III-3. FREQUENCY MULTIPLICATION WITH THE STEP RECOVERY DIODE

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The step recovery diode has been discussed in several papers (References 1 and 2). Recently, diodes have become available with attractive combinations of short transition time, long lifetime, low series resistance, and high breakdown voltage. These parameters are all related to the efficiency and power handling capability of frequency multipliers using these diodes. Special frequency multipliers were constructed to explore the relations among the diode characteristics and the performance of multipliers. To make multipliers suitable for such study, the circuits were constructed to eliminate resonances except at the input and the output frequency even for high order multiplication. Diode current was measured by building into the multiplier a current sampling resistor immediately adjacent to the diode. The value of the resistance is kept small, and the voltage developed across it is observed with a Hewlett-Packard sampling oscilloscope having a bandwidth of 5 gc. The output circuits of these multipliers were tunable cavities coupled to the diode so that operation could be observed at many different multiples of the input frequency.

The operation of these multipliers is characterized by substantial independence of input and output circuit tuning. The input circuit resonates at the input frequency with the self bias resistance adjusted for the input power level. The diode stores charge on the forward part of the drive cycle and gives back the charge to the circuit during negative drive. At some point on the negative cycle, the charge stored in the diode is exhausted, and the current which flowed through it up to that time is diverted through the output tank circuit. The sudden pulse of current with rise time equal to the diode transition time excites the output tank circuit causing oscillation at its natural frequency. The voltage developed by this oscillation drives the diode once again into forward conduction so that it stores charge. Therefore unless the lifetime of the diode is too short, the charge in it is not exhausted, even though the voltage impressed upon it oscillates, until the same point on the input cycle comes around again. The diode therefore remains a low impedance most of the time except for a fraction of one output cycle per input cycle. It is essential that the series resistance be low to avoid excessive dissipation in the diode. For input power levels of one watt, currents of one ampere or more peak circulate through the diode.

A fourier analysis of representative waveforms shows that the current generated at the n^{th} harmonic can be at most $1/\pi n$ of the current circulating through the diode. Thus to obtain high efficiency the circulating current must be large compared to the input current from the drive generator. This implies that the diode must be part of a resonant circuit which multiplies the current. Thus even for a lossless diode, efficiency and bandwidth are related in the input circuit. Unit efficiency would require, in addition to lossless diodes and circuits, that the output impedance seen by the diode be $\pi^2 n^2$ times the input impedance. From the discussion above, the diode input impedance is nearly equal to its series resistance. The loaded Q required in the output circuit can be determined from the output purity desired. Adjacent harmonics are essentially equal in available amplitude to the desired output frequency so the output tuned circuit must be sharp enough to reduce these neighboring side bands to an acceptable level.

Multipliers designed according to the information given are producing 20 mw in X-band and 200 mw in L-band. Best operation so far is in the lower band where overall efficiencies are approaching 30 percent for multiplication orders of 10 to 20. Investigation is continuing to obtain better diodes and improved performance.

REFERENCES

1. Moll, J. L., Krakauer, S. and Shen, R., "P-N Junction Charge Storage Diodes," Proc. IRE, Vol. 50, No. 7, pp. 43-53, January 1962.
2. Krakauer, Stewart M., "Harmonic Generation, Rectification, and Lifetime Evaluation with the Step Recovery Diode," Proc. IRE, Vol. 50, No. 7, pp. 1665-1676, July 1962.