Chapter 6

Variations of the WC J-Pole for a Few Commercial Applications

6.1 Introduction

In the previous chapter, the WC J-Pole antenna was analyzed and detailed parametric investigations on the antenna impedance characteristics showed that the antenna operating frequency and bandwidth can be easily tuned by adjusting the size parameters. There are two antenna resonances that can occur close to each other, forming an overall wide operating band that can cover applications ranging from 1500 to 2500 MHz or for future applications in a portion of the ultra-wide band from 3 to 5 GHz [1]. The antenna dimensions can be adjusted for dual-band applications, as we discuss in this Chapter.

6.2 Wideband Compact Antenna for Covering Applications from GPS to Bluetooth Bands (WCJP #1)

Figure 6-1 shows dimensions of a version of the WC J-Pole antenna for an operating frequency band covering from GPS (1570 MHz) to Bluetooth (2500 MHz) bands (WCJP #1). The impedance match and gain characteristics were calculated over the complete band from 1500 to 2600 MHz and are plotted in Figs 6-2 and 6-3. A VSWR value below 2 is commonly accepted for determining the impedance bandwidth for antennas in personal wireless devices. Figure 6-2 shows that the antenna has an acceptable impedance bandwidth of 990 MHz (49 %) extended from 1.525 GHz to 2.515 GHz for a 2:1 VSWR, which covers from the GPS to the Bluetooth bands. The computed gain data in Fig. 6-3 shows that the gain is very stable over its full impedance bandwidth.

There are a large number of uses for this wideband antenna in personal wireless applications. Mobile phones, personal digital assistant devices (PDAs), and laptop computers are the potential applications. Tremendous importance is also given in the United States, as well as in Europe to the development of third-generation (3G) wireless personal communication systems. These systems are known as IMT-2000, or UMTS in Europe; the frequency bands are shown in Table 6-1. Transition from analog personal radios using the AMPS band at 800-900 MHz to digital radios (2G) at 1900 MHz PCS band require wireless phones to operate in both bands. Likewise, the transition from 2G to 3G personal radios will require systems, and therefore antennas, to operate in PCS band as well as IMT-2000 band. Therefore, the WCJP #1 is a good candidate for such a transition.

New applications are arising that will be included in mobile phones. One prominent example is Bluetooth. Applications using the Bluetooth (2400-2483 MHz) band include: wireless headsets for mobile phones, synchronization of mobile phones and PDAs with desktop computers and laptops, mobile phones in a handheld remote device to control other Bluetooth-enabled appliances. Another prominent area of interest in the next generation of wireless personal communication systems is the integration of GPS in phones. This market will be bustling with activity in the next few years because of the FCC's mandate that requires all mobile phone manufacturers to include position location feature in the so called E911 specification. This feature allows 911 operators to pinpoint a mobile phone user's location through GPS technology.

Table 6-1 Frequency Bands for a Few Wireless Applications.

Wireless Applications	Frequency Band (MHz)	Bandwidth (MHz)
GPS	1570.42-1580.42	10 (0.7%)
DCS-1800	1710-1880	170 (10.6%)
PCS-1900	1850-1990	140 (7.3%)
IMT-2000/UMTS (3G)	1885-2200	315 (15.5%)
ISM (including WLAN)	2400-2483	83 (3.4%)
Bluetooth	2400-2500	100 (4.1%)
U-NII	5150-5350 / 5725-5825	200 (3.8%) / 100 (1.7%)

