A Novel Structure of CPW-Fed Microstrip Patch Antenna for Ultra Wide Band (UWB) Application

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Abstract : Now a day's, Due to tremendous growth in wireless communication in the aspect of need of higher data transfer rate and portable and compact device, the requirement of antenna having simple structure, compact size, stable radiation pattern while retaining extremely broad frequency range is on high demand. However UWB antenna design especially for portable device has some challenges including the ultra wide band performance of impedance matching and radiation stability, compact antenna size, constant group delay and low manufacturing cost for consumer electronics application. Microstrip antenna became very effective candidates for wireless communication systems due to their low profile, wide impedance bandwidth, and compact size, ease of fabrication, etc. In this paper, a novel design and analysis of a coplanar wave guide (CPW) fed ultra wide band microstrip patch antenna is proposed for UWB Applications. The antenna consists of Elliptical patch of major and minor axis of 32 mm and 24 mm fed through CPW line having width 3 mm. The proposed patch antenna is elliptical in structure which gives larger degree of freedom and flexibility in the design, compare to circular configuration and can also provide circular polarization by means of proper selection of feed line of ellipse while CPW fed provide good impedance matching. The antenna is overall size of 50×35×1.6 mm3 and assumed to fabricate on RT Duroid substrate whose dielectric constant is 2.32.The proposed antenna is simulated and exhibit impedance bandwidth of 2.4 GHz to 10.6 GHz (8.04 GHz) for S11≤ -12 dB with stable radiation patterns, better impedance matching, low VSWR and reasonable gain over UWB.

Index Terms - UWB Microstrip antenna, coplanar wave guide (CPW) antenna, Elliptical patch antenna, HFSS

I. Introduction

Since 2002, when the US Federal Communication Commission (FCC) approved the unlicensed use of UWB band in the frequency range of 3.1 GHz to 10.6 GHz [1], The researcher gets much attention to use this spectrum for UWB communication system for short data transmission due to its inherent properties of low power consumption, high data rate and simple configuration which led the great demand of UWB antenna [2-4]. With the rapid growth of UWB systems, antennas are said to be electronic eye of world in communication system and hence various types of antennas are being design for UWB applications [5-6]. Commonly, UWB refers to a signal or system that has a large relative bandwidth i.e. more than 20% or large absolute bandwidth of more than of 500 MHz in order to FCC definition,2002 [7]. The design of antenna for UWB application should satisfy the properties like wide bandwidth, stable radiation pattern, constant gain, high radiation efficiency, constant group delay, low profile and easy manufacturing [8]. The microstrip ultra wideband (UWB) antennas have get much attention concerning their advantages such as simple structure, narrow bandwidth, low profile, high data rate transfer, easy integration with monolithic microwave integrated circuits (MMICs), and ease of fabrication [9-10]. Thus, UWB antenna has become the most promising solution for future short-range high-data wireless communication applications, ultra-wideband (UWB) for short-range (10 m), peer-to- peer ultra-fast communications and for many more applications. This has triggered the researcher's world over to dwell deep in design of UWB antennas. UWB antennas are getting widespread popularity due to their various superior qualities [11-13]. They can be constructing to use short pulse technique to get high range resolution while radiating energy in particular direction. Meanwhile UWB signals can be used to track and determine accurate position of objects. In multipath environment, the performance of UWB antenna is better to that of narrowband system because a UWB short pulse allows return from distinct scatterers to be identifying by using time delay [14].

