Ka Band Direct Modulation using Sub Harmonic Mixer for Satellite Application

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Abstract

In this paper, a Ka-band direct modulator using sub-harmonic mixer is designed and analysed. The design and development of inexpensive, high power LO sources is one of the major challenges for researchers. Ka-band direct modulator comprises of Wilkinson power divider, Lange coupler, Sub-harmonic mixer using APDP and Micro-strip filters. Rigorous analysis and design techniques were used to design all components. A sub-harmonic mixer operates at half the LO frequency eliminating the need for frequency doublers, a filter and an amplifier at LO circuit. It also provides better conversion loss with very good isolation as shown in results. It rejects fundamental and other odd harmonic mixing products as well as even harmonic of LO. Coupled line topology was selected to get sharp cut off in minimum length of the circuit and for its compactness. Direct I/Q Ka-Band QPSK modulator works for data range of 50-100 Mbps. It has image rejection better than –25 dB over the RF frequency 29.875 GHz band and a better conversion loss of –8 dB for LO frequency of 14.3575 GHz. Here QPSK technique used two BPSK modulator systems to get various advantages related with data rate and bandwidth.

Key Words: I/Q Modulator, Ka-Band, Sub-harmonic mixer, satellite applications.

1. Introduction

The paper introduces a sub-harmonically pumped I/Q vector modulator using direct modulation technique. Direct modulation or Zero-IF have gained lots of importance during these years where it finds its absolute usage in on-board modulation techniques as it offers various advantages like compact size, low power consumption and high bandwidths. Zero-IF also offers other advantages like flexibility between analog and digital domain, high linearity and minimal spurious responses. However, as every coin has two sides, it offers various disadvantages like DC offset which has been taken care of. A comparison of Zero-IF with other modulation techniques like Low-IF and conventional Standard-IF is given in Table 1.

Table 1. *Difference between standard IF, low IF and zero IF*

S. No.	Parameter for comparison	Standard IF	Low IF	Zero IF
1.	DC Offset	No	No	Yes
2.	High-Q band pass filter	Required	Low-Q will work	Not required
3.	Compact Size	No	Yes	Yes
4.	Cost	Not attractive	Cheap	Cheaper
5.	Power consumption	More	Less	Lesser
6.	LO Leakage	No	Almost No	Yes
7.	Image Problem	Yes	Little	No
8.	Sensitive to IIM2 (second order inter-modulation distortion)	No	No	Yes
9.	Flicker Noise	No	No	Yes

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Sub-Harmonically pumped mixer is used as it really becomes useful at high frequencies where it is difficult to achieve required LO drive level. It allows us to use LO at half the required frequency with trade off of 2-3 dB conversion loss.

2. Architecture used for QPSK Modulator

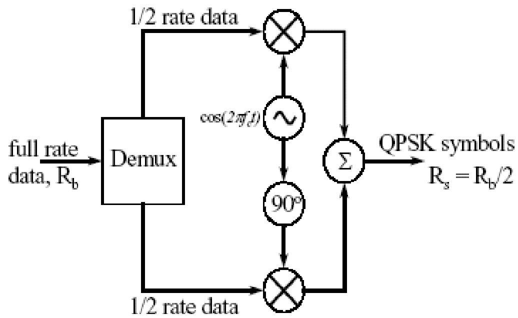

Fig 1. Original Block Diagram of QPSK Modulator

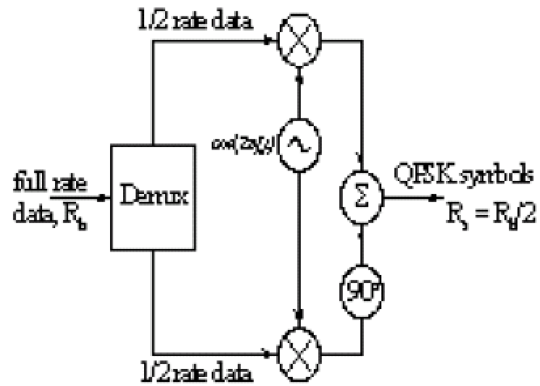

Fig 2. Modified Block Diagram of QPSK Modulator

It can be seen clearly from the above two figures that the only difference is of 90 degree phase shift which do not affect the output (can be proved mathematically) but allows us to reduce size since both phase shifting and adding function in Fig 2 can be achieved using Lange Coupler.

