DESIGN OF PRINTED DIPOLE ANTENNA AND ITS APPLICATIONS IN UMTS MOBILE COMMUNICATION NETWORKS

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Key words: UMTS, Printed Dipole Antenna

ABSTRACT

This paper presents the design of a printed dipole antenna which works at UMTS (Universal Mobile Telecommunications System) band. The design of the printed dipole antenna which is one of the types of antennas used in these networks is examined. A printed dipole which can be used in UMTS communication applications and works at 2,1 GHz rezonance frequency was designed. It is simulated by the Ansoft HFSS, the 3D finite-element-method (FEM) electromagnetic EM Simulator. A practical application of this antenna has been realized and the resonance frequency is measured. Both practical measurements and the simulation results are consistent with the design of the antenna.

1. INTRODUCTION

UMTS network architecture is GSM based and the differences between these networks are radio frequency band, radio units, radio interfaces and radio access.

One of the antenna types that used in both in GSM and UMTS networks is printed dipole antenna.

The design of a printed dipole antenna which works at UMTS band is examined. For the dipole design, HFSS (High Frequency Structure Simulator) by Ansoft which uses Finite Element Method (FEM) is used.

By using the simulation software, the antenna return loss change by frequency is realized. Constructing of the antenna a printed circuit board which has $\varepsilon_r = 2{,}38$ is used. Return Loss measurement is relalized by using Agilent 8714ES RF Network Analyzer.

2. ANTENNA TECHNIQUES USED IN MOBILE COMMUNICATION AND PRINTED DIPOLE ANTENNA DESIGN

2.1. Printed Dipole Antenna with Integrated Balun

As shown in Figure 2.1., the printed dipole antenna has a co-axial feed line which behaves like unbalanced-to-balanced and a microstrip balun between two printed dipole strips. Both the length of the dipole strip and microstrip balun is approximately quarter of the wavelength (λ/4). The base surface of the microstrip line and dipole antenna strips are on the same plane. The hole lets the feed point 2 be at the same phase with the feed point 1. Because of the 180º phase difference between the upper strip and the bottom surface, there is 180º phase difference between the feding point 2 in the printed dipole strip and the feding point 1 [3].

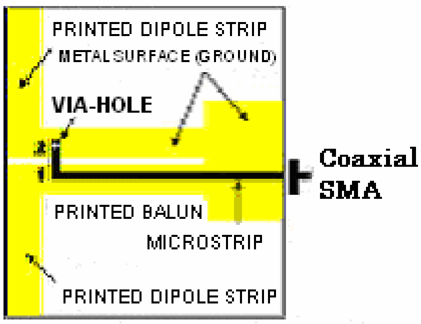

Figure 2.1. : Printed Dipole Antenna with Microstrip Balun [3]

2.1.1. Folded balun

A folded balun (Figure 2.2.) provides a direct connection between the dipole and the coaxial line. Outer conducter is connected to a pole which is fed by a imitation central conducter. Outer conductor goes with feeding dipole side by side λ/4 distance and is connected to ground. The other pole is directly connected to the shield of the feeder coaxial. The outer conducter of the coaxial and the extra line are two lines in the grounded three line.

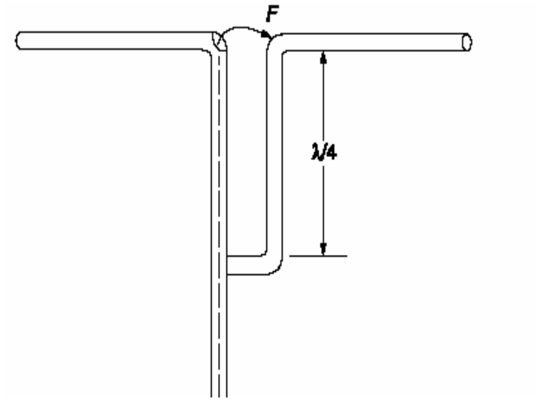

Figure 2.2. : Folded Balun [6]

