OEM Application Note

April 2001

# PC Card and Mini PCI Antenna Integration Notes

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## Introduction

ORiNOCO Integrated PC Cards and Mini PCI Cards are designed for integration into portable ICT devices (for example, notebook computers, handheld scanners, PDAs, etc).

Neither of these cards includes an integral antenna, and therefore the integration platform must provide one or two antennas, and possibly an antenna diversity switch.

This Application Note provides the integration engineer with a list of tips for designing and placing suitable antennas for use with these cards; states what is required of an external antenna diversity unit; and describes a possible antenna diversity unit and antenna diversity switch.

The Application Note ends with some hints on how to perform functional testing using standard ORiNOCO tools, and suggests at which point to perform production testing.

When an ORiNOCO Integrated PC Card or Mini PCI Card is integrated in a platform, the integration engineer must provide one or two external antennas.

The Integrated PC Card incorporates an antenna diversity switch which can select the better antenna for reception at any time. If external antenna diversity is required, the internal diversity switch can be disable by software.

The Mini PCI Card is available in two variants: one with the internal antenna diversity switch enabled, and one with the internal diversity switch disabled. When using diversity antennas with the variant which has the antenna diversity switch disabled, the integration engineer must also provide an external antenna diversity switch.

Once the design decisions have been made, the integration should be checked to confirm that the system behaves as expected.

Additionally, at some point during production the radio performance of units should be tested.

## Antenna Design Considerations & Design Tips

Some tips for designing small antennas and integrating them in platforms such as notebook computers are given below:

- When designing a small antenna, attention should be paid to the operational bandwidth and antenna efficiency, and not to the radiation pattern, as in the case of conventional antennas. The radiation pattern is of secondary importance, because small antennas, as a function of their size, have hardly any directivity.
- Antennas should not be expensive components: at least small antennas should never be. An antenna should be just a conveniently bent piece of metal or a piece of PCB print. In many cases it is possible to modify an existing mechanical part to assume the additional role of antenna.
- Implementation should not result in unnecessary degradation of an antenna's efficiency. For instance, if the antenna is implemented as just as a piece of metal surrounded by other metal or non-lossy plastic (for example, ABS) the efficiency won't be poor. On the other hand, printing the antenna on a lossy PCB material (for example, FR4) can result in a serious efficiency (and gain) degradation.
- A plastic housing could affect antenna efficiency or performance, depending on the type of plastic used, and its distance to the antenna. However, lossy plastic, for example, carbon filled plastic, is much less commonly used than ordinary ABS, which is virtually lossless. The various sorts of (PE) foam materials that can be used for antenna support are also virtually lossless. Nevertheless, a plastic housing still represents a sort of dielectric loading and tends to lower an antenna's operational frequency – hence final antenna tuning can be done only when the antenna is in its final housing.
- Some antenna types require a significant clearance (that is, no metal objects are allowed in the vicinity). These types include dipoles and sleeves and are usually called "electric current antennas" referring to electrical current as the source of radiation. These antennas are less suitable for integration into ICT platforms because of the lack of adequate vacant and metal-free space.

  However, antennas such as slot, notch, IFAs and patch require the presence of a large ground as they use it as their own ground plane. These antenna types are therefore easier to integrate into ICT platforms, and mounting them at the edges or corners of the ground plane often contributes to improving omnidirectionality.
- When integrating antennas into notebook PCs, the best position in terms of quality of the RF link is in the screen, as this offers the most stable operating environment. It is physically higher than other locations in the PC, and offers flexibility in achieving optimal spatial separation and orientation of the antennas.
- If coaxial cables are fed through the hinges of the screen, it is important that the cable selected can withstand being flexed thousands of times without deterioration of the RF parameters. Cable rigidity is an important parameter and should be tested thoroughly before a final choice is made.

