Design of a Low-Cost High Isolation Subharmonic Mixer in mm-waves using Schottky Diodes

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Abstract—**This paper presents a new topology of a diode-based Sub-harmonically pumped resistive mixer (SHPRM) for millimeter waves with a focus on free band available around 60 GHz. In this topology, a local oscillator (LO) of quarter of the frequency is needed in comparison to the fundamental mixer (e.g., 14 in place of 56 GHz). The band of operation of the mixer for RF is 57-59 GHz, for IF is 1-3 GHz and LO is at 14GHz. Because of reduction in the required LO frequency, there is a momentous decrease in complexity of the overall radio front-end. This saves the dc power consumption and the area required for the chip. In this way, for a high-frequency system, the Subharmonic mixer renders a substantial reduction in cost. The mixer is implemented in microstrip technology using Rogers substrate which was fully characterized via full-wave EM simulations. The working principle of the Subharmonic mixer is demonstrated used in a millimeter-wave system. Here main design parameters were the conversion loss and isolation between all the three ports. Hence the overall design objective was to produce a low cost and low loss scheme, having excellent isolation while keeping it simple.**

***Index Terms*—Schottky diodes, high linearity, low Power consumption, millimeter-wave integrated circuits, mixers, 60 GHz, subharmonic, 60GHz ISM band.**

I. Introduction

The fast progress of wireless technologies, predicts the universal and ubiquitous wireless systems in businesses and homes to egress in coming days. One of the ultimate goals of the 4G and next generations is to facilitate these wireless systems. This increase in interest for wireless communication has swayed regulatory authorities to furnish new opportunities with lenient radio parameters in unlicensed frequency spectrum. At millimeter-wave frequencies around 60 GHz, a range of 7GHz unlicensed spectrum, where only short-range communication is possible because of atmospheric oxygen characteristics that avoids interference and facilitates the frequency spectrum usage [1]-[5] is available. This spectrum is useful for ultra-wideband (UWB) short-range wireless local area networks (WLANs) with high data rate applications, such as speedy office or home wireless network. Conventional microwave UWB technology (3.1– 10.6GHz band) is one of the most active focus areas in academia, industry, and regulatory circles. Because of the power spectral density limitations (−41 dBm/MHz) the microwave UWB overlays existing wireless services (PCS, Bluetooth, GPS and IEEE 802.11 WLANs) without considerable interferences. In comparison to the traditional technology of UWB, [see Fig. 1] communications in the unlicensed band (57–64 GHz) can support high data rate in Gb/s [6–7]. Low ratio of bandwidth over center frequency provides an extra advantage by making the transceiver design simple. Yet, it is a challenge for the 60 GHz indoor environment for UWB wireless networks. Due to the characteristic power limitations and properties of the wireless channel propagation, 60 GHz communications is short-ranged. This feature of high signal weakening permits an efficient frequency-reuse allowing making small indoor units for hotspot secure wireless connectivity [8].

Since the 1960s, UWB technologies have been applied in radar systems. Due to this involvement of academia and industry has tremendously increased since 1990s. For applications like WLAN Bridge, wireless TV, high-resolution recording camera, or wireless Internet download of lengthy files etc., network with capacity of 100s of Mbps may be required. Besides communication, these devices can be used for imaging, sensors, measurements and vehicle radars. This high rate network capability can be achieved by increasing the spectral efficiency or/and by using an increased bandwidth [9]. Here comes the limitation of the availability of low-cost products and equipment in mm-band as it is difficult and costly to make stable oscillators with low phase-noise and high power at mm-waves. It is challenging for an RF unit designer to downconvert a received signal in mm-waves like 60GHz. Local oscillators with large output power in this frequency range often comprise expensive and large waveguide resonators. A Subharmonic mixer provides a substitute to high frequency LO. It also offers inherently wide separation/isolation between LO and RF, which in fundamental mixing is small.

Mixers generally require a specific/fixed minimal LO power above which they perform frequency-translation efficiently and below which there is a significant performance

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degradation. It can be hard at mm-waves to fulfill this power requirement using an integrated oscillator. Subharmonic mixing allows using LO at low frequency, where the power output and performance of phase noise is better to that of the fundamental frequency. This method has been implemented successfully in several mm-wave mixer applications [10]–[11]. Unlicensed bandwidth allocated for UWB purposes, in the 60 GHz band is continuous and wide. It also has less restriction on power levels [see Fig. 2]. Hence 60GHz band is attractive for it gives us flexibility and high capacity. Also due to small size of 60GHz radio, multiple-antenna solution is simple which is not easy at lower frequencies. In comparison to 5 GHz system, the high-frequency systems have form factor approximately 140 times smaller and it is easier to integrate them into consumer electronic products [12].

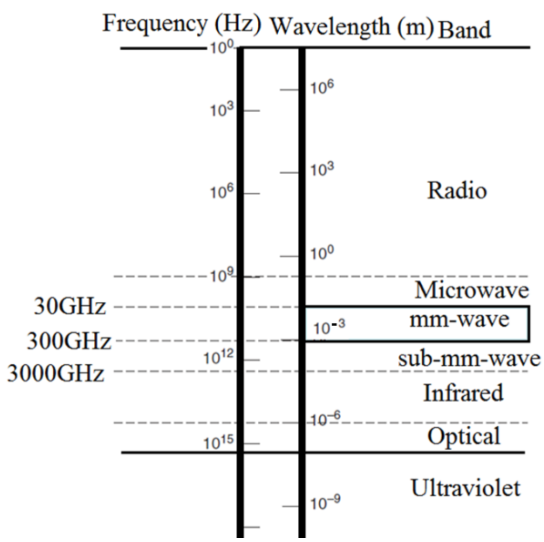


Figure 1: Electromagnetic Spectrum distribution

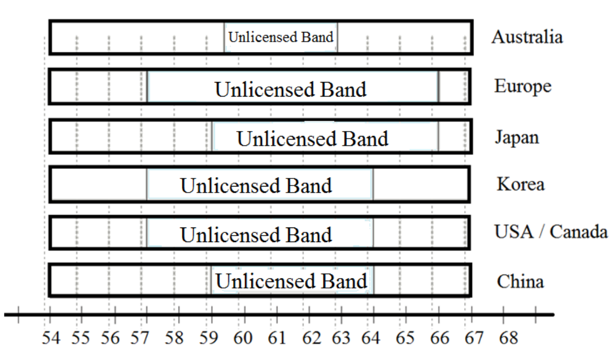


Figure 2: Frequency band ranges for various geographical regions

It is interesting to develop low-power Subharmonic mixers as these circuits offer a variety of design alternatives to the system designers, like the capability to use lower-frequency LO signals having superior phase noise performance than high-frequency LO signals. Also subharmonic mixers are used in direct-conversion (zero- IF) receivers for eliminating the harmful phenomenon of LO self-mixing, that deteriorates the baseband information [13], [14]. In this paper a 4x subharmonic passive mixer that is both low-power and low-voltage is presented. The mixer uses a complementary current-reuse technique [15].

