

GAMIC Weather Radar Signal Processor

ENIGMA IV

Digital Receiver and Signal Processor for enhanced Radar Data

GAMIC designs and manufactures ENIGMA IV, the advanced weather radar signal processor for single and dual polarization. It comprises two components – the intermediate frequency digitizer (IFD) converts your radar output to a stable and high quality digital signal while the host provides clean output data by applying powerful algorithms and corrections.

POWERFUL CORRECTION ALGORITHMS

To get the best out of your weather radar data, ENIGMA IV comes with powerful algorithms to ensure high data quality and reduced disturbances. Digital Doppler velocity processing enables more accurate velocity data and **better clutter mitigation**. The velocity based clutter filters provide 40 dB or better clutter rejection, resulting in less ground clutter. Dual polarization based **rain and gas attenuation correction** are inevitable for reliable rain rate retrievals, especially for sensitive X-band radars. Further data improvement features comprise the **removal of multi-trip echoes, RF interferences, and sun spokes**.

ENIGMA IV is highly configurable, including speckle remover (via reflectivity, velocity, spectrum width, or dual pol moment), thresholding (NOISE, CCOR, SIGPOW, RHOHV, SQI), and KDP interpolation.

NEW FEATURES FOR ENHANCED DATA

GAMIC's signal processor ENIGMA IV just got better with some new features to get even more out of your data. Those new features include the following:

- » **Fuzzy logic classification and flagging** of range gates for ground clutter, multi-trip echoes, wind-turbine clutter, RF interference, and sun spokes
- » **Improved random phase multip-trip detection** and mitigation
- » **Adaptive clutter filtering**
- » **Additional output moments** (clutter phase alignment, standard deviation, SQI 2nd/3rd trip, classification flags, real and complex cross spectrum)
- » **Improved thresholding** including the new classifier flags

COMPREHENSIVE OUTPUT MOMENTS

Besides typical single polarization radar moments reflectivity (Z), radial velocity (V), and spectral width (W), ENIGMA IV provides **output of enhanced dual polarization moments** which are essential for any contemporary processing and further usage of weather radar data. Those comprise ZDR, KDP, RHOHV, PHIDP, and much more. All radar moments are provided uncorrected and corrected.

For **comprehensive data quality and signal analysis**, ENIGMA IV serves some more output variables like signal-to-noise ratio (SNR), signal quality index (SQI), clutter power (CCOR), power spectrum (DFT), and more.

For a non-exhaustive list of ENIGMA IV output moments, a hardware description, and technical specifications, see back of this datasheet.

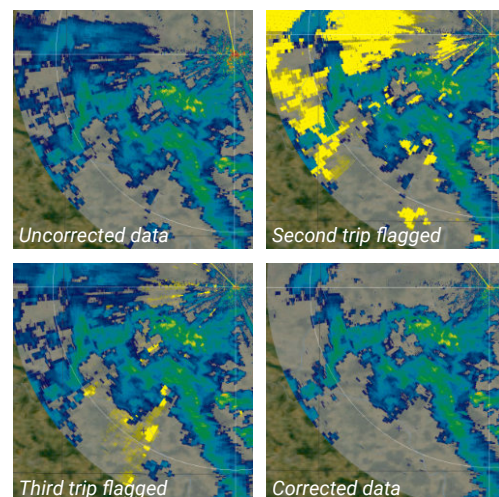


Features

- » **Weather radar signal processor** for rapid scanning and analysis of scientific quality and accuracy
- » **Digital Doppler processor-receiver** with pulse compression
- » **Powerful correction and mitigation** of clutter, interferences, multi-trip echoes, and more
- » **Comprehensive output data**

Technical Details

- » Intermediate frequency digitizer (IFD) and host
- » IF frequency of 60 MHz (other optional)
- » Dynamic range:
 - >110 dB (2 μ s pulse width)
 - >105 dB (0.8 μ s pulse width)
- » Typical base resolution: 25–125 m
- » Range: 10–400 km
- » PRF: 10–3000 Hz
- » Up to 8,000 range bins
- » Host with standard rack mount



Intermediate Frequency Digitizer (IFD)

| | |
|-------------------|------------------------------|
| Receiver Inputs | 3 Channels (H, V, Reference) |
| Internal Channels | 5×16 bit (2×H, 2×V, 1×Burst) |
| Frequency | 60 Mhz (other optional) |
| Dynamic Range | >110 dB @ 2 μs pulse width |

Host (ENIGMA PC)