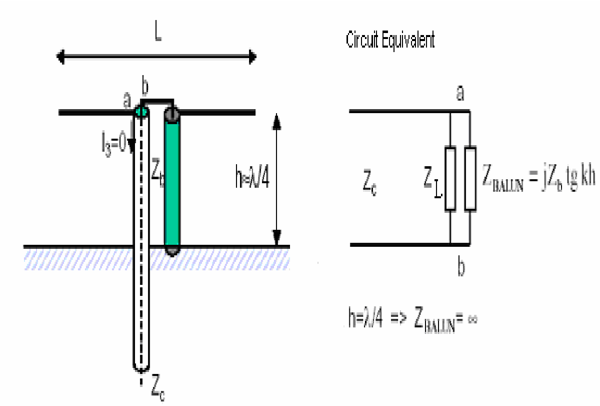

Figure 2.3. : Circuit Equivalent of Balun[4]

If $h = \dfrac{\lambda}{4}$, resonance frequency, Z_{BALUN} is infinitive.

$$Z_{BALUN} = JZ_b tg \frac{2\pi}{\lambda}\frac{\lambda}{4} = \infty \quad [4] \qquad (2.1.)$$

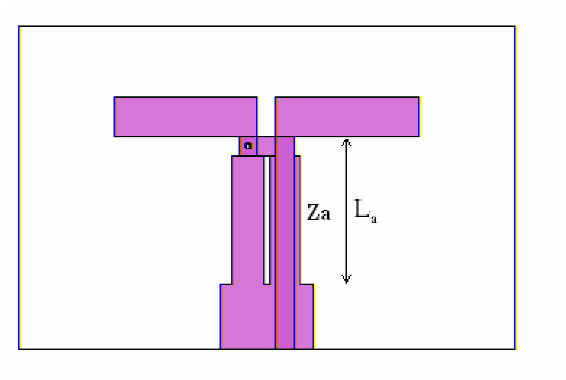

Figure 2.4. : Printed Dipole Antenna

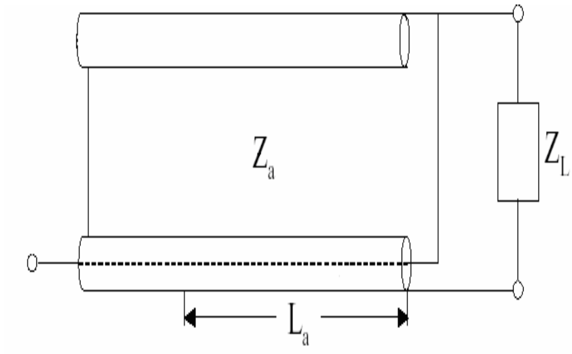

Figure 2.5. : Co-axial Equivalent of The Printed Dipole Antenna

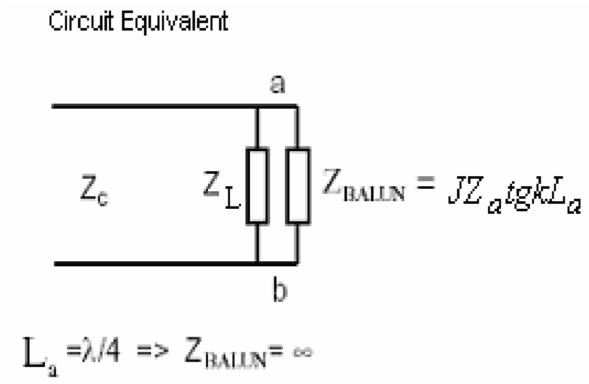

Figure 2.6. : Circuit Equivalent of The Printed Dipole Antenna

If $L_a = \dfrac{\lambda}{4}$ resonance frequency, Z_{BALUN} is infinitive.

$$Z_{BALUN} = JZ_a tg \frac{2\pi}{\lambda}\frac{\lambda}{4} = \infty \qquad (2.2.)$$

