41st Annual Frequency Control Symposium - 1987

COMPACT AND SIMPLE x 3 (9 to 27 GHz) PLL FREQUENCY MULTIPLIER USING HARMONIC PHASE DETECTION

Jordi Berenguer, Javier Bará and Adolfo Comerón.

Departamento de Electrofísica. E.T.S. Ingenieros de Telecomunicación de Barcelona
Universidad Politécnica de Cataluña
Apartado 30002, 08080-Barcelona, Spain.

SUMMARY

Frequency multiplication in the microwave and millimeter-wave range can be performed in compact form using harmonic phase detectors, in which the VCO phase is directly compared to a multiple of the reference frequency internally generated in the same device. In this paper we present a x3 P.L.L. frequency multiplier following this technique that phase-locks a 27 GHz Gunn diode VCO to a 9 GHz reference, in a simple and compact arrangement. The Gunn diode frequency is controlled via the voltage applied to it. The phase detector used is a balanced mixer, implemented with a 90° microstrip hybrid ring and Schottky diodes, and designed at the 9 GHz reference frequency. This system can be employed through the microwave and millimeter-wave ranges to obtain low order odd-index frequency multiplications.

INTRODUCTION

The expansion of satellite communication systems demands for receivers with good sensitivity and dynamic range. This often requires designs involving coherent detection and the use of local oscillators with high spectral purity /1/.

The design of low phase noise oscillators in the microwave and millimeter-wave range is usually implemented by phase-locking a Voltage Controlled Oscillator (VCO) to a spectrally pure reference signal (indirect synthesis by phase locked loops) /2/ /3/. This technique often calls for frequency multipliers, where the locked oscillator frequency is a certain multiple of a more stable frequency, and the phase detection is made at lower frequency after down-converting the VCO's high frequency by means of a harmonic mixer or regenerative frequency dividers /4/.

Indirect frequency multiplication by small odd multiples can be performed in a very compact manner using harmonic phase comparators, in which the phase of the VCO is directly compared to the multiple of the reference frequency generated internally in the same device /5/ (Figure 1).

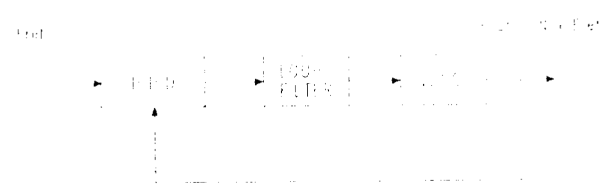


Fig. 1 - Block diagram of small odd multiples P.L.L. frequency multiplier using harmonic phase detector.

In this paper we present a x3 P.L.L. frequency multiplier following this technique which allows to phase-lock a 27 GHz VCO to a 9 GHz reference, in a simple and compact arrangement.

THEORY OF THE HARMONIC PHASE DETECTOR USING A 180° HYBRID RING

The phase detector function can be performed by a balanced mixer with DC coupled IF port. In the microwave range this is usually implemented with a microstrip 90° or 180° hybrid and Schottky diodes. (Figure 2).

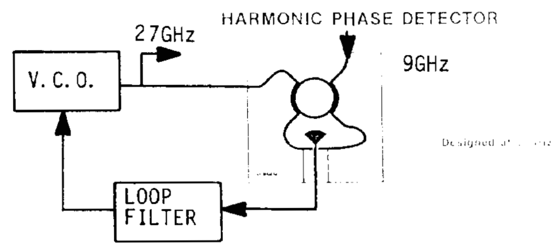


Fig. 2 - Block diagram of x3 (9 to 27 GHz) PLL frequency multiplier, with a microstrip hybrid structure as phase detector.

This structure has the property of behaving as a hybrid at odd multiples of the frequency at which the lengths of the lines connecting the ports are $\lambda/4$. Although a bandwidth reduction and a certain degradation of the hybrid are involved, they do not affect the harmonic phase detection ability.

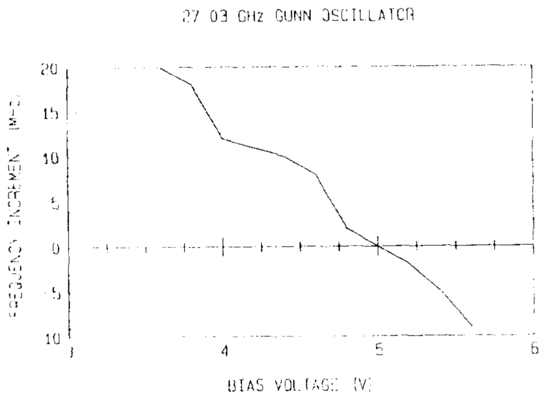
As a result, a phase detector realized with a balanced structure using a 180° hybrid ring (or equivalent) can be used to perform a frequency multiplication by an odd factor in a set-up like that sketched in Figure 1.

