# NDR684

Four Channel, Wide Bandwidth, High Performance 18 GHz SDR in a Low SWaP, Ruggedized Package

**Designed for the most difficult RF environments, the NDR684 offers 4 wideband 500 MHz receive channels that can be independently or phase coherently tuned for search, survey and direction finding (DF) applications.**

The NDR684 is a four receive channel software defined radio, combining a super-heterodyne RF front end that provides 1 MHz to 18 GHz frequency coverage with an AMD Xilinx RFSoC for digitization and signal processing. The 500 MHz bandwidth channels are digitized, formatted into VITA 49 packets and are transmitted over a 100 GbE interface. Additional signal bandwidths can be realized through digital channelization. The NDR684 is enclosed in a small form factor, ruggedized package ready for airborne, vehicle, and fixed site installation.

## Key Features

- Four High Performance Rx Channels
- 1 MHz to 18 GHz Frequency Coverage
- 500 MHz Bandwidth per Channel
- Calibrated RF Performance Across Frequency
- Independent and Coherent Tuning
- Fast Frequency Hopping
- Selectable Wideband Digital Downconverters (DDCs)
- Low SWaP, Ruggedized
- VITA 49 Streaming on 100 GbE
- Restful API Command and Control
- Commercial Off-the-Shelf (COTS)

Product Web Page:

## Specifications at a Glance

| Category | Output | $F_{Min}$ | $F_{Max}$ | Frequency Tuning | Timing Inputs | CPU Enabled | GPU Enabled |
|---|---|---|---|---|---|---|---|
| Platform | Digital | 1 MHz | 18 GHz | Indep. & Coherent | 10 MHz, PPS | - | - |

| Max Rx Channels | Max Tx Channels | $IBW_{Max}$ | $SFDR_{Typ.}$ | Weight | Typ. Power Consumption | Interfaces | ADC bits/ DAC bits |
|---|---|---|---|---|---|---|---|
| 4 | 0 | 500 MHz | 80+ dB | 5.4 lb. 2.5 kg | 73 W | 100 GbE | 14 |

# Specifications

| Model: | NDR684 |
|---|---|
| **Environmental Specifications** | |
| Temperature (Operating) | -40 to +70 °C, cold plate surface temperature under typical operating conditions |
| Temperature (Storage) | -40 to +85 °C |
| Size | 6.45 x 9.45 x 1.9 inches<br>164 x 240 x 48 mm |
| Weight | 5.4 lb.<br>2.5 kg |
| Power (Typ.) | 73 W |
| Voltage Input Range | +12 Vdc (10 to 15 V accepted) |
| Enclosure | Metal |
| **Digital Specifications** | |
| FPGA | Zynq RFSoC |
| CPU/ GPU | None accessible/ No GPU |
| Memory | None accessible |
| Storage | None accessible |
| User I/O | J6:<br>• 100 GbE for VITA 49 streaming of I/Q data. MT38999 connector with a 12 Fiber MPO connector inside. |
| | J2:<br>• Mighty Mouse connector<br>• 1 GbE network port for PS command and control. |
| | J3:<br>• Mighty Mouse connector<br>• PS RS232 console<br>• +12 V power Input |
| | J4:<br>• Mighty Mouse connector<br>• Write Protect - 5 V pull-up, ground pin to enable writing<br>• 1PPS Input (see later)<br>• JTAG for programming/ debugging<br>• GPIO, one 3.3 V output, two 3.3 V inputs |
| | Indicator LEDs:<br>• Ready LED - green after boot unless an error occurs<br>• Error LED - off after boot unless an error occurs |

| Model: | NDR684 | |
|---|---|---|
| **Digital Specifications** | | |
| Wideband Digital Down Converters (DDCs) | Bandwidth (MHz) | Sample Rate (MS/s) |
| | 500 | 675.84 |
| | 250 | 337.92 |
| | 125 | 168.96 |
| | 62.5 | 84.48 |
| | 31.25 | 42.24 |
| | Up to 48 available at varying rates. Multiple DDCs may be applied to an individual channel (see page 11) | |
| **RF Specifications** | | |
| Frequency Range | 1 MHz to 18.25 GHz | |
| Channel Bandwidth | Up to 500 MHz | |
| Channels | J7, J8, J9, J10:<br>• 4 Physical Channels (Front panel SMAs)<br>• 5 W limiter (37 dBm) on each channel | |
| RF Input Level for Full Scale Output | -28 dBm | |
| Maximum RF Input Without Damage | < 650 MHz | +15 dBm |
| | > 650 MHz | +27 dBm |
| Tuning Time [1] | <100 µs | |
| Noise Figure (Typ.) | 12 dB | |
| Input IP3 (Typ.) [2] | 0 dBm | |
| Spurious Free Dynamic Range (Typ.) [3] | 80+ dB | |
| Internal Spurs [4] | Internal spurs (EIL) < -100dBm, with the exception of 10 spurs < -90dBm | |

Continues...

[1] Tuning between any two frequencies over operating range

[2] Measured with 2 CW tones at -9 dB-full-scale of the A/D input power

[3] Highest in-band spur compared against a single CW tone at -9 dB-full-scale of the A/D

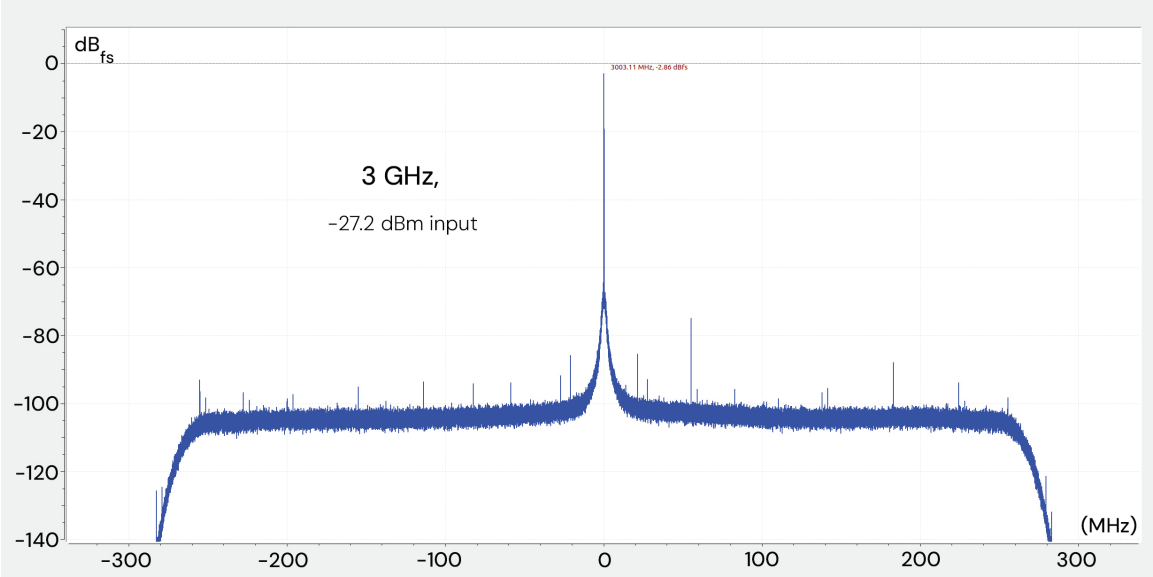
[4] Highest in-band spur translated to equivalent power at the Rx input connector

