International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 6 (2015) pp. 16035-16040

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Design and Analysis of A Simple Dual Band Dielectric Resonator Antenna For Wireless Communication

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Abstract

A simple dual band coplanar dielectric resonator antenna is designed for millimeter wave frequencies ranging from 30GHz to 300GHz. The antenna arrays operate at 37.5GHz and 43GHz simultaneously. The distinguishing features of this antenna are large bandwidth, high speed data transfer, compact dimensions, pencil beam radiation and no beam crossover. The applications are 4G, 3G and WLAN networks.

Keywords: VSWR, Quality factor, Radiation pattern, Dielectric constant, polarization, excitation, feed, coplanar wave guide, scattering parameters for insertion loss(S_{21}) and return loss(S_{11}),CST,TE,TM,TEM

Introduction

Communication has proved to be an inevitable yet powerful process in not only modern times but also since times immemorial. Antenna plays a pivotal role in establishing communication between two entities. The notion behind designing different antennas is to achieve an uninterrupted communication with high speed data transmission without any loss of information provided all the technical specifications as well as performance parameters are met at a reasonably low cost. Some of the mandatory parameters are Voltage Standing Wave Ratio (VSWR), which is 1:1.5 in this design, Quality factor (Q) is observed to be high, Radiation pattern result is found to be 4dB and the radiation is observed across side lobes and main lobe but not below ground layer. The dielectric constant of the selected dielectric disk resonator antenna is 34.73.The Polarization observed is circular. The design metrics and performance measuring techniques pave way to a robust architecture.

Antenna Design

A. Introduction to Antenna Design

The antenna is initially chosen according to the type of application intended. For wireless communication in 4G networks and satellite communications, a dual band resonant frequency responsive antenna is chosen. This antenna comprises of a ground layer, substrate layer, Dielectric and a patch. The antenna has been fabricated on FR4 micro strip or glass epoxy .The permittivity and dielectric constant of the materials influence the frequency response. The feed lines and radiating elements are photo etched on the dielectric substrate. The thickness‘t’ of the antenna is the influencing factor for the resonant frequency. The design is carried out using Ansys HFSS version 13.0.

B. Feed and excitation for the antenna

Among the many types, four types of feed observed are micro strip line, coaxial probe, aperture coupling and proximity coupling. The excitation methods that can be used for this antenna are coaxial probe, aperture coupling with micro strip feed line, aperture coupling with a coaxial feed line ,Direct micro strip feed line, coplanar feed soldered through probe, slot line, strip line, conformal strip and dielectric image guide. The aperture coupling with a perpendicular feed and conformal strip feed is presented.

C. Mode of operation and DRA Arrays

The various modes existing in the waveguide are TE (Transverse Electric), TM (Transverse Magnetic) and TEM (Transverse electromagnetic). The modes observed for this antenna are $TM_{110,}$ TM_{01} and TE_{111}. The air gap affects the resonant frequency, resonance resistance and resonant impedance when a hole is drilled for the probe feed.

The antenna gain for a single DRA is found to 5dBi. So, an array of antennas is introduced to augment antenna gain. The DRA has radius a=5.96mm, height=9.82mm and dielectric constant r_a =16. A rectangular slot of length L=8 and width W=0.8mm is made at the centre of the antenna. A process called stub matching can be used to enhance the band width but impedance matching can be done only in case of micro strip feed antenna.

D. Coplanar Waveguide

The millimeter waves have wave guiding media such as Hollow metal waveguides, planar transmission lines, quasi planar transmission lines and Dielectric Integrated circuits. The wave guiding media used here is planar transmission line. Among the three types of coplanar waveguides namely Conventional CPW, Conductor backed and micro machined CPW, any of the above can be chosen depending on the nature and requirement. It has a capacitive membrane shunt switch. The membrane has a thickness ‘T’, Length ‘L’ and width ‘W’. The CPW is also implemented in MEMS (Micro Electro Mechanical Systems).

Formulae

A. For variation of bandwidth

The variation of bandwidth is obtained from the half–power impedance bandwidth, with the air gap radius *d*. The half–power impedance bandwidth is defined as

$(f - f_L)/f_R \times 100\%$,

Where, f_U and f_L denote upper frequency and lower frequency respectively. The upper and lower frequencies have the half resonant resistance and f_R is the resonant frequency of the DR antenna. It is seen that, with the presence of the air gap, the antenna bandwidth increases and reaches a maximum value of about 24% at $d = 0.6a$, which is nearly two times of that for no air gap presence. To verify the far field radiation patterns we must use a finite size ground plane, The far field radiation patterns of a DRA with a=0.1706e, a/h=1.67, f/a=0.95 A r=8.9, and a circular ground plane of radius 1.297e are computed, as Excellent agreement between computed and measured results is obtained.

B. Calculating length, Width and Frequency

Due to the fringing effects, electrically the antenna looks greater than its physical dimensions. An extension on each end by a distance *3L*, which is a function of the effective dielectric constant $\boldsymbol{\varepsilon}_{R\,eff}$ and the width-to-Height ratio (*W/h*), is made.

A very popular and practical approximate relation for the normalized extension of the length is shown.

$L\text{eff} = L + 2\Delta L$

Since the length of the patch has been extended by 3Δ on each side, the effective length of the patch is now $L = \lambda/2$ for dominant TM010 mode with no fringing

Simulation

The simulation is performed using CST (Computer Simulation technology).The results are found to be in agreement with theoretical evaluations.

