Programmed Oscillator Development

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This article describes the addition of programmed oscillators in the Block III receiver/exciter subsystems at DSS 14 and DSS 43 for Pioneer 10 support during Jupiter flyby. A brief description of the tracking requirements of the mission and the subsystem modifications to incorporate the programmed oscillators is given.

I. Introduction

Programmed oscillator development for the Block IV receiver/exciter and the time sync exciter has been discussed in previous progress reports (Refs. 1 and 2). However, before the Block IV becomes available in the network, there will be a need for a programmed oscillator, the first requirement being to track *Pioneer 10* during Jupiter flyby. To meet this requirement, the programmed oscillator is being adapted to the Block III receiver/exciter subsystems at DSSs 14 and 43 to support tracking until Block IV subsystems become available.

II. *Pioneer 10* Tracking Requirements

Before discussing the adaptation of the Block IV programmed oscillator to the Block III receiver/exciter, the Jupiter flyby doppler ranges, rates, and accelerations are presented and a plan for tracking during this period discussed.

Figure 1 shows typical plots of doppler ranges, rates, and accelerations expected during the flyby period. With these expected ranges a large frequency offset is developed in the probe receiver during each pass. It is desirable to reduce this frequency offset prior to handover from one station to the next to minimize the phase error in the probe receiver and thereby increase the probability of transfer without loss of lock. This is significant at Jupiter distances since loss of lock would not be detected until 100 minutes later (two-way transmission time). The offset in the probe receiver can be minimized by linearly ramping the frequency of the uplink transmitter with the exciter programmed oscillator.

The frequency profile during flyby while using the technique of ramping the exciter programmed oscillator at DSSs 14 and 43 is shown in Fig. 2. Details during the occultation period of Jupiter and its Moons have been omitted—one-way tracking during this period has been assumed. Since the exciter is programmed at a linear rate, knowing the frequency rate, the starting time, and the rest frequency at the end of the program makes it very likely that doppler data can be obtained during this period.

Estimated maximum significant positive and negative errors that will occur during the flyby period resulting from doppler are shown in Table 1. Errors resulting from linear programming are not included. This rate can be selected so that it does not produce a significant error. The estimated maximum error in the probe is approximately 10 degrees; this error will cause no significant degradation in the command link. The DSS receivers, however, do accumulate significant errors which can be reduced to approximately 10 degrees by programming either the receiver or exciter or a combination of both. A third-order loop design would also reduce these errors, and such a design has been used to track *Mariner* Mars 1971 at DSS 14 on an R&D basis. The third-order loop, however, is being investigated for use in the Block IV receiver.

III. Block III Programmed Oscillator Modifications

The frequency range of the Block IV programmed oscillator does not permit its use directly in the Block III exciter and receiver. The Block III modifications required to accommodate the Block IV programmed oscillator are discussed in the following.

A. Exciter

The existing and modified block diagrams are shown in Fig. 3. The programmed oscillator must be inserted into the exciter ahead of the phase modulator at 22 MHz. Since the Dana synthesizer output frequency range is 40 to 51 MHz, it is necessary to convert the Dana synthesizer output frequency to 22 MHz by mixing with a standard frequency. 25 MHz was selected as the standard to minimize interference from intermodulation products resulting in the mixer.

B. Receiver

The existing and modified block diagrams are shown in Fig. 4. The programmed oscillator can be inserted into the receiver at 69 MHz after the $\times 3$ frequency multiplier. The Dana synthesizer's output of 48 MHz is mixed with a voltage-controlled oscillator (VCO) operating at 21 MHz. A VCO gain of 1200 Hz/volt at 21 MHz is used to maintain the existing loop gain.

C. Programmed Oscillator

The programmed oscillator described in Ref. 2 will have additional *manual* (operator control) capability so that it can be used without a computer in this application. Additional storage will be incorporated to provide for programming the frequency sweep to begin at a specified GMT and stop at a predetermined handover frequency. A sweep rate and corresponding start time will be entered manually by the operator and easily verified with a front panel digital display. With this added feature, sweep rates can be stored well in advance of the time at which the sweep is to occur. The control assembly will have the capability of storing up to four sweep rates (with corresponding start times). The frequency sweeps required for the complete pass can then be programmed in advance, and no adjustments would be required during tracking.

