Modified Printed Dipole Antennas for Wireless Multi-Band Communication Devices

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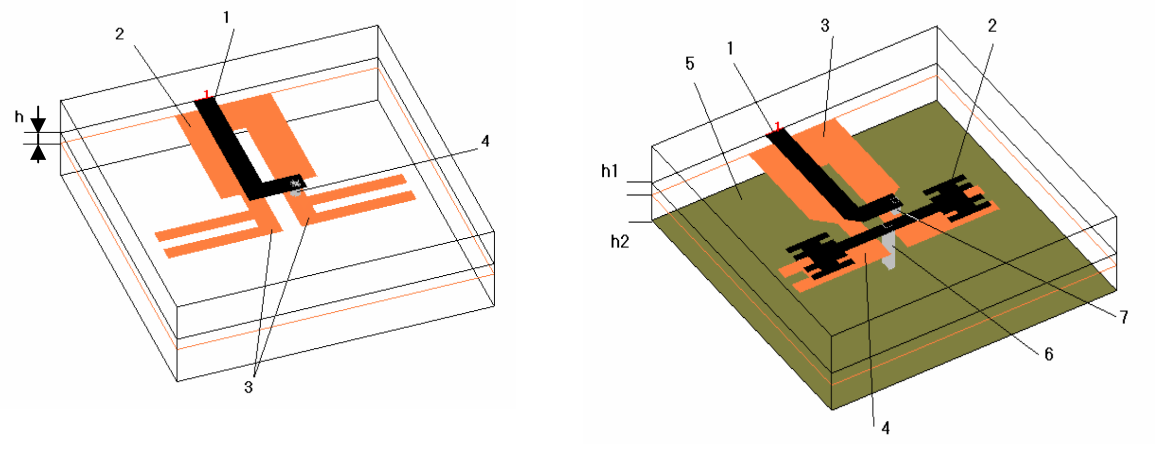
Abstract: The trend in the wireless mobile industry is to aggregate multiple communication protocols in a single device. With the new Digital Signal Processors (DSP) capable of executing over 10 billion instructions per second, currently it is possible to run multiple communication protocol on the same platform [1] . The limiting factors in designing multi-protocol communication devices are the antenna and the Radio Frequency (RF) front end. The subject of this paper is the antenna. A multi-band omni-directional printed antenna is the most attractive solution for this purpose, from both cost and manufacturability. In this paper, starting with the micro-strip printed dipole, by adding additional layers, we derived two antennas, a Modified Printed Dipole Omni-directional and a Modified Printed Dipole Directional antenna, where the last one is very similar to a double Planar Inverted-F Antenna (2-PIFA). With no loss of generality, the frequency bands covered in the design example are the WLAN bands at: 2.4-2.487, 5.15-5.25, 5.25-5.35 and 5.74-5.825 GHz. The multi-band antenna is part of the Sandbridge Technologies Software (SW) defined radio design platform described in [4]

Introduction

Designing a new better antenna usually assumes three possibilities: 1. a variation of an existing design, 2. a combination of features of two or more antenna types, 3. an entirely new idea [2] . In the following we present a multi-band antenna design based on the second criteria. The oldest of all the antennas is the isotropic dipole. The gain of the isotropic dipole is 2.2 dB and it is omni-directional. In mobile wireless communication devices there is a need for omni-directional antennas, like the isotropic dipole but with higher gain and low cost. In micro strip technology the closest to the dipole is the printed dipole antenna. The shape of the printed dipole is a narrow rectangular strip with width less than 0.05 λ_0 and total length less than 0.5 λ_0, where λ_0 is the resonant frequency. The theory of the printed dipole is completely described in the literature [3] . Besides gain and directionality, if the hand held device is designed for multiple communication protocols than the same antenna must be able to cover multiple frequency bands. Above all this, the antenna has to be as less disturbed as possible by the presence of the human body and ground planes. In order to meet all this requirements we propose the two antennas mentioned in the abstract.

