BUILDING OF A HIGH PRECISE AND COMPACT SYNTHESIZER IN E- BAND BY MEANS OF GUNN OSCILLATOR AND MMIC CHIPSET[1]

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ABSTRACT

This paper describes a high precise, compact, and low-priced Synthesizer assembled by using a Gunn Oscillator and a MMIC Chip-set. Additionally, a simple but well designed Transition enables a direct mounting of the Harmonic Mixer on the end of waveguide. The Synthesizer generates an output signal between 70 and 75 GHz within a accuracy of ±5 Hz.

INTRODUCTION

More and more different fields of application for microwave- / millimetre wave circuits have been generated. Standardisation centres - in Germany the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig and Berlin - are interested in millimetre waves recently. They are developing methods of measurement for the realisation and dissemination of the SI units with the lowest possible uncertainty for many years. The interest in frequency is based on the possibility of measure and realise this unit in a very precise way. In former times frequencies in MHz range have been used widely.

We show an application at 70 GHz. It is used for the representation of the international Volt [1]. By applying an alternating current to a cooled Josephson Junction, steps with constant voltage are created. This voltage is very tiny. To produce an output voltage of 10 V, a frequency of 70 GHz and around 10.000 junctions in series are required.

A 70 GHz signal can relatively simply be produced by using a Gunn Oscillator. The problem lies in the necessary accuracy of the created frequency of 10^{-10}, that means ±5 Hz!

The presented paper describes the assembly and test of the 70 GHz Synthesizer.

CONCEPT OF 70 GHZ SYNTHESIZER

The simple way in stabilising a millimetre wave signal at 70 - 75 GHz is the use of a precise, bulky, and expansive frequency-locking counter (FLC). Also, it can not recommended for mobile operation because of it’s heavy weight. The idea lies in developing a MMIC Chipset [2], which allows also to produce such voltage- standards in small to medium quantities. Figure 1 shows a schematic of the proposed 70 GHz Synthesizer. It’s specification are a tuning range from 70 to 75 GHz in steps of 1 MHz, an output power of 15 dBm, and an adjusted frequency accuracy of ± 5 Hz.

The assembly should as compact as possible, only Gunn Oscillator, Isolator, and Power Divider form a module in waveguide technique. Together with a Rubidium time base Oscillator they are creating the only two external modules.

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Both frequency and output power are controlled by a personal computer.

The first PLL stabilises an internal 6 GHz VCO versus the Rubidium time base Oscillator. The VCO is followed by a frequency times three Multiplier and a voltage controlled Amplifier. The output signal is tuneable over frequency from 17 to 19 GHz (by VCO) and output power from 5 to 15 dBm (by Amplifier). The 4th Harmonic of this 18 GHz VCO serves as LO signal for the Harmonic Mixer. All other Harmonics are suppressed due to a suited matching network. The same is valid on the RF port, here the 1st Harmonic is well matched at 70 to 75 GHz. This RF signal is coming from Gunn Oscillator via 20 dB Coupler and waveguide - coplanar line Transition. The resulting IF signal around 1 GHz is fed into 2nd PLL and is also compared with the Rubidium time base Oscillator. Using this 2nd PLL, frequency steps of 1 MHz are possible for the Gunn Oscillator.

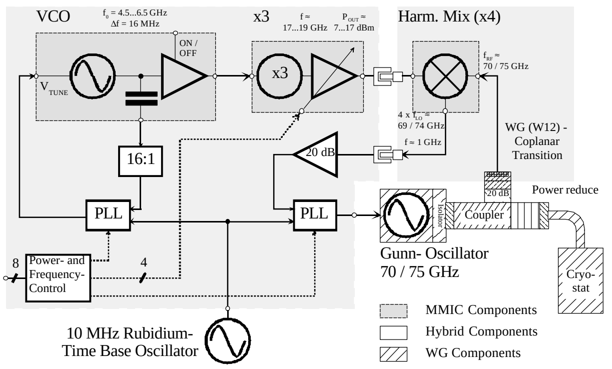

Fig. 1: Schematic of the 70 GHz Synthesizer. The Microwave modules are to be seen left (18 GHz VCO with 1st and 2nd PLL) and right (Harmonic Mixer including waveguide - coplanar line Transition). The waveguide module (Gunn, isolator, and 20 dB Coupler) is depicted in the lower right.

Key components like VCO, frequency times three Multiplier, Amplifier, and Harmonic Mixer are designed and built up as MMIC's, and that means a drastically reduction in module size is achievable. The quarter micron PH25 technology by UMS foundry was chosen as MMIC process.

ASSEMBLY OF 70 GHZ SYNTHESIZER

The Synthesizer is divided into four parts: Rubidium time base Oscillator, commercial Gunn Oscillator, 18 GHz module, and Harmonic Mixer module.

The Rubidium time base Oscillator serves as an ultra precision frequency standard at 10 MHz.

