Nordic Radar Solutions

ABISS - a unique radar system for weapon and bomb scoring

In general, three critical attributes are desired for an instrumentation radar dedicated weapon- and bomb scoring to ensure its versatility

- **multiple target cluster scoring**
- **medium-resolution imaging capability and**
- **fast data acquisition**

The ABISS has these attributes.

The ABISS system will normally consists of two units, a container containing the ABISS radar system and the operator control console.

The container includes a lift and foldable roof which allows to stow the antenna and antenna pedestal inside the container when the ABISS system is not in use. This further protect the entire system from the local environment at the training range. The container lift and roof are fully automated and requires no manual effort to exercise. The container outline is shown below.

The operator control console will typically be located at a suitable location where the range personnel oversees training operations.

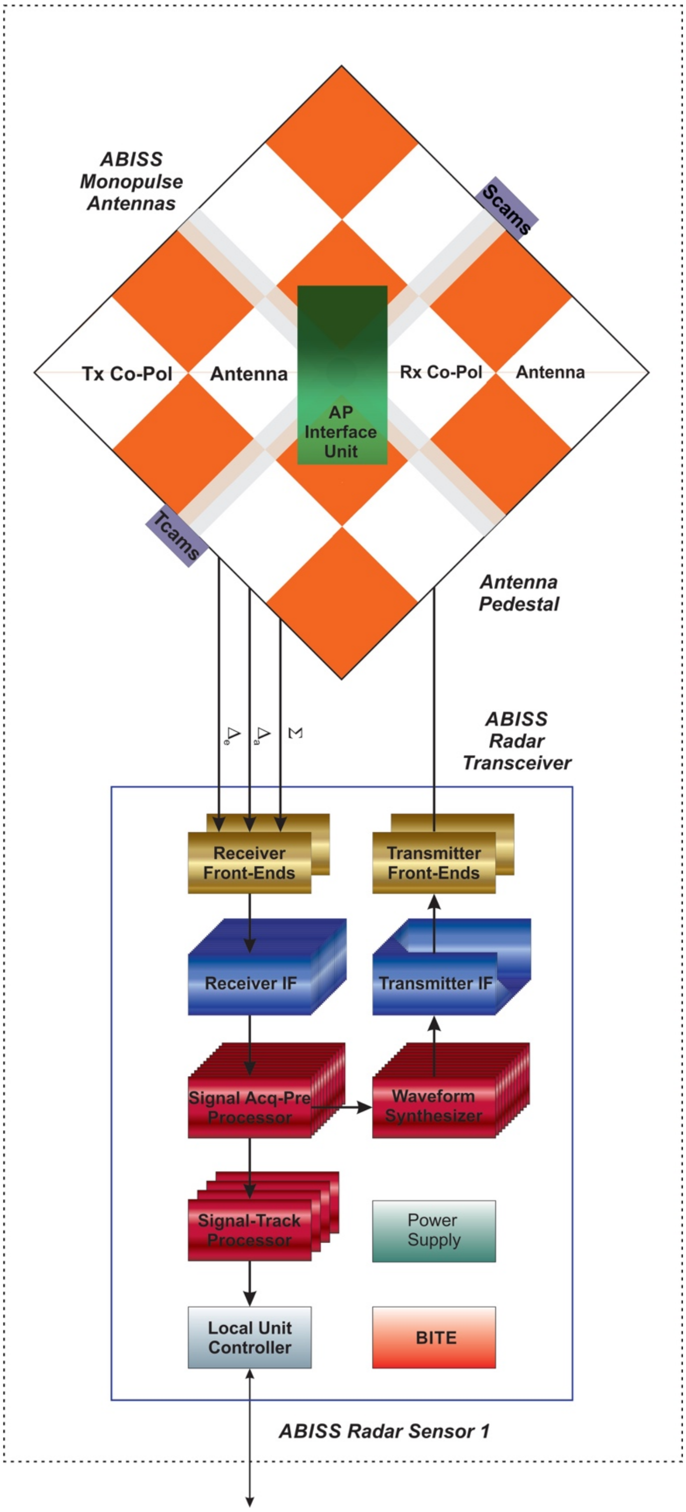
ABISS Radar Sensor

The ABISS primary sensors are the monopulse (MP) multiple-waveform doppler radar (MWFDR) RSs that each is constituted by the ABISS Radar Transceiver (RT) and the ABISS Monopulse Antennas (MPAs). The radar sensor operates in the K_a-Band (approximately 35 GHz). These two units may be physically collocated and supported by the AP. Alternatively, the AP supports the MPAs that in turn are connected to the RT by waveguides. In the latter case at some shooting ranges it might be benificial to install without an AP, e.g., the roof of a control tower while the transceiver is placed inside the control tower.

Monopulse Antennas

The MPAs in turn are composed of a transmit antenna and a receive antenna. Both antennas are based on an innovative very low-loss slotted waveguide (SWG) array design with inherent *beam steering* capability and support of multiple beams.
The antennas are physically separated and electromagnetically isolated in order to prevent exterior leakage from the transmitter to the receiver.
The receive antenna facilitates advanced monopulse operation including a sum channel and two difference signal channels (azimuth and elevation). Moreover, in contrary to the vast majority of monopulse antennas, the sum channel and difference channels operates independently thereby providing optimal usage of the available antenna aperture.