Personal area networks (PAN) that use several-gigabits short-range data transmission between devices like hard-drives, MP3 players, HDTV receivers, storage devices etc. are in great demand [16]. The key requirements for such mm-wave systems are: cost-effectiveness, superior performance, mass producibility and low power consumption. Thus small size of digital wireless transmitter finds interest in direct upconversion and small size of receiver systems is desirable in down-conversion [10]. This technique can save circuit count and is acceptable for low mw frequencies. For mm-wave frequencies, LO leakage becomes problematic to the antenna as the carrier signal and sidebands are in close proximity, where separation of signals becomes challenging. The impulsive nature and low emission of the Ultra-Wideband (UWB) radio leads to security enhancement in communications. It is also suitable for indoor hostile environments because of its capability to penetrate through walls [13].

II. Subharmonic Mixing: Concept, Design and Simulation

A. Concept and operation

A mixer [see Fig. 3] is an integral part of any microwave system whether it is intended for communication, tracking, ranging or instrumentation. It is broadly characterized by its conversion loss, LO-RF isolation, RF & LO frequency range and 1dB compression input. There is a wide range of RF and LO signals, which makes it an obvious choice for communication applications. Some typical applications of mixers include military Radar, satellite communication, test & instrumentation, and Point-to-Multi-Point radio communications etc. Wide frequency ranges for RF and LO signals, low conversion loss, High LO to RF isolation, High RF to IF isolation and high IP3 (input) are some desirable features of a mixer.

A subharmonic (SHP) mixer reduces the problem of filtering as the fundamental LO signal is well-beyond from the wanted signal. The unwanted second/even harmonic signal is inhibited on the output side as it remains confined inside the pair of diodes. Subharmonic topology is a good choice for mixers as it can eliminate the number of multiplier-stages, needs no DC power and is equally good for upconversion and down conversion [15]. There are various types of mixers and the choice of a particular type depends on application. Single side band (SSB) mixers give low conversion loss as well as superior performance of image rejection. But their combiners/dividers need extreme accuracy in phase and amplitude. Various topologies for the subharmonic mixers are shown in Fig. [4-9].

The working principle of a subharmonic mixer is very simple. The diodes connected back-to-back act as frequency doubler.

Hence require a LO signal ½ of the usual frequency. The nonlinearity of diode functions as a resistive frequency multiplier and produces the 2nd harmonic of the LO to combine with the RF signal to generate the desired output frequency. The I-V characteristics of an antiparallel diode pair are symmetric, suppressing the fundamental combinations of the RF and LO input signals, giving better conversion-loss. A nonlinear device like diode or transistor can produce a versatile range of harmonics [17] and other products of input frequencies. Filtering is required to distinguish between the wanted and unwanted frequency components [18-20].
Anti-parallel diode pair mixer scheme is the most commonly used subharmonic configuration [see Fig. 4]. This contains a diode pair in parallel with reversed polarity. So the pair of diode conducts on positive as well as negative halves of the LO cycle, causing a 2x LO frequency products. This way the fundamental mixing products are suppressed and conversion loss of the IF products is improved.

B. *Design of Subharmonic Mixer*

This section qualitatively describes operation of the mixer and an in-depth analysis of the circuit. Fig.[5-8] show the various topologies of mixers found in literature.

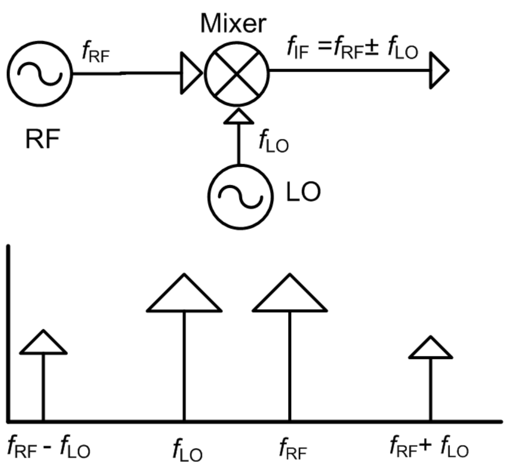


Figure 3: Basic operation of Mixer

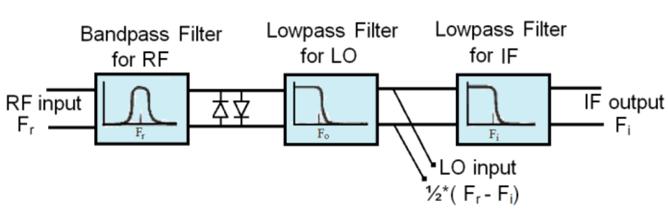


Figure 4: Block diagram of a basic 2x Subharmonic mixer

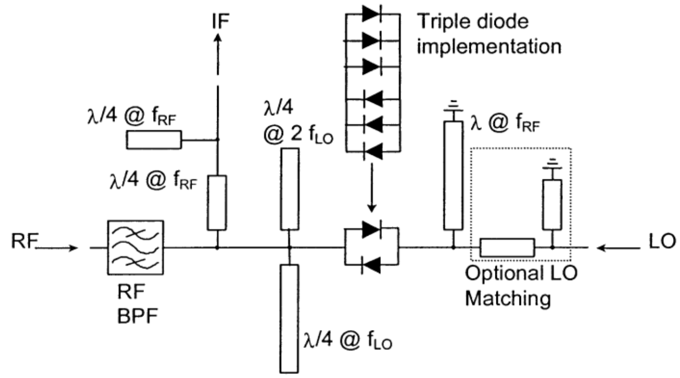


Figure 5: A 4x Subharmonic Mixer topology using triple diode implementation [21]

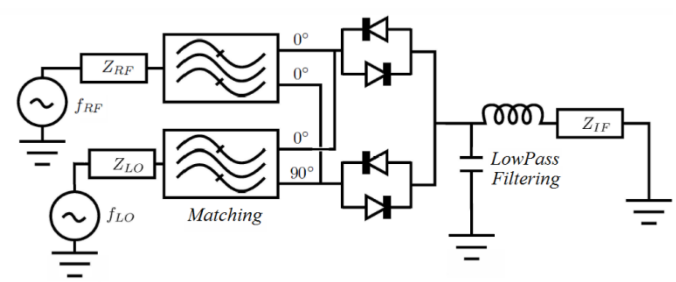


Figure 6: A 4x Subharmonic Mixer topology using 2 APDPs [18]

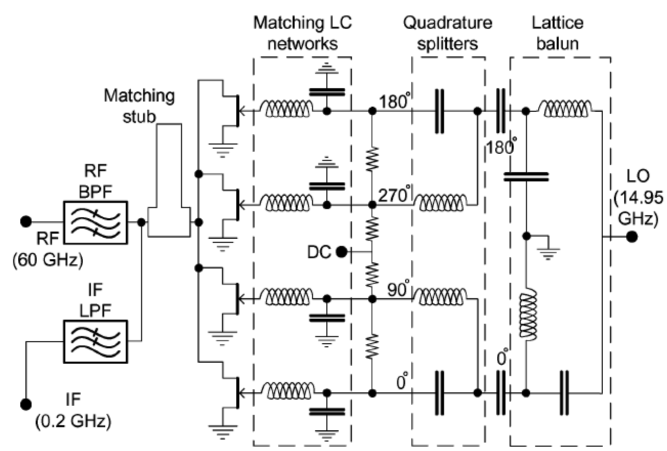


Figure 7: A 4x Subharmonic Mixer topology using transistors [22]

