Pioneer Venus Entry Simulator

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To assure successful tracking of the four Pioneer Venus probes, it is necessary for the deep space station receiver operators to be familiar with the characteristics of the received signals. As an aid for training the operators for this mission, signal simulators have been developed which completely duplicate the probe signals. This article describes the method used for generating these test signals.

I. Introduction

During the entry phase of the Pioneer Venus mission (Ref. 1), the one large and three small probes will be tracked with both closed- and open-loop receivers. Only one opportunity exists to have a successful track. It is important, therefore, that adequate operator training be provided to assure successful tracking. To aid in operator training, a simulator is being developed that completely duplicates the characteristics of all four probe signals. The method of simulating one of the characteristics, the doppler frequency profile of these probes, is discussed in this article.

II. Doppler Profile Generators

Voltage-controlled crystal oscillators (VCXOs) are used as the simulation signal sources. Doppler frequency simulation is obtained by generating a control voltage profile for the VCXOs that is identical to the desired frequency profile. Applying this voltage profile to the VCXO input generates a simulation signal with the desired frequency profile. A typical doppler profile is shown in Fig. 1. To simplify the design, the profile has been divided into two segments: the first segment from time t_0 to t_1, the second segment from t_1 on.

A. Segment 1

Using the method of averages, a second order polynomial was derived which closely approximates each doppler profile curve. The polynomial is in the form of

$$E_1(t) = a_0 + a_1 t + a_2 t^2 \quad (1)$$

Each of the terms of this equation is generated independently as shown in Fig. 2. A step voltage is first generated by means of a relay closure, which is applied to the input of a double integrating circuit. This step voltage, E, can be defined as:

$$E \equiv b_0 \quad (2)$$

The output of the first integrator (point A) is:

$$V_1(t) = \frac{E}{RC}\int_0^t dt = \frac{Et}{RC} \equiv b_1 t \qquad (3)$$

This is then integrated a second time yielding (point B):

$$V_2(t) = \frac{-E}{R^2C^2}\int_0^t t\,dt = \frac{Et^2}{2R^2C^2} \equiv b_2 t^2 \qquad (4)$$

The input step voltage and the integrator outputs are then resistively summed, using appropriate attenuations, for reducing the "b" coefficients in expressions (2), (3), and (4) to the "a" coefficients of expression (1). The voltage developed across the common summing resistor R4 is the desired waveform, but reduced in amplitude. The voltage across R4 is then amplified to the required VCXO control level by an inverting operational amplifier (A1).

B. Segment 2

To generate the second portion of the profile after time t_1 (Fig. 1), another voltage approximation was made using the circuit shown in Fig. 3. When the relay is closed shortly after t_2, a step voltage E is applied to a resistive divider, R5 and R6. The voltage across R6 (E_{R6}) is then applied to the series network R7, R8 and capacitor C. The output voltage $E_2(t)$ across R8 and C is then:

$$E_2(t) = E_{R6}\left[1 - \frac{R_8}{R_7 + R_8}\exp\left(t/(R_7 + R_8)C\right)\right] \qquad (5)$$

When the relay first actuates the output is a step:

$$E_2(t) = E_{R6}\frac{R_8}{R_7 + R_8} \qquad (6)$$

at which time the capacitor starts charging at a rate determined by the time constant $(R_7 + R_8)C$ and becomes asymptotic to a final value of E_{R6}. Actual circuit values used are shown in Fig. 3. Circuit performance and the predicted doppler profile are plotted together in Fig. 4 to show their propinquity.

The voltage $E_2(t)$ is isolated by a unity gain operational amplifier whose output is summed with $E_1(t)$ at the input of amplifier A1 (Fig. 2). The output from A1 is, therefore, the composite of the two voltages that is used for controlling the VCXO frequency.

The voltage E_1 is short-circuited at time t_1, and E_2 is enabled at t_2. During the interval between the two times, the test signal is temporarily turned off to duplicate the loss of the received signal during the entry phase of the probes.

III. Conclusion

A method for generating test signals which closely duplicate the characteristics of the received signals from the Pioneer Venus probes has been completed. Using these methods, a breadboard unit, which duplicates one of the small probes, has been constructed and successfully tested.

