MILLIMETER-WAVE SOLID STATE TRANSMITTER COMPONENTS

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ABSTRACT

Recent trends in millimeter-wave solid state transmitter components are reviewed. Specifically, the progress of the developments of IMPATT and Gunn Oscillators, Power Combiners, phase and injection locking techniques and upconverters are presented.

INTRODUCTION

In recent years, there has been a rapid growth of millimeter-wave system applications. This trend can be attributed to the decided advantages of using millimeter-wave systems over microwave and optical counterparts. The millimeter-wave systems require much smaller antennas and provide wider bandwidth than the microwave systems. In addition, the millimeter-wave systems provide better penetration capabilities through fog, clouds and dust than the optical systems. In this paper, recent progress and trends in the development of selected solid state transmitter components for millimeter-wave systems will be reviewed.

IMPATT AND GUNN SOURCES

Figure 1 shows the state-of-the-art output power achieved at various frequencies with CW and pulsed double-drift IMPATT and Gunn oscillators. For IMPATT diodes, pulse powers of 25 W at 35 GHz, 15 W at 94 GHz, and 520 mW at 217 GHz have been obtained. CW powers of 2.3 W at 40 GHz, 1 W at 94 GHz, and 50 mW at 220 GHz have also been achieved. The peak power shown in Figure 1 is measured at less than 1% duty factor with 100 ns pulse width. With wider pulse widths and increased PRF, peak power output gradually decreases toward the value of CW operation. Below 100 GHz, the power output follows I/f characteristic, indicating that the device power is thermally limited. Beyond 100 GHz, the power output follows I/f^2 characteristic, implying that the device is limited by device-circuit impedance matching. Since IMPATT oscillators provide much higher output power than Gunn oscillators, INPATT sources are better suited for high power transmitter applications. On the other hand, GaAs Gunn devices have lower AM noise, therefore, they are more useful for low noise, low power transmitter systems.

POWER COMBINING TECHNIQUES

To achieve higher power output than a single diode can provide, power combining techniques are currently being developed to accumulate power from a number of IMPATT diodes for millimeter-wave applications. Two approaches have been pursued to achieve higher power. For systems where the bandwidth is important, millimeter-wave oscillators and amplifiers are combined using 3 dB hybrid couplers. The development in this area has been concentrated at 60 GHz for covert communications. Figure 2 shows a two-stage V-band amplifier using four diodes in the output stage. Using silicon double-drift diodes on diamond heat sinks, output power of 1.5 W from two diodes and 2.4 W from four diodes have been obtained at 60 GHz.

The second approach is a resonant cavity combiner configuration first suggested by Kurokawa (1). The advantage of this approach is the ability to combine a large number of diodes to achieve high power. The disadvantage of this approach is that the resonant cavity limits the bandwidth of the combiner to less than 1%. Figure 3 shows a four-diode combiner which produced over two watts of CW output power. A development program is currently underway to achieve 100 W peak output power at 94 GHz. Already 20 watts peak power from two diodes, and 40 watts peak power from four diodes have been achieved.

PHASE AND INJECTION-LOCKING OSCILLATORS

For certain system applications, the FM noise of the oscillator close to carrier must be kept low to ensure receiver sensitivity. To meet these requirements, phase and injection-locking techniques have been developed. Figure 4a shows the block diagram of a 94 GHz Gunn oscillator phase-locked to a crystal oscillator reference signal. The measured phase noise characteristics of the phase-locked oscillator is shown in Figure 4b. Significant improvement in phase noise can be seen within the locking band. The locking bandwidth is determined by the locking loop to typically 1 to 10 MHz.

Another method of achieving a low-phase noise spectrum is the injection-locking technique with a low noise signal input. One way of achieving a high CW output power and low FM noise simultaneously is to injection lock a CW IMPATT oscillator with a phase-locked oscillator as shown in Figure 5. Also shown is the spectrum of a CW IMPATT source as a free running and injection-locked oscillator. It appears that the FM noise of the oscillator is improved by means of injection-locking.

UPCONVERTERS

In many millimeter-wave transmitter systems, upconverters are used. The upconverter receives an IF signal input f_{IF} and a RF millimeter-wave signal (f_{RF}); and it generates RF signal outputs at $f_{RF} \pm f_{IF}$. The lower sideband, f_{RF} - f_{IF} is rej ected by the bandpass filter connected at the output. The performance of the single sideband upconverter is shown in Figure 6. A maximum power output of 7.5 dBm can be obtained with +18 dBm IF input power and +17.3 dBm RF input power; both single and balanced configurations are used. The single-ended configuration offers a simple design, whereas the balanced configuration provides greater dynamic range.

