X-523-67-527

NASA TM X- 63069

CARRIER REPRODUCTION IN A DIVERSITY RECEIVER

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OCTOBER 1967

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GREENBELT, MARYLAND

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INTRODUCTION

To determine the velocity of a moving target, ranging systems measure the doppler component of a known frequency. In most ranging systems the known frequency is the carrier frequency of the transmitter. The doppler component of the received frequency is extracted and used in a computer program to determine the velocity of the target. The exact method of extracting the doppler component varies with the ranging system, however, in all systems, the received frequency (transmitted frequency plus or minus the doppler frequency) is regenerated as a relatively clean signal. In continuous wave ranging systems which measure doppler on the carrier, the received frequency is regenerated by summing all of the receiver local oscillators including the phase locked voltage controlled oscillator (VCO).

BASIC DIVERSITY SYSTEM

In a predetection combining diversity receiving system, there is more than one VCO. Each of these VCO's may be at a different frequency and phase.

The block diagram of Figure 1 shows a portion of a typical polarization diversity phase locked receiver. In theory, VCO #1 operating at frequency f_p is varied by the primary loop and tracks any frequency change in the combined received signal. The VCO's (#2V and #2H) in the secondary loops then track the phases in their respective legs only. If the characteristics of the primary loop (VCO #1 loop) and the two secondary loops are properly designed, the practical circuits can be made to approach this theory. It has been observed in diversity tracking systems that the two secondary VCO's may be at different frequencies.* This difference may be caused by multipathing, ionospheric, and atmospheric effects on the two polarizations. The combination of transmission path effects and the practical circuit realization leaves some doppler to be tracked by the individual secondary loops.

The problem arises as to how to reconstruct the received frequency. The primary VCO will be included in the reconstruction process, but which secondary VCO should be used?

*The author first noticed the effect of differing secondary VCO frequencies on the APDAR developed by R. E. Taylor of the RF Systems Branch.

CONDITIONS AND ASSUMPTIONS

Since there are two secondary VCO's, the problems which arise are:

1. Which secondary VCO has the correct doppler information?
2. Is either VCO the correct one to use?
3. If this information changes from one polarization to the other polarization, how do I switch the VCO without interrupting the continuity of velocity data?

To establish a base for answering these questions, certain assumptions (which I believe are reasonable) are made:

1. Under the conditions of two received signal strengths, (one signal below threshold the stronger one is the correct one.)

2. Under equal or approximately equal signal strengths, the average of the two frequencies is correct.

3. Under equal or approximately equal signal strengths, the average phase is correct.

4. Under any and all considerations the frequency difference between the two received signals will never be more than a few cycles per second.

CARRIER VCO DERIVATION

A method of deriving a VCO signal which can be used to reconstruct the received frequency has been conceived. This method as used in conjunction with a polarization diversity receiver is shown in Figure 2. In Figure 2:

$$f_V = f_p + f_1$$

$$f_H = f_p + f_2$$

The frequencies f_1 and f_2 may differ up to several cycles per second. In order to generate a frequency which is the mean of these two frequencies and bear some relationship and probability to being the correct frequency, the circuit inside the dotted lines in Figure 2 was conceived.

The frequencies (f_1 and f_2) are each fed to separate phase detectors whose reference frequency is supplied by a third VCO generating a frequency f_3. The output of each phase detector is switched on or off by the AGC voltage from the respective receiver channel. The output of VCO #3 is then supplied to the doppler extractor for reconstruction of the received frequency.

On the basis of the aforementioned assumptions we have the best frequency source available in that:

1. Under the conditions of one strong and one weak signal, the VCO in the channel having the greatest signal-to-noise ratio predominates.

2. Under equal signal strengths in the two channels, the average frequency and phase of the two secondary VCO's is used.

3. Under the condition where the maximum signal strength is varying from channel to channel, the changeover is smooth and automatic.

The output of the phase detectors 2V and 2H (Figure 2) after the low pass filters may be represented by:

$$C_V = A \cos \dot{\phi}_{2V}$$

$$C_H = A \cos \dot{\phi}_{2H}$$

The phase excursion of VCO #3 from the center frequency is then represented as

$$\dot{\phi}_3 = K(C_V - C_H)$$

where K is the VCO gain in degrees/volt and

$$\dot{\phi}_3 = KA\left(\cos \dot{\phi}_{2V} - \cos \dot{\phi}_{2H}\right)$$

Differentiating and rearranging the terms, using some trigonometric identities, we get

$$\Delta\phi_3 = \frac{\Delta\phi_{2V} - \Delta\phi_{2H}}{2}\left(KA\left(\sin \phi_{2V} + \sin \phi_{2H}\right)\right)$$

thus the change in ϕ_3 is equal to the average difference of ϕ_{2V} and ϕ_{2H}.

