An Ultra-Broadband Planar Millimeter-Wave Mixer with IF Bandwidth covering 0.5 to 34 GHz

Alexander Feldman, Utkarsh Unnikrishna, Irfan Ashiq, Amarpal Khanna
Microwave Components
National Instruments, Santa Clara, CA, USA.
paul.khanna@ni.com, utkarsh.krishna@ni.com

***Abstract*— This paper presents a uniplanar passive ultra-broadband microwave mixer with 33 GHz to 67 GHz RF bandwidth and 0.5 to 34.5 GHz IF bandwidth in down-converter application with 9 ± 2 dB conversion loss. The presented mixer topology is a mode conversion single balanced mixer with CPW-to-slotline RF balun and combined CPW LO and IF. An external diplexer is used as a frequency selective device to separate the LO and IF signals. This mixer is equally efficient in up & down converter applications.**

***Keywords*— Balun, uniplanar, broadband, millimeter wave mixer, diplexer, CPW to slotline transistion, Suspended Stripline.**

I. Introduction

There is a broad range of applications for mixer devices including communication and data transceivers, radar systems and test and measurement instruments. The operational bandwidth requirement of such systems is rapidly expanding into the millimeter wave frequency range. The emerging applications may require tens of gigahertz of bandwidth. Consequently, there is demand for frequency conversion devices capable of converting a very broadband millimeter wave input signal into a multi-decade bandwidth IF signal for the purpose of signal processing. Some of the other key requirements include low and flat conversion loss, good linearity and spurious performance.

Most of the uniplanar millimeter wave single balanced mixers reported so far have been limited in IF bandwidth due to the restriction imposed by the various planar architectures [1] [2] [3] [4]. This paper presents a ultra-broadband uniplanar mixer design capable of down-converting a wideband millimeter wave signal 33.5 GHz to 67 GHz. With local oscillator at 67.5 GHz, IF bandwidth of 0.5 GHz to 34 GHz has been achieved. This configuration represents the widest IF bandwidth ever reported in this frequency range of uniplanar mixers in addition to low conversion loss of 9dB with flatness of + 2dB. Second and third order spurious rejection is better than 40 dBc typically. OIP3 value greater than 0 dBm was measured across most of the band.

II. Mixer Design

A simplified schematic of the single balanced mixer is shown in Fig. 1. The complete mixer consists of three parts:

1. Ultra-broadband CPW to Slotline balun
2. Beam-lead diode tee with slot line RF input to CPW IF/LO
3. Non-Contiguous Diplexer for LO input and IF output.

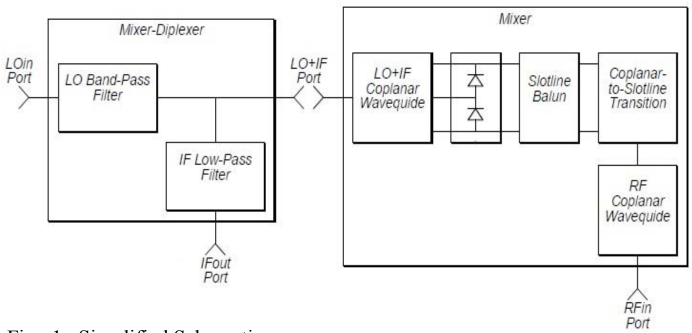

Fig. 1. Simplified Schematic

A. Ultra-broadband CPW to Slotline balun design

The balun consists of a CPW to Slotline suspended transition implemented on 10 mil Alumina with Er of 9.9. A single-ended RF signal propagating along the input CPW is launched into the slotline balun using a coplanar waveguide-to-slotline transition.

The ground plane of the CPW transitions into one of the slotline metal conductors as shown in figure 2. The ground planes are stitched with bondwires to prevent any degenerate slotline modes from propagating in the CPW. The signal conductor of CPW is converted into the second metal conductor of the slotline. The mode conversion from CPW to slotline is accomplished using the open circuit structure. The 3D model is shown in figure 2 and its S-parameter simulation response is shown in figure 3.

