Frequency Generation and Control: Atomic Hydrogen Dissociator

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This article describes a long-life hydrogen gas discharge source for the JPL hydrogen maser. The lifetime of this source has been extended from approximately 6 months to 2 years or more by changing the geometry of the RF power coupling mechanism. Other improvements over the older type source are: (1) the gas discharge may be started without increasing hydrogen pressure, and (2) an acceptable impedance match to the RF power generator can be achieved over a broader range of operating hydrogen pressures.

I. Introduction

The hydrogen maser uses a collimated beam of hydrogen atoms. These are prepared in an RF discharge dissociator such as that shown in Fig. 1. The present JPL discharge bulb is fabricated of 7740 Pyrex glass tubing, 50 mm in diameter $\times$ 64 mm in length, with a capillary tube 6.5 mm in diameter for the entrance of hydrogen. Opposite the capillary tube is a glass multitube collimator consisting of an array of 800 tubes, 50 μm in diameter. Dissociated atoms traveling in the direction of the collimator axis are used in the maser oscillator process. The collimator provides a pressure drop from the discharge source bulb to the vacuum chamber to maintain the optimum discharge pressure of approximately 100 μm.

II. Design Concept

An RF network is required to couple the output of a crystal controlled 125-MHz, 5-W source to the hydrogen gas discharge in the bulb. This network must present a good impedance match to the power source over the normal range of operating gas pressures used in the masers.

Figure 2 shows the dissociator bulb inserted in the coupling network used previously at JPL. Here, a tuned 1:9 step-up transformer couples the RF energy to a pair of thin electrodes on opposite sides of the bulb. The resulting voltage on these electrodes was apparently high enough to cause the glass wall adjacent to each electrode to sputter glass internally and produced a thin, yellow film on the surface. It is thought that the buildup of this film allowed recombination of the atoms to molecular hydrogen, a process which depletes the supply of atoms. As the film became thicker, the maser output power gradually decreased and finally ceased. This chemical action resulted in an approximate dissociator life of 6 months before maser output power degradation became noticeable and replacement with a new dissociator was necessary. No attempt has been made to analyze the composition of this film.

A new RF coupling network was designed which has resulted in a dissociator lifetime in excess of 2 years. The criterion of this design was to lower the RF voltage gradient across the dissociator bulb by an order of magnitude over the previous design described above. This new RF coupling network with a dissociator bulb inserted is shown in Fig. 3. The circuit consists of a single-turn coil of copper strip around the bulb, which is matched with a series-parallel L-network to the 50-Ω VHF power source. A single turn of 2-mm copper wire was tried, but the resulting discharge was not as uniform as with the 25-mm strip.

III. Conclusion

The new RF coupling network has been operating for 2 years with no noticeable degradation. This new circuit configuration has also demonstrated two other operating improvements over the previous circuit: (1) It is no longer necessary to increase hydrogen gas flow when igniting the discharge, which is a very desirable feature since changes in gas flow can have a deleterious effect on maser frequency stability. (2) A good impedance match to the VHF power source is maintained over a wider range of operating gas pressures than previously achieved.