The above assumes that the two VCO generated signals are of equal amplitude. Amplitude adjustment Q_V and Q_H are incorporated to balance these signals.

The voltage sensitive switches, SW_V and SW_H are actuated by the coherent AGC detector. When a secondary loop loses lock the signal from that VCO is removed from the regenerator circuit. This prevents the free running VCO in the unlocked loop from affecting the carrier regeneration circuitry.

CONCLUSION

A method has been devised which will supply, to the doppler extractor, a signal bearing frequency and phase characteristics which are similar to that of the received signal. Under the assumption stated this will be the correct frequency and phase information and resolves the problems associated with reconstruction of the received frequency. Using this method the doppler extractor will receive a frequency which has no abrupt switching transients yet is phase related to the strongest received signal. Full coherence is not claimed because the output of VCO #3 will be some average frequency and phase and not necessarily the exact frequency and phase of either secondary VCO. This method can be readily used in polarization diversity systems, or in space diversity systems where receiving antennas are placed some distance apart in an effort to overcome signal fading. This method may also be applied to frequency diversity systems in a "back up" ranging system.

ACKNOWLEDGMENTS

The author gratefully acknowledges the helpful discussions regarding the feasibility of this concept with Edmund Habib and Vincent DiLosa.

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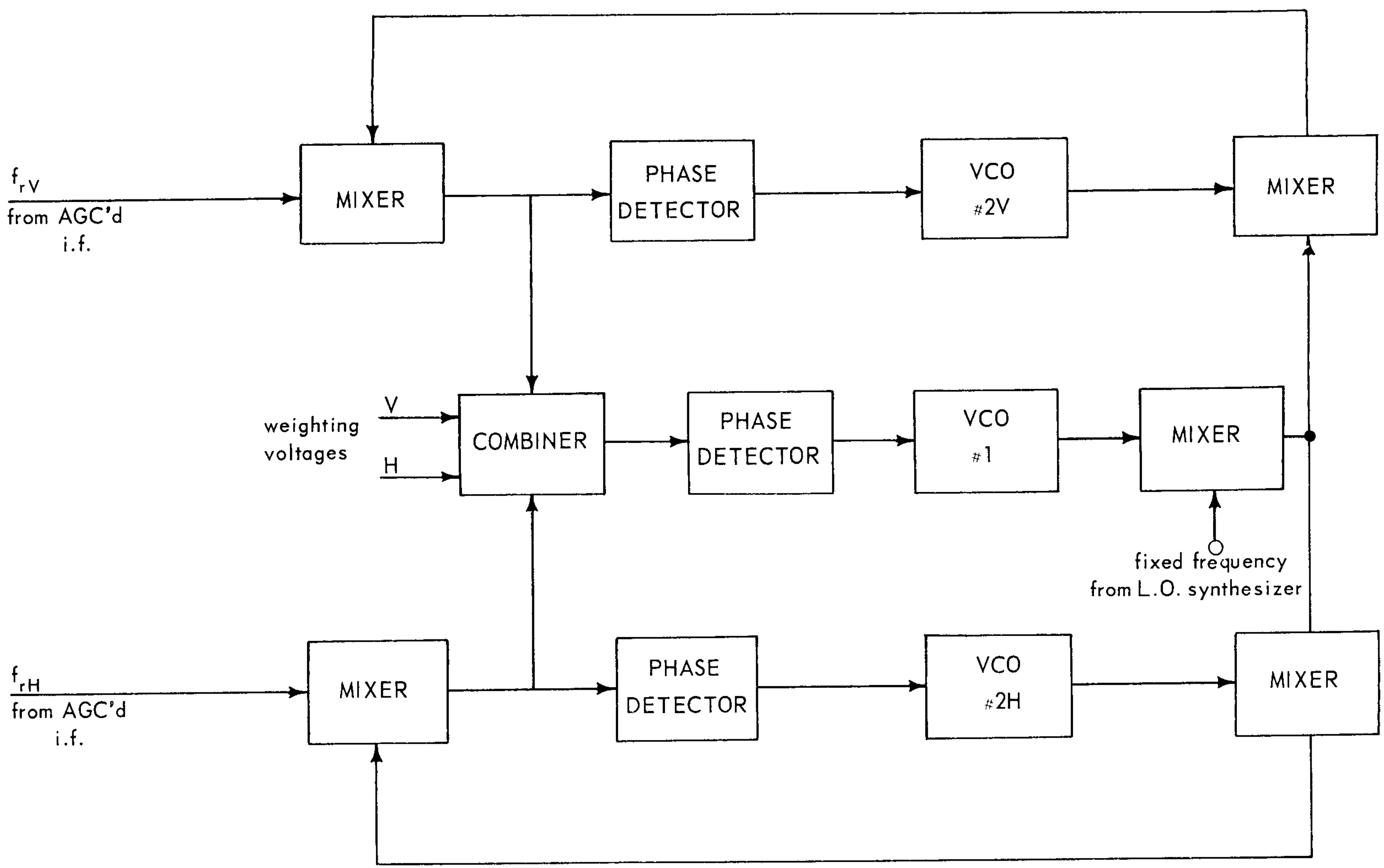

