Hydrogen Maser: Low Phase Noise, L-Band Frequency Multiplier

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A 100 to 1400 MHz discrete component ×14 frequency multiplier was developed to determine the lowest phase noise achievable with present technology. The 1/f phase noise spectrum of the multiplier measured 11 dB lower than the hydrogen maser frequency standard and 13 dB better than a high-quality step recovery diode multiplier.

I. Introduction

This design is the result of an effort to improve the 100 to 1400 MHz frequency multiplier used in the receiver of the hydrogen maser frequency standard. The objective is to design a multiplier with low phase noise and good long-term stability while eliminating highly sensitive adjustments that are difficult to tune and maintain in alignment over long periods of time. Bandwidth and dynamic range are secondary requirements as the multiplier is driven from a narrow-band constant output 100-MHz source.

II. Design Approach

The reduction of phase noise requires special techniques that have been developed from recent investigations into this area (Ref. 1). $1/f$ noise (flicker of phase noise) that is present in linear active devices can be significantly reduced through the application of negative feedback. Conversely, positive feedback gives rise to $1/f^3$, or flicker of frequency noise which is characteristic of oscillators. At high frequencies, however, negative feedback is difficult to apply around an entire amplifier, but the same effect can be achieved by introducing local feedback (usually emitter degeneration) at each stage. The amplifiers used in the multiplier are commercial units supplied by Avantek which employ wideband, class A stages with negative feedback. Good phase stability is achieved with wideband amplifiers because the matching networks are low Q. The only tuned elements present are passive tubular filters, which select the desired harmonics from the multipliers.

The foremost advancement in achieving low phase noise nonlinear devices has been the Schottky barrier or hot carrier diode which is a majority carrier device and has virtually no charge storage in the depletion region. Since mixers and doublers are practically the only nonlinear devices that employ Schottky barrier diodes, design flexibility is rather restricted by excluding the use of step recovery diodes, transistors, or other minority carrier devices.

III. Circuit Operation

The circuit shown in Fig. 1 multiplies up to 800 MHz with doublers, mixes with the original 100 MHz to obtain 700 MHz, and finally doubles to 1400 MHz. The $\times 4$ is actually a doubler driven at near maximum input power so that there is enough power left in the fourth harmonic to filter and amplify with a reasonable amount of gain. Since the signal is processed through many stages, the signal levels must be kept high and the losses minimized in order to prevent degradation of the signal-to-noise ratio. This requires the consideration of many different multiplication methods, in order to obtain a good match of the input-output levels of the various components without excessive padding or amplification.

IV. Noise Performance

Figure 2 shows the power spectral density of phase noise in the $1/f$ region for the multiplier and also for an advanced design step recovery diode multiplier built by Zeta Laboratories, which shows promise for improved noise and stability over conventional designs. The noise level of the present and future hydrogen masers is plotted along with the reduction in noise level that the $\times 14$ multiplier receives due to the correction of the phase-locked loop in the receiver.

V. Conclusions

The $\times 14$ multiplier requires a good ground plane along with a dual power supply with some distribution filtering. If low leakage is desired, a large module is needed with sufficient room inside to disconnect the hard lines and insert pads when setting the levels at the various stages. Thus, while the noise performance of the multiplier is excellent, the high-cost difficult packaging, and low efficiency represent serious disadvantages when compared to a compact step recovery diode multiplier. In this application, although the noise of the discrete multiplier is 13 dB below that of the step recovery diode multiplier, the 23 dB of correction applied by the receiver would lower the noise of the step recovery multiplier to 11 dB below the noise level of the Mark III hydrogen maser, and thus retain a comfortable noise margin for any future improvements in maser performance. At the present time Zeta Laboratories is building, under contract to JPL, an advanced design 1400-MHz step recovery diode multiplier for possible use in the hydrogen maser.

Reference

1. Meyer, R., and Sward, A., "Frequency Generation and Control: The Measurement of Phase Jitter," in *The Deep Space Network*, Space Programs Summary 37-64, Vol. II, pp. 55–58. Jet Propulsion Laboratory, Pasadena, Calif., August 31, 1970.

