Tracking Assistor for DSN Receivers

R. L. Sydnor and J. W. MacConnell
Communications Systems Research Section

The tracking assistor improves the performance of DSN receivers at fast doppler rate and high noise level by removing the stress in the phase locked loop of the receiver. The assistor is basically a down-up converter inserted in the 24-MHz feedback path of the receiver that removes the loop stress by subtracting the doppler, which is computed by a programmed local oscillator (Ref. 1). Since the input and output frequencies are nearly identical, special filtering and construction techniques are required to achieve the extremely high isolation necessary to prevent undesired phase modulation within the loop.

The synchronous assistor was employed during superior conjunction of MM'71. During this period it was possible to obtain ranging data, a measurement not possible with either of the receivers in their standard or third-order loop configuration.

I. Introduction

Tracking spacecraft with high doppler rates and low signal levels can cause receiver lock to be difficult or impossible to maintain. A solution to this problem is the use of a programmed oscillator (PO) to subtract the predicted doppler from the received signal. In such a configuration, the voltage-controlled oscillator (VCO) is only required to track the error between the calculated and actual doppler. When the doppler is predicted accurately, the VCO will not be required to track doppler rates or accelerations. Ideally, with such a system the VCO will always be operating at its rest frequency. The actual system resulted in the VCO operating between zero and 10 Hz from rest, while the conventional system without tracking assistance operated as high as 250 Hz from rest frequency. Large doppler accelerations (which often broke lock in the conventional system) were removed from the assisted receiver, thereby allowing a far more reliable lock when operating near the signal threshold.

II. System Description

The DSIF Block III receiver (Fig. 1) obtains its first local oscillator signal (S-band) by multiplying the VCO frequency by 96. When a doppler rate is present, the

VCO must move from its rest (center) frequency to provide the proper local oscillator (LO) frequency. By placing a mixer immediately following the VCO and subtracting the predicted doppler generated by a PO, the VCO will only be required to move from its rest frequency an amount ϵ (Fig. 1) equal to the difference between the actual and calculated doppler. To implement an assistor, a problem arises because the doppler frequency varies from zero to about 250 Hz. When the doppler is very small, it is extremely difficult to separate the VCO frequency from the desired VCO plus doppler frequency. The VCO leakage into the output must be at least 100 dB below the desired output to keep spurious phase modulation of the S-band LO less than one milliradian. The final solution utilized a down-up converter that reduced the undesired outputs to a negligible amount.

The Block IV receivers will contain a programmable synthesizer, which may be interfaced to a computer to form a PO. It is therefore unnecessary to implement any additional hardware for the Block IV receivers to obtain synchronous assist.

III. Electrical Description

As shown in Fig. 2, the VCO output (approximately 23.4 MHz) is first mixed with 18.4 MHz from a synthesizer referenced to the station frequency standard. The resultant 5 MHz is filtered in a six-section minimum-loss filter. This filter and the mixer attenuate the VCO and synthesizer signals about 90 dB below the 5-MHz output. The output from the PO contains the predicted doppler with a frequency bias of 18.4 MHz that mixes directly with the 5 MHz generated by the initial mixing of the VCO, thereby regenerating the 23.4-MHz VCO frequency. The second mixer provides an additional 30 dB of attenuation to any remaining VCO signal present on the 5-MHz signal, resulting in an overall attenuation of 120 dB from the VCO output. An auxiliary output is also provided for open-loop tracking by mixing the 5-MHz station reference with the 18.4 MHz plus doppler from the PO. Since these frequencies are nearly the same as in the main output, modules B and C are identical.

IV. Mechanical Considerations

In all the modules care must be taken to ensure good shielding between mixer inputs and output, filter sections, and power supply decoupling circuitry. Semirigid coax was employed throughout. Good coax is especially important between module A and module B in order to prevent the 5-MHz station reference from leaking in and causing undesired phase modulation. Well-shielded coax should be employed between this system and the peripherals (station standard, synthesizer, receiver VCO, and the PO) if 100 dB isolation is to be maintained.

V. Conclusion

The tracking assistor system was constructed and tested with Mariner Mars 1971 (MM'71) during superior conjunction. Ranging data were obtained during periods when it was impossible to get satisfactory data with any other available system.

