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W-BAND GaAs GUNN DIODE HARMONIC POWER COMBINERS

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ABSTRACT

In this paper the combination of second harmonic power from mupltiple GaAs Gunn oscillators at W-band was investigated. The power combiner operating in a subharmonic mode involves two or three GaAs Gunn oscillators connected together by a 3 dB short-slot coupler. In two-oscillator combiners the second harmonic power of individual oscillator is 16 mW and 15 mW respectively. The combined power at 91.5 GHz is 23mW. In three-oscillator combiners the second harmonic power of individual oscillator is 7 mW, 7 mW, and 6 mW respectively. The combined power at 92 GHz is 14.5 mW. In both cases the combining efficiency is greater than 70 %.

INTRODUCTION

Since the advent of millimeter wave system the demand for a low noise, high power sources increases rapidly. In the past, GaAs Gunn diodes have been used to provide low noise sources. But the output power and operating frequency of these devices are limited by the low DC to RF conversion efficiency, low device impedance and poor heat sink. GaAs diodes do notoperate in fundamental mode at a frequency as high as 90 GHz. At W-band GaAs Gunn oscillators only deliver second harmonic power in the range of 20-30 mW. In order to satisfy the requirements of some transmitters and the pump of some parametric amplifiers at shorter millimeter wave band, various techniques for combining power from millimeter solid-state sources have been developed by many suthors in the recent years.[2]-[7].Mizushina [5] presented a method for combining fundamental power from Gunn diode oscillators at X-band. The combiners consisted of 3 dB short-slot couplers. Barth [7] and Sowers [6] have developed a technique for combining second harmonic power at W-band. They use the single-cavity multiple -devices technique. This paper describes an experimental harmonic power combiner, consisting of a 3 dB coupler. The approach is similar to Mizushina, but used at W-band for harmonic power combination. W-band single diode oscillator with 20 mW power output designed by one of the authors [8] is first reviewed. This is followed by a description of design of power combiner.In two-oscillator combiner, 23 mW harmonic power with 74 % combining efficiency was achieved at 91.5 GHz. While in three oscillator combiner 14.5 mW harmonic power with 70 % combining efficiency was obtained at 92 GHz.

PRINCIPLES

1. Gunn oscillator with second harmonic power output

Fig. 1. depicts the cross-section view of a Gunn oscillator with second harmonic output. It consists of (1) Gunn diode, (2) radial resonantor, (3) cylindrical cavity, (4) D.C. bias pin and (5) waveguid WR-10. A coupling aperture exists between two resonantors and a second aperture couples second harmonic power from resonantor to output port of WR-10.

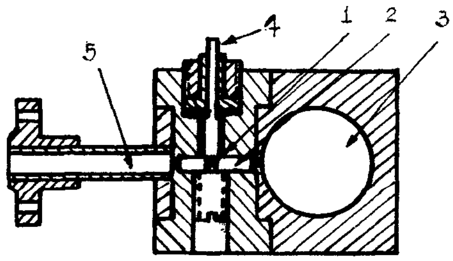


Fig. 1 Cross-section view of a single oscillator

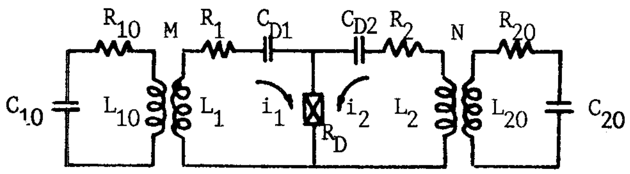


Fig. 2 Equivalent circuit of Gunn oscillator

Fig. 2 shows the equivalent circuit of a Gunn oscillator at W-band. It contains a fundamental frequency circuit and a harmonic frequency circuit as well. C_{10}, L_{10}, R_{10} and C_{20}, L_{20}, R_{20} denote the equivalent parameters of the cylindrical resonantor at fundamental and harmonic frequency respectively. Similarly, C_{D1}, L_1, R_1 and C_{D2}, L_2 , R_2 represent the equivalent parameters of device reactance, radial resonantor and external load. R_D is the resistance of Gunn diode. It is negative at fundamental fraquency and is a nonlinear functionof diode current. It is well known that there are two possible modes with different fundamental frequencies existing in a strongly coupled circuit. In general, a single Gunn oscillator is tuned in a mode having higher frequency stability. The resistance of the Gunn diode at harmonic frequency will never be negative because of the limited characteristic of GAAs material at W-band.It results in the fact that the second harmonic circuit of the oscillator can not be self-excited. The harmonic circuit is excited by the second harmonic current of total diode current. When properly tuned, the load resistance receives maximum harmonic power. At 94 GHz second harmonic power more than 20 mW was obtained.

2. Design of harmonic power combiners

Fig. 3 is the circuit diagram of a two-oscillator combiner using a 3 dB short-slot coupler.

