SIERRA WIRELESS

Antenna Diagnosis

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APN Content Level	BASIC		INTERMEDIATE	✓	ADVANCED		Confidentiality	Public	✓	Private	

Hardware Compatibility	Product Line	AirPrime	Series	Q26xx	
				SL60xx	
				WMPxx	

Software Compatibility	Series	All

1 Version

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2 Introduction

This Application Note (APN) is provided to Sierra Wireless distributors and clients to aid more rapid development of embedded applications using the Sierra Wireless portfolio of cellular solutions. To request a new application note, please contact your regional Sierra Wireless Product Marketing Manager.

3 Overview

This application note presents different antenna diagnosis solutions including their inherent limitations and different degrees of antenna default detection.

Antenna diagnosis can be used to improve the reliability of a GSM link in the case of a main antenna failure by switching to a secondary one. Diagnosis can also be used as part of a production testing to check the complete connection from the GSM device to the antenna.

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

4 Glossary

Initials	Definition
ADC	Analog to digital converter
TS	Base Transceiver Station
CE	Conformité Européenne (European Conformity)
CS	Circuit Switched
GSM	Global System for Mobile Communications
RF	Radio Frequencies
VSWR	Voltage Standing Wave Ratio

5 Solutions Review

Different methods of antenna analysis provide feedback from different aspects. The general solutions are reviewed in the following sections.

5.1 Network Supervision

Based on GSM network monitoring, a dedicated software is used to check the GSM received signal on a given radio channel using the AT+CCED command. Any significant drop in signal strength can be interpreted as an antenna fault and used to select a second antenna.

- Considerations:
  - No hardware circuitry required. Only software needed to implement network monitoring and alarm detection.
  - A defective or disconnected antenna will lower the received signal. However, the radio link budget can be modified by many other factors which can reduce the reliability of this solution with mobile devices.
  - his solution will only work with GSM devices that can see a network.

5.2 Reflected Power Measurement

Checking antenna VSWR is a standard method to detect antenna faults. This can be done during transmit bursts, using RF circuitry, where a directive coupler associated to voltage detectors or power measurement components can provide the reverse and forward transmit power levels needed to estimate the VSWR. Any VSWR increase will give an indication of a problem with the antenna.

- Considerations:
  - Due to the required RF hardware and the associated software, this can be a costly solution.
  - Accuracy can be good. However, as the GSM transmit power is not constant, some calibration may be needed.
  - The VSWR can be modified by antenna changing environment without affecting the link budget significantly, making an alarm threshold difficult to set.
  - This solution will work only during a CS call.

5.3 Current Detection

To avoid the requirement of being GSM attached, a network independent solution has been developed. This consists of using a dedicated antenna with a DC path to ground through an embedded resistor. If a DC voltage is applied to the antenna and the current is monitored, it can determine if there is a fault.

This status can be either a binary pass/fail using a GPIO. More detailed information can be provided through the use of an ADC enabling the application to make an intelligent decision, i.e. antenna connected, disconnected, short circuited to ground, or short circuited to battery voltage.

Note: Some automotive antenna makers currently provide antennas with an integrated 10kΩ resistor.

