Direct QPSK Modulator for Point-to-Point Radio Link at 23 GHz

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Abstract – **In this paper design and characteristics of a simple direct QPSK modulator for terrestrial point-to-point radio link is presented. This modulator enables compact, low cost and high efficiency transmitter. Good sideband suppression, greater then 25 dB is obtained in frequency range 21.0 to 24.0 GHz, without tuning. The insertion loss is less than 8 dB in 3-GHz bandwidth and the carrier suppression is about 22 dB.**

Keywords – **Branch-line coupler, Wilkinson divider, Schottky barrier diodes.**

I. INTRODUCTION

In this work the design of direct QPSK modulator for a new generation of a digital microwave links at 23 GHz is presented. The trend in terrestrial telecommunications is to increase the spectral efficiency and transmission capacity, which is illustrated with the requirements for RF spectrum mask and channel spacing (Fig. 1.) issued by the European Telecommunications Standards Institut [1]. In order to meet these requirements sophisticated amplitude and phase modulation techniques (QPSK, 16, 64 QAM) have to be used.

In modern wireless systems heterodyne solution for modulation and demodulation is being replaced by direct or homodyne modulation and demodulation which, gives the advantage of the suppression of the IF circuits (low costs, system simplification, reduced assembly). Conventional transmitters usually require an IF modulator followed by complex chain of mixers, filters and amplifiers. If a microwave mixer is used to up convert the modulated signal from a low frequency to the transmission frequency, it is impractical to filter out the unwanted sidebands and leakage of LO signal. Therefore, a direct modulation seems to be a very attractive means of realizing low-cost transmitter, especially at millimeter-wave frequencies where cost remains a major factor restricting the widespread use of wireless systems.

II. MODULATOR DESIGN

The configuration of QPSK modulator consisting of two balanced mixers, power divider and branch-line coupler is shown in Fig. 2.Carrier signal is applied to the divider which drives the LO ports of the two mixers.

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Quadrature signals (I, Q) of equal amplitude are applied to the IF ports of the mixers. Outputs of the mixers are then combined through the 90^0 hybrid where either the upper (f_c+f_{IF}) or lower (f_c-f_{IF}) sidebands cancels at the hybrid output while other sideband adds. The sideband that adds is determined by which IF input leads or lags the other, or which of the branch-line input ports is terminated with 50 Ω

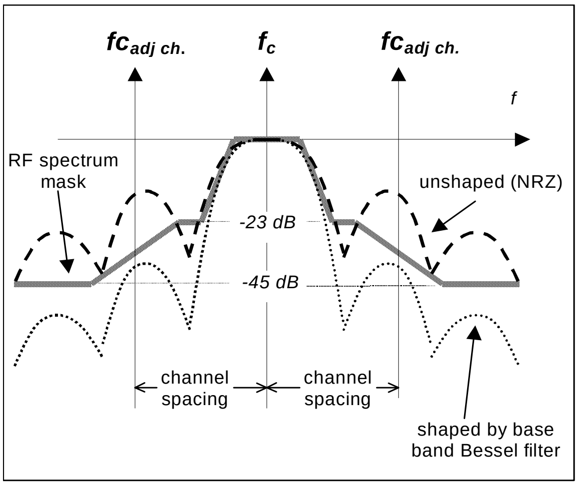


Fig. 1. RF spectrum mask issued by ETSI 198 300 standards

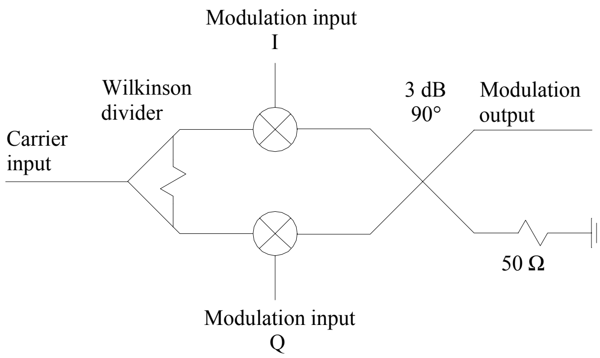


Fig. 2. Block diagram of QPSK modulator

In this configuration, carrier suppression is directly related to the LO/RF isolation of the mixers, while undesired sideband suppression is related to the amplitude and phase balance of the mixers, Wilkinson divider and branch-line coupler.

