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Millimetric Wave Seeker for Third Generation Antitank Guided Missiles

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ABSTRACT

For the third generation antitank guided missiles (ATGMs) with fire-and-forget and top attack capabilities, a noncoherent millimetric wave (MMW) active radar seeker has been configured with all weather capabilities. To meet the stringent dimensional and weight constraints and beamwidth requirements of ATGM, a *W*-band system has been designed with trans-twist antenna with a compact comparator. The paper covers the system description and critical design issues, and presents the performance results achieved so far. Areas for improvements, especially for achieving a higher range, have also been pointed out.

1. INTRODUCTION

The third generation ATGMs are characterised by their lock-on-before-launch (LOBL) and fire-and-forget capability. In addition, these missiles should have a top attack trajectory which renders them more lethal against tanks. To design a missile with the above-mentioned capabilities, a seeker system is required, which can always orient itself towards the target and home on to it. Also, the seeker should be small in size and weight as is required by all ATGMs and should have ECCM and all-weather capability. To meet the above requirements, a pulsed millimetric wave (MMW) radar was chosen for the seeker. To keep the seeker size within permissible limits, the *W*-band was chosen. It has the following capabilities :

a) Always pointing the seeker antenna towards the target (angle tracking).

(b) Tracking the target in range.

(c Stabilising the seeker antenna in the presence of missile manoeuvres.

2 SYSTEM DESCRIPTION

The seeker system consists of antenna, transmitter receiver, onboard signal processor and homing head stabilisation system. The system block diagram is given in Fig. 1. The transmitter sends a pulsed *W*-band signal through the antenna and the target return, received through the antenna and receiver modules, is passed on to the onboard signal processor. The return contains both range and angle information of the target. The signal processor extracts this information, performs closed loop range tracking on the target and gives the extracted angular error signals to homing head stabilisation. The stabilisation system, in turn, rotates the antenna mechanically so as to cancel the angular error. Thus, closed loop angle tracking is established in both azimuth and elevation planes. The stabilisation unit also stabilises the antenna by keeping the antenna on the electrical boresight direction inspite of missile manoeuvres.

For extracting the angular error information of the target, noncoherent angle processing based on

