Introduction to the nRF21540 RF FEM for range extension

Nordic Tech Webinar

Pål Kastnes / Technical Marketing Manager

February 2022

Today's speaker

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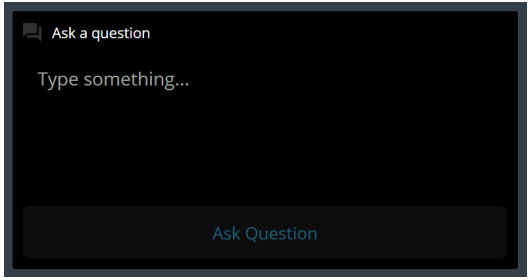
Product Management

NORDIC SEMICONDUCTOR

Practicalities

- Duration: about 60 minutes
- Questions are encouraged!
  - Please type questions in the top of the right sidebar
  - All questions are anonymous
  - Try to keep them relevant to the topic
  - We will answer towards the end
- The chat is not anonymous, and do not use for questions
- Go to DevZone if you have more questions
- A recording of the webinar will be available together with the presentation at webinars.nordicsemi.com



{ DevZone

Agenda

- Why and when is an RF FEM needed?
- nRF21540 RF FEM technical overview
- nRF21540 DB overview
- Software and hardware tools to kickstart development
- Q&A

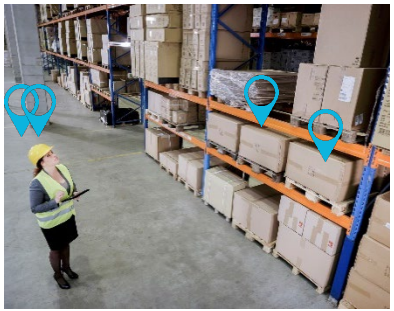
Complementary to our product line

nRF21540 highlights

1. Between 6.3-10x the range in a symmetric link with integrated PA/LNA
2. Output power adjustable to +/- 1 dB around 10/20 dBm to remain within regulatory boundaries
3. Easy setup with nRF52 and nRF53 Series and attractive price/performance combination possible

Applications

Asset Tracking



Increased range for big warehouses

Less units needed to cover same space

Industrial

Increased range

Audio

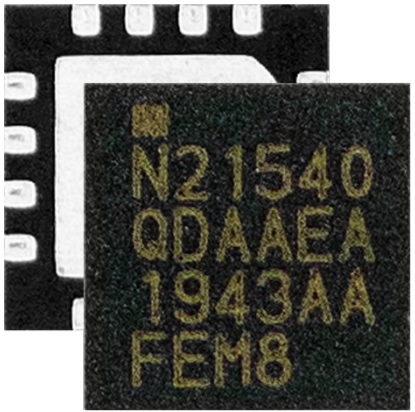
Higher link budget requirement

Smart Home

Robust connection for bigger homes

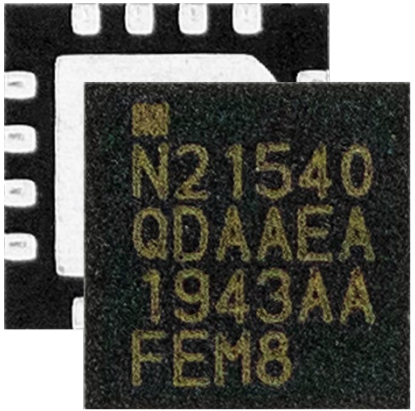
nRF21540 overview

- RF front-end module (FEM)
- Supports
  - Bluetooth LE, Bluetooth mesh
  - Thread/Zigbee
  - 2.4 GHz proprietary
- +13 dB receive gain, 2.5 dB NF
  - Up to 5 dB improvement in RX sensitivity
- Configurable TX output power up to +21 dBm



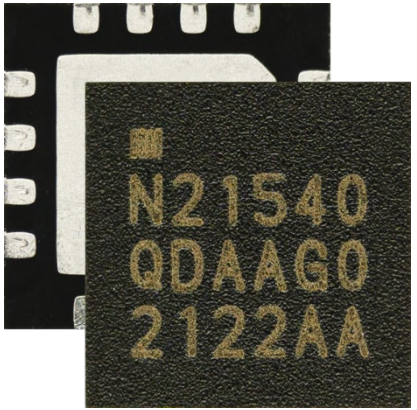
nRF21540 overview

- SoC + nRF21540 configurable to be ARIB, ETSI and/or FCC approved
- Interfaces and TX gain control
  - GPIO control, SPI control or a combination
  - TX gain control, antenna switching and power modes