Modulator presented here is designed as a double-sided integrated circuit, which consists of microstrip lines, slot lines and CPW. Microstrip lines are on the top side of the modulator in order to facilitate integration with adjacent circuits realized with microstrip lines as power amplifiers at the output port and frequency doubler at the carrier port. Modulator has the following advantages:

1. high isolation between carrier input and modulated output port is obtained due to unique feature of slot ring which is fed by microstrip and slot lines[2],
2. a DC return path is not required because slot lines are used,
3. for a base band input circuit, simple configuration achieved with only a wire soldering is sufficient.

Modulator is fabricated on RO 3010 substrate ε_r=10.2, h=0.254 mm using four matched Si- Schottky barrier diodes MP 2X6903. The key components, which are responsible for amplitude and phase balances: Wilkinson divider and branch-line coupler are designed using electromagnetic simulator package IE3D[3]. Characteristics of these components are optimised in frequency range 22.0 GHz-23.6 GHz.

Photograph of the realized QPSK modulator (22.3 X 18.1 mm) is shown in Fig. 3. Carrier (LO) and output ports as well as Wilkinson divider and branch-line coupler are on the top side of the modulator. The I and Q ports, two mixers and simple notch filters designed to suppress carrier signal, are on the bottom side of the circuit.

III. MEASURED PERFORMANCE

In order to check amplitude and phase balance at I and Q arms, the QPSK modulator is tested as a demodulator. Measurement is performed by automated test equipment in frequency range 21.0 GHz to 24.0 GHz. Two RF signals, whose frequencies are mutually shifted for 2 MHz, are applied at carrier and modulated ports of the modulator. The carrier level during the measurements was 10 dBm.

Modulator is measured both, with carrier signal applied at Wilkinson divider and with carrier signal applied at branch-line coupler. Measured amplitude and phase balances are shown in Fig. 4. and Fig. 5. respectively.

Amplitude unbalance is less then 0.5 dB for both cases while phase unbalance is smaller with carrier signal applied at branch-line coupler and less then 7^0 in frequency range 21.0-24.0 GHz. According to simple analysis[4] this will result to sideband suppression greater then 24 dB in the whole frequency range.

Spectrum of the modulated signal at 23 GHz with 10 dBm carrier level is shown in Fig. 6. The Q-port and I-port are excited with a regular periodic waveforms either 1 or –1 with a duration of T=454 μs. Amplitude of a modulated signal is adjusted to Upp=0.8 V (+2 dBm) in order to provide a maximum carrier suppression. After accounting for a total IF input power of +5 dBm and test cables losses, the conversion loss calculates to less then 8 dB. Carrier and sideband suppression are approximately 15 dB and 27 dB, respectively.