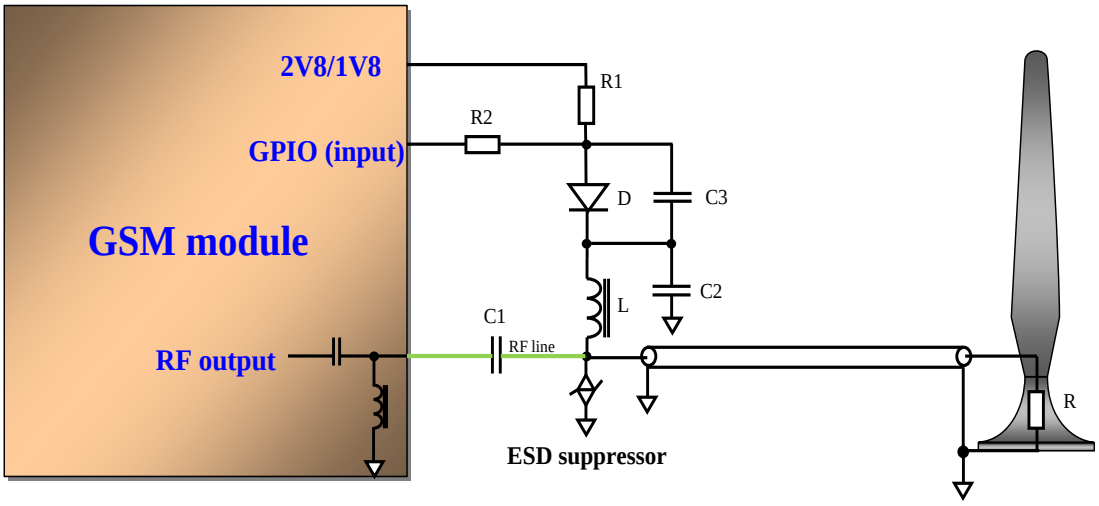
- Considerations:
  - A specific antenna is needed with a resistive path to ground.
  - Some circuitry is needed to interface a GPIO or an ADC to the GSM module, and some dedicated software is required for monitoring and alarm detection.
  - Accuracy for this solution is very good. There is no need to see a GSM network.
  - This can be used to check correct antenna connection during production testing.

6 Current Detection Application

In this section, two different application schematics are presented. The first uses a GPIO as a voltage comparator to provide a simple pass/fail antenna status, and the second uses an ADC for a more complete diagnosis.

6.1 GPIO

6.1.1 Schematic



6.1.2 Description

A voltage divider is made using R1 and R through the 2V8/1V8 signal. The divided voltage is connected to a GPIO, set as an input, and used as a voltage comparator.

Two statuses are provided:

- Antenna disconnected: the GPIO (input) is set high to 2V8/1V8. This high voltage must be in the GPIO VIH min to max range specification.
- Antenna connected: the GPIO (input) is set low. This low voltage must be in the GPIO VIL min to max range specification.

Note: An antenna short circuit to battery voltage will provide the "Antenna disconnected" diagnosis and antenna short circuited to ground the "Antenna connected" one.

6.1.3 Signals and components description:

- 2V8/1V8: antenna detection supply; can be one of the available 2V8 /1V8 supplies or a GPIO set as an output.
- GPIO (input): GPIO set as an input and used to check the antenna status.
- RF output: antenna output of the GSM module, DC grounded with most of the Sierra Wireless products.
- R: antenna embedded resistor (10k).
- R1: used to set the current in the antenna resistor R.
- R2: GPIO protection (during reset, if wrongly set as an output).
- D: diode for GPIO and 2V8/1V8 protection in case of antenna short circuit to battery voltage.
- C1: DC isolation with the internally DC grounded module output (DC rating ≥ 50V).
- C2: decoupling capacitor at GSM frequencies (DC rating ≥ 50V).
- C3: decoupling capacitor to prevent D from rectifying any radiated GSM signal (DC rating ≥ 50V).
- L: blocking inductor at GSM frequencies ($2\pi fL \geq 500\Omega$).
- ESD suppressor: must have very low parasitic capacitance to minimize losses and be free of harmonics generation (therefore diodes cannot be used). The 0402ESDA-MLP1 from Cooper Bussmann has been sucessfully used.

6.1.4 Practical Values

R	R1	R2	C1	C2	C3	L	D
10kΩ	270kΩ	10kΩ	33pF	33pF	33pF	82nH	BAS16

Components size: 0402 or 0603

Using this set of components, the circuit works with either 2V8 or 1V8 supply and a respective GPIO.

6.1.5 Useful AT Commands

The following commands are valid for the AirPrime Q2686 and SL6087 modules.