Initial receiver acquisition will be similar to the present method, using existing predict formats, and the acquisition procedure will be based on monitoring the doppler. Adjustment of the receiver frequency to obtain lock will be accomplished with the present acquisition control knob or by manual programming of the synthesizer. Exciter and receiver monitoring will be the same as in the present Block IIIC configuration.

IV. Concluding Remarks

Programming the Block IIIC exciter and receiver during the Jupiter flyby will minimize the probe receiver and ground receiver loop phase error. This will increase the probability of maintaining two-way lock during handover and also provide the possibility of obtaining two-way doppler data during this period.

The Block IV programmed oscillator design is being adapted to the Block IIIC Receiver/Exciter Subsystem for installation at DSS 14 and DSS 43 and will contain additional manual control capabilities to enable the operator to manually preset the program prior to the tracking period.

References

1. Wick, M. R., "Programmed Oscillator Development," in *The Deep Space Network*, Space Programs Summary 37-66, Vol. II, pp. 127–132. Jet Propulsion Laboratory, Pasadena, Calif., Nov. 30, 1970.
2. Wick, M. R., "DSN Programmed Oscillator Development," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. VIII, pp. 111–124. Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1972.

Table 1. Doppler phase error[a]

DSS	43	63	14 and 43	43
Track	Pre-periapsis	Pre-periapsis	Periapsis	Post-periapsis
DSS receiver $2B_{L_0}$	12	12	48	48
Probe receiver doppler:				
Range	−3	−4	−5 +5	+7
Rate	−5	−3	−3	+6
Acceleration	−3	−1	+7	−3
Estimated maximum total	−11	−8	+9	+10
DSS receiver doppler:				
Range	−8	−13	−15	+23
Rate	−4	−10	−16	+25
Acceleration	−6	−3	+23	+8
Estimated maximum total	−18	−26	−31	+56
DSS receiver noise error (degrees rms)	12	12	17	17

[a]In degrees pK.

