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Broadband Double Balanced Diode Mixer Using a Marchand Balun With Vertical Coupling Structure

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Abstract

In this paper, a broadband double balanced mixer is presented using a wideband Marchand balun implementation by vertical coupler. Frequency is selected as 1.0 ~ 3.7 GHz for RF, 1.14 ~ 3.84 GHz for LO, and 140 MHz for IF signals. When LO signal with 7 dBm at 2.64 GHz is injected, a conversion loss of 7.5 dB and RF to LO isolation of -45 dB are obtained. Also, an average conversion loss of 9 dB and RF to LO isolation of -25 dB are obtained for frequency band of 1.0 ~ 3.7 GHz.

key Words : broadband mixer, wideband Marchand balun, vertical coupler.

I. Introduction

In wireless communication systems, a mixer is one of the most important system components and it has been developed for broadband performance using hybrid. However, hybrid circuit can hardly be realized with broadband performance in conventional microstrip line structure [1, 2].

Balun is a mean to transform the symmetric signals into asymmetric ones, and vice versa, which are generally used in an amplifier and mixer. The conventional Marchand balun inherently has a narrow bandwidth [3]. Although the need for wide bandwidth increases considerably, the even-mode impedance required for the coupled section would be too large to be realized with microstrip circuits.

However, in this paper, a wideband Marchand balun is suggested such that $\lambda/4$ short parallel coupled line section is replaced by $\lambda/4$ short vertical coupled line section to overcome the limitation of implementation of microstrip circuits. Also, a broadband diode mixer is designed using this Marchand balun and discussed for its microwave characteristics.

II. A Broadband Marchand Balun and Double Balanced Mixer

For conventional parallel coupled line, a coupling coefficient (k) consists of mutual capacitance (C_m) and self capacitance (C_a) which is

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given by

$$k = \frac{C_m}{(C_m + C_a)} \tag{1}$$

Also, for a parallel plate, capacitance (C) is well known as $C = \varepsilon A / d$, where ε is a dielectric constant for the substrate, A is overlapped area for the parallel plate, and d is the distance between the plate. In this case, C corresponds to C_m in Eq. (1). From this equation, gap size of the conventional parallel coupled line can be determined [4].

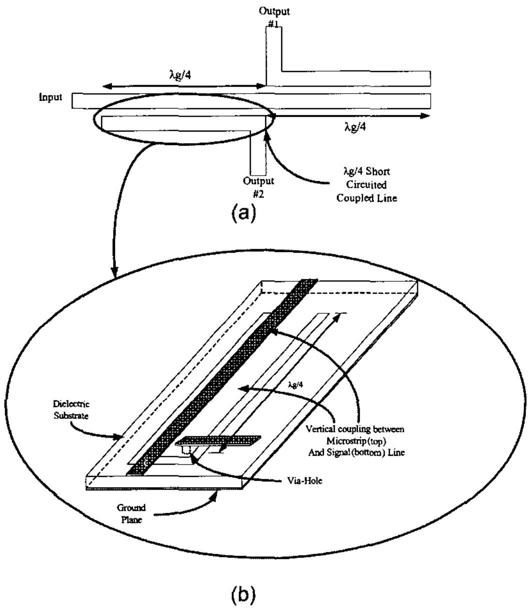
As stated above, the even-mode impedance of $\lambda/4$ parallel short coupled line is too high and the coupled line can hardly be realized, if one wants to get a 3 dB coupler as shown in <Fig. 1(a)>.

In this paper, a new design for realizing very high even-mode impedance in $\lambda/4$ short coupled line in <Fig. 1(a)> is suggested using vertical coupling structure as shown in <Fig. 1(b)>. This structure maintains a microstrip characteristic and shows broadband response. The Marchand balun suggested in this paper is designed with EM simulation tool, HFSS (ver. 9.2.1).