To set a GPIO as an output (GPIO19 in the following example): **AT+WIOM=1,"GPIO19",1**

To set this GPIO at high level: **AT+WIOW="GPIO19",1**

To set a GPIO as an input (GPIO25 in the following example): **AT+WIOM=1,"GPIO25",0**

To read this GPIO: **AT+WIOR="GPIO25"**

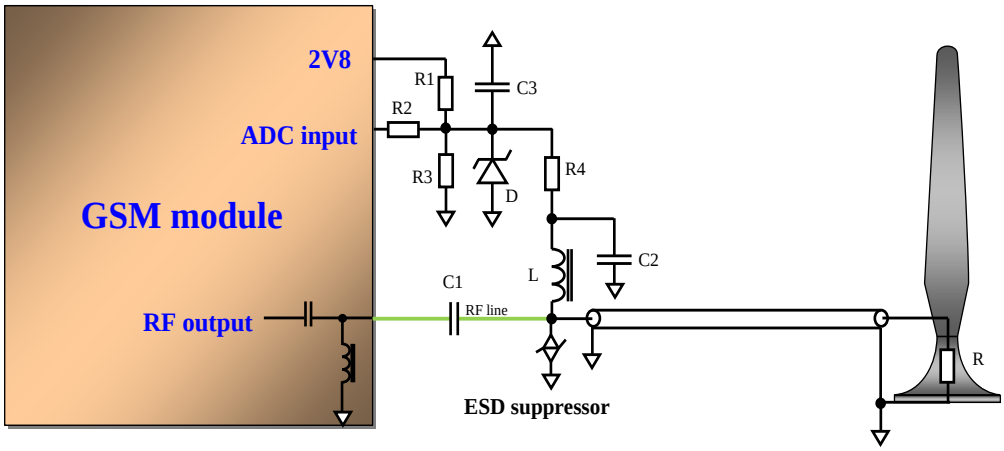
The response will be: **+WIOR: 1** with antenna not connected and: **+WIOR: 0** with connected antenna.

Some GPIOs (like GPIO25) can be used as interrupt inputs.

Refer to your particular product's "AT Commands Interface Guide" for complete information.

6.2 ADC

6.2.1 Schematic



6.2.2 Description

The 2V8 supply provides a DC current to the antenna resistor R through a resistive bridge. The resulting voltage is measured using an ADC.

Four different status are available:

- Antenna short circuited to ground.
- Antenna ok.
- Antenna disconnected.
- Antenna short circuited to battery voltage.

6.2.3 Signals and components description:

- 2V8 : antenna detection supply, provides a current to the R1, R4, R branch.
- ADC input: ADC from the GSM module. Most ADCs on Sierra Wireless embedded modules are 10 bit resolution with a 0 to 2V input range. Check your particular GSM unit's PTS for details.
- RF output: antenna output of the GSM module.
- R: antenna embedded resistor (10k).
- R1: used to set the current in the antenna resistor R.
- R2 : ADC input protection.
- R3: used to adjust the input voltage to the ADC input voltage range.
- R4: resistor used with D as voltage limitation in case of antenna short circuit with battery voltage (up to 24V).
- D: Zener diode for over voltage protection.
- C1: DC isolation with the internally DC grounded module output (DC rating ≥ 50V).
- C2: decoupling capacitor at GSM frequencies (DC rating ≥ 50V).
- C3: decoupling capacitor to prevent D from rectifying any radiated GSM signal.
- L: blocking inductor at GSM frequencies ($2\pi fL \geq 500\Omega$).
- ESD suppressor: must have very low parasitic capacitance to minimize losses and be free of harmonics generation (therefore diodes cannot be used). The 0402ESDA-MLP1 from Cooper Bussmann has been sucessfully used.

6.2.4 Practical Values

The suggested following components values are for a 0 to 2V ADC input range:

R	R1	R2	R3	R4	C1	C2	C3	L	D
10kΩ	10kΩ	10kΩ	10kΩ	1kΩ	33pF	33pF	33pF	82nH	BZX884C2V4

Components size: 0402 or 0603.

The resulting nominal antenna diagnosis voltages are:

Antenna diagnosis	Short circuit to GND	Connected	Disconnected	Short circuit to 12V
ADC input (V)	0.23	0.95	1.38	2.4
ADC output (0 to 1023)	118	486	705	1023

The "ADC output" is the decimal output of a 10bit ADC with 0 to 2V input range.

The different components' tolerances must be considered to set the diagnosis thresholds.