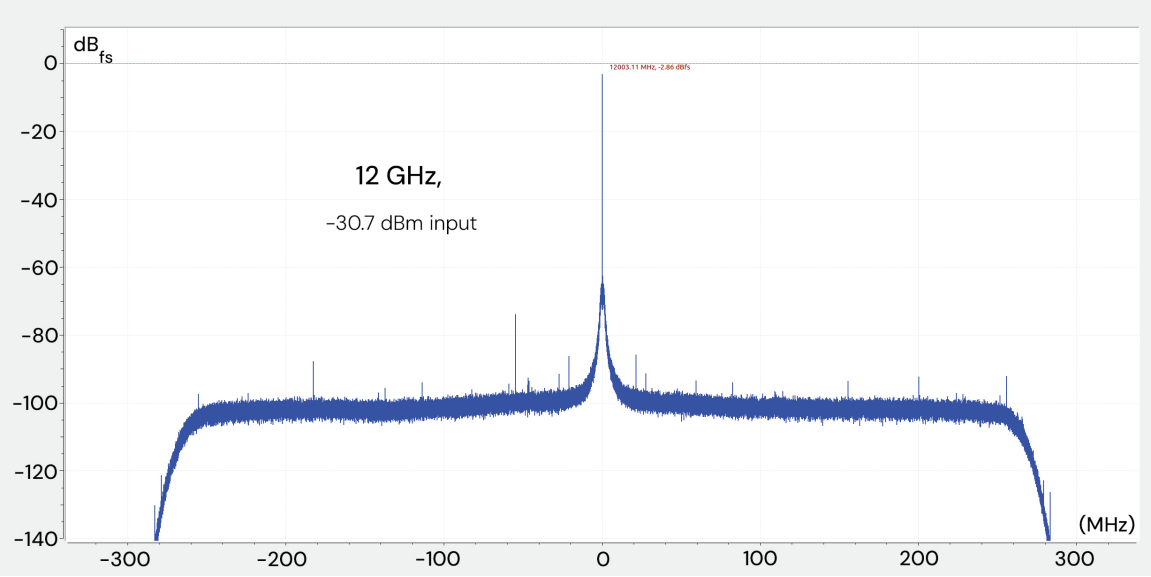
## Specifications

| Model: | NDR684 |
|---|---|
| **Clocking** | |
| Reference | J11:<br>• 10 MHz input (front panel SMA)<br>• Input level: 0 dBm ± 3 dB |
| PPS Input | Yes (a pin in J4). Used for accurate timing of digitization and digital signal processing. |
| GPS Input | No |

| Model: | NDR684 |
|---|---|
| **Other** | |
| Export Classification | 5A991.b |
| CE-Marked | - |

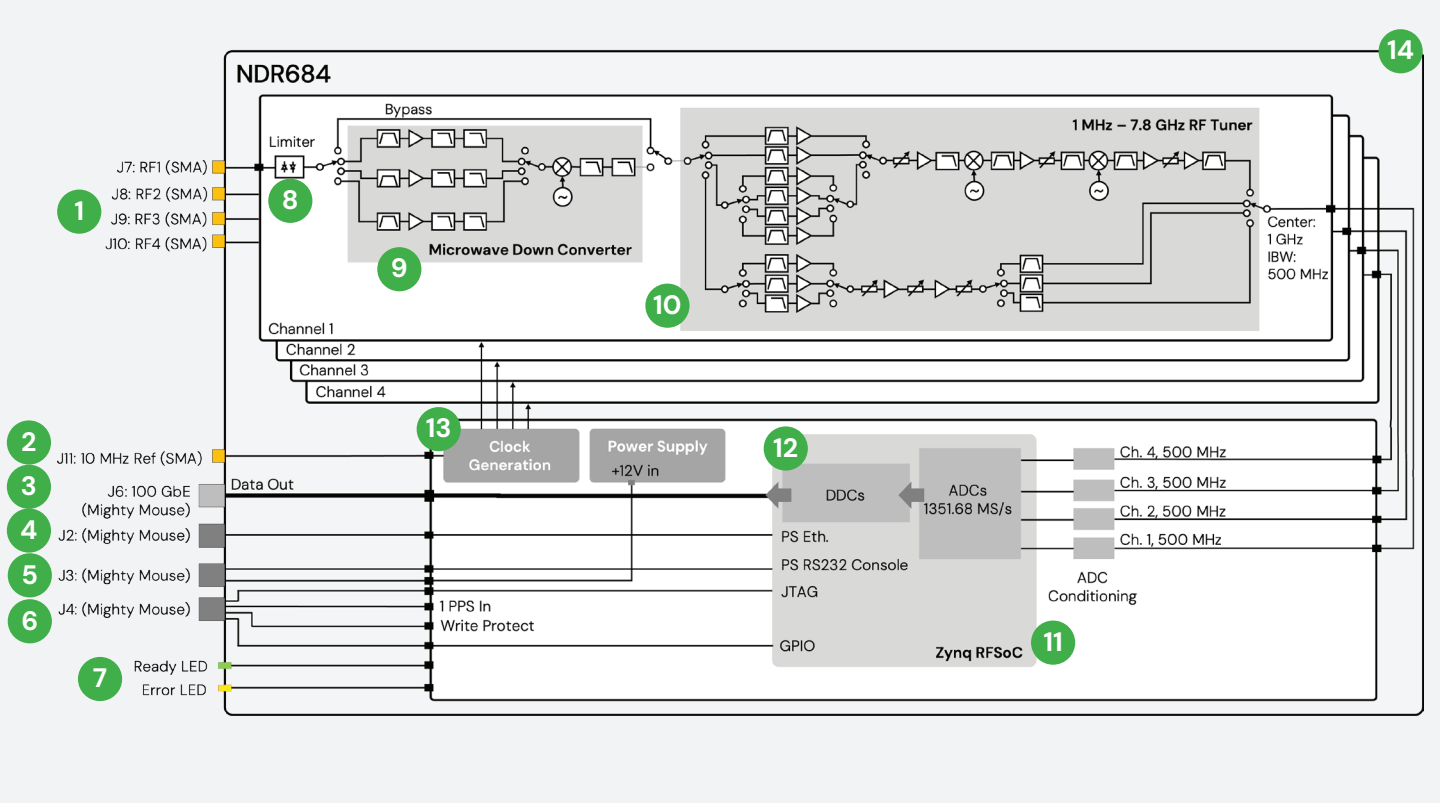
*Data subject to change without notice.*




*These plots were taken from a single unit to illustrate performance at room temperature for one channel.*

## NDR684 Block Diagram




## Features of Note

Numbered items may be highlighted on the block diagram and/or exploded view.

1. Front panel RF inputs **J7, J8, J9, J10** (SMA)

2. **J11**: External 10 MHz reference input (SMA). Accepts an external 10 MHz to lock a 100 MHz Ovenized Crystal Oscillator (OCXO).