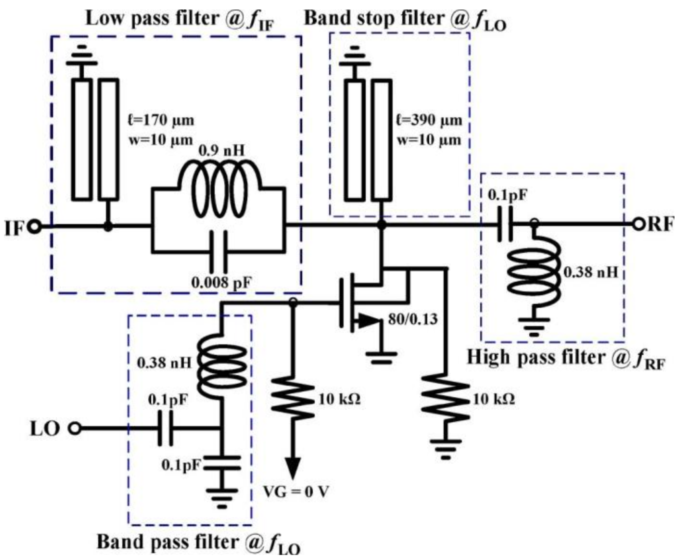


Figure 8: Schematic of 2x SHM [23]

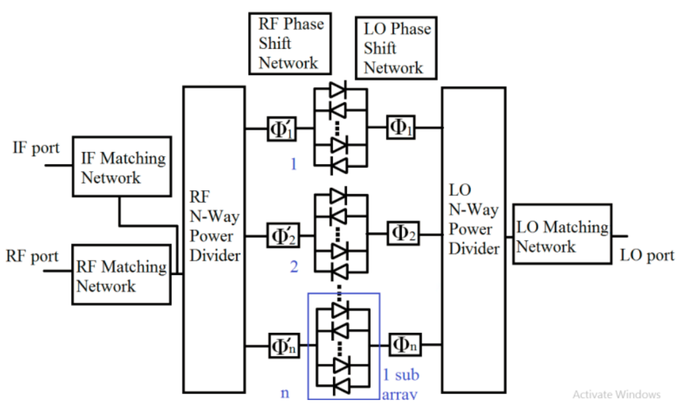


Figure 9: A generic high order Subharmonic Mixer configuration using multiple antiparallel diode pairs

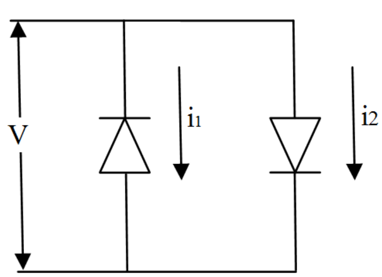


Figure 10: Antiparallel-diode pair with voltage V

Fig. 9 describes a general concept for high order Subharmonic mixing. The detailed mathematical model of this general high order mixer is presented. The circuit can be used for 2x, 4x, 8x,.etc. The power dividers and phase shifters for LO and RF signals in the architecture utilize idle frequency components. In comparison to the general mixers having 1 pair of antiparallel diode configuration, theoretically this circuit has advantages of improved conversion loss, high isolation and wide dynamic range because of phase cancellation of idle frequencies. Each sub-array consists of 1 or more pairs of diode [24-25]. Schottky diode mixers are used at the start of receivers [26] to downconvert the signal, despite the progress of submillimeter-wave low-noise amplifiers [27-28].

LO dividers and phase shifters with π/n phase offset can realize f =│a1fRF ± 2a2fLO│ output components where the low-order idle mixing products that correspond to a1=1 & a2= 1,2,3,…,n-1 are terminated by cancellation of phase. Greater the idle frequency components, the lower the conversion loss is. The general behavior of antiparallel pair of diodes and the mixing operation of this configuration can be described by the mathematical treatment as follows. The currents [24] passing through diode 1 and diode 2 as shown in Fig. 10 are termed as:

$$i_{ins1} = -i_s(e^{-\alpha V} - 1) \quad (1)$$

$$i_{\mathrm{ins2}} = i_s(e^{\alpha V} - 1) \quad (2)$$

The composite conductance g_o can be obtained by adding the individual conductance, i.e,

$$g_o = g_{o1} + g_{o2} = \frac{\mathrm{di1}}{\mathrm{dV}} + \frac{\mathrm{di2}}{\mathrm{dV}} = \alpha i_s(e^{\alpha V} + e^{-\alpha V}) = 2\alpha i_s \mathrm{cosh}\alpha V \quad (3)$$

Usually when LO modulates the diodes conductance, we can put

$$\mathrm{V} = V_{LO}cos(\omega_{LO}\mathrm{t} + \Phi_k) \quad (4)$$

into (3) to get the composite conductance as:

$$g_o = 2\alpha i_s \mathrm{cosh}\alpha V = 2\alpha i_s \cosh[\alpha V_{LO}\cos(\omega_{LO}\mathrm{t} + \alpha_k)] \quad (5)$$

This can be expressed as the following series:

$$g_o = 2\alpha i_s[I_o(\alpha V_{LO}) + 2I_2(\alpha V_{LO})\cos(\omega_{LO}\mathrm{t} + 2\Phi_k) + 2I_4(\alpha V_{LO})\cos(4\omega_{LO}\mathrm{t} + 4\Phi_k) + \cdots] \quad (6)$$

For the voltage V applied,

$$\mathrm{V} = V_{RF}cos(\omega_{RF}\mathrm{t} + \acute{\Phi}_{\mathrm{k}}) \quad (7)$$

The total current relation is

$$i_t = gV_{RF}cos(\omega_{RF}\mathrm{t} + \acute{\Phi}_{\mathrm{k}}) \quad (8)$$

$$i_t = 2\alpha i_s V_{RF}cos(\omega_{RF}\mathrm{t} + \acute{\Phi}_{\mathrm{k}})[I_o(\alpha V_{LO}) + 2I_2(\alpha V_{LO})\cos(\omega_{LO}\mathrm{t} + 2\Phi_k) + 2I_4(\alpha V_{LO})\cos(4\omega_{LO}\mathrm{t} + 4\Phi_k) + \cdots] \quad (9)$$