CONCLUSIONS

The progress in the development of some millimeter-wave solid state transmitter components has been reviewed in this paper. With demonstrated high power capabilities and noise reduction techniques in these components, potential applications in the area of telemetry at millimeter-wave frequencies can be realized.

REFERENCES

1. Kurokawa, K. and F. M. Magathaes, “An X-band 10-Watt Multiple-IMPATT Oscillator”, Proc. IEEE, Vol. 59, No. 1, January 1971, PP 102-103.

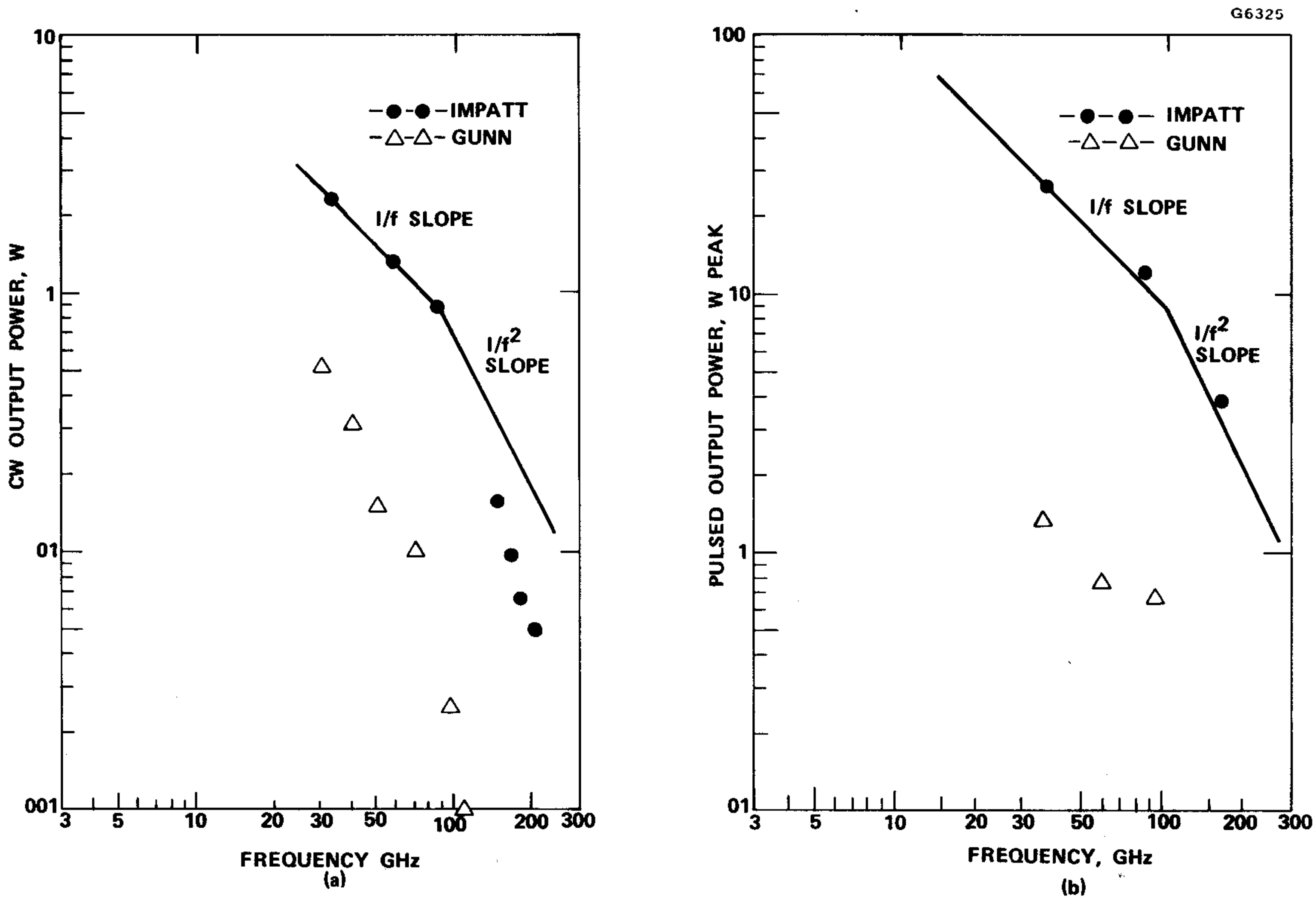
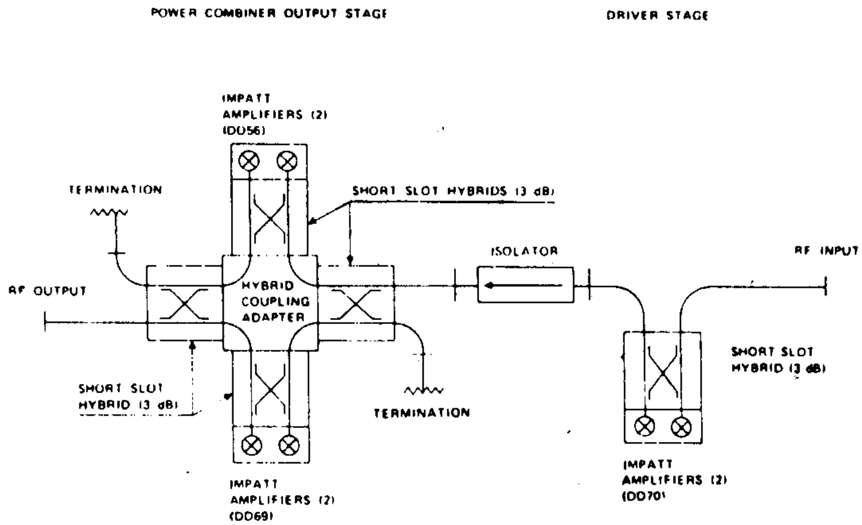