Reference

1. Miller, R. B., "Pioneer Venus 1978 Mission Support," in *The Deep Space Network Progress Report 42-27*, pp. 28–35, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1975.

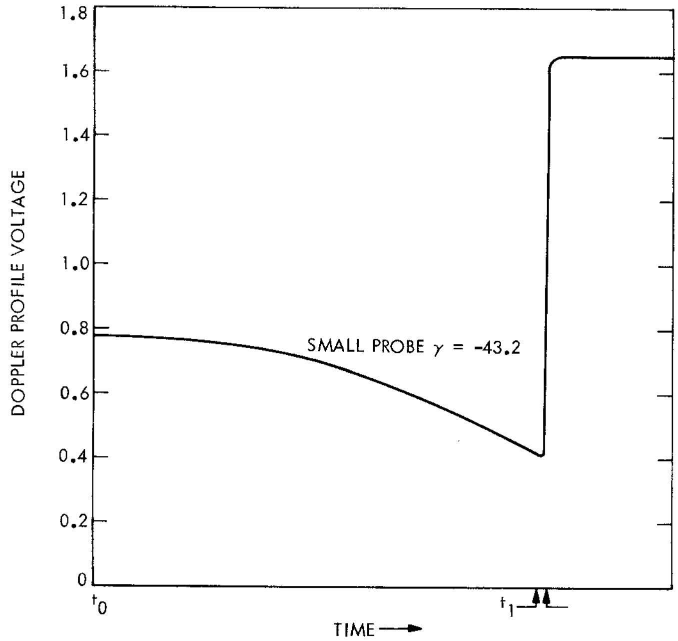

Fig. 1. Doppler profile voltage vs time

