MULTI-DIODE KA-BAND OSCILLATORS USING HYBRID PLANAR CIRCUIT DESIGN

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Abstract

Design and performance of integrated power combining Ka-band oscillators will be presented in this paper. Planar circuitry is employed for DC-biasing and matching of the semiconductor devices, whereas the resonator is built up using waveguide techniques. Thus high Q-factor of the waveguide is combined with planar fabrication techniques.

TWO and FOUR diode power combining devices have been realized. Up to 630 mW CW-output power at 34 GHz has been achieved using Gunn-elements. The maximum total efficiency amounts to more than 4 %.

A VCO with 700 MHz tuning range delivers an output power of around 60 mW at 33 GHz.

Several 39.5 GHz Gunn oscillators with integrated harmonic mixer (factor 11) have been built for a phase locked communication system. The output power ranges from 80 to 150 mW with a single Gunn-element.

Introduction

The utility of mm-waves for various applications in the commercial field or for military purposes has been shown /1, 2/. The lack of high power solid state oscillators and the demand for an easy to process, but reproducible and reliable integration technique hampered wide spread applications. In this paper an oscillator concept will be put forward meeting these requirements.

Planar circuitry is employed for DC-biasing and matching of the semiconductor-devices, Impatt- or Gunn-elements, the frequency determining part, the resonator, is built up using waveguide techniques. The high Q-factor of waveguide thus is combined with planar fabrication techniques. This approach exhibits the advantage of being easily exchangeable with standard waveguide components, which are available almost exclusively in the mm-wave range. Hybrid planar oscillators, with TWO and FOUR power combined semiconductor devices as well as voltage controlled oscillators and sources with integrated harmonic mixer have been realized. Their data will be presented.

TWO-device-oscillator

The basic approach, the use of two diodes mounted in antiseries at the same loco of a waveguide has been proposed by Geller and Cohn /3/ earlier. But because of the coaxial type of diode connection, the described construction is not suited for the mm-wave range. We made a planar approach and inserted a sheet of RT-Duroid, type 5880, between the two diode caps, figure 1.

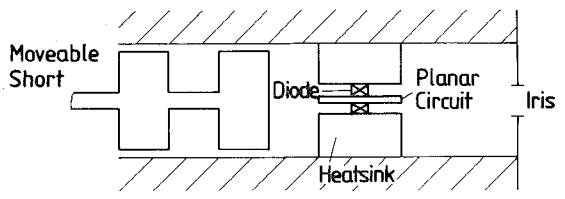

Figure 1: Schematic outline of the oscillator circuit

As DC-connection and RF-filters are printed on both sides of the board, this gives the possibility of separate bias of both devices. The diodes are mounted in the center of the waveguide, while the planar circuit is embedded in between. This diode-holder, shown in the midth of figure 1, is furnished with SMA-jacks for bias connection on both sides. For tuning and matching the entire oscillator unit is completed using a moveable backshort on one side and a length-iris combination on the other side of the holder. Figure 2 shows a built-up oscillator for Ka-Band (26,5-40 GHz) application.

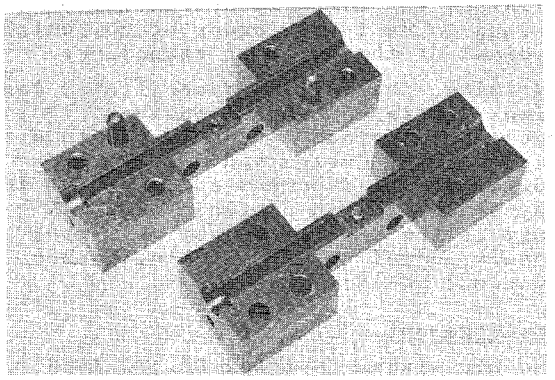

Figure 2: TWO device holder-unit, opened

The results employing Gunn-elements from different manufacturers are assembled in table 1. A combining efficiency of around 100 % has been achieved. Depending on the devices being used, output power values of 150 to 300 mW around 35 GHz have been performed. The maximum total efficiency (DC to RF) amounts to 4,27 %, a value which has not been reported yet in the Ka-Band frequency range using commercially available Gunn-elements