It is easy to see that current contains $|a_1 f_{RF} \pm a_2 f_{LO}|$ frequency components only for which a1+ a2 is an odd number.
The individual currents in each sub-array as shown in Fig.9 are given as:

$$i_1 = 2\alpha i_s V_{RF} cos(\omega_{RF} t + \acute{\Phi}_k)[I_o(\alpha V_{LO}) + 2I_2(\alpha V_{LO}) \cos(2\omega_{LO} t + 2\Phi_1) + 2I_4(\alpha V_{LO}) \cos(4\omega_{LO} t + 4\alpha_1) + \cdots] \quad (10)$$

$$i_2 = 2\alpha i_s V_{RF} cos(\omega_{RF} t + \acute{\Phi}_2)[I_o(\alpha V_{LO}) + 2I_2(\alpha V_{LO}) \cos(2\omega_{LO} t + 2\Phi_2) + 2I_4(\alpha V_{LO}) \cos(4\omega_{LO} t + 4\Phi_2) + \cdots] \quad (11)$$

$$i_3 = 2\alpha i_s V_{RF} cos(\omega_{RF} t + \acute{\Phi}_3)[I_o(\alpha V_{LO}) + 2I_2(\alpha V_{LO}) \cos(2\omega_{LO} t + 2\Phi_3) + 2I_4(\alpha V_{LO}) \cos(4\omega_{LO} t + 4\Phi_3) + \cdots] \quad (12)$$

$$i_n = 2\alpha i_s V_{RF} cos(\omega_{RF} t + \acute{\Phi}_{2n})[I_o(\alpha V_{LO}) + 2I_2(\alpha V_{LO}) \cos(2\omega_{LO} t + 2\Phi_{2n}) + 2I_4(\alpha V_{LO}) \cos(4\omega_{LO} t + 4\Phi_{2n}) + \cdots] \quad (13)$$

Setting same angle for phase-rotation for the RF signal and the LO signal, i.e.

$$\Phi_k = \acute{\Phi}_k = \frac{2k\pi}{n}, for\ k = 1,2,3, \ldots, n \quad (14)$$

The below identity exists:

$$\sum_{\acute{k}=1+cn}^{n-1+cn} \left[\sum_{k=1}^{n} \cos\left(2\acute{k}\frac{2k\pi}{n} \pm \frac{2k\pi}{n}\right)\right] = \sum_{\acute{k}=1+cn}^{(c+1)n-1} \left\{ \sum_{k=1}^{n} \cos\left((2\acute{k} \pm 1)\frac{2k\pi}{n}\right)\right\} = 0$$

For n >1 and c is a fixed number like c = 0,1,2,3 etc.
The total current of each sub-array can be represented as

$$i_t = 2\alpha i_{s.} 2n V_{RF} cos(\omega_{RF} t + \acute{\Phi}_{2n})[2I_n(\alpha V_{LO}) \cos(2n\omega_{LO} t + 2n\Phi_{2n}) + 2n.\, 2\alpha i_s V_{RF}.\cos(\omega_{RF} t + \acute{\Phi}_{2n}) I_{2(n+n)}(\alpha V_{LO}) \cos[2(n+n)\omega_{LO} t + 2(n+2)\,\Phi_{2n} + \cdots] \quad (15)$$

Simplification of the above relation by ignoring the low energy frequency components, the total current can be approximated as:

$$i_t = 2n.\, 2\alpha i_{s.} V_{RF} cos(\omega_{RF} t + \acute{\Phi}_{2n}).\, 2I_n(\alpha V_{LO}) \cos(2n\omega_{LO} t + 2n\Phi_{2n}) \quad (16)$$

Equ. 16 shows that $f_{iddle} = |a_1 f_{RF} \pm a_2 f_{LO}|$ are removed by phase cancellation with suitable LO phase shifters, for a1=1 & a2=cn+1, cn+2, cn+3,…(c+1)n-1 (n > 1). Fundamental mixing component is removed for n=1. On the other hand, RF phase shifters can also obviate idle frequencies $f_{iddle} = |2k_1 f_{RF} \pm \acute{k}_2 f_{LO}|$ where k1=1, $\acute{k}_2 = cn+1, cn+3, cn+5$.

The above treatment shows that the only mixing products remain are $\omega_{RF} \pm 2n\omega_{LO}$ with $f_{iddle} = |k_1 f_{RF} \pm k_2 f_{LO}|$ & $f_{iddle} = |2k_1 f_{RF} \pm \acute{k}_2 f_{LO}|$ reused. The idle frequency components are reactively terminated to save power loss.

Port isolation can be enhanced in this circuit architecture. As $f_{RF} = 2n\ f_{LO}$ for each diode sub-array of mixer, net phase difference of the RF power leakage to LO port can be expressed as:

$$\frac{2k\pi}{n} + 2n.\frac{2k\pi}{n} = 2k\pi + \frac{2k\pi}{n} \quad (17)$$

Considering the case of uniform RF power leakage for each diode sub-array, the following identity can be used.

$$\sum_{k=1}^{n} cos\left(2k\pi + \frac{2k\pi}{n}\right) = \sum_{k=1}^{n} cos\ \frac{2k\pi}{n} = 0 \quad (18)$$

Obviously phase cancellation eliminates the sum of leakage power. Leakage RF signal encounters a short, resulting in high RF-LO isolation. Similarly the net phase difference of the LO power leakage is

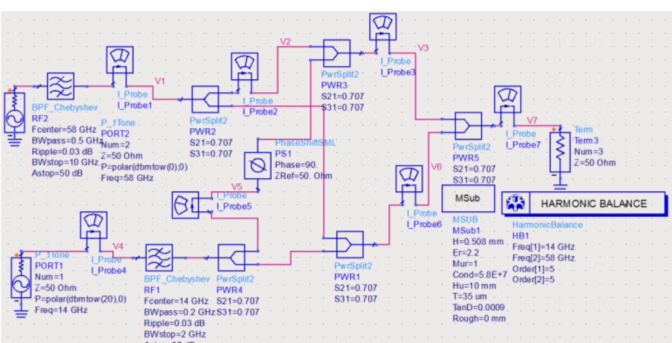
$$\frac{2k\pi}{n} + \frac{1}{2n}.\frac{2k\pi}{n} = \frac{k\pi}{n^2} + \frac{2k\pi}{n} \quad (19)$$

If n is large, the 1st term can be ignored, rendering with $\frac{2k\pi}{n}$. Hence the LO power leakage to IF/RF port can be annihilated by phase cancellation. Stub circuits for the idle frequencies have some deficiencies. They can furnish a reactive termination to 1 idle frequency and not to others. Thus for those other frequencies, the stub circuits may have significant effects. These circuits can also increase the conversion loss. Also the stub circuits do not cover a range of frequencies but allow open/short for only single frequency [29-30]. And the design of filters is very difficult because the requirements for the operational passband and the stopband for the idle frequencies are very stringent. Stub circuits for idle frequencies and design of the difficult filters required are replaced by the LO and RF phase shifters and power dividers [31].

In multiple diode pair sub-array, since diodes are in parallel, the resultant resistance of diodes is decreased causing an improvement in conversion loss. This mixer is implemented in microstrip technology in order to take advantage of the small size, low-mass and ease of interfacing with other media [16].

