# Antenna Designs for Notebook Computers:
# Pattern Measurements and Performance Considerations

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## Introduction

The proliferation of WiFi connectivity has brought with it the need to embedded antenna solutions for a variety of platforms. The most common integration effort recently has been associated with laptop and notebook portable computers. Historically, this includes the PCMCIA card, the USB 802.11 dongle, and the totally integrated solution with radio and antenna in notebook base or screen (lid). Each of these efforts represented a learning process for the industry specifically with respect to production performance variability, radiation efficiency, pattern coverage, and cost. Cost reduction has been the trend in all aspects of WiFi integration with specific minimum requirements for performance.

This paper describes several issues related to the integration of WiFi antennas into notebook computers—specifically choice of location and resulting pattern coverage, radiation efficiency, and antenna design factors relating to cost. In addition, it is intended to illustrate some of the pitfalls, successes, and performance expectations achievable with certain designs and possible solutions for improvement.

## WLAN Antenna Requirements

WLAN antennas used in remote devices generally must meet minimum requirements for VSWR <2.0 or better over the entire operating frequency range. In some cases, VSWR<1.5 is stipulated. In addition, there has been a trend on behalf of manufacturers to use one antenna that can operate in any of the 801.11 bands, so that coverage is nominally from 2.3-2.4 and 4.9-5.9 GHz. Specifications for radiation efficiency although useful, are usually supplanted with a specification for percent angular coverage with gain above a specified threshold in a desired plane. Antenna placement becomes an issue for uniform coverage, as well as for schemes utilizing pattern or polarization diversity.

## Secondary Design Considerations

Selection of the antenna element design is predicated upon several factors, but the cost/performance trade-off is perhaps the most significant. Form factor and fit are also issues that drive the design and size of the antenna solution to the limit. Related to these issues, the preference for antenna location and a variety of locations have been tried ranging from behind the display screen to the sides of the base to the sides and top of the display. The selection of the antenna location determines the pattern, gain, transmission line loss, dominant polarization, etc. In addition, with the drive toward thinner and larger area displays, as well as the inclusion of other feature components, the antenna size and therefore bandwidth has generally been stressed. This has resulted in production issues where tuning at the low band is adversely affected by antenna fine scale position variability with respect to the dielectric and metal surrounding

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structures. As a result, antenna testing and/or production binning is sometimes required to meet performance requirements. Reducing the antenna sensitivity to these effects by employing specific broadband designs or dielectric loading can be curative but may increase cost or overall performance.

Production assembly costs can also be an issue with associated antenna mounting hardware adding to labor intensity and every effort is made on behalf of producers to minimize these costs. Recent designs being completed by the authors utilize an adhesive backed broadband monopole antenna pair that is suited for direct integration with a radio chipset in the display unit. This approach eliminates the 0.5 meter transmission line and associated loss (~3 db at 5 GHz) with base mounted radio implementations.

**Antenna Location Selection**

Choice of antenna location is usually limited in any embedded design due to industrial design space constraints and interference considerations. Since diversity is standard in the 802.11 protocol, antenna location is important in establishing performance of the system in some operating environments. Some typical examples of antenna placement options are shown in Fig.1.

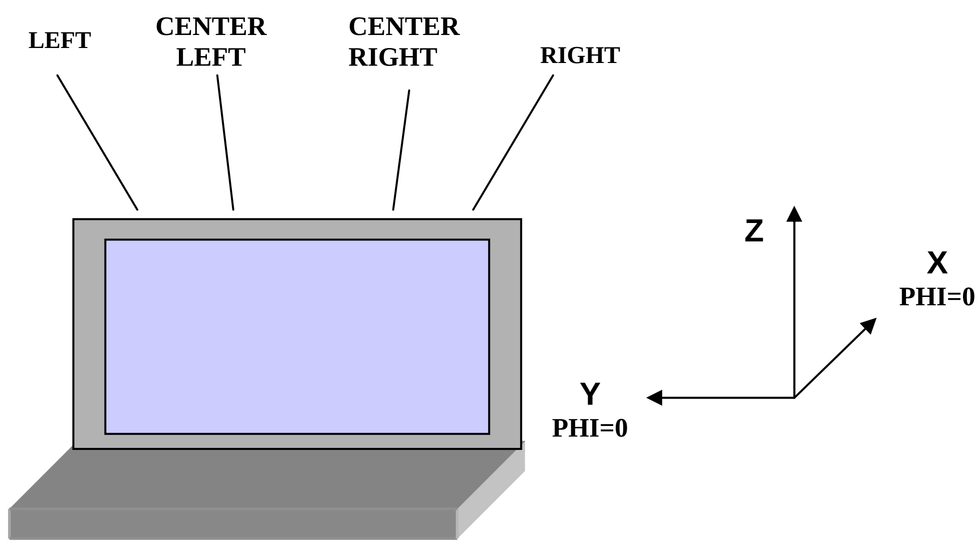


Figure 1. Antenna mounting configuration options

Since the height in the z-dimension is limited, antennas having current distributions along the y-direction are typical. Examples are transmission –line antennas, such as the inverted “F” antenna (IFA) and multi-resonant inverted L variants. Slot antennas having primary radiative currents along the z-direction also have utility in this application, since the display screen and laptop lid are electrically conductive. The authors have conducted extensive simulation and testing for the F- and L-designs in standard 15” laptop lid configurations and present some typical data for the positions specified in Fig.1. Refer to Figure 2 for simulated far-field radiation plots at 2400 MHz using antennas fitting an 18 x 3 x 5 mm form factor.

