Analysis of Cavity Introduced Aperture Coupled Feed Antenna

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Department of Electrical Engineering

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Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be a cause for disciplinary action by the Institute and can also evoke penal action from the sources that have thus not been properly cited, or from whom proper permission has not been taken when needed.

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Approval Sheet

This thesis entitled Analysis of cavity introduced aperture coupled feed micro-strip antenna by Shikhar Jain is approved for the degree of Master of Technology IIT Hyderabad.

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Dedicated to

My Friends and Family

Analysis of Cavity Introduced Aperture Coupled Feed Antenna

Introduction

Need of micro-strip patch antenna

An antenna plays a vital role in wireless communication. As the device size is shrinking rapidly, there is a strong need of reduction of size of antenna. The antenna should be mounted on the device. In such circumstances Micro-strip patch antenna is most innovative area with cost effectiveness and ease of fabrication. A micro-strip antenna can be fed with several techniques, i.e. transmission line feed, inset feed, coaxial probe feed, proximity feed and aperture coupled feed. In present design aperture coupled feed technique is used.

Aperture coupled feed technique

In this feed technique two different substrates i.e. patch substrate with radiating element on the top of it and feed substrate with feed strip line at the bottom of it with different dielectric constant are used and a highly conductive ground plane is introduced between these substrates. For electromagnetic coupling between these substrates a rectangular slot is created on conductive ground plane. Although the original prototype of antenna circular coupling aperture, but later is was realized that rectangular aperture provides better coupling. Application of aperture coupled antenna in GPS, paging, cellular phone, GSM, WLAN, WACN, collision avoidance Radar where frequency ranges from 800 MHz to 94 GHz. [1]

Proposed design

This project is solely consisting of idea of achieving high operational frequency, larger bandwidth, and higher gain without reducing the antenna size. The design proposed in this project involves using both the substrate of silicon with different thickness for CMOS compatibility. A cavity at the bottom of patch substrate is etched out and deposits an insulating layer of silicon dioxide inside the cavity. The effect of variation in different physical dimension of proposed design is simulated in HFSS software. The various features are listed below. For description refer [1]

Constant features

Patch substrate dielectric constant, Patch substrate thickness, Micro-strip patch length, Micro-strip patches width, Feed substrate dielectric constant, Dielectric Silicon dioxide thickness

Variable features

Feed substrate thickness, Slot length, Slot width, Feed line width, Feed line position relative to slot, Position of the patch relative to the slot, Cavity size (length x width), Cavity depth

What is cavity?

For better coupling reason rectangular cavity is etched on silicon substrate. Anisotropic etching of Silicon substrate can be performed using TMAH solution. 25% TMAH solution (with no dilution) gives etch rate of 6um/min. [2]