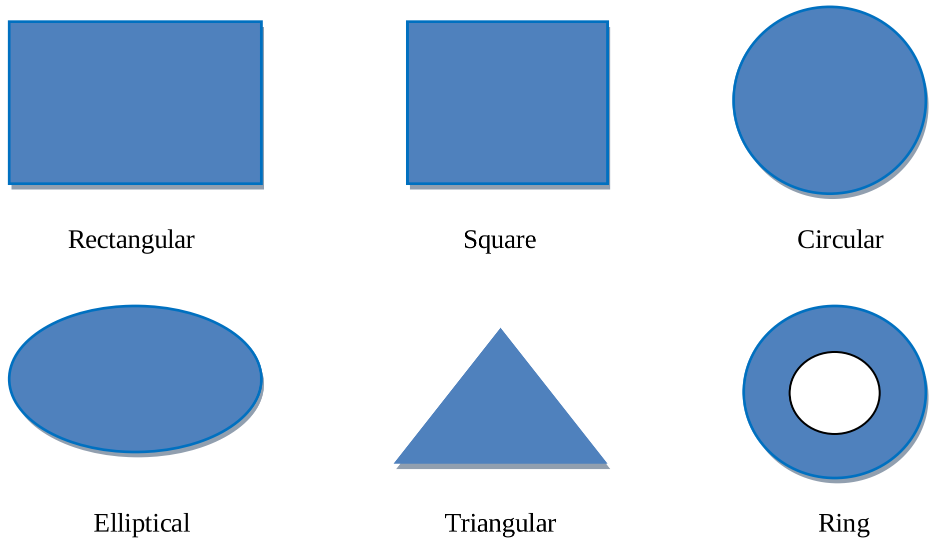
In this paper, a novel design and analysis of a coplanar wave guide (CPW) fed ultra wide band microstrip patch antenna is proposed for UWB Applications. The antenna consists of Elliptical patch of major and minor axis of 32 mm and 24 mm fed through CPW line having width 3 mm. The proposed patch antenna is elliptical in structure which gives larger degree of freedom and flexibility in the design, compare to circular configuration and can also provide circular polarization by means of proper selection of feed line of ellipse while CPW fed provide good impedance matching. The antenna is overall size of 50×35×1.6 mm3 and assumed to fabricate on RT Duroid substrate whose dielectric constant is 2.2.The proposed antenna is simulated and exhibit impedance bandwidth of 2.4 GHz to 10.6 GHz (8.04 GHz) for S11≤ -12 dB with stable radiation patterns, better impedance matching, low VSWR and reasonable gain over UWB. Ansoft High frequency structure simulator (HFSS) v15 has used to design and simulate the antenna which works on the principle of finite electromagnetic method (FEM). The FEM technique uses triangular shape meshes for surface meshing and tetrahedron shape meshes for volumetric meshing. Both these geometries are chosen as with these geometries two dimensional and three dimensional regions respectively can be meshed.

1.1 Microstrip Patch Antenna

The Microstrip antenna is likely most successful and revolutionary technology ever. The Microstrip patch antenna is most used antenna in the field of military, missile, aircraft, spacecraft, mobile & satellite communication and medical due to owing advantages such as light weight, low profile, easy and low cost fabrication, mechanical robustness and versatility in terms of electromagnetic characteristics [6]. It can operate at microwave frequencies (f > 1 GHz). Of course patch antenna has some disadvantages; one well known is narrow bandwidth and low efficiency. However even these shortcomings have been overcome by deploying several techniques to increase the bandwidth and very wideband Microstrip antennas have been developed.

It consists of a metallic "patch" on top of dielectric substrate and it has ground plane below the dielectric material. The patch is fed through different method viz. line fed, probe fed, proximity fed, aperture fed, CPW fed etc to activate the Microstrip antenna [15]. The patch is designed so its pattern maximum is normal to patch i.e. broadside radiator. The position of the feed has to be changed as before to control the input impedance matching. The patch, Microstrip transmission line and ground plane are made of high conductive material typically of copper. There may be several shapes of patches of Microstrip antenna but most common shape are rectangular, circular, elliptical, square and triangular.

Some Common Patches Shapes:



The radius of circular patch is given as [16],

$$a = \frac{F}{\sqrt{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}}} \quad (1)$$

Where, $F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}}$

The effective radius of semi major axis of elliptical patch is given by [17],

$$a_{eff} = a\left\{1+\frac{2h}{\pi\varepsilon_r a}\left[\ln\left(\frac{a}{2h}\right)+(1.41\varepsilon_r+1.77) + \frac{h}{a}(0.268\varepsilon_r+1.65\right]\right\}^{1/2} \quad (2)$$

Even mode resonance frequency: $f11 = \frac{15}{\pi e a_{eff}}\sqrt{\frac{q11}{\varepsilon_r}}$ (3)

q11 = -0.0049e + 3.788e2 - 0.7278e3 + 2.314e4 (4)

Odd mode resonance frequency: $f11 = \frac{15}{\pi e a_{eff}}\sqrt{\frac{q11}{\varepsilon_r}}$ (5)

q11 = -0.0063e + 3.8613e2 - 1.3151e3 + 5.2229e4 (6)

