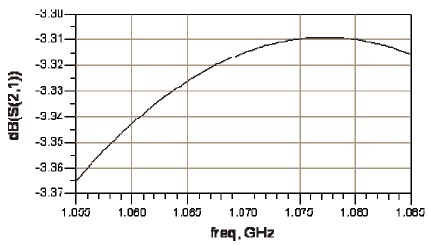

Figure 6. Port 2, coupling factor.

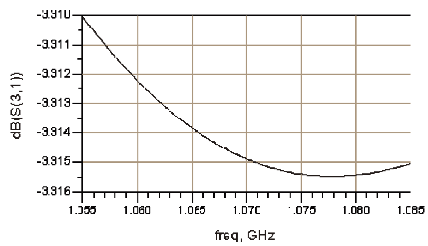

Figure 7. Port 3, coupling factor.

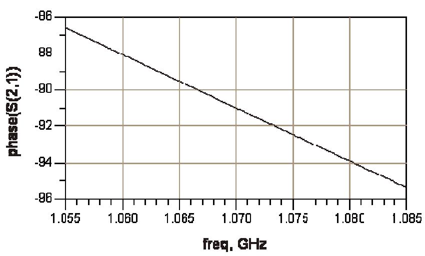

Figure 8. Port2, phase of coupling factor.

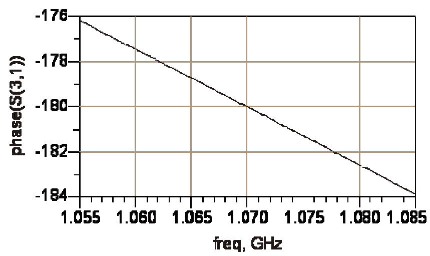

Figure 9. Port3, phase of coupling factor.

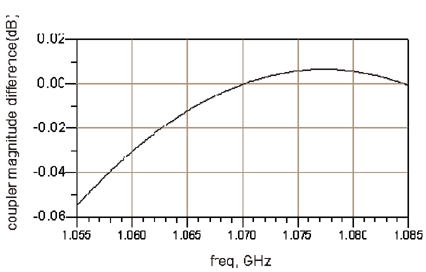

Figure 10. Power difference between port 2 and 3.

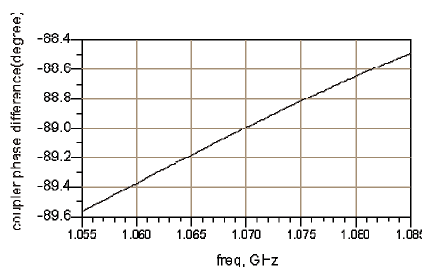

Figure 11. Phase difference between port 2 and 3.

One of the most important challenges in the coupler design is equal power dividing and accurate phase difference. The magnitude difference of the coupler output ports is depicted in Figure 10 at desired frequency band. As it can be seen, the difference is equal to 0 dB at center frequency of 1070 MHz and changes slightly at this frequency bandwidth. Therefore, the novel coupler exactly divides the signal because the value is approximately constant at the local oscillator frequency bandwidth.

The phase difference of the coupler output ports is depicted in Figure 11 at desired frequency band. As it can be seen, the value is approximately equal to 90° at center frequency of 1070 MHz and changes slightly at the frequency bandwidth. This phase difference is accepted for all of the mixers used in receivers and 1° error is negligible.

The novel coupler phase difference is as good as the conventional Branchline couplers and its power dividing is better. Moreover, the coupler size is very small compared to the conventional one and is suitable for using at frequency of 1070 MHz with the 30 MHz bandwidth.

4. DIMENSIONS COMPARISON

One of the most important purposes at the novel coupler design was the miniaturization. The conventional Branchline couplers have large dimensions at low microwave frequency. Table 2 represents the novel coupler dimensions in comparison with the conventional one and Figure 12 shows actual size layout of the novel coupler. This layout is depicted using AutoCAD software for implementation on RO3210 as substrate.

Table 2. Dimension comparison.

	Conventional	Miniaturized
Length	26.996 mm	15.286 mm
Width	28.363 mm	13.407 mm

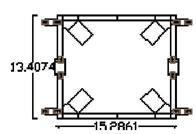

Figure 12. Actual size layout of the novel coupler.

5. APPLICATION OF NOVEL COUPLER IN DIRECT CONVERSION 3G UMTS RECEIVERS TOGETHER WITH THE EVEN HARMONIC MIXERS

Most of the 3 G mobile receivers are based on Direct conversion configuration and some of them employ even harmonic (EH) mixers to conquer on Direct conversion problems.

In EH mixers, the local oscillator operates at half of the RF input frequency, so its output frequency is 1055 MHz to 1085 MHz (which its center frequency is 1070 MHz) in the 3G receivers. (The downlink frequency is 2110 MHz to 2170 MHz with center frequency of 2140 MHz).

The LO output signal must be divided by two parts which have −90 degrees phase difference for Inphase and quadrature mixers. Therefore, we need a 90 degrees coupler which can accurately split LO power with 90° phase difference.

Small novel coupler is designed to be used together with 3 G EH mixers and has satisfactory characteristics at half of the 3 G downlink frequency.

6. CONCLUSION

A novel enhanced miniaturized coupler at 1070 MHz has been developed. A size reducing about 27% and accurate coupling has been achieved.

ACKNOWLEDGMENT

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