EXPERIMENTAL RESULTS

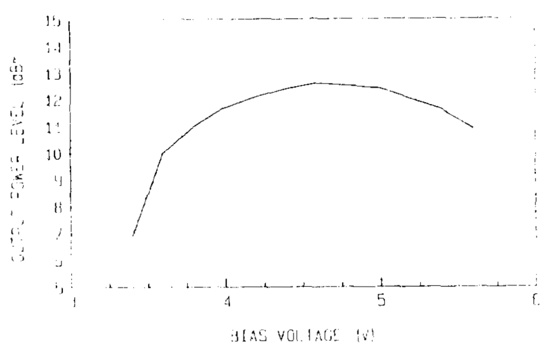
A x3 frequency multiplier between 9 and 27 GHz using a harmonic phase detector following the set-up of Figure 2 has been built. It is part of a coherent receiving system designed for the propagation experiments on the 12, 20 and 30 GHz beacons on board of the European Space Agency Olympus Satellite, to be launched by 1988. The 27 GHz output is employed as local oscillator for the first mixer in the 30 GHz channel chain.

The phase detector uses a microstrip hybrid structure like that shown in Figure 2 made in 0.01" Cu-clad 217 and designed at the 9 GHz fundamental frequency. A pair of AsGa Schottky diodes in a T-package provide for the nonlinear function.

The 27 GHz VCO consists of a cavity mounted Gunn diode. The frequency is controlled by varying the diode bias voltage. Figure 3a shows the VCO frequency increment referred to 27.03 GHz versus the d.c. bias voltage and Figure 3b shows the ripple in the VCO output power level.



(a)



(b)

Fig. 3 - 27.03 GHz V.C.O. a) Frequency increment versus bias voltage. b) Output power level versusbias voltage.

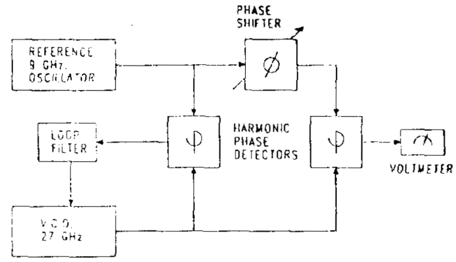


Fig. 4 - Harmonic phase detector characterization set-up.

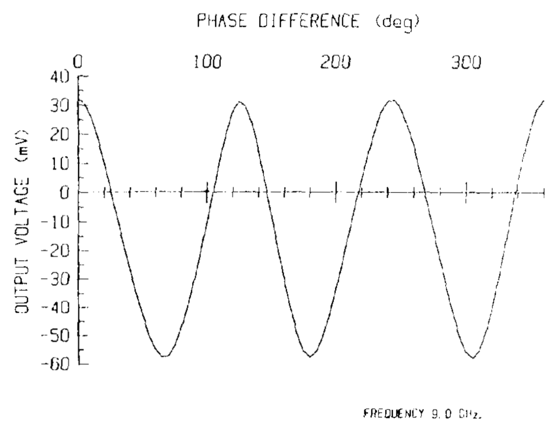


Fig. 5 - Harmonic phase detector D.C. output voltage, versus 9 GHz port phase shift.

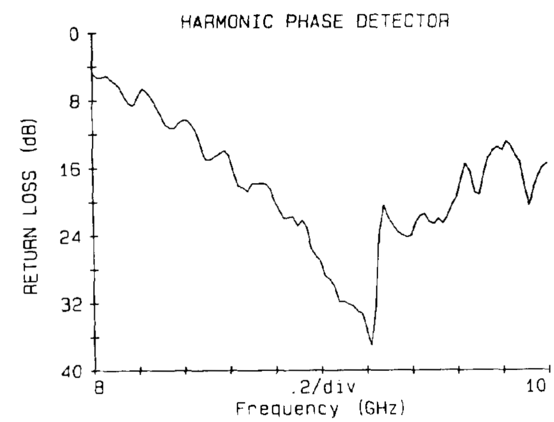


Fig. 6 - Harmonic phase detector return loss measured at the 9 GHz port.

