BAT15-04W

The Low Barrier Schottky Diode BAT15-04W as a Mixer for Ku-Band LNBs

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1 Introduction

This application note shows Infineon's BAT15-04W low barrier Schottky diode used in a singly balanced mixer for Ku-band applications. The frequency band covered in this report is the high band from 11.55 GHz to 12.75 GHz.

A functional block diagram of a universal LNB is shown in Figure 1. The building blocks for which Infineon offers devices are depicted in red.

The abbreviation H (horizontal) and V (vertical) represents the electrical polarization of the electromagnetic wave transmitted by the satellite. At first the received linearly polarized wave is amplified via a multistage amplifier chain and afterwards down converted by the active mixer. The IF signal is further amplified so that the following data processing can be applied.

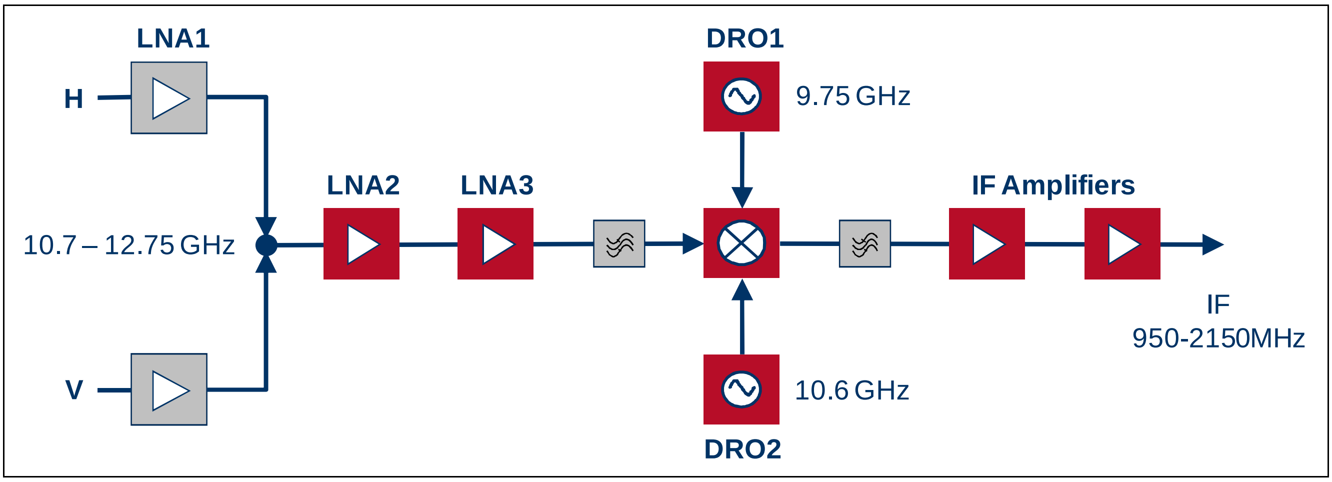

Figure 1 Blockdiagram of a universal Ku-Band LNB

An overview of the occupied frequencies is shown in Table 1. A graphical view of the frequency bands is depicted in Figure 2 which visualizes also the down conversion of the received RF signal bands from the RF-Lowband / RF-Highband to the IF-Band (0.95GHz to 2.15GHz). These received bands include the TV-channels which are transmitted from the geostationary satellites.

Table 1 Universal LNB specification

	Lowband	Highband	Switching Mode
LO	9.75 GHz	10.6 GHz	- Switching between the two frequency bands (local oscillators) is done by a 22kHz tone generated by the receiver when selecting a certain channel - Switching between horizontal and vertical polarization is done by the voltage of the power supply when selecting a certain channel
RF	(10.70 – 11.9) GHz	(11.55 – 12.75)GHz	

