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Signal Processor for Millimetric Wave Radar Seeker for Antitank Guided Missile

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ABSTRACT

The missile borne signal processor for the millimetric wave active radar seeker of the third generation type antitank guided missile (ATGM) system with lock-on-before-launch capability is discussed. The range and angle tracking systems are described and the results are presented. Feasible improvements in signal processor using coherent-on-receive scheme for achieving higher ranges, have been identified and are being implemented.

INTRODUCTION

The millimetric wave (MMW) radar seeker is based on lock-on-before-launch (LOBL) scheme. The target information as detected by the ground-based signal processor is loaded to the missile borne signal processor (MBSP) for tracking the target in range and angle. To realise these functions for onboard real time implementations, high performance devices are required and hardware packaging in the allotted space is very critical. The hardware consists of the three circuits, (i) range tracking circuits, (ii) angle tracking circuits, and (iii) interface circuits.

This paper deals with the range and angle tracking techniques employed in the antitank guided missile seeker and their current status.

2. RANGE TRACKING

Radar range measurement consists of the determination of the time delay between transmitted and received pulse of a given signal. The difference between received signal and delayed reference is measured using time discrimination, and correction is applied to the reference as per error signal. Time discrimination plays an important role in range tracking as it limits the achievable tracking accuracy. There are two types of time discrimination circuits for use in range tracker, viz., (a) split gate range tracker, and (b) leading edge tracker.

When signal-to-noise ratio (SNR) is high, the pulse edges are well defined and the differentiating circuit in the leading edge tracker can give correct indication. But when SNR is low, the differentiating circuit cannot give proper position of the edge. Hence, the leading edge tracker is not considered suitable and the use of split-gate range tracker is resorted to. In the split-gate range tracker, the received target echo is integrated in a pair of rectangular gates which are staggered in time, as shown in Fig. 1. The difference in the integrated outputs will indicate the direction and magnitude of the error. This error is applied to the gate positioning circuit, which in turn corrects the gate to get the error signal zero.

Energy in early gate (EGT)
$e1 = \int_{EGT} Es \, dt$
and in late gate (LGT) :
$e\,2 = \int_{EGT} Es \, dt$

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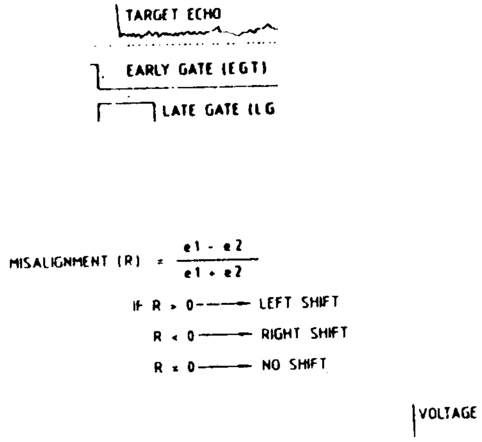

Figure 1. Split-gate range tracking.

The split-gate range tracking output is obtained as

$$R = \frac{e1 - e2}{e1 + e2}$$

and range error

$$\sigma \quad \frac{\tau}{Kr\sqrt{2.S/N}}$$

Where *Es* is the target echo signal τ pulse width, and *Kr* is the range sensitivity curve slope

The overall hardware block diagram is shown in Fig. 2. The output of the envelope detector is passed through low pass filter and sum signal is extracted by adding $s+d$ and $s-d$. This signal is integrated in two gates (early gate and late gate) and sampled in A/D converter. The digital data are integrated over 1000 pulse repetition intervals to get sufficient SNR. After getting sufficient SNR, range shift is estimated and track gates are corrected through a voltage to time convertor, accordingly.