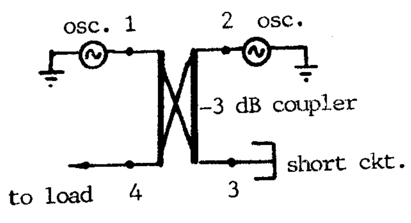
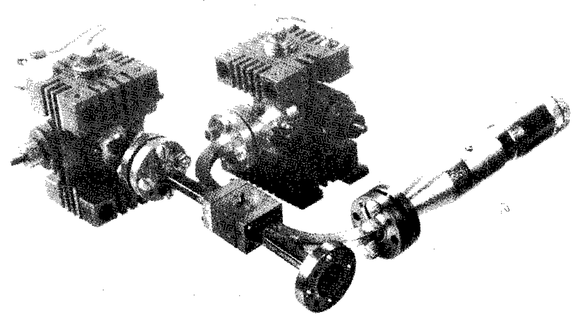
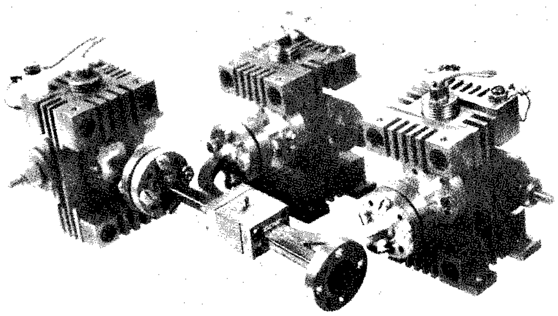


Fig. 3 Circuit diagram of two-oscillator combiner

Power is delibered by a 90 GHz oscillator from port 1 to port 4 and 3. A part of power is injected into oscillator 2 due to the reflection of short circuit at port 3. Since the free running frequency of GaAs diode oscillator is near 45 GHz,which is half of the fundamental frequency , ,this type of forced oscillation is refered to as subharmonic entrainment mode. Both steady-state solution and stability condition were given in [1]. In order to increase the synchronization bandwidth, it is not necessary to tune the locked oscillator in a higher frequency stability mode.



(a)



(b)

Fig. 4 Assembly view of 90 GHz power combiners

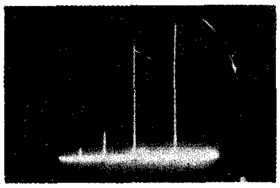
RESULTS

Power combiners with two and three GaAs diodes have been accomplished and measured. Table 1 lists the experimental results. With two diodes, combining power of 23 mW was measured at 91.5 GHz with 74 % cimbining efficiency. But in three diodes case

TABLE 1

Diode no. type (WI/57)	Individual performance		Combined performance		
	f (GHz)	P_o (mW)	f (GHz)	P_o (mW)	combining eff.(%)
1	94	20	(single)		
2	—	16	91.5	23	74
3	—	15			
4	—	7			
5	—	7	92	14.5	72
6	—	6			

the combined power output is reduced to 14.5 mW with combining efficiency kept at 72 %. The reduction of power is due to dissimilarity between individual oscillators. When all three oscillators are tuned approximately to a same frequency, power output of each oscillator is reduced to 6-7 mW.



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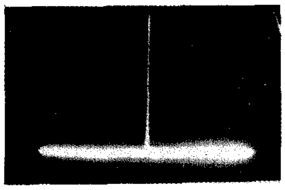

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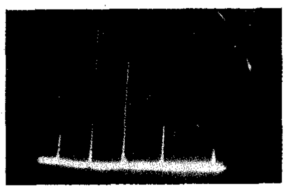
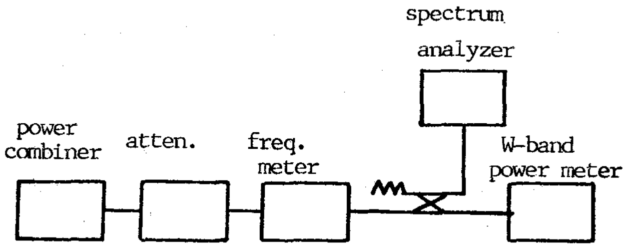


(c)



(d)

Fig. 5 Spectrum of 90 GHz combiner and test set

Fig. 5 shows the spectrum lines measured with a two-oscillator combiner in which (a) is the spectrum lines before locking, (b) is the spectrum line during locking, and (c) is the spectrum lines after locking. Fig. 5(d) is the block diagram of test set up. The bandwidth of synchronization is approximately 30 MHz.

CONCLUSION

An experimental harmonic power combination with Gunn diodes has been successful at W-band. It may satisfy the requirements of some low power level transmitters and parametric amplifiers. More than 40 mW combined power at W-band is expected if Gunn diodes can be selected in advance and the designs of individual oscillator and the short-slot coupler could be improved.

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