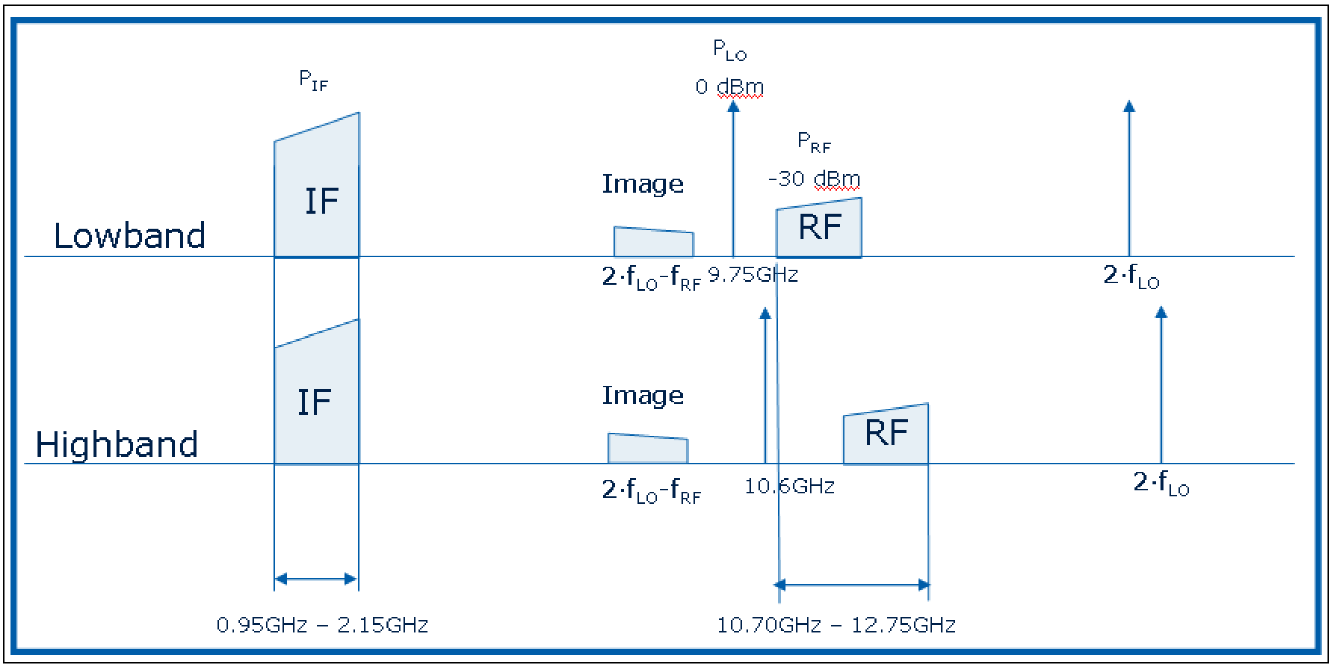

Figure 2 Specified Frequencies for LNB (Ku-Band)

2 RF Schottky Diode

The device characteristic of the Schottky diode is similar to a typical one sided abrupt pn diode which follows the same current voltage characteristic as being shown in equation (1). However, there are some magnificent differences between the pn junction diode and the Schottky diode. For example, the Schottky diode exhibits a lower forward voltage drop (0.15V to 0.45V) than the pn diode (0.7V to 1.7V). Furthermore, the voltage drop of Schottky diodes in forward direction can be adjusted by the applied contact material and also zero biased Schottky diodes can be processed based on p-doped materials.

Moreover, pn junction diodes belong to minority semiconductor devices suffering on the recombination velocity of the minority carriers in the space charge region, whereas, the Schottky diodes are controlled by the charge transport over the barrier from the majority carriers. This leads to very fast switching action of the Schottky diodes and makes it very attractive for RF application in the mm wave range like mixers.

$$I = I_S(T) \cdot \left(\exp\left(\frac{qU_d}{nkT} \right) - 1 \right) \qquad (1)$$

(k: Boltzmann factor, n: ideality factor, I_S: saturation current, U_d: voltage, T: temperature)

In normal forward operation at room temperature and moderate doping concentration ($N_d < 10^{17}$ cm^{-3}) the following charge transports can be identified:

- Transport of electrons from semiconductor over the barrier to the metal
- Tunneling of electrons through the barrier
- Recombination in the space charge region
- Injection of holes from the metal to the semiconductor

The ideality factor n corresponds to the gradient of the IU-characteristic in forward operation and can be extracted within the linear region of the log(I(U)) diagram as shown in Figure 3Figure 3. Furthermore, the nonlinear behavior of the device corresponds to the fast switching from the conductive state to the non-conductive state by the LO signal. As the ideality factor n increases, the nonlinearity of the device is reduced and the capability for frequency mixing is reduced, as well. Therefore, for mixer applications the ideality factor of the Schottky diode should be as small as possible, typically, smaller than 1.1.