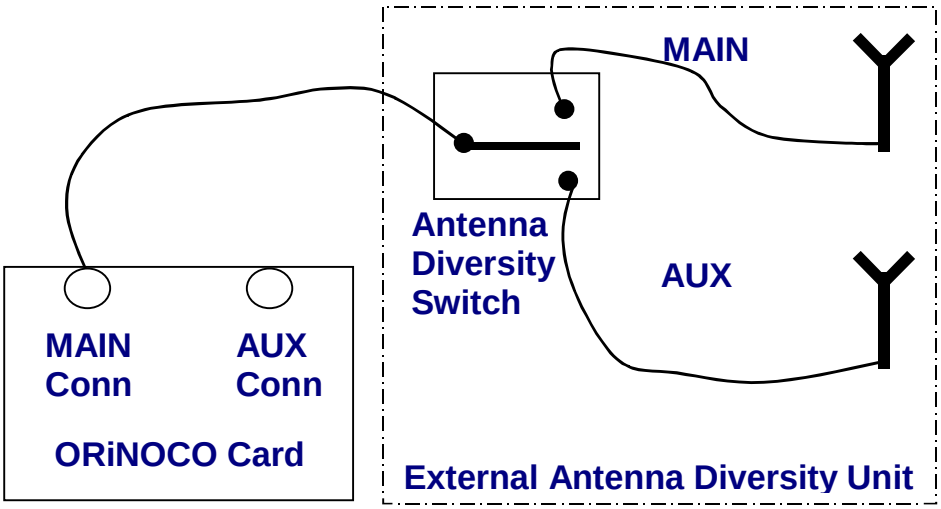
- Use high-quality RF coaxial cable with a high shielding density, as the cable may be close to sources of interference, such as a processor, and introduce common mode noise. The choice of RF cable is a trade-off between shielding, insertion loss, rigidity and price.
- RF coaxial cables may become unwanted radiating elements for noise picked up from the host system. In order to remain compliant with regulatory requirements, it may be necessary to connect the shielding of the cable to the chassis ground of the integration platform.
- When choosing the location for the integrated antenna, the possible presence of RF noise nearby must be considered. For instance, antennas placed very close to some fast digital logic may pick up higher order harmonics from the clock. With PCs operating at hundreds of MHz, 2.45 GHz can be even less than 10th harmonic. On the other hand, ORiNOCO radio sensitivity is better than -90 dBm.
- A simple test for detecting noise which affects the receiver can be performed in the early phase of integration using ORiNOCO Client Manager. This test is described in the section Checking Integration in a Functional System.

# External Antenna Diversity

The ORiNOCO Integrated PC Card and the Mini PCI Card support internal antenna diversity or external antenna diversity. When internal antenna diversity is used no extra effort is required from the system integrator. However, when external antenna diversity is used the integrator must implement an external Antenna Diversity Unit (ADU).

Agere does not offer an ADU as a standard product, but can offer design and implementation support.

The basic set-up of an External Antenna Diversity Unit can be represented as:




## Antenna Diversity Unit (ADU) Requirements

The ADU must have two antennas integrated into it, along with a simple, low-loss, low-distortion, diversity switch.

Each of the two antennas has to be:

- Physically small;
- Omnidirectional — as far as possible;
- As power-efficient (that is, as high gain) as possible;
- Low cost and easy to manufacture.

There is some overlap in the antenna requirements listed above: whenever an antenna is very small (electrically small) it is by default to a large degree omnidirectional — this being the reality determined by

the laws of physics. Hence the first two requirements (antenna must be small and omnidirectional) are more or less the same and inseparable.

As far as the (microstrip) antenna power efficiency is concerned, we have to be careful and select a low loss substrate. In practice, the dissipation factor (loss tangent) should be less than 0.01, which means that the antenna gain reduction resulting from loss introduced by the substrate should not be more than 0.5 dB. From the commonly used substrates, we can choose between two materials (all the others being either too expensive in terms of material or processing):

- Rogers RO4003 has a Dissipation Factor of 0.002 (well below the limit) which would result in a substrate introduced antenna gain reduction in the order of 0.1 to 0.2 dB.
- GTEK has a Dissipation Factor of around 0.01 (just on the limit of what is considered an acceptable value) which would result in a substrate introduced antenna gain reduction in the order of 0.5 dB.

It is worth mentioning that the antenna dielectric losses are not only dependent on the PCB substrate dissipation factor, but also on the geometry of the antenna and the corresponding distribution of the EM fields in the substrate and in the air.