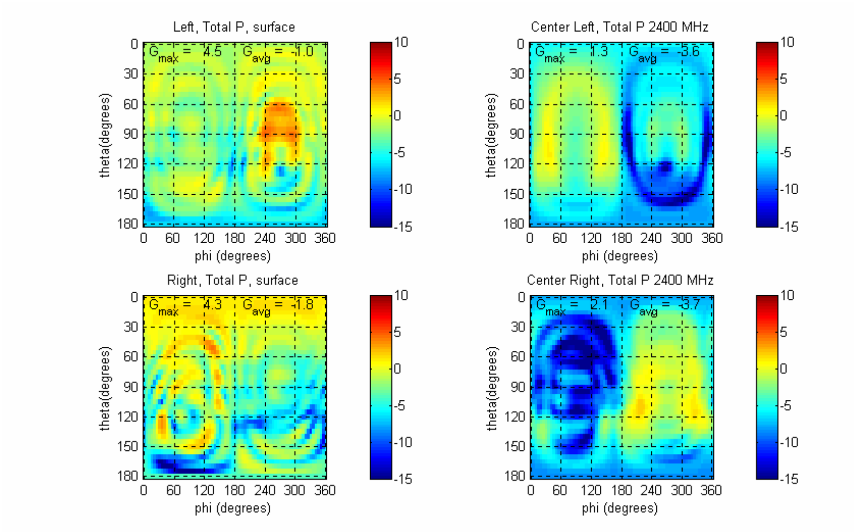


Figure 2. Far Field Simulated Patterns for Antenna Locations (2400 MHz, total field). (Clockwise from upper left: Left, Center Left, Center Right, Right)

Note that azimuthal cuts (□ □̃are nearly symmetric with greatest field strength at the left- and right-most positions. These positions also allow for radiation in the z-direction for multi-floor coverage. Simulations and measurements have also been made for antennas rotated about the y-axis. These studies also indicate that more complex pattern diversity schemes may be suited to this application.

The plots in Fig. 2 are for total field components rather than for components in Horizontal (x,y) or Vertical (z) directions. Analyses and tests indicate dominant horizontal with lesser vertical contribution. The coverage for total field is shown in Fig. 3 for a multi-band dielectrically loaded L-antenna where pattern diversity combining has been used to indicate the total coverage contribution from each antenna. Note that 90% coverage is available with a provided gain above –4 dBi. If the vertical field component is considered, only 40% coverage is achieved at the same gain threshold and a maximum of 80% coverage is available at –10dBi.

Multi-band slot antennas or broadband monopoles have been devised to provide a greater vertical field component [1,2,3] and some industry leaders have driven more complex pattern diversity configurations.

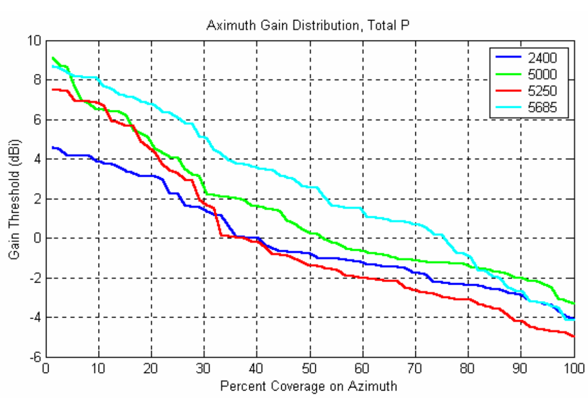

Figure 3.  Percent AZ-coverage versus gain threshold (total field)

Range measurements for a similar configuration are shown in Figure 4 illustrating the utility of a pattern-diversity combining scheme.

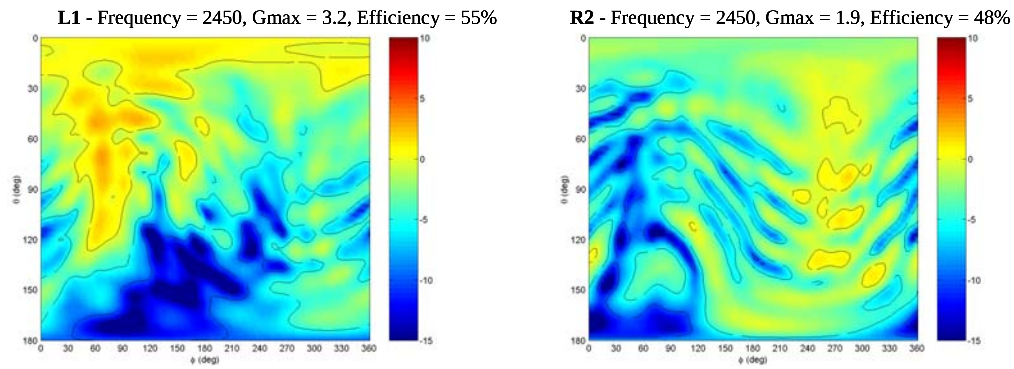


Figure 4.  Measured Right and Left Antenna Far Field Patterns (total field)

Manufacturing considerations suggest designs that are suited for rapid integration into a variety of platforms with minimal impact due to detuning effects from nearby objects either in assembly or use.  In order to achieve this degree of reliability, some manufacturers have opted for broadband or reconfigurable antennas with integrated radio chipsets and these are expected to gain favor in future applications.

**References:**

[1] Zinati, M. and R. Bancroft, " Independently Tunable Dual-Band Slots for 802.11 and WLAN Bands," Antennas Systems and Short range Wireless Proceedings, Denver, Oct. 6, 2004.
[2] Behdad, N, and K. Sarabandi, "Dual Resonator Slot Antennas for Wireless Applications," IEEE AP-S Int. Symp. Digest, Monterey, California, June 20-25, 2004.
[3] SkyCross, Inc. www.skycross.com