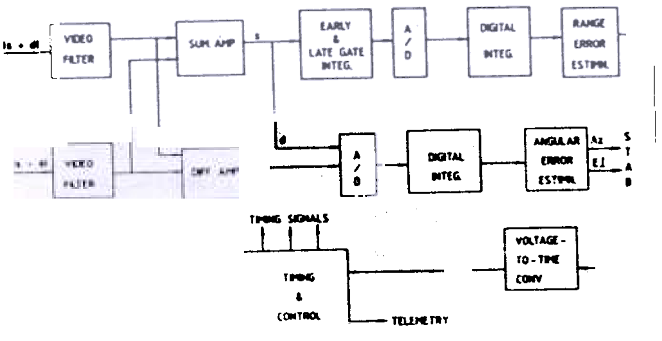

Figure 2. Block diagram of missile-borne signal processor.

3. ANGLE TRACKING

The seeker system is of two channel monopulse receiver type. To convert the three channels (sum, azimuth and elevation difference) into two channels, time multiplexing of difference signal is adopted. Since the carrier is generated using IMPATT source, it has got chirp in the carrier. To process this kind of signal, one has to go for noncoherent signal processing scheme only. In this scheme the sum and difference (d)signals are added and subtracted at RF level and $(s+d)$, $(s-d)$ signals are formed. These signals are detected. Angle extraction scheme at video stage, i.e. after envelope detection is adapted. This process is called amplitude-based-sngle (ABA) processor. The output of ABA processor (Fig. 3) is :

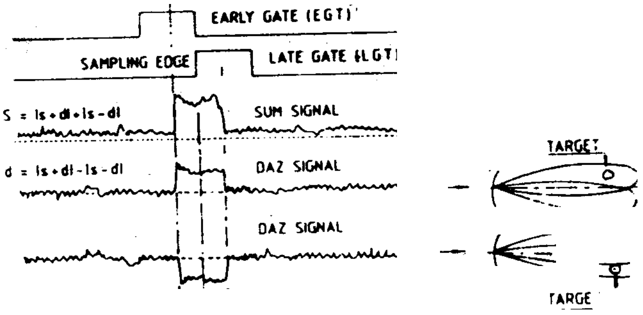

Figure 3. Amplitude-based angle tracking.

$$R_{ABA}\,(\text{sq}) = \frac{|s+d|^2 - |s-d|^2}{|s+d|^2 + |s-d|^2}$$

Simulations were carried out and the performance of the ABA processor was compared with that of an exact processor. Simulation shows (Fig. 4) that ABA processor is robust in the presence of glint. ABA processor has shown better performance in the presence of thermal noise and multipath.

The envelope-detected signals are passed through low pass filter and added, and subtracted to extract magnitude of sum and difference and sign of the difference signal. These signals are sampled with leading edge of the late gate (which always tracks the centroid of the pulse). The sampled *s* and *d* signals are integrated over 1000 pulse repetition intervals to get sufficient SNR. After getting sufficient SNR, angular errors are estimated through the stored antenna pattern. These error signals are fed to the stabilisation system to correct the antenna position.

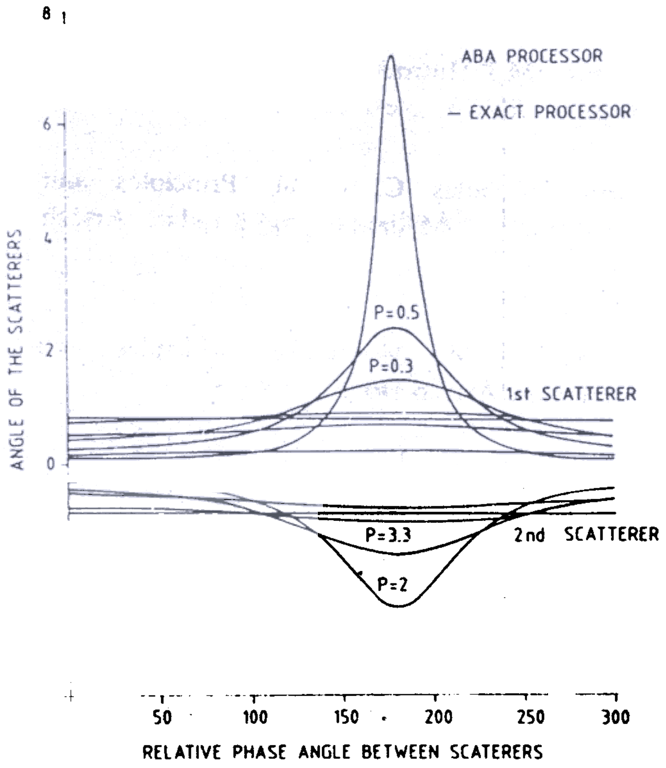

Figure 4. Glint performance of ABA processor.