3. Design of QPSK Modulator

3.1 Wilkinson Power Divider

It is used to divide the input LO power into two parts for two BPSK modulators used for I and Q vectors. Insertion loss of approximately -3dB (as desired) is obtained for ports 2 and 3. Also, isolation better than –25 dB is obtained between port 2 and 3. A resistance of 100 ohm is used for this purpose between these ports. Simulated results are shown in Fig 3 to Fig 5.

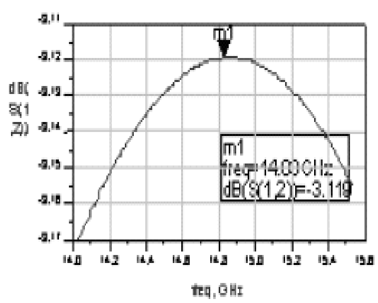

Fig 3. Insertion Loss S(1,2)

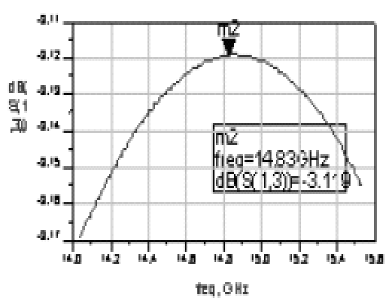

Fig 4. Insertion Loss S(1,3)

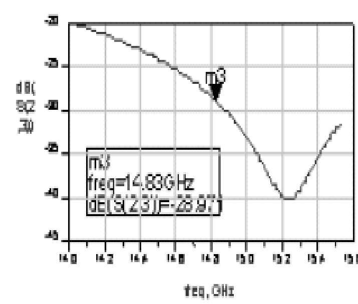

Fig 5. Isolation S(2,3)

3.2 Sub-Harmonic mixing using APDP

Mixer that is pumped at half the LO frequency to mix the incoming signal with second harmonic of the junctions conductance waveform is called a sub-harmonic mixer. The biggest advantage it provides is that it allows us to use LO at half the required frequency. The use of anti-parallel diode pair (APDP) offer several advantages like reduction in conversion loss by suppressing fundamental mixing products and low noise figure.

A generic circuit of a Schottky diode HP APDP HSCH-9251 is used which provides following advantages:

- Reduced conversion loss by suppressing the fundamental mixing products.
- Lower noise figure through suppression of local oscillator noise sidebands.
- Inherent self-protection against large peak inverse voltage burnout.

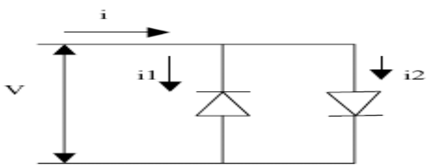

Fig 6. Anti-Parallel Diode Pair

3.3 RF and LO Filter using single section microstrip coupled line.

Here we have used single section band pass filter with center frequency 14.8375 GHz and 29.68 GHz with bandwidth 600 MHz at -40 dB rejection. Coupled line filter is compact. Width, spacing and length is calculated using

$Z_{oen, n+1} = 1/Y_o [1+(J_{n, n+1}/Y_o)+(J_{n, n+1}/Y_o) 2]$

$Z_{oon, n+1} = 1/Y_o [1-(J_{n, n+1}/Y_o)+(J_{n, n+1}/Y_o) 2]$

$J_{n, n+1}/Y_o = pi*f_{bw}/2(g_n g_{n+1})$ ½ …………………where n=1 to n+1

$J_{N, N+1}/Y_o = pi*f_{bw}/2(g_N g_{N+1})$ ½

Width and Spacing for both filters are calculated to be 0.1mm and 0.064mm respectively while length for LO filter is 1.67mm and for RF filter is 0.79316mm.