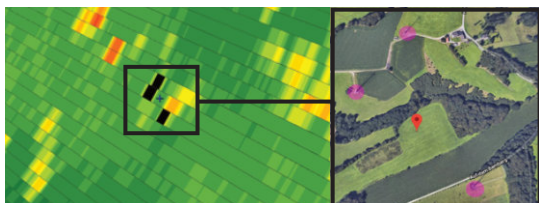
| | |
|------------------------------|---|
| Typical Base Resolution | 25–125 m |
| Range | up to 400 km |
| PRF (Pulse Repetition Freq.) | 10–3000 Hz |
| Number of Pulse Widths | 4 with independent configurable matched filters (up to 1280 taps) |
| Dual PRF Modes | None, 2/3, 3/4, 4/5 |
| Processing Modes | PPP (Pulse Pair Processing), FFT, DFT, Staggered PRT |
| Connection to IFD | Fibre optic, 1 Gbit/s |
| Enclosure | Standard 19" rack mount (3 or 4 HU), depth 420 mm or custom |
| Power Consumption | <150 W, 100–230 V, 50/60 Hz |

Output Data

| | |
|--------------------|---|
| Reflectivity | Corrected Reflectivity (Z) Uncorrected Reflectivity (UZ) Attenuation Corrected Reflectivity (AZh) |
| Doppler Velocity | Radial Velocity (V) Folded Radial Velocity (VF) Spectral Width (W) |
| Signal Analysis | Clutter Power (CCOR) Signal Quality Index (SQI) In-Phase/Quadrature Signal (I/Q) Logarithmic Power (LOG) Signal Noise Ratio (SNR) Censor Map Power spectrum (DFT) |
| Dual Polarization | RhoHV PhiDP KDP ZDR Attenuation Corrected ZDR LDR (H-transmit) RhoH (H-transmit) |
| New Output Moments | Clutter Phase Alignment (CPA) Standard Deviation (SRD) SQI Second / Third Trip (SQI2/SQI3) Classification Flags (CLASS) Cross Spectrum (Real & Complex) |

NEW: Wind Turbine Clutter Detection

Everyday more wind turbines are installed within the range of radar systems. An increasing problem appears in the evaluation of weather radar data due to dynamic wind turbine clutter. Addressing this problem, **ENIGMA IV has a built-in wind turbine clutter detection algorithm**. The example images show detected wind turbines marked in black, red dots represent original wind turbine coordinates.



STATE-OF-THE-ART SIGNAL PROCESSING HARDWARE

The ENIGMA IV signal processor consists of a **powerful host PC** (ENIGMA PC) and a 19" companion device called **IFD (Intermediate Frequency Digitizer)**. The IFD can be installed either in an IT rack or head-mounted behind the radar antenna. It can be used in any common weather radar installation.

The IFD controls the transmit timing of the connected radar by applying trigger signals and performing the data acquisition accordingly. It comes with three separate input channels for horizontal, vertical, and burst (transmit signal / reference) signal measurement which enable **full dual polarization capability**. The IF signal is digitized at an intermediate frequency of 60 MHz (other frequencies optional) and the radar echo data is tagged with corresponding time and elevation/azimuth angle information. For **optimum sensitivity and dynamic range** a digital filter is applied which matches the transmitted pulse length perfectly. The generated raw echo data is provided to the host PC through an optical fibre connection of 1 Gbit/s for further processing.

The ENIGMA IV signal processor is very versatile and can be used for **magnetron, klystron, or solid-state radars**. In case of non-solid-state radars, the IFD is able to measure the IF frequency and apply an **AFC (automatic frequency control)** for proper reception. For solid-state radars the complete output signal is generated by the IFD utilizing **pulse compression** technology.



Data Quality Algorithms

| | |
|------------------------------|---|
| Attenuation | Rain and Gas Attenuation Correction |
| Range Normalization | 1/r ² Range Normalization |
| Configurable Speckle Remover | Reflectivity (2D), Velocity, Spectrum Width, Dual Polarization Moment |
| Configurable Thresholding | NOISE, CCOR, SIGPOW, RHOHV, SQI |
| Multi-Trip Removal | Second Trip / Third Trip |
| Interference Removal | RF Interferences, Sun Spokes |
| KDP Interpolation | Configurable (Gaussian, B-Spline, 0.125–5 km) |

Other Features and Specifications

| | |
|-----------------------------------|---|
| Time Averaging | Adjustable time samples (8–1024) or dynamic angle syncing |
| Sector Blanking | 32 configurable azimuth/elevation sectors (0.05° resolution) |
| I/Q Recording | Pulse-wise, 32 bit IEEE floating point format to internal HD |
| Configuration | FROG-MURAN network capable GUI, telnet, or built-in HTTP server |
| Status Output | ASCII BITE and log messages via telnet port, HTTP server interface |
| Status Information | Host (CPU load and temperature, memory usage, voltages) IFD (power supply, temperatures) A/D converter status AFC status Sector blanking status No. of pulses for auto-correlation |
| Matched Filter Designer | GUI application for semi-automatic calculation of matched filter coefficients (for transmitter pulse) and verification. |
| AFC (Automatic Frequency Control) | Comprehensive AFC configuration and visualization |