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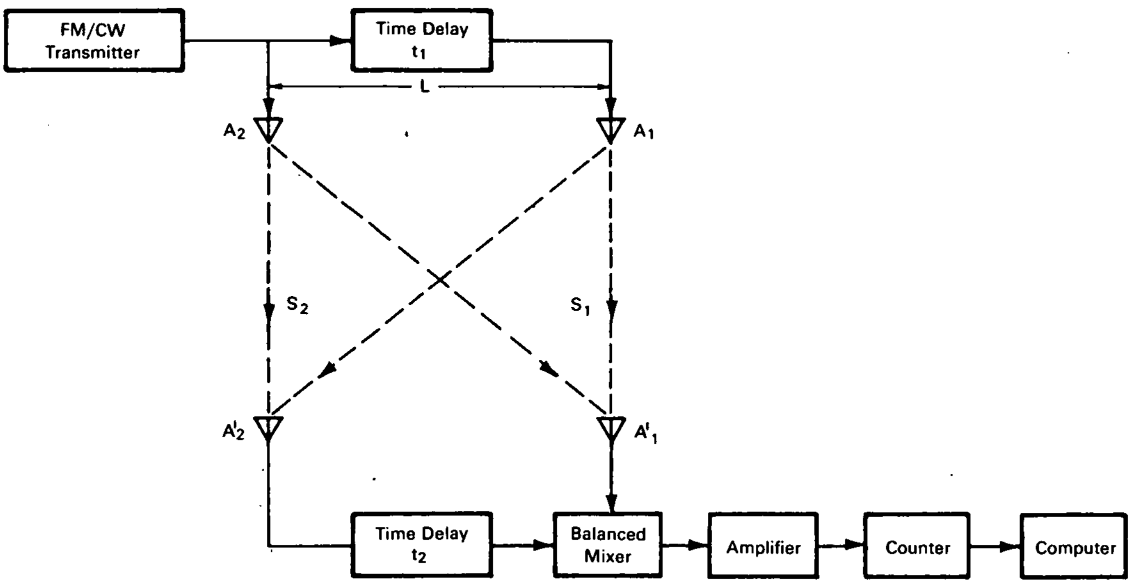
FM/CW System Measures Aircraft Attitude



The problem: Measuring the attitude (pitch or yaw) of an approaching aircraft relative to a ground station. The measurements need be accurate only to within ±0.5° over an angular range of ±10°.

The solution: A radar system employing a linearly swept FM/CW transmitter on board the aircraft which transmits through two antennas to a ground-based receiver. An attitude deviation causes a difference in the air-to-ground path lengths of the transmitted signals, resulting in an instantaneous frequency difference at the receiving antennas from which the attitude (angle) is computed. Fixed time delays between the signals are introduced in the system to provide a means of determining the sense (+ or −) of the angle.

How it's done: If only the absolute value of the angle within the range of ±10° is required, the same signals are simultaneously transmitted through antennas A_1 and A_2 For this condition, the absolute value of the angle in radians is approximately equal to $(S_1 - S_2)/L$, where L is the calibrated distance between the two transmitting antennas, and S_1 and S_2 are the respective path lengths (dashed lines) of the signals from the transmitting to the corresponding receiving antennas. It is therefore only necessary to determine the range difference, $S_1 - S_2$, to obtain the value of the angle. The system obtains this range difference from a frequency difference ΔF in accordance with the equation used for FM/CW altimeters. On substituting the value of ΔF obtained from the receiver output, and the known quantities L, the transmitter sweep rate $\dot{f}$, and the velocity of light C into

(continued overleaf)

this equation, the magnitude of the angle is approximately equal to $C\Delta F/\dot{f}L$. In order to determine the sign of the angle, the system is modified by introducing a time delay t_1 into the signal radiated from antenna A_1 and a slightly different time delay t_2 into the signal passing from the receiving antenna A'_2 into the balanced mixer. Bandpass filters in the amplifier separate the signals from the balanced mixer to yield a difference frequency corresponding to the algebraic ($\pm$) value of the range S_1-S_2. The amplified signal is passed into a counter where the difference frequency is measured. In terms of the known parameters of the system and the range difference (S_1-S_2), this difference frequency is given as:

$$\Delta F \simeq \dot{f}\left(\frac{S_1 - S_2}{C} + t_1 - t_2\right).$$

The output from the counter is passed into a computer where the algebraic value of the angle is computed using the above approximate equation and the known relationship between the range difference and the distance (L) between the transmitting antennas.

Notes:

1. This system is not intended to replace present in-flight attitude measurement systems; it may have application in conjunction with ground control approach systems at airports.
2. Inquiries concerning this invention may be directed to:

   Technology Utilization Officer
   Marshall Space Flight Center
   Huntsville, Alabama, 35812
   Reference: B65-10290

Patent status: NASA encourages the immediate commercial use of this invention. Inquiries about obtaining rights for its commercial use may be made to NASA, Code AGP, Washington, D.C., 20546.

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Marshall Space Flight Center
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