The antennas are primarily optimised with respect to a high angular accuracy capability, high gain and a low side lobe level (SLL).



Transmitter Front-End and Receiver Front-End

The transmit antenna and the receive antenna are connected to the Transmitter Front-End (TFE) and the Receiver Front-End (RFE) respectively.
The transmitter is build on state-of- the-art microwave (MW) circuitry including solid-state power amplifiers that depending on the requirements varies from 2 W to 80 W.
The RFE is also build on state-of-the-art MW circuitry comprising low-noise amplifiers (LNAs),

microwave filters, oscillator synthesiser at 39.2 GHz and balanced mixers. The receiver noise figure for each receiver is very low. The Transmitter Front-End are Receiver Front-End are constituted from a large number of partially customized commercial off-the-shelf (COTS) waveguide (WG) components and physically placed on the same metal board and in the same enclosure. The use of a *heterodyne* transceiver as opposed to a *homodyne* transceiver allows for using a high operational radar frequency with spurious-free transmission and reception.

Transmitter IF and Receiver IF modules

The radar sensor employs a superheterodyne topology and the intermediate frequency IF frequency band. A half-octave wide frequency band facilitates up to sixteen simultaneous and independent frequency channels. These frequency channels in turn facilitate support of multiple antenna beams. The Transmitter IF Board (TIFB) and Receiver IF Board (RIFB) are build on high-end COTS MW circuitry ensuring a relative smooth half-octave frequency response. Fixed-gain and variable-gain amplifiers are used to dynamically adapt the radars sensitivity to cope with the huge dynamic range experienced by the radar from one installation to another, but also to cope with huge targets at close range and small targets at medium ranges.

Real-Time Pre-Processor

The Real-Time Pre-Processor (RTPP) is the central processing unit of the ABISS system and it is responsible for *target detection, track initialisation, track prediction and filtering and track deletion.* As a consequence the RTPP is also responsible for *antenna mount control* (mechanical) and *antenna beam steering* (electrical).
The RTPP is constituted by the Signal Pre-Processor (SPP) module, the Waveform Synthesiser (WFS) module and the Track Pre-Processor (TPP) module.
The RTPP employs sophisticated NRS proprietary software that exploits recent advantages in signal processing and tracking technology.

Signal Acquisition & Pre-Processor Board module

The Signal Acquisition & Pre-Processor Board (SAPPB) employs a 4×channel analogue to digital converter (ADC) with up to 1 Gbs^{-1} sampling rate as required by the wide bandwidth of each frequency channel. By using state- of-the-art 16 bit ADCs, an impressive dynamic range of 90 $dBFS \cdot Hz^{-1}$ is obtained (meaning that in a 1 Hz bandwidth a simultaneous detection can be made of two signals differing 78 dB in amplitude - assuming 12 dB signal-to-noise ratio (SNR) being the detection threshold).

Waveform Synthesiser module

The Waveform Synthesiser is supported by a 2 channel digital to analogue converter (DAC) with up to 1 Gbs^{-1} sampling rate as required by the wide bandwidth of each frequency channel.
Each output frequency channel is capable transmitting multiple carriers simultaneously.

Each carrier in turn is synthesised and can be completely controlled independently of each other, but are derived from an extremely stable reference crystal oscillator insuring perfect control of both absolute and relative transmit frequencies.

Each carrier is capable of

1. Transmitting the following basic waveforms: Fixed CW, FSK CW, linear FMCW. Arbi- trary coded frequency and phase patterns are facilitated by the use of direct digital synt- hesiss (DDSs). Advanced waveforms include: identical ideal sequence (IIS) multi-carrier phase coded (MCPC) continuous-wave (CW), consecutive ordered cyclic shifts (COCS) of a chirp-like sequence (CLS) MCPC CW and mutually orthogonal complementary sets (MOCS) MCPC adapted for CW usage.
2. The waveforms can be time multiplexed with arbitrary durations. Each time slot can be configured independently of previous time slots
3. Transmits time slots are fully synchronised with the receiver samples within 1 sample accuracy
4. The power envelope of each time slot can be controlled

Each different firing evaluation scenario phases mayhave individual optimal radar signals waveforms. Moreover, each of the phases may benefit from a different target illumination pattern throughout the duration of the scenario phase.
Accordingly, the WFS module will control the transmitter (Tx) to transmit a time-variant signal thereby illuminating the target with different signal characteristics. The receiver (Rx) is synchronised to actual waveform pattern in order to obtain an optimal matched filter response.

Signal & Tracking Processor module
The SPP incorporates a real-time Doppler analyser and an advanced *target recognition* capability. A powerful embedded computer and a likewise powerful field-programmable gate array (FPGA) facilitate execution of the dedicated ABISS algorithms in real-time.
The TPP module incorporates advanced multi-object tracking (MOT) software that makes real-time estimates of the target state vector for multiple objects as detected by the ABISS radar sensor. Detected objects are classified as primary, secondary and auxiliary targets.
The RTPP processes APIU position encoder information, that is, azimuth and elevation data from the APIU and also information for antenna boresight stabilisation from the ASFU (refer to [3]) and generates the necessary antenna drive control signals to maintain track on the main target.
The RTPP also sends all sensor data to the OCS for weapon scoring estimation.

