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UWB COMPLIANT CROSSBREED CPW PATCH ANTENNA

Engineering

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ABSTRACT

The design and analysis of Coplanar Waveguide-fed Ultra-Wide Band antenna have been investigated. The antenna was etched on a single layer FR-4 substrate stretching 50mm x 50mm in dimension. The parameters of the antenna are simulated and optimized with FEM based ANSOFT HFSS V13. The amalgamation of rectangular and trapezoidal, Polyhedron, structure to realize the wide frequency range to cover UWB band (3.1 to 10.6 GHz) is proposed. The elliptical structure is used to provide a high gain and Omni directional radiation pattern. The arc shape slot provides the tri band and notch characteristics and the cross shape slot to reduce radiation loss and backward radiation. The projected antenna with bandwidth covering 2.4-15.50 GHz range, with good Omni directional patterns and Gain of 6.2843dB, Directivity of 6.673 dB. The antenna suits the applications such as Bluetooth, Zigbee, WiMAX, WLAN, Satellite Communications, And Military Communications meeting UWB requirements.

KEYWORDS

Ultra Wideband, Microstrip, Return loss, VSWR, Permeability, Dielectric

INTRODUCTION

The micro strip antenna can be configured to offer high gain, ample elements depends on feeding provision. Multiple frequencies can be deployed into a single patch either by using single feed network [1] or via many networks when the frequency separations are small. Enhanced efficiency and wide bandwidth is achieved by thick substrates with lower range of dielectric but requiring larger element size [2]. Multi frequency patch antennas with enhanced Bandwidth, Efficiency, gain and directivity at higher operable frequency region may be implemented using 2-D electromagnetic crystal substrate [3] materials. The discontinuities in a micro strip patch [4] reduce the length of resonating micro strip antenna and radiation efficiency as well.

A thicker and minimum dielectric constant substrate is desirable in efficiency, bandwidth and radiation view point but at the cost of antenna size [5]. Hence a trade-off must be reached between antenna proportions and performance [6].

Antenna bandwidth can be boosted by use of multiple resonators, different impedance matching, feeding techniques, and slot [7] arrangement. The optimized arrangement of slots reduces the size [8] considerably with escalation of frequency ratio and multi frequency working. With preferred notching ability UWB accommodating design by printed rectangular slots of different shapes is employed in [9] which cover up comparatively reduced frequencies than the proposed one.

Here the hybrid patch antenna [10] is used with slots [11].Slit is added to give notch characteristics. The anticipated radiation pattern is achieved by the study [12] on the dipole and patch antennas. CPW feeding is adopted due to its noteworthy features [13] related to antenna performance.

ANTENNA DESIGN METHODOLOGY

The design requirements for the UWB antenna needs the frequency span of 3.1 GHz to 10.6 GHz which means that the antenna impedance must accomplish a bandwidth of 7.5 GHz in order to avoid a hefty return loss and matching issues. Constant group delay and phase linearity is also essential for specified frequency range. This point up to that the UWB antenna be required to have less likely the dispersion of pulses.

A. *Radiating patch*

A coalesced structure design is implemented on radiating patch. The design flow of the antenna is discussed below.

1) *Elliptical structure*: An elliptical patch on a microwave PCB can spread out circularly polarized waves. And the antenna requires only one feed, and simple geometrical shape enabling theoretical analysis to be carried out in a standard coordinate system.

It affords Omni directional pattern and covering frequency range 3.1-10.6 GHz. The fringe fields at the rim of the substrate and elliptical patch are taken into consideration in the formula. For an ellipse of semi major axis a and semi minor axis b, the foci are at where

$$C = (a^2 - b^2)^{0.5}$$

$$a = \frac{p}{(f(\mu\varepsilon)^{0.5})}$$

$$\varepsilon_0 = 8.854 * 10^{-12}$$

$$\mu_0 = 4\pi * 10^{-7}$$

Where μ - permeability (1); ε - Permittivity of the substrate.(4.4) (for FR4-epoxy substrate)
For ellipse,
Semi major axis, a = 13mm
Semi minor axis b = 9mm
Frequency for the antenna is taken as 3.21 GHz. p is an empirical constant ranging from 0.27 to 0.29.Normally it is taken as 0.275 which agrees well with empirical value. The eccentricity of the ellipse is E_c= C/a.

The eccentricity is limited to a range of 10-28 % for preferred circularly polarized radiation. E_c is taken as 11.62% of the value of semi major axis

2) *Trapezoidal structure* Trapezoidal shape to improve the wideband impedance matching is introduced.