3. **J6:** The 100 GbE connector (MT38999 connector with a 12 Fiber MPO connector inside), for high speed data communication.

4. **J2**: Command and control over a 1 GbE link using JSON queries over UDP (Glenair Mighty Mouse connector - mating connector type 805-002-16MT13-31SB)

5. **J3:** (Mighty Mouse connector - mating connector type 805-002-16MT13-31SC):
   - PS RS232 Console to connect to the PS (Linux) side of the RFSoC;
   - 12V input (9-16V range)

6. **J4**: (Mighty Mouse connector - mating connector type 805-002-16MT13-31SD):
   - Write protect (5V pulled high, ground to enable writing)
   - 1PPS input, 3.3V single-ended
   - JTAG, standard interface for programming/ debugging
   - PL GPIO, one 3.3V output, two 3.3V inputs

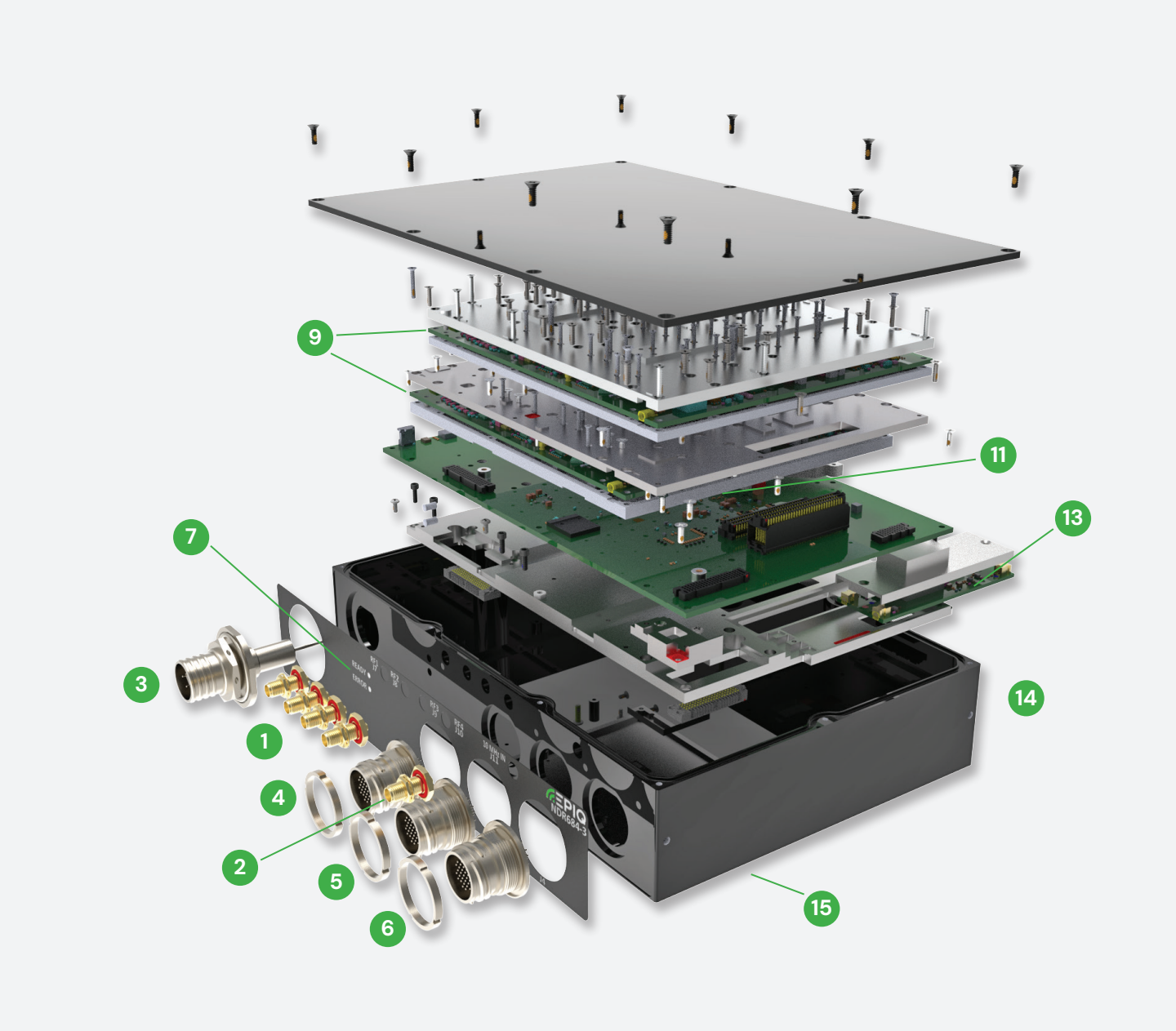
7. Status LEDs:
   - Ready LED (green) - on after boot unless error occurs.
   - Error LED (flashes yellow during boot then off unless an error occurs)

8. Each RF input has a power limiter to protect it from damage.*

9. High performance microwave down converter per channel

* Visible on only one or other view

## Anatomy of an NDR684




10 High performance super-heterodyne signal chain per channel. Output is a 500 MHz bandwidth signal centered at 1 GHz.*

11 Digitization is performed in an AMD Xilinx Zynq RFSoC.

12 Digital output streams generated at full 500 MHz/ channel and lower rates using pre-programmed digital down converters (DDCs).*

