Design of Ultra Wide-Band Single Balanced Schottky Diode Mixer

M. Y. Algumaei, N. A. Shairi, Z. Zakaria and I. M. Ibrahim
Centre for Telecommunication Research and Innovation (CeTRI),
Fakulti Kejuruteraan Elektronik dan Kejuruteraan Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM), Melaka, Malaysia
noorazwan@utem.edu.my

***Abstract*— In this paper, an ultra wide-band single balanced diode mixer based on multi-section coupled line balun is presented. It is important in applications such as microwave imaging, military and civilian radars, wireless communication and microwave instrumentation. The proposed mixer is simulated in ADS software with Local Oscillator (LO) power level ranges from 3 to 17 dBm, a fixed Radio Frequency (RF) power level of -10 dBm and an Intermediate Frequency (IF) input frequency of 100 MHz. The simulated results showed that the conversion loss is greater than -15 dB for RF frequency from 3 to 10 GHz.**

***Index Terms*— About; Conversion Loss; Coupled-line Balun; Intermediate Frequency; Local Oscillator; Radio Frequency; Schottky diode; Single Mixer; Ultra wide-band;**

I. INTRODUCTION

RF and Microwave mixer is one of the most important components of RF front end system. As shown in Figure 1, where two frequencies beat together in a nonlinear element to generate two different frequencies [1].

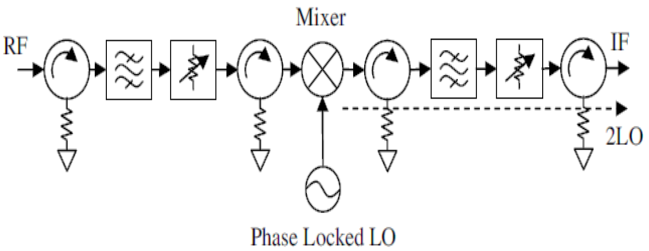

Figure 1: Typical diagram of the transceiver simulator [2].

In general, a mixer is a three-port electronic device that uses a nonlinear or time-varying element to achieve frequency conversion [3], where two of these ports are "input" ports and the other port is an "output" port. The nomenclature for the three mixer's ports are the Radio Frequency (RF) port, the Local Oscillator (LO) port and the Intermediate Frequency (IF) port. As a basic knowledge, there are several classes of mixer designs with different classifications, either diode or FET mixers, such as single-ended mixers, single-balanced mixers, and double-balanced mixers, where these mixers have different circuit configurations depending on their specifications and applications that may be suitable from one to another [4].

Single balanced diode mixers find enormous applications in modern microwave systems. They are used in applications such as microwave imaging, receivers, radars, communication, instrumentation etc. Many of these applications concentrate on frequencies from 3 to 11 GHz range. A discrete single balanced mixer circuit solution for these applications operating from 3 to 11 GHz with good conversion loss is presented in this paper.

Many research work have studied single balanced mixer as reported in [5], [6] and [7]. However, these mixers have limitations on bandwidth. Thus, this paper overcome the limitations of bandwidth by using multi-section coupled-line balun.

II. SYSTEM MODEL

The single mixer system model is depicted in Figure 2. It consists of 180^0 phase shift balun, two matching circuits, two Schottky diodes and low pass filter. The LO signal input is divided equally into two Schottky diodes. The RF signal input is also divided equally, but is 180° out of phase at the Schottky diodes. The LO and RF signals are mixed in these two Schottky diodes. The signals appearing from the two diodes can be combined at the Intermediate Frequency (IF) port. Thus, the output signals combined which contain even harmonics of the LO signal and the down-conversion signal is taken by the low pass filter. The LO and RF ports are isolated by the multi-section balun. The IF port is isolated from both the RF port and the LO port by the low pass filter. This type of balanced mixer is advantageous for its avoiding air bridges and crossing transmission lines that deteriorate the performance of the circuit and make the manufacture more complicated.

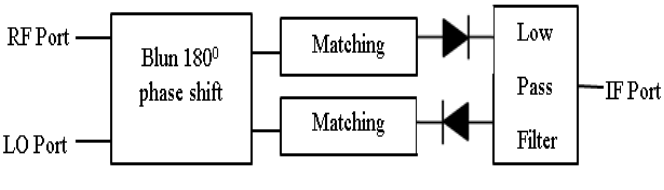

Figure 2: Equivalent single balanced mixer circuit.

III. SINGLE BALANCED MIXER DESIGN

The design of single balanced mixer can be done by the following procedures such as the selection of the diodes, 180^0 hybrid coupler (balun) design, IF low pass filter design, matching circuits design for the diode. The description of each part is showed below.

A. Diode Selection

The selection of the diode is critical for use in mixer design which involves a trade-off between cost, convenience, ease of manufacture and performance. However, the diode should have strong non-linearity, low noise, low distortion and good frequency response in the desired region of operation. The device selection also depends on device material and structure which includes dot matrix diode, packaged diodes and beam lead diodes. Hence, a packaged diode made up of silicon (SMS7621) is selected, due to its features and applications which operates successfully at frequencies below 12 GHz. Schottky diode is used as a switching device. It consists of two diodes in series. Figure 3 shows the modelling of diode.

