# Fundamental Wave Injection Locked 2nd Harmonic Gunn Oscillators at 94 GHz

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Abstract

A new frequency processing system for mm-wave coherent Radar system is discussed briefly to demonstrate the utility of fundamental wave injection locked second harmonic Gunn oscillators. The design and performance of this type of oscillator is the subject of the presented paper. In a CW-mode the oscillator has an output power of 10 dBm which is sufficient to serve as the LO of a balanced mixer. In a pulsed mode (duration 90 nsec, PRF=50 kHz) the oscillator delivers about 15 dBm with a phase ripple below ±4°. The suitability of this pulsed oscillator to drive a 3 stage 30 dB injection locked impatt amplifier is shown.

## I. Introduction

Common coherent mm-wave Radar systems use a frequency up-converter to achieve fixed phase relation of the intermediate frequency between transmitted signal and local oscillator signal.

In this paper an alternative method is proposed employing fundamental wave injection locked (FWIL) 2nd harmonic Gunn oscillators. The simplified block diagram of a 94 GHz coherent Radar frontend using this method is shown in Fig. 1.

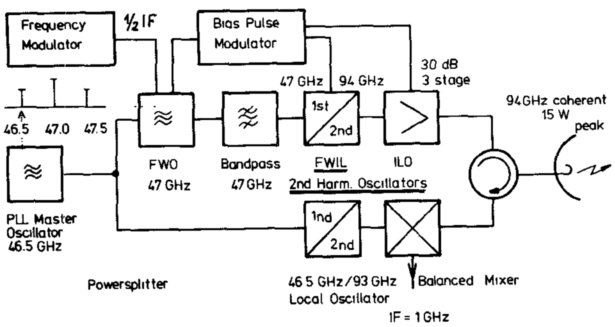


Fig. 1 Simplified Blockdiagram of a 94 GHz Coherent Radar Frontend using FWIL 2nd Harmonic Oscillators

Here, a 46.5 GHz master oscillator locks a CW second harmonic Gunn oscillator at its fundamental frequency which produces 10 mW LO power at 93 GHz for the receiver. On the other hand the master oscillator locks a frequency modulated fundamental wave Gunn oscillator (FWO) onto the lower sideband. The sideband to carrier offset is half the desired IF of the frontend. The carrier passes a bandpass filter to lock an FWIL second harmonic Gunn oscillator at its fundamental frequency (47 GHz) while the sidebands are suppressed by about 40 dB. Suppression is improved significantly since the output waveguide of the FWIL 2nd harmonic oscillator cuts off the fundamental frequencies. Both, the FWO and the FWIL 2nd harmonic oscillator are pulsed. The 94 GHz output power (15 dBm peak) of this arrangement is well suited to drive a pulsed 30 dB injection locked Impatt oscillator chain (ILO) yielding 15W peak power at 94GHz.

In the following the design and performance of the FWIL second harmonic oscillator are described.

## II. Principle of Operation

The basic design of the second harmonic Gunn oscillators is discussed extensively in an earlier paper /1/. The cross sectional view of a fundamental wave injection locked second harmonic oscillator is shown in Fig. 2c. (Figs. 2 next page)

In principle we have a combination of a fundamental and a 2nd harmonic oscillator in one housing. Fig. 2a shows the fundamental wave oscillator with its output port, a U-band waveguide, to the left. An R-band waveguide acts as a backshort, reflecting all frequencies below 60 GHz like a real backshort as shown in Fig. 2a. Its position is about 1/4 of a fundamental wavelength away from the diode ($l_1$).

Fig. 2b shows the second harmonic oscillator with the R-band waveguide output port to the right. The distance of the backshort from the diode has to be about 3/4 of the 2nd harmonic wavelength. Fig. 2c shows the combination of both oscillators in one mount. Here, a resonant iris transmitting the fundamental wave and reflecting the 2nd harmonic wave is inserted between the U-band waveguide and the diode mount. The iris represents the backshort for the second harmonic wave. The output frequency is determined by the distance $l_1$. The second harmonic output power depends on the distance $l_2$. The width of the diode mount waveguide



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was chosen as 0.63 $\lambda_o$ to fulfil the condition

$\lambda_{g\ fund} = 3\lambda_{g\ 2nd\ harmonic}$ (see /1/)

where $\lambda_o$ is the free space wavelength of the fundamental wave.

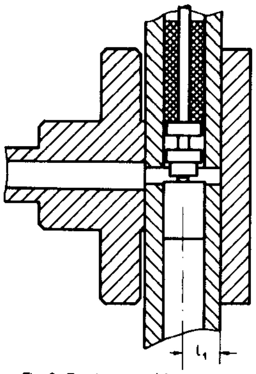

Fig. 2a Fundamental Wave Oscillator

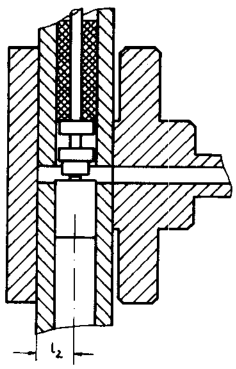

Fig. 2b 2nd Harmonic Wave Oscillator

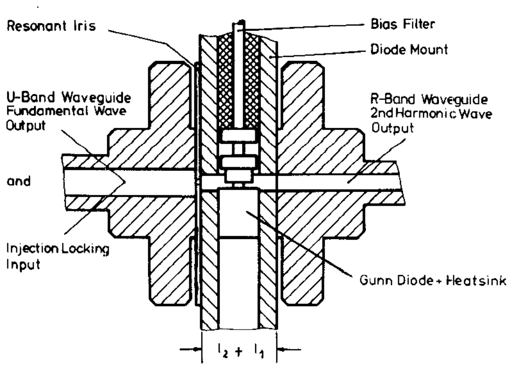


Fig. 2c Fundamental Wave Injection Locked 2nd Harmonic Oscillator

Figs. 2 Principle of Operation

## III. CW-Oscillator

The measured performance of the CW-Oscillator is listed in Table 1.