13 Internal clock generation enables independent or phase coherent operation of channels.

14 Compact, ruggedized metal chassis

15 Cold plate surface for thermal relief (underside)

## Why Pick an NDR Platform?

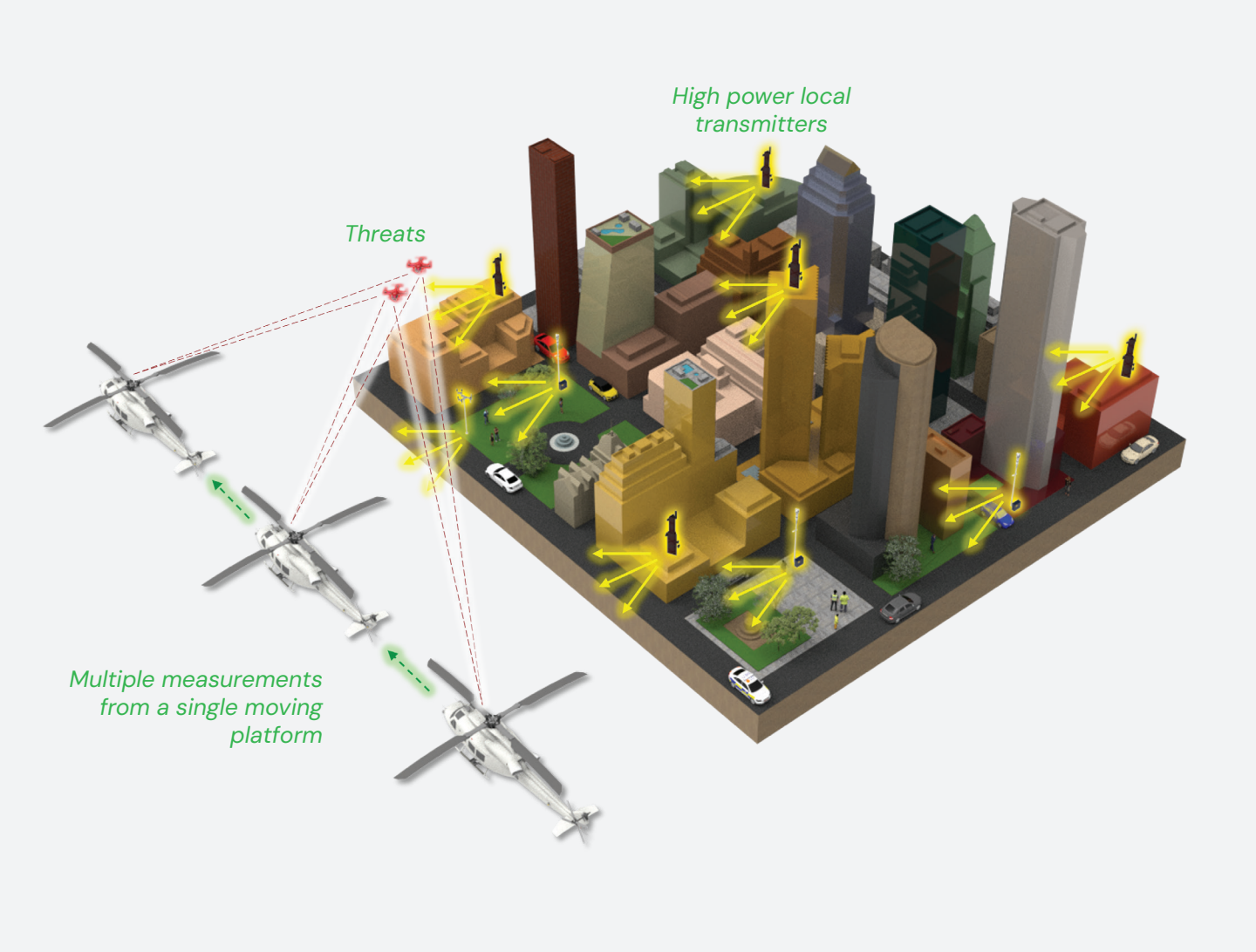
NDRs are extremely high performance radios, and therefore do not have the same SWaP-C attributes as an Epiq Sidekiq M.2 card. So why pay more in terms of size, weight, power and cost? Not every situation requires an NDR – in a less congested RF environment, an NDR may be overkill. However, for platforms that have to sense, identify and locate difficult signals in challenging environments with powerful interferers nearby, they are some of the best available.

The image below shows such a scenario where the NDR684 is deployed in an airborne application, executing a direction finding mission in a congested city environment with many interferers – FM and TV broadcast, cellular base stations, and more. The high performance front end of the NDR684 eliminates those interferers and still allows for detection of the signal of interest. NDRs are also frequently used for TDOA in systems performing geo-location across multiple platforms.

Key aspects that have made NDRs indispensable for such systems include:

- Impressive in-band dynamic range under very strong signal conditions
- Very tight sync/coherency across channels for beam forming etc.
- Tight amplitude and phase accuracy between channels for direction finding
- Support for DDC options
- Fast scanning while maintaining coherency
- Precise synchronization to external timing references
- Support for system calibrations to 18, 40 GHz
- Ease of integration

For a more in-depth look at some of these aspects, see our whitepaper here.



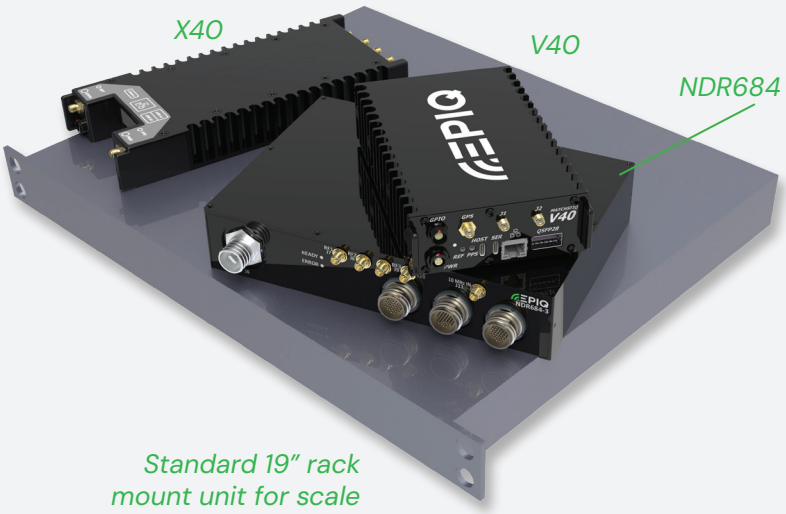
## NDR684 Features

The features of the unit are grouped according to the following diagram.

# Low SWaP, Rugged Platform

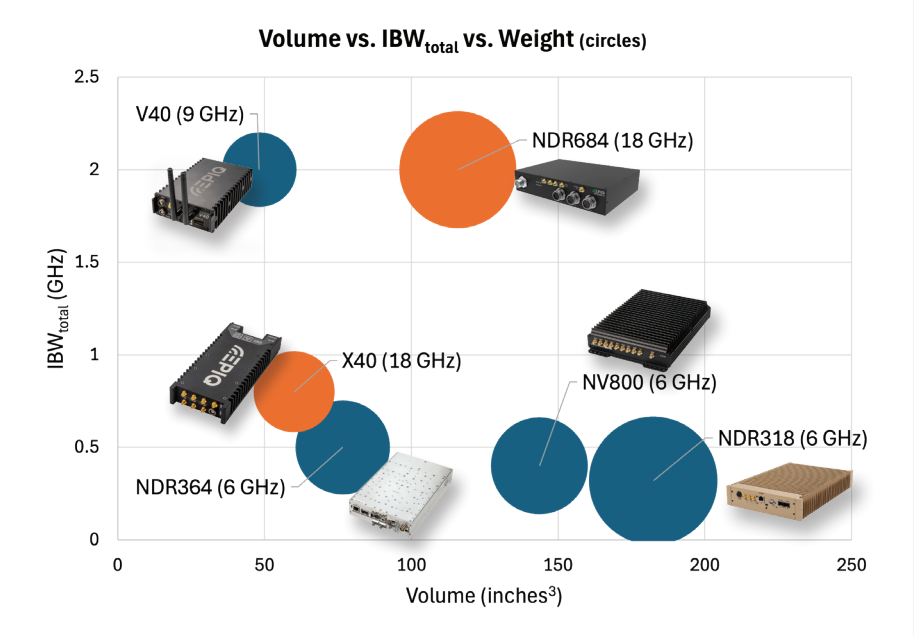
1.

The NDR684 is designed for the most challenging RF environments. It is packaged in a rugged metal housing designed to be compliant with MIL-STD-810H. A visual is provided showing relative sizes of the NDR684 alongside other Epiq low SWaP platforms and a standard 1U 19" rackmount unit for scale.