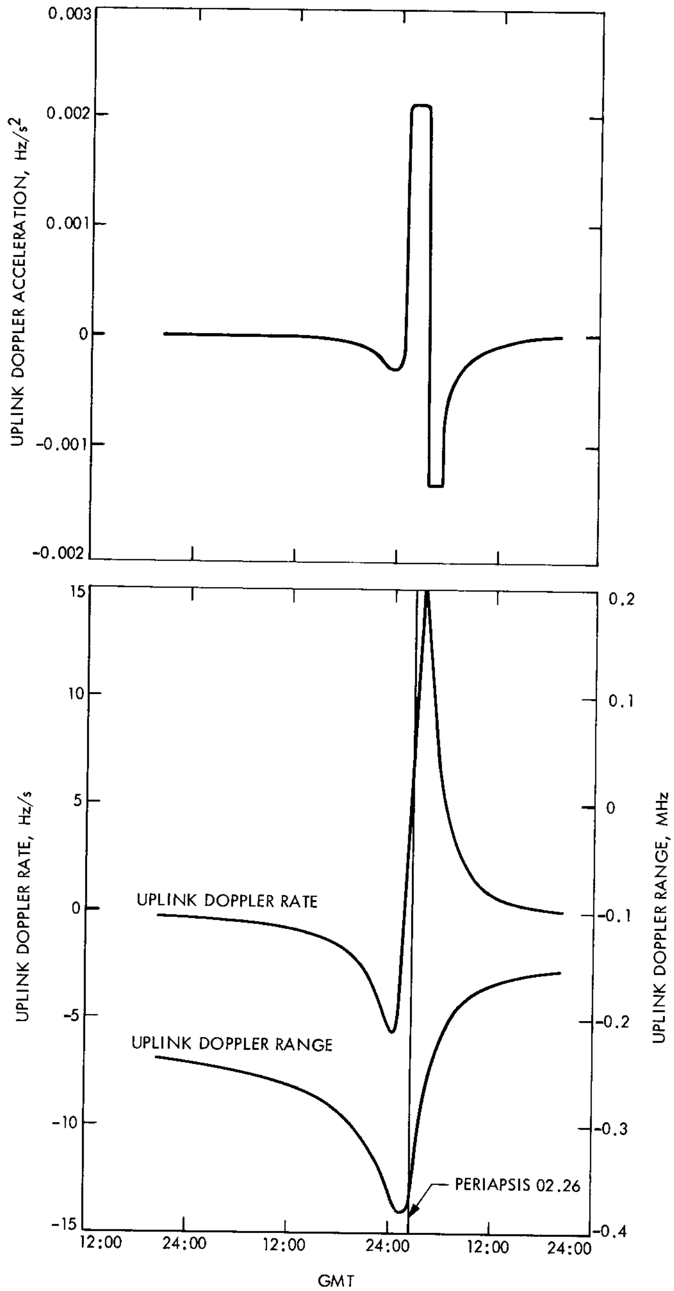

Fig. 1. Jupiter flyby doppler

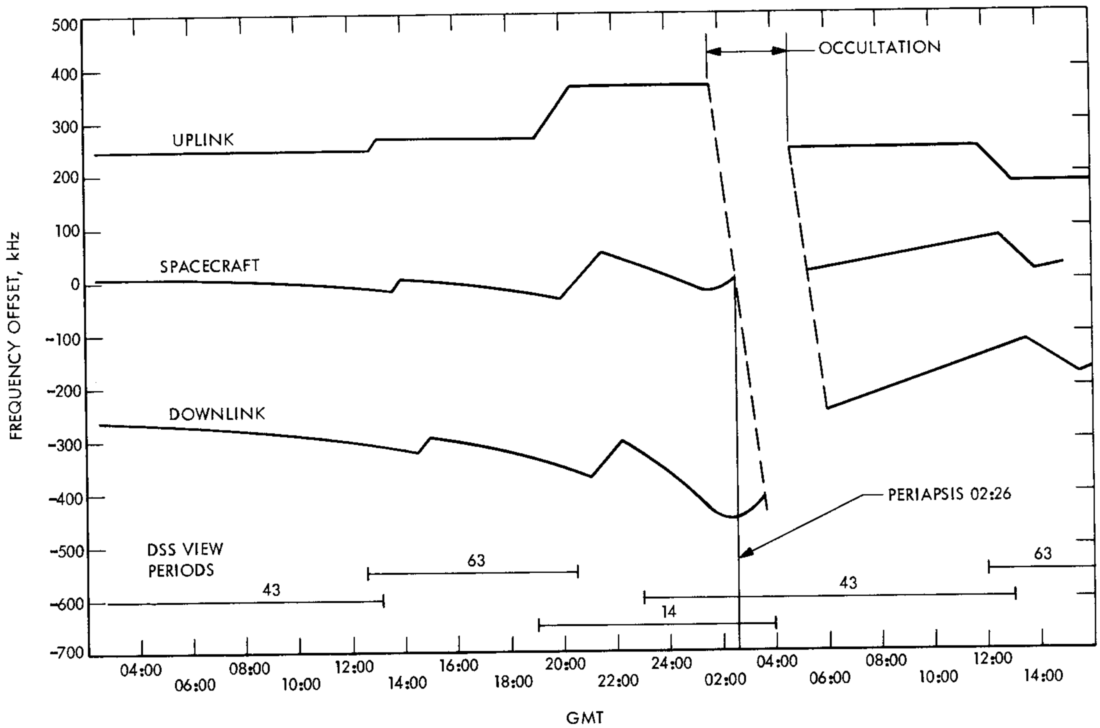

Fig. 2. Jupiter flyby frequency profile