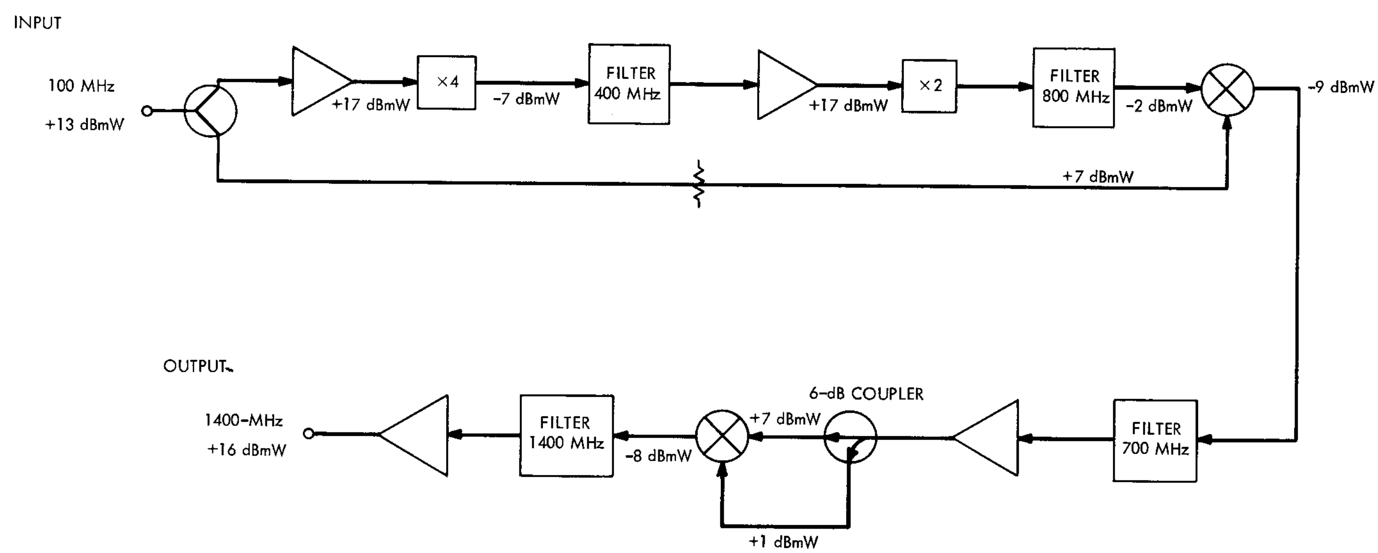

Fig. 1. × 14 Multiplier block diagram

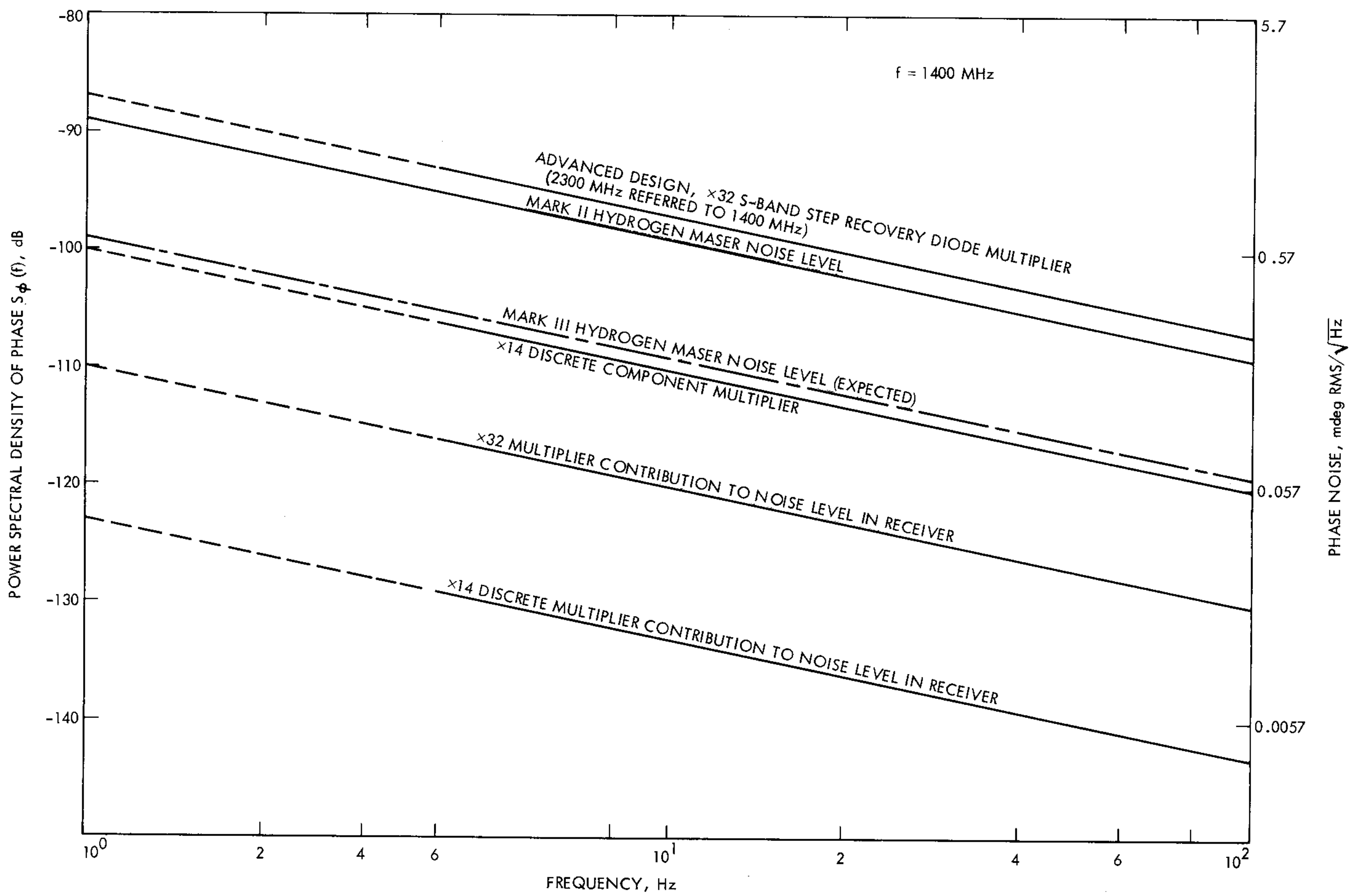

Fig. 2. Power spectral density of phase noise