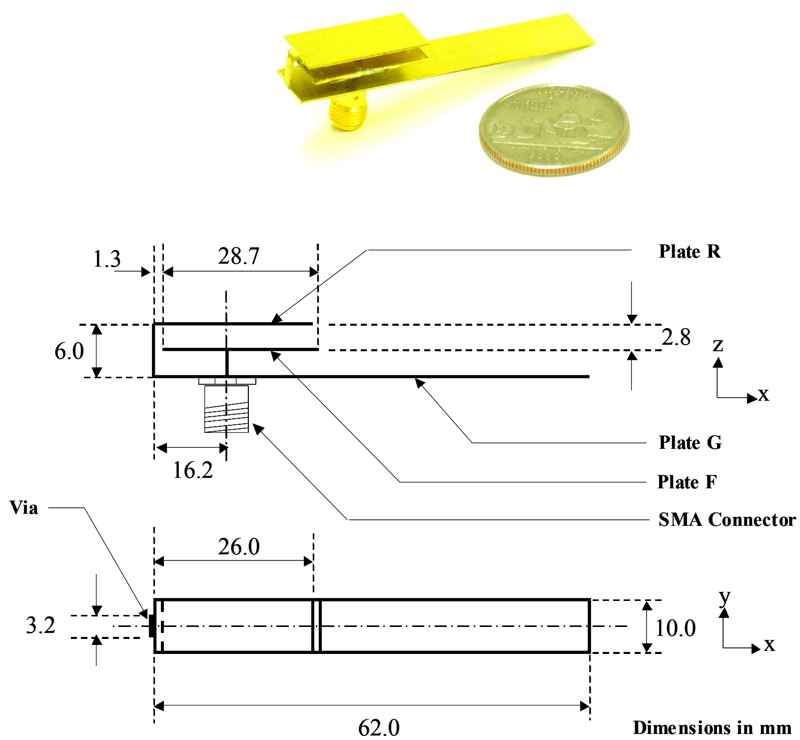


Figure 6-1 Wideband compact J-pole antenna (WCJP #1) designed to cover frequency bands from GPS to Bluetooth bands.

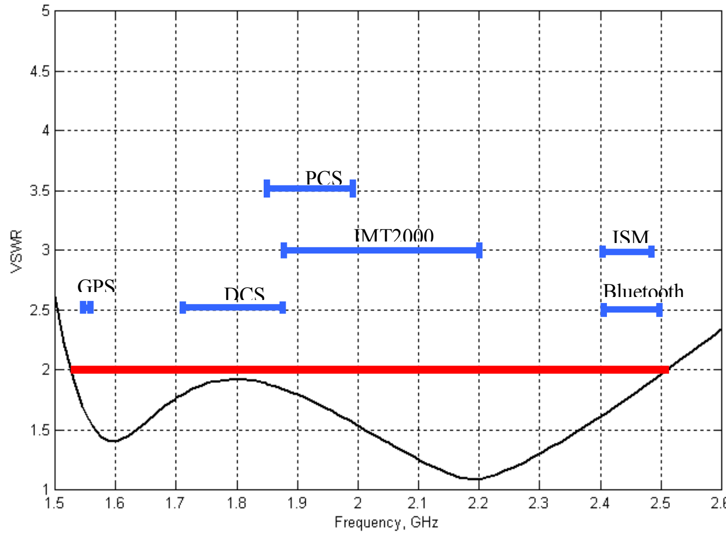


Figure 6-2 VSWR values computed using IE3D for the WC J-Pole of Fig. 6-1 relative to 50-Ohms. Note an impedance match (VSWR≤2) is achieved for the frequency bands of interest.

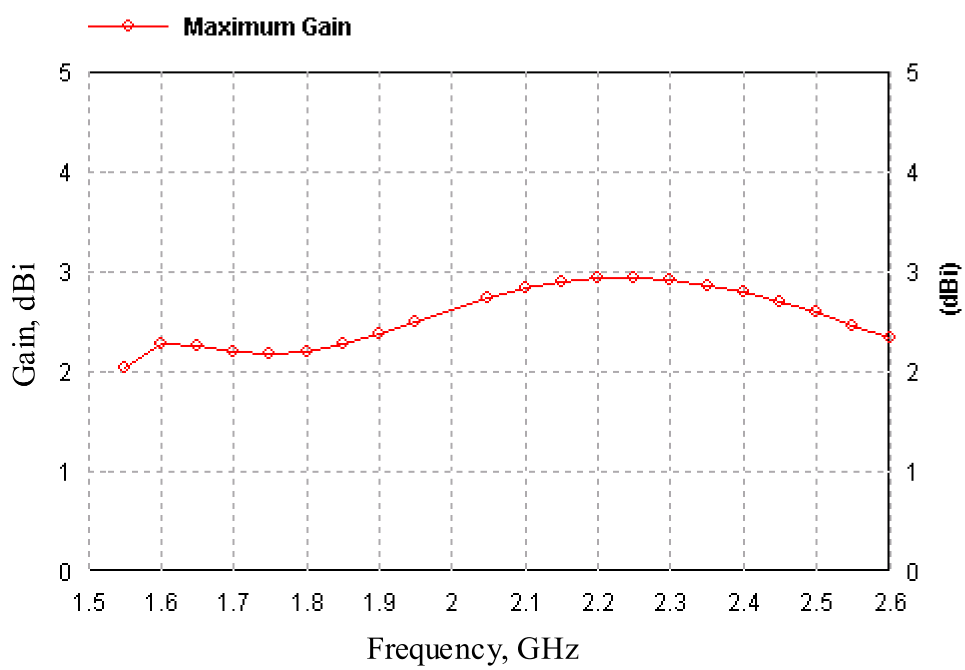


Figure 6-3 Computed values of maximum gain over the WCJ-Pole operating band.

