AirPrime RC76xx Antenna Diagnosis Application Note

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APN Content Level	BASIC		INTERMEDIATE	✓	ADVANCED		Confidentiality	Public	✓	Private	✓

Hardware Compatibility	Product Line	AirPrime	Series	RC76xx	

Software Compatibility	ALL	Document Type	Application Note	✓	Technical Note	

1 Introduction

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2 Overview

This application note presents the antenna diagnosis solution and inherent limitations for AirPrime RC76xx Series modules.

Antenna diagnosis can be used to improve the reliability of the RF link in case there is a main antenna failure when switching to a secondary one. Diagnosis can be included as part of product testing to check if there is a complete connection from the 4G device to the antenna.

The final part focuses on practical implementations of using an antenna with an integrated resistor.

3 Antenna Diagnostic Solution

3.1 Schematic

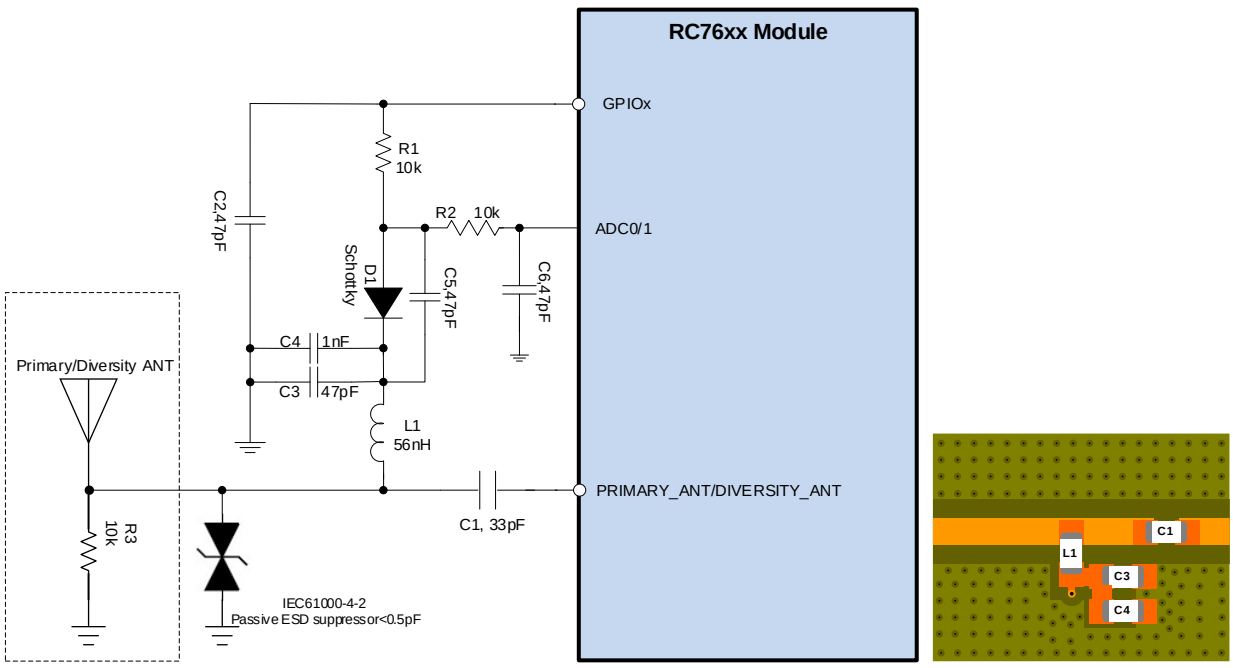


Figure 1. Sample External Primary and Diversity Antenna Diagnostic Diagram

3.2 Description

The antenna diagnostic feature allows the AirPrime RC76xx embedded module to determine if the primary/diversity antenna connected to the module is open, shorted, or normal. The antenna connected to this interface needs to have a DC resistance to ground of 10 kΩ ± 1k embedded inside.

