A 260 GHz Planar Balanced Doubler

A. Maestrini[†], M. Favreau[††], S. Toutain[†††] and G. Beaudin[†]

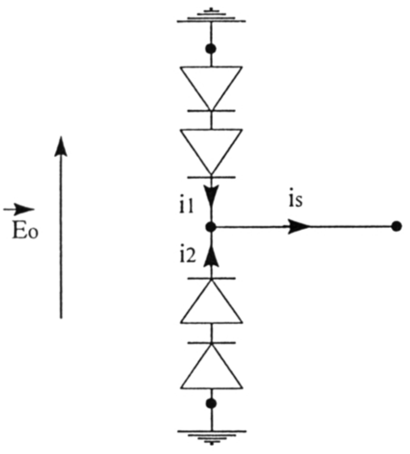
[†] DEMIRM - Observatoire de Paris, 61 av. de l'Observatoire - 75014 Paris
[††] Matra Marconi Space, 61 av. des Cosmonautes - 31402 Toulouse cedex 4
[†††] ENST de Bretagne, B.P. 832, 29285 Brest cedex

Abstract : We are developing a solid state local oscillator chain at 260 GHz for a Schottky unbiased subharmonicaly pumped mixer working at 500 GHz. The fundamental source is a wide band Gunn oscillator. The output signal is generated by a N. Erickson - like balanced planar doubler with UVa SC3T2 planar chip.
An E-H tuner located in the input wave guide, closed to the diodes, allows wide band performances and a good input matching. An ABmm millimetre vectorial network analyser was used to measure the influence of each stub on the input matching and the output power.
Measurements made with an Anritsu WR5 power sensor gave us 6.5 mW at 210 GHz and 6 mW at 261.5 GHz with one UVa SC3T2-B0 when using no isolator between the Gunn source and the multiplier. The same power sensor gave us 39 mW at 130 GHz for the Gunn source power.

1 Design

We designed a 260 GHz balanced doubler with the help of the papers and the personal advice of Neal Erickson [Erickson, 90, 93, 94, 96].

The UVa SC3T2-B0 anti parallel four-anodes chip is located inside the input waveguide. The signal generated by the diodes is coupled to a coaxial line, which inner conductor goes through the walls of the output waveguide and couples the 260 GHz signal to it.
For optimising the input matching an E-H plane tuner is added closed to the diodes (at one guided wavelength). At the output, an H-plane tuner is also added.
Thanks to the symmetry of the design, the TE_{20} and TE_{10} modes at 260 GHz cannot be coupled to the input waveguide. Only the TM_{11} mode at 260 GHz can be strongly coupled. To cut this mode, the height of the input waveguide is reduced.
Moreover, due to the balanced configuration, no odd harmonic can be generated by the chip :