The proposed wideband antenna is a very good candidate for use in many applications with future mobile phones, PDAs, and laptop computers because it offers a single antenna solution.

6.3 Dual-Band Compact Antenna for Personal Wireless Communications, Bluetooth, and U-NII bands (DCLA #1)

The geometry of the proposed dual-band compact low-profile antenna (DCLA #1) is shown in Figure 6-4. The structure is a WC J-pole except that the dimensions are different and an extra parasitic element is added. Note that the feed plate is partially covered by the top plate. The analysis in the previous chapter showed that a resonance occurs in the 5-GHz region due to radiation of the feed plate portion unshielded by the top plate. A parasitic rectangular plate is added to the structure at the same height as the feed plate. This extra parasitic plate creates a resonance at the 5-GHz band.

Figure 6-5 depicts the computed and measured impedance of the antenna and shows that there are two very wide bands with return loss below –10 dB (or 2:1 VSWR), one from 1.83 GHz to 2.52 GHz (31.7 % bandwidth) and the other from 5.05 GHz to 5.39 GHz (6.5 % bandwidth). The lower band of the antenna can cover then the following bands in use today: PCS-1900, IMT2000, UMTS, ISM, WLAN, and Bluetooth bands. The other band of the antenna covers two of the three 5 GHz unlicensed national information infrastructure (U-NII) bands, which spans from 5.15 GHz to 5.35 GHz.

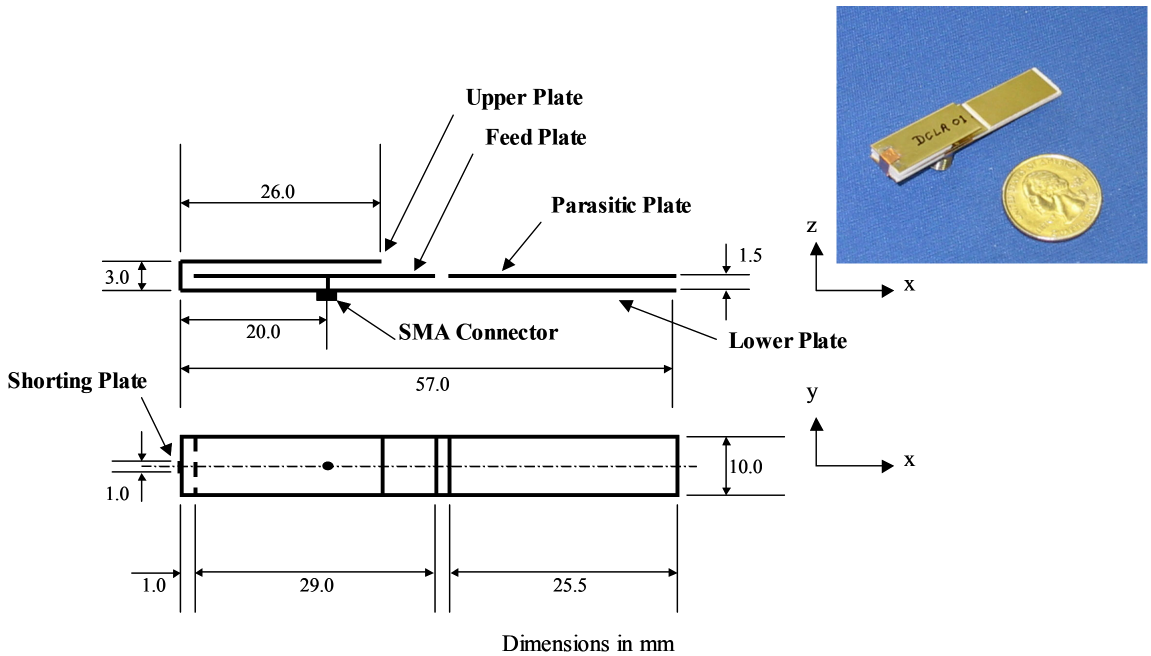


Figure 6-4 Geometry of the dual-band compact antenna and its prototype (DCLA #1).

