TRI-BAND PATCH ANTENNA

ECE 5324
Antenna Theory and Design
University of Utah

Abstract:

A compact planar inverted F patch antenna (PIFA) with a single feed and short is designed for operation in three frequency bands; GSM (880 MHz – 960 MHz), DCS (1710 MHz – 1880 MHz) and ISM (2400 MHz – 2480 MHz) (adapted from [1]). The return loss, bandwidths and radiation patterns in these operating bands are measured to be satisfactory.

Introduction:

Helical antennas and Patch antennas have greatly affected the mobile communication. Helical antennas are designed for dual band operations and have proved to be very effective, however its drawbacks are, it protrudes out of the phone, has undesirable radiation characteristics and design for tri-band operation is very difficult. (very few/no designs are available.)

Due to the recent trends in miniaturization of mobile phones, patch antennas are considered as a better substitute to helical antennas. Patch antennas can be designed in different forms due to which their dimensions are reduced to a great extent [2]. Aesthetically, phones with these antennas are more appealing as the antennas are inside the phone. Another advantage is that the radiation of these antennas is reduced in the direction towards the head due to the radiation characteristics of the patch antennas which is in the direction of the patch [3].

Several dual band patch antenna designs are available that provide GSM (Global System for Mobile Communication: 880 MHz – 960 MHz) and DCS (Digital Cellular System: 1710 MHz – 1880 MHz) operations. The goal of this paper is to design a patch antenna that supports a third frequency band for ISM (Industrial, Scientific and Medical) operations (2400 MHz – 2480 MHz).

A PIFA with a meandered slit, single feed and short is designed to resonate in the 3 required frequency bands. The design and experimental results are discussed in the following sections. Simulation results using Sonnet-Lite 10.51 are also discussed.

Antenna Design:

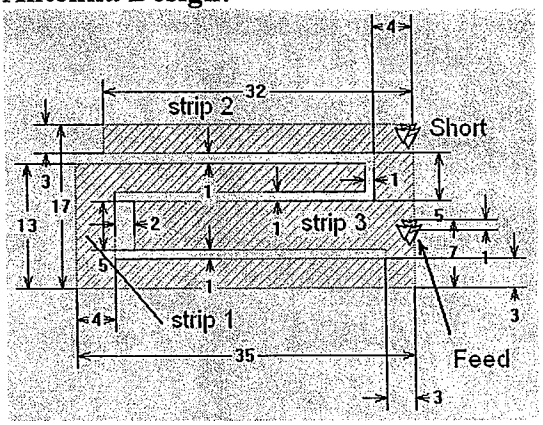


Figure 1: PIFA Schematic

Figure 1 shows the design of the tri-band patch antenna. The volume of this patch is 35x17x15 mm^3. The dimensions of the ground plane are 75x75mm. Foam with a relative permittivity of 1and width 15mm is used as the dielectric substrate.

The antenna is designed by cutting a 2 shaped slit in a rectangular patch. This slit basically divides the patch into three radiating elements shown in figure 1 as strip 1, 2 and 3 which resonate at three different frequency ranges [1].

Due to the short on the patch all the lengths are in terms of quarter wavelengths of the frequency bands. The longest strip - strip 1 has a path length (79mm) approximately equal to $\lambda/4$ (83mm) of the GSM frequency band. Strip 2 has a path length (41 mm) equal to $\lambda/4$ (41.66mm) of the DCS frequency band. Strip 3 has path length (30mm) equal to $\lambda/4$ (30.6mm) of the ISM frequency band. The feed and short location and the width of the substrate also affect the return loss. By adjusting these parameters the required matching is achieved.

Simulated Results:

In order to test the performance of this PIFA prototype, Sonnet-Lite 10.51 software was used for the simulations. Figure 2 shows the simulated return loss for this PIFA.