3.4 Three-Port Lange Coupler

Both operations viz. phase shift of 90 degrees and adding of signal after mixing is accomplished by using a Lange Coupler. As can be seen from Fig. 7, approximately 90-degree phase shift is obtained (as required). Fig. 8 shows insertion loss to be close to –3dB (again as desired)

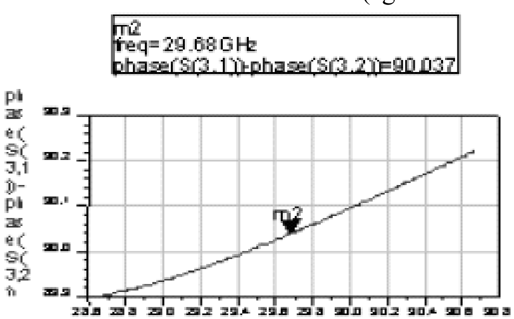

Fig 7. Phase S(3,1) – Phase S(3,2)

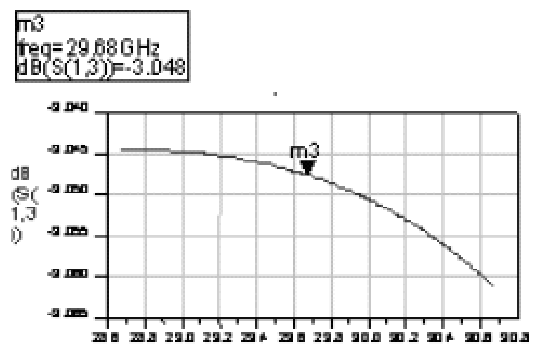

Fig 8. Insertion Loss S(1,3)

4. Simulated Results for Full Design using Agilent ADS2003A

We found very less imbalance of 0.01dBm in QPSK Modulator for upper and lower frequency of desired RF. In our design RF-upper = 2*LO+IF =29.7GHz & RF-lower = 2*LO-IF =29.65GHz. The RF carrier at 29.68GHz has suppression of –328.65dBm. LO Leakage is approximately –67.282dBm is obtained which offers the advantage of reduced DC-offset and low LO-Leakage.

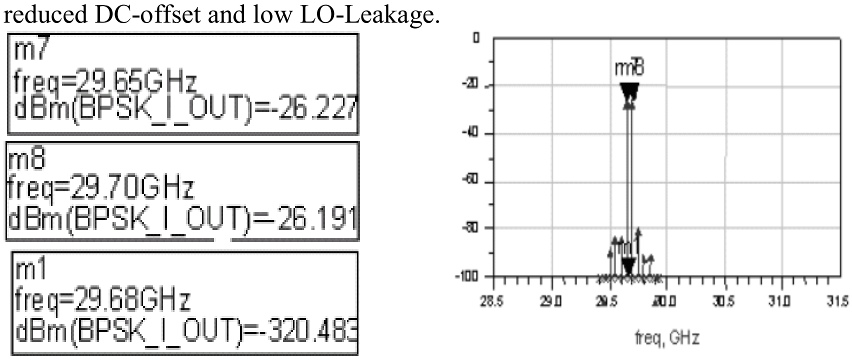

Fig 9. Imbalance for first BPSK input (I-Vector)

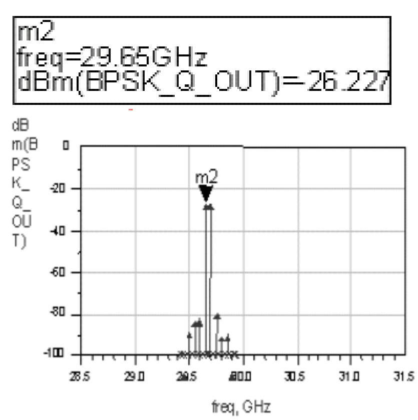

Fig 10. Imbalance for second BPSK input (Q-Vector)

