V-1. Phase Stability of Varactor Frequency Multipliers

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In the Stanford Linear Accelerator, power at 476 Mc is transmitted by a two-mile coaxial line parallel to the accelerator structure. At 30 points along the length of this coaxial line, separated by 333-1/3 feet, a few watts of power are coupled out and multiplied by varactor diode sextuplers to the accelerator operating frequency of 2856 Mc. This power is then amplified and transmitted to the accelerator structure to provide acceleration to the electron beam.

The maximum electron beam energy and energy spectrum are, in part, a function of the phase stability of the varactor frequency multipliers. A specification of 1° differential phase stability for one week was established for the frequency multipliers. That is, each multiplier must remain within 1° of all other multipliers. At the end on one week, manual rephasing is performed if necessary.

Phase stability data was obtained using six multipliers and three different types of diodes.

The measurements were performed on a waveguide phase bridge of the direct-comparison, two-video detector type. This bridge was designed for maximum mechanical stability and electrical symmetry, and was operated in a temperature stabilized environment. The resulting measurement accuracy is better than ±0.1° for periods of one week.

Mesurements were made of phase stability as a function of temperature, bias, frequency and drive power. Table I presents a summary of the results.

TABLE I

Phase Stability of Varactor Frequency Multiplier

TEST	RANGE OF VARIABLE	PHASE SHIFT
Phase stability vs temperature	±8°C	1° per degree C
Phase stability vs bias	±2 volts	1° per volt
Differential phase stability vs frequency	±120 kc at 2856 Mc	0.1° per 120 kc
Differential phase stability vs common drive power	±0.1 db	$\Delta\phi < 0.2°$

The phase stability as a function of temperature was quite uniform in all units tested. It is rather difficult to separate that portion due to the diode and that portion due to the tuned circuits. Based on the estimated tuned circuit Q's and estimated coefficients of expansion, the observed phase shift could be attributed entirely to changes in the tuned circuits. The possible range of environmental temperature will run from +40 to +120°F. An oven which will maintain ±0.1°C over the ambient temperature range is feasible, and the resulting phase stability vs temperature would be ±0.1°

Phase stability as a function of bias presents no problem in the design of frequency multipliers for the linear accelerator. It will be necessary to use a well regulated dc supply as a source of fixed bias. With a coefficient of 1° per volt, almost any conventional regulated supply will be adequate, and negligible phase shift will result.

It is anticipated that the operating frequency of the linear accelerator may be changed by as much as ± 120 kc about the nominal operating frequency of 2856 Mc. This will be done to compensate for changes in the operating frequency of the accelerator structure due to small temperature variations. For this reason, it was necessary to determine the differential phase stability of frequency multipliers as a function of frequency. In this test, it was assumed that all the phase shift observed can be attributed to the phase shift of the various tuned circuits in the multipliers. The input frequency to two multipliers was changed by ± 20 kc, with a resulting change in output frequency of ± 120 kc, and $\pm 0.1^\circ$ phase shift was observed, as noted in Table I.

Phase stability vs drive power is the most difficult problem in the design and use of varactor frequency multipliers in the Stanford Linear Accelerator. It is planned to regulate drive power to ± 0.1 db per week. It has been found that a proper choice of fixed bias voltage can minimize phase shift as a function of drive power, yielding a phase shift of less than 0.2° for the above range. In addition the following factors may be of importance and are under study: drive power level to each multiplier; minimum capacitance of varactor; tuning procedure; selection of diodes; and shunting of varactor with a fixed capacitance.

The results presented here indicate that, with proper control of the environmental conditions and operating parameters, varactor frequency multipliers have adequate phase stability for use in the Stanford Linear Accelerator. Work is continuing in an effort to make the phase instability of frequency multipliers a negligible factor in this application.