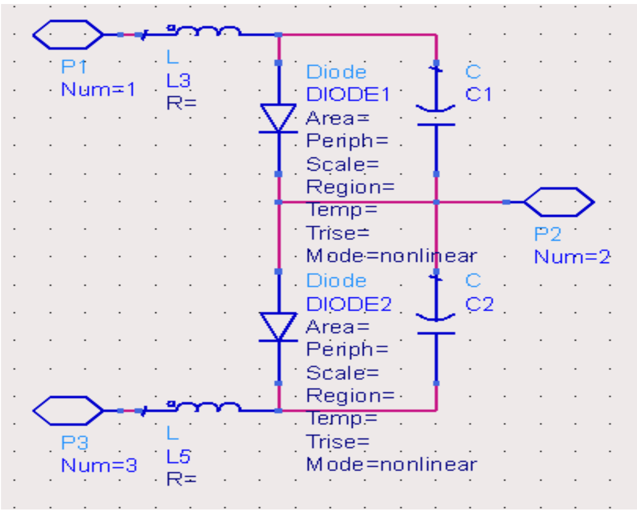

Figure 3: Schematic of Schottky diode

B. Matching Circuits

Small signal resistance of the Schottky diode varies from 40-100 ohms [8]. It has been matched to LO and RF fundamentals to RF & LO fundamentals. The diode's junction capacitance has been estimated as C1. The diode's reactance at RF is given by X(RF) =1/(2π*f(RF)*C1) and this is absorbed into RF matching circuit. Similarly, diode's reactance at LO frequency is given by X(LO)= 1/(2π*f(LO)*C1) and this has been absorbed into LO matching circuit. The diode's reactance at IF is twice that at RF frequency [8]. The matching circuit was designed to resonate out this reactance and thus match diode's IF impedance to the load.

C. IF Low Pass Filter Design

A low pass filter is used in the down-conversion mixer[9]. IF Low pass filter presented on Figure 4 is used for extracting the range of down conversion frequency. The filter is simulated with ADS software. The filter is designed microstrip line filter and the filter is said to have insertion loss close to 0 dB and return loss less than -10 dB over the frequency band from 3 GHz to 11 GHz as shown in Figure 5.

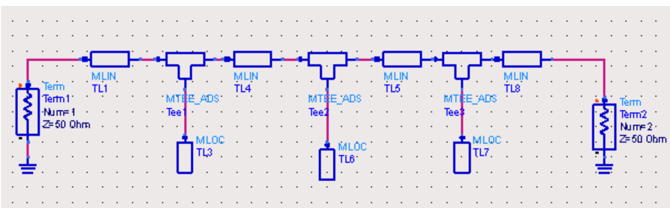

Figure 4: Schematic of Low Pass Filter

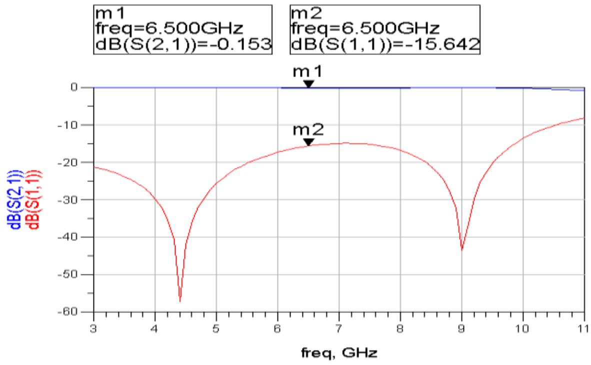

Figure 5: Low Pass Filter results

D. Balun Circuit

A multi-section coupled-line microstrip is used as a balun for the single balanced mixer as shown in Figure 6. In this paper, coupled line balun based on [10] is realized by cascading several of coupled-line sections. This balun delivers a good impedance matching for mixer and consistent 180^0 phase shift over RF range 3 GHz to 11 GHz.

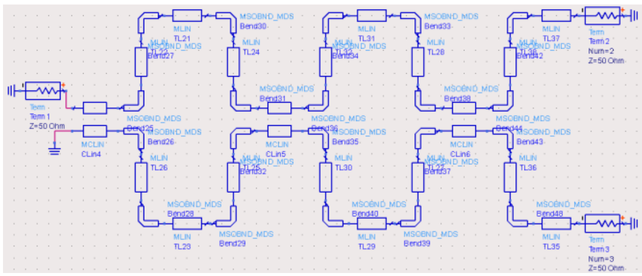

Figure 6: Schematic of Balun Circuit

Figure 7 represents the simulated S-parameters of balun design which is designed using ADS software. The simulated results indicate the insertion loss S21 and S31 is around -5 dB and the return loss S11 is less than -10 dB over the ultra wide-band range. In Figure 8, the phase shift of 180^0 between port 2 and port 3 by observing the S21 and S3 is presented.