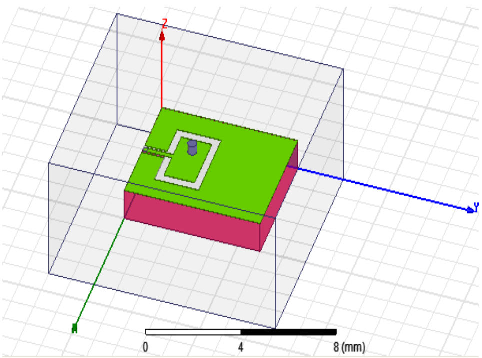

Figure 4(a): 3D structure depiction of Dielectric resonator antenna

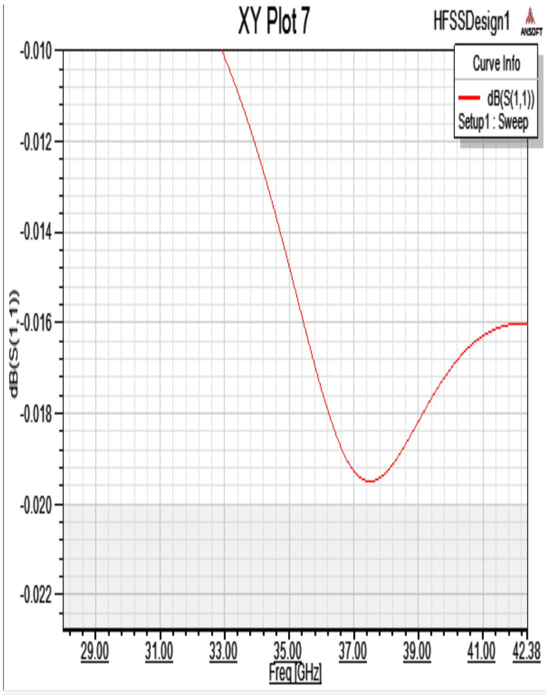

Figure 4(b): scattering parameter S_{11}

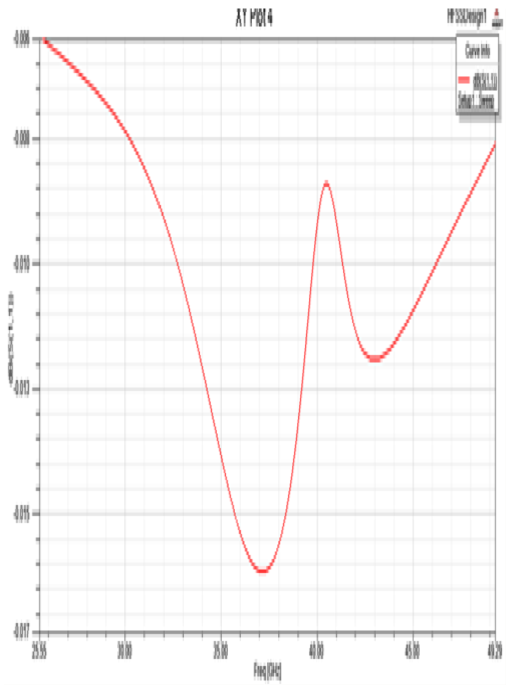

Figure 4(c): scattering parameter S_{11} for dual band

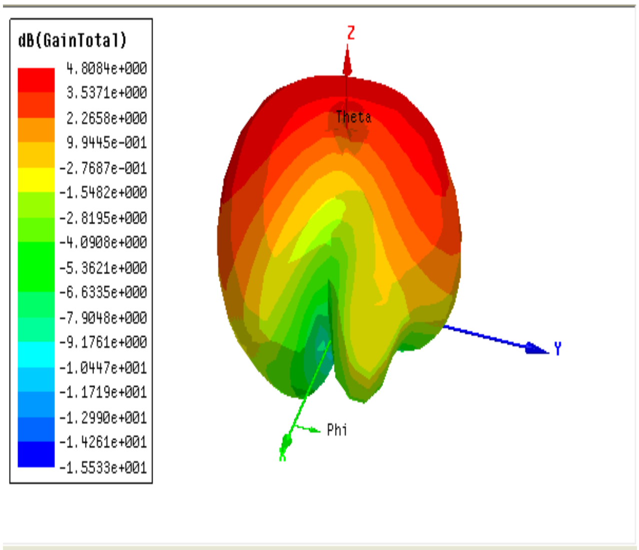

Figure 4(d): Radiation pattern

Conclusion

In this paper, the dual band coplanar dielectric resonator antenna is designed for millimeter wave frequencies and the results are simulated using the HFSS element. Therefore, from this design the unwanted signals are minimized by the dielectric constant. From the simulated results, the antenna arrays were observed to be operating at 37.5 and 43 GHz. These values are very close to the desired designed frequencies (38 and 44 GHz). The gain of the designed single band antenna is found to be 3dB and the gain of the four element antenna array has increased to 6.4dB

The millimeter waves are ranged from 30GHz to 300GHz so that it allocates large amount of band width. The existing systems are designed for single band only but this design can operate in dual band as well. Hence, the designed antenna is capable of receiving two different frequencies simultaneously. Applications include multi standard wireless receivers such as front end modules for the defense purpose, WLAN standards, 4G, 3G, and satellite applications.

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