C. Simulation

Here an example of a 4x Subharmonic mixer is illustrated to verify the above mathematical modeling. Initially the design was carried-out using the ideal components. After the concept validation using ideal power divider and phase shifter, the circuit was implemented on microstrip using Rogers RO5880 substrate. High frequency mixing Schottky diodes of Skyworks DMK2308 having low junction capacitance, low series resistance and high cutoff frequency are used in implementation. The performance of the linear part of the circuit was separately investigated before the full-circuit modeling [see Fig. 11]. The design approach is modular and step-wise progress of the circuit architecture is elaborated using the figures. The RF frequency used here is 58GHz, LO frequency is 14GHz and IF corresponds to 2GHz. The conversion loss is optimized for LO power and optimal power level of LO comes to be 17dBm in this case. In Fig. 11, the linear circuit containing power dividers, power combiners and quadrature hybrid is shown. Current is measured at various nodes indicated as V1, V2,..,V8 of the circuit and power levels corresponding to these nodes at specified frequencies are calculated. The power levels in dBm corresponding to the voltage nodes are termed as P1, P2,.., P8 [see Fig. 12]. After checking the performance of linear circuit, the non-linear behavior of the device i.e., Schottky diode was investigated using simulation in harmonic balance analysis. Fig. [13-14] show the harmonics generated by exciting a single diode using a 60GHz source. The behavior of an anti-parallel pair of Schottky diode excited with a single frequency was then inquired. It was found that the even order products are extremely suppressed using this anti-parallel configuration. Fig. 15 shows the circuit for harmonic balance simulation analysis of an anti-parallel diode pair. Fig. 16 shows the suppression of the even order harmonics of the diode. Then two-tone excitation analysis of the diode pair was done. The phase of both the sources was same but different power levels were applied [see Fig. 17]. This is in fact the 2x subharmonic mixing. The IF product generated after mixing of RF (at 30GHz) with 2xLO (2x14GHz) at 2GHz shows the 2xsubharmonic action [see Fig. 18]. The reader should not be worried of the high loss and consequently small levels of the IF signal. It was in fact just to elaborate the idea of mixing without matching network and optimization. Next the 4x Subharmonic mixer was implemented using ideal components. Besides isolation and bandwidth, the main focus of design was low conversion loss.