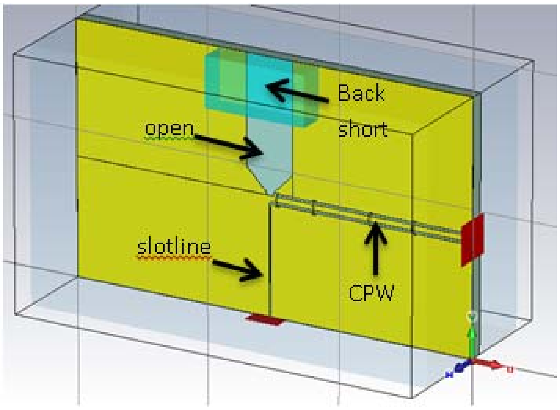

Fig. 2. 3D model of the balun

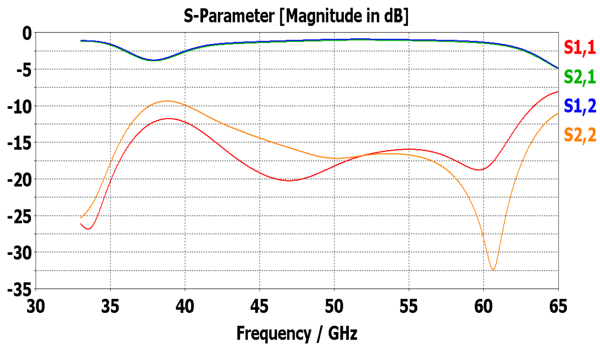

Fig. 3. S-parameters of 3D model of the balun

B. Beam-lead diode tee with Slot line RF input to CPW IF/ LO

A Metelics MGS903 GaAs schottky beam-lead diode-tee IC with Rs = 7ohms, Cj =0.6pF (GB310) constitutes the mixer core and is connected across two slot conductors. The output coplanar waveguide connects to the junction of the diode tee into which LO signal is fed and from which IF signal is extracted. The RF to LO isolation is enhanced due to the fact that LO signal is applied to a virtual ground point for the RF balun and by terminating the slotline into high impedance slotline gap at the junction of the output CPW as shown in figure 4.

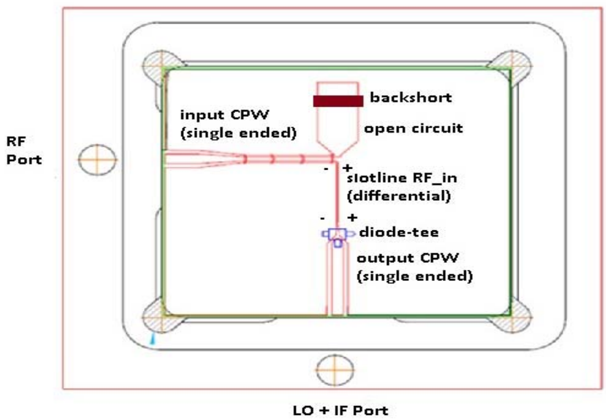

Fig. 4. Mixer diagram with diode tee

The back-short is a gold ribbon bridge that is placed across the open circuit. The RF bandwidth of the mixer structure is also enhanced by optimizing the position of the back-short on the open circuit as highlighted in figure 2.

C. Diplexer for LO in and IF out

The frequency separation of LO and IF signals is done by means of a stand-alone three-port non-contiguous diplexer [5]. The diplexer is implemented on Suspended Stripline (SSL) technology with 5 mil dielectric substrate (Er = 2.1).

As shown in figure 5, the common port of the diplexer connects to the output CPW of the mixer and passes the LO and IF signals. The low-pass filter of the diplexer outputs the IF signal from the mixer and the bandpass filter allows the LO signal into the mixer. The diplexer was designed and simulated in CST, with its measured response displayed in fig 6.