FOUR-device-oscillator

The good results, achieved with the two device structure encouraged us to investigate a four device version. Two diodes are

mounted on each broadwall of the waveguide at the same loco, again a sheet of RT-Duroid is inserted between the diode caps. Because the SMA jack dimensions are large in comparision to the holderunit, separate bias of the four diodes was not accomplished, but it was seen from former experiments with the two-device-units, that parallel biasing does not lead to difficulties with Gunn-elements. Figure 3 shows a four-device holder-unit for Ka-Band application. A movable back short and a length-iris combination again complete the design of the entire oscillator unit.

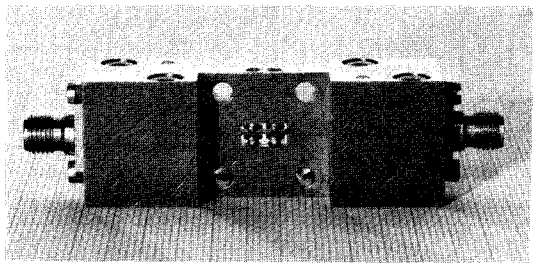

Figure 3: FOUR device holder unit

Table 2 presents the performed results with µA Gunn-elements, type MA 49 177. 630 mW of output power at 33.5 GHz has been achieved. The combining efficiency in this case is 98 %, the total efficiency amounts to 3.0 %.

Voltage Controlled Oscillator (VCO)

Another possibility to use the described type of hybrid planar circuit oscillator design is to change one of the Gunn-elements into a varactor-diode, thus giving a VCO. Because of the nearly identical package dimensions of the devices being taken (Gunn-element: µA type MA 49 177; varactor diode: Thomson-CSF type AH 154) no mechanical alterations of the holder-unit have to be performed, only the position of the backshort and the length-iris combination have to be newly optimized.

Table 3 gives the data of different VCO-units. Concerning the tuning range of 700 MHz at 32.7 GHz the output power variation with a minimum value of 56 mW lies below 1.6 dB.

Figure 4 shows the temperature behaviour of the 380 MHz tuning range VCO at 31.5 GHz. Frequency deviation and output power are displayed as a function of the tuning voltage applied to the varactor-diode with temperature as parameter.

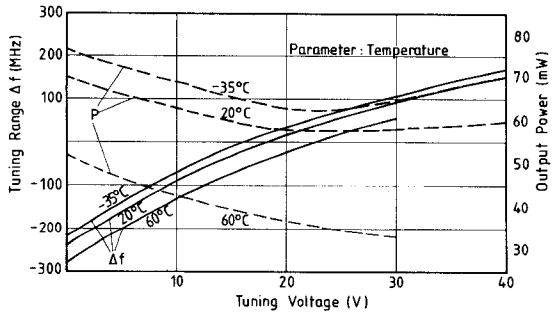

Figure 4: Temperature behaviour of a VCO

For a given tuning voltage (20 V) the frequency drift for the temperature range -35° to 60°C is 60 MHz, while the output power variation is 2.3 dB over the entire temperature range.

Oscillator With Integrated Harmonic Mixer

A VCO can be taken to build up a quartz-controlled RF-source. In this case a harmonic mixer with a quartz-derived LO is necessary for the phase locking. Providing a C-Band LO-signal - that means factor 11 mixing - the entire oscillator component has to contain additional elements, like RF-Coupler, Harmonic Mixer and IF-Coupler.

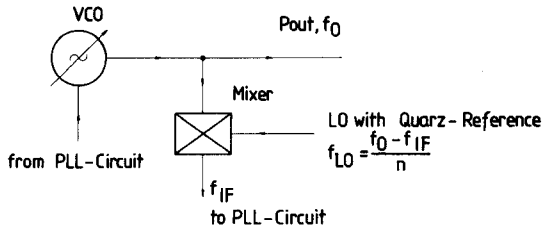

Figure 5: Blockdiagram of an oscillator with integrated harmonic mixer.