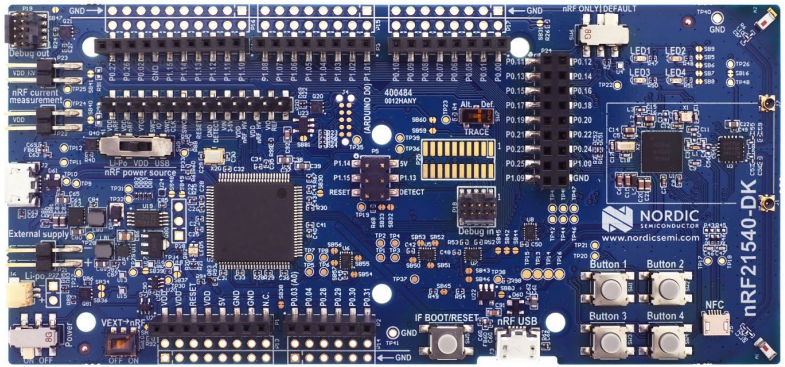


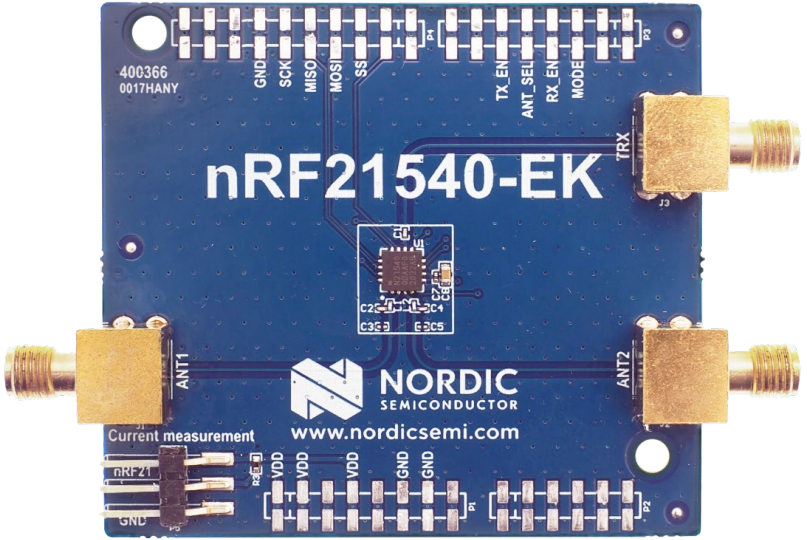
nRF21540 overview

- Single ended 50 Ω matched input and output
- Antenna diversity support (Thread/Zigbee)
- No bypass mode support
- Operating Conditions
  - 1.7 to 3.6V supply range
  - -40°C to +105°C
- Package Variants
  - 4x4mm QFN16, 0.65mm pitch

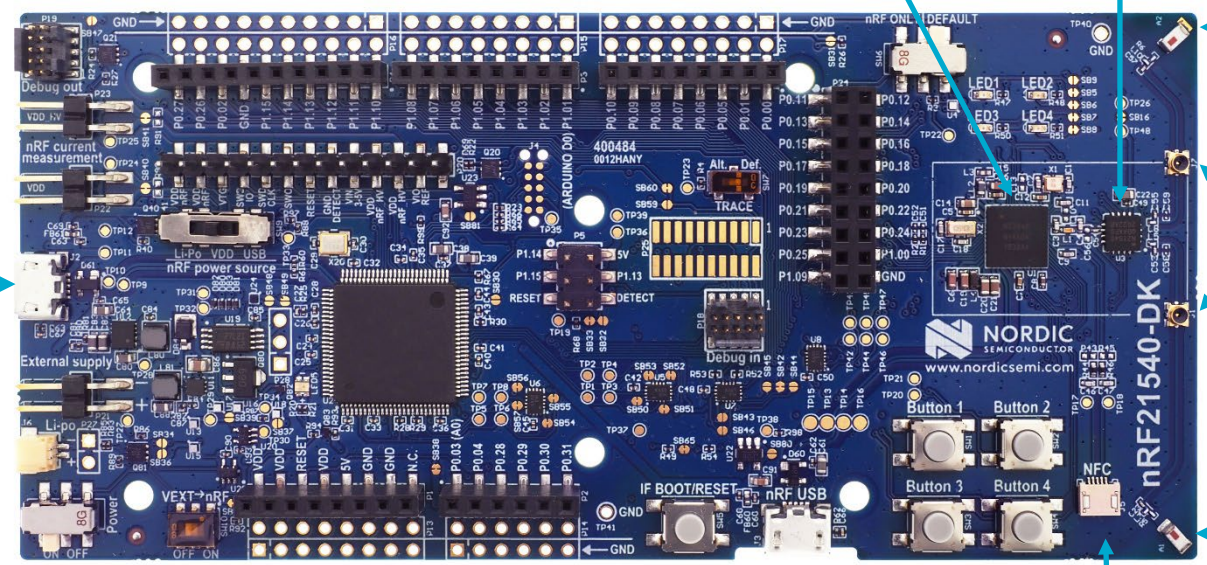


nRF21540 Development Bundle (DB)