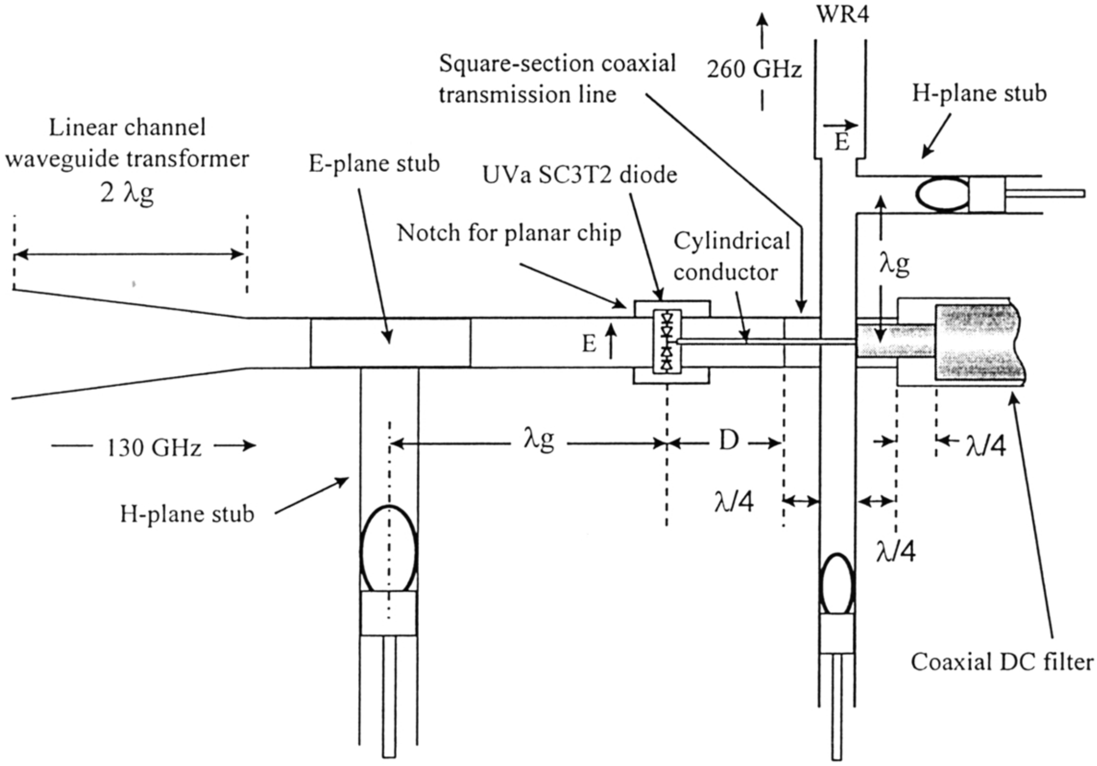


$$\begin{cases} i_1(t) = \sum_{n=0}^{\infty} a_n \cdot e^{i.n.\varpi_0.t} \\ i_2(t) = i_1(t + T/2) \quad \text{T is the period} \\ i_s = i_1 + i_2 \end{cases}$$

$$\Rightarrow i_s = \sum_{n=0}^{\infty} a_n \cdot e^{i.n.\varpi_0.t} (1 + e^{i.n.\pi})$$

$$\Rightarrow i_s = \sum_{n=0}^{\infty} a'_{2n} \cdot e^{i.2n.\varpi_0.t}$$

The main difficulty of the conception consists in designing the input cavity. Dimensions should be determined for both the pump frequency and the output frequency.
Our conception relied on the assumption that the input matching was to be cared in priority because of the high quality factor of the input cavity. As we had no possibility to do RF computerised simulations, we did not optimise the cavity for the output frequency. We chose its dimensions as small as possible to decrease the losses at the output frequency, and we considered that the output backshorts would be able to control the output matching.
We chose a simple design that was optimised thanks to a scaled model. We assumed that the dimensions of the input cavity had to be correlated much more to the frequency than to the RF parameters of the diode : we approximated the diode by a piece of dielectric and we decided to locate it where the electric field was maximum. We relied on the E-H tuner to adjust the matching.



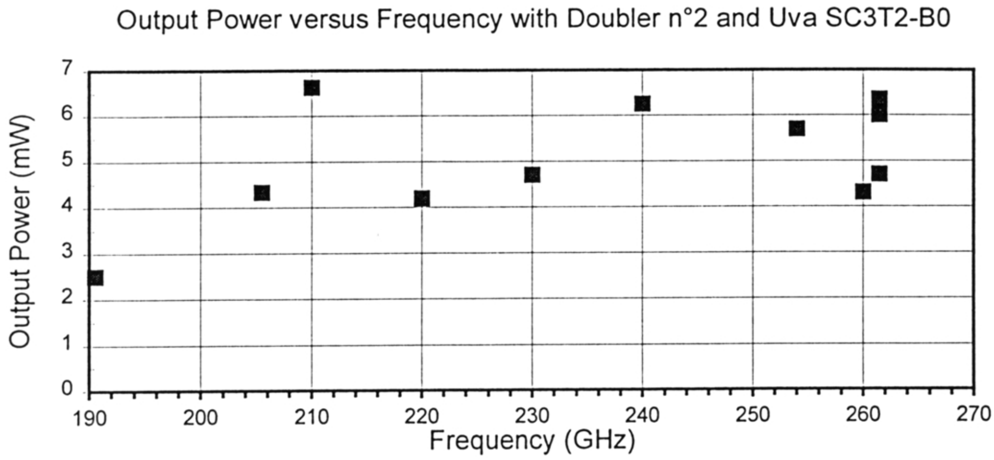
Schematics of the 260 GHz balanced doubler

2 Power performances

Power measurements were made with Anritsu TC Mount MP84B n° M06677 in WR5 waveguide standard, with an Anritsu power meter ML4803A and the adaptator MP717A n°M16265. The power sensor was connected to the WR4 output waveguide of the doubler thanks to a one centimetre long WR5 waveguide. The power meter is not calibrated above 140 GHz, so the measurements have to be taken with care.