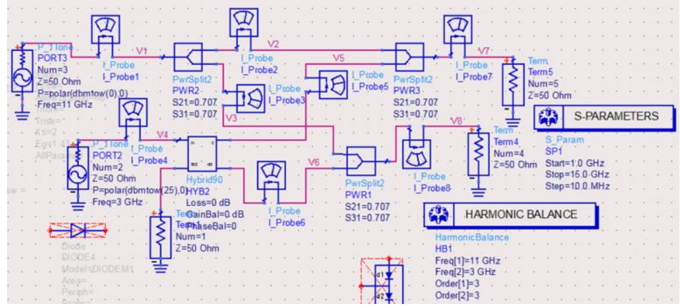


Figure 11: The exemplary linear circuit for a typical Subharmonic mixer

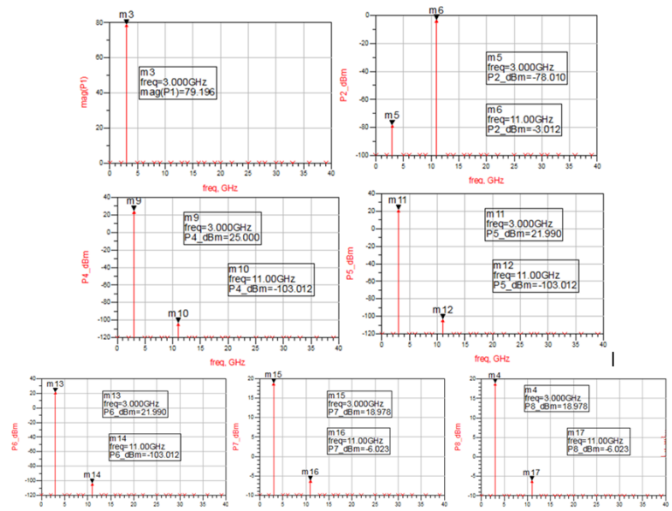


Figure 12: Power levels of the various signals as shown in Fig. 11

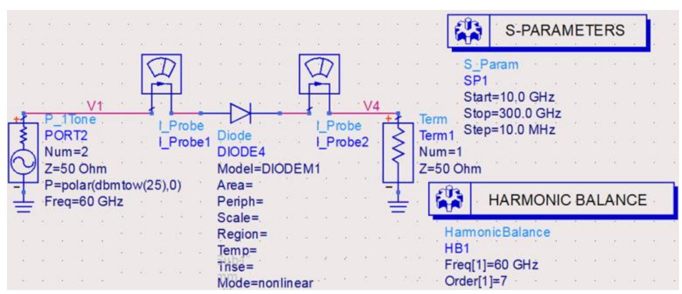


Figure 13: Simulation of non-linear behavior of a typical diode

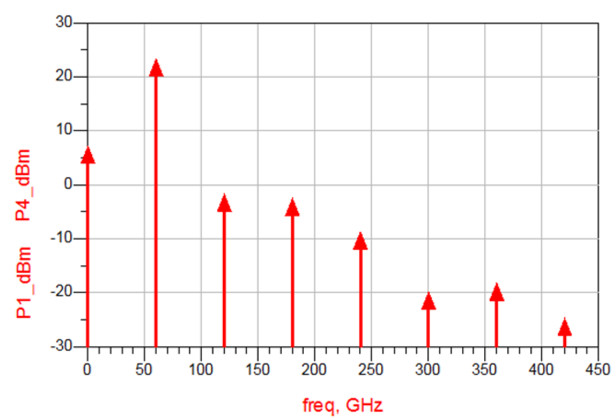


Figure 14: Output power of a diode for 60GHz input

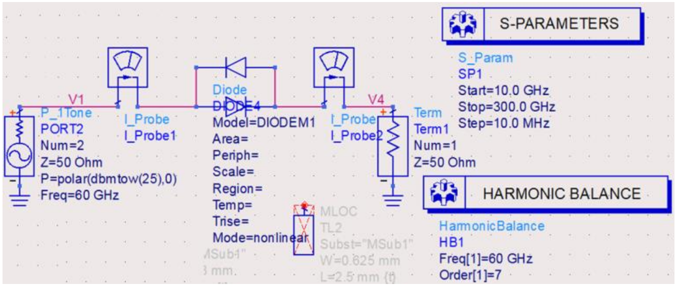


Figure 15: Circuit for simulation of behavior of a typical APDP

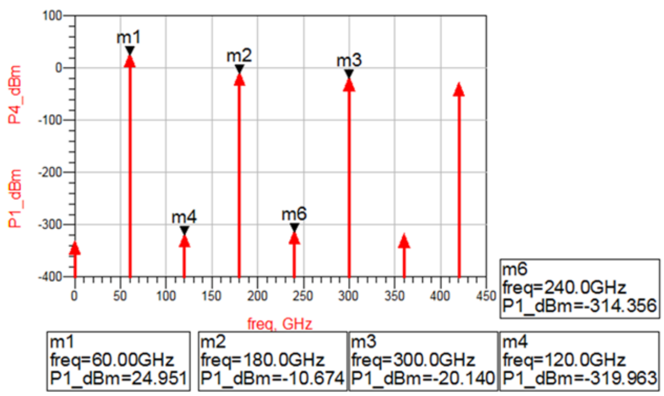


Figure 16: Cancellation of even harmonics using APDP

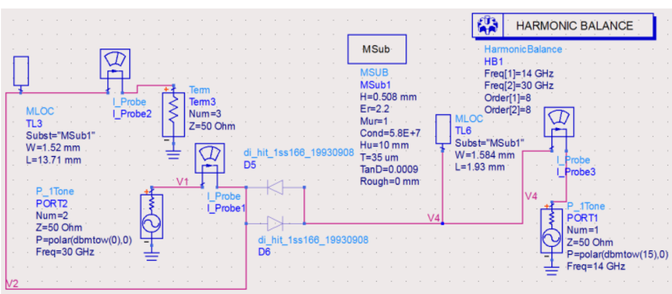


Figure 17: Schematic for a 2x Subharmonic mixer

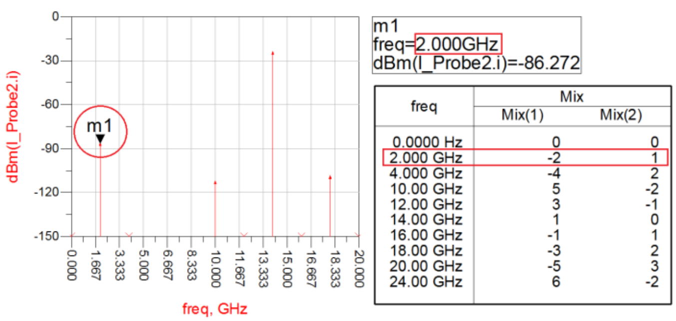


Figure 18: The mixing product at 2GHz is generated by the 2xsubharmonic action, where LO is at 14GHz and RF at 30GHz

Fig. 19 shows the schematic diagram of the 4x Subharmonic mixing circuit using 2 APDPs, power divider and quadrature hybrid. It is the concept validation schematic diagram of the 4x subharmonic mixer. The circuit employs ideal components. The conversion loss is shown in Fig. 20. After that microstrip implemetation was done. Fig. [21-23] show the wilkinson divider for RF frequency and its results.

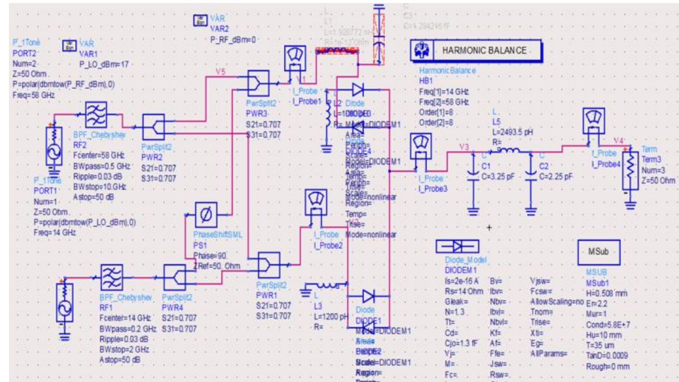


Figure 19: Schematic diagram of a 4x Subharmonic mixer (RF=58GHz, LO=14, IF=2)

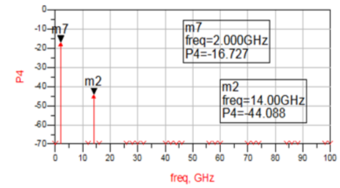


Figure 20: Conversion Loss of above circuit (16.727dB)

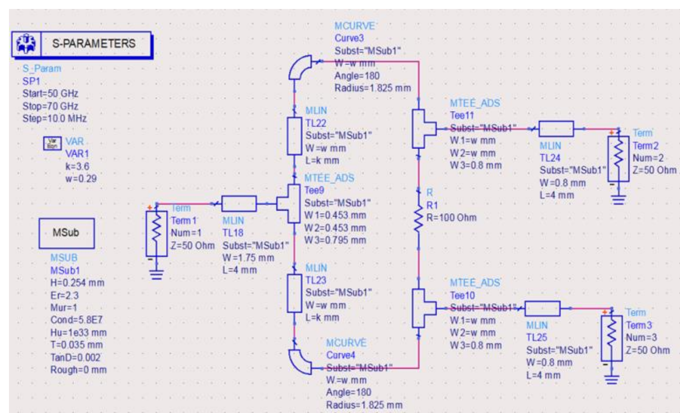


Figure 21: Microstrip circuit of Wilkinson divider at 58GHz

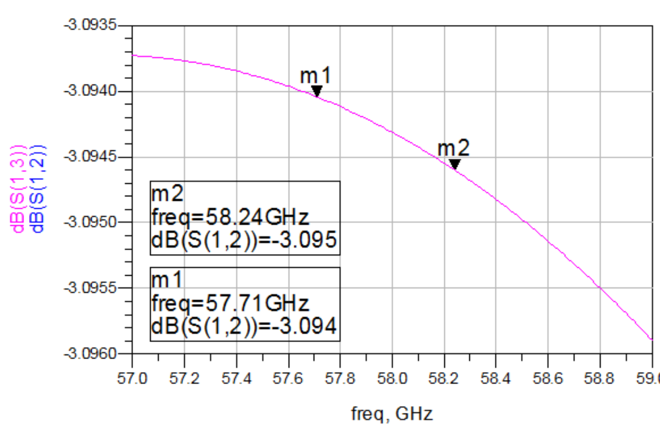


Figure 22: Frequency response of Wilkinson divider at 58GHz (insertion loss)

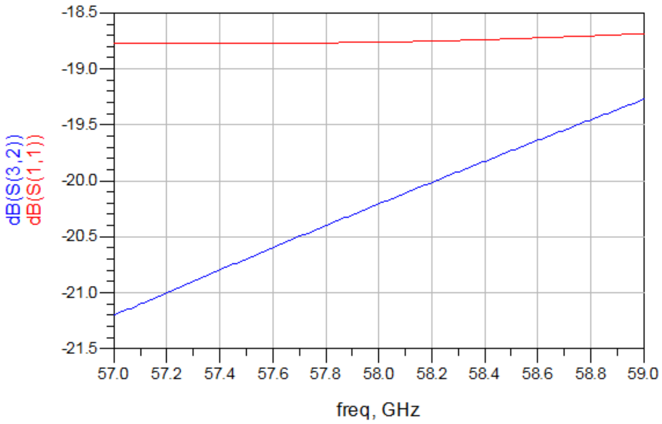


Figure 23: Frequency response of Wilkinson divider at 58GHz (Output ports Isolation & Return loss of input port)

Fig. [24-25] show the microstrip implementation of quadrature hybrid for LO frequency and its results. Fig. [26-27] show the matching circuit between the diode-pair and the quadrature hybrid for LO.