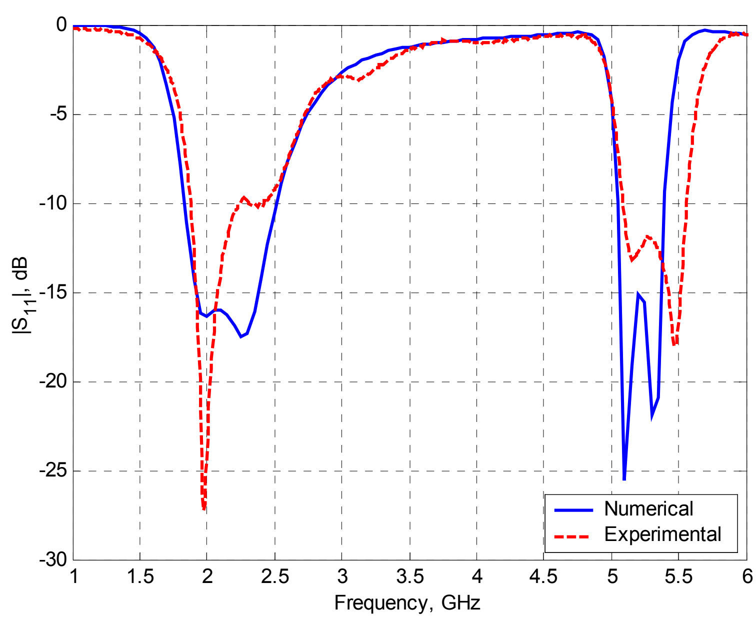


Figure 6-5 Computed and measured $|S_{11}|$ of the dual-band compact antenna of Fig. 6-4. A 10-dB return loss (-10 dB S_{11}) corresponds to a 2:1 VSWR.

Radiation patterns, gain, and radiation efficiency of the antenna were also measured and are shown in Figures 6-6 to 6-8. The radiation patterns in Fig. 6-6 show an omni-directional pattern behavior. Figure 6-7 shows that the gain is about 2.5 dBi in the 2-GHz band and 6.5 dBi in the 5-GHz band. Figure 6-8 shows that the radiation efficiency in the two bands is about 85 %. Omni-directional pattern, a gain above 2.5 dB, and a radiation efficiency of 80 % are considered good performance for antennas used in handheld wireless devices.

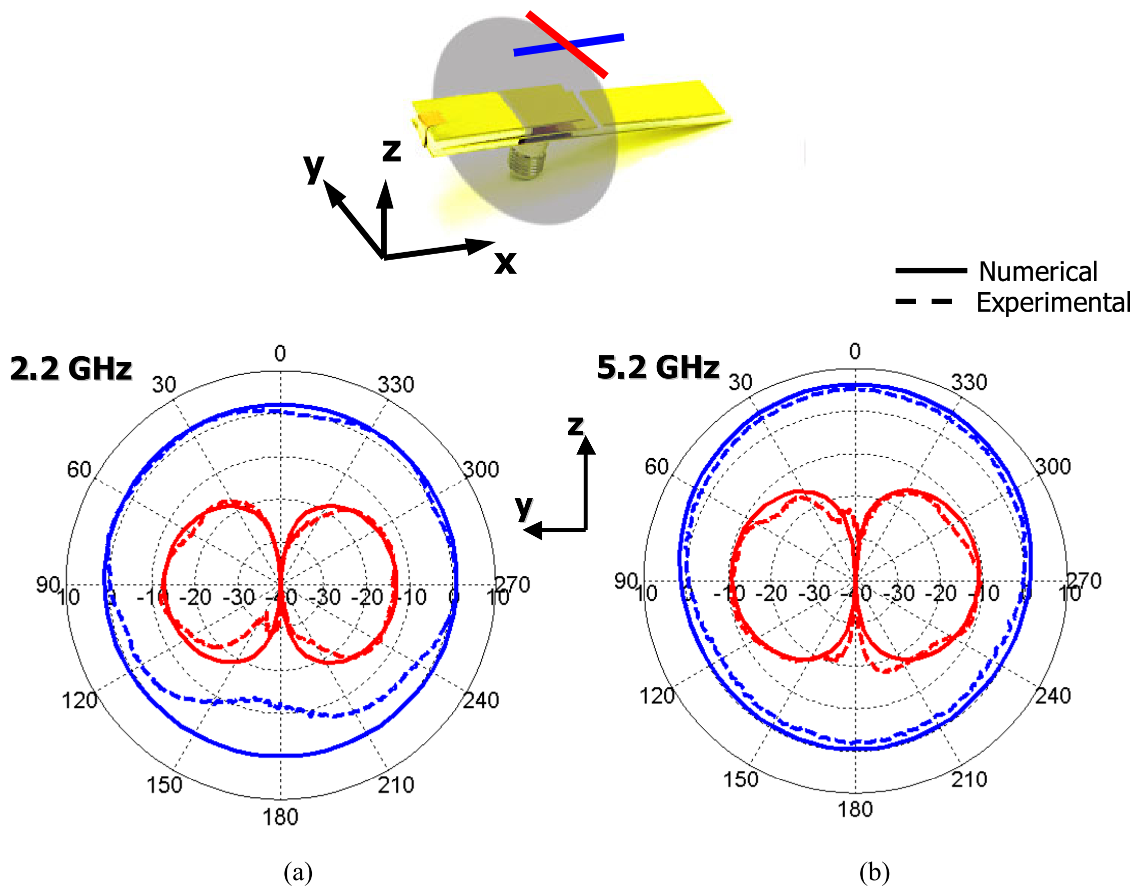


Figure 6-6 Computed (solid curves) and measured (dashed curves) radiation patterns of the dual-band compact antenna of Fig. 6-4 in the frequency bands of interest in the yz plane for both E_θ (red curves) and E_ϕ (blue curves) cuts: (a) 2.2 GHz and (b) 5.2 GHz.