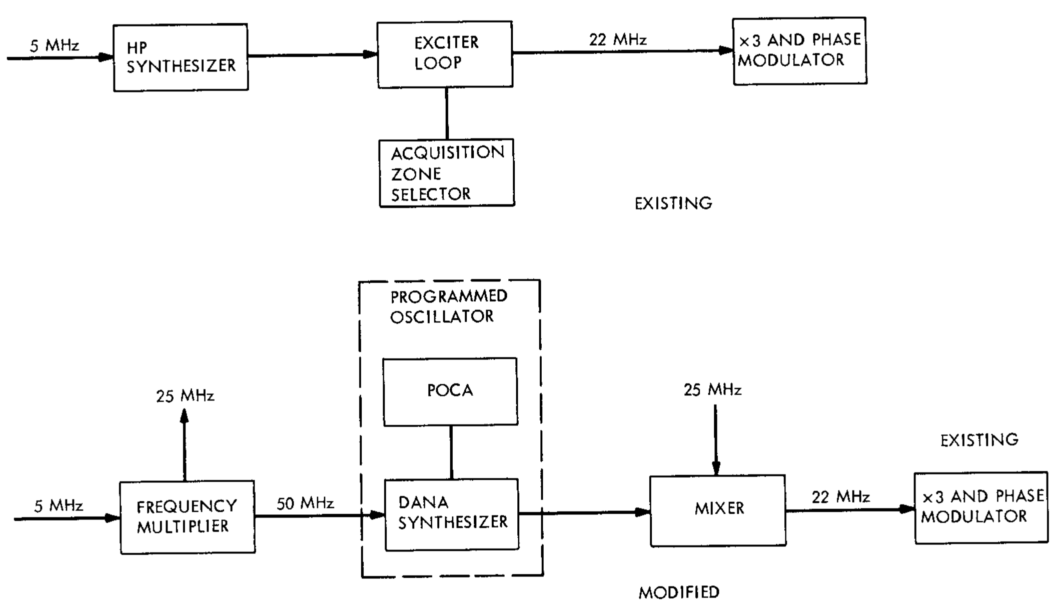

Fig. 3. Exciter block diagram

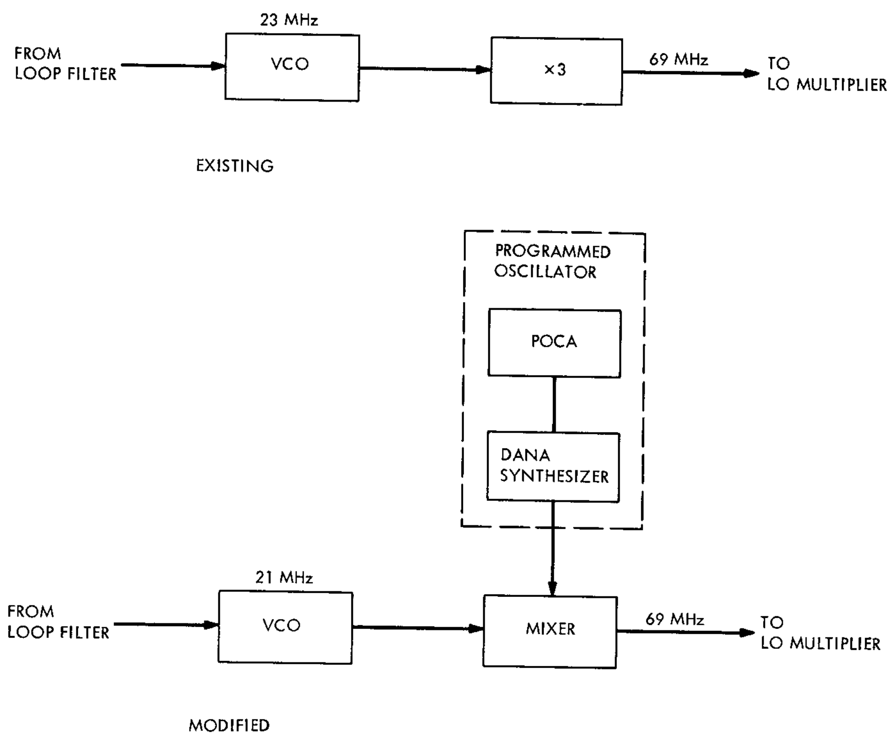

Fig. 4. Receiver block diagram