The efficiency numbers mentioned above are estimates which could be verified by means of EM simulation and or prototyping.

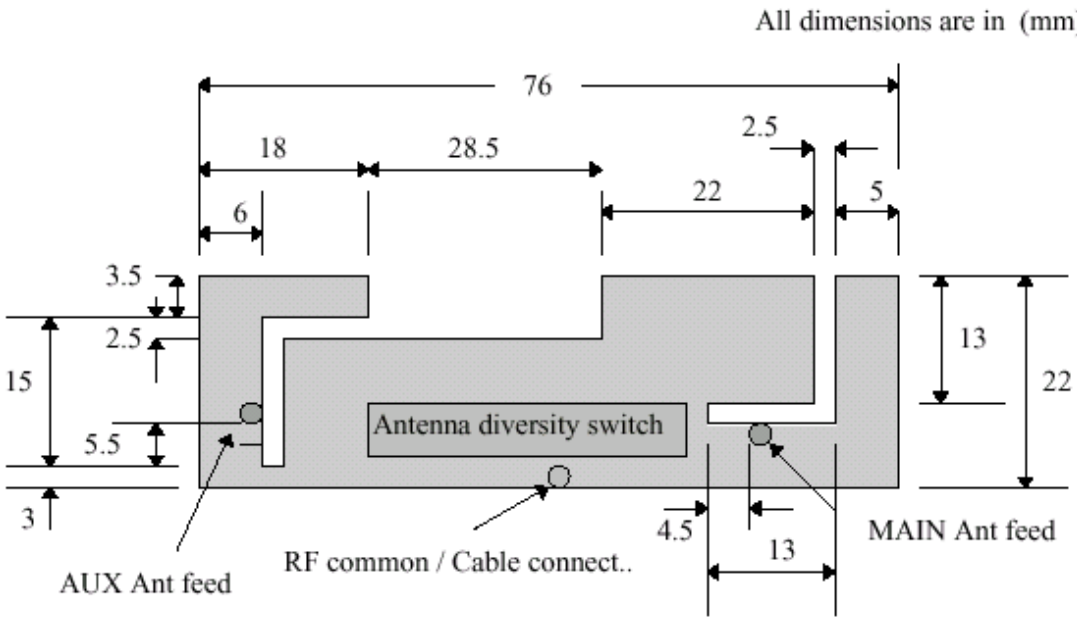
The ADU proposed in this document is made on RO4003.

## Physical description of the ADU

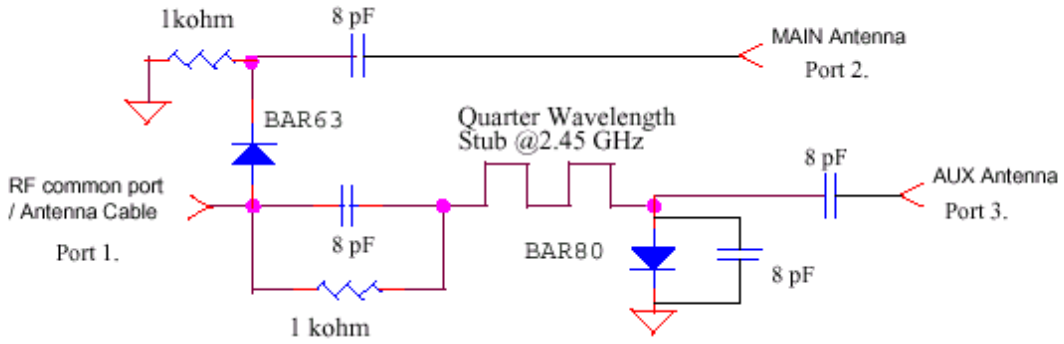
The ADU described below incorporates:

- Two Notch Antennas, referred to as the MAIN and the AUXiliary antenna, implemented in microstrip on the small RO4003 PCB;
- SPDT (Single Pole - Double Terminal) Antenna Diversity Switch consisting of two PIN diodes and some passive components and microstrip traces.

Approximate dimensions and the form of the Notch Antennas are presented in the diagram below:




The schematic of the Antenna Diversity Switch is:




The switch is controlled by injecting +3 V / 0 V DC voltage through the RF coax cable to Port 1 (RF common port) — see the schematic above — which turns the switching PIN diodes into ON/OFF state.

