

A MM-WAVE FREQUENCY DIVIDER

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ABSTRACT

At lower GHz frequencies, frequency dividers are widely used - in conjunction with PLL circuits - for frequency stabilization. This was, up to now, difficult for mm-wave frequencies.

This paper presents, for the first time, a mm-wave frequency divider with a division ratio sufficiently high (e.g. 8) so that digital dividers can be used next. The mm-wave divider is based on a combination of analogue and digital components, and it may easily be realized using (monolithically) integrated circuits.

1. INTRODUCTION

The realization of frequency synthesizers and frequency stabilization at frequency of a few GHz often is done using digital prescalers together with PLL-circuits, e.g. /1/. At mm-wave frequencies, up to now, this technique was not possible, and more complicated arrangements including double PLL circuits or multipliers with high multiplication factors had to be used (/2/, Fig. 1). Basically, some concepts for analogue frequency dividers are well known, e.g. /3/, /4/; these, however, are difficult to realize at mm-wave frequencies and require expensive mm-wave amplifiers. Especially for the 80 GHz range, however, where different sensor systems for traffic applications are planned, simple, integrable and low cost solutions for frequency stabilization are required. Further applications may be synthesizers for mm-wave radar and communication systems.

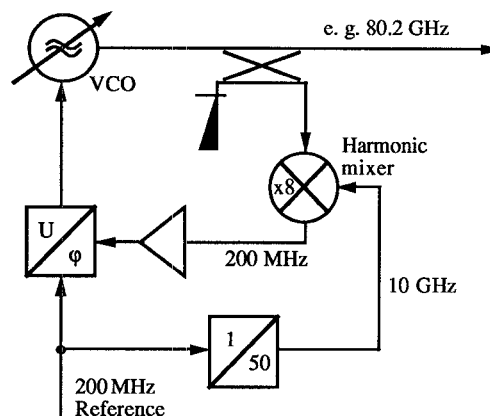


Fig. 1: Typical mm-wave PLL stabilization as used up to now.

2. DIVIDER CONCEPT

A block diagram of the new concept presented in this paper is shown in Fig. 2. The mm-wave signal is downconverted in a harmonic mixer, where an auxiliary oscillator serves as LO. After some amplification, the IF is digitally divided and mixed again (in an SSB mixer) with the auxiliary LO frequency. If the harmonic ratio n of the harmonic mixer and the ratio of the digital divider are equal, the output frequency is the mm-wave frequency divided by n . To maintain a single, unique signal, the maximum output IF frequency of the harmonic mixer must not exceed half the frequency of the auxiliary oscillator. For maximum bandwidth, this leads to the relation

$$f_1 = f_{0\max} / (n+1/2)$$

(f_1 : frequency of auxiliary oscillator,
 $f_{0\max}$: maximal mm-wave input frequency)

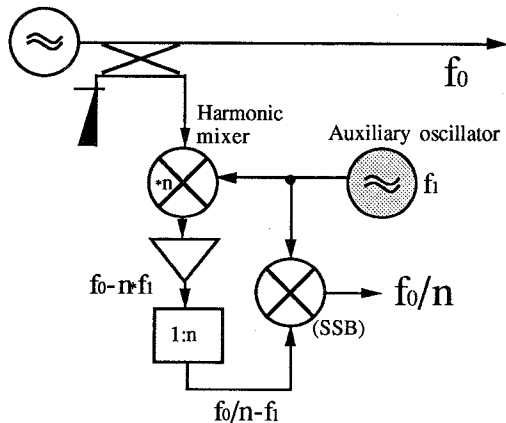


Fig. 2: Basic block diagram of mm-wave frequency divider.

For the 80 GHz example given in this paper with $n=8$ this results in an auxiliary frequency of $f_1 \approx 9.5$ GHz, a maximum input frequency of the digital divider of 4.7 GHz, and a usable bandwidth of 4...4.5 GHz. The bandwidth may be improved at the expense of a lower division ratio together with an increase of the frequencies of auxiliary oscillator, amplifier and digital divider. On the other hand, harmonic mixers are available for frequencies far beyond 100 GHz, e.g. /5/, /7/; thus this principle can be extended into the sub-mm-wave range.

Basically, all the components of this type of frequency divider can be (monolithically) integrated. The auxiliary LO may be a DRO; its frequency stability does not affect the division procedure.

3. EXPERIMENTAL RESULTS

A first set-up of this mm-wave divider was tested in the 30 GHz range using a harmonic mixer as described in /5/, a digital divider from 0.5 to 2.5 GHz, a standard amplifier and mixer and a sweeper as auxiliary oscillator. The mm-wave input level was approximately -15 dBm, the required LO power level 6...8 dBm, and the amplifier gain 27 dB. A few typical results of the output spectrum of the 30 GHz divider are shown in Fig. 3.