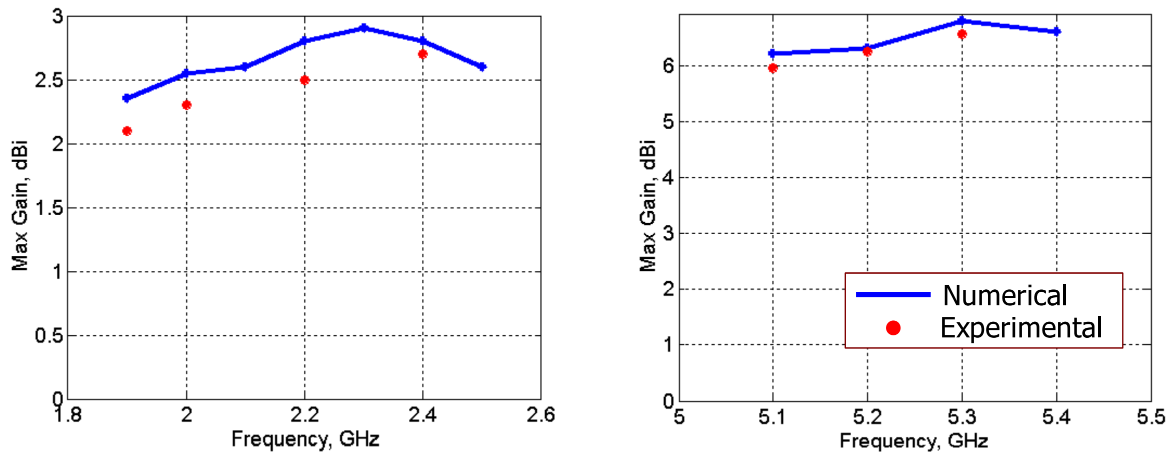


Figure 6-7 Computed and measured gain of the dual-band compact antenna of Fig. 6-4.

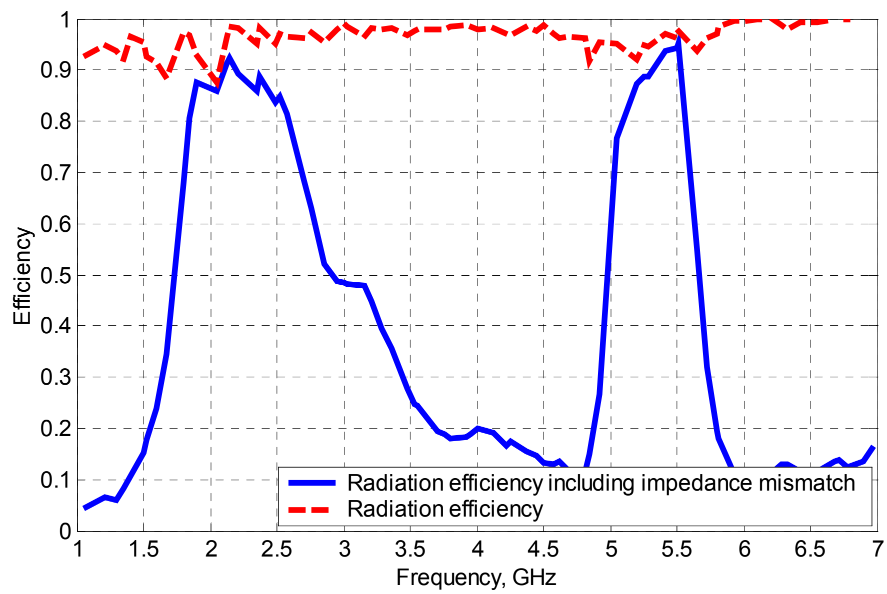


Figure 6-8 Measured radiation efficiency of the dual-band compact antenna of Fig. 6-4 using the wideband Wheeler cap method described in Chapter 3.