Figure 1. Block Diagram Diversity Lock Loop

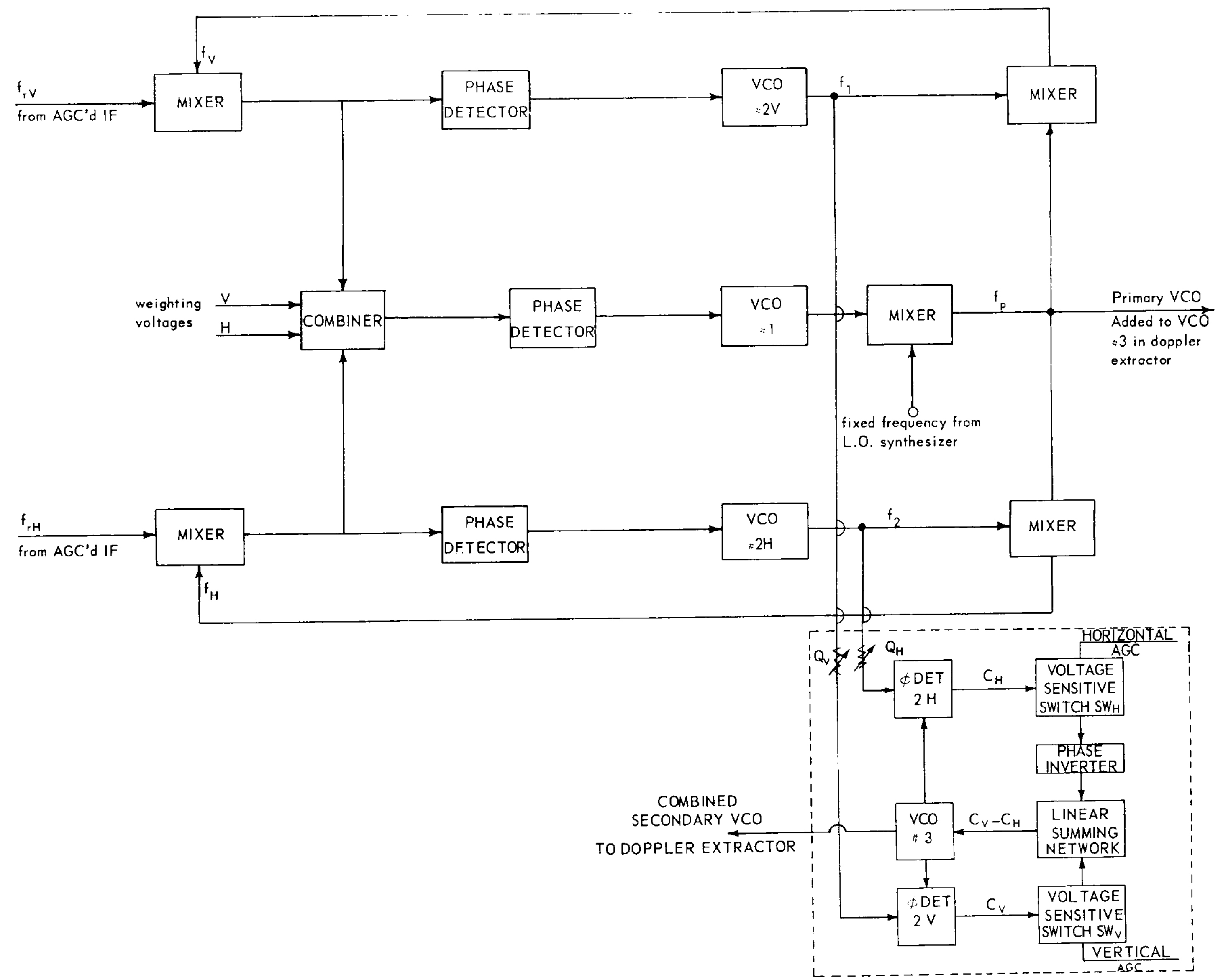

Figure 2. Block Diagram VCO Combiner for Doppler Extraction