developed all solid-state X, C, Ku, and Ka band dual-channel receivers with twin antenna switching (< 40 ns) eliminating plume effects. A highly sensitive receiver with 50 dB dynamic range and highly flexible erasable programmable logic device-based decoder has been qualified for missile-borne environmental conditions. This airborne system has a unique feature of a choice of one out of 16 frequencies over which the module can be addressed and responded back.

Radio Proximity Fuse

Radio Proximity Fuse

A state-of-the-art solid-state Radio Proximity Fuse (RPF) with PN coded waveform using BPSK modulator at low power operation (transmitter power < 2 W at Ku band) with immunity to possible noise jamming techniques has been developed. This system has been successfully flight-tested after qualification through rigorous ground tests.

Technology Focus highlights the technological developments in DRDO, and also covers the products, processes and technologies.

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Technology Focus

BULLETIN OF DEFENCE RESEARCH & DEVELOPMENT ORGANISATION

MISSILE CONTROL & GUIDANCE TECHNOLOGIES

The preliminary design of a guided missile leads to control and guidance scheme comprising control and guidance laws. The required trajectory deviation of a missile is sensed and computed by the guidance and the control executes guidance command to correct the deviation.

The control and guidance scheme is a software intensive activity which encompass development, operation, validation of guidance and control mechanism, navigation, sensor-signal or image processing, simulation, automatic testing, pre-launch preparation, and post-flight analysis.

The success of missile control and guidance technologies developed by DRDO is commendable for it has been achieved against great odds.

The hardware modules of missile guidance include Inertial Navigation System (INS), optics or radar-based missile-borne seeker, ground-based tracking radar systems, radio frequency up and down-links (missile link with ground system), digital computers with rugged communication links, guidance laws and signal processing.

Missile trajectory control or regulation, as demanded by guidance, needs generation of side forces which is accomplished by aerodynamic or thrust vector control. This control is achieved using electrohydraulic, electropneumatic, and electromechanical actuation systems. The precision positioning of the control is realised by a closed-loop servo system comprising actuators with power packs, position sensor, and processing and power electronics.

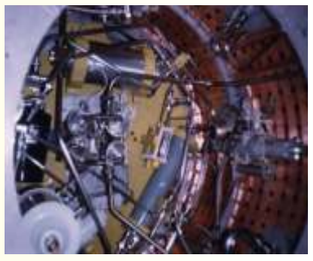
DRDO has developed a number of missile control and guidance technologies under its Integrated Guided Missiles Development Programme, and demonstrated their functionality, reliability, and flight qualifications.

Many subsystems of this programme are under production by different industries. Stringent quality requirements, verified by extensive tests during qualification cycle, have been exercised during hardware development. The quality of the software developed has been ensured by independent verification and validation.

This issue of *Technology Focus* highlights some of the major missile control and guidance technologies developed by DRDO, which are in use in various missile systems.

Electrohydraulic Actuation System

A high power Electrohydraulic Actuation System has been developed for aerodynamic, thrust vector, fin tip, re-entry, and flex nozzle control of missiles. The system consists of actuators, pump motor package, integrated power pack, and control electronics. It is capable of generating forces from 1 ton to 16 ton with bandwidth varying from 10 Hz to 30 Hz for eight actuation channels. The operating hydraulic pressure varies from 210 bar to 280 bar. The system is qualified for high vibrations and shock levels with wide temperature range.



Electohydraulic Actuation System

Electropneumatic Actuation System

A lightweight, medium power, blow-down, self-cleaning Electropneumatic Actuation System has been developed for short-range surface-to-air missiles. The system employs compressed air, stored in a spherical titanium air bottle, for canard, wing, and tail control of the missile at 400 bar pressure. The package delivers a power of about 500 W for 50 s. The system consists of actuators, air bottle, pyro valve, pressure regulator, and control electronics and is capable of generating a force of 150 kgf to 500 kgf with bandwidth of 10 Hz to 25 Hz at an operating pressure of 20 bar to 25 bar. The system is qualified for the air-breathing propulsion system, which generates vibration of 22 g in 1 kHz to 2 kHz frequency range.

