

Practical Design Considerations for Tri-Band Microstrip Patch Antennas

A. S. Türk¹, #M. E. Aydemir², E. Göse³, M. İlarıslan⁴

¹Department of Electronics Engineering, Yıldız Technical University
Istanbul/TURKEY, asturk@yildiz.edu.tr

^{2,3}Department of Electronics Engineering, Turkish Air Force Academy
Istanbul/TURKEY, m.aydemir@hho.edu.tr, e.gose@hho.edu.tr

⁴Aeronautics and Space Institute, Turkish Air Force Academy
Istanbul/TURKEY, m.ilarıslan@hho.edu.tr

1. Introduction

Microstrip antennas are becoming increasingly popular and are widely used in microwave and millimeter-wave circuits [1, 2]. Owing to the implementation of the electronic device only on the PCB, the microstrip antenna has received a great deal of attention [3]. In this paper we present some practical design considerations for the 3-band microstrip antennas. In our work, after the theoretical foundations are defined, the characteristics of the microstrip antenna is experimentally studied. It is not very convenient to analytically design these types of antennas therefore most of the work in this field is implemented by computational electromagnetics methods or hardware experiments [3]. The E.M. analysis is implemented by the Full-Wave EM Analysis Method [4,5]. In this method, the Method of Moments (MoM) is involved along with the Geometrical and Physical Theory of Diffraction. The selection of mentioned methods depends on the ratio of the structure (antenna) size to the wavelength. Therefore, when used together, the results are always very close to actual measurements.

On the other hand, multi-band antennas are a must for today's personal electronic communication devices. Especially the GSM, Bluetooth and 4G are among the most common digital communication protocols [6,7,8]. Today, most portable computers, personal and professional communication systems have each 3 of these systems on a single PCB. The frequency allocation for these systems is given in Table 1.

Table 1: Frequency Allocation for the GSM, Bluetooth and 4G systems

System	Dedicated Frequency Range
GSM	0.9 & 1.8 GHz
Bluetooth	2.4 GHz
4G	3.5 GHz

As a single antenna is used for all these frequencies, it is important that the antenna bandwidth and radiation pattern meet these different system requirements. In this study, a novel microstrip patch antenna is developed for this purpose [5,9]. The variation of the resonant frequencies w.r.t. the antenna dimensions are studied and design considerations are developed for further studies.

2. Theory

Early antenna problems were solved by analytical integration of the fields. With this technique, it was very hard to manipulate solutions into a form where the computational effort is minimized. The increases in the computer industry in both speed and storage capabilities has fostered the growth in antenna modeling to the point where personal desktop computers have

enough capability to do very sophisticated and computationally intensive antenna design problems. To a large extent, the advancement in numerical antenna modeling is directly dependent on and parallels the continued advancement and availability of super computers with increased speed and memory. It also has profited by the development of interactive computer graphics for visualizing device geometry and field distributions, and the advancement of numerical analysis techniques. Computerized solutions can be broken into the two main areas of numerical techniques and high frequency/asymptotic techniques. The code best suited for a particular antenna problem depends on the type of antenna, the shape, size, and material properties of the antenna and surrounding structures, the operating frequency, and the available computer resources.

Numerical methods are based on solving Maxwell's equations with either integral equations (IE) or differential equations (DE) [10]. DE methods can handle complicated geometry and material properties while IE methods, like method of moments (MOM) [11-12], excel in open boundary problems. Far fewer unknowns are required in IE methods, but the matrices are full, leading to considerable numerical difficulties. In contrast, for the DE methods, the matrices are sparse, banded and symmetric, and allow very efficient matrix methods to be used. In general, MOM is the technique of choice for antenna problems involving small (less than 10λ (wavelengths)) bodies with perfectly conducting surfaces or thin dielectrics. This method gives an exact solution for the near far-fields, the input impedance, and the efficiency. The structure is broken up into sections of wires or plates of dimension $\lambda/4$ to $\lambda/10$. Unfortunately, for structures much greater than 10λ , this technique quickly approaches the limits of most computers both in memory and computational time required. Above 10λ , high frequency (asymptotic) techniques, such as the geometric theory of diffraction (GTD) [10], give a good approximation to the actual solution. The GTD technique uses ray tracing and diffraction to predict the relative far-field patterns. It is easy to use and can model very large structures quickly. It cannot determine input impedance and absolute field intensities, however, and can give erroneous solutions for certain structures where there are resonances. It also is not good for modeling structures with fine structural details less than a wavelength in size. Various hybrid techniques are also used to combine the MOM with a GTD code to model large structures accurately.