The set-up employed for the characterization of the harmonic phase detector is sketched in Figure 4. The DC output voltage of the harmonic phase detector was recorded versus the phase shift introduced on the 9 GHz port (Figure 5). For a 9 GHz power of -2 dBm and a 27 GHz power of 0 dBm the harmonic phase detector slope was 2.65 mV/°.

The return loss at the phase detector 9 GHz port when it was pumped with a +4 dBm 27 GHz signal has also been measured (Figure 6). The isolation obtained between both ports is shown in Figure 7.

Figure 8 shows the improvement of the 27 GHz oscillator spectral purity when locked using this technique to a more stable 9 GHz frequency. The P.L.L. noise bandwidth is 21 KHz, with a damping coefficient of 1.14 and a 5 KHz loop filter resonance frequency. The hold-in range is 6 MHz.

CONCLUSIONS

A very compact x3 frequency multiplier from 9 to 27 GHz has been presented. It is based on P.L.L. techniques with harmonic phase detection that can be employed through the microwave and millimeter-wave ranges to obtain low order odd-index frequency multiplications.

In the coherent receiver final configuration, the 9 GHz frequency will be generated by a FET VCO, itself ultimately locked to a 5 MHz quartz standard, the quartz oscillator stability being transferred in this way to the 27 GHz VCO.

REFERENCES

[1].- W. P. Robins, "Phase Noise in Signal Sources". Peter Peregrinus, 1982.

[2].- R.G. Davis, M.J. Lazarus, "Phase Locking of mm-Wave Two-Port Gunn Oscillator By Bias Tuning". Microwave Journal, June 1986, pp. 103-107.

[3].- V. Manassewitsch, "Frequency Synthesizers Theory and Design". John Wiley & Sons, 1980.

[4].- K. Honjo, M. Madihian, "Novel Design Approach for X-Band GaAs Monolithic Analog 1/4 Frequency Divider". IEEE Trans on MTT-34, no. 4, April 1986, pp. 436-441.

[5].- F.M. Gardner, "Phaselock Techniques". John Wiley & Sons, 1979.

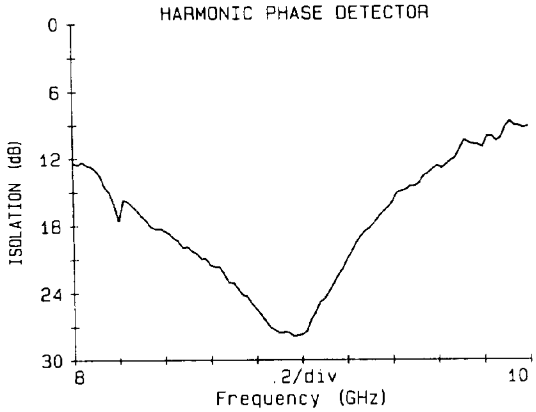
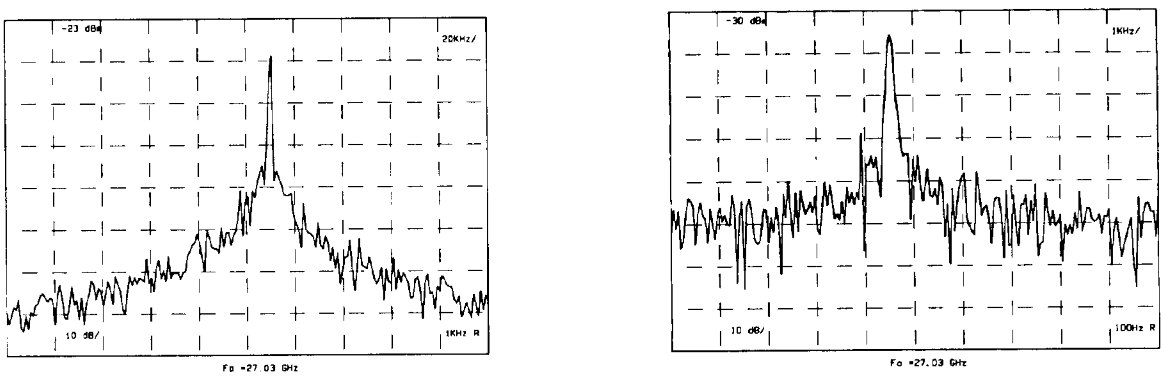


Fig. 7 - Harmonic phase detector isolation between ports, measured at 9 GHz.



(a) (b)

Fig. 8 .- 27 GHz V.C.O. spectrum. a) Free running. b) Locked. (Note the difference in frequency span and resolution bandwidth between a) and b)).