Where, a = Radius of Circular patch
f_r = Operating frequency
ε_r= Dielectric Constant
h = Height of Substrate
a_{eff} = Effective radius of elliptical patch

II. PROPOSED ANTENNA STRUCTURE

Unlike the conventional UWB microstrip antenna using a solid ground plane on other side, in this design, the two grounds were etched on same plane of the monopole of length "L1" and width "W1" respectively. The above design skills are introduced to obtain the ultra wide band accompanied with good impedance matching over the entire operating band. The diagram of antenna structure has shown in Figure (1).The patch antenna is assumed to be fabricated on RT Duroid substrate whose dielectric constant is 2.2 and thickness is "H". The length and width of the RT Duroid substrate are represented by "L" and "W" respectively. The major and minor axis of elliptical patch is represented by "a" and "b" respectively and the signal is fed through a coplanar waveguide having line width and length "W2" and "L1" respectively. The antenna is overall size of 50×35×1.6 mm3 and copper is used for patch and plane designing of antenna. The elliptical patch gives the greater flexibility and freedom to design antenna compare to circular while CPW-Fed provide good impedance matching. Ansoft HFSS (High Frequency Structure Simulator) v14 has used to design and simulate the antenna which works on the principle of FEM (Finite Element Method). The FEM technique uses triangular shape meshes for surface meshing and tetrahedron shape meshes for volumetric meshing. Both these geometries are chosen as with these geometries two dimensional and three dimensional regions respectively can be meshed.

TABLE-I

Design Parameters of Proposed CPW-Fed Microstrip Antenna

Parameters	Value
Over All size of antenna, L×W×H	50×35×1.6 mm3
Length of Substrate, L	50 mm
Width of Substrate, W	35 mm
Height of Substrate, H	1.6 mm
Length of each Ground Plane, L1	23 mm
Width of each Ground Plane, W1	16 mm
Length of Feed Line, L1	23 mm
Width of Feed Line, W2	3 mm
Major Axis of Elliptical Patch, a	32 mm
Minor Axis of Elliptical Patch, b	24 mm
Dielectric Constant of substrate	2.2

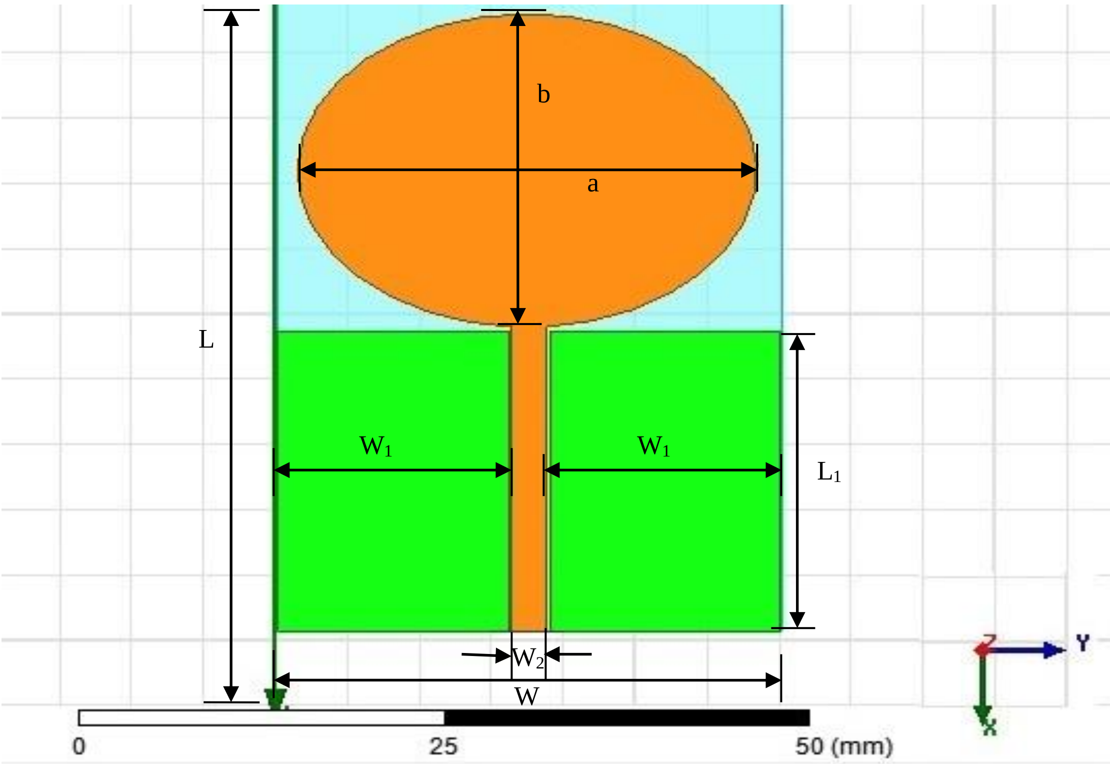
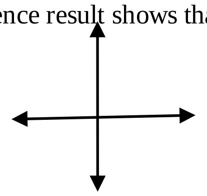