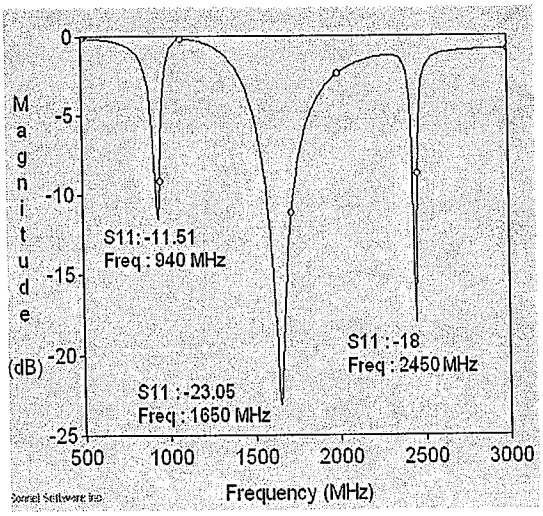


Figure 2: Simulated Return Loss

The response shows 3 notches at the 3 different frequency bands. The DCS frequency band is not correct but at 1750 MHz S11 is -10 db and hence the design was fabricated.

Experimental Results:

Figure 3 shows the measured return loss for the fabricated prototype PIFA.

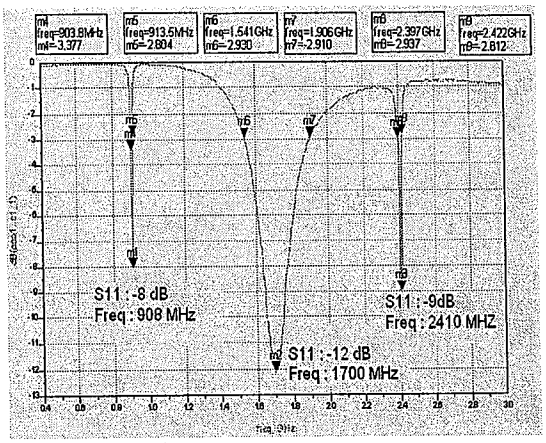
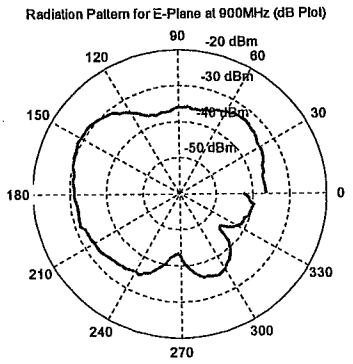


Figure 3: Measured Return Loss

The response shows the required 3 bands and these experimental results match satisfactorily to the simulated results. The power reflected is 15% for the GSM band, 6.3% for DCS band and 12.5% for the ISM band which shows that matching is achieved. The measured bandwidths for S11of -3 dB are 9.7 MHz for GSM band, 365 MHz for DCS band and 25 MHz for ISM band.

For a patch antenna the direction of maximum radiation is in the z direction (direction of the patch); $\theta = 0$ [3]. Figure 4-6 shows that the measured radiation patterns for the designed antenna satisfy this condition approximately.



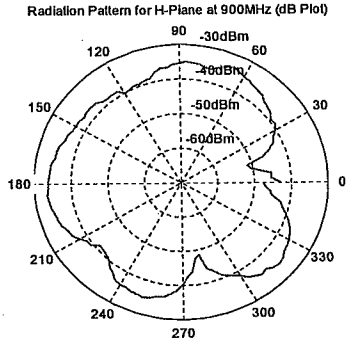
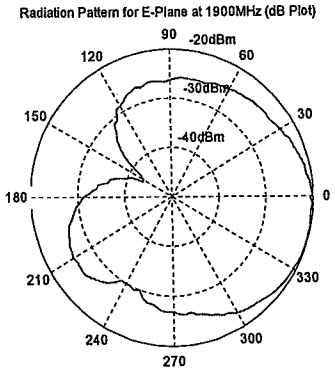


Figure 4: Radiation Pattern E and H planes for GSM band.