2.2. Calculations of the Dimensions

The length of the dipole arms and the balun is quarter of the wavelength. To calculate the wavelength, the following formula is used.

$$\lambda = \frac{c}{f\sqrt{\varepsilon_{reff}}} \quad [6] \qquad (2.3.)$$

λ: Wavelength, c: Speed of Light = 3.10^8 m/s, ε_{reff} : Effective Dielectric Constant

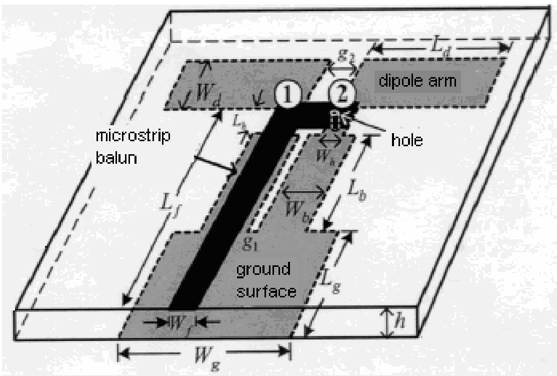

Figure 2.7. : The geometry of The Printed Dipole Antenna [3]

The dielectric constant of the assembled printed circuit board is measured. After measuring the capacity of the board, dielectric constant is calculated by the following equation.

$$C = \varepsilon \frac{A}{d} \qquad (2.4.)$$

C= 255 pF, board area A=133,34.10^{-4} m^2, dielectric thickness d=1,1.10^{-3} m are measured.

$$\varepsilon = \varepsilon_0 \varepsilon_r \qquad (2.5.)$$

$\varepsilon_0 = 8{,}85.10^{-12}$ F/m and $\varepsilon_r = 2{,}38$ F/m is found.

ε_{reff} : Effective Dielectric Constant of the microstrip transmission lines,

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2\sqrt{1 + 10H/W}} \quad [6] \qquad (2.6.)$$

H: Dielectric layer thickness, W: Strip thickness

For ε_r = 2,38 F/m, H = 1,1.10-3 m, W = 6.10^{-3} m,

ε_{reff} = 2,1 is found.

The resonance frequency is 2,1 GHz. If we get ε_{reff} = 2,1, f = 2,1 GHz, $\frac{\lambda}{4} = L_d$ = 24,6 mm is found. The parts of the printed dipole $\frac{\lambda}{4} = L_d = L_b + L_h$ = 24 mm are designed.

3. ANSOFT HFSS

HFSS, is a 3D EM simulation software which is produced for RF and wireless design by Ansoft Company. At the first time it was introduced as a first commercial software simulating complex 3D geometrics in 1990. The software allows the design engineers to use the finite element method[1].

HFSS is a software package which calculates s-parameters and full wave fields for random shaped 3D passive structures. The structures are simulated using the Finite Element Method (FEM).

Analyzing antennas, waveguide components, RF filters and many other structures is as simple as drawing the structure, specifying material characteristics, and identifying ports and special surface characteristics. HFSS automatically generates field solutions, port characteristics, and s-parameters. It is quickly able to calculate antenna metrics such as gain, directivity, far-field pattern cuts, far-field 3D plots, and 3dB beamwidth[1].

3.1.Finite Element Method (FEM)

In order to generate an electromagnetic field solution, Ansoft HFSS employs the finite element method. In general, the finite element method divides the full problem space into thousands of smaller regions and represents the field in each sub-region (element) with a local function.

In Ansoft HFSS, the geometric model is automatically divided into a large number of tetrahedra, where a single tetrahedron is basically a four-sided pyramid. This collection of tetrahedra is referred to as the finite element mesh[7].