Heterogeneous Processing Platform

The signal processing and tracking algorithms are supported by a *heterogeneous computational platform* involving

1. A FPGA board where detection and doppler filtering is carried out in near-real-time.
2. A graphical processing unit (GPU) board that provides ultra fast monopulse processing and highly accurate angular estimates.
3. A central processing unit (CPU) motherboard where further signal processing, tracking and finally miss distance indicator (MDI) information reported to the user.

Jointly, advanced signal processing and tracking algorithms executed on the heterogeneous processing platform the RTPP is capable of producing the following target data as applicable to *auxiliary target*, *primary target* and *secondary targets* in real-time (RT):

- Doppler signal vs time
- Distance, azimuth angle, elevation angle and radial velocity vs time
- Signal-to-noise ratio vs time

The following derived data are immediately available:

- Velocity, radial acceleration vs distance and time
- Signal-to-noise ratio vs distance and time
- 3-D trajectory: Vertical and horizontal trajectory as a function of distance
- Estimated accuracies of state variables

Power Supply Unit

The RSs and ASFU Units are all equipped with a dedicated Power Supply Unit (PSU) that basically is responsible for providing stable low-voltages of sufficient ampere ratings as required by the individual units.

Local Unit Controller

The Local Unit Controller (LUC) is responsible for local control of the ABISS RSs. Inter-unit communication capability is established through a dedicated ABISS protocol.
In simple terms, the LUC bridges control from the ABISS OCS to the ABISS RSs. The primary functions of the LUC include:

- Interfacing with the GSC in the OCS
- Radar Sensor local control
- Execution of local human-machine interface (HMI) commands
- APIU interfacing to the RTPP

Antenna Pedestal

For high dynamics and accurate pointing the ABISS system includes a two-axis AP that inclu- des ruggedised mounts for the support of the RSs, the APIU and possibly including the ASFU including Search Camera (SCam) and Tracking Camera (TCam).

Antenna Pedestal Interface Unit

The APIU that is physically located at the AP houses most of the AP electronics like servos, Antenna Pedestal Interface (API) printed circuit board (PCB) and power supplies and software for the two independent axis digital servo control systems, and for antenna control. The APIU is controlled by the Antenna Control Unit (ACU) part of the RTPP (through LUC) with real- time pointing information commanded by the RTPP. For safety reasons the APIU includes limit switches and emergency breaks.

ABISS Operator Control System

The entire ABISS system is accessed, configured and controlled from the ABISS OCS. For safety reasons the OCS will be located in a protected position and may therefore **not** normally be collocated with the other ABISS sensor units. Instead it could be located in a control tower and managed by the range safety officer (RSO). Basically, the OCS is constituted by a ruggedised COTS laptop running on a standard commercial operating system.

Configuration Module

The ABISS configuration module facilitates operator entry of information pertaining to the upcoming firing scenario. Such *a priori* information is very beneficial for the operation of the ABISS system.

Nearly Real-Time Post-Processor

The miss distance analysis is obtained by the Nearly Real-Time Post-Processor (NRTPoP) that in turn is constituted by the Signal Post-Processor (SPoP) module and the Track Post- Processor (TPoP) module. The NRTPoP employs advanced NRS proprietary software that ex- ploits recent advantages in signal processing and tracking technology.
The algorithms embedded in the NRTPoP closely resemble algorithms in the RTPP in the RSs. However, the absence of requirement on true real-time performance facilitates a more in-depth analysis where *track smoothing* replaces *track filtering*. This leads to extremely accurate MDI results.

In summary, the NRTPoP is capable of producing the following smoothed target data as applicable to *auxiliary target*, *primary target* and *secondary targets* in nearly real-time (NRT):

- Velocity, radial acceleration vs distance and time
- signal-to-noise ratio vs distance and time
- 3-D trajectory: Vertical and horizontal trajectory as a function of distance
- Estimated accuracies of state variables

Subsequently, the miss distances quantities and associated statistical figures are produced inclu- ding:

- Single projectile
- Round of projectiles
- Multiple rounds of projectiles.

Global System Controller

The Global System Controller (GSC) is the primary controlling unit for the ABISS system. Basically, the GSC bridges control from the ABISS OCS to the ABISS RSs. The primary functions of the GSC include:

- Interfacing with the LUCs in the RSs and ASFU
- Execution of local HMI commands
- Distribution of global HMI commands to RSs and ASFU
- Data recording

Operator Control Console

The Operator Control Console (OCC) provides user-friendly operator control of the ABISS system through an innovative HMI design The OCC consists physically of a monitor displaying the shooting result and a laptop with software that makes provision for manual antenna control and target cluster selection.
Data may also - on demand - be transmitted real-time via the internet to the pertinent remote units for further analyse.