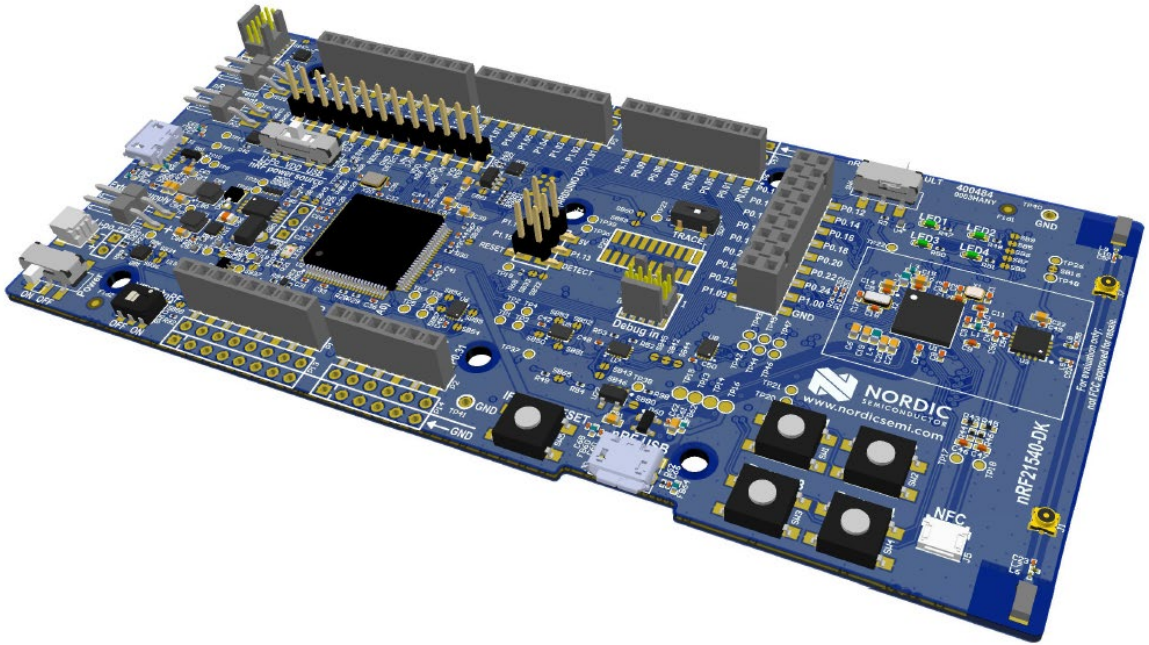


nRF21540 DK

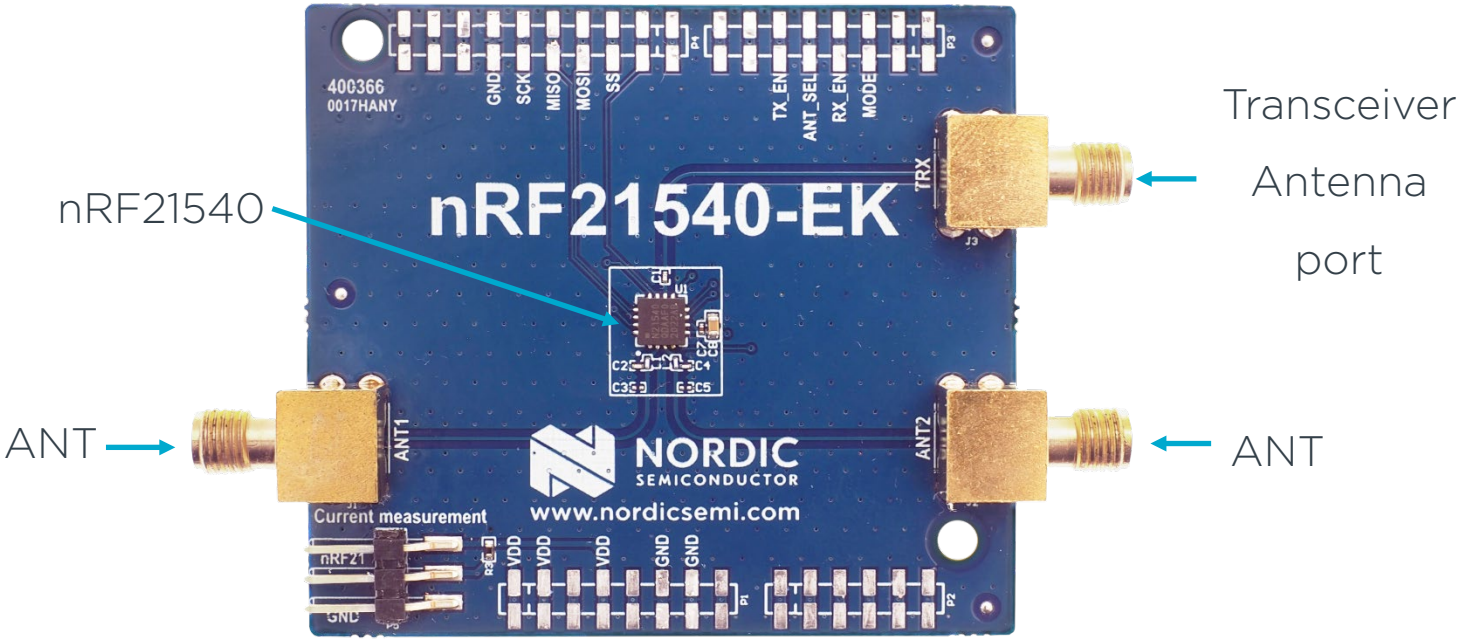


nRF21540 DK

- nRF52840 DK with integrated nRF21540
- Useful if you want to test RF performance of a “finished” product
- Removed QSPI on nRF52840 DK to use pins to control nRF21540

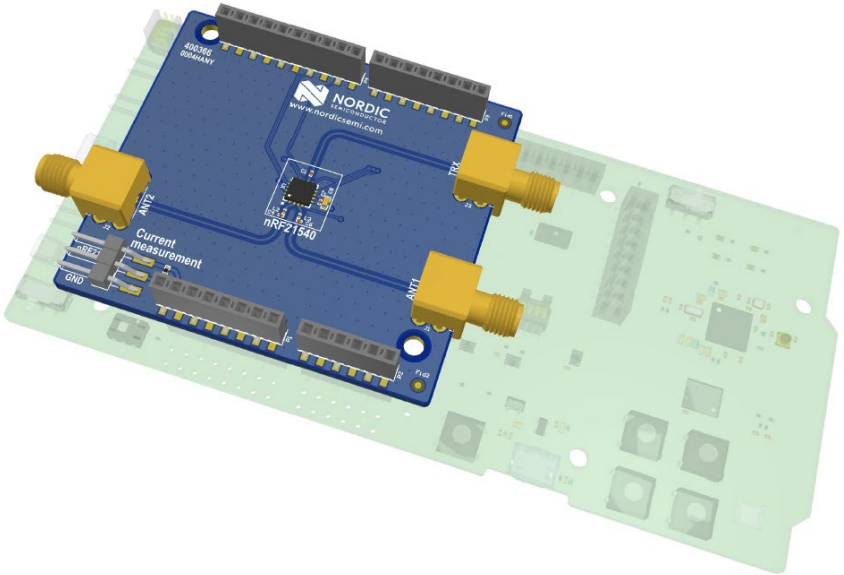


nRF21540 Evaluation Kit (EK)