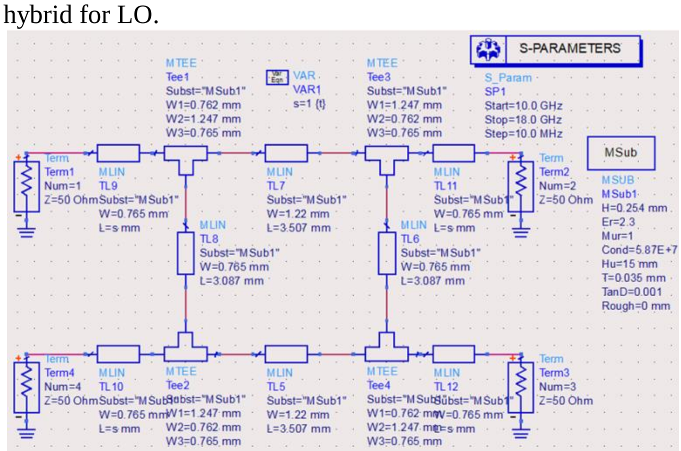


Figure 24: Microstrip realization of a 90° Hybrid at 14GHz

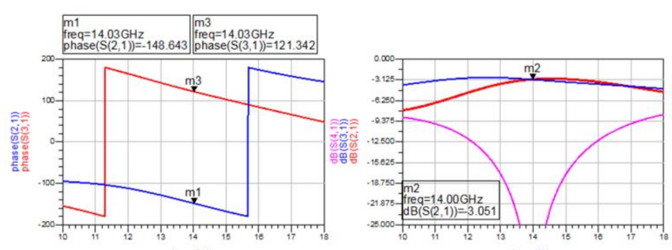


Figure 25: Frequency response of 90° Hybrid at 14GHz

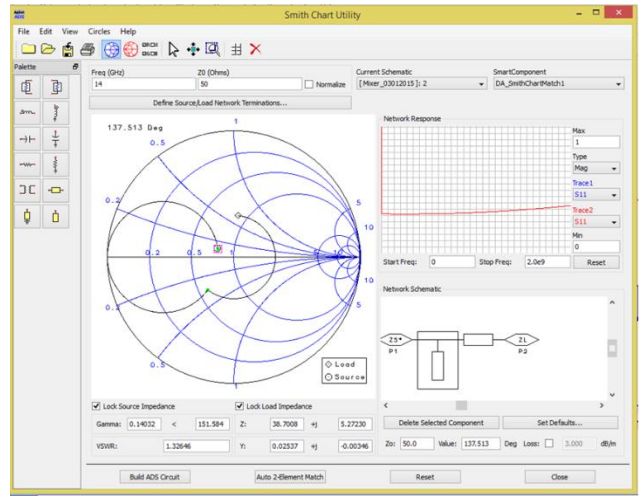


Figure 26: Matching network for LO using Smith Chart

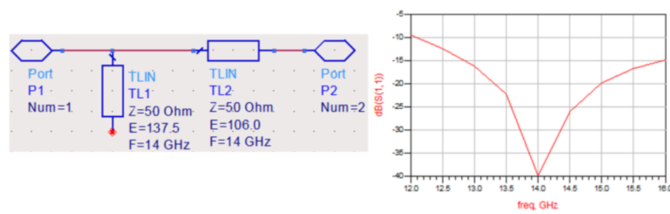


Figure 27: Matching network with frequency response at 14GHz

The complete microstrip circuit was shown in Fig. 28 and the conversion loss response in Fig. 29. The loss of the mixer was optimized tuning the matching networks slightly. The idea of multiple pair diode array was tested and shown in Fig. [30-31]. Here the circuit for 2 APDP in an array, m=2 was shown in Fig. 30. Fig. 31 depicts the optimized conversion loss and the suppression of undesired harmonics and intermodulation products. Reasonably good performance of mixer was achieved as shown in terms of low conversion loss [see Fig. 32] and excellent ports isolation [see Fig. 33]. Fig. 34 shows the fabrication-ready layout of the 4x Subharmonic mixer.

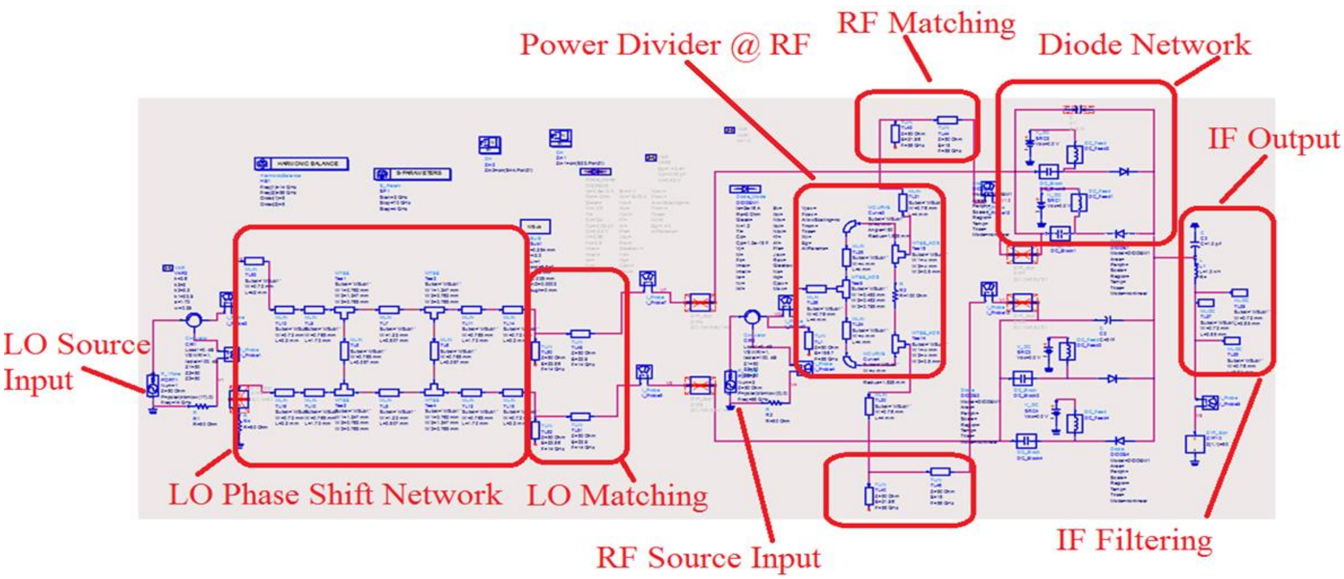


Figure 28: Microstrip realization of 4x Subharmonic Mixer with LO at 14GHz, RF at 58GHz and IF at 2GHz

