NOVEL DUAL-BAND WLAN ANTENNAS WITH INTEGRATED BAND-SELECT FILTER FOR 802.11 a/b/g WLAN RADIOS IN PORTABLE DEVICES

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ABSTRACT: Novel dual-band WLAN antenna system with integrated band-select filter is designed. This integrated antenna design system provide VSWR <2:1 for both 2.4–2.5 GHz and 4.9–5.85 GHz with omni-directional radio patterns. Based on these features, a novel architecture for a dual-band WLAN radio Front-End in portable devices can be achieved. © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1868–1872, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22601

Key words: WLAN antenna design; WLAN front-end circuit design; WLAN filter design

1. INTRODUCTION

Recent advancements of wireless local area network (WLAN) technology extend its application from traditional computer networking to many other applications. The new applications of WLAN are multimedia distributions, voice on Internet protocol (VoIP), security systems, etc. The major differentiation between WLAN and traditional wired LAN solutions is mobility. Therefore, increasing number of WLAN applications are now embedded in portable devices. Because of the popularity of WLAN applications, single band WLAN radios seem insufficient to meet these fast-increasing demands.

In this article, novel dual-band antennas, printed F and printed dipole antenna, with integrated band-select filter are presented. The designed integrated filter provides not only signal separation but also the impedance transformation between the 50-ohm output port of a radio front-end circuitry and the input port of the antennas. This impedance transformation feature increases the high band impedance bandwidth of the original printed F antenna design by >100%. This integrated antenna design systems provide VSWR <2:1 for both 2.4–2.5 GHz and 4.9–5.85 GHz with omni-directional radiation patterns. These features simplify the radio design task and increase the radiation efficiency of a dual-band WLAN radio. Based on these features, a novel architecture for a dual-band WLAN radio Front-End in portable devices can also be proposed. Comparing with the traditional dual-band architecture as shown in Figure 1, the proposed architecture in Figure 2 is based on a band-select antenna provides a higher integration in the front-end active circuits, which leads to a smaller form factor for portable devices. The proposed antenna system can significantly simplify the traditional dual-band front-end (Fig. 1) into a more easily integrated dual-band front-end design (Fig. 2).

2. ARCHITECTURE

The conventional topology for a dual-band wireless LAN radio is shown in Figure 1. The front-end circuit consists of two antennas, a double pole double throw (DPDT) switch, TX and RX diplexers, and PAs and LNAs. Recent technologies allow the dual-band transceiver and base-band circuits built in a single package or dual packages.

Recent trends of portable devices are concentrating on incorporating WLAN capability. For most portable devices, it is difficult to implement the diversity antenna as Figure 1 due to limited space resulting in insufficient space for special diversity and high coupling between antennas [1]. In addition, some portable devices like PDA, cellular phones, and portable data processors may have more than one integrated radio. Therefore, single antenna dual-band radio is a more practical solution for portable electronic devices. Figure 2 is a proposed topology for a dual-band WLAN radio in portable devices. The front-end circuit consists of an antenna, diplexer, two single-pole double throw (SPDT) switches, and two PAs and two LNAs. The uniqueness of this topology is that there is only one diplexer used in the front-end circuit. The switches, LNAs, and PAs can be easily integrated into one or two devices. In addition, the diplexer can be integrated with antenna, which becomes a band-select antenna. Therefore, the entire radio front-end can be achieved by a band-select antenna and a dual PA/LNA module with integrated SPDT switches.

3. DESIGN

3.1. Printed Dipole Antenna Design

A modified printed dipole antenna is designed to support wideband operation. The dipole antenna is realized on a Rogers RT/Duroid 6010 substrate with 10.2 dielectric constant, 0.0023 tangent loss, and 1.27 mm thickness. Figure 3 illustrates the layout of the designed antenna and the dimensions optimized for a wideband operation between 2.1 and 6.4 GHz as simulated by an FDTD program. Antenna is etched on a 60 mm × 54 mm substrate, and return loss measurement is performed using a vector network
Figure 3 Printed dipole antenna dimensions in millimeters. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 4 Simulated and measured return loss of the dipole antenna. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 5 Printed F antenna dimensions in millimeters. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 6 Printed F antenna measured return losses. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

analyzer. Figure 4 shows the measured return loss compared to the simulated return loss. The fabricated antenna operates between 2 and 6.6 GHz showing a good match with the simulated return loss. Radiation patterns of the printed dipole antenna are measured for the \( xy \), \( xz \), and \( yz \) principle planes at 2.4 and 5.8 GHz. The measured radiation patterns show good omni-directional properties required for such applications.