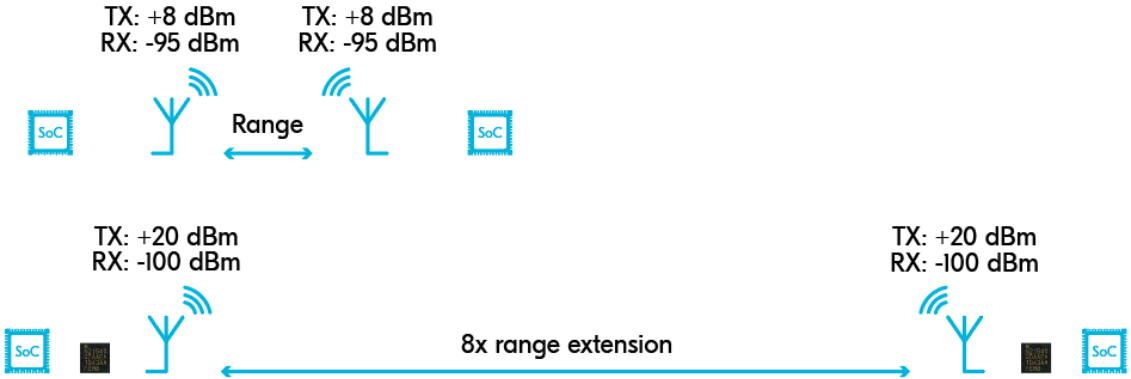


nRF21540 EK

- Includes two additional SMA connectors to monitor RF performance of nRF21540 shield using desired lab equipment
- Shield compatible with nRF52 & nRF53 DKs, as well as other vendors DKs



Up to 10x range increase



- Between 6.3-10 x the range in a symmetric link
  - Valid for all nRF52 Series SoCs and the nRF5340 SoC
- Up to ~5 dB improvement in RX sensitivity
- Useful for Bluetooth Low Energy, Bluetooth mesh, Thread and Zigbee and 2.4 GHz proprietary applications

Increased link robustness

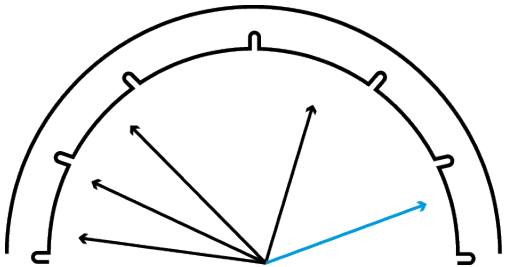
- Up to 20 dB increased link budget
  - Up to 17 dB from TX, up to 5 dB from RX
- Minimize packet loss and retransmissions
  - Improved communication latency
- Dynamic output power adjustments
  - Customers can optimize link budget via RSSI measurements to improve link robustness when link environment or link range changes

nRF21540 actual link budgets

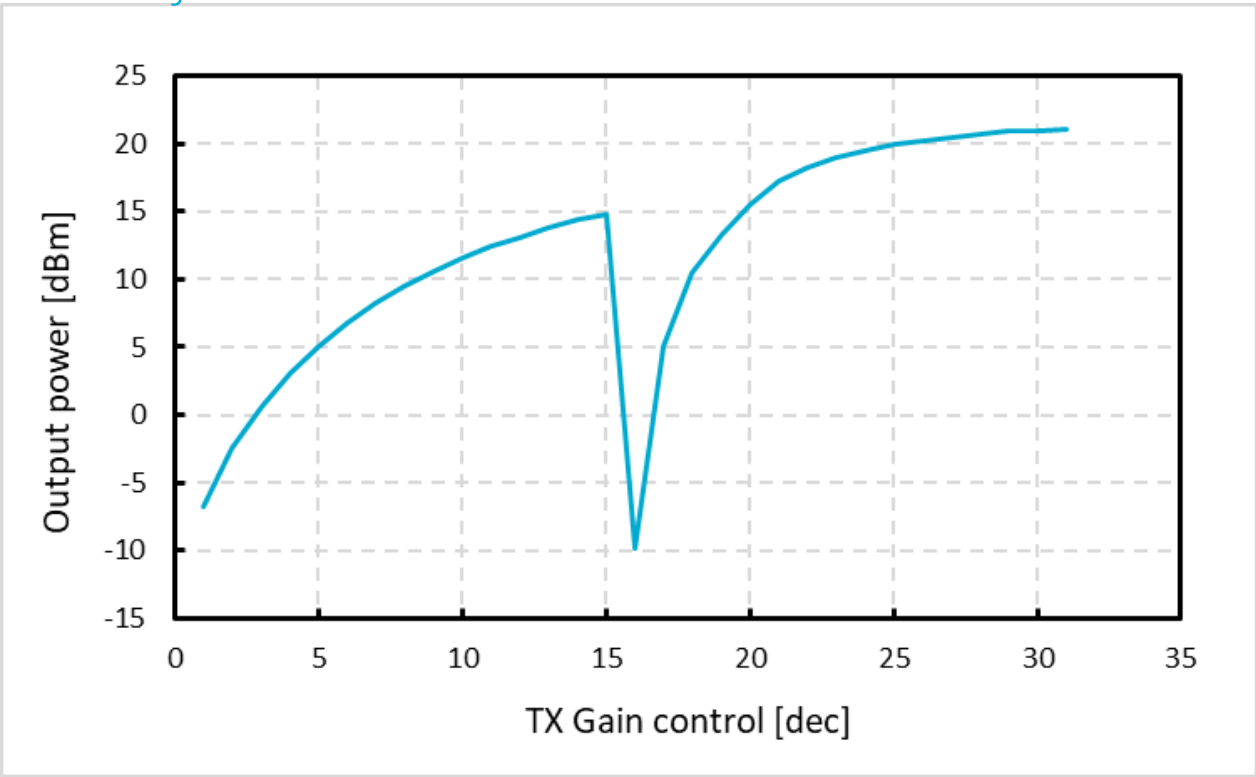
	nRF 5340	nRF 52840	nRF 52833	nRF 52832	nRF 52820	nRF 52811	nRF 52810	nRF 52805
RX sens. (dBm)	-98	-95	-96	-96	-95	-97	-96	-97
ΔRX (dB)	2	5	4	4	5	3	4	3
TX (dBm)	3	8	8	4	8	4	4	4
ΔTX (dB)	17	12	12	16	12	16	16	16
Link Budget (dB)	**19**	**17**	**16**	**20**	**17**	**19**	**20**	**19**
LB (mW)	79	50	40	100	50	79	100	79
ΔRange	9x	7.1x	6.3x	10x	7.1x	8.9x	10x	8.9x