The Insertion Loss and Isolation for each of the two SPDT switching positions is presented by the table below:

| | **$V_{switching}$ = +3 V**<br>**MAIN Ant selected** | **$V_{switching}$ = 0 V**<br>**AUX Ant selected** |
|---|---|---|
| **RFcomm ⇒ MAIN Ant** | Low loss<br>$S_{21}$ = -0.9 dB<br>$VSWR_{11}$ = 1 .. 1.2 | Isolation<br>$S_{21}$ = -16 dB |
| **RFcomm ⇒ AUX Ant** | Isolation<br>$S_{31}$ = -10 dB | Low loss<br>$S_{31}$ = -1.3 dB<br>$VSWR_{11}$ = 1.25 .. 1.4 |

Of course, we would like to achieve as low as possible Insertion Loss through the switch when in the ON state, since this directly impacts the Tx power and the Rx sensitivity (Rx noise figure), and these two factors determine the range. The Insertion Loss towards the MAIN antenna is of even more importance since that antenna is involved in both Tx and Rx operation (AUX is just an optional Rx antenna).

The Insertion Loss of -0.9 dB through the switch towards the MAIN antenna and -1.3 dB towards the AUX is a good result.

However, the Switch Isolation (Insertion Loss through the switch towards the unwanted, that is, switched off, antenna) is also an important parameter, with an impact on the performance of the antenna selection diversity function. More precisely, for effective antenna diversity, the cross-talk between antennas must be minimal (preferably -20 dB, and definitely at least -10 dB). Diversity switch isolation must therefore be even better, or at least the same: there is no point in constructing the antennas in such a way that antenna cross-talk minimization is negated by the cross-talk through the switch.

The isolation in our case lies somewhere between -10 dB (just enough) and -16 dB (comfortably enough) and constitutes a sufficiently good result.

## Placement of the Antenna Diversity Switch

The recommendations given here for minimizing performance loss apply equally to the placement of an external Antenna Diversity Switch as to the ORiNOCO Card itself.

2.4 GHz interference can feed through the antenna, through the Antenna Diversity Switch board or directly into the front-end of the receiver on the ORiNOCO Card. Disturbance will manifest itself as an increase in the noise level of the radio. The ORiNOCO radio has a superior noise level, resulting in a maximum Signal to Noise ratio (SNR), which is the main variable in the quality of a wireless link. If the noise floor is deteriorated by 2.4 GHz interference this will affect the SNR and thus deteriorate link performance. From a user perspective, this means that the range, or coverage area, is limited.

- Ensure that the Antenna Diversity Switch/ORiNOCO Card is placed out of the vicinity of clocks, processors, memories and high-speed devices and busses.
- Do not place the Antenna Diversity Switch/ORiNOCO Card near fast digital circuitry and provide a ground plane in the adjacent area.
- Consider covering the area around the Antenna Diversity Switch/ORiNOCO Card with a metal enclosure, which can act as EMC shielding. Make sure that there is sufficient clearance area and drilled holes to allow air flow.
- Make sure that the power supply feeding the ORiNOCO Card is properly decoupled, so that interfering signals do not deteriorate the performance by conducted noise through the power supply.
- A potential source of 2.4 GHz noise in an LCD screen assembly, for example, in a laptop, is the LCD inverter/switcher board. The Antenna Diversity Switch/ORiNOCO Card should ideally be kept away from this potential source of interference.