For additional context, the graph shows example wide band SDRs from Epiq. The x-axis takes the published dimensions to produce a cubic volume in inches$^3$. The y-axis aims to show the total spectrum that can be monitored at any instant, produced by multiplying the number of receive channels by the bandwidth of each. The V40 and NDR684 both score very well, as does the X40. Factoring coverage to 18 GHz (the orange dots), and the NDR offers the most bandwidth over the widest frequency range in the smallest package of the entire Epiq SDR range. Note that other models offer features that are not shown on the graph such as transmit, accessible on-board GPU etc. that the NDR684 does not.

Overall the NDR684 provides the best combination of high performance access to spectrum up to 18 GHz in such a small package.



*The NDR684 employs Glenair front panel connectors which feature an anti- decoupling ratchet mechanism that locks into radial teeth on the plug barrel. This allows the Series 805 to stay mated even when under high vibration.*

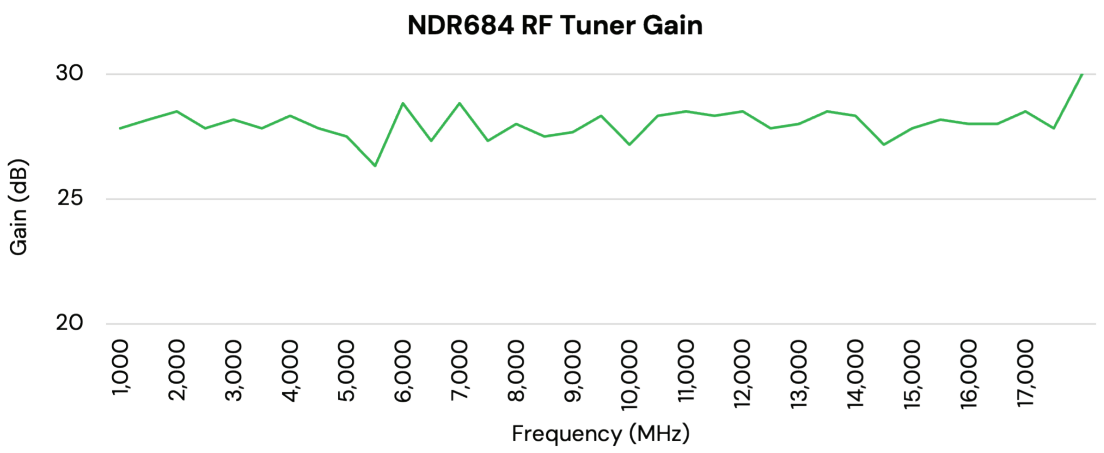
*For optimum thermal management, the unit must be bolted to cold plate. Threaded mounting holes are provided on left and right sides (locking 4-40 Helicoils) and on the bottom of the chassis (locking 6-32 Helicoils), as shown in the illustration.*

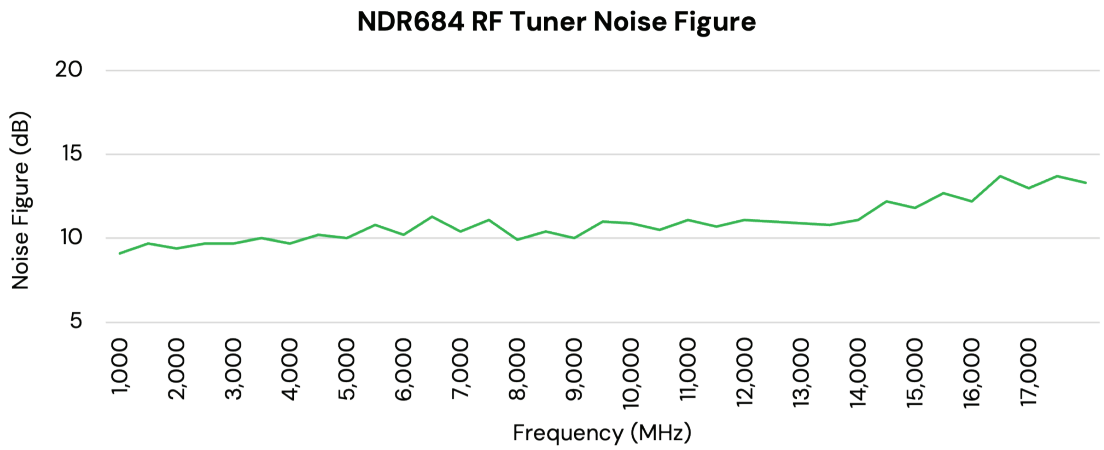
## Wideband High Performance

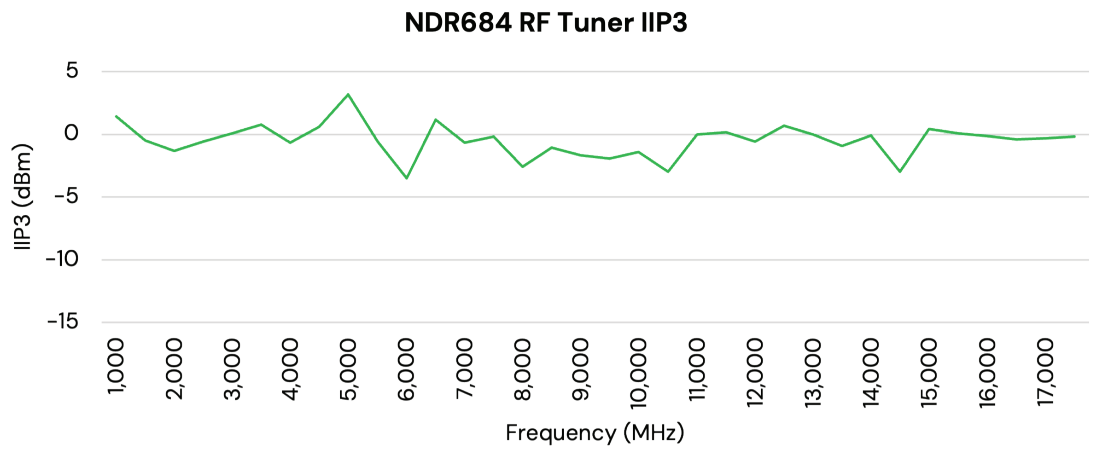
2.

The NDR684 employs independent channels, each with a super heterodyne signal chain, a filter-first design, and many stages of filtering to maximize rejection of unwanted signals.