The Gunn Oscillator delivers it's output signal to the cooled Josephson Junctions of the voltage standard. Together with isolator and 20 dB Coupler they form the waveguide module.

The 18 GHz module in figure 2 contains a ceramic carrier on upper side with all MMIC's with exception of Harmonic Mixer to generate the 18 GHz signal. This part is shielded from other parts to prevent self oscillation and raise of noise floor. Also on the upper side PLL's and other tuning elements are to be find on FR4 substrate as well as the bias circuitry on the backside (not to be seen).

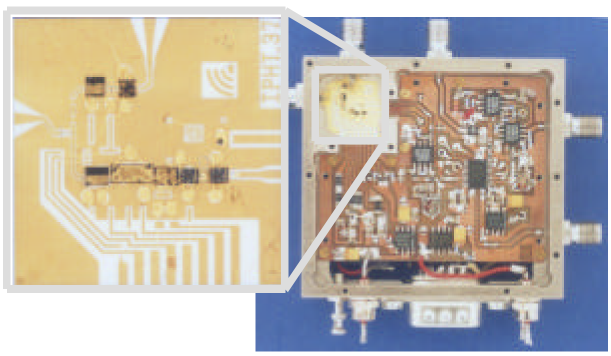

Fig. 2: The 18 GHz VCO module. In the upper left the micro wave part is depicted with all MMIC's (with exception of Harmonic Mixer), assembled on ceramic. The PLL's and other tuning elements are to be find on FR4 substrate as well as the bias circuitry on the backside (not to be seen). Size: 60 x 55 x 23 mm³.

The Harmonic Mixer module in figure 3 contains the Harmonic Mixer MMIC itself, the bias and matching networks, and the waveguide - coplanar line Transition. The latter one was carefully designed to make a direct connection between waveguide output of 20 dB Coupler on Gunn Oscillator module and coplanar line input of Harmonic Mixer MMIC. The Transition consists of both a directly fed asymmetrical antenna structure and a coplanar line on a small ceramic piece [3]. The antenna radiates through the ceramic into the behind located waveguide.

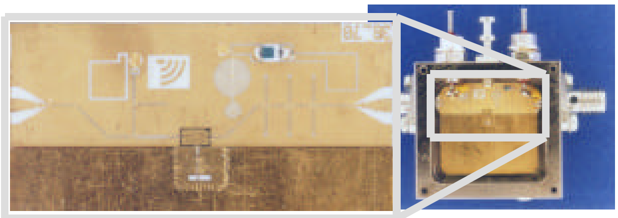

Fig. 3: Harmonic Mixer module. Left picture in the middle, the Harmonic Mixer MMIC is depicted with matching networks on ceramic. Below the Mixer MMIC, antenna of the waveguide - coplanar line Transition is to be seen. This antenna is fed by a waveguide looking perpendicular into metal plate. Size: 30 x 28 x 17 mm³.

MEASUREMENT RESULTS

After module assembly first measurements are carried out on the modules itself.

The VCO is tuneable between 17 and 19 GHz with an output power of 10 to 15 dBm. The suppression of unwanted Harmonics is always better than 30 dB. The phase noise behaviour is estimated from spectrum measurements. Phase noise is £ = -62 dBc/Hz @ 10 kHz off at a carrier frequency of 18 GHz.

The Mixer module could be measured only in an indirect way, because of different terminals (two coplanar line and one waveguide). At first a test structure for the waveguide - coplanar line Transition was built up. The measurements are performed on the back-to-back configuration, using a HP 8510 NWA with a 110 GHz extension. Measurements show an insertion loss of approx. 5 dB for one Transition and a reflection coefficient at waveguide port of -10 dB.

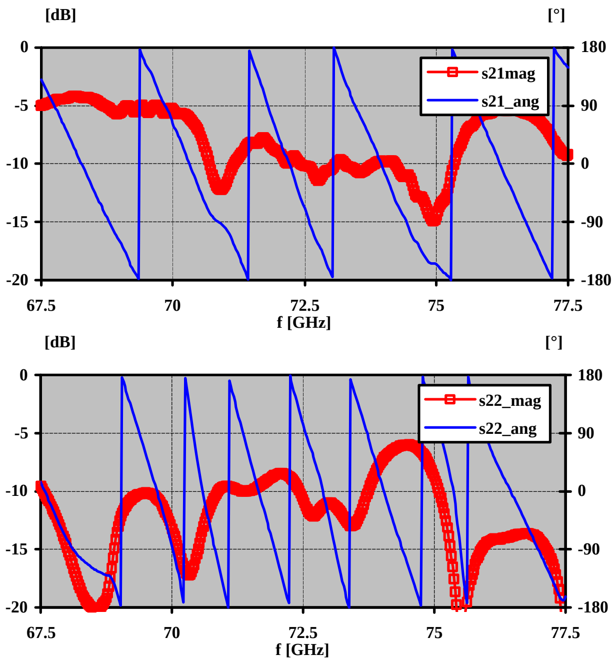

Fig. 4: Insertion loss (top) and a reflection coefficient (bottom) over frequency for waveguide – coplanar line Transition. The measurements are performed on the back-to-back configuration.