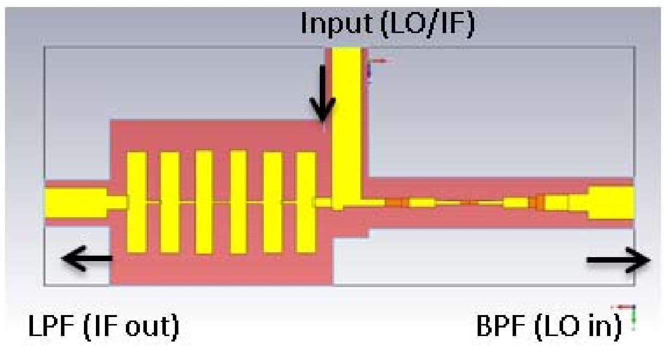

Fig. 5. 2D layout of the diplexer

The lowpass section of the diplexer is designed using a 13th order stepped impedance filter synthesized by implementing series $\frac{\lambda}{8}$ high impedance and shunt $\frac{\lambda}{2}$ low impedance resonators. The bandpass section is implemented using five

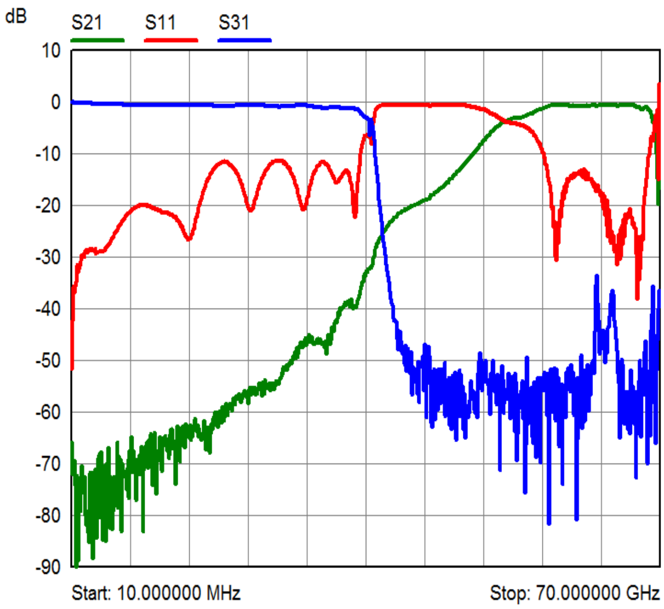

Fig. 6. Measured result of the diplexer

broadside coupled sections.

As shown in figure 6, LO to IF leakage is suppressed by 60dBc, with less than 1dB loss in the lowpass (IF) and bandpass (LO) bands. The SSL nature of the diplexer design provide an advantage of high Q and minimal loss in the passband.

III. FABRICATION

The mixer is shown on the right side and the diplexer on the left side of the figure 7. Gold plated brass was used for the mechanical housing and recessed cavities. High frequency microcircuits require high accuracy machining of the mechanical cavities and tight tolerance etching of the PCB. Mechanical machining accuracies better than 0.5 mils and PCB etch tolerance of better than 0.5 mils were held in order to achieve a good correlation between simulated and the measured results.

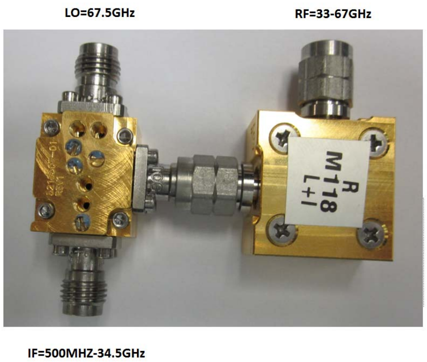

Fig. 7. Mixer and Mixer-diplexer modules

IV. MEASURED RESULTS

Conversion loss of the mixer was measured using a calibrated Agilent 70GHz N5227 PNA. Figure 8 shows measured conversion loss data of the mixer. External LO source was set at fixed 67.5GHz with power of +17dBm. Input RF frequency was swept from 33GHz to 67GHz, with fixed power of -12dBm.