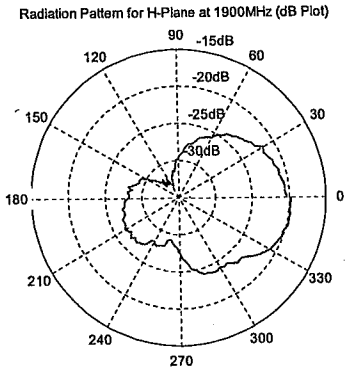
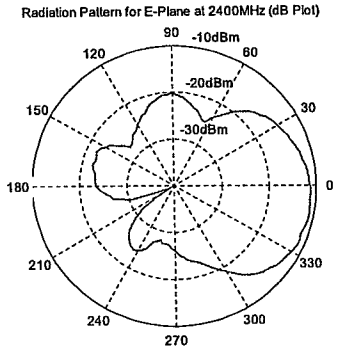


Figure 5: Radiation Pattern E and H planes for DCS band.



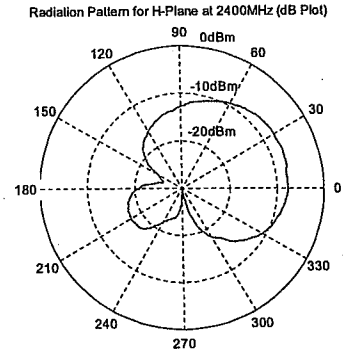


Figure 6: Radiation Pattern E and H planes for ISM band.

The patterns in figure 4 are undesirable (signal strength higher in $\theta = 180$ as compared to $\theta = 0$) and this may be due to the small dimensions of the ground plane. Figure 5 and 6 shows that the patch in the ISM band obeys the maximum radiation in $\theta = 0$ direction.

Difficulties Encountered During Design:

The prototype is a very compact design and the adjustments in the dimensions made a huge difference in the performance. In order to adjust the GSM or DCS band, any alterations made to the lengths of strips 1 and 2, affected the ISM band (The return loss was very high though the frequency band was not much affected). Hence the simulations were finalized for the second frequency band at 1650 MHz.

The location of the feed point and the width of substrate also affect the performance of the antenna. The original design [1] uses a substrate thickness of 8 mm which did not give the required results. A substrate thickness of 15mm has given satisfactory results. Figure 7 shows the return loss for different feed point locations and different widths of the substrate.

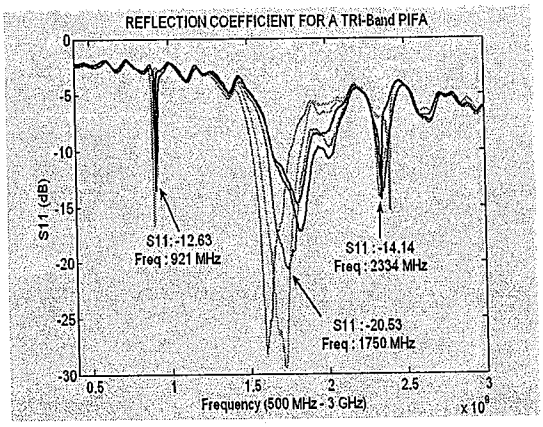


Figure 7: Return Loss for different feed locations and widths of substrate.

Conclusion:

A compact planar inverted F antenna for tri-band operation (GSM, DCS, and ISM) is designed (adapted from [1]). The dimensions of this PIFA are 35x17x15 mm. The experimental results of return loss, bandwidth, and radiation pattern for this prototype are similar to the results of simulations obtained using Sonnet-Lite software and are measured to be satisfactory.

Acknowledgements:

We thank Dr. Gandhi, Bryan Stenquist, and Qingxiang for their assistance and guidance.

References:

1) Dongsheng Qi, Binhong Li, Haitao Liu, "Compact Triple-Band Planar Inverted-F Antenna for Mobile Handsets," *Microwave and Optical Technology letters, vol 41 June 20, 2004.*
2) PIFAs for Internal Mobile Phone Antennas.
3) Warren L. Stutzman, Gary Thiele "*Antenna Theory and Design,*" 2nd edition.

Fabricated Patch