The voltage dependent junction capacitance C_j follows the equation (2) with the model parameter U_j which refers to the junction voltage and M as the grading coefficient (M = 0.5 for a uniformly doped diode).

$$C_j(U_d) = C_{j0} \cdot \left(1 - \frac{U_d}{U_j}\right)^{-M} \tag{2}$$

Based on the small signal equivalent circuit the frequency conversion is also directly influenced by the serial resistance R_s and the junction capacitance C_j as shown in equation (3). Both C_{j0} and R_s should be as small as possible and this characteristic figure of merit is represented by the cutoff frequency f_c which should be as high as possible (3). The serial resistance R_s decreases and the junction capacitance C_{j0} increases by increasing the device area A so that a first order analysis shows that the cut off frequency is independent of the junction area. However, second order effects reveal that the cut off frequency can be increased by decreasing the junction area.

These and the non-linear junction capacitance C_j affect the mixer performance directly so that we have to optimize the Schottky diode appropriately in order to meet the mixer specification.

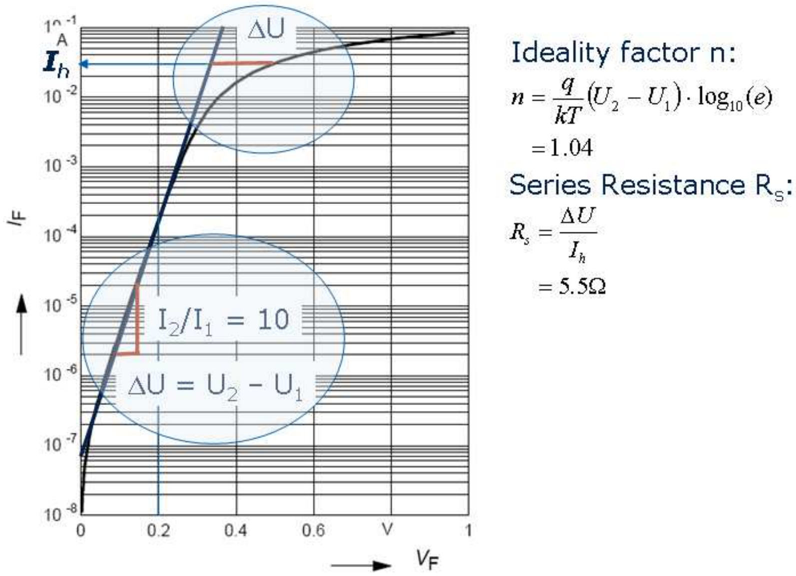

Figure 3 The serial resistance R_s causes at high currents (I_h) a voltage drop ΔU between the extrapolated straight line and the measured I(U) curve. The ideality factor n corresponds to the gradient of the IU-characteristic in forward operation and can be extracted within the linear region of the log(I(U)) diagram

3 Design concept of a singly balanced mixer

The topology of the mixer used in this concept study is shown in Figure 4. It is a simplified schematic of the schematic actually used in simulation.

The amplified RF signal and the LO signal are applied at the sum port and the delta port of a 180°-hyb rid (e.g. a rat-race coupler). The balanced LO signal at the hybrid's output drives ("pumps") the two Schottky diodes included in the BAT15-04W package. The IF signal is fed from the common pin of the two diodes though a lowpass filter to the IF output pin. Additionally a radial open stub suppresses the RF and LO signal at the IF output

Two shorted stubs are used to shorten the IF mixing products on the "RF side" of the mixer while providing a high impedance at LO and RF frequency. Shortening unwanted signal at the single ports reduces conversion loss significantly.