Antenna Description

The Modified Omni-Directional Printed dipole antenna is illustrated in Figure 1 a.



(a) (b)

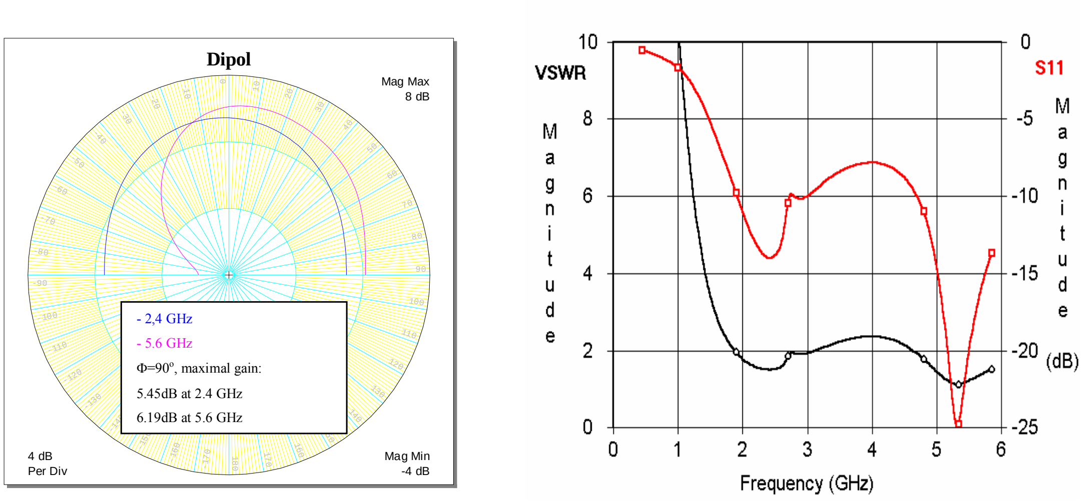
Figure 1 a. Omni-Directional Modified Dipole, 1. ML, 2. CSP, 3. Split Dipole (2 strips), 4. Short ML to CSP.
b. Directional Modified Dipole 1. ML 2. Directive Dipole 3. CSP balloon 4. Split Dipole 5. Ground Plane 6. Shorting of the Directive Dipole to the ground. 7. Shorting ML to CSP.

The antenna structure consists of two conductive layers, first is the Micro-strip Line (ML) and the second is the split dipole and Coplanar Strip (CPS) balloon line – with a shorting via at the end of the ML. Between the conductive layers there is a dielectric substrate with permittivity ε_{r1}. The overall dimensions of the antenna will depend on the ε_{r1} value, in the sense that the size will decrease with the increase of ε_{r1}.

The novel characteristics of this antenna can be enumerated as:

1. The geometric shape is obtained by splitting the classic dipole in 2 or more conductive strips following the general printed dipole conditions, strip width less than 0.05 λo, and the total length less than 0.5 λo. The splitting will increase the total gain by reducing the surface wave loss and the loss in the conductive layer. On the other hand, the number and the shape of the conductive strips also affect the bandwidth of the antenna. A certain number of "via holes" (not shown in the figure) are added around the dipole. As a result, the loss caused by surface waves and radiation in the dielectric substrate are reduced (pseudo photonic crystal [5]).

2. The antenna feed is realized using a balloon from ML to coplanar strips CPS. The ML is connected to one strip of CSP via a conductive shorting pin at the end of the ML. In this arrangement the position of the shorting pin and the slot of CPS are very sensitive to the antenna performance related to the gain "distributions" in the frequency bands. The goal is to have approximately the same gain in all frequency bands. In the Figure 2 a and b are presented the directivity gain and, VSWR and S11 as function of frequency, for the 2.4 and 5.4 GHz bands.



(a) (b)

Figure 2 a. Directivity gain for the 2.4 and 5.6 GHz frequency bands. b. VSWR and S11 as a function of frequency.