The GPIOx provides a DC current to the antenna resistor R3 through R1, D1, and L1. The resulting voltage is measured using an ADC.

Three different status are available:

- Antenna short circuited to ground
- Antenna normal
- Antenna disconnected

Table 1: ADC Characteristics

	Min	Nom	Max	Units
ADC Voltage Range	0.1	0.9	1.7	Volts
Resolution	-		15	Bit
Voltage/ADC step		~0.001		Volts

The following example illustrates the antenna states and resistance values for a typical limit setting using either ADC0 or ADC1.

Table 2: Antenna Diagnostics Ranges

Antenna State	Min ADC Volt	Max ADC Volt	Antenna Resistance Range
Short	0	0.741V	~ ≤ 7 kΩ
Normal	0.742V	1.017V	7 kΩ < x < 13 kΩ
Open	1.018V	1.700V	≥ 13 kΩ

3.3 AT Commands for ADC

External ADC input are avaliable for customer use. Listed below are the available AT Commands.

Example: ADCx

AT!ADC?EXT_ADCx

return ADC Value= 0x27 (39)

Voltage calculation: Decimal value 39 x 0.001 = 0.039V

3.3.1 ANT Diagnosis AT Commands for RC76xx (without an Antenna Diagnosis option)

- AT+WIOCFG - This command is used to query/configure control of the specified I/O port.
- AT+WIOW - This sets the I/O port as an output and sets the requested I/O pin value.
- AT!MADC - This command reads customer accessible ADCs.

Note: Refer to the AirPrime RC76xx AT Command Reference Guide for the correct syntax.

4 GNSS Antenna Diagnostics

4.1 Principle of Operation

Once connected to the GNSS antenna port, the active GNSS antenna is powered by a Buck/Boost converter. The current drawn by the active GNSS antenna is continuously converted into voltage before being applied to an ADC that can be read either automatically (polling) or on demand.

A current limited power switch (Load Switch) is associated to protect the circuit in case of short-cut or active GNSS antenna over-current consumption. In such a case, the emergency power shutdown can then be triggered to prevent damage.