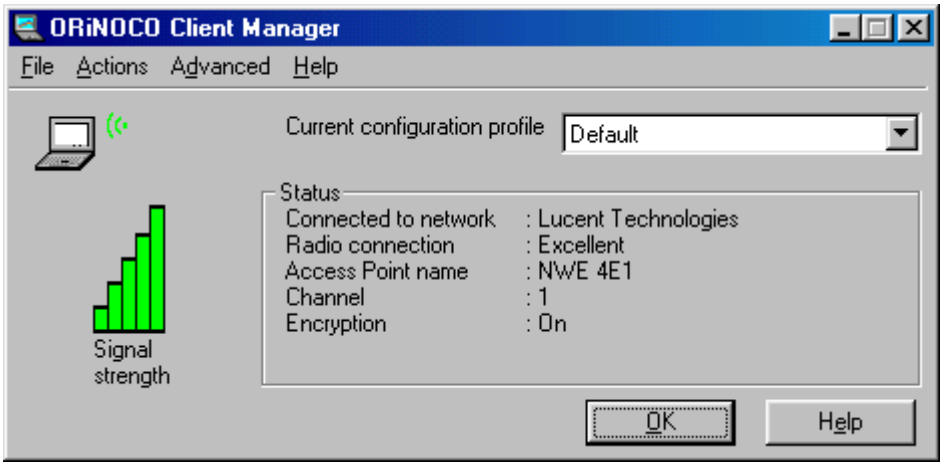
## Checking Integration in a Functional System

It is important that during development of a new platform, optimum positions for the ORiNOCO Card, antenna and external Antenna Diversity Switch are selected by using the guidelines in this Application Note. It is advisable to check the outcome of design decisions taken by performing noise measurement tests on initial prototypes.

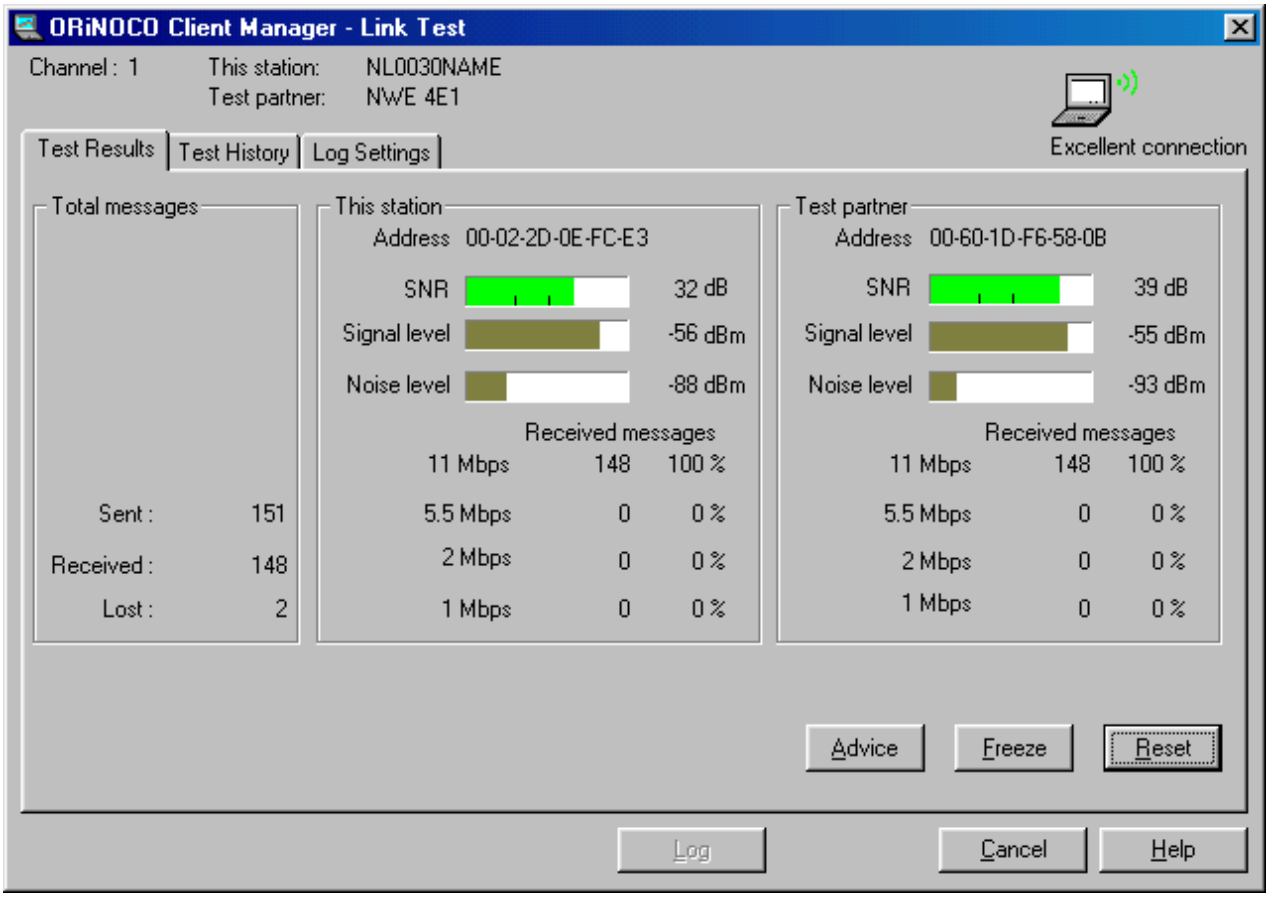
The ORiNOCO Card and Client Manager software tool can be used to determine the level of interference under different circumstances, compare results, and decide whether integration requires changing. The Client Manager provides a history overview function and allows you to write the results to a comma-separated log file, which allows data processing in, for example, a spreadsheet program.