Antenna of this type will have bandwidth of 100MHz approximately at resonant frequency of 1.5GHz with VSWR of 2.1 or less. This confines its application to areas which does not need huge changes in frequencies often. Thus it needs a patch antenna providing the low loss and directivity in a flat package over a wide frequency range. This is obtained by trapezoidal structure which also improves peak gain.

3) *Rectangular structure* This shape is commonly employed in microstrip antenna. As the antenna is loaded with a dielectric substrate, the length of the antenna decreases with the increasing relative dielectric constant of the substrate. The fringing field increases the electrical length of the antenna a little in turn shortens resonant length of the antenna. The design equation of a rectangular structure is,

$$W = \frac{c_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

$$\Delta L = h\left[0.412\,\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right]$$

$$L = \frac{1}{2f_r\sqrt{\mu_o\varepsilon_o}\sqrt{\varepsilon_{reff}}} - \Delta L$$

Where W- width; L – Length of the patch

ΔL - effective length; h - substrate thickness

ε_{reff} - effective dielectric constant

c_o - free space velocity of waveform.

B. Band-notched design

Number of narrowband wireless services like WLAN, HIPERLAN/2, WiMAX shares spectrum with Ultra Wide Band. This results in interference between the UWB system and other schemes.

To alleviate this problem, filters can be used which increases complexity, size and weight of the system and brings in insertion loss for the transceivers. To surmount it, band-notched techniques can be deployed by embedding slots on radiating patch.

1) *Embedding slot:* Familiar and straightforward way to achieve band-notch characteristics. No retuning required for the previously determined dimensions once it is applied to antenna. The notch frequency can be given as

$$f_{notch} = \frac{c}{2L\sqrt{\varepsilon_{eff}}}$$

At the f_{notch}, current is intense around the boundaries of the slot and is oppositely directed between the interior and f_{notch}. This causes the desired high attenuation in the vicinity of f_{notch}.

2) *Arc shape slit:* A 0.5mm thickness circular shaped slit provides notch-band characteristics and also possessing a tri-band characteristics. The width defines bandwidth.

3) *Cross shape slot:* A 10x10mm cross shape slot is cut to overcome the limitation of FR-4 substrate also providing less radiation loss and minimizes backward radiation.

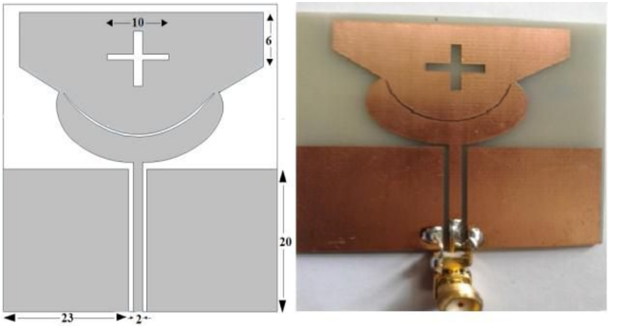

Figure 1.Fabricated antennand its layout (values in mm)

A 1mm gap in CPW feeding offers better UWB impedance matching.

RESULTS

The resultant antenna performance is simulated through HFSS and the results are weighed against measured ones.

A. Return loss (S_{11})

Return loss is a measure of the effectiveness of power delivery from a feed to antenna.

RL (S_{11}) = - 20 log10 (Γ) dB

Where, S_{11} = reflection coefficient of antenna from feed.

S_{11} values fall short on -10dB covers the measurement. Return loss = **- 41.5 dB**is achieved maximum here.

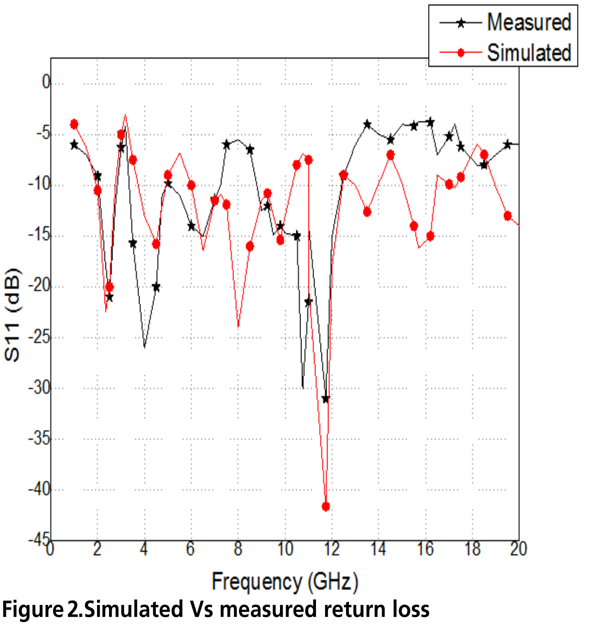

Figure 2.Simulated Vs measured return loss

B. VSWR

The VSWR is an assessment of the impedance misalliance between the antenna and the feed line.