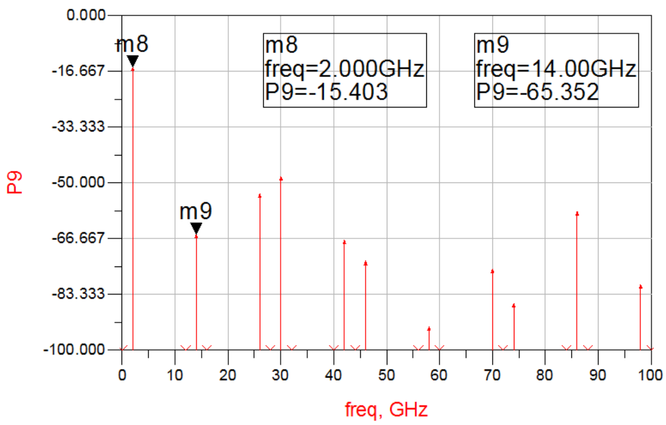


Figure 29: Conversion Loss of 4x Subharmonic mixer referred to 0dBm RF Power

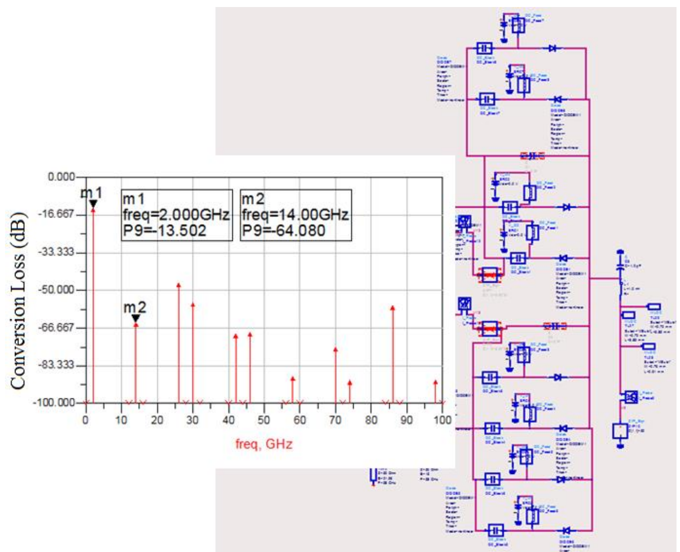


Figure 30: Conversion Loss (m=3 results in better conversion efficiency than for m=2) referred to 0dBm RF Power

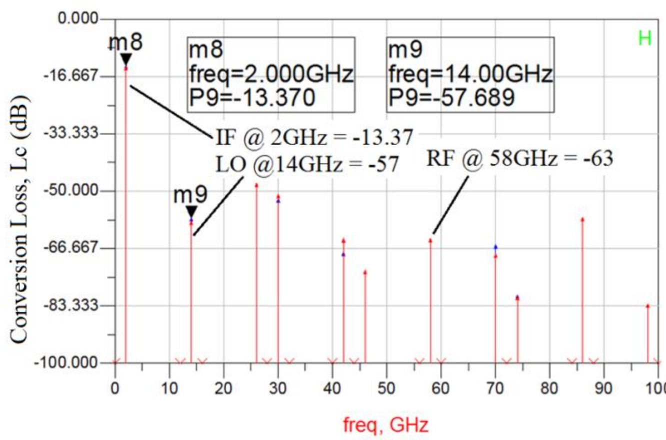


Figure 31: Conversion Loss for m=2 after optimization referred to 0dBm RF Power

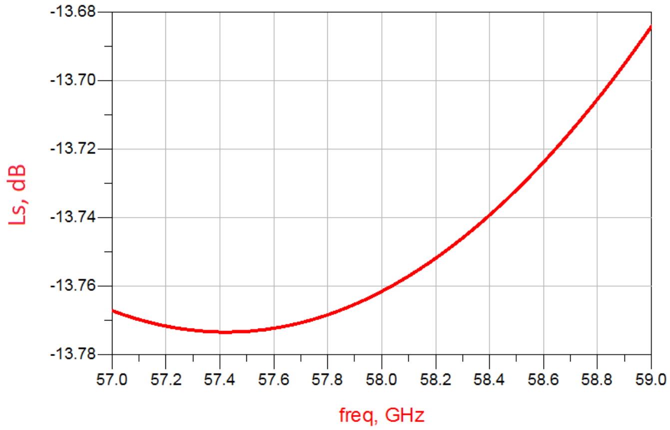


Figure 32: Conversion Loss of the Mixer

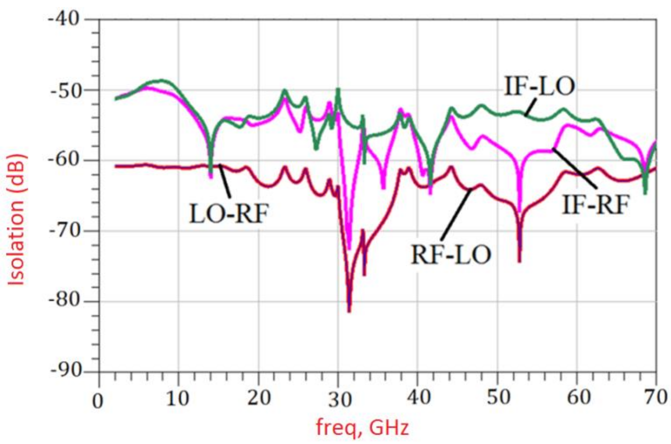


Figure 33: All three Port-Isolation (IF-LO, IF-RF, LO-RF, RF-LO)

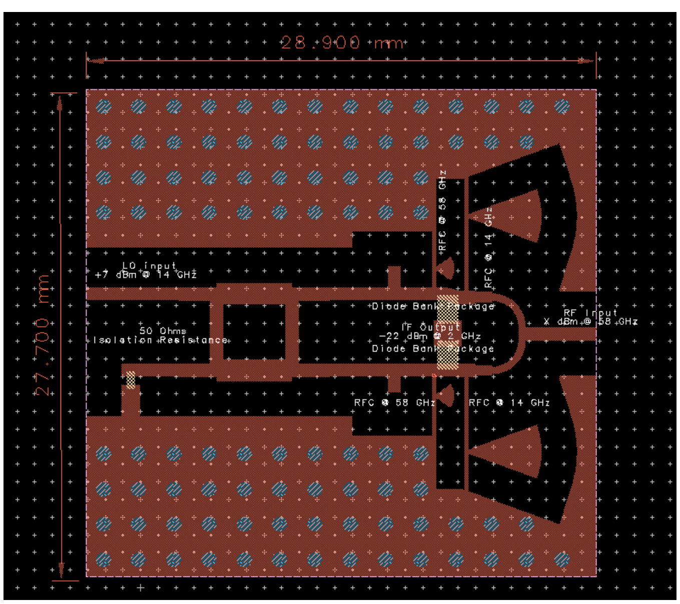


Figure 34: Final Layout of the 4x Subharmonic mixer

III. CONCLUSION

A 4x subharmonic mixer at v-band is designed using Schottky diodes and implemented in microstrip to achieve smaller size as it is a requirement of compact WLAN transceivers. Rogers substrate 5880 was used. The full-wave EM simulation was performed in Advanced Design System (ADS) software. Co-simulation was performed using the momentum model of the phase-shift network, the Wilkinson divider, matching networks and the lowpass filter in ADS. A stepped impedance lowpass filter at IF is used to block any unwanted frequencies. LO matching networks consist of a transmission line and an open stub which are easy to implement. The scheme of multiple diode pairs in an array was also tested; due to increase in pair of diodes in an array, the conversion loss was improved. But the reduction in loss was not very significant/appreciable in the receive chain in comparison to its cost in terms of the complexity addition of the circuit. The conversion loss comes out to be 13.4dB. The mixer has an excellent isolation performance. The port isolation RF-IF, RF-LO, LO-RF & LO-IF is better than 50dB.

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