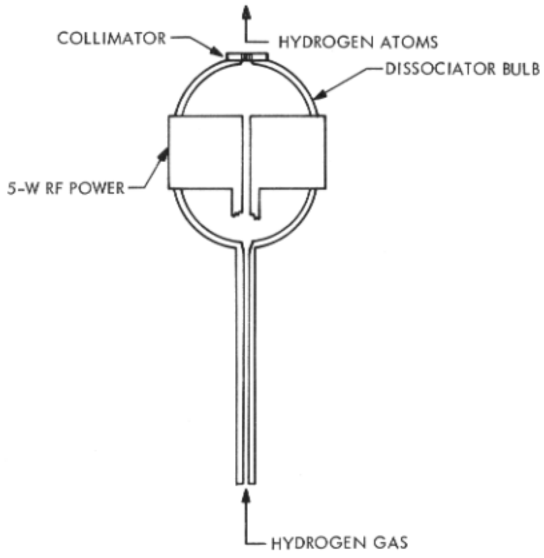


Fig. 1. Dissociator bulb schematic

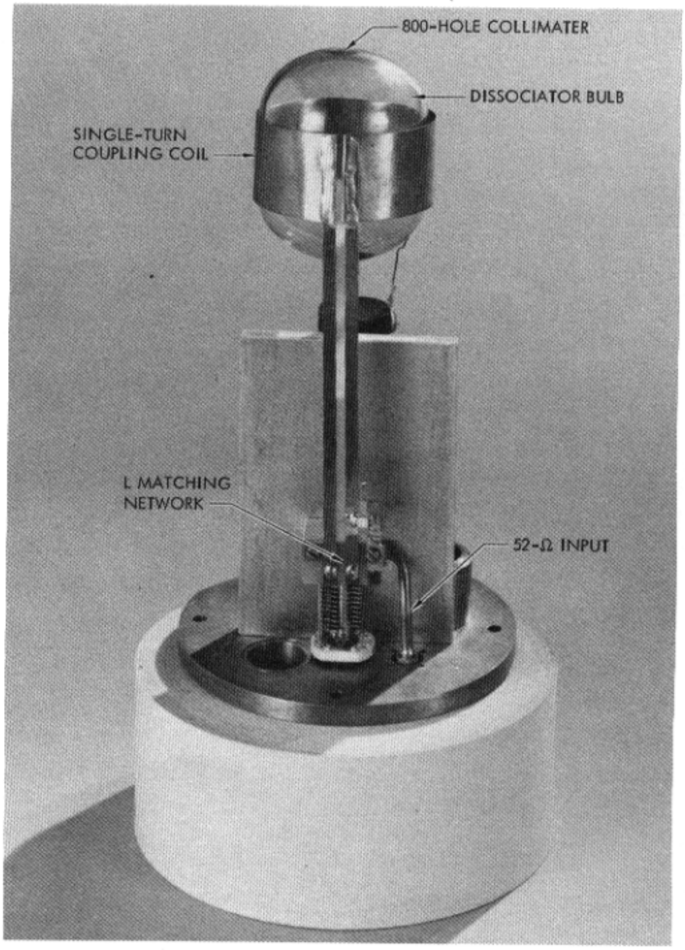


Fig. 3. New RF coupling network

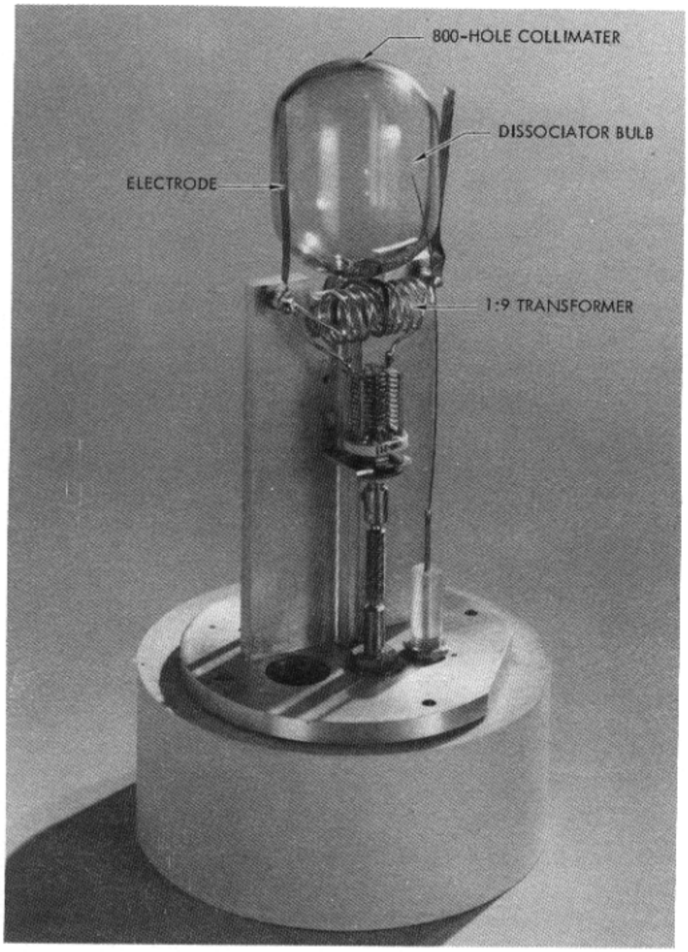
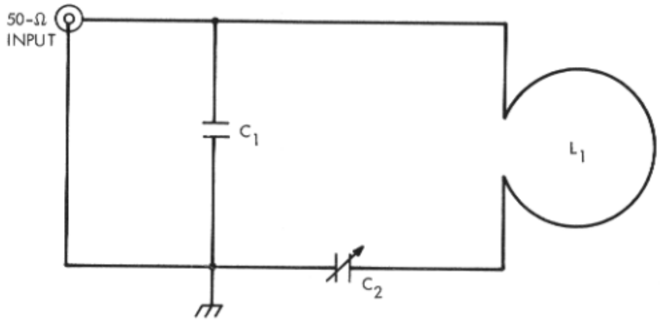


Fig. 2. Original RF coupling network



C_1 68 PF, 500 WV dc

C_2 2.7 TO 19.6 PF

L_1 DISSOCIATOR COUPLING LOOP. SINGLE-TURN COPPER STRAP, 25 mm WIDE, 0.25 mm THICK, 50 mm DIAMETER, 0.14 μH

Fig. 4. Schematic diagram of RF coupling network