Gunn source power : the Gunn source n° H 249 from J.C. Carlstrom was biased with 9.5 V and 0.22 A. We used a WR8 to WR6 waveguide transformer to connect it to our WR5 power sensor. We measured 39 mW at 130 GHz, that was in good agreement with the measurements made by J.C. Carlstrom.

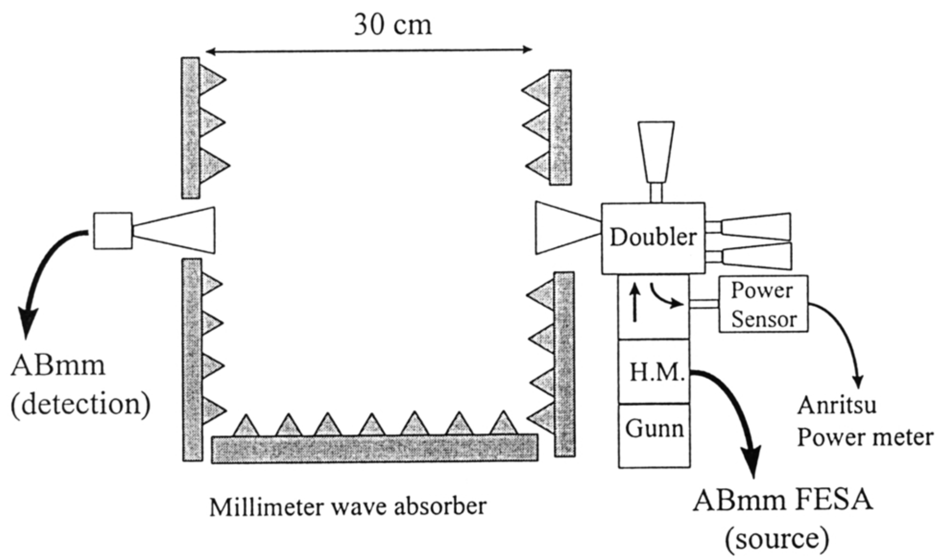
Output power : we had tested an SC3T2-BO which pad to pad capacitances were 11.5 fF and 11.4 fF (measurements made by the University of Virginia). When using no isolator between the Gunn source and the multiplier we had obtained the following results :



Without isolator, the tuning is critical and we noticed a strong dependency within the frequency. When using a narrow band circulator, we had obtained 3 mW at 260 GHz. With this doubler, we made measurements of the input matching. Unfortunately it had to be dismounted for diode replacement.
In the same doubler bloc, without isolator, an SC3T2-C0 with 14.6 fF and 14.9 fF of pad to pad capacitances, gave us 1.5 mW at 260 GHz and 4 mW at 210 GHz. This doubler was used to measure the influence of the output tuners.

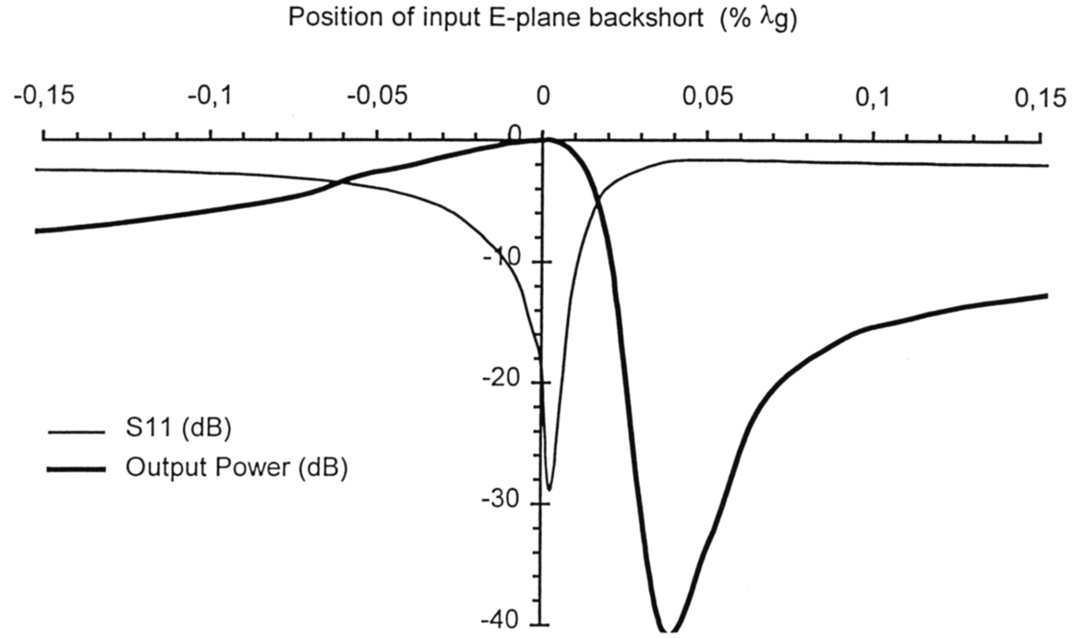
3 RF performances versus backshorts position