Electopneumatic Actuation System

Electromechanical Actuation System

Electomechnaical Actuation System

An Electromechanical Actuation System with brush and brush-less DC motor has been developed and flight-tested in various missiles. It is a maintenance-free system with minimum number of components used for fin and jet vane control besides actuators, power supply, and control electronics. It is capable of delivering power of 100 W to 2000 W with bandwidth of 5 Hz to 15 Hz, operating voltage ranging from 24 V DC to 70 V DC and maximum current of about 100 A. It can drive four actuation channels.

Electromechanical Actuator

A high power, lightweight linear Electromechanical Actuator essentially consists of a brush-less DC motor and a satellite roller mechanical screw with linear variable differential transformer (LVDT) as a position sensor. The product can withstand very high shock and vibration levels and generates a force of 2 ton with a bandwidth of 10 Hz. It is used for driving the control surface and jet vane of a missile with maximum piston velocity of 200 mm/s.

Linear Electromechnical Actuator

Electropneumatic Actuator

Electropneumatic Actuator comprises pneumatic flow relay valve (FRV), actuator assembly, and linear feedback potentiometer. The FRV is an open centre jet-pipe-type, flow control valve exclusively used for closed-loop missile control system. This unique valve is specially designed to control high flow in pneumatic actuator. Three types of actuators are in use in missile control systems and are capable of developing a force of 150 kgf to 700 kgf with a bandwidth of 10 Hz to 30 Hz.

Electopneumatic Actuator

Electrohydraulic Actuator

An Electrohydraulic Actuator handles high stiffness and load inertia. This linear actuator with electrohydraulic servo valve uses a LVDT for position feedback. The hydraulic supply input to the servo valve varies from 210 bar to 280 bar, depending on the application. These actuators are capable of developing 1 ton to 16 ton of load with high acceleration. The bandwidth of these flight-qualified actuators varies from 10 Hz to 20 Hz.

Electohydraulic Actuator

Electrohydraulic Servo Valve

The Electrohydraulic Servo Valve is a high gain, fast response, spool-type flow control valve. Maximum operating pressure of the valve varies from 210 bar to 280 bar and rated flow varies from 10 lpm to 15 lpm with a bandwidth more than 200 Hz. The valve confirms to international standard ARP 490 E.

Electrohydraulic Servo Valve

Servo Amplifier System

This miniaturised system is used to drive the fin actuators of a missile as per command from control and guidance computer. It delivers a power of 100 W and can drive two electric servo motors, each comprising an active 90 Hz band reject filter and a differential output power amplifier. The unit works on ±15 V DC and ± 28 V DC and delivers a closed-loop bandwidth of about 20 Hz. The system has been flight-tested.

Servo Amplifier

Digital Autopilot

A Digital Autopilot based on 87C196 KC microcontroller operating at 16 MHz clock has been developed for the control and guidance of short-range antitank missiles. An on-chip EPROM comprises an 8 kbyte program code of control and guidance software. Sixteen ADC and four DAC channels of 12-bit resolution configure sensor input and actuator commands. Optimised software techniques have been used to circumvent the non-usage of floating-point processor. The unit is designed to withstand 300 g, 3 ms shock level apart from high vibrations and temperature excursions.

Digital Autopilot

Analog Autopilot

The Analog Autopilot comprises amplifiers, filters, and limiters to control the flight of short-range missiles. It receives commands from an onboard guidance unit and feedback from inertial sensors. The output is used to drive the flow control valves of the three electropneumatic actuators of the missile. The unit works on ±15 V DC derived from an onboard voltage regulator. The autopilot is specially qualified for very high lateral acceleration levels.

Analog Autopilot

Hybrid Servo Controller

A Hybrid Servo Controller has been developed as a position control servo amplifier for hydraulic actuation system. It accepts command and feedback signals in DC and controls the current flowing into the torque motor coils of eight servo valves. The unit consists of four hybrid modules, each comprising two servo amplifiers. It weighs about 1.5 kg and operates on 28 V DC.

Hybrid Servo Controller

Onboard Computer

A rugged onboard computer supporting distributed system architecture has been developed for the navigation, control and guidance of the missiles. The system is designed using Intel 80386-based processor with 80387 coprocessor operating at 16 MHz. Separate boot EPROM, application EPROM banks, MIL-STD-1553B bus module supporting two channels of BC/RT/MT are some of the special features of the computer. Intelligent analog and digital I/O modules based on Intel 87C 196 micro-controller comprising ADC and DAC channels control the interface functions. The computer has been successfully flight-tested.