The theoretical gain obtained this way has 5.7 dB for the 2.4 GHz frequency band and 7.5dB for the 5.4 GHz band.

By adding a third layer to the omni-directional antenna, we obtain a Modified Directional Dipole Antenna as depicted in Figure 1 b. The goal, by adding the third layer, was both to reduce the influence of the human body (hand) and/or ground planes and to increase the gain. The geometric configuration consists of three conductive layers: first is the ML and the directive dipole, the second is the split dipole and the CPS balloon line with shorting via at the end of ML and, the third is the reflective ground plane. The directive dipole is shorted to ground through the shorting via. Between the first two layers the dielectric permittivity ε_{r1} is much higher than ε_{r2} the dielectric permittivity between the second and the third layer. The height of the second layer h_2 is twice the size of the first layer h_1.

The novel characteristics of this second antenna can be enumerated as:

1. The geometric shape of the dipole, the inner layer, is obtained by splitting the classic dipole in 2 or more conductive strips as described before. As described before, the number of slits and the depth of the slot will affect the bandwidth at high frequencies, while the length of the dipole will affect the lower frequency band.
2. The shape of the directive dipole, the upper layer, is a derived PEANO3 fractal shape [6] ; it increases the total gain by reducing the surface waves and the loss in the conductive layer. The number of conductive strips has effect on the high frequency bandwidth while the length of the dipole is sensitive to the lowest frequency band.
3. A number of via holes around the dipole (not shown in the figure) will increase the total gain by reducing the surface waves and radiation in the dielectric material.

The performance of the final antenna is shown in Figure 3. It can be seen that the total gain for the two frequency bands are 8.29dB at 2.5 GHz and 10.5 dB at 5.7 GHz.

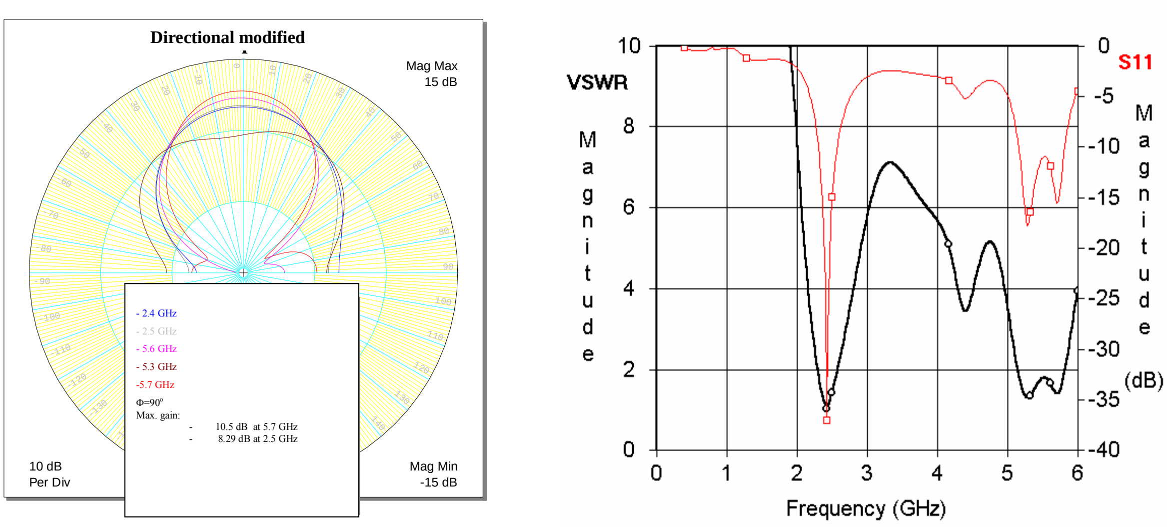


Figure 3 (a) Directivity Gain. (b) VSWR and S_{11} as function of frequency

CONCLUDING REMARKS

Starting with known antenna geometry we designed two antennas with enhanced performance to be used in mobile multi-protocol wireless communication systems.

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