4.2 Schematic

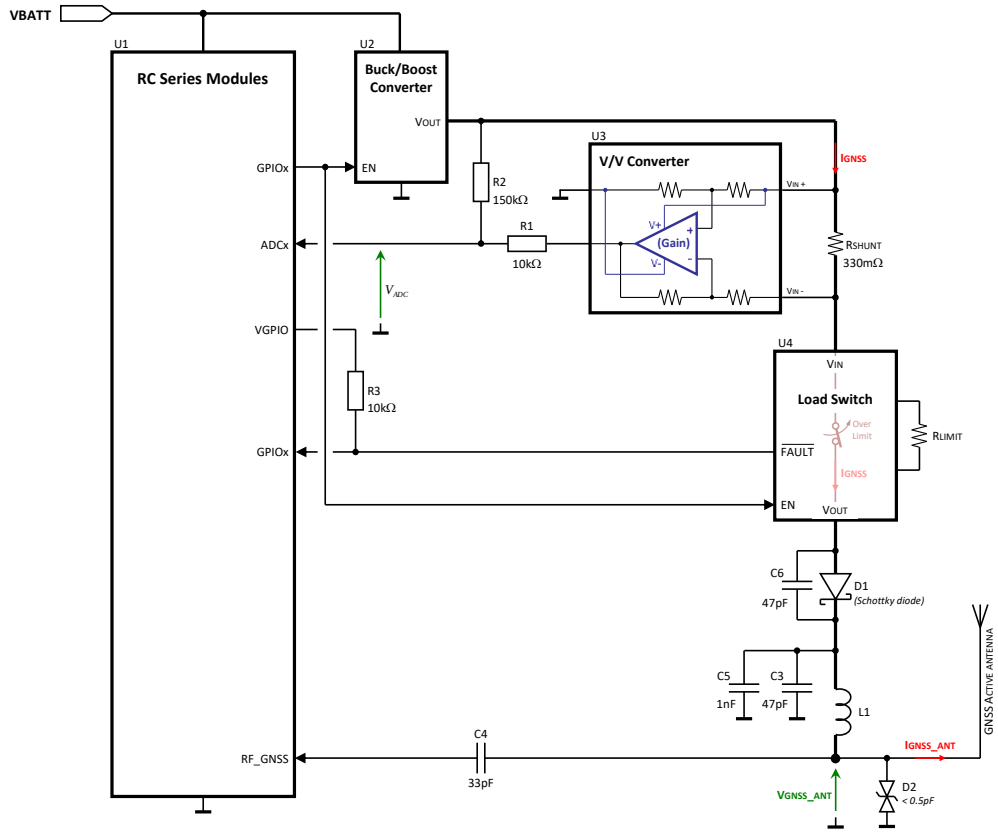


Figure 1 Recommended GNSS Diagnostic Circuit

4.3 Functional Analysis

4.3.1 D1 - Schottky Diode

D1 is a Schottky diode that provides a protection against a reverse voltage that could come from the GNSS antenna port. Due to a very low cut-in voltage ($V_F \approx 0.3V$), only a small part of the voltage supply is lost (easily balanced by slightly increasing the output voltage of the DC/DC converter).

C6 is placed in parallel (as close as possible) to D1 to avoid Radiated Spurious Emissions (RSE).

Example of suitable component:

- ON SEMICONDUCTOR: MBR120VLSFT1G

4.3.2 D2 - Ultra-Low Capacitance ESD Suppressors

D2 is an ESD suppressor that provides protection against ESD that could come from the GNSS antenna port.

Example of suitable component:

- Cooper Bussmann: 0402ESDA-MLP1 Polysurch™

4.3.3 U1 – AirPrime RC Series Module

U1 is an AirPrime RC Series module. It allows the GNSS antenna diagnostic via the use of related ADC, GPIOs, and AT commands.

4.3.4 U2 - Buck/Boost DC/DC Converter

U2 is a DC/DC converter. Depending on the GNSS active antenna power supply requirement, U2 can be either:

- VGNSS < VBATT => Step-down converter (Buck)
- VGNSS > VBATT => Step-up converter (Boost)

Example of suitable component:

- Texas Instrument: TPS61240

4.3.5 U3 - Current-shunt Monitor

U3 is a current-shunt monitor (also called a current-sense amplifier). The output voltage is linearly proportional to the current flowing in the R_{SHUNT} resistor.

The purpose of this circuit is to provide a current consumption indication that can be easily monitored by an ADC. This value can be read either automatically (polling) or on demand.

Example of suitable component:

- Texas Instrument 200V/V: INA216A4 or INA190A4-Q1 (automotive grade)
- Texas Instrument 50V/V: INA216A2 or INA190A2-Q1 (automotive grade)

4.3.6 U4 - Precision Adjustable Current-Limited Power-Distribution Switches

U4 is a current-limited, power-distribution switch intended for applications where precision current limiting is required.

The purpose of this circuit is to quickly interrupt the voltage supply to the active GNSS antenna in the event of an overload. The cut-off limit is fixed by R_{LIMIT} to a value slightly higher than the maximum current required by the active GNSS antenna.

Example of suitable component:

- Texas Instrument: TPS2553-Q1 (automotive grade)

Note: The overcurrent limitation setting must both ensure normal power supply to the active GNSS antenna and provide effective protection of the GNSS antenna diagnostic circuit.

4.4 GNSS Antenna Status

Voltage range at ADC for three antenna states should be pre-defined with the customer application:

- Antenna short circuited to ground.
- Antenna normal.
- Antenna disconnected.

By reading the voltage at ADC with the AT command AT!MADC, the status of the GNSS antenna port can be checked.