This dual-band, compact, low-profile antenna (DCLA) was developed to be embedded in wireless fixed and mobile devices and is ready to be introduced into future systems including third-generation personal radios, Bluetooth third-party, and wireless LAN applications. The improvement of this antenna over other dual-band antennas is that its two bands are very wide, while the size of the antenna remains small. In fact, this antenna covers the current 2G- as well as the 3G-system frequency bands, from 1.83 to 2.52 GHz. This wide coverage of the antenna lower operating band can help the 2G-to-3G personal radio transition go smoothly. In addition, the DCLA can also be used in the 5-GHz U-NII bands (5.15-5.25 GHz and 5.25-5.35 GHz bands), including the ISM band, which is the useful band for the next generation of wireless LANs. Wireless devices that cover both of these bands simultaneously are in commercial development.

6.4 Dual-Band Compact Antenna for 2.45/5.25 GHz WLAN (DCLA #2)

In this section, a variation of the previous dual-band antenna (DCLA #1) is presented for WLAN applications. Figure 6-9 shows this WLAN dual-band version of antenna (DCLA #2a). The dimensions of this promising design are 4.5 by 4.5 by 40 mm^3. It is smaller than the DCLA #1 shown in the previous section. This design was found from simulation trials using IE3D method of moments code. The return loss of this simulation is show in Fig. 6-10. However, during the experiment phase, a coax cable built to feed the antenna because the antenna is too small to solder the SMA connector directly onto it. Therefore, the simulation should include this coax cable in the design. Figure 6-11 shows the effect of the coax cable that was built onto the antenna by comparing the measured return loss of antenna with the coax cable and numerical return loss of the antenna excluding the coax. Obviously the detuning effect due to the coax is not negligible.

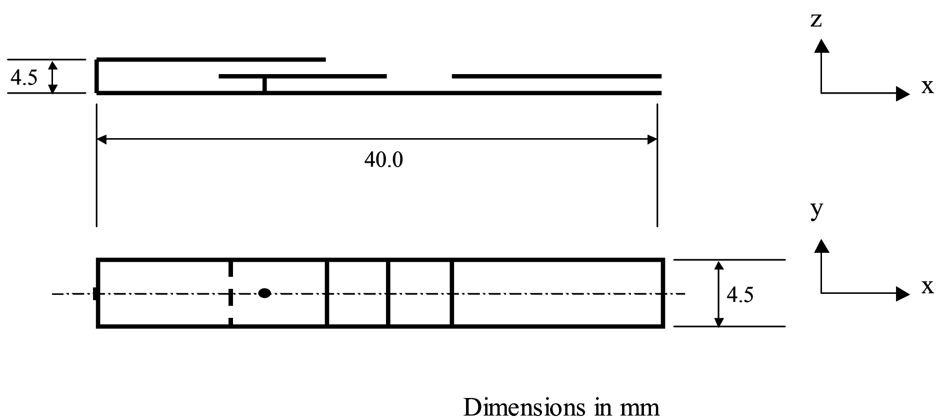


Figure 6-9 Overall dimensions of the DCLA #2a structure for WLAN used in IE3D simulation.