An Excel spreadsheet can be used to ease the different min/max calculations, as shown in the examples below.

Input data:

Components	tolerance	min	typ	max	unit
R (antenna)	5%	9.5	10	10.5	kΩ
R1	5%	9.5	10	10.5	kΩ
R2	5%	9.5	10	10.5	kΩ
R3	5%	9.5	10	10.5	kΩ
R4	5%	0.95	1	1.05	kΩ
Rinput ADC	10%	900	1000	1100	kΩ
V_{2V8}	2%	2.74	2.80	2.86	V
V_Z	5%	2.28	2.4	2.52	V

Calculation results:

R_{input} ADC 1000 kΩ	Short circuit to ground (R=0)			Connected (R=10kΩ)			Disconnected (R=10MΩ)			Short circuit to 12V/24V		
	min	typ	max	min	typ	max	min	typ	max	min	typ	max
ADC input voltage (V)	0.21	0.23	0.26	0.87	0.95	1.04	1.28	1.38	1.48	2.28	2.4	2.52
ADC output (0 to 1023)	105	118	132	444	486	530	654	705	758	1023	1023	1023

This practical example has been designed for a 10 bit ADC with 0 to 2V input range and using a 2.8V reference, but it can be scaled to different specifications. Refer to the GSM module datasheet for complete ADC characteristics.

6.2.5 Useful AT Commands

The following commands are valid for the Q2686 and SL6087 modules with the "AUX-ADC" input used.

To read all ADCs: **AT+ADC?**

Response will be: **+ADC: 3600,1418,960,818**

3600 is the 3600 mV battery voltage, **1418** is the BAT-Temp ADC voltage in mV, **960** is the AUX-ADC input voltage in mV with antenna connected and **818 is** the temperature (refer to the PTS for mV to °C conversion).

To only read the AUX-ADC and get a value in milivolts: **AT+ADC=0,2?**

Answer will be this form with antenna connected condition: **+ADC: 0,960**

0 indicates milivolt unit is used, **960** is the ADC input voltage in milivolts unit when antenna is connected.

Please refer to the product's "AT Commands Interface Guide" documentation for complete information.

6.3 PCB Design Guidelines

The following RF design rules are required to route the antenna connection:

- RF connections must be 50Ohm impedance and as short as possible to minimize losses.

  Line structure can be microstrip, stripline or coplanar waveguide.

  Free simulation software (Appcad from Agilent, TxLine from AWR…) can be used to tune the line width according the PCB stackup and to check losses as a function of frequency.
- RF traces with right-angle bends must be avoided; round bends or 45° corners are prefered.

- Audio and digital signals should be routed away from the RF lines to prevent coupling.
- It is recommended to embed the measurement connections on inner PCB layers to prevent interference from or on these lines.
- The RF hot point of L must be on the RF line (no T shape connection) and C2 must be close to L with a short and direct ground connection.
- ESD suppressor: located as closest as possible to the antenna connector, with one pad on the RF line (no T connection!) and the second pad directly on a massive ground (use at least 3 ground vias to inner ground layers).

7 Useful Links

- Antenna switching design: “Antenna Switch Application Note“ and others from Sierra Wireless: *http://www.sierrawireless.com/en/Support/Downloads.aspx*
- Hirschmann antennas: *http://products.hirschmann-car.com/SepiaPIMWeb/files/GPS%201890%20LP_P_Daten_0211.pdf*
- AGILENT (Appcad download): http://www.hp.woodshot.com/
- AWR (TxLine download): http://web.awrcorp.com/Usa/Products/Optional-Products/TX-Line/
- COOPER BUSSMANN: http://www.cooperindustries.com/content/public/en/bussmann/products.html
- ESD protection page: http://www.cooperindustries.com/content/dam/public/bussmann/Electronics/Resources/Data%20Sheets/Bus_Elx_DS_4367_0402ESDA-MLP1.pdf

8 Support

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9 Document History

Level	Date	History
001	May 12, 2006	Creation (document reference: WM_ENG_Q2501_APN_001)
2.0	September 27, 2012	Re-written. New template and new reference (2170022) used.

10 Legal Notice