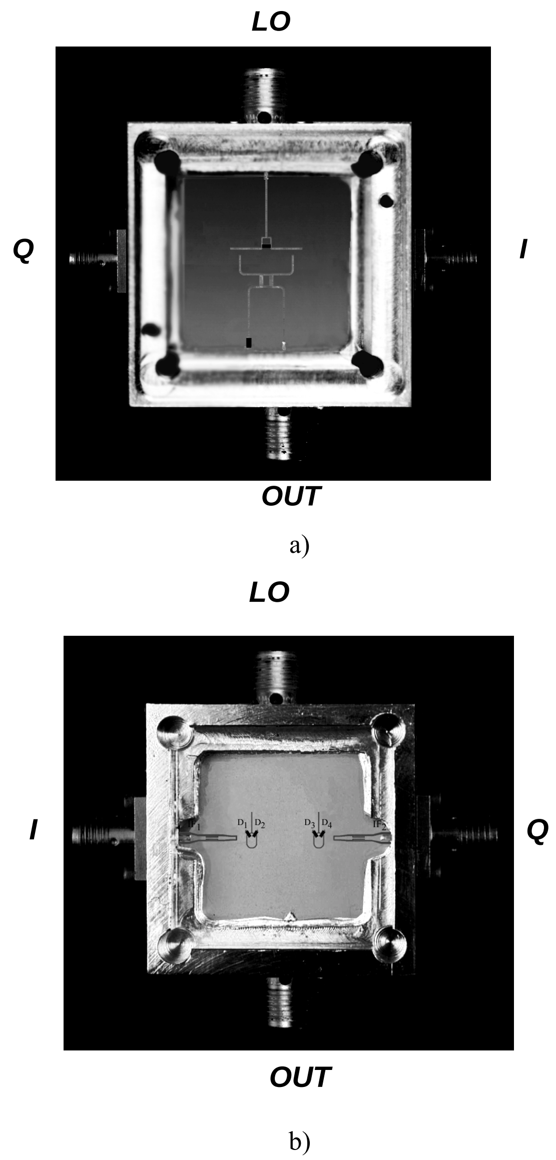


Fig. 3. Photograph of QPSK modulator: a) top view, b) bottom view

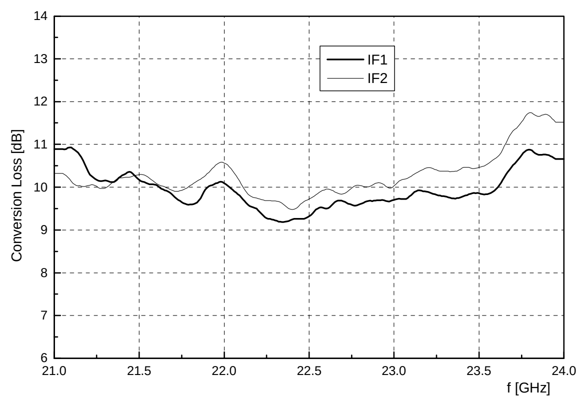


Fig. 4. Amplitude balance with carrier signal applied at Wilkinson divider

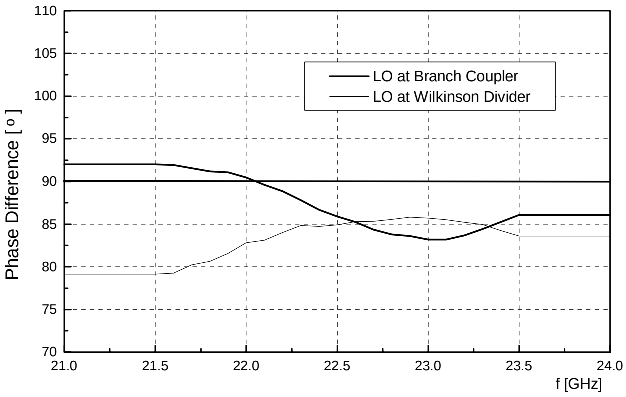


Fig. 5. Phase balance with carrier signal applied at: a) Wilkinson divider and b) branch-line coupler

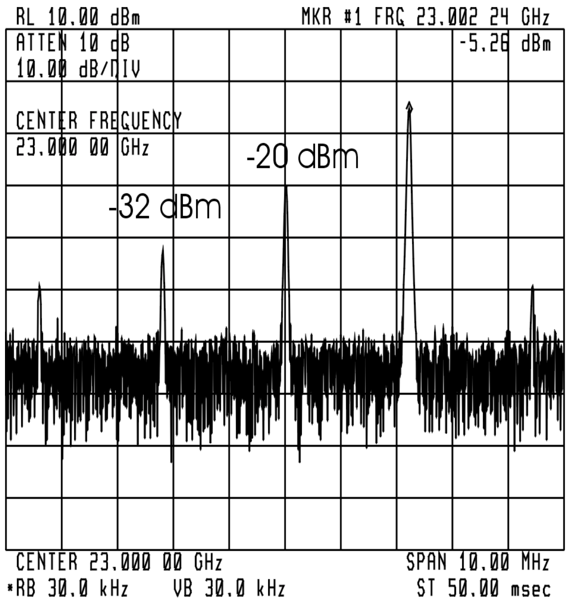


Fig. 6. Spectral plot of the output signal at 23 GHz modulated with periodic train of pulses

Spectral performance of the modulator driven with shaped pseudo-random bit stream (Upp=0.4 V) is shown in Fig. 7. Two 4 Mbit/s data bit streams, one of which is delayed for half of the pulse duration with respect to the other, are applied at I and Q arms. It is seen that spectrum of O-QPSK modulated signal meets the RF mask requirements (Fig. 1.). First lobes are 26 dB suppressed with respect to the maximum and first nulls are well marked. If the amplitude of modulation signals increases (Upp=0.6 V), the spectrum of the output signal is degraded as it is shown in Fig. 8. First lobs are about 23 dB below the maximum and required RF spectrum mask is not satisfied.

Direct QPSK modulator is integrated with power amplifiers at the output port and with frequency doubler at the carrier port.