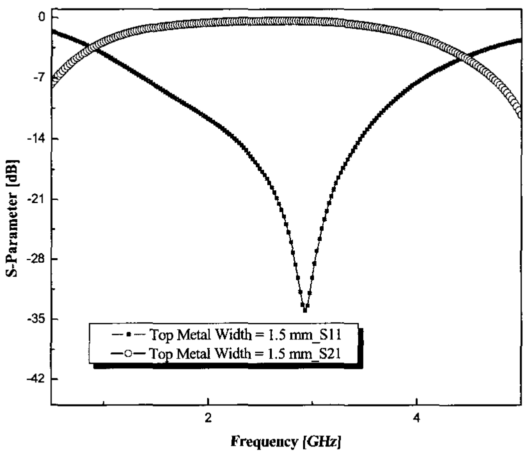
<Fig. 2> shows the simulation results for the vertical coupling structure. From the results, the bandwidth is better than 107 % with 49.3 Ω impedance of top metal.

<Fig. 3(a)> shows the measurement results of insertion loss and return loss characteristics for the Marchand balun. <Fig. 3(b)> illustrates the measurement results of phase difference and magnitude difference for the broadband Marchand balun between two output ports, which are 3 dB ± 0.5 dB and 180°±2° respectively with 115 % bandwidth.

A double balanced mixer is composed of two single balanced mixer coupled in parallel and 180° out of phase [5]. The diodes are arranged in a star configuration. The star modulator is the more commonly used configuration in practical mixer. So, the double balanced mixer uses two baluns rather than one as in the single balanced mixer. The merits of a double balanced mixer include



<Fig. 1> (a) General planar Marchand balun and (b) Vertical coupling structure of Marchand balun



<Fig. 2> Simulation results for the vertical coupling structure

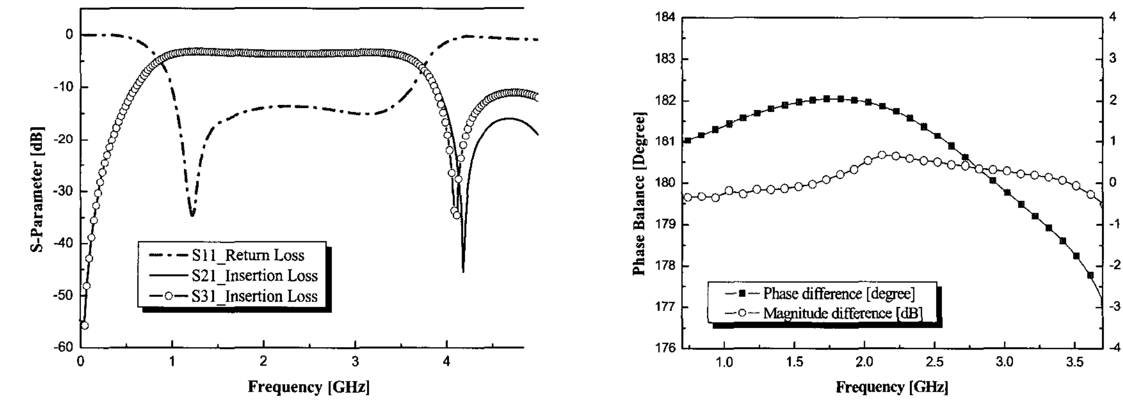
high dynamic range, good port-to-port isolation, and rejection of even-order spurious responses [6].

RF band for the mixer is selected for 1 GHz ~ 3.7 GHz, the LO band is from 1.14 GHz to 3.84 GHz and IF frequency range is consequently determined to be 140 MHz. Four HSMS-8101 Schottky diodes from Agilent are used for the nonlinear devices. The Agilent ADS (ver. 2005A) is used for the simulation tool.