At 260 GHz, we used our ABmm network analyser and an WR8 Anritsu power sensor to measure the influence of the tuners on the input matching and the output power. The Gunn was isolated by a narrow band circulator. The doubler was loaded with a WR4 feed horn. The detector was a home made Schottky whisker contacted diode mixer in WR8 waveguide, loaded with a 110 GHz horn. Distance between the two horns was sufficient enough to have no standing waves (VSWR = 1.01). This distance insured a perfect linearity, a sensibility of a few 0.01 dB and a dynamic of about 50 dB. In addition phase stability was excellent (4° of derive in 2 hours at 260 GHz).

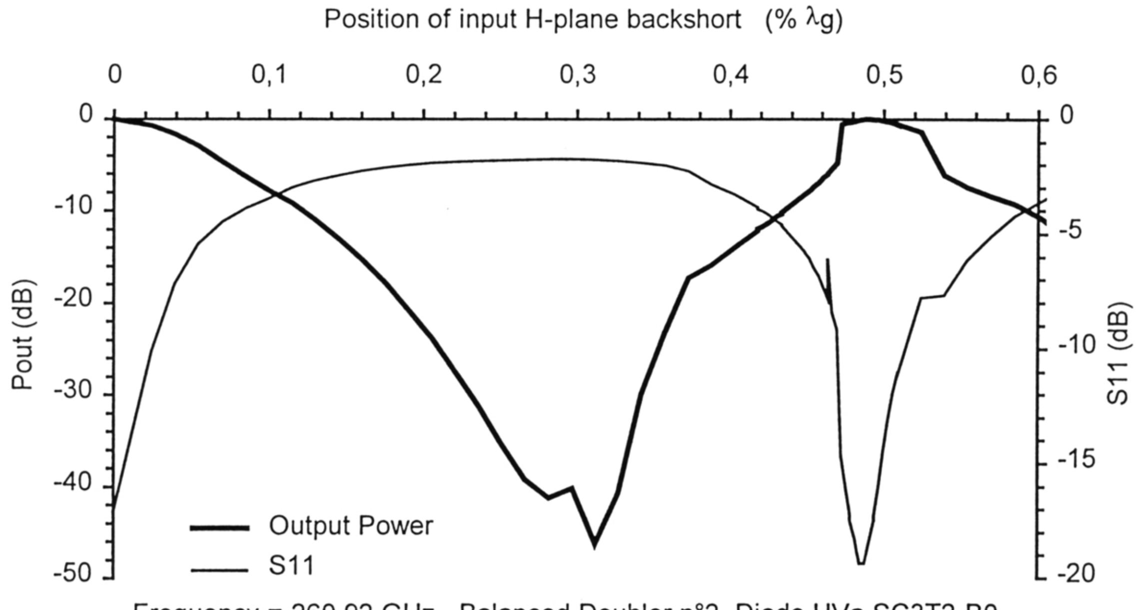


Optimisation of the 260 GHz Balanced Doubler
with ABmm Vectorial Network Analyser

In the two following experiments we have optimised doubler n°2 mounted with an SC3T2-B0 diode chip. Then, we have moved one backshort. The voltage applied to the doubler diodes was unfixed. It was dependent on the RF power coupled to the diodes.