3.2. Printed F Antenna Design

A printed F antenna (PIFA) [2] is designed to support dual-band operation. The antenna is realized on a Rogers RT/Duroid 5880 substrate with 2.2 dielectric constant, 0.0009 tangent loss, and 0.787 mm thickness. Figure 5 illustrates the layout of the designed antenna, and the dimensions of the fabricated antenna, which is etched on a 40 mm \( \times \) 40 mm substrate. The return loss measurement plotted in Figure 6 shows that the fabricated antenna operates at the frequency bands 2.4–2.62 GHz and 5.45–5.8 GHz. The measured radiation patterns of the antenna are shown in Figure 7 for the \( xy \), \( xz \), and \( yz \) principle planes at 2.4 and 5.8 GHz with good omni-directional characteristics.

3.3. Band-Select Filter Design

The diplexer design for the band-select antenna design need to not only separate the high band and low band signal from or to antenna, but also perform impedance transformation between antenna and external circuits. The circuit topology is shown in Figure 8, where L1 to L3 can be constructed by connection bond-wires and C2 is the DC block for the filter. Both series L-C resonators at low and high band paths perform a short circuit at the opposite band. The series L-C resonator at the in-band frequency of the path is either capacitive or inductive shunt component. For the high
band path, at high band frequency the resonator is equivalent to a shunt inductor, which is in series with C1 to perform impedance matching between the high band input port and the common port. Similar principle is applied to the low band design.

The diplexer is built on a passive silicon substrate with the size of $1.2 \times 0.97 \times 0.2 \text{ mm}^3$. The design is optimized with ADS Momentum, which is based on the method of moments [3] and is validated with measurement. The die photo and the comparison between measurement and simulation are shown in Figure 9. Excellent agreements were found between measurement and simulations. The insertion loss of low band is 0.7–0.8 dB and the insertion loss for high band is around 0.8–1.2 dB.

3.4. Integration

Because the diplexer size ($0.97 \times 1.2 \text{ mm}^3$) is relatively small compared with the size of the antenna, the diplexer is implemented at the interface of the antenna feed. At the antenna input, a $1.5 \times 2 \text{ mm}^2$ slot is generated between the antenna and the input transmission line for the filter die pedestal. The interconnections between the diplexer, the antenna, both the low and high band transmission lines are achieved by 1.3 mil gold bond-wires.

4. PERFORMANCE

In the previous sections, the design of the antenna, diplexer, and the method of integration were presented. The diplexer is cascaded
Figure 8  Topology of diplexer with impedance transformation. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 9  Comparison between measured (symbol) and simulated Insertion loss of the diplexer. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 10  Comparison between the bandwidth of the original printed F antenna (line with symbol) and the bandwidth of band-select antenna system (line). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 11  Insertion loss of band-select printed F antenna with the renormalization of the antenna input impedance. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 12  Comparison between the impedance bandwidths of the original printed dipole antenna (line with symbol) and the band-select printed dipole antenna system (lines). [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]

Figure 13  Insertion loss of band-select printed dipole antenna with the renormalization of the antenna input impedance. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com]
A PLANAR BANDPASS FILTER USING BUTTERFLY RADIAL STUB

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ABSTRACT: A bandpass filter using a single-slotted butterfly radial stub connected in shunt with a short-circuited section of a microstrip transmission line is proposed. A two pole filter based on the proposed structure has been designed, analyzed, and fabricated. A good agreement between the measured and the simulated results is observed. © 2007 Wiley Periodicals, Inc. Microwave Opt Technol Lett 49: 1872–1875, 2007; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.22600