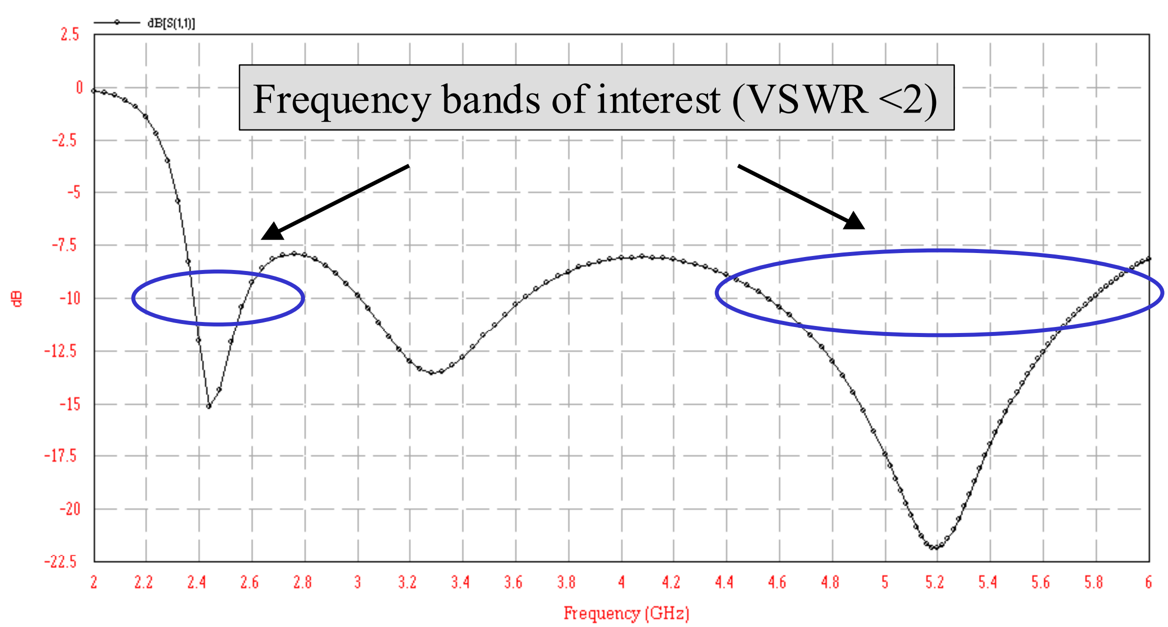


Figure 6-10 Computed return loss of the DCLA #2 for WLAN shown in Fig. 6-9.

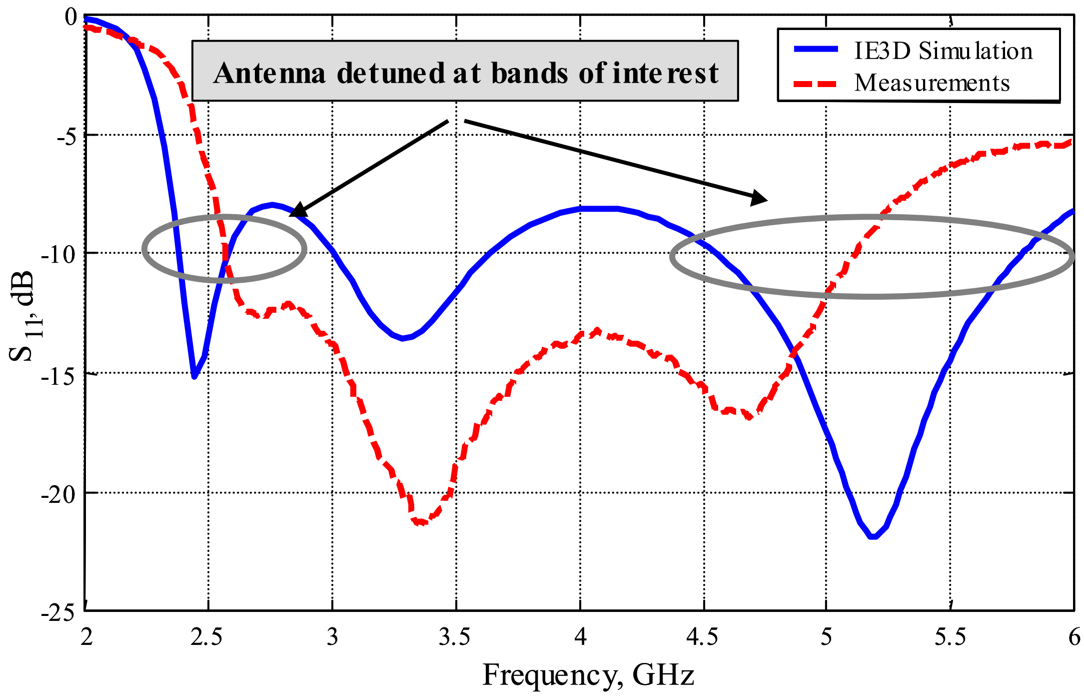
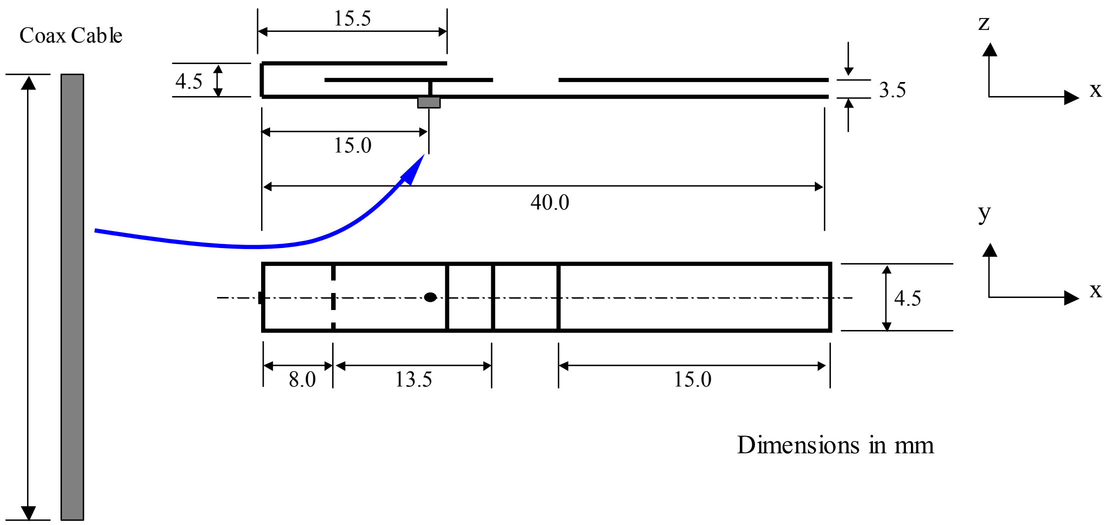