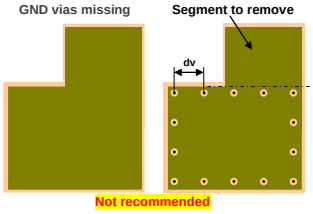
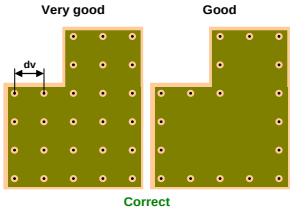
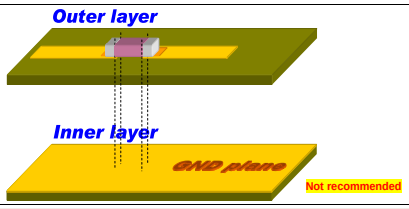
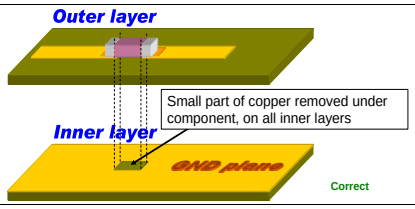
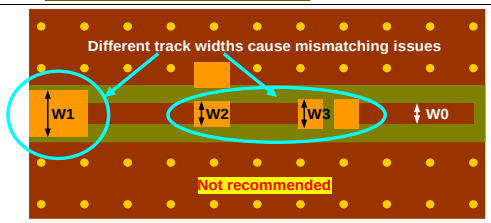
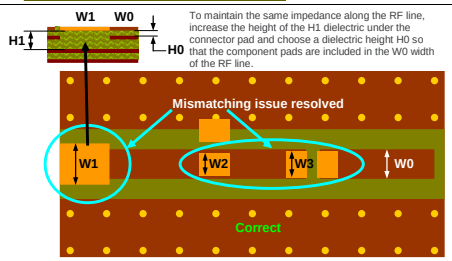
5 Routing Recommendations

Connected to the RF tracks, the routing of the antenna diagnostics components must follow some rules to not degrade the RF performances.

5.1 Routing Rules

For both WWAN and GNSS Antenna Diagnostics circuits, the following key elements must be carefully routed in strict compliance with the basic rules of radio frequency design.

Table 3: Routing Rules for WWAN and GNSS Antenna Diagnostic Circuits

Rules	Topics	Not Recommended	How to Optimize
1	Ground plane (GND) For a 2GHz / FR4 application, dv ≤ 1.75mm.		
2	Lowering the parasitic capacitance		
3	Impedance steps issue occurs when multiple pad widths are placed on the same RF line.		

5.2 Routing the Antenna Diagnostic Circuits

5.2.1 Key Components to Route with Care

All components related to the RF paths must be carefully considered and routed. However, with regard to the antenna diagnostic function for WWAN and GNSS ports, the following components must be carefully routed in strict compliance with the basic rules of radio frequency design.