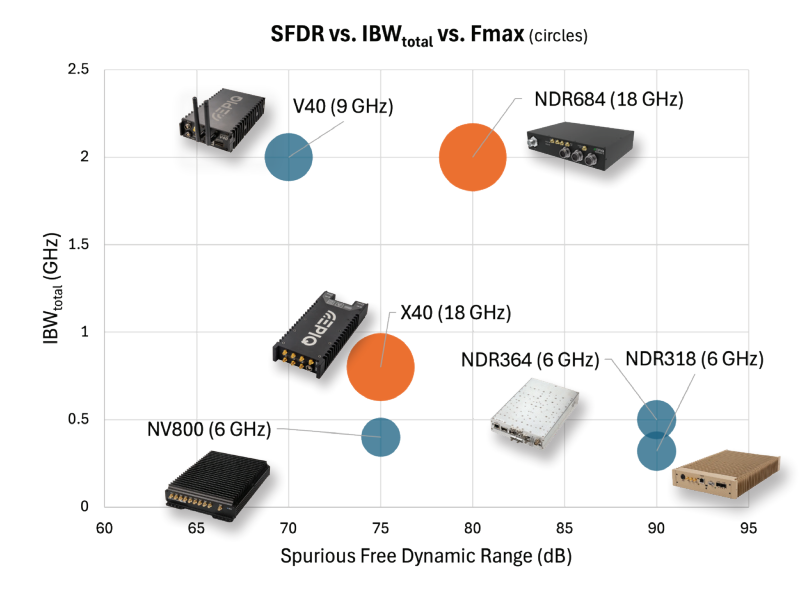
During a factory cal. each channel is calibrated to a nominal gain value to provide an equalized RF response for gain, noise, and linearity across frequency, temperature, and AGC. Example plots taken from one unit are shown below. Note that in addition, spectral plot examples are shown on page 3.



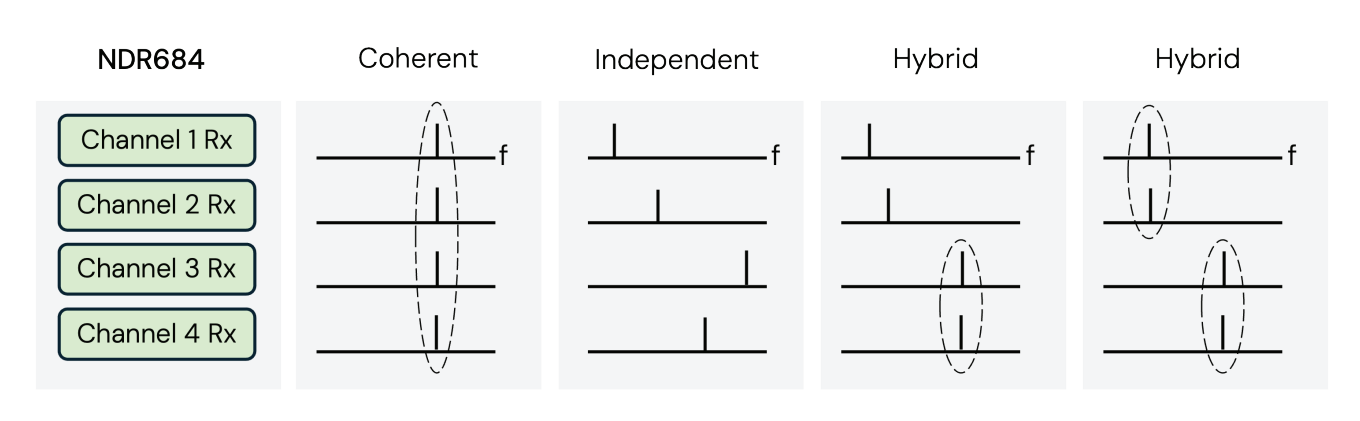
To give some context, the graph opposite compares the total bandwidth available (IBW x number of channels) with the published spurious free dynamic range (SFDR) for comparable Epiq radios. The NDR684 provides similar total bandwidth as the Matchstiq V40 direct sampling SDR, but greater SFDR and wider tuning range.




## Flexible Channels

3.

The NDR684 offers flexible assignment of receive channels as shown in the diagram below. It can switch between independent channels for maximum search coverage and dynamically change to coherent operation on two or more channels for direction finding. In addition, it has been designed for fast tuning to accommodate frequency hopping, while maintaining coherency.



# Configurable Bandwidths

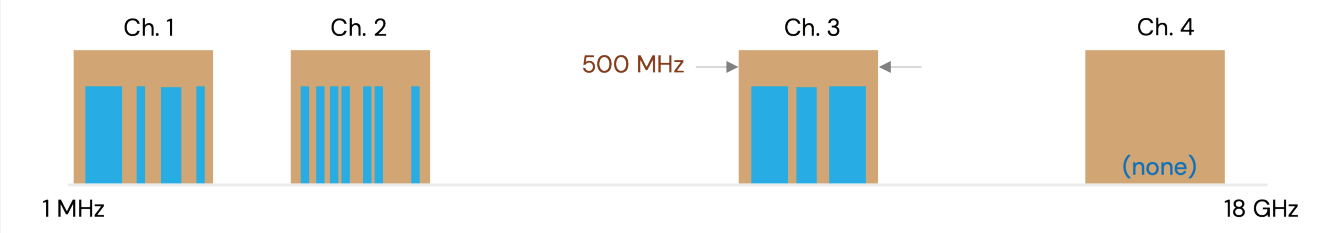
4.

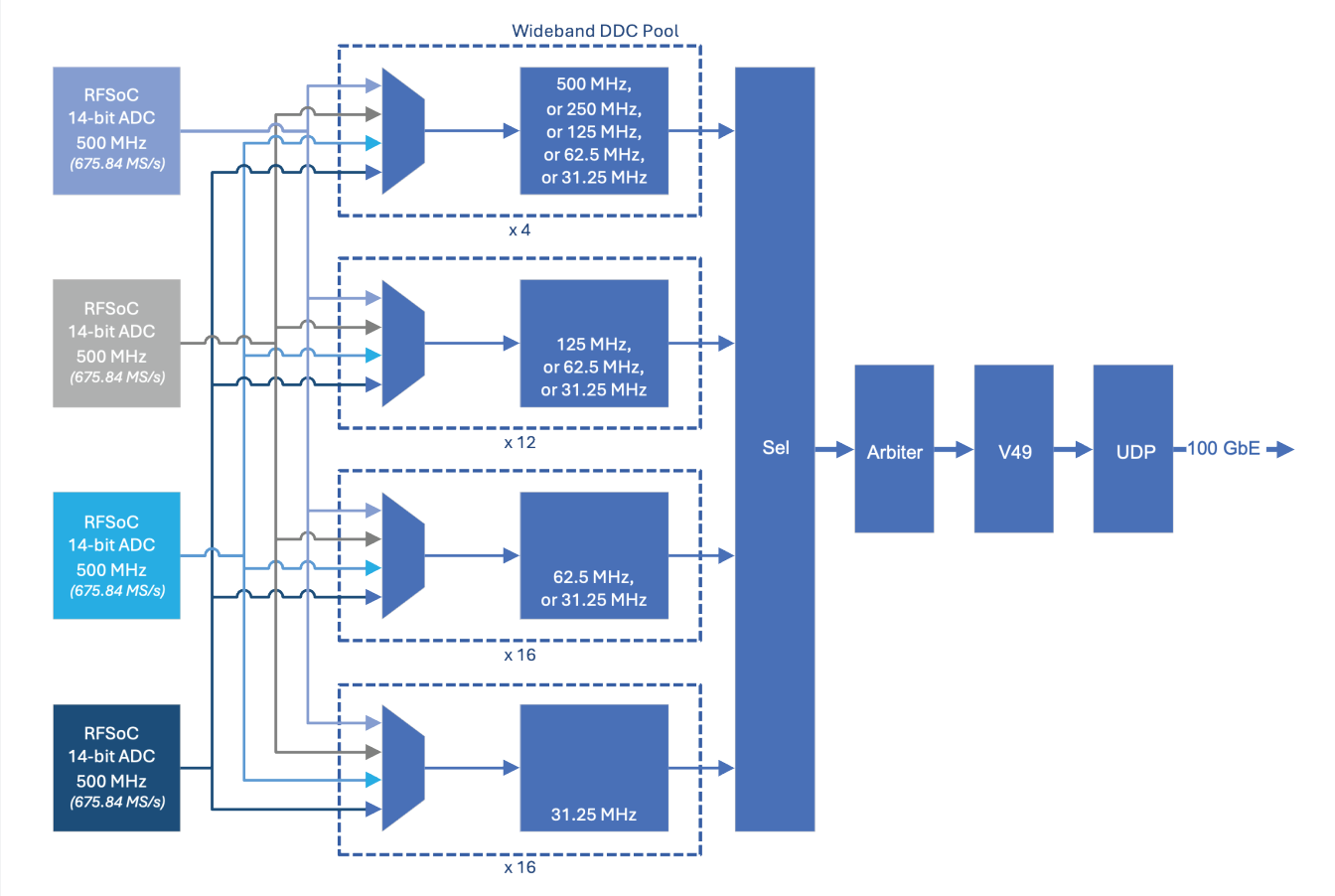
Each of the four independent channels may be tuned to different portions of the spectrum, as shown in the diagram (top, brown rectangles). However, the unit is also equipped with a large pool of wideband Digital Down Converters (DDCs) with varying available bandwidths. These may be applied to arbitrary center frequencies within each channel's data stream. Up to 48 are available.