4. INTERFACE

To synchronise transmitter/receiver and ground-based signal processor with the missile-borne signal processor, pulse repetition frequency (PRF) is generated in MBSP and given to all other subsystems. The azimuth, elevation selection signal is generated and given to receiver by MBSP. All the timing and control signals are generated using erasable programmable logic device (EPLD).

5. TEST RESULTS

The total hardware has been realised in the allotted space in (Fig. 5) by using dedicated chips like multiplier accumulators (MAC), EPLDs and EPROMs. Flexibility is provided for PRF change and the number of pulse integration. Hardware performance was evaluated with simulated signals and it is meeting system specifications. All the subsystems were then integrated and evaluation of closed loop range tracking performance against different types of vehicles was carried out during outdoor trials. Angle tracking measurements (Fig. 6) were also carried out and compared with the compact antenna range (CAR) in *d/s* pattern of the antenna.

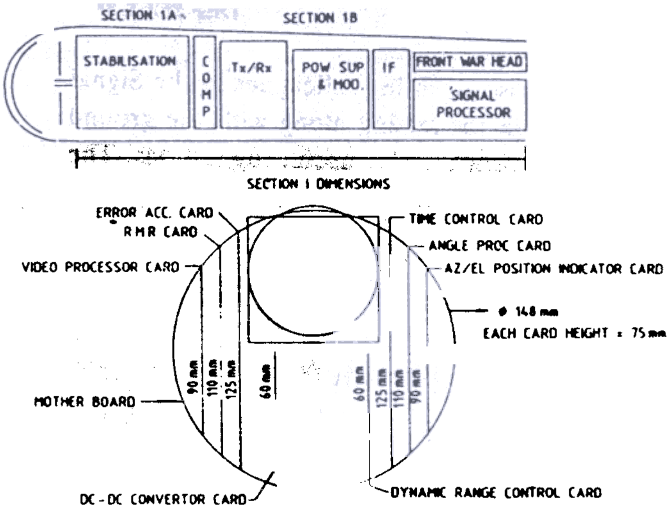

Figure 5. Layout details of PCBs.

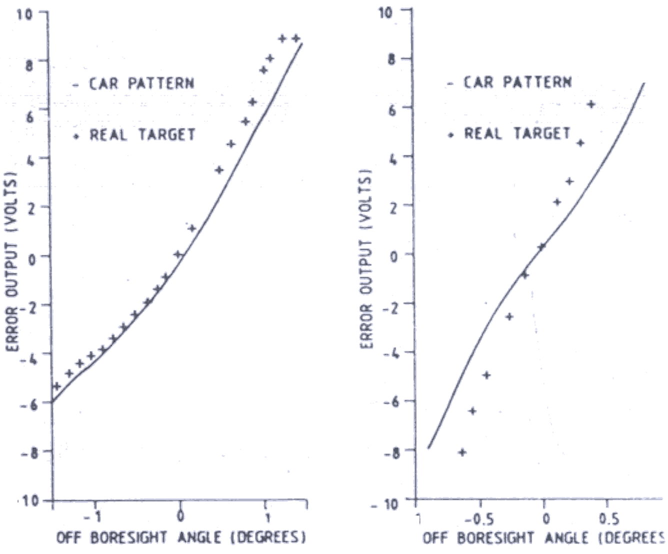

Figure 6. Comparison of angle tracking measurements with (
azimuth *d/s* pattern, and (b) elevation *d/s* pattern.

6.SUMMARY

Conceptual validity of tracking algorithms has bee established. A subsystem has been integrated with R front-end. Real-time closed loop range and ang tracking measurements were carried out. Feasib improvements to achieve required range have bee identified and these are under implementation.

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