Adjustable output power

- Output power adjustable to +/- 1 dB around 10/20 dBm (ETSI/FCC limits), upper limit 21 dBm
- User programmable modes for TX gain
- Worldwide coverage with one device with different output power settings possible
- Easy adjustments possible via SPI, GPIOs or combination of both



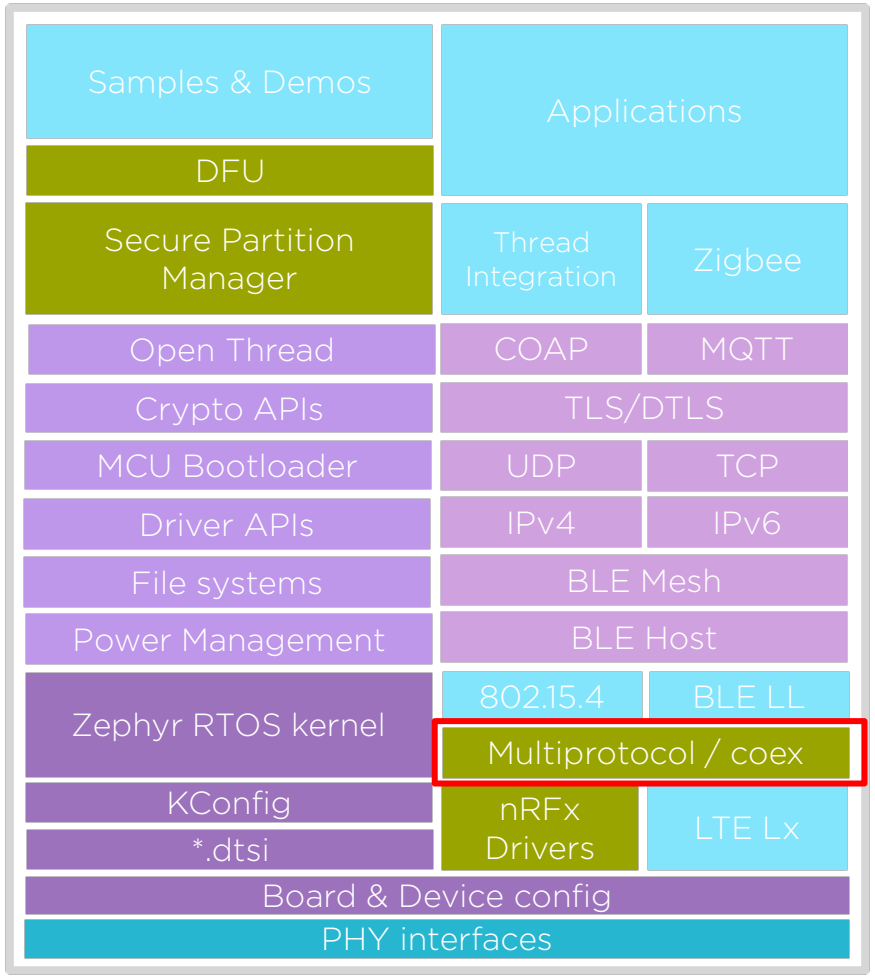
Gain adjustment



*TX Gain Behavior, device calibration for 20 dBm

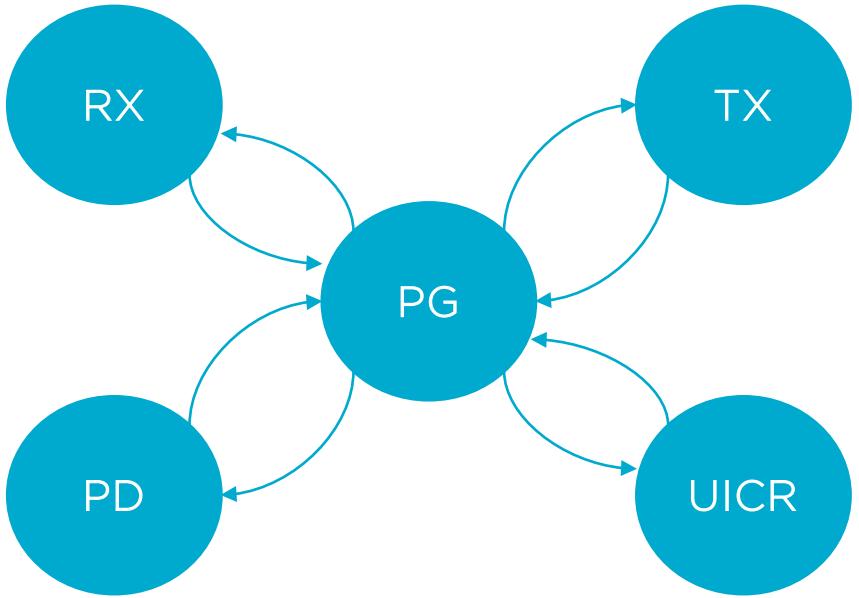
Easy setup

- Integrated and supported in nRF Connect SDK (see figure)
- Built into Multi Protocol Service Layer (MPSL)
- Driver Support in nRF Connect SDK and nRF5 SDK for Thread and Zigbee v4.0.0



Operational states

- Power Down (PD)
- Program (PG)
- UICR Program (UICR)
- Receive (RX)
- Transmit (TX)
- Changing states controlled via pins PDN, RX_EN, TX_EN or via SPI registers 0x00 and 0x01



FEM control

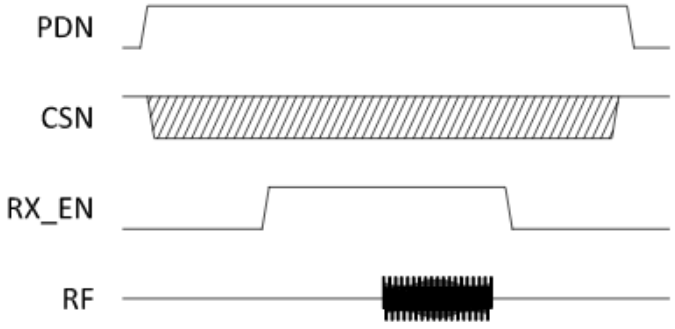


Figure 1. Pin control RX state

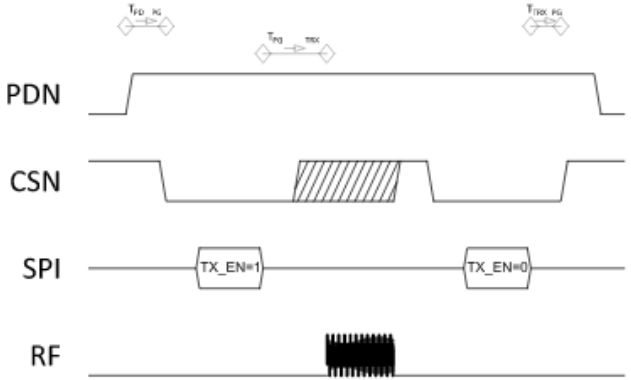


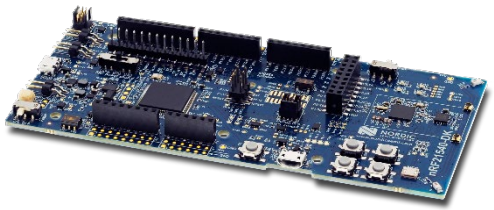
Figure 4. SPI control TX state