Multiple DDCs may be applied to each channel, keeping in mind the overall constraint of the capacity of the 100 GbE offload – see below for a worked example[1]. Note that the user is responsible for not over-prescribing the network connection.

A data flow diagram is shown at the bottom of the page.

| Bandwidth (MHz) | Sample Rate (MS/s) |
|---|---|
| 500 | 675.84 |
| 250 | 337.92 |
| 125 | 168.96 |
| 62.5 | 84.48 |
| 31.25 | 42.24 |



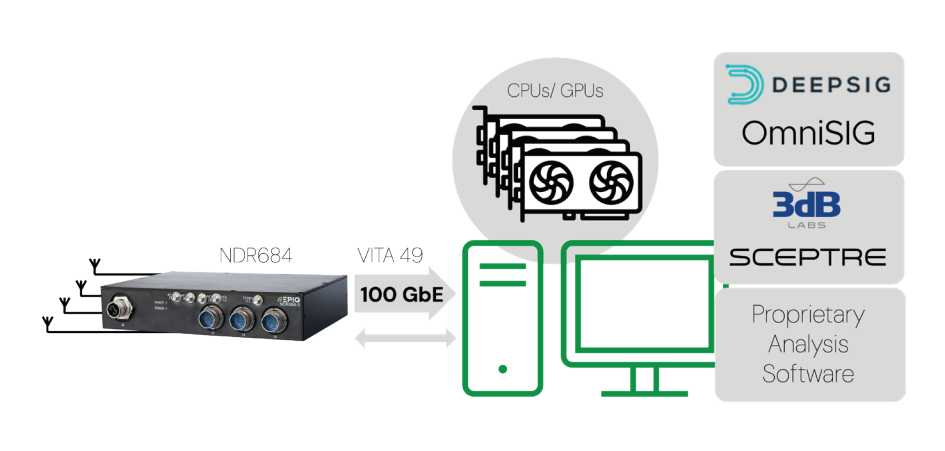

[1] Each sample is 32 bits + packet overhead. So a rough example calculation would be if a user wanted 32 DDCs, each at 62.5 MHz – that would require 84.48 MS/s, each needing 32 bits+ making 2.7 GS/s per stream. 32 of them would require 86.52 Gb/s, likely filling the 100 GbE pipe.

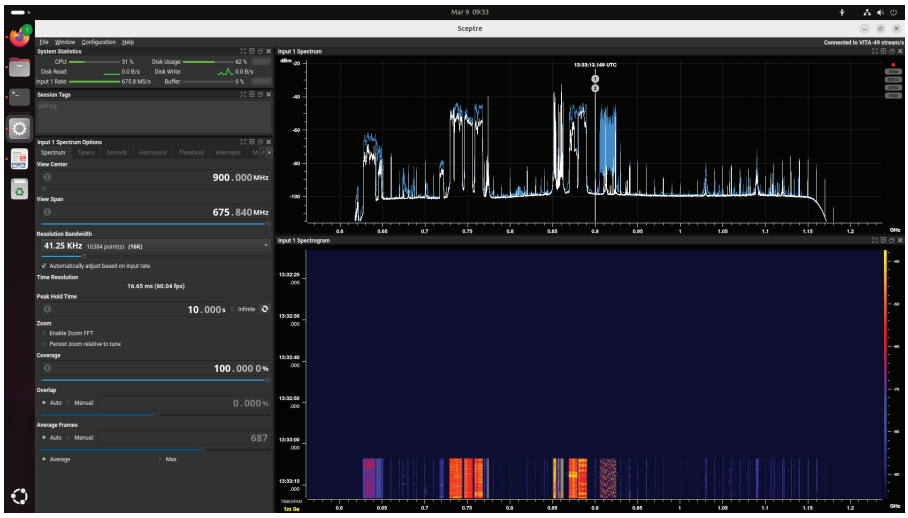
# Compatible

5.

The typical use model for NDR684 is to be deployed near an antenna array to minimize losses, and then to stream IQ data over fiber to powerful servers capable of digesting and analyzing RF data. To facilitate this, data is formatted in standard VITA 49 packets, with command and control performed through JSON commands and queries over UDP. It uses the same Restful API & ICD as other NDRs, with the same reputation for easy integration.

Once the data is transferred it may be ingested by standard analysis tools such as DeepSig's OmniSIG, 3dB Lab's Sceptre, or proprietary analysis software. The screenshot at right shows Sceptre performing analysis using samples streaming from an NDR684.



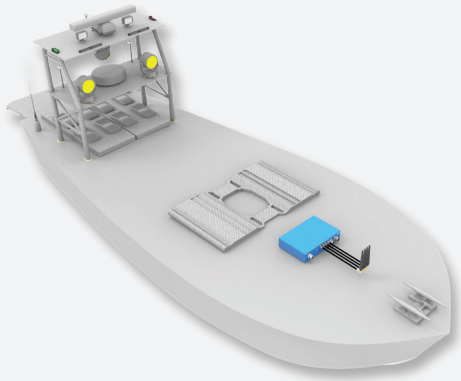
# Deployment Examples

## Digital Radio Head

The NDR684's 100 GbE VITA 49 streaming, compact footprint and robust metal enclosure allow it to be deployed next to an antenna to optimize RF performance while providing digitized Ethernet packets back to a central processing node over fiber optic cabling. This avoids the need to run lossy coax to the antenna, or to be constrained in system component placement.