Mixer measurements were carried out by using a mm-Wave Source instead of a Gunn Oscillator. The value for conversion loss is only an estimation. We think that -15 ±5 dBm (depends on S_{21} of our Transition) are available at the Mixer RF input port. The rest of power is used for the 20 dB Coupler, Transition and matching losses in bond wires between Transition and Mixer MMIC. The measured output power was around -35 ±5 dBm at IF port, that means the conversion loss is around 20 dB.

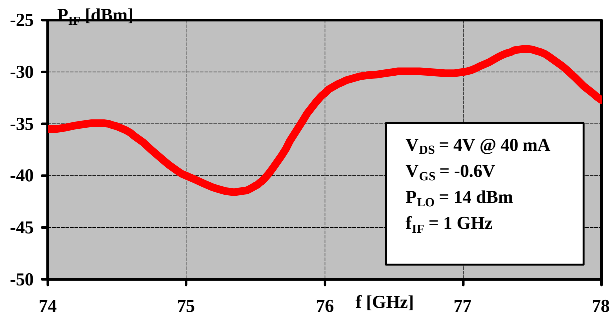

Fig. 5: Measured IF output power at IF port with estimated RF power of P_{RF}: -15 ±5 dBm, that means a conversion loss of around 20 dB.

The matching at the LO port is better 10 dB over a frequency range 17.6 to 19 GHz. The IF - LO isolation is better than 60 dB. This is due to the suitable matching networks on all three Mixer ports, especially the LO signal is short circuit at every port.

SYSTEM MEASUREMENTS

The final measurement was carried out with all modules at the IPHT in Jena, Germany. The stability of various Gunn Oscillators output signals is proofed of ±5 Hz in a frequency range 70 to 75 GHz. This is around one magnitude worse than using the bulky FLC.

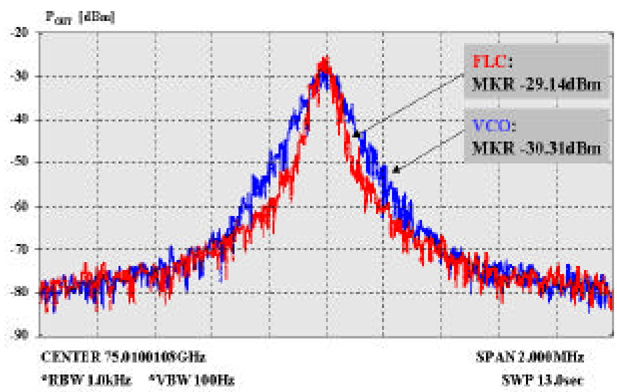

Fig. 6: Phase noise behaviour of the Gunn Oscillator. Estimations are carried out with our VCO to £ ≈ -41 and with FLC to £ ≈ -52dBc/Hz respectively at f = 75 GHz and 100kHz off carrier.

The difference is found in a different phase noise behaviour of the used 6 GHz VCO. Figure 6 depicts the phase noise behaviour of the Gunn Oscillator. Values are read off at f = 75 GHz and 100kHz off carrier for Gunn Oscillator with: our VCO with £ ≈ -41 and FLC with £ ≈ -52dBc/Hz respectively.

CONCLUSIONS

A high precise and compact Synthesizer is assembled by using a Gunn Oscillator and MMIC Chipset. The proposed concept permits the use of any millimetre wave source. This Synthesiser is used in a deep temperature measurement apparatus for representation of the international Volt by means of cooled Josephson Junctions. The Synthesizer is divided into four parts: a 18 GHz VCO, Harmonic Mixer, Gunn Oscillator, and Rubidium time base Oscillator. Besides to all other a special waveguide - coplanar line Transition for the interconnection of Gunn Oscillator and Harmonic Mixer has to have been established. The Synthesizer is able to generate a signal between 70 and 75 GHz, only depending on the used Gunn Oscillator, within a accuracy of ±5 Hz and with an output power of 15 dBm.

REFERENCES

[1] H.-G. Meyer, G. Wende, L. Fritzsch, F. Thrum, M. Schubert, F. Müller, R. Behr and J. Niemeyer, “Improved Primary Josephson Voltage Standard with a New Microwave Driving Source”, IEEE Transactions on Applied Superconductivity, Vol. 9, No. 2, pp. 4150-4153, June 1999.

[2] R. Tempel, W. Lütke, J. Herrmann, I. Wolff, “Coplanar MMICs for Sensor Applications at 25GHz”, 1996 IEEE Intern. Microwave Theory and Techn. Symposium (MTT-S), pp. 277-280, June 17-21, 1996, San Francisco, USA.

[3] W. Simon, M. Werthen, I. Wolff, “A Novel Coplanar Transmission Line to Rectangular Waveguide Transition”, IEEE MTT-S Int. Microwave Symposium Digest, pp. 257-260, 1998.