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Oscillator for 122GHz: Frequency multiplier from 61GHz and amplifier

The design of a passive frequency doubler and a sub-harmonic mixer for 122GHz requires a strong signal on 61GHz. Two multipliers using several amplifiers were based on different frequencies (10.2 and 15.3GHz) and built for the planned 122GHz doubler. Different strategies are presented for 61GHz oscillator processing.

1. Mechanical and electrical construction

The housing for the modules was milled brass and plated in an alkaline medium (pH 8.2, at 72 degrees).

The substrates used were Al_2O_3, AIN and Quartz (0.254 or 0.127mm). The Al_2O_3 and AIN ceramics were cut for me on a guided XY table (Diamond Ritz device, ATV, technology). The quartz substrates were cut to the correct size from the wafers (see section 6). The mechanical level between MMICs and the ceramics was adjusted by reducing the height of the substrate. MMICs and ceramics were attached with silver conductive adhesive (Ablebond 84-1LM3) at the appropriate points of the modules. Chips and conductors were connected by bonding (Highbond, model 572) using 13µm gold thread. Impedance adjustments were carried out by applying small “gold flags” on the strip lines as necessary and fixed with silver conductive adhesive. The DC power circuits suggested in the data sheets for the MMICs were used (single layer ceramic capacitors and gate resistors) and coupling between modules with capacitors. Detailed descriptions can be found in earlier publications [1-4].

2. Measurements

Performance measurements were performed with an MP716A V band sensor and an ML4803A power meter by Anritsu. For coaxial connection a waveguide to coaxial transition from Suncor was used and switches (MI-wave, 410V, about 0.7dB attenuation). A variable attenuator by Hughes was used to measure strong signals. The spectral properties of the RF output was measured with an HP spectrum analyser (70000 system with harmonic 11970V mixers).

3. Signal sources for 61GHz

3.1. Module A

The module was designed as a six times multiplier (Fig 1). The input frequency is approximately 10.2GHz (4 - 5dBm). The signal is tripled by a CHX2093a MMIC

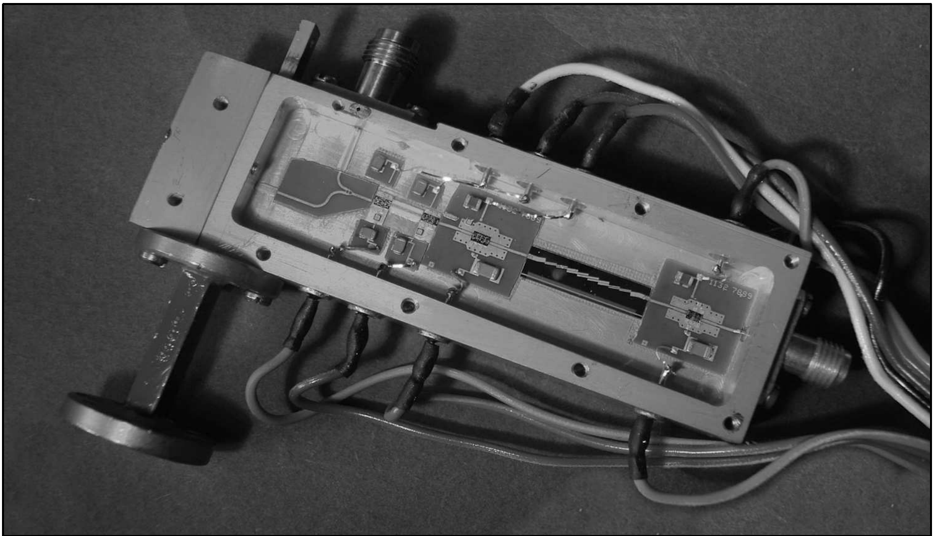

Fig 1: Module A. A six times frequency multiplier from 10.2 to 61GHz. The input signal is fed via an SMA socket (bottom right). The frequency is trippled, the signal is filtered (30GHz stripline filter), amplified, doubled to 61GHz and amplified. The MMICs used are clearly visible. A Wilkinson divider splits the output signal between a 1.85mm coaxial connector and A V band waveguide.

(United monolithic semiconductors, UMS), followed by a quartz strip line filter for 30GHz (insertion loss approximately 3.2dB). The power is increased to approximately 12dBm by one chip (CHX2092a - UMS, or HMC518 - Hittite) and then doubled to 61GHz by a third MMIC (CHX2192 - UMS). This signal is increased by an additional chip (HMC-ABH209-Velocium/Hittite) to approximately 16 - 17dBm and then fed into a Wilkinson divider. The split power feeds a coaxial socket (1.85mm V socket, Anritsu) and a waveguide (V band). The output was measured as 12 - 13dBm from both outputs.