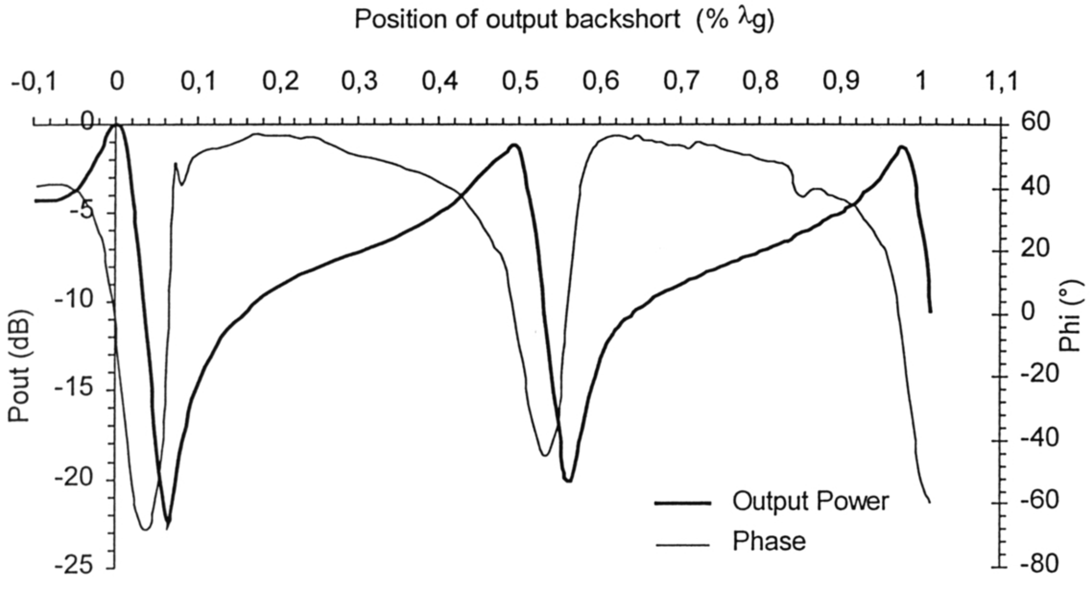


Frequency = 260.92 GHz Balanced Doubler n°2, Diode SC3T2-B0

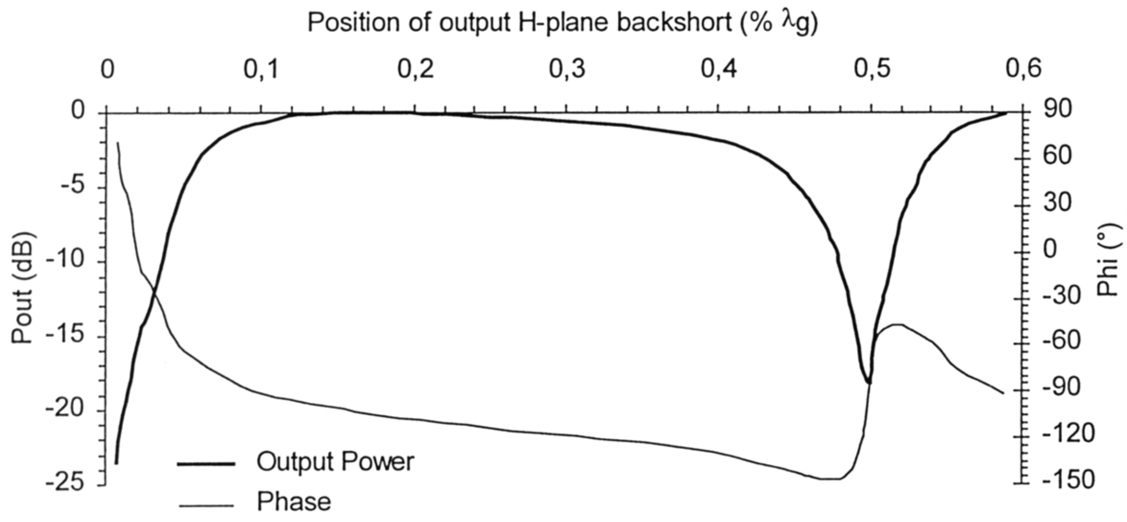


Frequency = 260.92 GHz Balanced Doubler n°2, Diode UVa SC3T2-B0

In the next two experiments, we have used the same procedure but with doubler n°2 mounted with an SC3T2-C0 diode chip. When moving the output backshorts, we noticed that the input matching and the bias were nearly fixed. S11 was always better than -20dB.



Frequency = 260.0 GHz Balanced Doubler n°2, Diode UVa SC3T2-C0



Frequency = 260,0 GHz Balanced Doubler n°2, Diode UVa SC3T2-C0

4 References

Erickson, Neal, « High efficiency submillimeter frequency multipliers », IEEE MTT 1990

Erickson, Neal & Rizzi, « A high Power Doubler for 174 GHz Using a Planar Diode Array», Fourth International Symposium on Space terahertz technology, 1993

Erickson, Neal & Rizzi, « A balanced doubler using a planar diode array for 270 GHz », Fifth International Symposium on Space terahertz technology, 1994

Erickson, Neal, private communication, University of Virginia, March 96.

This work was performed in the frame work of ESA contract # ITT A0/1-3022/95/NL/PB