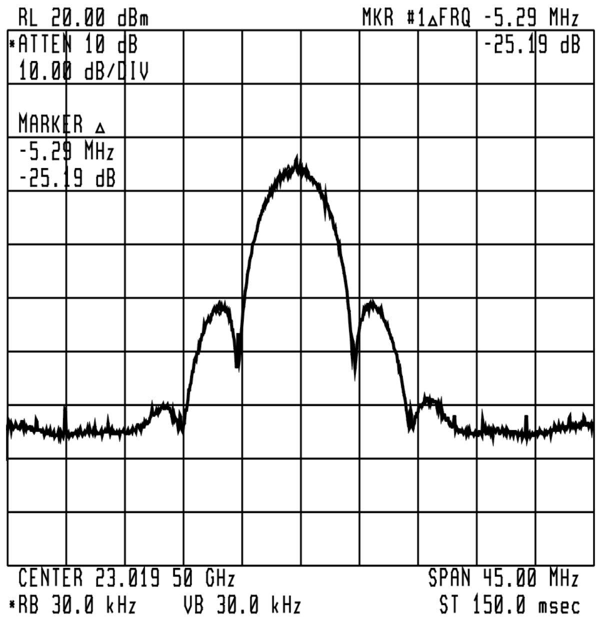


Fig. 7. Spectral plot of the output signal at 23 GHz modulated with pseudo-random data train Upp=0.4V

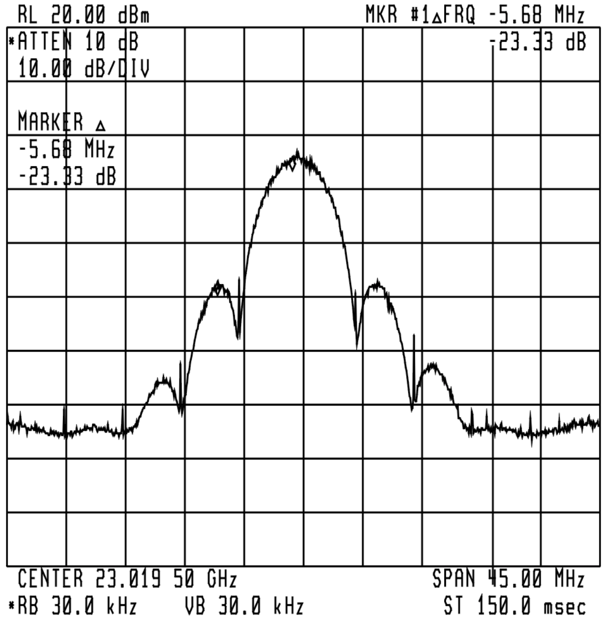
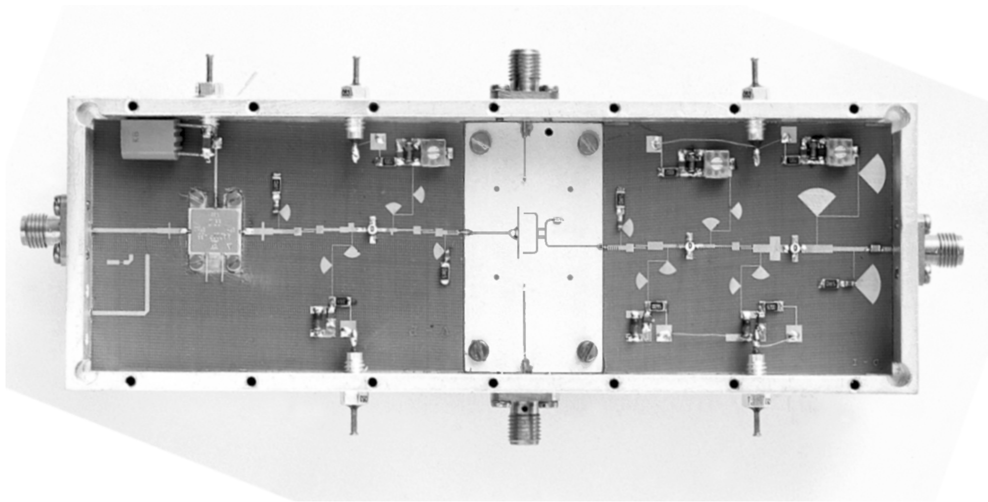


Fig. 8. Spectral plot of the output signal at 23 GHz modulated with pseudo-random data train Upp=0.6V

Photograph of an integrated transmitter for a new generation of point-to-point radio links for 8 Mbit/s data transmission is given in Fig. 9. Power amplifiers and doubler both, are fabricated on Teflon Fiberglas substrate (εr=2.17, h=0.254 mm) and consequently a width of 50Ω-transmission line is almost twice as wide as that one fabricated on RO 3010 substrate. In order to integrate circuits with different line widths a special comb transition is designed[5].