3.2. Module B

This module was designed as a four times multiplier (Fig 2). It is fed via an SMA female (left of Fig 2). The input frequency is approximately 15.3GHz. The MMIC HMC XDH158 (Hittite) quadruples this to 61.2GHz. The output signal (approximately -3 to -4dBm) is filtered using a 60GHz quartz strip line filter (with only 4.1dB attenuation!). This is followed by an amplifier chip (HMC ABH241 by Velocium / Hittite, 22 dB gain) bringing the output to 13 - 14dBm. Due to this high RF gain, in combination with the geometry of the structure, there is a significant tendency for the module to oscillate. This problem can be fixed by two measures. The amplifier chip was screened from the MMIC by a partition in the housing and an upstream 3dB attenuator (stripline “T” construction). Thus, a stable output was achieved of approximately 13dBm at 61GHz. The signal output is a 1.85mm connector (right of Fig 2).

4. Power amplifier for 61GHz

The first attempt used a Wilkinson divider feeding two amplifier chips (HMC-

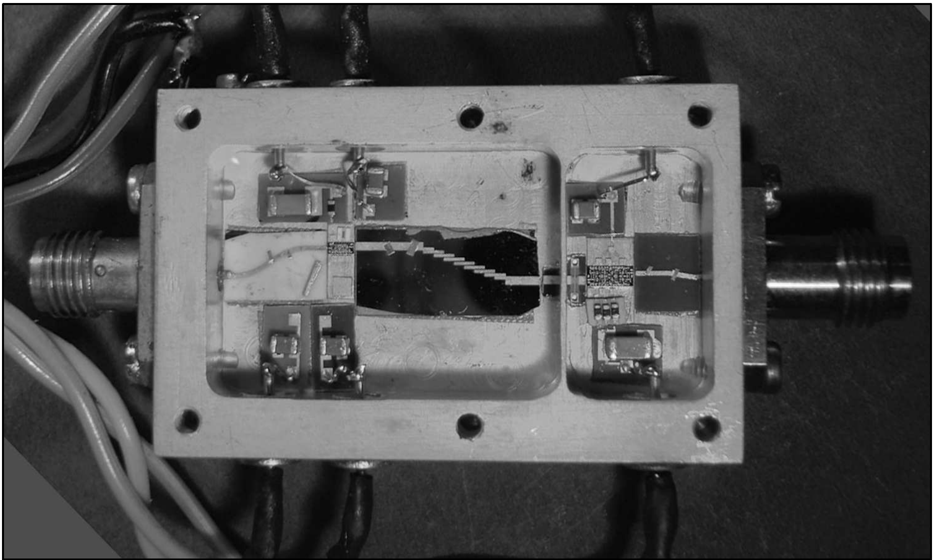

Fig 2: Module B: Frequency quadrupler, the stripline filter, in a small housing, the 3dB attenuator and finally the amplifier MMIC.

ABH209) in parallel separately coupled to the V band rectangular waveguide. An output power from 18.5 to 19dBm encouraged me to build module C shown in Fig 3.

4.1. Module C

The 61GHz signal is fed in via a 1.85mm V plug (right of Fig 3) and amplified to approximately 16dBm with a driver HMC-ABH209. This feeds four parallel

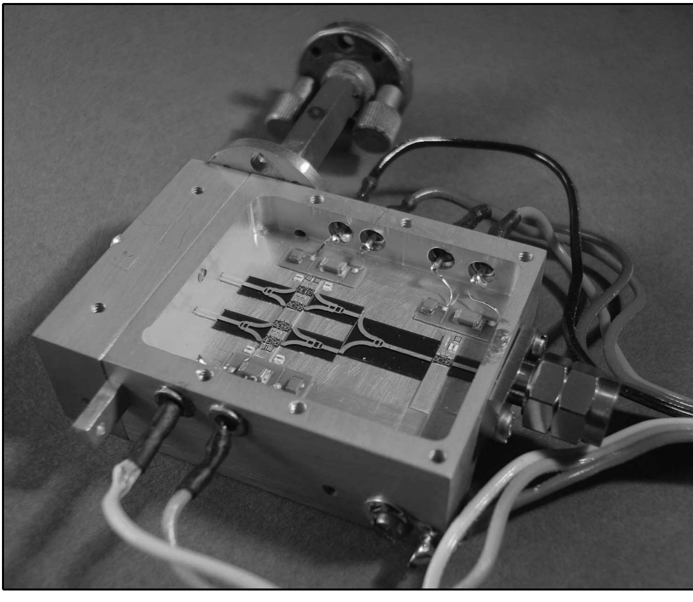

Fig 3: Module C: Power amplifier for 61GHz. The signal is fed in at the right to a driver chip then to four parallel MMICs and then to the waveguide. The two blocks forming the side of the waveguide can be seen. The slightly raised platforms giving a level surface between the MMICs and the quartz substrate for the chips can be seen.