FIGURE 1 STATE-OF-THE-ART OF MILLIMETER-WAVE SOURCES (a) CW (b) PULSED.



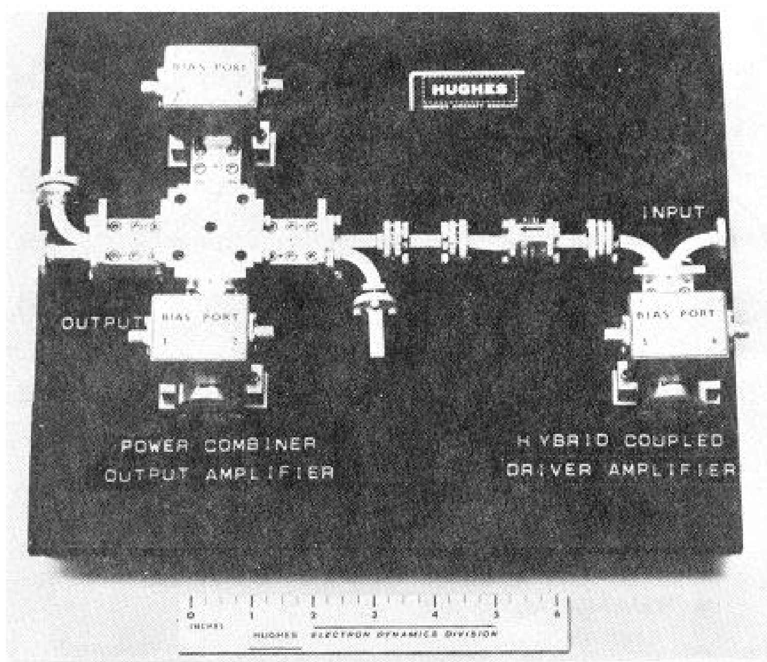


FIGURE 2 PHOTOGRAPH AND BLOCK DIAGRAM OF A TWO-STAGE V-BAND IMPATT AMPLIFIER/COMBINER

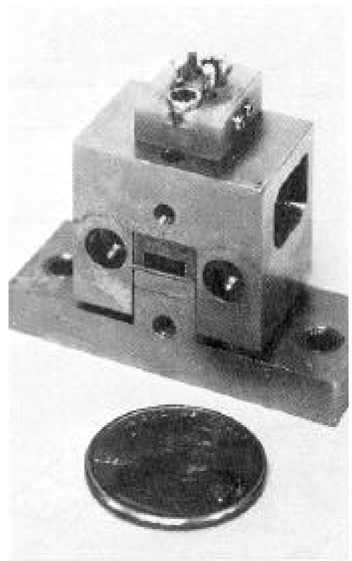