Motivation

Reducing size of antenna

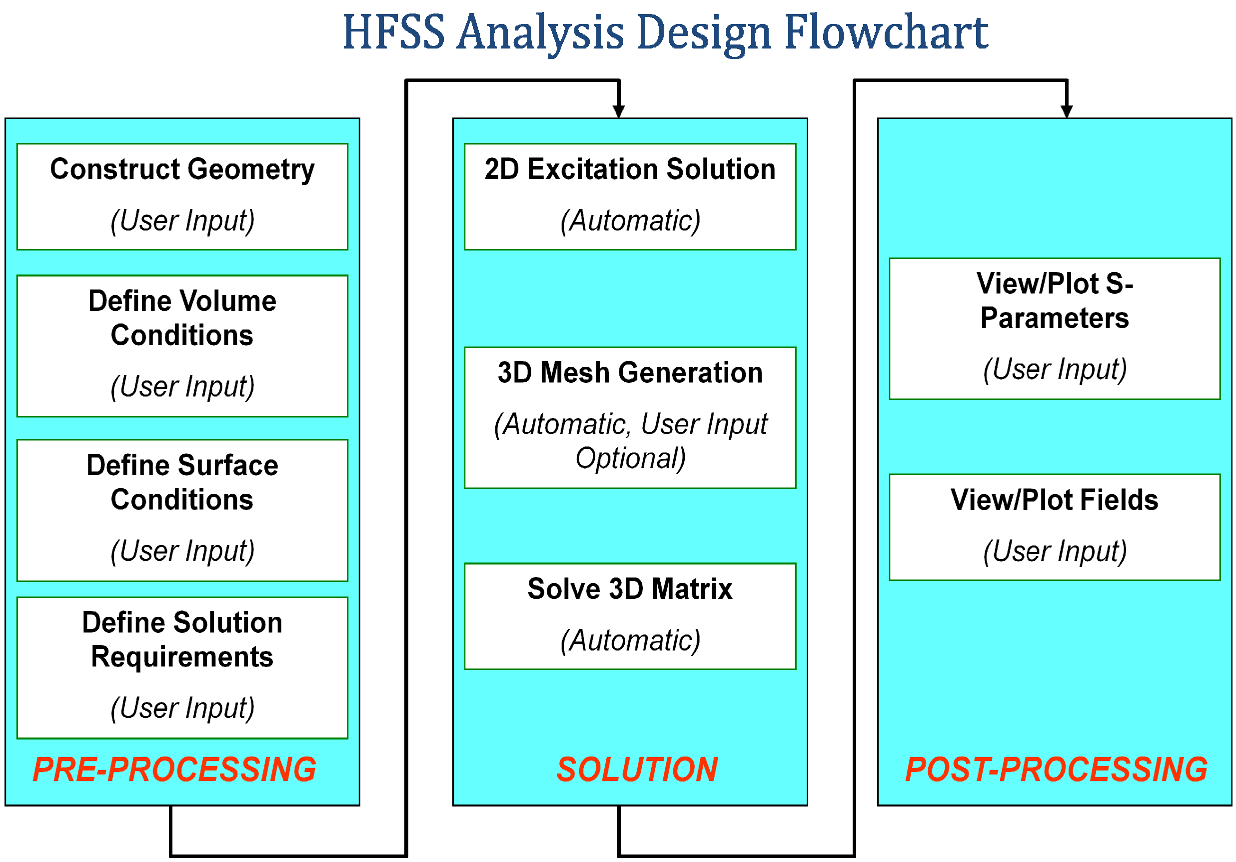
As the world is moving towards terahertz frequency band application, the size of planar antenna will enter in the order of micrometer dimensions. As the substrate thickness cannot be reduced much further otherwise the substrate will break. Hence the antenna dimension is reduced but thickness as well as the dielectric constant is not reduced. This will result in more return loss, smaller radiation range, less gain etc. That's why to avoid so much of demerits the planar antenna is converted into 3D antenna with cavity etched at the bottom of patch substrate. As the cavity is air the loss in the non radiating direction will be more.

Low temperature Cu-Cu bonding

The highly conductive layer of copper (for CMOS compatibility) is sandwiched between patch substrate and feed substrate. Normally it is not possible to have such kind of structure in CMOS technology. Thermo-compression bonding made it possible. For certain temperature, atmospheric pressure, forces and proper procedure a successful Cu-Cu wafer bonding is achieved, which motivated to apply this concept for the fabrication of aperture coupled antenna.[3]

Method

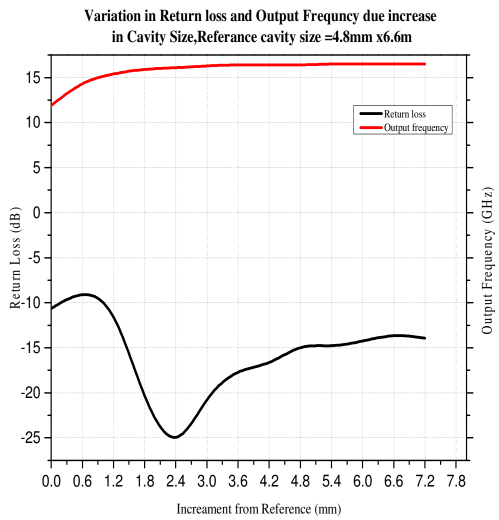
This project is entirely simulation in HFSS software. Different features listed in variable features above are varied and the change in return loss, VSWR, ETR (emission test report), radiation pattern are observed. Generally the number of adaptive passes are taken to be 15 throughout the project, delta S=0.02, Frequency sweep is taken in interpolating mode. The design flow is given below [4]