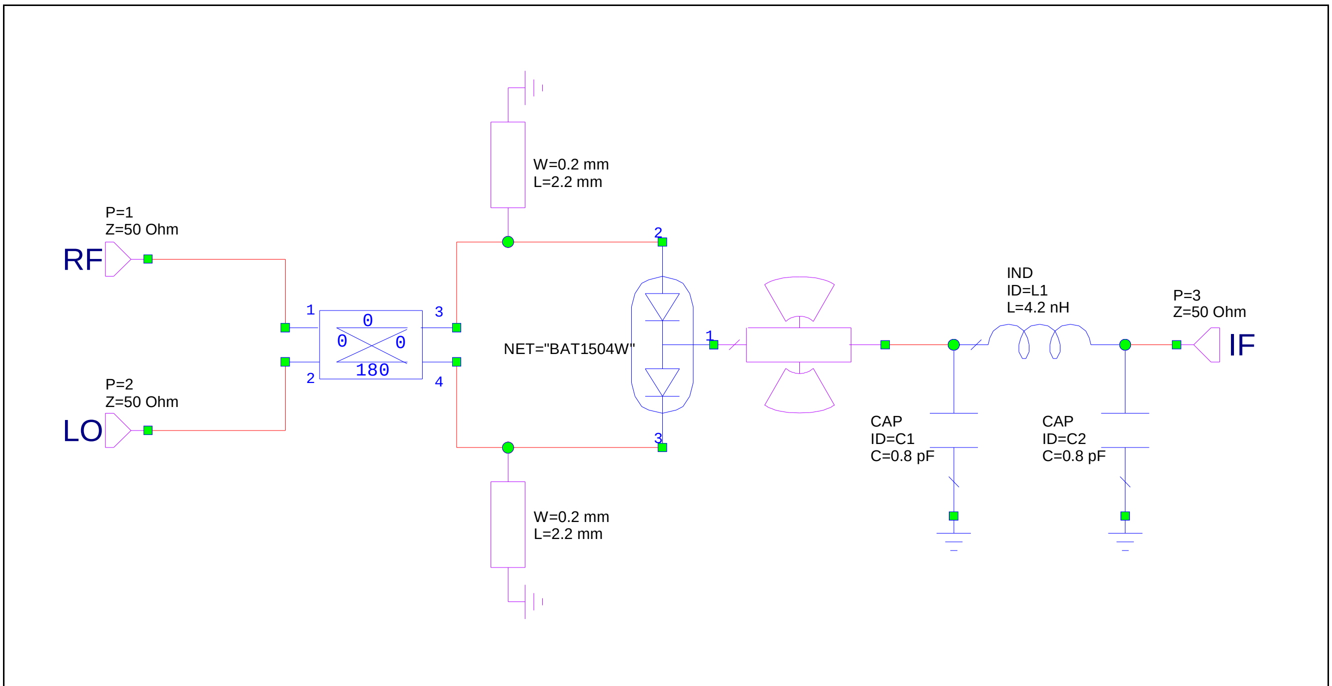

Figure 4 Mixer Topology

3.1 Simulation results

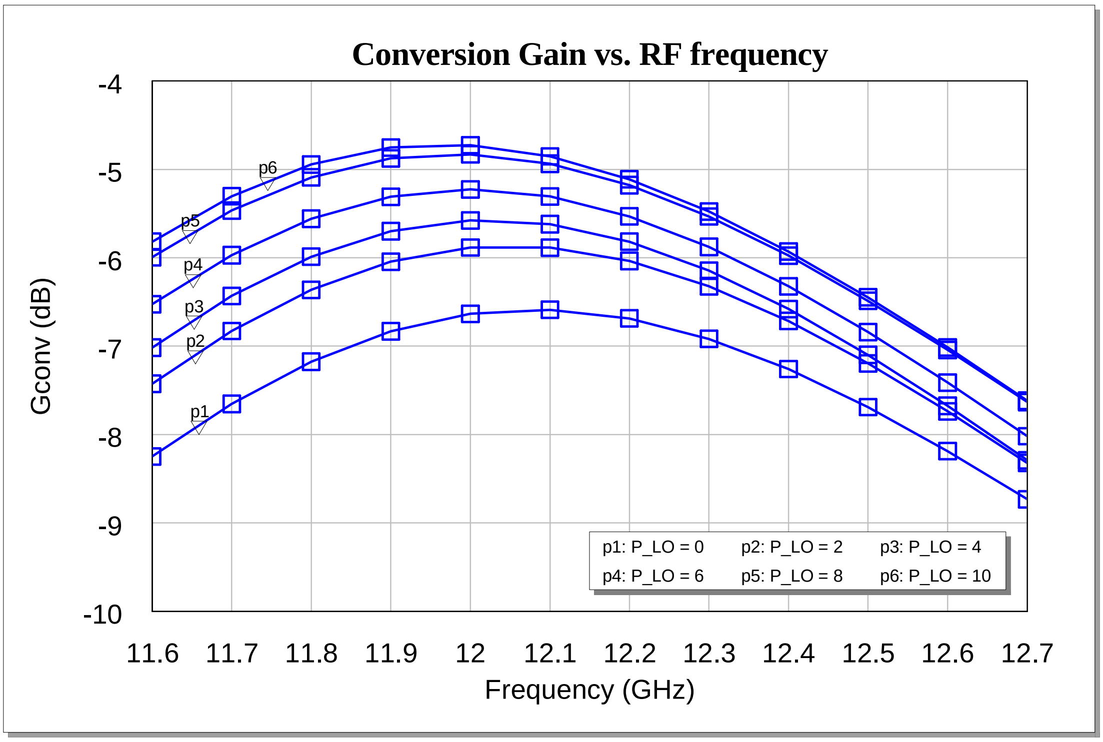

Figure 5 Conversion Gain over RF frequency with LO Power at 10.6 GHz as a parameter.