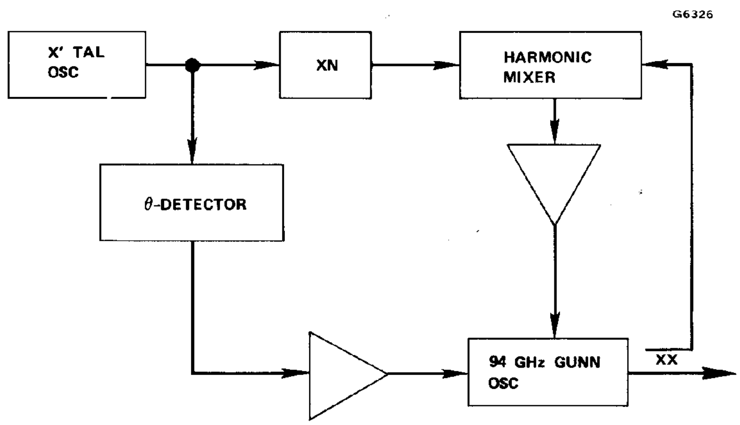
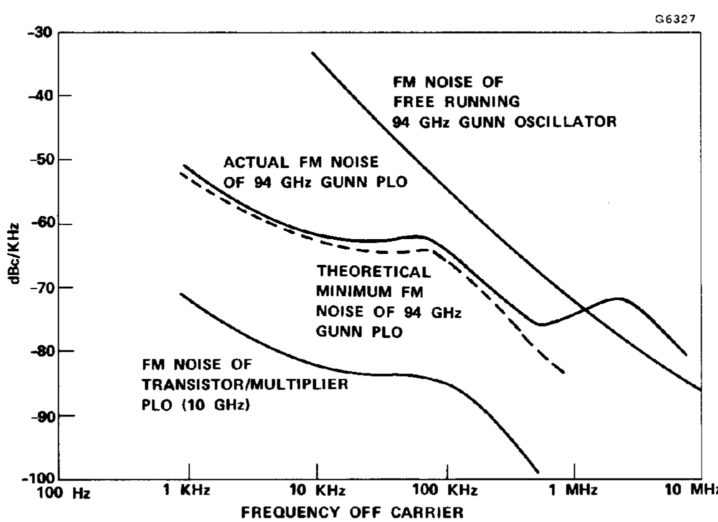


FIGURE 3 V-BAND FOUR-DIODE COMBINER

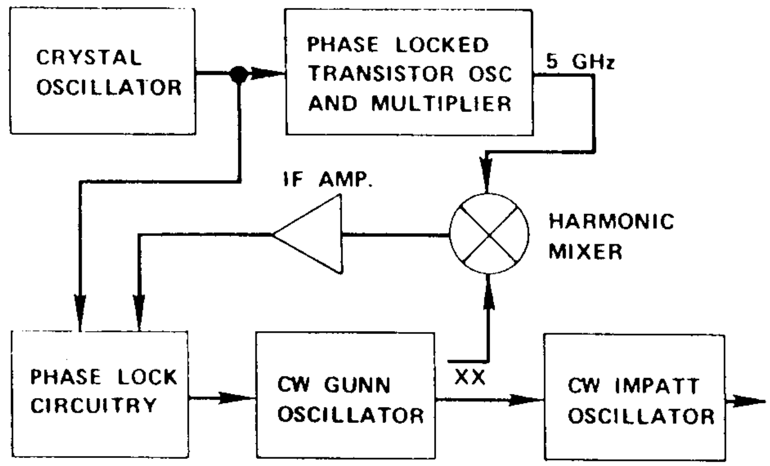


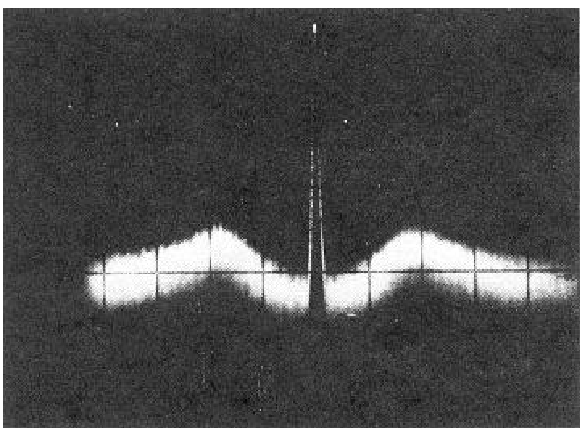
(a)