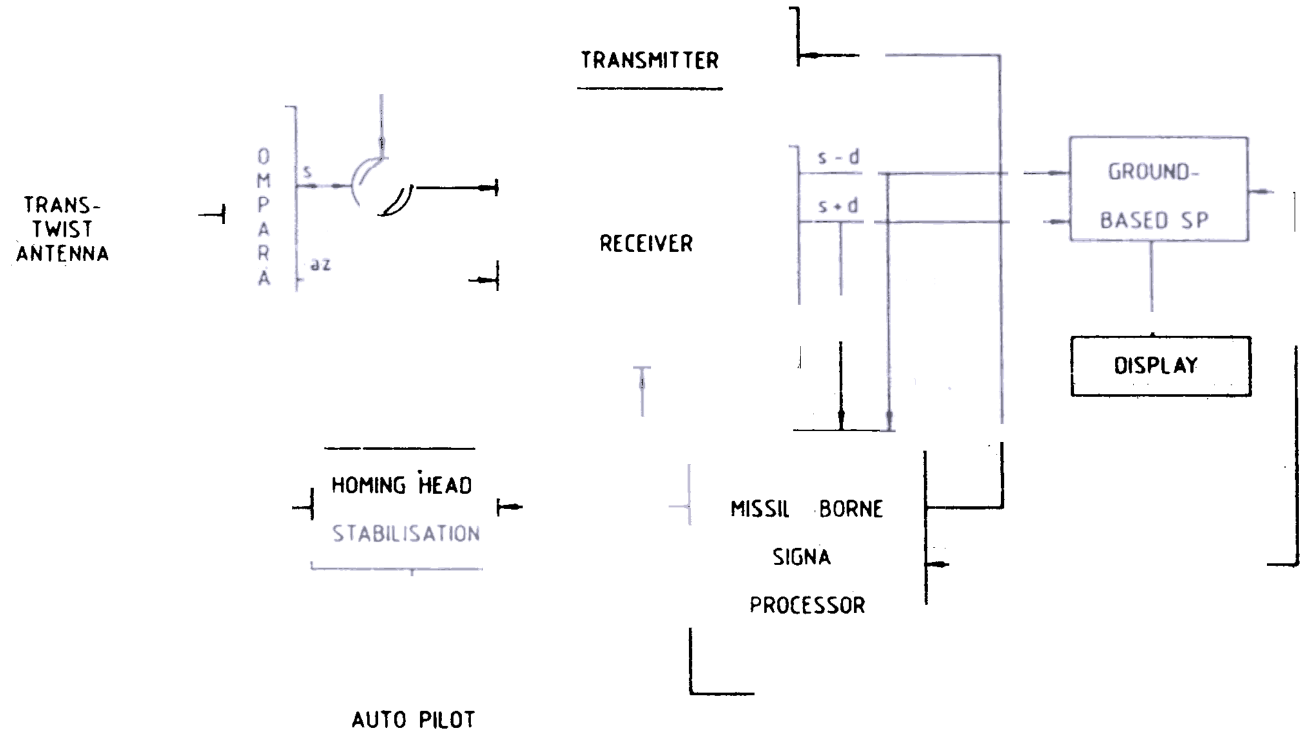

Figure 1. Block diagram of the MMW seeker head.

monopulse principle[1] is used. The antenna is a trans-twist antenna with four-horn monopulse feed and a compact comparator. The transmitter uses IMPATT diodes for its *W*-band pulsed source. The receiver is a two-channel monopulse receiver which time multiplexes the angle information of elevation and azimuth planes on the same channel. The signal processor (SP) performs split gate range tracking on the target[2], and extracts the angular error through amplitude-based angle (ABA) processing[1,3].

The basic working of the angle tracking system is illustrated in Fig. 2. In the antenna, *s* & *d* signals are formed using monopulse, where the *d* signal contains the information about the angular error off boresight. The relative phase of *s* and *d* signals contains the information about the direction of angular error. Since, noncoherent processing is used, this phase information has to be preserved before applying noncoherent techniques. This is done by adding and subtracting the *s* and *d* signals in intermediate frequency (IF) before giving to square law detection. After detection, the $|s+d|^2$ and $|s-d|^2$ are added and subtracted again to form sum & difference signals. The ratio difference/sum is given as angular positions of the target. The true angular error off boresight *vs* angular error output curve is shown in Fig. 3.

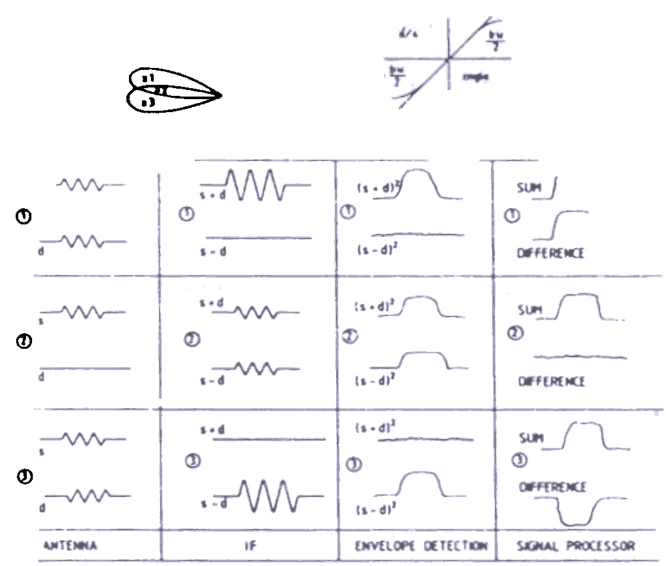

Figure 2. Basic working of the angle tracking system.

3. CRITICAL DESIGN ISSUES

From the performance point of view, the following issues are critical to the system.