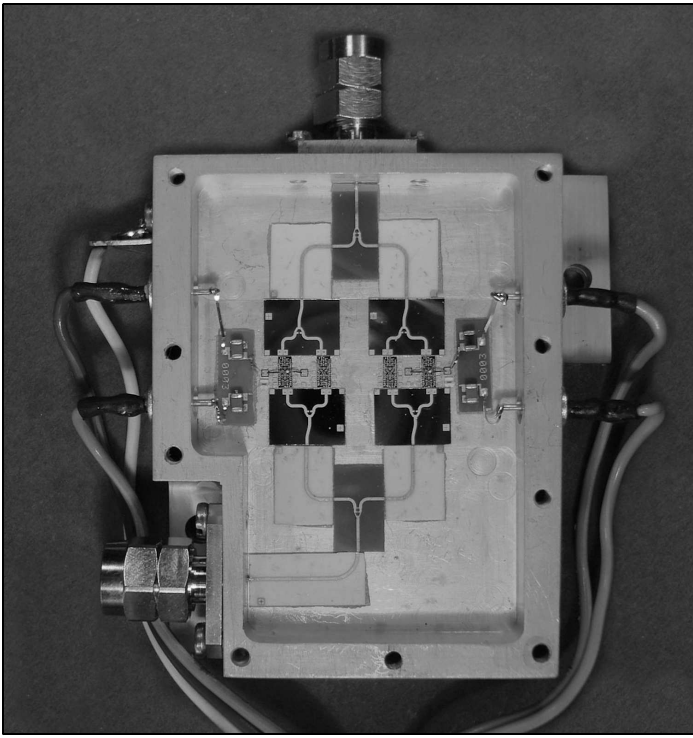

Fig 4: Module D: Power amplifier for 61GHz. The signals input and output is by coaxial connections. Wilkinson dividers distribute the power.

power amplifier chips (HMC-ABH209) via Wilkinson dividers. The output of two pairs of MMICs are merged and then coupled into the waveguide spaced at a distance of 1λg apart (left of Fig 3). Despite looking like substrates pieced together the output was 20.9dBm (120mW). This is more than the Schottky diodes to be used to double need (they run into "saturation" at 19.5dBm).

4.2. Module D

This design (Fig 4) has two changes from module C: the input and output are coaxial; the driver stage could be removed because the more powerful HMC-ABH241(Velocium/Hittite) MMICs were used for improving performance. The four Wilkinson dividers, designed for 76GHz, were on the MMIC substrates (0.127mm quartz). They work extremely well between 60 and 90GHz. However, the four high gain chips in the chosen environment tend to oscillate badly (despite the use of ample damping material), so they could only be operated at reduced power. The power output achieved was disappointingly low.

4.3. Module E

This was a "scaled down" version of module D using only two HMC-ABH241 chips (Fig 5). The coaxial module is extremely compact (28mm x 25mm) and requires only 6 to 8dBm input power. The light oscillation behaviour of this module can be easily mastered. The signal at the output is more than 120mW.

4.4. Module F

This design uses some unusually designed substrates for pairing of the four MMICs. The relatively narrow band (0.1-27mm quartz substrate) structures were originally calculated for 70GHz. However, since the RF simulation (Sonnet) at a frequency of 60 to 61GHz predicted

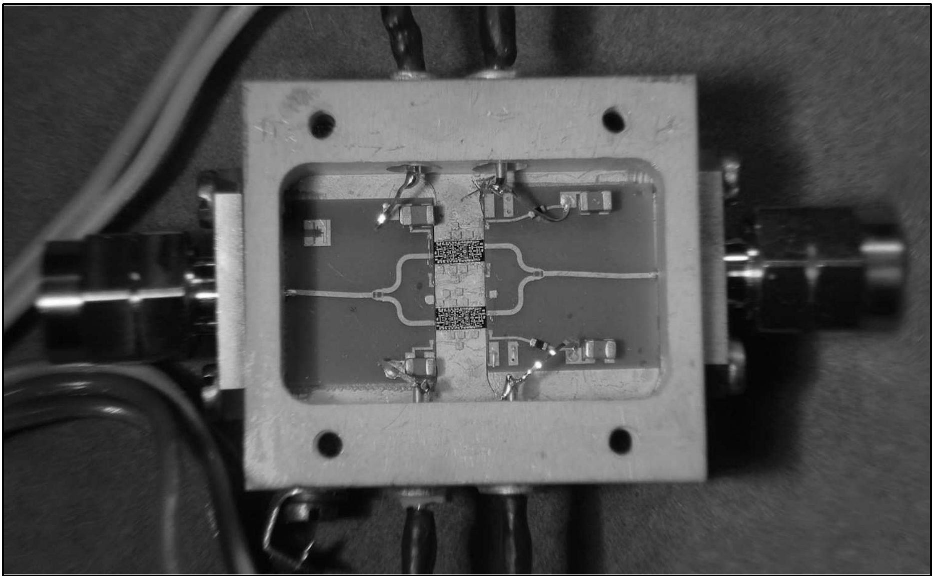

Fig 5: Module E: Power amplifier for 61GHz. This compact coaxila model is fed by the 1.85 mm connector and requires only low driver power.