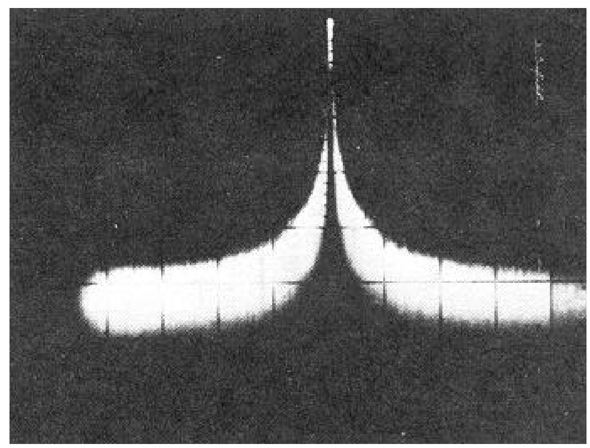
(b)

FIGURE 4 SSB FM NOISE OF 94 GHz GUNN PLO, dBc/KHz.





a) STABILIZED IMPATT OSCILLATOR



b) FREE RUNNING IMPATT OSCILLATOR

fo = 58.3 GHz, Po = 3- mW
SCALES 0.5 MHz/DIV., 10dB/DIV.

FIGURE 5 PLO/ILO TECHNIQUES FOR GENERATING MILLIMETER-WAVE HIGH POWER, LOW NOISE SIGNALS

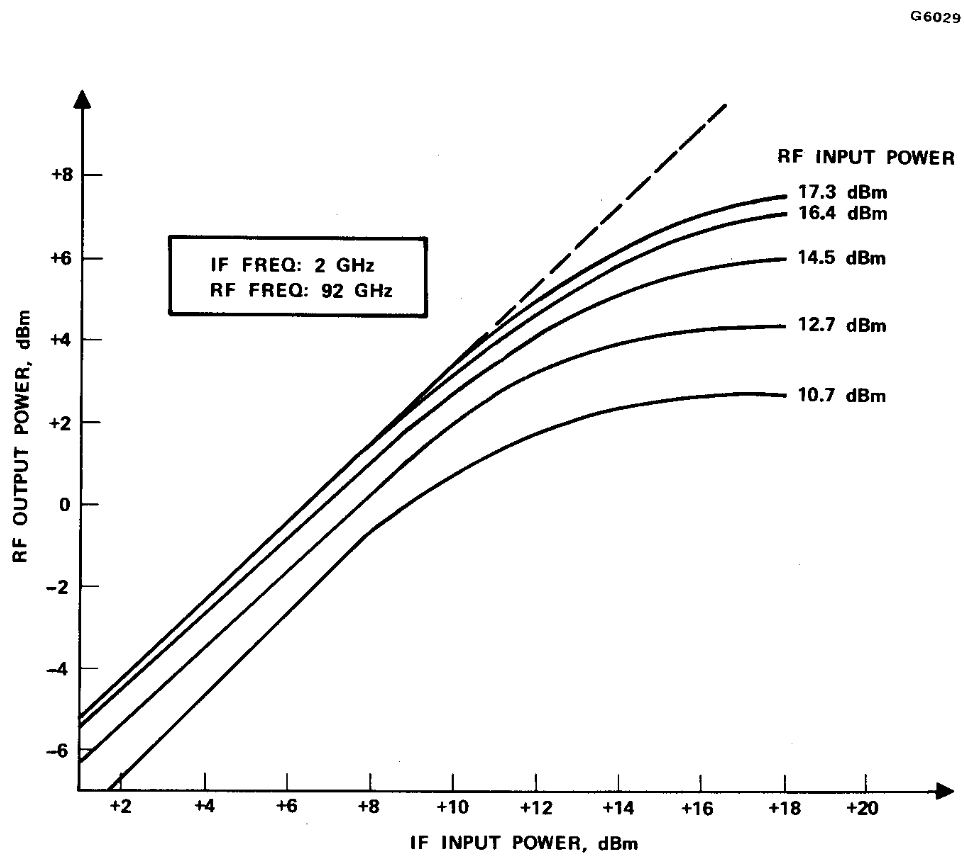


FIGURE 6 SINGLE SIDEBAND UPCONVERTER INPUT/OUTPUT CHARACTERISTICS OF SINGLE-SIDEBAND UPCONVERTER.