V-7 A THIN FILM X-BAND VARACTOR QUADRUPLER

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Microwave integrated circuit components continue to be reported and in many applications have exhibited performance equal to or exceeding existing conventional components. Most of these components fall into the category of single frequency band operation, as is normal for phase shifters, mixers, amplifiers, T-R switches, etc., and single values for wave propogation factor and transmission line loss are adequate for design parameters. Multiplier generation involves two or more frequency bands of operation and consequently poses the additional problems of treating the propogation medium and its microwave circuitry losses over a large frequency range. In microstrip transmission line this problem is particularly severe because of the variation of the velocity of propogation factor as a function of frequency as well as impedance. This effect has been characterized for ceramic substrate by Vincent,[1] and results indicate that it can be minimized by choosing impedance of 50 ohms or greater. Circuit losses increase rapidly as a function of wavelength, however, and can be minimized only by keeping microstrip line lengths to a minimum. It follows from these considerations that multiplier designs, in particular the multifrequency circuits such as shorted stubs, etc., should contain microstrip lines of 50 ohm or greater where feasible, and should be of minimum length, especially for higher frequencies.

A second and equally important consideration for integrated circuit multiplier design (as well as other components) is the technique of mounting the active device, or varactor, in the circuit pattern. For ceramic substrate, shunt mounting is impractical because of difficulties in drilling holes in the ceramic and series connection in the circuit pattern is dictated. A beam lead varactor is the logical choice of varactor style for this mounting scheme, primarily because of the ease with which it can be bonded into the circuit pattern. Other pertinent factors involved in using the beam lead device include reduction of parasitic device parameters and the ability to replace varactors without destroying the circuit pattern.

Based on the aforementioned design considerations, a beam lead varactor suitable for frequency multiplication from S-to X-band was designed and fabricated. Figure 1(a) shows the schematic diagram for the 2.125 to 8.5 GHz varactor quadrupler designed using the beam lead varactor and resonate microstrip transmission lines for filters. Interconnecting transmission lines form matching transformers and provide circuit tuning.

Open and shorted stub transmission lines and interconnecting lines are 50 ohms impedance where practical. Transformers are provided by quarter wavelength transmission lines with impedance determined by $Z_t = \sqrt{R_d R_o}$, where R_d is the effective real impedance of the varactor and R_o is the terminating load. The resulting output, idler, and input circuit representations, for center frequency only, are shown in Figures 1(b), 1(c), and 1(d), respectively. For the purpose of circuit design, measured values of C_j and L_s were used. R_d was determined initially from theory and tables published by Burkhardt and later optimized experimentally.

Circuit designs were examined using these parameters and microstrip transmission line data using an existing laboratory computer program which summarizes the various circuit elements at one particular frequency in an ABCD matrix array and presents the resulting impedance variation as a function of frequency on a Switch Chart display. Since the multiplier design is narrow band, this technique was useful in optimizing circuit parameters and studying possible problem areas caused by fabrication difficulties (line width variation, etc.).

Experimental data for the design shown in Figure 1 are presented in Figures 2 and 3. Varactor parameters include $\gamma = 0.45$, $V_b = 26V$, $R_s < 2$ ohms. Conversion loss for 2.125 to 8.5 GHz frequency conversion is <5.9 db from 10 to 225 MW power input with VSWR less than 1.5:1. The 3 db conversion efficiency bandwidth is slightly less than 5% with maximum VSWR 1.6:1. Spurious harmonics at the output were found to be >40 db below the output signal for the third and fifth harmonics and >30 db for the fundamental and second harmonic. For fixed bias operation, all harmonics were >20 db below the output signal over a 2% bandwidth.

Physical size of the multiplier with its associated bias circuit is 0.400 x 8.30 x .040 inches. Substrate thickness is 0.020 inch and is unglazed alumina (Al_2O_3). Bias circuitry is formed on 0.010 inch glazed alumina and is attached to the primary substrate.

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References

1. Vincent, B. T., "Ceramic Microstrip for Microwave Hybrid Integrated Circuitry", presented at the 1966 International G-MTT Symposium, Palo Alto, California.

2. Burkhardt, C. B. "Analysis of Varactor Frequency Multipliers for Arbitrary Capacitance Variation and Drive Level", The Bell System Technical Journal, April 1965, pp. 675-692

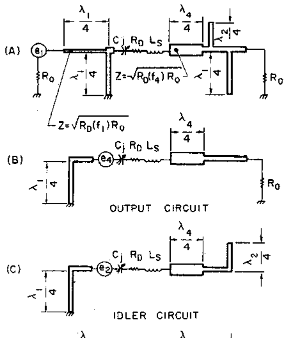

FIG. 1 - Schematic Diagram of a 2.125 to 8.5 GHz Multiplier

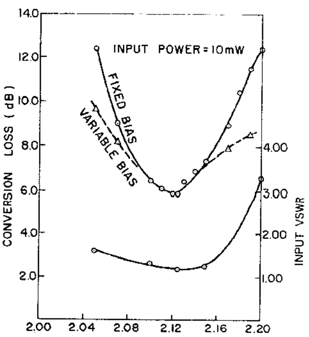

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FIG. 2 - Input VSWR and Conversion Loss vs Frequency

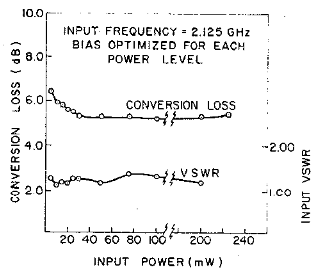

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FIG. 3 - Input VSWR and Conversion Loss vs Input Power