relatively low loss properties, this module was built (Fig 6). Driver IC and amplifier MMICs are as described in module C. Almost 120mW was measured at the coaxial output of this module, which is the same value as in module C. A test with other MMICs at 70GHz is on hold.

5.

Generation of the output frequencies of 10.2 and 15.3GHz

This is a rather trivial issue for those familiar with microwave construction, just two options are used in practice.

The direct use of a frequency synthesiser coupled to a 10MHz reference is easiest for 10.2GHz.

In this case the author used 15.3GHz from a PLL stabilised fixed frequency oscillator. The signal at 119,244MHz was amplified, doubled and filtered. The power at 238,488MHz was 8dBm and fed to a phase controlled oscillator (HMC535LP4, Hittite) that produces 64 times the input frequency giving approximately 10dBm at 15.263GHz. Dual oven crystals are good for the stable 10MHz reference signal but connection to a GPS signal is also a popular solution.

6.

Thanks

I would like to thank the employees of Rohde and Schwarz, Munich, especially Dr. Hechtfischer (DG4MGR) and W. Hohenester for supplying the ceramic substrates and the 5 mil quartz for the various power couplers. W. Hohenester generously carried out the sawing of the sensitive quartz substrates. The PLL stabilised fixed frequency oscillator for 119.-244MHz was made by Michael Kuhne (DB6NT). Finally, I wish to thank my

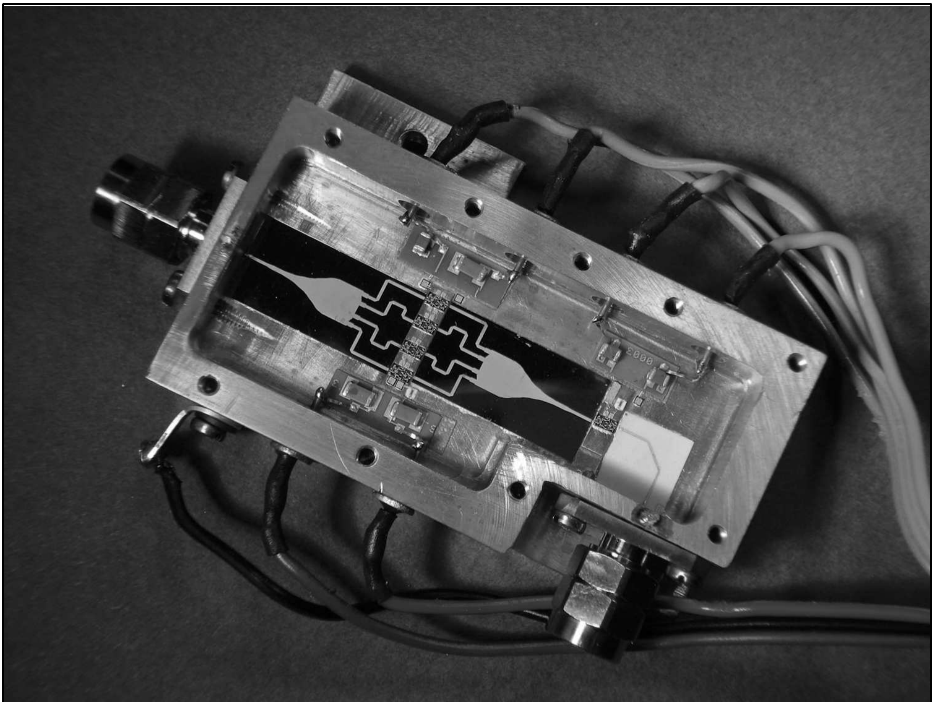

Fig 6: Module F: Power amplifier for 61GHz. This experimental setup does not use Wilkinson couplers but a special multiport system. The RF is fed to the coaxial connector and then to a driver MMIC and then the four amplifier chips. Energy losses in these quartz substrate are similar to those of the Wilkinson system used in module C.

friends Max Münich (DJ1CR, Max Planck Institute for Physics, Munich) and Jochen Ehrlich (DF3CK) for their ongoing support and advice.

7.

References

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