- FEM control signals must be synchronized with the radio activity
- Integrated into MPSL, Multi Protocol Service Layer
  - Supports Bluetooth LE and 802.15.4 (Zigbee & Thread)
  - FEM support activated by kconfig setting

nRF21540 DB support

nRF21540 DK

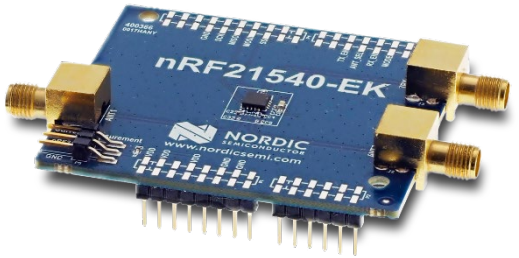
- Development kit with nRF52840 and nRF21540
  - Similar to nRF52840 DK but without QSPI flash
- Supported as build target in nRF Connect SDK
  - Bluetooth peripheral UART sample
- Will automatically add MPSL support for Front-End Modules for Bluetooth and Thread/Zigbee
  - For Bluetooth only supported with Nordic SoftDevice controller
- Direct Test Mode and Radio Test example support



nRF21540 DB support

nRF21540 EK

- Evaluation kit with nRF21540
  - Shield form factor for nRF52 and nRF53 Series DKs
- Supported as shield in nRF Connect SDK
- Will automatically add MPSL support for Front-End Modules when added to project for Bluetooth and Thread/Zigbee
  - For Bluetooth only supported with Nordic SoftDevice controller
- Can be used as template for adding nRF21540 support to custom PCBs