Applying the described design technique above, these 3 elements can be realized on the same RF-board together with the Gunn-elements' DC-connection. Planar technique and lumped elements - for the IF decoupling - are used. The printed board is built into a modified holder-mount, furnished with SMA connectors and connected to a moveable backshort and an appropriate length iris combination to build up the entire oscillator unit. Oscillators of this design have been taken for a Railway Communication Link at 39.5 GHz. The frequency stability being achieved with type AH 615 Gunn-elements from Thomson-CSF is $5 \cdot 10^{-7}$/°C from -20 to +50°C with an output power of 150 mW_{max}. The tuning range amounts to 60 MHz. The mixer diode being applied for this application is NEC-type ND 5558.

Conclusion

It has been demonstrated that the hybrid planar circuit design approach is well suited for the construction of Ka-band-Gunn-oscillators; TWO and FOUR device units as well as VCO's and Gunn-oscillators with integrated harmonic mixer have been built with good performance.

The application of the described design for higher frequencies (60 or 90 GHz) and for Impatt-diodes seems to be possible, corresponding oscillators are under development now.

References

/1/ H. Meinel and B. Rembold, Commercial and scientific applications of mm- and sub-mm-waves, The Radio & Electronic Engineer, July/Aug. 1979, p. 351-60.

/2/ L.R. Whicker and D.C. Webb, The potential military applications of mm-waves, AGARD Conf. on "Millimeter and sub-

millimeter wave propagation and circuits", Munich 1978, Proc. 245, p. 1-1-6.

/3/ B. Geller and M. Cohn, Supressing parametric oscillations in IMPATT amplifiers, MSN, April 1978, p. 92-7.

Manufacturer	Type No.	Unit No.(s)	V_{op}(V)	I_{op}(mA)	f_{op}(GHz)	P_{out}(mW)	η_{DC-RF}(%)	η_{comb}(%)
Microwave Associates	49 172 special	102 358	6	490	36	78	2.6	
	49 172 special	102 398	6	420	36	75	3.0	
		& 102 358 102 398	4.6	890	38.5	175	4.27	114
		& 102 358 102 398	6	875	35.5	185	3.52	121
	49 177	112 389	4.9	1145	36	165	2.95	
	49 177	112 399	4.7	1087	36	150	2.93	
		& 112 389 112 399	4.1	2380	36.1	310	3.17	98
Thomson-CSF	AH 609	209	4.6	1300	36	100	1.67	
		224	4.6	1270	36	100	1.71	
		& 209 224	4.8	2480	35.5	193	1.62	96

Table 1: Data of TWO diode power combining oscillators

Manufacturer	Type No.	Unit No.(s)	V_{op}(V)	I_{op}(mA)	f_{op}(GHz)	P_{out}(mW)	η_{DC-RF}(%)	η_{comb}(%)
Microwave Associates	49 177	112 319	4.8	1205	36	155	2.68	
		112 369	4.7	1110	36	165	3.16	
		112 379	4.7	1179	36	165	2.97	
		112 409	4.8	1160	36	155	2.78	
		& 112 319 & 112 369 &	4.55	4600	33.5	631	3.0	98
		& 112 379 & 112 409	4.6	4550	35.8	530	2.53	83

Table 2: Data of FOUR diode power combining oscillators

Semiconductor	Manufacturer	Type No. Unit No.	V_{op}(V)	I_{op}(mA)	f_{min} (GHz)	Tuning range (MHz)	Output power	
							minimum (mW)	variation (dB)
Gunn	/uA	MA 49177 112389	4.6	1140	32.7	700	56	1.6
Varactor	Thomson-CSF	AH 154 1505	0-30					
Gunn	/uA	MA 49177 112399	4.7	1150	31.5	380	58	0.8
Varactor	Thomson-CSF	AH 154 1533	0-40					

Table 3: Data of voltage controlled oscillators (VCO's)