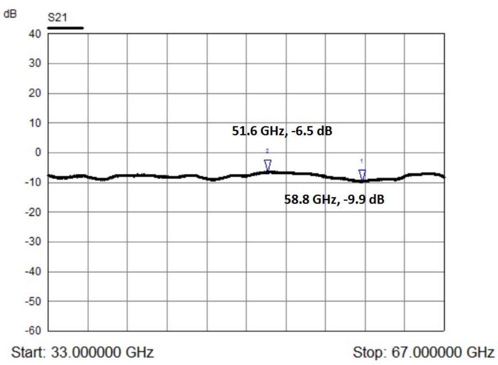

Fig. 8. Conversion Loss (dB) vs. RF Freq. (GHz)

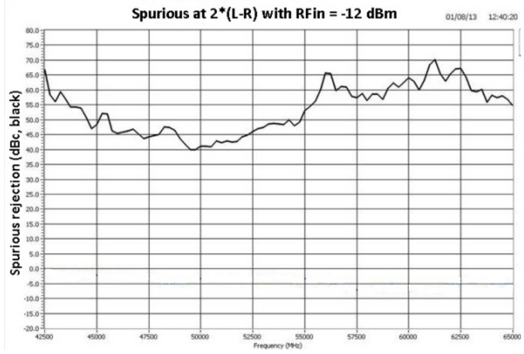

Fig. 9. 2x(L-R) spurious rejection (dBc) vs. RF Freq. (MHz)

Spurious rejection of better than 40 dBc at 2R-L and 2L-2R (figure 9) was measured across the band with RF input level of -12 dBm. OIP3 of -1 +/- 2dBm was obtained across the band as shown in figure 10.

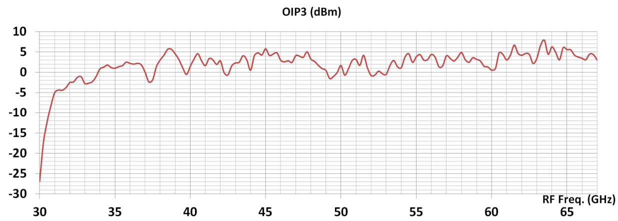

Fig. 10. Output IP3 (dBm) plot vs RF. Freq. (GHz)

V. APPLICATION

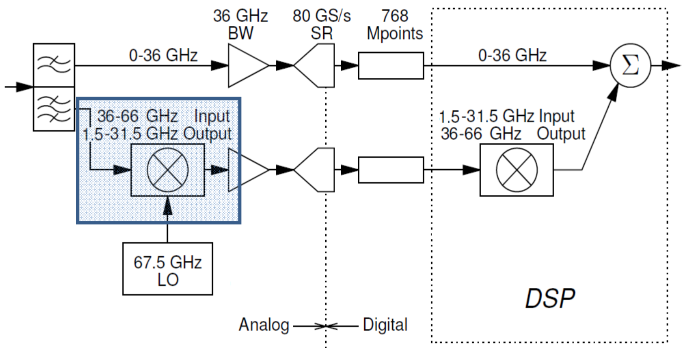

Fig 11. DBI System block diagram.

One of the applications for such a wideband mixer is in high frequency real-time oscilloscopes. In a Digital Bandwidth Interleaving (DBI) system (Fig. 11) used in such scopes, the total band of interest is divided into two bands by a diplexer in the analog microwave front-end. The higher band is first down-converted with minimum loss and distortion before digitization whereas the lower band is directly digitized, as shown. The digitized bands (higher and lower) are then stitched back to recreate the time domain signal. In the DBI block diagram shown [6], the band from 36 – 66 GHz is down-converted by the mixer presented here using a fixed high side LO signal at 67.5 GHz. The down-converted signal of 31.5 - 1.5 GHz is then amplified, digitized and used to recreate the real-time signal.

VI. CONCLUSION

This paper describes an ultra-broadband uniplanar mmw mixer on a 10 mil alumina using a CPW-Slotline-SSL architecture. This mixer covers an IF bandwidth of 0.5 to 34.5 GHz which is the highest reported to date for RF frequency up to 67 GHz. Excellent spurious performance of better than 40 dBc and OIP3 of 0 dBm has been measured across the band.

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