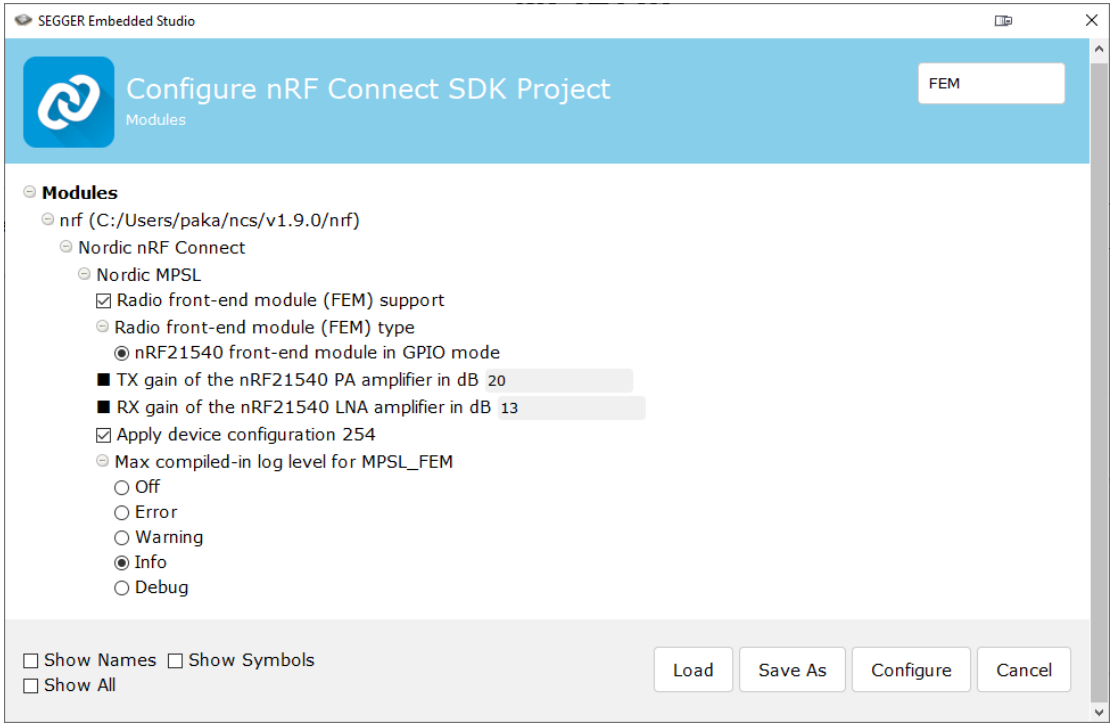


Adding nRF21540 support in SW

```
/* Copyright (c) 2021 Nordic Semiconductor ASA
 *
 * SPDX-License-Identifier: LicenseRef-Nordic-5-Clause
 */

/ {
    nrf_radio_fem: nrf21540_fem {
        compatible = "nordic,nrf21540-fem";
        tx-en-gpios = <&arduino_header 11 GPIO_ACTIVE_HIGH>;   /* D5 */
        rx-en-gpios = <&arduino_header 9 GPIO_ACTIVE_HIGH>;    /* D3 */
        pdn-gpios = <&arduino_header 15 GPIO_ACTIVE_HIGH>;     /* D9 */
        ant-sel-gpios = <&arduino_header 10 GPIO_ACTIVE_HIGH>; /* D4 */
        mode-gpios = <&arduino_header 8 GPIO_ACTIVE_HIGH>;     /* D2 */
        spi-if = <&nrf_radio_fem_spi>;
    };
};

fem_spi: &arduino_spi {
    status = "okay";
    cs-gpios = <&arduino_header 16 GPIO_ACTIVE_LOW>; /* D10 */

    nrf_radio_fem_spi: nrf21540_fem_spi@0 {
        compatible = "nordic,nrf21540-fem-spi";
        status = "okay";
        reg = <0>;
        label = "FEM_SPI_IF";
        spi-max-frequency = <8000000>;
    };
};
```

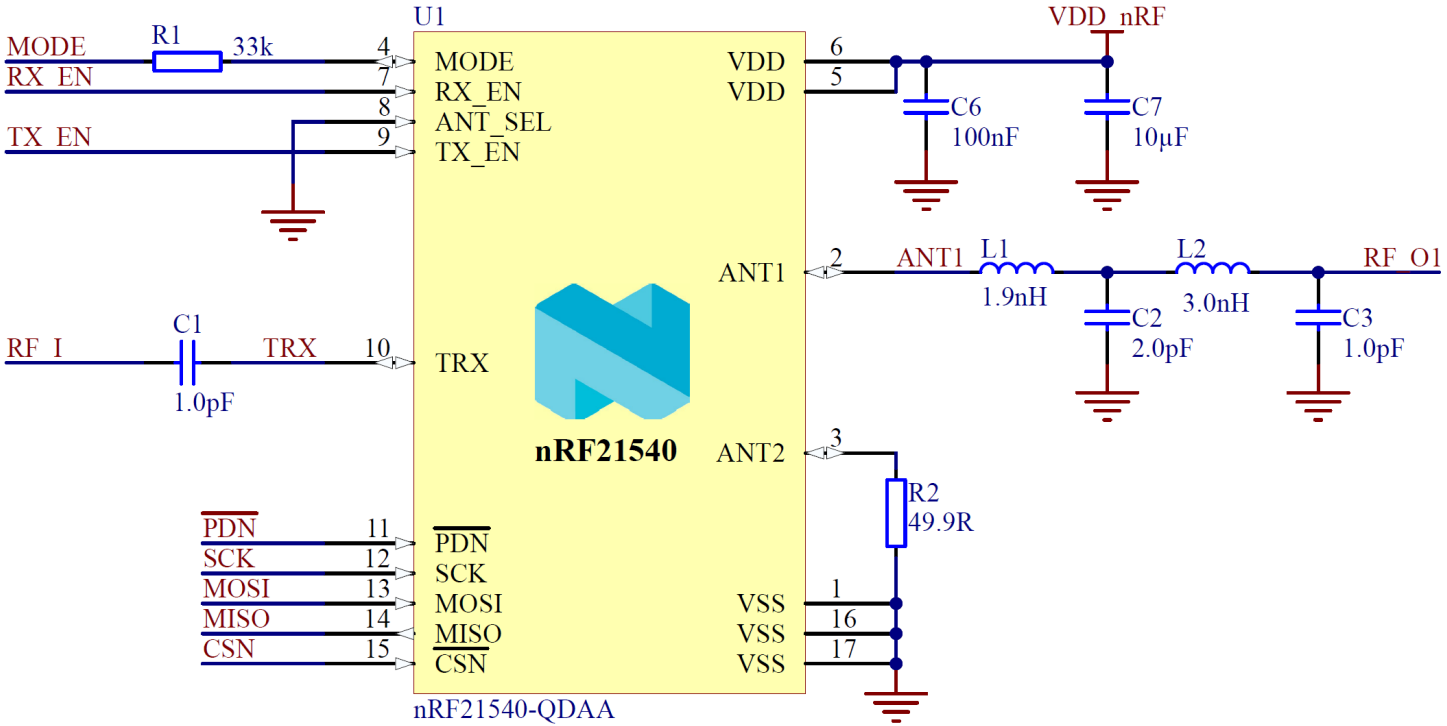
- Support for nRF21540 integrated in DK and EK .dts board files
- Set pins for GPIO interface and which SPI module to use