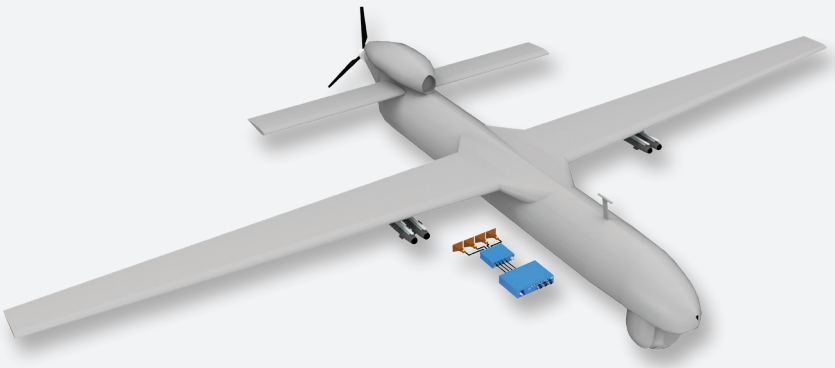
## Counter-UAS

Operating as an edge node in a distributed network, the NDR684 can monitor many links at once by digitizing and channelizing large slices of spectrum to maximize probability of intercept. It can then swiftly switch over to direction finding with 4 phase-coherent channels to pin-point threats using applications such as 3dB's Sceptre software suite.



## 40 GHz Receive System

The NDR684 makes a natural pairing with the NDR504 high performance four channel 40 GHz down converter. Both units are extremely compact and SWaP-efficient, and both are built for flight having been designed with MIL-STD-810H in mind.



## Other Examples

- UxS Payload
- Fast Scanning Tipping Receiver
- Direction Finding
- Test & Measurement
- ELINT
- COMINT

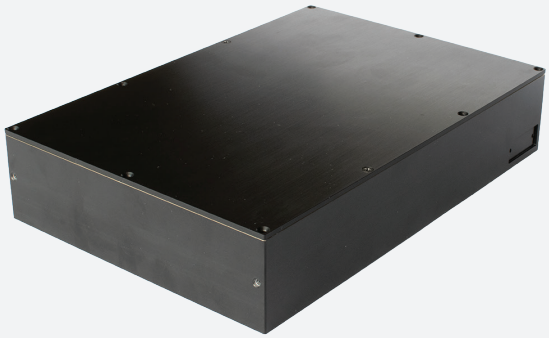
## The Epiq Family of Products

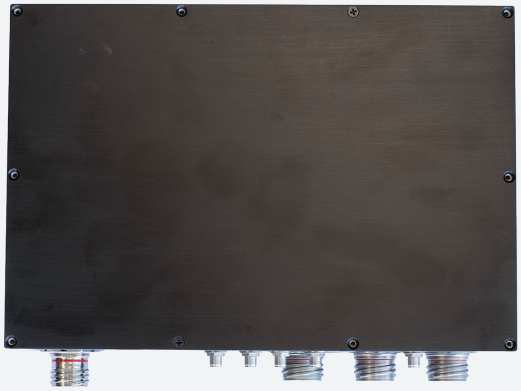
The NDR684 is part of our Platforms group of products that allow VITA 49 streaming of IQ data. The NDR364 is also super heterodyne-based with extremely good out-of-band rejection and a wide IBW suitable for scanning and DF, while the V40 represents an example of a direct sampling wideband SDR suitable for very fast scanning. The full Epiq SDR/ Tuner product range is available in the comparison table here.

| **Product** | **NDR684** | **NDR364** | **Matchstiq V40** |
|---|---|---|---|
| | | | |
| **Description** | Compact Wide IBW 4 Channel 18 GHz SDR | Low SWaP High Perf. 6 GHz SDR | Low SWaP 9 GHz Multi-GHz IBW SDR |
| **Output** | Digital | | |
| **Max Channels Rx/ Tx** | 4/ 0 | 4/ 0 | 1/ 1 |
| **Frequency Range** | 1 MHz - 18 GHz | 20 MHz - 6 GHz | 1 MHz - 9 GHz |
| **IBW Max/ Ch.** | 500 MHz | 125 MHz | 2 GHz |
| **SFDR Typ.** | 80+ dB | 90 dB | 70 dB |
| **CPU?** | - | | Yes |
| **GPU?** | - | | |
| **Typ. Power Consumption** | 73 W | 38 W | 40 W |
| **Interface e.g.** | 100 GbE Ethernet, etc. | 10 GbE Ethernet etc. | 100 GbE Ethernet, etc. |

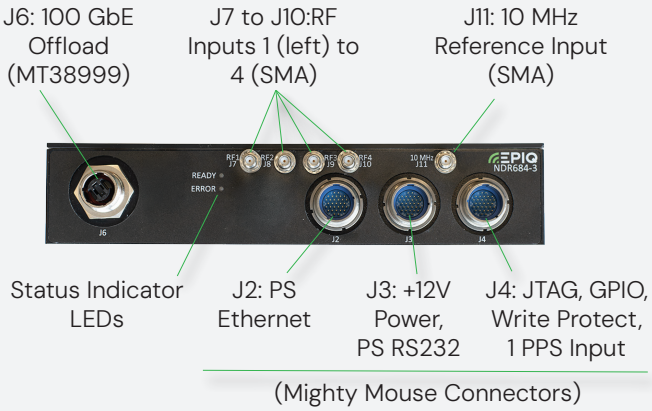
Maximum number of Rx, Tx channels, often not simultaneously. SFDR = Spurious Free Dynamic Range. IBW = Instantaneous Bandwidth. Interface example, often others present also.

## NDR684 Physical Views





A) Left & right sides: Locking 4-40 Helicoils
B) Bottom: Locking 6-32 Helicoils




(No accessible interfaces on rear panel)

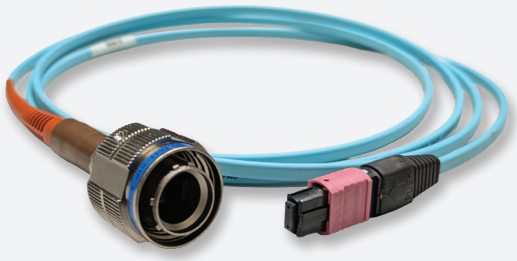
## Optional Accessories

### NDR684 Accessory Kit

The kit includes the following hardware:

Generic 120V bench top fan

Breakout test cable harness (~3 feet)



100 GbE (J6) MT38999 to MPO cable (~1m)

Note that the accessories above may also be ordered individually.

*Specifications subject to change without notice.*

*Epiq Solutions exports its products strictly in accordance with all US Export Control laws and regulations which shall apply to any purchase or order.*

## ABOUT EPIQ

Epiq Solutions develops high performance tools for engineering teams and government-focused organizations requiring situational awareness and detailed insight into their RF environments in order to identify and act against wireless threats.

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