III. Experimental Results

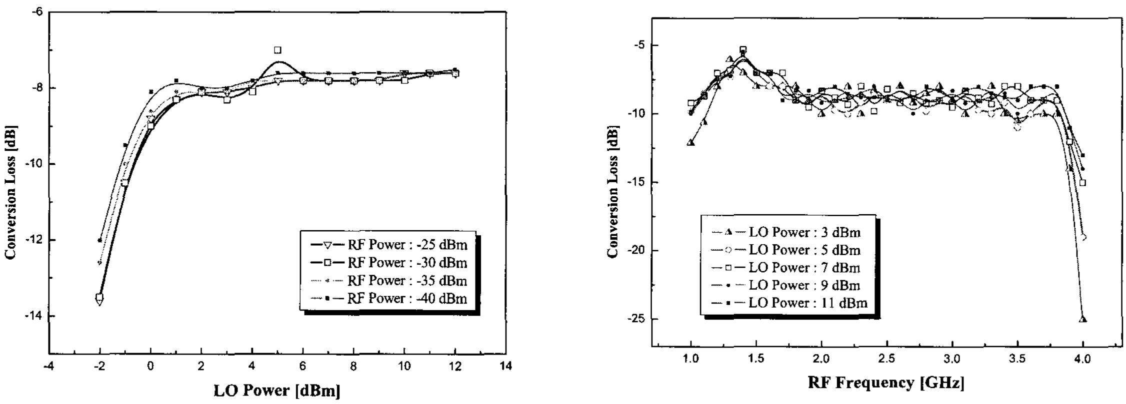
<Fig 4(a)> shows the measurement results that the conversion loss versus LO power with variable RF power. One of the important characteristics for the mixer is the conversion loss, which is defined as the loss of the RF signal power when it is converted to the IF frequency. The LO and RF frequencies are 2.5 GHz and 2.64 GHz, respectively. The RF and LO power are varied from -40 dBm to -25 dBm and from -3 dBm to 14 dBm, respectively. The conversion loss decreases with LO power and becomes saturated at approximately 7 dB above an LO power greater than 2 dBm.

<Fig. 4(b)> shows the measurement results for the conversion loss versus frequency band from 1



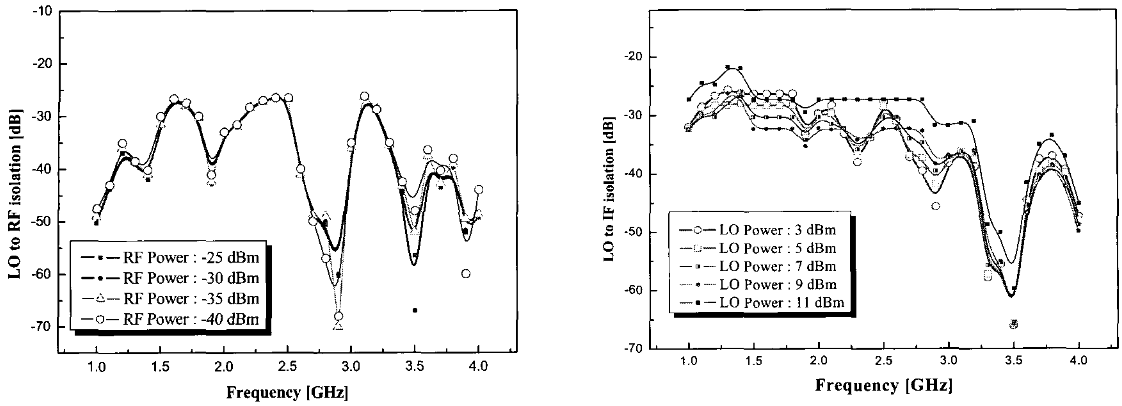
(a) (b)

<Fig. 3> Measurement results for the broadband Marchand balun (a) S-parameter (b) Balanced parameter