3.1 Null Depth

The *d*-output of the antenna can vary from -*s* to +*s* for different angular positions of the target. At

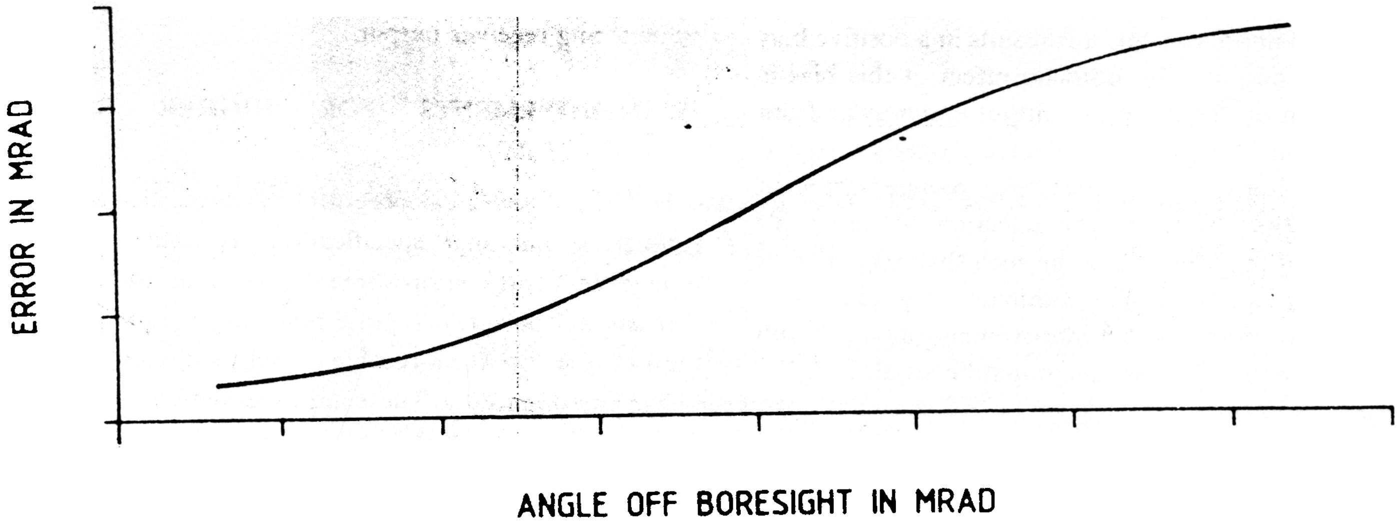

Figure 3. ABA processor output.

boresight, the value of *d* output is zero. Since we are dealing with a practical system, the *d* output can never be zero. The minimum magnitude of the *d* relative to the *s* signal is called the null-depth of the system. The depth of this null decides the sensitivity of the system during angle tracking along line of sight (LOS) and also the speed with which the antenna is brought back to LOS (in terms of the well-defined monopulse slope parameter)[3]. The null depth also decides indirectly the crosstalk between orthogonal plane difference signals. A typical value for this parameter is of the order of 30 dB.

3.2 Phase Imbalance

Since this is a noncoherent system, the only phase imbalance that can affect the performance is between *s* and d in the radio frequency (RF) stage till $(s + d)$ and $(s - d)$ are formed. If a is the phase imbalance in radians between *s* and *d*, then one can take one signal as *s* and the other as $d \cos a$. Then, according to Ref. 1, the angular error output becomes $2ds/(s^2 + d^2 \cos^2 a)$. For large values of *d* (say $d = s$), the ratio becomes $2/(1 + \sec^2 a)$ which is less than the true value of 1. Hence, RF phase imbalance has the effect of compressing the angular error curve. Simulation results for 20 degree phase imbalance are as shown in Fig. 4. As this effect is significant, proper phase trimming of *s* and *d* channels is very essential to have the imbalance within 10 degrees.

3.3 Gain Imbalance

The gain imbalances between *s* and *d* channels affect the angular error output significantly. It can be easily

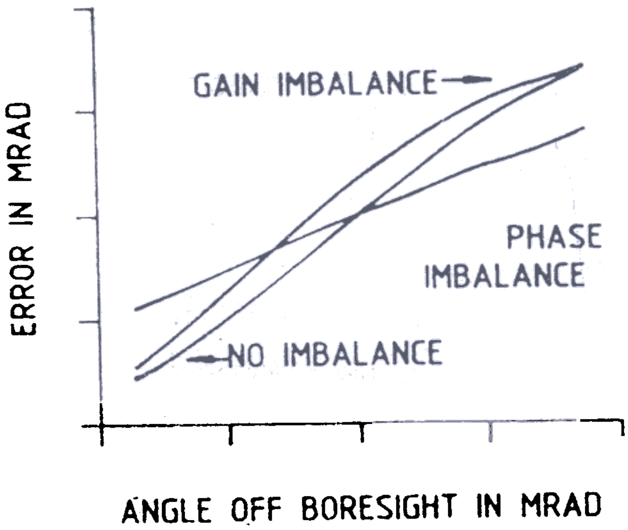

Figure 4. Imbalance effect.