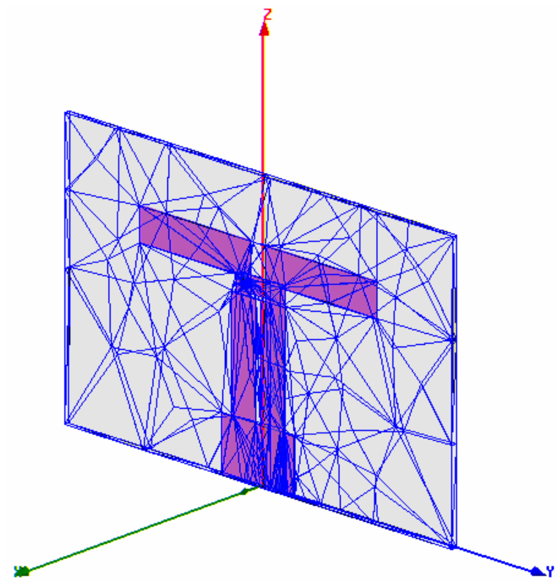

Figure 3.1. : Mesh of the the model analized.

4. SIMULATION AND APPLICATION OF THE 2.1 GHz PRINTED DIPOLE ANTENNA WITH MICROSTRIP BALUN

The printed dipole antenna with a microstrip balun is assembled on a printed circuit board (PCB). The antenna is simulated by the 3D software Ansoft HFSS using Finite Element Method.

4.1. Printed Dipole Antenna Model Simulated

Design simulation and construction of the printed dipole antenna 2,1 GHz resonance is assembeled on copper double sided printed circuit board (FR-4). Microstrip balun and dipole arm dimensions are designed as, W_g = 15 mm, L_g = 10 mm, L_b = 21 mm, L_h = 3 mm, L_d =24 mm, g_2 = 3 mm, W_d = 6 mm, L_f = 34 mm, g_1 = 1 mm, W_h = 3 mm, W_f = 3 mm, h = 1.2 mm. (Figure 4.1.)

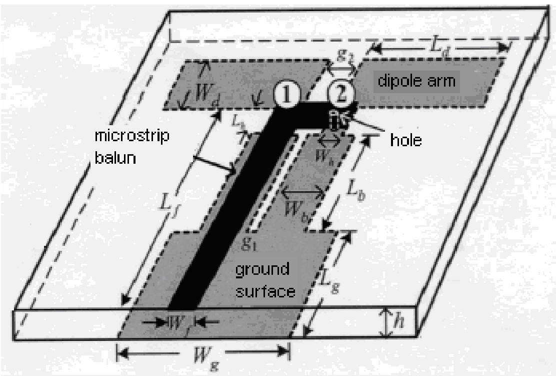

Figure 4.1. : The geometry of the Printed Dipole Antenna[3]

The photos of the designed antenna are at the below.

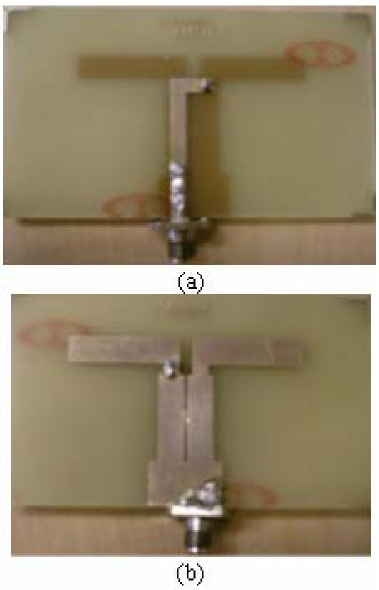

Figure 4.2. : 2.1 GHz Microstrip Printed Dipole Antenna a) Upperside b) Underside

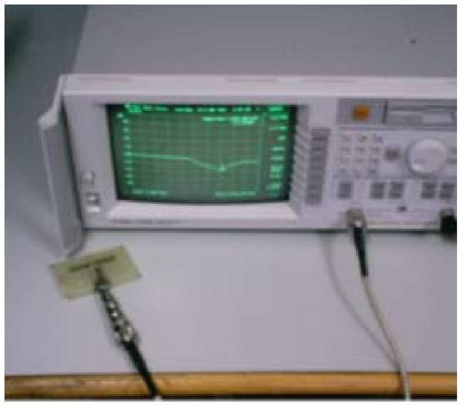

Figure 4.3. : Measurement Mechanism

Measurements are realized with Agilent 8714ES RF Network Analyzer (Figure 4.3.)