The tracking assistor could be substantially simplified and the isolation requirements reduced if a VCO frequency several MHz from the desired output frequency were employed. The only isolation required in the system shown in Fig. 3 is between the two 30-MHz signals, while the present assistor requires high isolation in four main signal paths. The simplified assistor would require only two identical mixer modules, and the new PO bias frequency could easily be generated by the PO program.

Reference

1. Emerson, R. F., "Programmed Oscillator Software Development for High Doppler Rate Orbiting spacecraft," in *The Deep Space Network Progress Report*, Technical Report 32-1526, Vol. XIII, pp. 48–53, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1973.

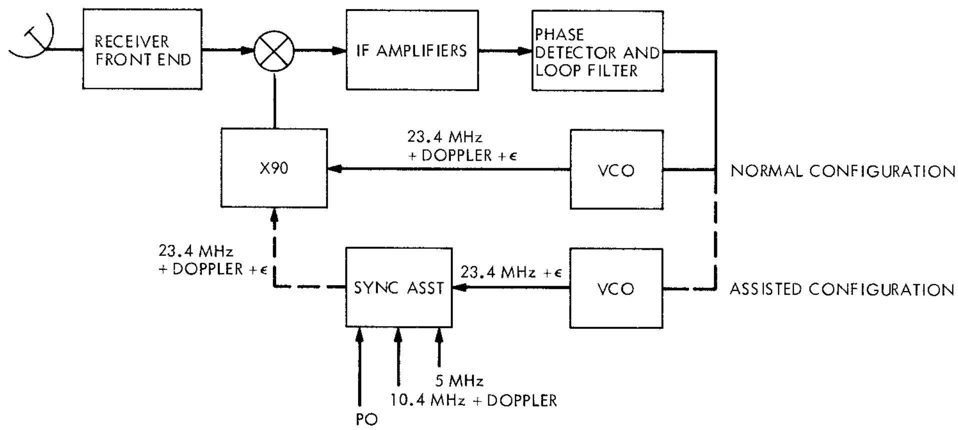

Fig. 1. Configuration modification of DSN receiver

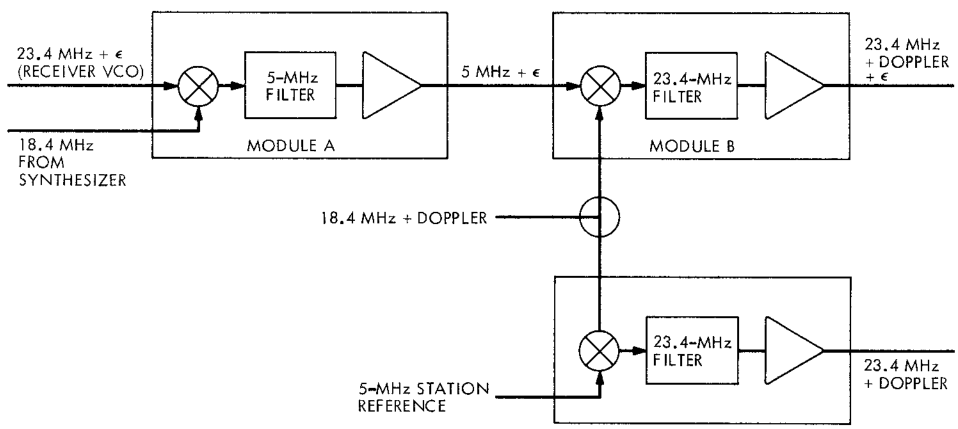

Fig. 2. Tracking assistor

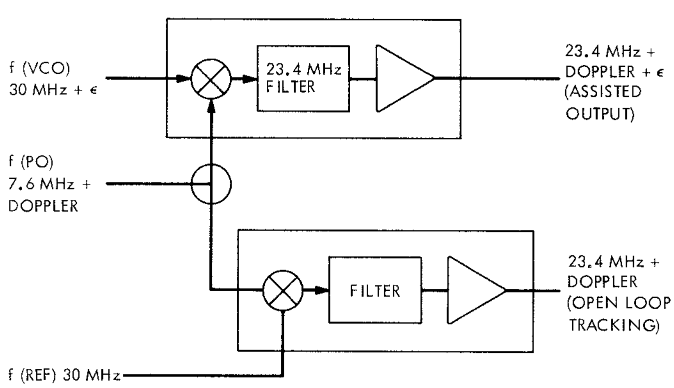

Fig. 3. Simplified assistor configuration