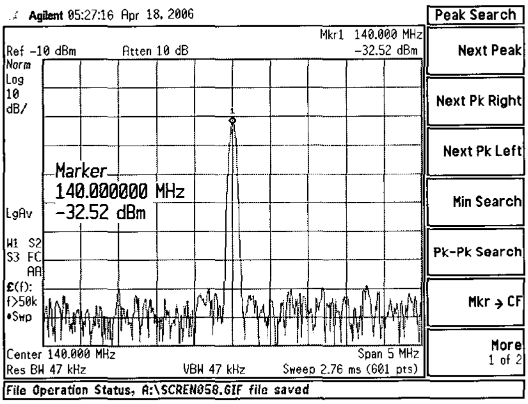
(a) (b)

<Fig. 4> (a) Conversion loss vs. LO power for several RF powers (b) Conversion loss vs. operation bandwidth for several LO power levels



(a) (b)

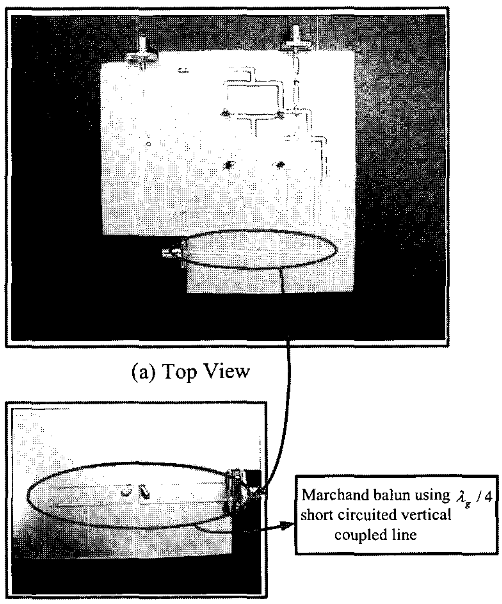
<Fig. 5> (a) LO to RF isolation vs. frequency for several RF power levels (b) LO to IF isolation vs. frequency for several LO power levels



<Fig. 6> Spectrum for IF output power

GHz to 3.7 GHz with variable LO power. The best and worst conversion loss are about 7 dB and 11 dB, respectively and average conversion loss is 9 dB. Increase in conversion loss is caused by the magnitude and phase difference within the band.

The isolation performance indicates the signal leakage from port to port in the mixer. <Fig. 5(a)> shows the LO to RF isolation versus frequency with variable RF power. From the measurement results, the LO to RF isolation is better than -25 dB with broadband frequency range of 1 GHz~3.7 GHz with variable RF power. Also, the



(a) Top View

(b) Bottom View

<Fig. 7> Photograph of the broadband Marchand balun mixer (a) Top view and (b) Bottom view

LO to IF isolation is good enough with broadband frequency range of 1 GHz ~3.7 GHz with several LO power levels as shown in <Fig. 5(b)>.

<Fig. 6> shows the spectrum at the IF port. From the result, the conversion loss of the mixer

is measured to be 7.5 dB for the RF power of -25 dBm at 2.5 GHz and the LO power of 7 dBm at 2.64 GHz.

<Fig. 7> shows the photograph of the broadband double balanced mixer which is fabricated on Teflon substrate with the dielectric constant of 2.6 and the thickness of 0.018mm.

IV. Conclusions

In this paper, the broadband double balanced diode mixer using wideband Marchand balun implemented by vertical coupling has been demonstrated successfully. The broadband double balanced mixer has been successfully implemented on the conventional microstrip structure and discussed for its superior characteristics. The Marchand balun shows the phase and magnitude characteristics of 180° ± 2° and 3 dB ± 0.5 dB for 1 GHz~3.7 GHz, respectively. When LO signal with the power of 7 dBm at 2.64 GHz is injected a conversion loss of 7.5 dB at 2.64 GHz is obtained. Also, RF to LO isolation of -25 dB is obtained for frequency band of 1 GHz~3.7 GHz.

The broadband double balanced mixer provides the possibility of usage in broadband wireless communication system.

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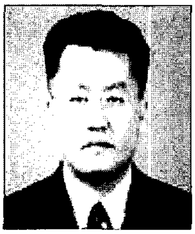

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