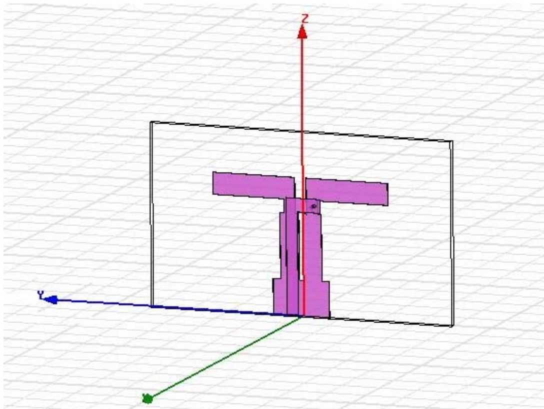

Figure 4.4. : HFSS Printed Dipole Antenna Model

4.2. Simulation and Measurement Results

For ε_{reff} = 2,1 and f = 2,1 GHz, $\frac{\lambda}{4}$ is equals 24,6 mm. Dimensions of the balun and the dipole arms are calculated according to $\frac{\lambda}{4}$ = 24 mm. The following return loss characteristics are realized after the measurements and simulations.

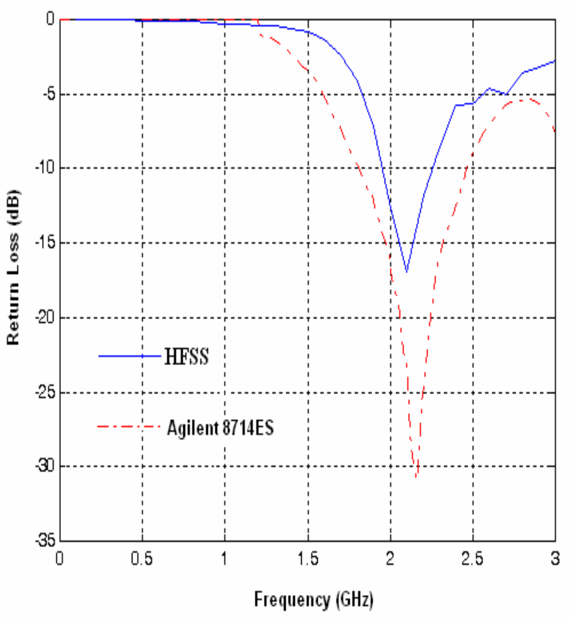

Figure 4.5. : The Return Loss (dB) Characteristics realised after the measurements and the simulations

As shown in the the Return Loss (dB) Graph (Figure 4.5), the resonance frequency measured 2,1 GHz in HFSS software and the rosonance frequency of the practical application is 2,160 GHz.

5. RESULTS AND SUGGESTIONS

In this study, a printed dipole which works at UMTS band is designed. For dipole design, HFSS (High Frequency Structure Simulator) software devoloped by Ansoft Company is used.

The Return Loss and the radiation patterns of the antenna is realised using the simulation software. A printed circuit board which has ε_r = 2,38 is used. Return Loss is is measured with Agilent 8714ES RF Network Analyzer.

The dielectric coefficient of the printed circuit board effects the dipole dimensions. The faulty measurement of the dielectric coefficient causes different resonant frequecies from 2,1 GHz.

In the design model the dielectric coefficient of the printed circuit board is measured as ε_r = 2,38. The dimensions are calculated using this value. Return Loss change by frequency is realised from simulation and measurement results. In HFSS, the resonance frequency is measured 2,1 GHz and it is measured 2,160 GHz in practical measurement results.

Both practical measurements and the simulation results are consistent with the design of the antenna.

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