| Table 1 | fundamental wave | 2nd harmonic wave |
|---|---|---|
| Free running frequency | 46.5 GHz | 93 GHz |
| Output power | 18 dBm | 10 dBm |
| Locking gain | 10 dB | |
| Locking range | 300 MHz | 600 MHz |
| External Q-Factor | 100 | 3300 |
| Bias voltage | 4.5 V | |

## IV. Pulsed Oscillator

The performance of the pulsed oscillator is shown in Table 2 and in the Figures 4, 5.

| Table 2 | fundamental wave | 2nd harmonic wave |
|---|---|---|
| Free running frequency | 47 GHz | 94 GHz |
| Output power | 21 dBm | 15 dBm |
| Locking gain | 10 dB | - |
| Locking range | 270 MHz | 540 MHz |
| External Q-Factor | 110 | 3400 |
| Phase ripple | ± 2° | ± 4° |
| Pulse duration | 90 nsec | 90 nsec |
| PRF | 50 kHz | 50 kHz |
| Bias pulse voltage | ≈ 9 V | |

A phase detector was used to measure the phase response of the locked pulsed oscillator. In Fig. 3 calibration curves for 0° and 180° phase difference are shown together with the measured phase response of the oscillator at the fundamental frequency.

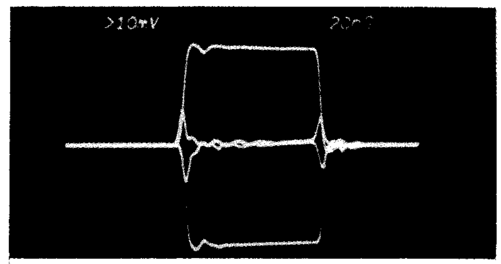

Fig. 3 Phase Detector Response

The transient behaviour extends to less than 10 nsec at the rise and the fall of the pulse. For the remaining 70 nsec of the pulse duration the phase ripple is below ±2°. The phase ripple is doubled at the 2nd harmonic wave (±4°).

The reason for the phase ripple was found to be a ripple on the bias pulse voltage as shown in Fig. 4. Here, the phase response (without cal. lines)

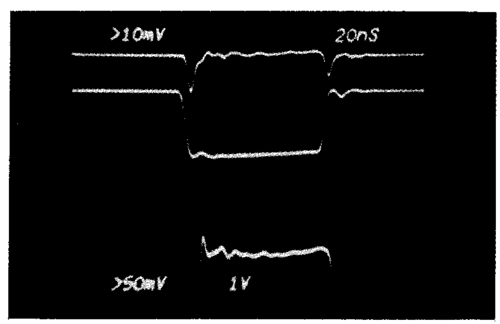


Fig. 4 Phase Ripple, 94 GHz Output Power and Bias Pulse Ripple

is shown above, the 2nd harmonic output power in the middle while the bias pulse ripple is shown below. It can be seen that the phase ripple and the bias voltage ripple are coincident.

To demonstrate the coherence between injection signal and output signal the spectra of the locked and unlocked pulses are shown in Fig. 5.

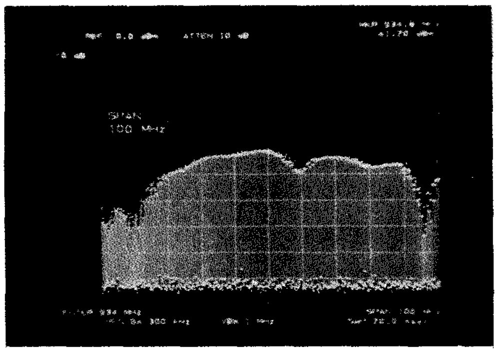

Fig. 5a Spectrum of the unlocked Pulse

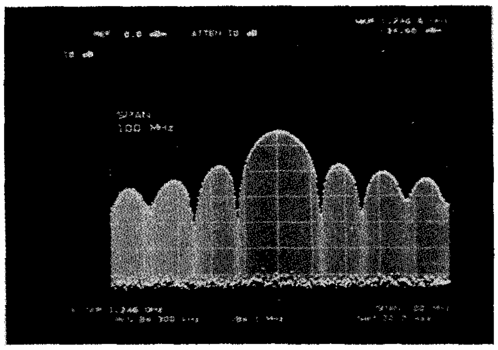

Fig. 5b Spectrum of the locked Pusle

The spectrum of the unlocked pulse is typical for a chirping pulse. The spectrum of the locked pulse exhibits a peak to valley ratio of about 40 dB which is typical for a highly coherent pulse.

## Reference

/1/ A Wideband, Backshort tunable Second Harmonic W-Band Gunn Oscillator, Helmut Barth Proc. IEEE MTT-S 1981