9. Photograph of the microwave transmitter

Microwave transmitters are manufactured for operation in two frequency ranges: around 22 GHz and around 23 GHz according to ITU-R recommendation for fixed radio transmission. Measured characteristics: side-lobe suppression and carrier leakage among N=48 transmitters are shown in Fig. 10. and Fig. 11. respectively.

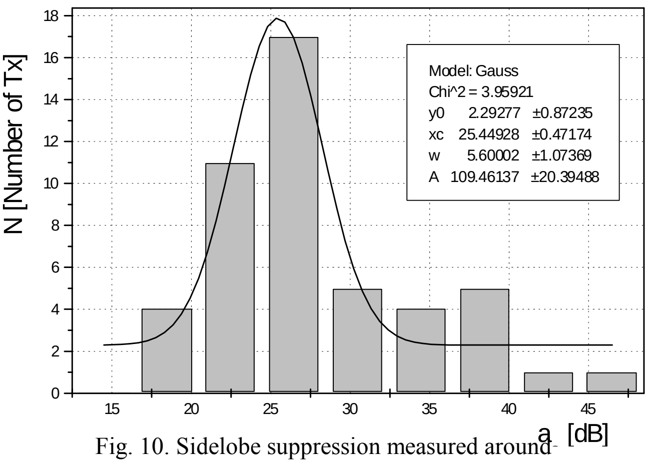


Fig. 10. Sidelobe suppression measured around 22 and 23 GHz for N=48 transmitters

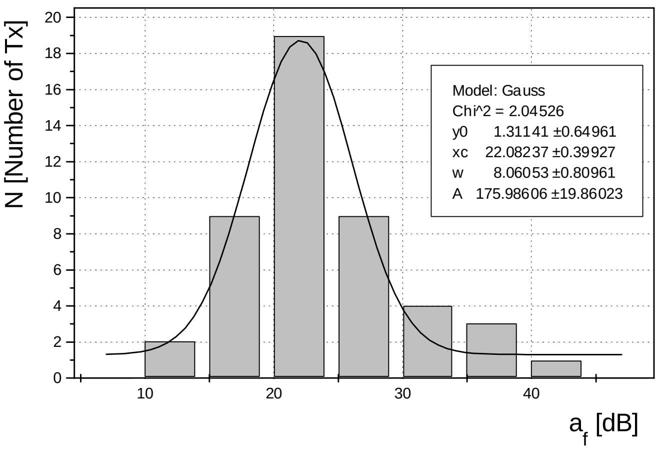


Fig.11. Carrier suppression measured around 22 and 23 GHz for N=48 transmitters

Majority of realized transmitters have side-lobe suppression greater than 25 dB and carrier suppression greater that 22 dB in both operating frequency ranges. It is possible to select transmitters for certain frequency range according to side-lobe or carrier suppression.

IV Conclusion

A simple direct O-QPSK modulator for terrestrial point-to-point radio link is designed and tested. This modulator enables compact, low cost and high efficiency transmitter. Good sideband suppression, greater then 24 dB is obtained in frequency range 21.0 to 24.0 GHz, without tuning. The insertion loss is less than 8 dB in 3-GHz bandwidth. In this modulator the carrier leakage (about 22 dB) is pretty high and it could be suppressed utilizing mixers with a greater LO/RF isolation or using subharmonically pumped mixers with unparallel diode pairs.

Acknowledgement

The authors would like to thank Ms. M. Marjanovic and Mr. M. Tasic for manufacturing of the test circuits.

References

[1] ETSI Standards CD, European Telecommunications Standards Institute, 1999.

[2] Ogawa, H., Aikawa, M. and Akaike, M., "Integrated Balanced BPSK and QPSK Modulators for the Ka-Band", IEEE *Trans. On MTT*, Vol. MTT-30, No. 3, March 1982, pp. 227-234.

[3] IE3D User's Manual, Release 4, Zeland Software, Inc. January 1997.

[4] Norton, D. E., Massa, S.A., O'Donovan, P., "I and Q Modulatiors for Cellular Communications Systems", *Microwave Journal*, October 1991, pp. 63.-80.

[5] Napijalo, V., " Comb Transition", to be published