Adding nRF21540 support in SW

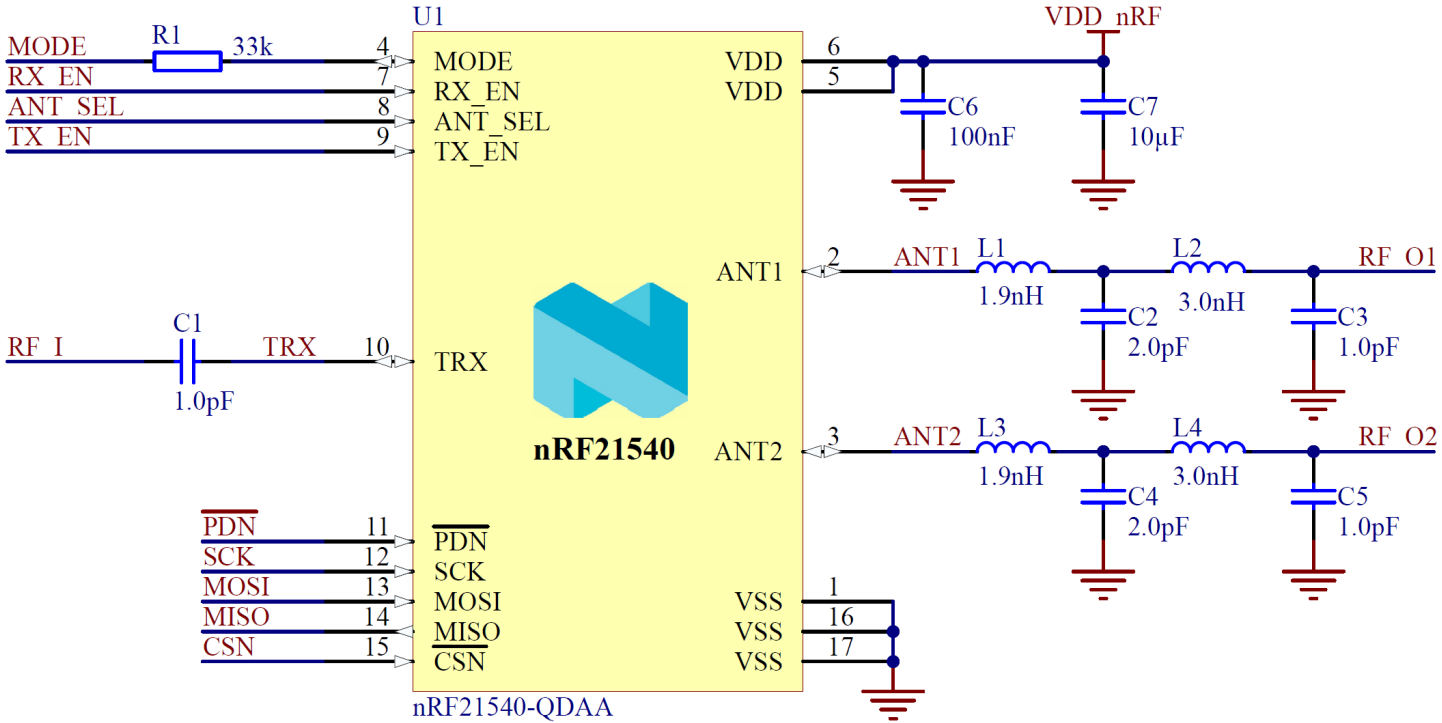


- Kconfig option available when using
  - nRF21540-DK
  - Board with nRF21540-EK as shield
- Use nRF21540-EK as template when adding support for your custom board

Reference circuitry single antenna



Reference circuitry dual antenna



Current numbers

- TX
  - 110 mA @ +20dBm output power
  - 38 mA @ +10dBm output power
- RX
  - 2.9 mA
- PG
  - 1.1 mA
- Power down current
  - 45 nA

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Q&A

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