The procedure below can be followed for checking the noise level:

1. Ensure that you have a compatible access point to which you can attempt to connect.
2. Install the Client Manager software tool — as distributed along with your card — or download it from the ORiNOCO web site (http://www.orinocowireless.com).
3. Connect an external antenna to the card and place it at least 30 cm away from the system in which it is being integrated and any other possible sources of interference.
4. Launch Client manager and check that the system is connected to an access point. A screen something like the following should appear:




5. From the **Advanced** menu select **Link Test**. The performance of the station under test and the test partner are dynamically displayed.




6. Select the **Test Results** tab and look in the **This station** area. The Noise Level of a properly integrated system should be -93 dBm or less. If this is not the case, it is advisable to review the placement of the antennas and of the diversity switch.
7. If the Noise Level is -93 dBm or less, then disconnect the external antenna and connect the antenna or antennas of the system in which the card is being integrated, and the Antenna Diversity Switch if applicable.
8. Repeat the check made in step 6. If the Noise Level is roughly the same, then there are no problems with interference. If the Noise Level is higher with the actual antenna than with the external antenna, then this indicates a source of noise somewhere near the antenna or diversity switch. In that case try relocating the antenna and diversity switch until a similar Noise Level to that recorded in step 6 is obtained.
9. Repeat the procedure for all frequency channels.

# Production Testing

The ORiNOCO Cards are fully functionally tested before they leave Agere's production facility, and therefore end-system testing can be limited to an antenna functional test.

Systems with ORiNOCO card, antennas, and external Antenna Diversity Switch incorporated should be tested before shipment. Systems which only incorporate antennas, offering the possibility of upgrading to wireless solutions at a later date, should include a production line test of the entire wireless system, namely, the radio, coax cables, external Antenna Diversity Switch, and antennas.

The actual moment at which antenna functional testing is made is a trade-off between cost and performance guarantee.

- For lowest possible cost, testing should start as early as possible, so that problems do not impact the production cost.

- For best performance verification, testing should take place at the latest possible production integration stage – after the parameters have been fixed – because the characteristics of the antenna are dependent on the total system.

Assume an example of two antennas and an Antenna Diversity Switch built inside the LCD screen area of a laptop PC. Testing should take place as early as possible; if we wait until the LCD area is fully integrated in the system, any failure requires disassembly of the complete system. However, the antenna characteristics depend on parameters such as:

- presence of LCD ground plane
- presence of surrounding plastic
- final mechanical placement.

**Conclusion**: A good time to perform an antenna functional test is after integration into the LCD screen, when it is surrounded with plastics, but before integration with the base computer unit; although there is always the risk that cable damage might occur in this phase.

If testing is required before integration into the screen, it is important that the antennas are wideband antennas, so that the external load factors mentioned above do not have a significant impact on the performance of the antenna.

# References

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2. *Small Antenna*s, K. Fujimoto, A. Henderson et al, Research Studies Press LTD, England
3. *Analysis, Design, and Measurement of Small and Low-Profile Antenna*s, K. Hirasawa et al, Artech House
4. OEM Application Note: *RF Cable Survey for 802.11 Embedded Applications*, Agere Systems Inc.

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