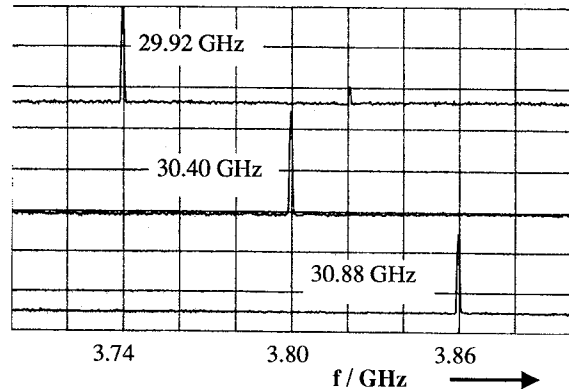


Fig. 3: Output spectra of mm-wave frequency divider for input frequencies of 29.92, 30.4, and 30.88 GHz.

Following this, a preliminary set-up was assembled to test this principle in the 80 GHz range, too.

As auxiliary oscillator, a dielectric resonator stabilized oscillator (DRO) was employed. A standard W-band mixer was used as harmonic mixer. To this end, an additional planar diplexer was added to separate the LO frequency (auxiliary oscillator, $f=9.55$ GHz) and the IF frequency (up to 4.5 GHz). Its transmission properties are plotted in Fig. 4. In the next step, a special planar integrated harmonic mixer using a planar doped barrier Schottky diode /8/ will be combined with the diplexer. The output of the mixer was amplified and fed to a digital frequency divider. Due to some difficulties with this divider, tests could be done, up to now, only up to 2.5 GHz; finally, this will be increased to 5 GHz. Fig. 5 shows three output spectra of the overall arrangement (using a standard X-band mixer instead of an SSB mixer, Fig. 2).

Due to the non-sinusoidal output of the digital frequency divider, additional spectral lines about 10 dB below the desired signal appear at the output of the divider. Their influence has to be investigated further. However, using a digital divider in the range of 2.3 to 4.6 GHz input frequency, an overall spurious-free bandwidth of more than 2 GHz can be achieved by filtering the output of the digital divider. These 2 GHz will be sufficient to lock and stabilize all types of mm-wave sources like Impatt and Gunn diodes. A special application may be the combination with monolithically integrated Impatt oscillators on silicon substrates /6/.

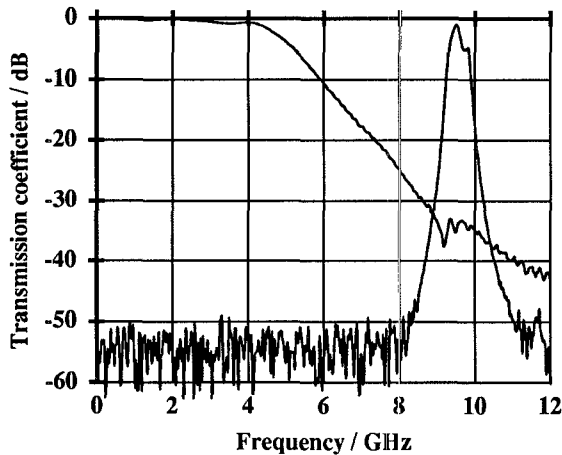


Fig. 4: Transmission characteristics of planar diplexer for the harmonic mixer

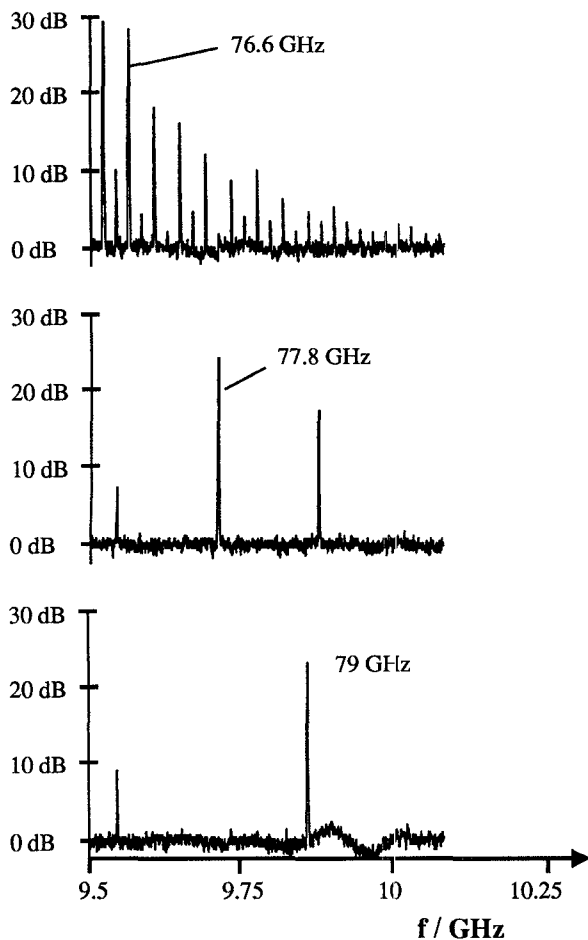


Fig. 5: Output spectra of mm-wave frequency divider for input frequencies of 76.6, 77.8, and 79 GHz

4. CONCLUSION AND FURTHER WORK

A new concept of a mm-wave frequency divider has been presented, as well as first results in the 30 and 80 GHz range. This principle can easily be extended into the sub-mm-wave range. Further investigation will cover the noise behaviour of the circuit, especially the influence of the auxiliary oscillator. Finally, it is planned to set up a complete stabilized 80 GHz source using planar integrated circuits.

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