- For WWAN: L1, C3, C4
- For GNSS: L1, C3, C5

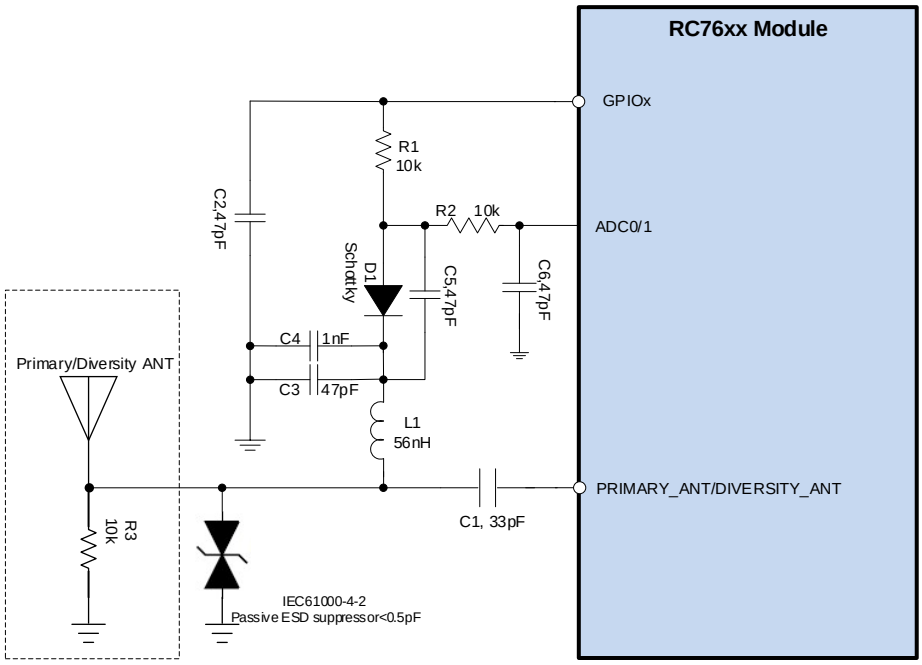


Figure 2 WWAN Antenna Diagnostics - Key Components to Route with Care

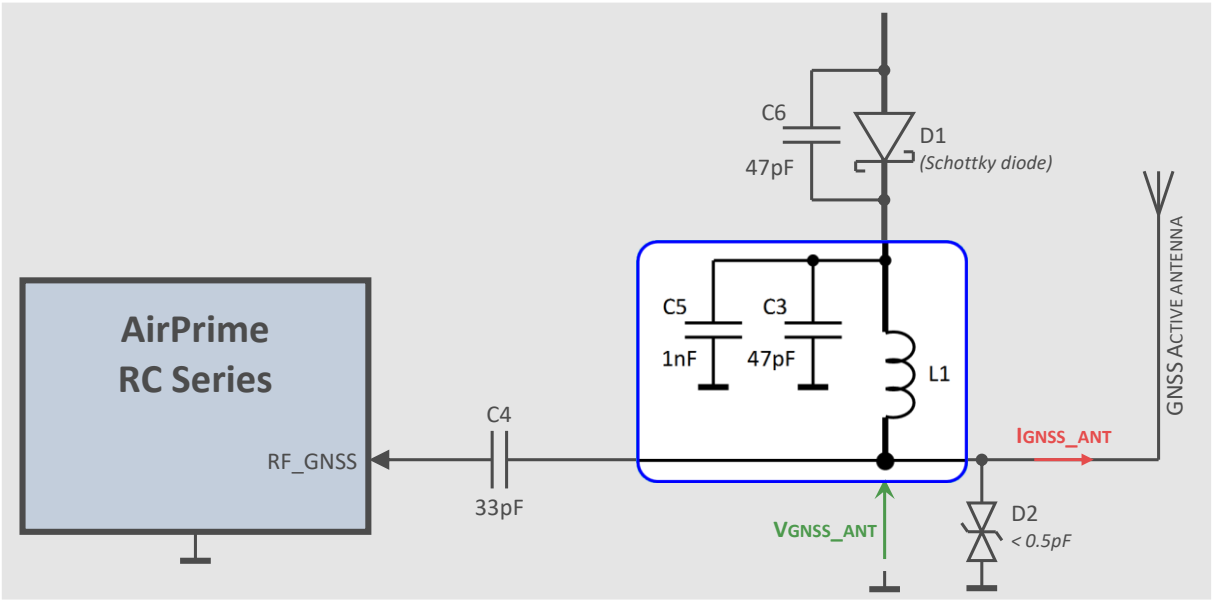


Figure 3 GNSS Antenna Diagnostics - Key Components to Route with Care

5.2.2 Example of Routing

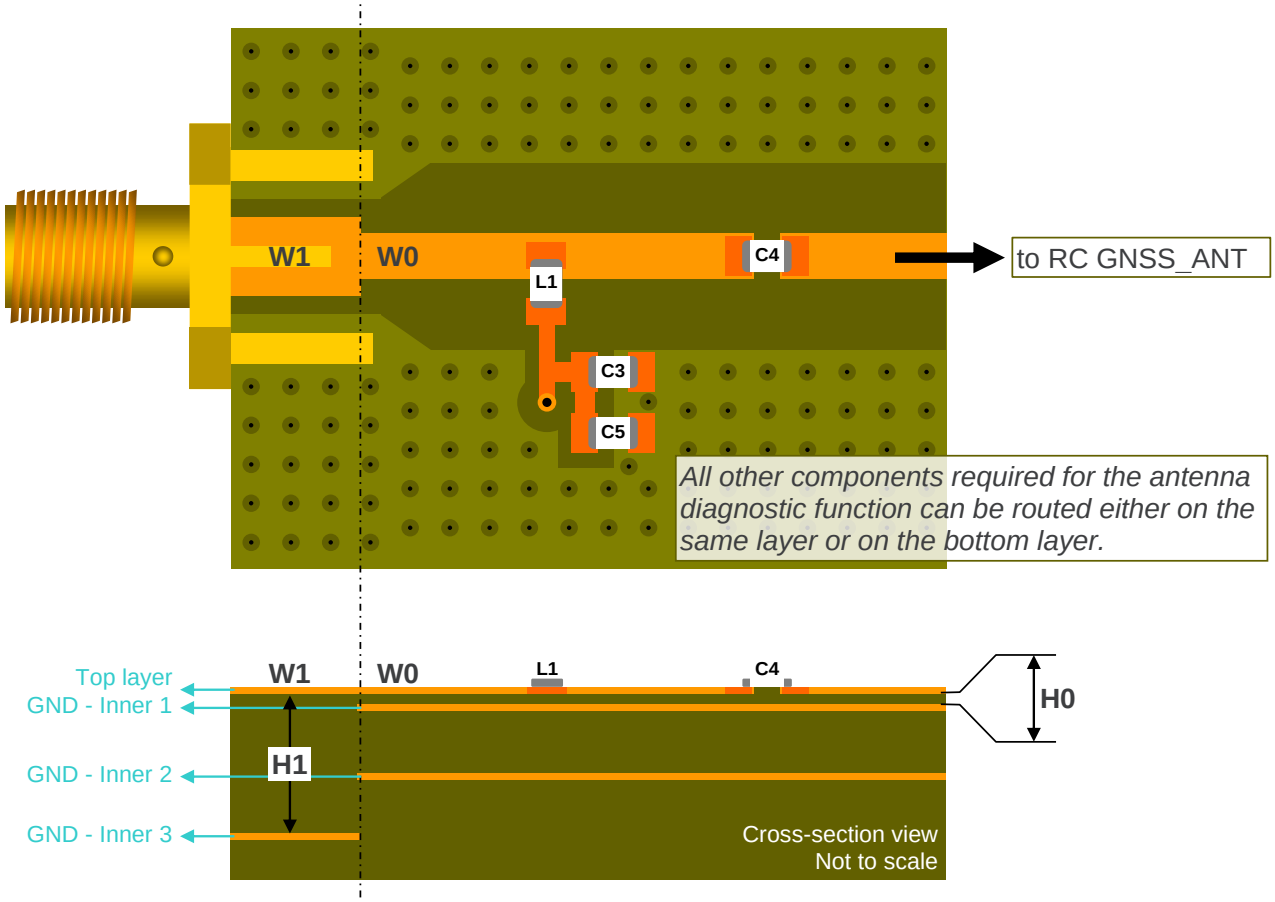


Figure 4 GNSS Antenna Diagnostics - Example of Routing of Key Components

6 Reference Documents

[1] AirPrime AR7 Series Antenna Diagnosis Application Note
Reference number: 2174175

[2] AirPrime RC76xx AT Command Reference Guide
Reference number: 41113566

[3] AirPrime WP Series Antenna Diagnostic Technical Note
Reference number: 2174215

7 Support

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8 Document History

Level	Date	History
1.0	December 18, 2020	Creation

9 Legal Notice

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