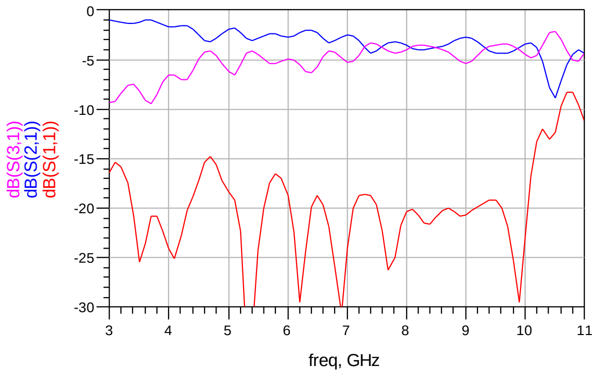

Figure 7. S-parameters of the balun circuit

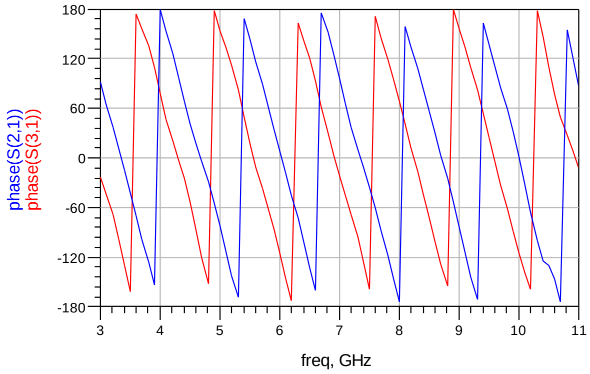

Figure 8: Phase response of the balun circuit for port 2 and port 3

IV. SIMULATION

The single balanced mixer described above is simulated with ADS software. Figure 9 shows the simulation setup of the designed mixer. LO power level is changed from range 3 dBm to 17 dBm to obtain the best possible conversion loss where the RF power level is fixed at -10 dBm.

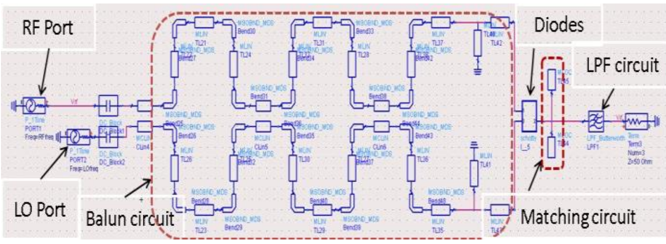

Figure 9: Schematic of single balanced mixer

The simulated results, as shown in Table 1, indicated that the conversion loss of the mixer is about 6 dB to 16 dB in the frequency range of 3 GHz to 10 GHz and IF frequency is 100 MHz, when the LO power level is 17 dBm with fixed RF level power is -10 dBm. Fig 10 gives the relationship between the LO power and the conversion loss. The conversion loss is better with higher LO power and the loss is increasing with higher frequency.

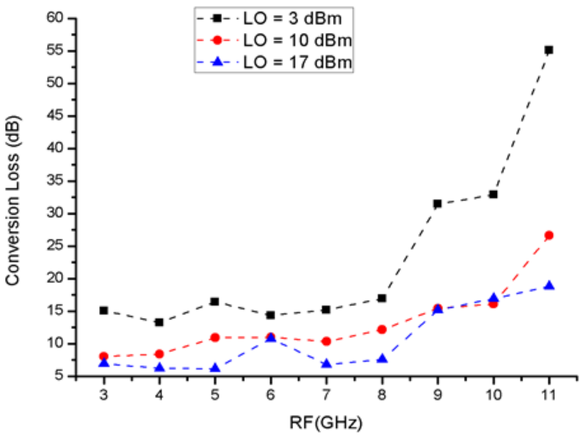

Figure 10: Simulated Conversion loss with various level of LO power

Table 1
Conversion Loss with various LO power level

RF freq	LO=3 dBm	LO= 10 dBm	LO= 17 dBm
3 GHz	15.077	8.06	6.934
4 GHz	13.266	8.413	6.234
5 GHz	16.452	10.927	6.171
6 GHz	14.346	11.002	10.789
7 GHz	15.208	10.333	6.82
8 GHz	16.947	12.155	7.576
9 GHz	31.468	15.418	15.161
10 GHz	32.918	16.104	16.944
11 GHz	55.11	26.642	18.838

V. CONCLUSION

In this paper, single balanced diode mixer is designed and simulated. The simulated results showed good conversion loss over ultra wide-band frequency range from 3 to 11 GHz. The simulated results indicate a better conversion loss at LO power level of 17 dBm and RF power of -10 dBm which is less than 15 dB. The presented mixer can be widely used in various application that could be integrated with other components such as UWB antenna [11], filter [12] [13], amplifier [14] and switch [15] for a complete UWB RF front-end system. Thus, it can be used in systems such as microwave imaging, military and civilian radars, wireless communication and microwave instrumentation.

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