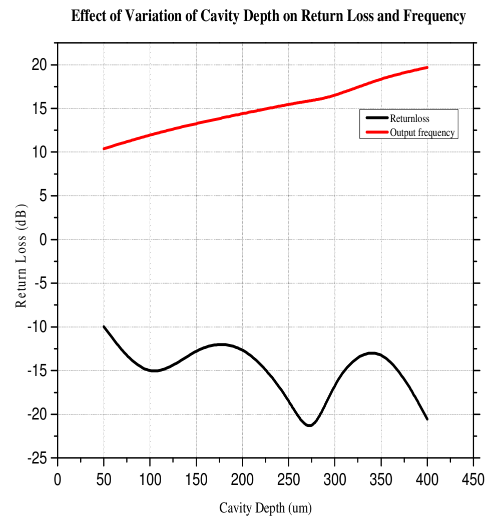


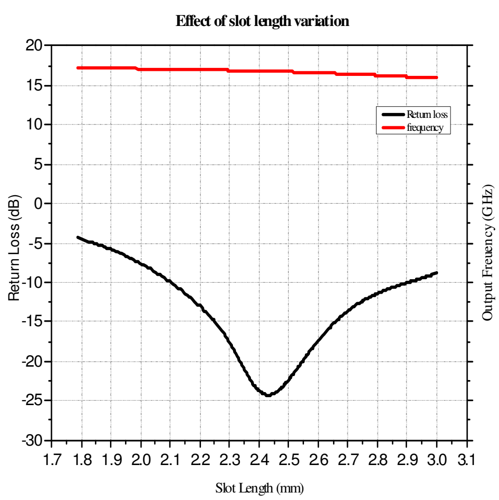
Limitation

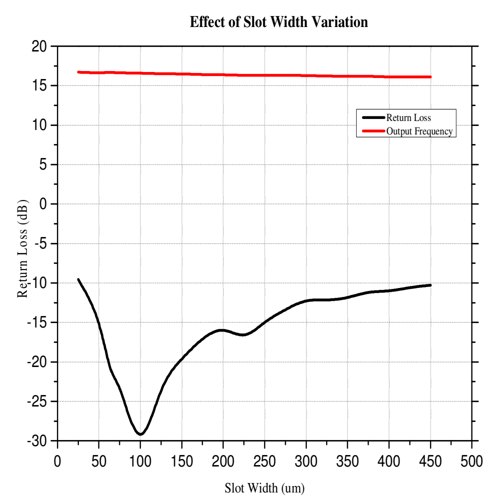
The patch dimension cannot be reduced too much with the same dielectric constant. Even with the cavity backed the patch substrate the return loss is high for smaller patch dimensions. For the sake of CMOS compatibility silicon substrate is used during entire project where different materials with lesser dielectric constant can be used to increase bandwidth. Two different substrates with different dielectric constants can be used to increase coupling.

Results









The above results shows how the return loss and frequency are varying with respect to

(i) Cavity dimension

(ii) Cavity depth

(iii) Slot length

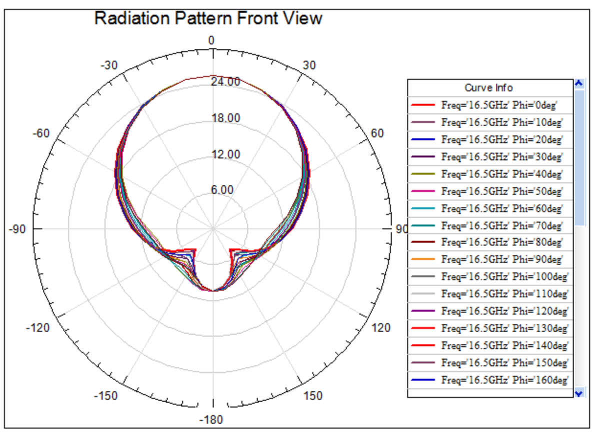
(iv) Slot width

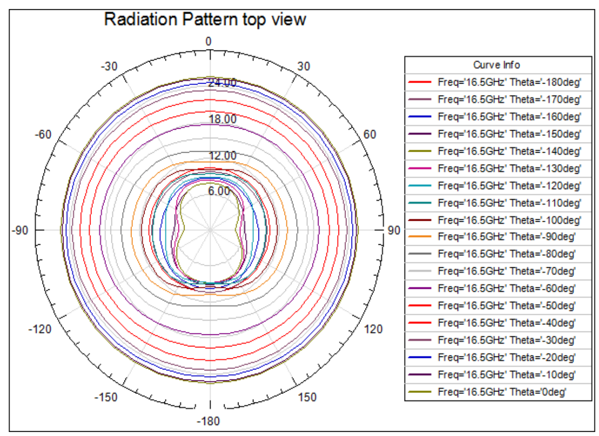
Conclusion

Finally an aperture coupled antenna with following parameters is obtained

Parameter	Values
Obtained frequency	16.48 GHz
Return loss (dB)	-13.835
Return loss	-0.01838+0.203061i
VSWR	1.5105
ETR(1 meter sphere)(dB)	25.6
ETR(3 meter sphere) (dB)	16.03
ETR(10 meter sphere) (dB)	5.57
Bandwidth (-6dB)	1.3 GHz

Radiation pattern





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