Key words: bandpass filters; microstrip filters; microwave filters; passive filters

1. INTRODUCTION

Bandpass filters are essential components in most of the microwave communication systems. These are used to pass the desired signals while suppressing the spurious frequencies. In these systems, the RF front-end requires low loss, compact, and lightweight filters to enhance the overall system performance. These filters can be designed and fabricated in various forms using various types of resonators. Planar filters in microstrip or similar form are particularly attractive because of their smaller size, ease of fabrication, low cost, and lightweight. The rapid growth of mobile and wireless communication systems has led to an increasing demand for such miniaturized filters since most of modern microwave systems have a limited space.

Several planar filter designs satisfy the above requirements; however, their out-of-band performance is often limited due to the periodic nature of the resonator elements of the filter. For example, a bandpass filter made of half wavelength long sections of transmission lines has a second passband appearing approximately at twice the fundamental frequency [1]. Cascading additional bandstop filters is the most straightforward method to suppress the harmonics. However, this would also increase the insertion loss in the passband and the overall circuit size [2].

Various forms of planar microstrip bandpass filter using compact resonators like stepped impedance resonator [3], hair pin resonators [4], net type resonator [5], and open loop resonators, etc., have been proposed to improve the out-of-band performance as well as make the filter compact. Recently, a miniaturized ring filter using four equally spaced butterfly radial stubs with local ground defects was proposed [6]. The etched slots in the ground plane, however, need extra fabrication efforts.

Generally, a radial stub and its variant, viz., butterfly radial stub, have been used for bandstop applications such as a bias-T [7]. In this paper, we present a miniaturized bandpass filter using resonators formed by butterfly radial stubs. The attractive features of the proposed design are simplicity in construction, wide band performance, suppression of the second mode, and moderate suppression of spurious response up to 3.75 times the fundamental centre frequency.

2. PROPOSED RESONANT STRUCTURE

The shape of the proposed structure resembles a butterfly radial stub. It is formed from a butterfly radial stub of radius \( R_0 \) and vertex angle \( \alpha \), which is connected to a transmission line of width \( W \) and length \( L \). The ends of the transmission line are shorted to the

with antenna to construct a band-select antenna. The comparison between the bandwidths of the original and the band-select printed F antenna system is shown in Figure 10. At the high band path of the band-select printed F antenna, the impedance matching between the high band input and the antenna input is significantly improved. Comparing with the original bandwidth of 5.45–5.8 GHz, and the bandwidth of the band-select antenna is found more than doubled, 5.15–6.19 GHz.

This impedance matching effect is further validated by the measurement of the filter insertion losses of each path with the renormalization of antenna input impedance. At low band, the renormalized insertion loss is less than 1 dB, which is in-line with the measurement in Figure 11. The insertion loss at the band-edge of the impedance bandwidth is found 1.67 dB, slightly higher than the 0.9–1.0 dB at the mid-band frequency. The 1.67 dB insertion loss is from 0.46 dB of mismatch loss and 1.21 dB from filter attenuation. Comparing with the 3–4 dB mismatch loss at these frequencies of the original antenna, the impedance transformation effect of the filter is proven.

The diplexer is also implemented with the printed dipole antenna. Because the printed dipole antenna was designed for wide impedance bandwidth, the effects of the impedance transformation were not found significant as shown in Figure 12. The main advantage of this design is that it completely covers the required bandwidth of 2.4–2.5 GHz and 4.9–5.85 GHz for 802.11 a/b/g wireless LAN applications. The renormalized insertion loss of the new design is shown in Figure 13.

5. CONCLUSION

In this article, novel band-select antenna systems are presented. Both can not only simplify the dual band WLAN front-end design into a novel topology for portable device application, but also provide better impedance matching between the front-end circuit and antenna. In addition, the proposed design can also perform impedance transformation, which significantly increases the radiation efficiency. All these features provide the easiest integration of dual-band WLAN radio into modern portable devices.

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