shown[1], that if the gain of the two channels has a ratio *g*, then the angular error output becomes $(1-g)/(1+g)$ at boresight which is nonzero. So the gain imbalance has the effect of shifting the boresight of the system from the true one. Simulation results for 3 dB gain imbalance is as shown in Fig. 4. To counter this effect, one has to use commutation between $(s+d)$ and $(s-d)$ channels. Also, if the system gain imbalance is fixed, one can attenuate one channel properly, so as to cancel out the imbalance. A typical imbalance that can be tolerated is of the order of 1 dB.

3.4 Bias due to Square Law Detection

The Square law detector output of noise always contains a DC component. When the detector output is integrated in the signal processor for signal-to-noise ratio (SNR) improvement, this results in a positive bias in the sum output. The ultimate effect of this bias is compression of angular error output curve away from boresight. To counter this problem, a properly designed high pass filter has to be put prior to integration to cancel out the DC term. The selection of the cut-off frequency of the filter should be such that maximum of the bias is cancelled with minimum degradation in signal. Figure 5 shows the improvement obtained with the use of high pass filter in simulation studies.

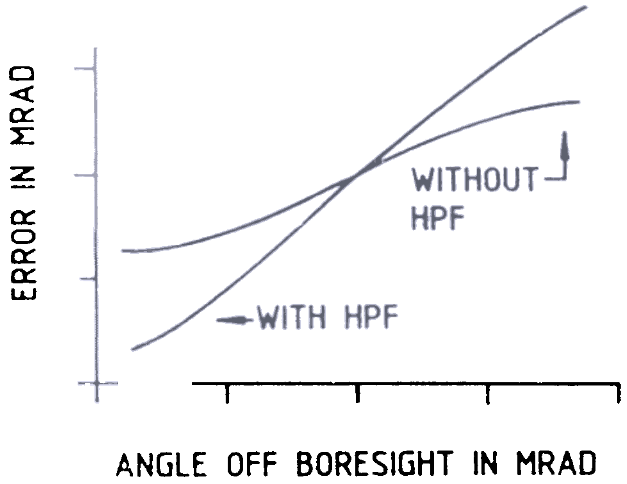

Figure 5. HPF effect

3.5 Angular Error Jitter due to Noise

It is well known[3,4] that the monopulse angular error output has a jitter which is inversely proportional to square-root of SNR. To limit the jitter to a permissible limit of 10 per cent of beamwidth, at least 16 dB SNR is needed at the SP integrator output. If one has to operate at a low SNR, or to reduce the jitter, some kind of predictive filtering, like Kalman filter has to be used at the angular error output before giving the error signal inputs to the stabilisation system.

4. RESULTS

All the seeker sub-systems have been tested and integrated successfully. Detection of outdoor targets and tracking of moving targets in range have been satisfactorily performed. Outdoor evaluation of closed loop angle tracking performance with stabilisation is in progress. A complete phase trimming methodology has been established in the compact antenna range facility, where the phase imbalance can be trimmed out by monitoring receiver output.

5. IMPROVEMENTS FOR HIGHER RANGE CAPABILITY

The present noncoherent system was designed to meet a given range specification. To achieve higher range capability improvements, such as increase of transmitter power, and pulse repetition frequency, and use of a coherent-on-receive signal processing scheme have been identified. These improvements are presently under implementation.

6. SUMMARY

The conceptual validity of the seeker system has been established and the critical design issues have been addressed. Outdoor test results for target detection, range tracking and open loop angle tracking are satisfactory; and closed loop angle tracking evaluation is in progress. Feasible improvements to achieve higher ranges are under implementation.

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REFERENCES

1. NERTU-SPARS Reports, Vols 1-25, Osmania University, Hyderabad.
2. Skolnik, M.I. Introduction to radar systems. Mcgraw-Hill Co., New York, 1980.
3. Sherman, S.M. Monopulse principles and techniques. Artech House, 1984.
4. Bogler, P.L. Radar principles with applications to tracking systems. John Wiley & Sons, New York 1990.