Analysis of a class of multi-frequency microstrip antenna for mobile handset

Antara Ghosal 1, Anurima Majumdar 2, Annapurna Das 3, Sisir Kumar Das 4

1,2 Department of Electronics and Communication Engineering
Gurunanak Institute of Technology

Abstract: This paper described the analysis and design of a square spiral Microstrip. The spiral is formed by introducing slot in a square patch. This spiral design is introduced to use a single structure for dual band/frequency operations by adding tuning elements. The design parameters for a rectangular patch antenna have been calculated from the transmission line model and using MATLAB. The simulation and modeling of this configuration has been done using Ansoft’s HFSS (High Frequency Structure Simulator) software. The resonant frequency and dimensions are computed from the cavity model for TM_{00} mode. The parameters of antenna such as return loss, VSWR, radiation patterns and gain have been found and design is optimized for best results. Experimental results are obtained using Network Analyzer and found good agreement with simulated results.

Keywords – Coaxial feed, spiral microstrip patch antenna, multiple frequency, mobile handset.

I. INTRODUCTION

Microstrip patch antennas can be manufactured in large quantities for their compact size, light weight, low profile, planar configuration, and low fabrication cost. Mobile handsets use these microstrip antennas which are embedded into the printed circuit board. Modern handsets should capable of operating at multiple frequencies for different mobile networks at different countries (900, 1800, 1900, 2400 MHz). This paper described the design of a spiral shaped single patch antenna operable at multiple frequencies, 1.6, 2.1, and 2.4 GHz. Ansoft HFSS software is used for analytical modeling and simulation. Theoretical and experimental results agree well.

II. ANALYSIS OF SQUARE AND SPIRAL MICROSTRIP ANTENNAS

In this paper a square patch is introduced first (Fig.1) and from the patch a square spiral is designed by removing copper as shown in Fig.2. This makes the antenna more light weight and multi-frequency operation.

The basic rectangular or square patch can be analyzed using cavity model [1-3]. The field in the interior region does not vary with z, because the substrate is very thin. The non zero field components are $E_z$, $H_x$, $H_y$ and the resonant modes are $TM_{mn0}$, where $m=0,1,2,3\ldots$; $n=0,1,2,3\ldots\ldots$; and $m$ and $n$ are not simultaneously zero [3]. The resonant frequencies of these modes are expressed by

$$ f_{r(mn)} = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \left[ \left( \frac{m\pi}{L} \right)^2 + \left( \frac{n\pi}{W} \right)^2 \right]^{1/2} $$

(1)

For $L>W>L/2>h$, the lowest order resonant frequency is for $TM_{100}$ mode ($m=1$, $n=0$):

$$ f_{r(100)} = \frac{1}{2\pi\sqrt{\mu\varepsilon}} \left[ \left( \frac{\pi}{L} \right)^2 + \left( \frac{\pi}{W} \right)^2 \right]^{1/2} $$

For $L>W>L/2>h$, the lowest order resonant frequency is for $TM_{100}$ mode ($m=1$, $n=0$):
For $W>L>h$, the lowest order resonant frequency is for $TM_{010}$ mode ($m=0$, $n=1$):

$$f_{r(010)} = \frac{1}{2L\sqrt{\mu\epsilon}}$$  \hspace{1cm} (2)

The mode field distributions for above two modes are shown in Fig. 1a.

![Mode field distributions](image)

**Fig. 1 a.** Mode field distributions

**b.** Fringing field distribution at the edges

It is known that the fringing fields at the edges (Fig.1b) of the patch produce good bore-site radiation pattern for $TM_{000}$ and $TM_{n00}$ modes, $m=1, 3, 5…$ and $n=1, 3, 5…$. For $m, n$ = even, no bore site radiation will be obtained.

For a square patch $L=W=\text{half guide wave length}$ produces two degenerate modes $TM_{010}$ and $TM_{100}$ having same resonant frequency.

Depending on the excitation, only fringing fields at the edge parallel to $x$-axis or $y$-axis, produce bore site radiation in space which forms an array of two slots separated by a distance $W + \Delta W = \frac{\lambda_{\text{eff}}}{2}$ as shown in Fig.1b. Here $\Delta W = h$ is the extra length due to fringing field extension [1].
III. SIMULATION AND MODELING

Bernard [5] has shown that the area of a square patch is reduced by forming a square spiral and two adjacent spiral arms are shorted as tuning elements to obtain dual frequency operation and best return loss is obtained as -14 dB. The author [5] has not described fully about the co-axial feed design and its impedance matching. In the present paper area of the patch is kept same as that of square patch but the total metal of the patch is reduced using the spiral. HFSS modeling and analysis are carried out for the structure as shown in Figs.2-3 where capacitive coupled tuning elements between successive spiral arms are used for multi-frequency operation.

![Spiral patch](image)

Fig.2 (a) Square spiral patch (b) $|S_{11}|$ vs f

The design parameters are: $W=L=33.7\,\text{mm}$, $h=1.6\,\text{mm}$, and substrate $\varepsilon_r=4.4$. The patch is excited from the back with a co-axial line probe. The probe position is optimized at $(12.6\,\text{mm},0\,\text{mm},0\,\text{mm})$ for best impedance matching with the 50 ohm feed line. The ratio of the radii of the inner and outer conductor of the coaxial line is 3.5 for 50 ohm input impedance and it is computed using FR4_epoxy. The inner conductor radius is taken as 0.5 mm and the outer conductor radius is taken as 1.75 mm.
Fig. 3. Square spiral patch with tuning arm at different positions

Fig. 4 (a) $|S_{11}|$ vs . Frequency of spiral design of Fig. 3a
(b) $|S_{11}|$ vs . Frequency of spiral design of Fig. 3b

From the above design of Fig 3 (a), multi- frequency response with very good return losses (better than -17 dB) at 1.55GHz, 1.98 GHz and 2.45 GHz is obtained as shown in Fig. 4. Therefore, the configuration with symmetrical tuning elements at the outer most spiral arms produces three distinct resonant frequencies which could be received by this antenna.

The radiation patterns of these configurations are also obtained from simulation results and found they are in good shape for bore side radiation as shown in Fig. 5.
Analysis of a class of multi-frequency microstrip antenna for mobile handset

The E-field and electric current distributions are also shown in Figs. 6 and 7 to support the bore side radiation characteristics.
Fig. 6 E-field distribution
IV EXPERIMENTAL EVALUATION

Since the configuration of Fig.3 (b) gives the best performance, a hardware design of this structure is made with W=L=33.7 mm, h=1.6 mm, and $\varepsilon_r=4.4$ as shown in Fig.8.

Fig.8 Hardware Design of Spiral patch
The antenna is tested using Vector Network Analyzer for return loss and radiation patterns. The test results are shown in Fig. 9. Analytical results and the experimental results are compared and found agree well.

![Fig. 9 Return loss vs freq. of the spiral patch antenna](image)

**III. CONCLUSION**

From the test results and from the simulation and the modeling of the hardware of the proposed antenna, a good impedance matching is observed near the frequencies 1.6 GHz, 2 GHz, and 2.4 GHz. The return loss and radiation patterns obtained suggest that this single configuration can be used in a multi-frequency mobile handset.

**REFERENCE**