2. Antenna Design Considerations

So far, many designs have been developed for the implementation of 3-Band microstrip antennas [3-5]. The size of the antenna in this study is calculated by [1,9,13]:

$$W = \frac{c}{2f_r} \sqrt{\frac{\epsilon_r + 1}{2}} \quad (1) \quad \text{and} \quad L = \frac{c}{2f_r \sqrt{\epsilon_c}} - 2\Delta l \quad (2)$$

where W and L are the patch width and lengths and Δl is the half wavelength. From here, W and L are found 30 and 30.5 mm's respectively. The parameters of interest are the d1, d2 and d3 in Fig. 1.

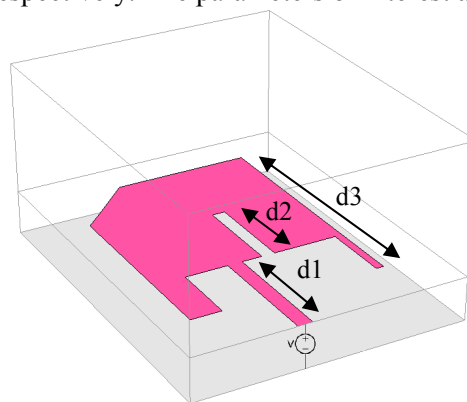


Figure 1: The microstrip patch antenna structure.

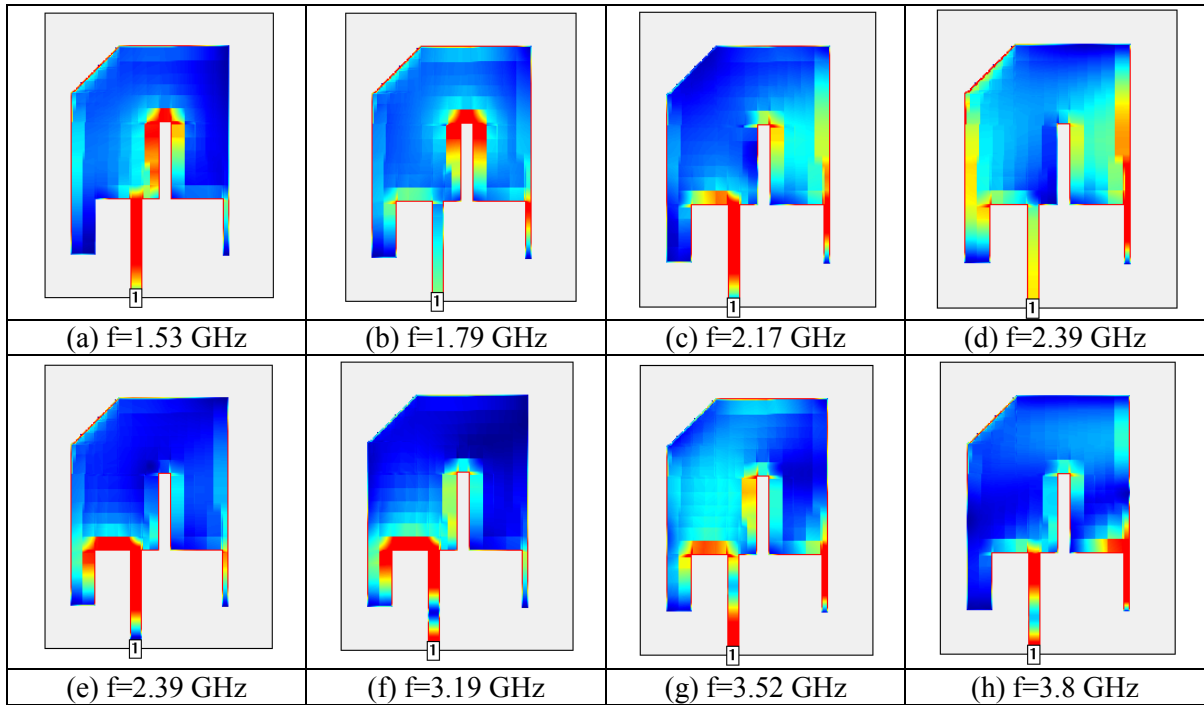


Figure 2: The current distributions on the antenna w.r.t. the excitation frequencies.

By inspecting the current distributions at 3 discrete frequencies on Table 1, it is seen that, the dimensions d_1 , d_2 and d_3 have the most effect on these frequencies (Fig.2). In this figure, the maximum value of the current density is 5.20 A/m. The red regions denote high values while the dark blue the lowest ones. It is possible to see the effect of the d_1 dimensions on the current, therefore radiation. The variation of these frequencies is given in Table 2 and the corresponding return loss (S_{11}) values are given in Figs. 2-4 respectively.