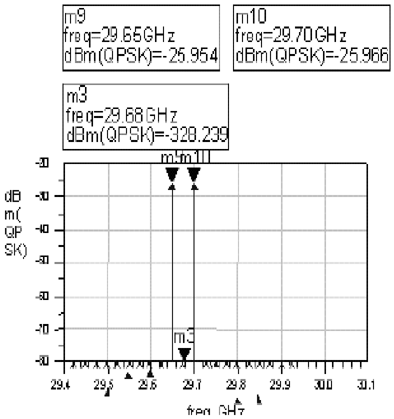

Fig 11. Imbalance for QPSK

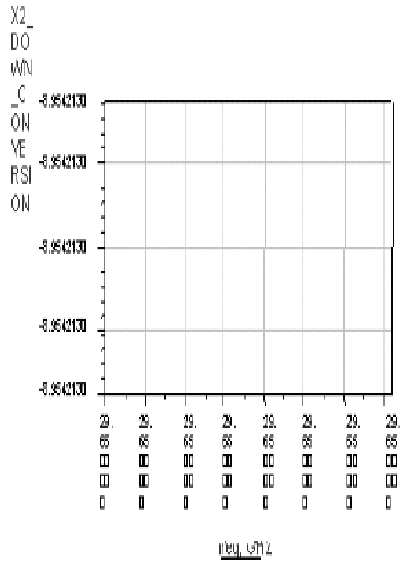

Fig12. Conversion Loss - QPSK

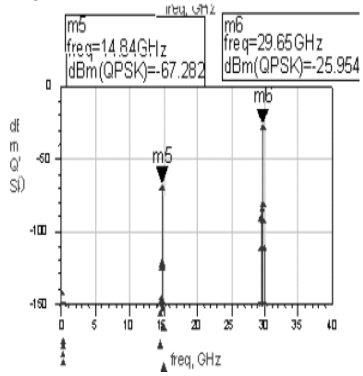

Fig 13. LO Leakage - QPSK

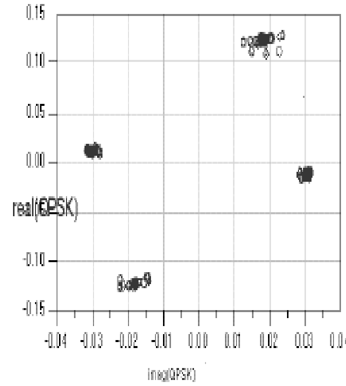

Fig 14. QPSK Spectrum of I/Q Vector Modulator

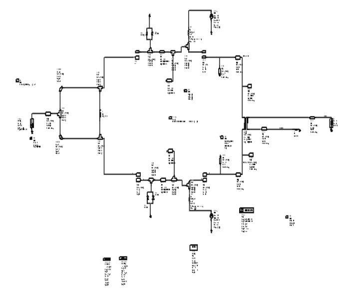

Fig15.ADSSchematic

5. Conclusion

A sub-harmonically pumped I/Q vector modulator is designed and analysed for Ka-Band. This design is aimed for satellite communication applications.

6. References

[1] Carchon, G.J.; Schreurs, D.M.M.-P.; de Raedt, W.; Van Loock, P.; Nauwelaers, B.K.J.C, A direct Ku-band linear subharmonically pumped BPSK and I/Q vector modulator in multilayer thin-film MCM-D, Microwave Theory and Techniques, IEEE Transactions on Volume 49, Issue 8, Aug. 2001 Page(s):1374 – 1382

[2] Bhattacharya A. N., Srivastava S. M., Garg V. K., Spurious and LO Harmonic Rejection in a balanced sub-harmonic mixer at Ku-band for satellite transponder, Asia Pacific Microwave Conference 2004.

[3] Philibert, W.; Verbiest, R., A sub-harmonically pumped I/Q vector modulator MMIC for Ka band satellite communication, Radio Frequency Integrated Circuits (RFIC) Symposium, 2000. Digest of Papers. 2000 IEEE 11-13 June 2000 Page(s):183 – 186

[4] Gupta Sanjeev, Batra Bhupesh, Kumar Namit, A novel approach to the design and implementation of 3 dB lange coupler for MMIC Ka-Band QPSK Modulator, XXVIII General Assembly of International Union of Radio Science URSI GA 2005.

[5] Maas, S. A., Microwave Mixers, Artech House, Boston, 1993

[6] Rhea, Randall W, HF Filter design and computer simulation, Noble Publishing Atlanta, 1994

[7] G. Matthaei , L. Young and E. M. T. Jones, Microwave Filters, Impedance-Matching Networks, and Coupling Structures. New York: McGraw-Hill, 1964.