Onboard Computer Electronics

Strap-Down Inertial Navigation System

A dynamically tuned gyro-based strap-down Inertial Navigation System is used for the short and medium range missiles. This accurate system, having three body-mounted gyros and three accelerometers, provides accurate position, velocity and Euler angle information of a missile with

respect to a reference coordinate system after processing the sensor output. The gyros and accelerometers are of the class of 0.3^0/h and 150 µg. A real-time navigation software to carry out the sensor modelling and navigational functions, and technologies to integrate, model, test, and calibrate the navigation system have also been developed. The system has been successfully flight-tested.


Inertial Sensor Cluster


Inertial Navigation Computer

Ring Laser Gyro Technology

A Ring Laser Gyro (RLG) of 0.01^0/h class has been developed using total internal reflection prisms. The complete optical processing, inspection, design of electronics for RLG control and measurement have been realised. The Gyros are presently under qualification testing.


Ring Laser Gyro

Day Seeker

A low volume, 140 mm dia, rugged Day Seeker for antitank missile guidance application has been developed. It features compact payload with 256 × 256 frame transfer CCD sensor, telephoto optics with 3^o field of vision, and auto iris mechanism. The seeker delivers a line-of-sight error accuracy that is less than or equal to ± 2 pixel. The bandwidth and tracking bandwidth of stabilisation servo system is more than 25 Hz and 2.5 Hz, respectively. It comprises a real-time image processor based on ADSP 21062 multiprocessor architecture for target tracking, and algorithm based on correlation techniques with drift correction and confidence measures. The seeker has long-range capabilities.


Visible Seeker

Imaging Infrared Seeker

A rugged Imaging Infrared Seeker, with day and night capabilities and same dimension as that of the of Day Seeker, has been developed for antitank missile guidance application. This seeker has compact payload with 128 × 128 LWIR MCT (8-12 µ) Focal Plane Array. Low-Noise Proximity Electronics, and JT Cooling System using high pressure (400 bar) pure nitrogen for fast cooling with flexible cooling pipes are the main features of this seeker. It consists of a stabilisation servo system designed to deliver tracking accuracy less than or equal to 1^o/s for a body rate of 30^o/s, and also to overcome the cooling tube flex


Imaging IR Seeker

torques. It also consists of a real-time image processor based on ADSP 21062 multiprocessor architecture having correlation tracking, wavelet tracking, and non-uniformity correction algorithms for target tracking.

Image Processing System

A real-time Image Processing System is used for scene matching techniques for improving the terminal accuracy of long-range missiles featuring TMS 320C80-based hardware platform. The system puts into action the correlation and model-based image matching algorithms in real-time and I/O communication using 1553 bus interface.


Image Processing System

Antenna Systems

Miniature antennas for radio-frequency transmitter, and receivers for missile-borne and ground-based systems have been developed and successfully deployed. Prime Focus, and Cassegrain Reflector Monopulse Antenna System for ground applications at Ku, Ka, and W band with beam width of 5^o and 2^o and gain exceeding 25 dB at Ku band and 35 dB at Ka band, respectively have been realised and qualified.


W Band Reflector

The other type of antennas developed are the Monopulse Corrugated Horn Antenna for optimised pattern with gain exceeding 25 dB and null depth exceeding 28 dB at Ka band; Lightweight (< 800 g) W band Trans-Twist Monopulse Antenna for seeker with gain exceeding 30 dB with a beam width less than 2°; Dielectric Loaded Miniature Surface-mount Antenna with wide beam width (> 70°) with gain exceeding 8 dB at Ku and Ka bands for command and datalink applications; and Slotted Waveguide Linear Array Antenna with tilted beam of 60° and gain exceeding 10 dB with a beam width of 10° minimum for radio proximity fuse application.


Trans-Twist Antenna and Radome

Command Guidance System

The Command Guidance System receives the ground guidance commands on its radio frequency channel. After proper demodulation and detection, it produce low frequency guidance commands for missiles. It also generates transmitting signals for the down-link. DRDO has


Receiver


Transmitter