Table 2: Patch Slot Dimensions

# of Slot	Minimum Size	Optimum Size	Maximum Size
d_1	16.8	18.8	20.8
d_2	12.3	14.3	16.3
d_3	37.8	39.8	41.8

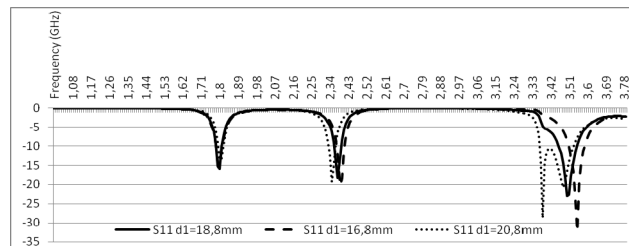


Figure 3: Variation of the return loss w.r.t. the d_1 antenna feed length

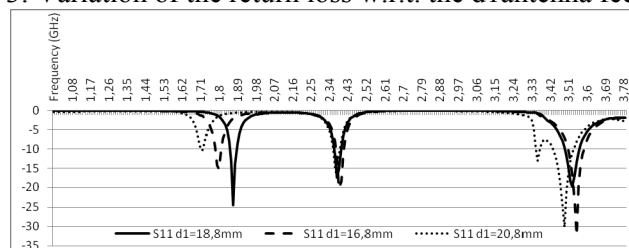


Figure 4: Variation of the return loss w.r.t. the d_2 slot length

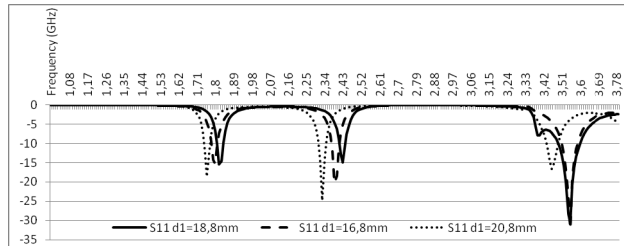


Figure 5: Variation of the return loss w.r.t. the d3 right side patch length

From these results, it is seen that The feeder section length d_1 determines the return loss for the 4G frequencies while, d_2 effects both the 4G and GSM frequencies and d_3 shifts all there frequencies in to consideration. The optimum frequency is adjusted with taking all these frequencies in to consideration. Further considerations may be discussed at the meeting.

References

- [1] C. A. Balanis, "Antenna Theory, Analysis and design", Third edition, New Jersey, John Wiley & Sons, 2005.
- [2] T. Gunel, I. Erer, "Application of Fuzzy Genetic Algorithm to the Problem of Synthesizing Circular Microstrip Antenna Elements with Thick Substrates", AEU - International Journal of Electronics and Communications, Volume 56, Issue 3, 2002, Pages 215–217
- [3] Hong-Twu Chen, "Experimental results of compact microstrip antennas", IEEE Antennas and Propagation Society International Symposium, Volume: 2, pp. 932 – 935, 1997
- [4] Howard, L.C.; Dunn, J.M., "A computationally efficient method for improving the speed of full wave analysis CAD programs for microstrip circuits " Microwave Symposium Digest, IEEE MTT-S International, pp. 1085 - 1086 vol.3, 1991
- [5] Hong-Twu Chen; Horng-Dean Chen; Yuan-Tung Cheng, "Full-wave analysis of the annular-ring loaded spherical-circular microstrip antenna" , IEEE Transactions on Antennas and Propagation, Volume: 45 , Issue: 11, pp. 1581 – 1583, 1997
- [6] Guifen Gu; Guili Peng, "The survey of GSM wireless communication system", International Conference on Computer and Information Application (ICCIA), pp. 121 - 124, 2010
- [7] McDermott-Wells, P., "What is Bluetooth?", IEEE Potentials, Volume: 23 , Issue: 5, pp. 33 – 35, 2005
- [8] Jamil, M.; Shaikh, S.P.; Shahzad, M.; Awais, Q., "4G: The Future Mobile Technology", TENCON 2008 - 2008 IEEE Region 10 Conference, pp. 1 – 6, 2008
- [9] S. Sari, "Design of 3-Band Microstrip Antenna for the Wireless Communication Systems," M.S. thesis, Dept. Electron. Eng., Yildiz Teknik Univ., Istanbul, Turkey, 2011.
- [10] Luppincot W and Lyon P., "Survey of Antenna Design Computer Models", Space Systems Development Department, Naval Research Laboratory, December 24, 1992.
- [11] Pirinoli P., Vecchi G, Orefice M, "Full-Wave Spectral Analysis and Design of Annular Patch Antenna With Electromagnetically Coupled Microstrip Feed Line", IEEE Transactions on Antennas and Propagation, Vol. 52, No. 9, pp. 2415-2423, September 2004.
- [12] Rawle W. D., "The Method of Moments: A Numerical Technique for Wire Antenna Design", High Frequency Electronics, pp. 42-47, February 2006.
- [13] C. A. Balanis, "Antenna Theory-Analysis and Design", Second Edition, John Wiley and Sons, Inc., 1997.