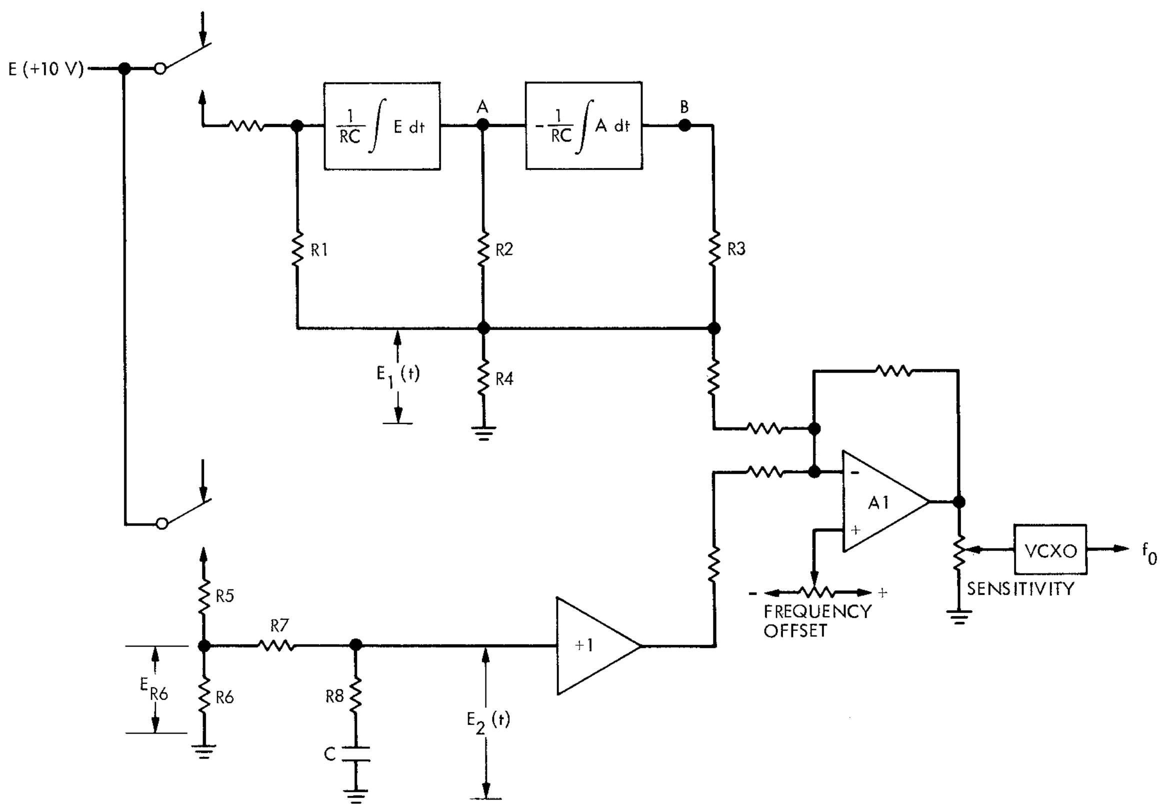

Fig. 2. Simplified diagram of the doppler profile generator

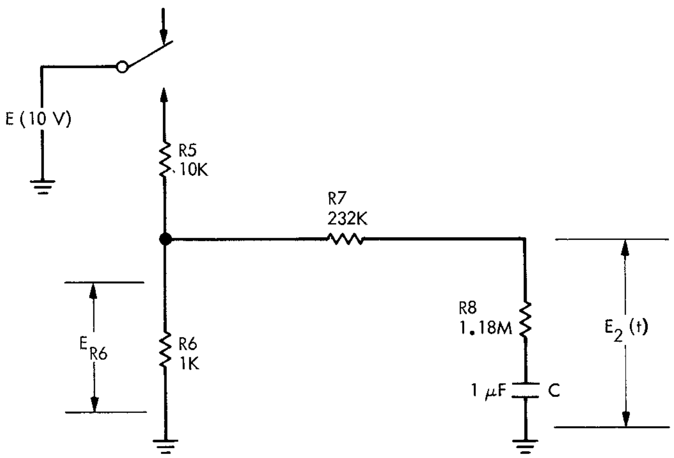

Fig. 3. Circuit for generating post-entry doppler profile

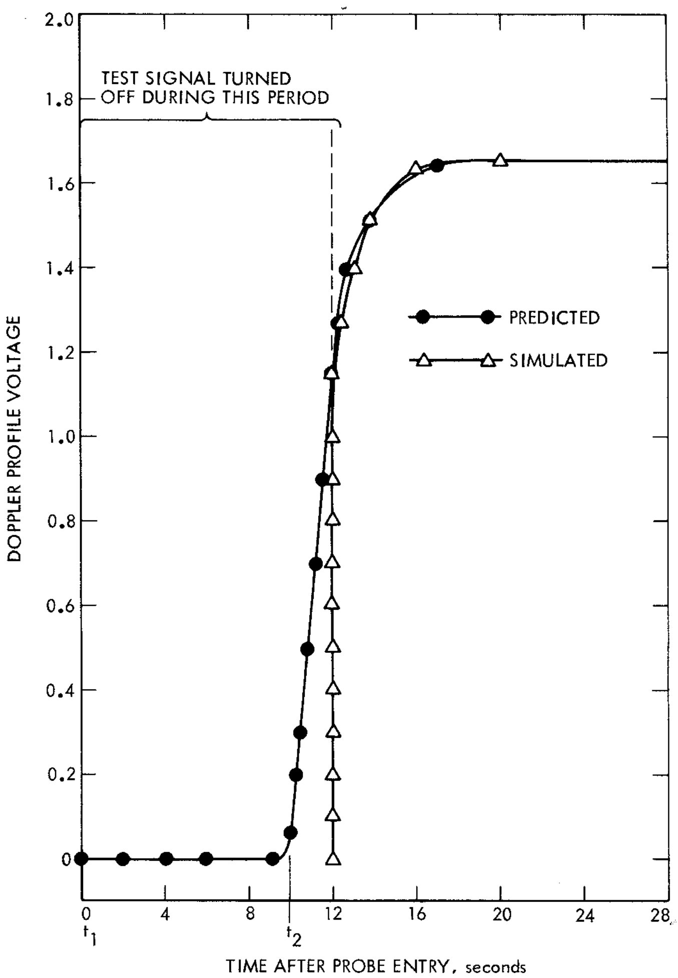

Fig. 4. Predicted and simulated doppler profiles