$$VSWR = (V_{max}/V_{min}) = (1+\Gamma)/(1-\Gamma)$$

where, $\Gamma = V_r/V_i = (Z_{in}-Z_s)/(Z_{in}+Z_s)$

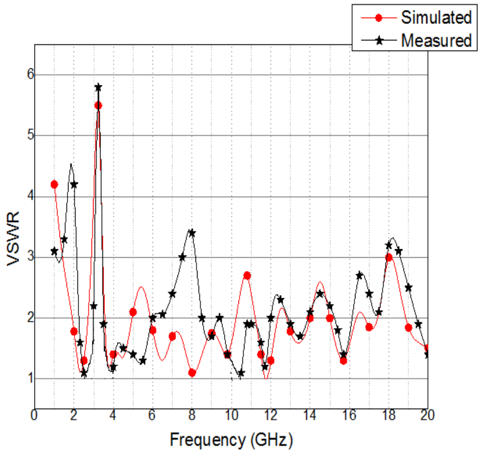

Figure 3.Simulated Vs measured VSWR

The greater the VSWR value higher the degree of mismatch and so the more power reflection to source. The ideal value of VSWR (~1) means that there is no power echo to the source reversely.

The antenna structure with both circular and cross shape slot provides the both return loss and VSWR optimum.

UWB Frequency revealed for the design with tolerable performance in terms of Gain and Return loss and desirable S_{11} for wideband frequency of (2.4-14.50) GHz

C. *Radiation pattern*

The radiation pattern is a graphical show of the far-field pattern of an antenna as a concomitant of spatial co-ordinates, elevation angle (θ) and azimuth angle (φ).

The gain of 6.2845 dB can be achieved at the resonant frequency showing more directivity.The reflection coefficient is best in antenna with both circular and cross shape slots because of fine matching. Both gain and directivity are increasing as number of the notch design is increased in the design.

The radiation pattern evaluated for far-field, Fraunhoffer, range using the formula,

$$R_f > \frac{2.D^2}{\lambda}$$

Where D - diagonal of the antenna dimension

λ - Wavelength of resonating frequency.

This model is used to determine the radiation pattern of the antenna for given directivity. The outline may follow different shape for each frequency ads spherical coordinates. The normalized radiation pattern of the resultant structure is shown here for the range of θ and φ values.

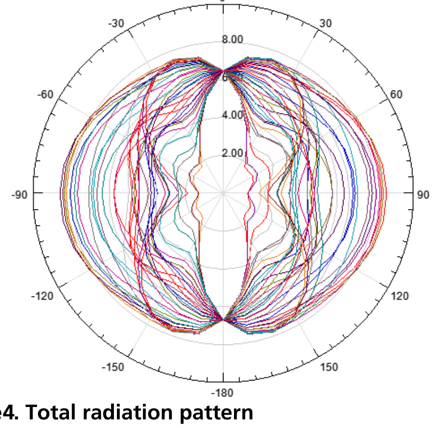

Figure4. Total radiation pattern

TABLE -I
PERFORMANCE OF THE DESIGN EVOLUTION

Parameters	Without notch design	With circular slot	With cross shape slot
Reflection co-efficient	-13	-27.0652	-41.451
VSWR	3.3	1.0454	1.163
Bandwidth	1.3GHz	2.10GHz	2.36GHz
Gain(dB)	1.450	5.019	6.2845
Directivity(dB)	2.881	5.093	6.673
Resonant frequency	17.889 GHz	4.1658 GHz	1.845 GHz
Frequency range	17.889-19.801	4.12 – 12.0	2.457- 14.450

Table I reveals the antenna parameters attained for the diverged structures which show the improved values justifying the plan

CONCLUSIONS

Micro strip square patch antenna has been designed and simulated using HFSS. The simulated result shows the return loss of -41.5 dB and Gain 6.2843dB. The frequency band also has significant range from2.457- 14.450 GHz with appreciable matching properties with VSWR of 1.163 with considerable 2.36 GHz bandwidth increment. The work shall be extended to modify the dimension, geometry and feeding method to make the antenna operates at multiple frequencies

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