Figure 6-11 Comparison of the measured $|S_{11}|$ values of the DCLA #2a built with a coax cable and the numerical results of DCLA #2a without the coax simulated using IE3D.

The antenna was simulated using a second code, an FDTD simulation software package, Fidelity, for the model including the coax cable (DCLA #2b) and was tuned to compensate the detuning effect due to the coax. Figure 6-12 shows the dimensions of the antenna with the coax included and Fig. 6-13 shows the measured and numerical return loss of the antenna with the coax attached. The reasons to go through this process of adjusting the structure of this antenna are to show the confidence between the numerical and measured values of return loss and that the antenna can be easily adjusted to adapt to the environment.



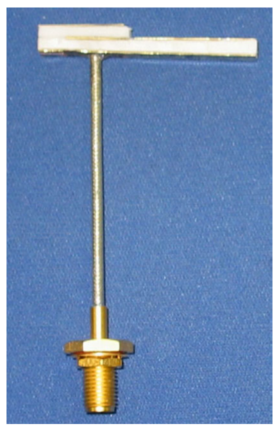


Figure 6-12 Dimensions of the DCLA structure for WLAN (DCLA #2b) including the coax cable and tuned to compensate the detuning coupling effects due to the coax.

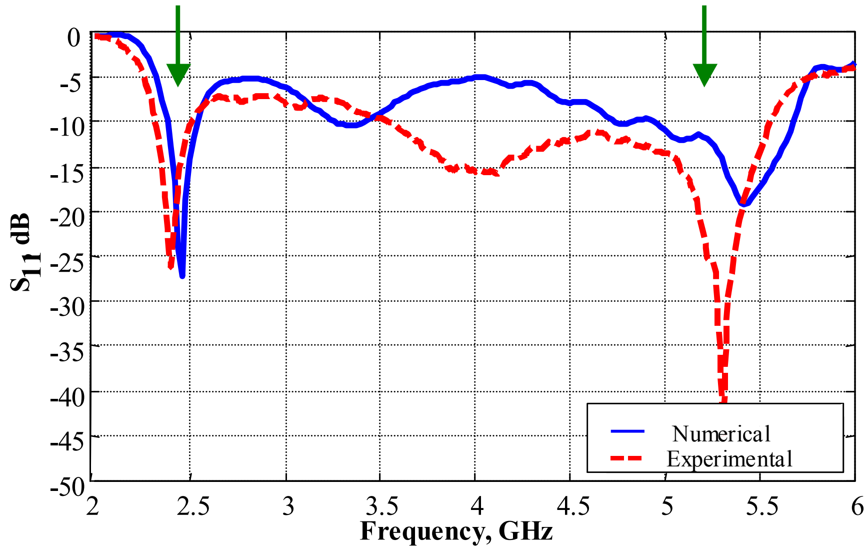


Figure 6-13 Numerical and measured return loss of the dual-band antenna shown in Figure 6-12 with the coax cable attached.

The DCLA #2 is a potential candidate for WiFi applications such as laptop computers. Most of the next generation laptop computers will have WiFi capability embedded. Because of its size and shape, the DCLA #2 can be easily embedded into the laptop computer. Figure 6-14 illustrates a good antenna placement into the laptop. This configuration enables spatial diversity that will improve signal reception and communication performance.

Figure 6-14 Example of antenna placement for the DCLA #2 in laptop computers that are WiFi enabled.

6.5 Summary

A few versions of the WC J-Pole antenna were presented for some personal wireless commercial applications. The antenna structure dimensions were adjusted to meet specific commercial operating bands. One design is a wideband antenna that covers an operating band ranging from 1525 to 2515 MHz. It can be used for wireless systems that need GPS, personal communication service, WLAN, and third-party device interaction, all in one device. The other two designs are dual-band antenna. One is for WLAN-specific systems using both 2.4 and 5-GHz and the other has a large operating band from 1.83 to 2.52 GHz and another band from 5.05 to 5.39 GHz. Numerical and experimental results were in good agreement.