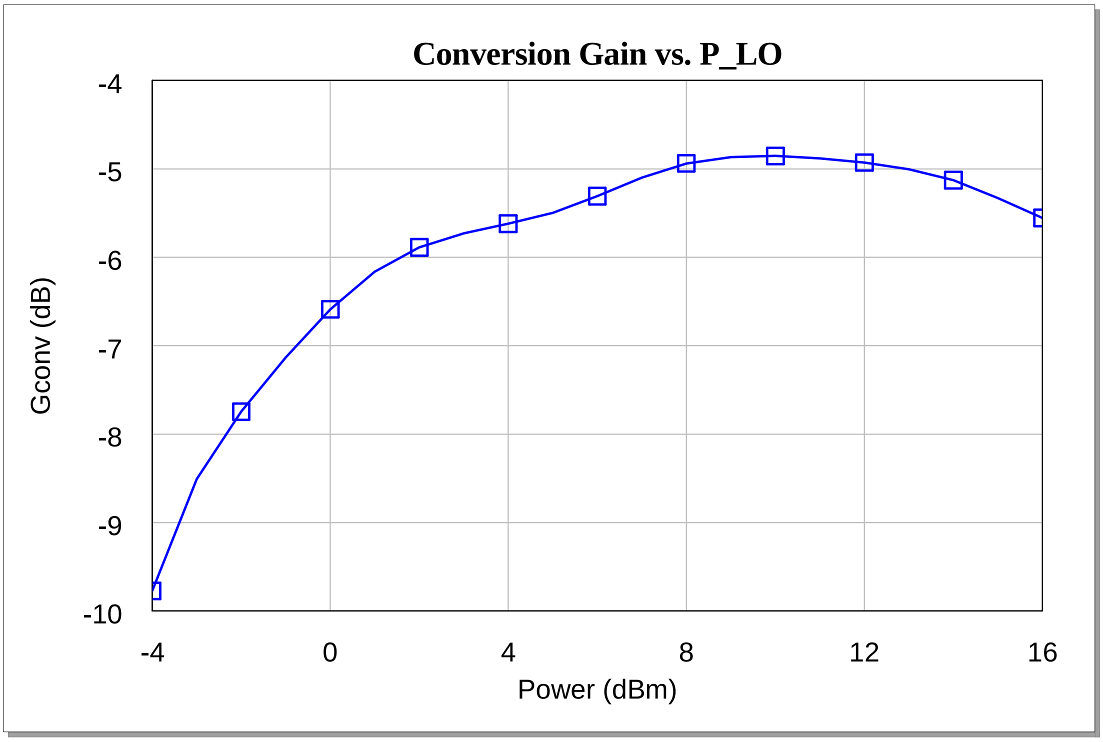

Figure 6 Conversion Gain over LO power at 10.6 GHz, RF power is -30 dBm at 12.1 GHz

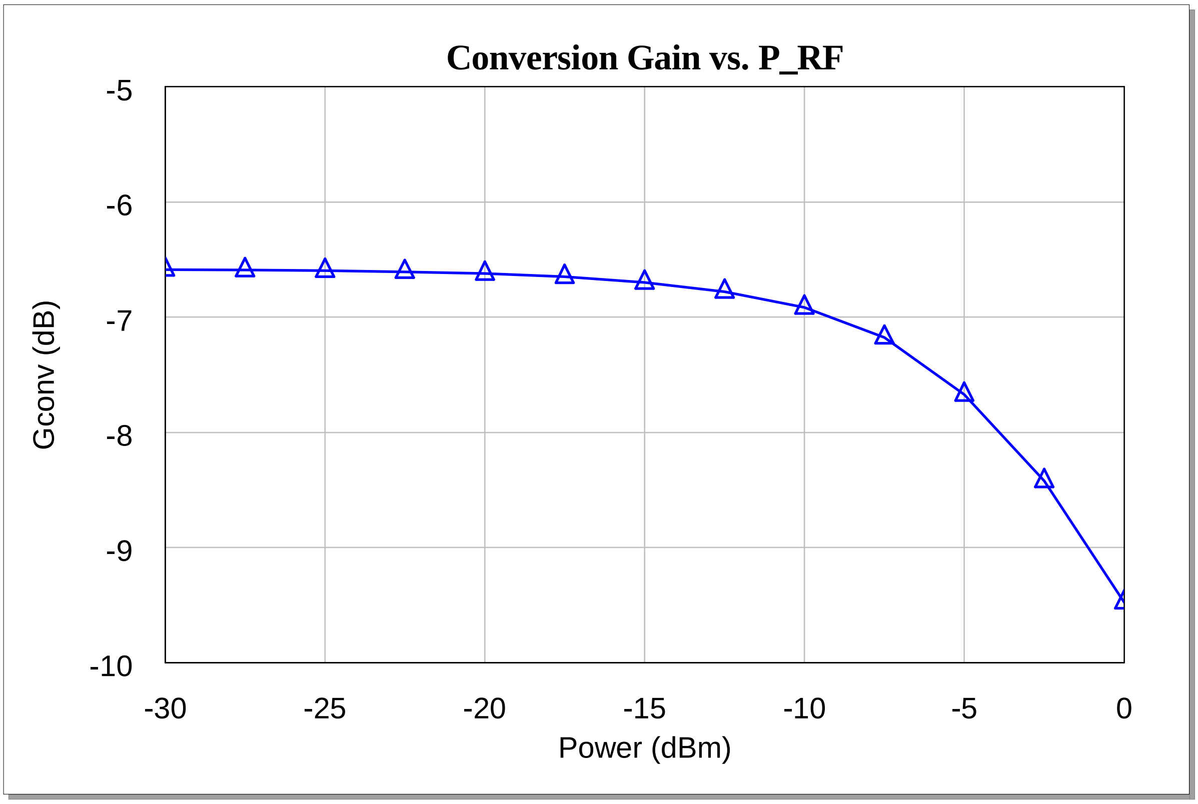

Figure 7 Conversion Gain vs RF power at 12.1 GHz, LO power is 0 dBm at 10.6 GHz

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