Figure (1):-Geometry of Proposed Antenna

III. Simulation Results and Discussion

Return loss (S_{11}) and Bandwidth: - Return loss refers as the loss of power in the signal returned due to mismatch in transmission line. The return loss of an antenna can be measured from return loss verses frequency plot. While the Bandwidth of antenna is the range of frequencies over which antenna can operate correctly and it can be calculated from return loss graph. Figure (2) is the measured curve of return loss for proposed structure. The simulated result shows that the impedance bandwidth of proposed antenna is 8 GHz (2.6 GHz to 10.6 GHz) for a return loss of -12 dB. The simulated result also indicates that the best value of return loss comes -19 dB at frequency 6.5 GHz. Hence result shows that proposed antenna can operate for UWB application.



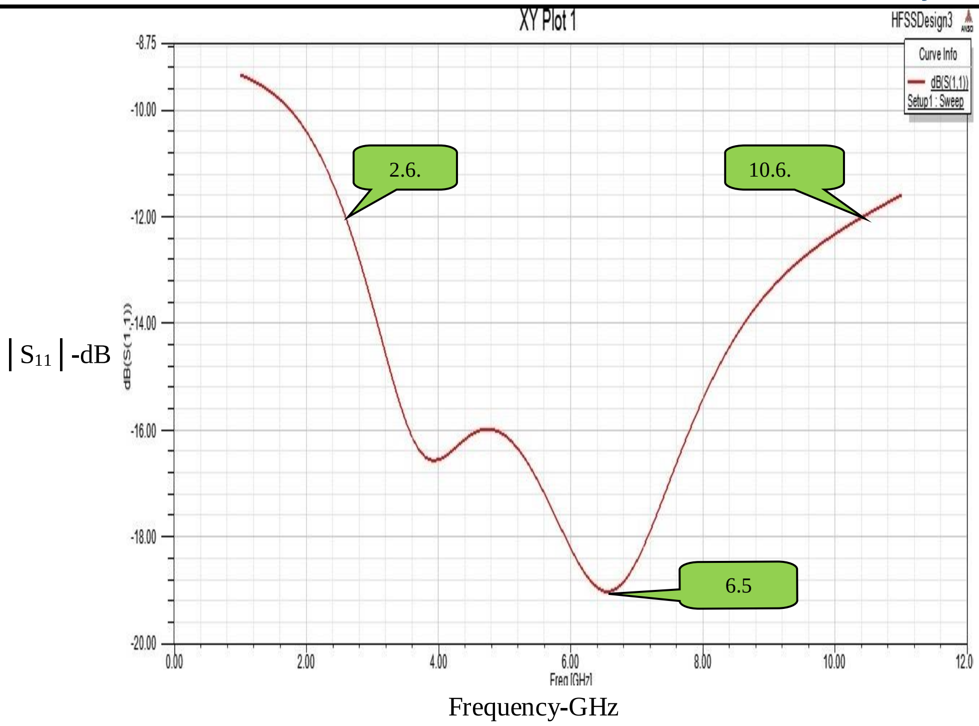


Figure (2):- The simulated return loss (S_{11}) of the proposed antenna

VSWR:-Voltage Standing Wave Ratio is the ratio of maximum voltage to minimum voltage in standing wave pattern along the length of transmission line structure. Its value lies in the range of 1 to plus infinity. Figure (3) shows the simulated result of VSWR of proposed antenna, it can be clearly seen from figure that VSWR of proposed antenna is less than "1.9" for whole impedance Bandwidth of proposed antenna of 8 GHz (2.6 GHz to 10.6 GHz) and best value for VSWR comes 1.5 at frequency 6.5 GHz which is good qualification for UWB applications.

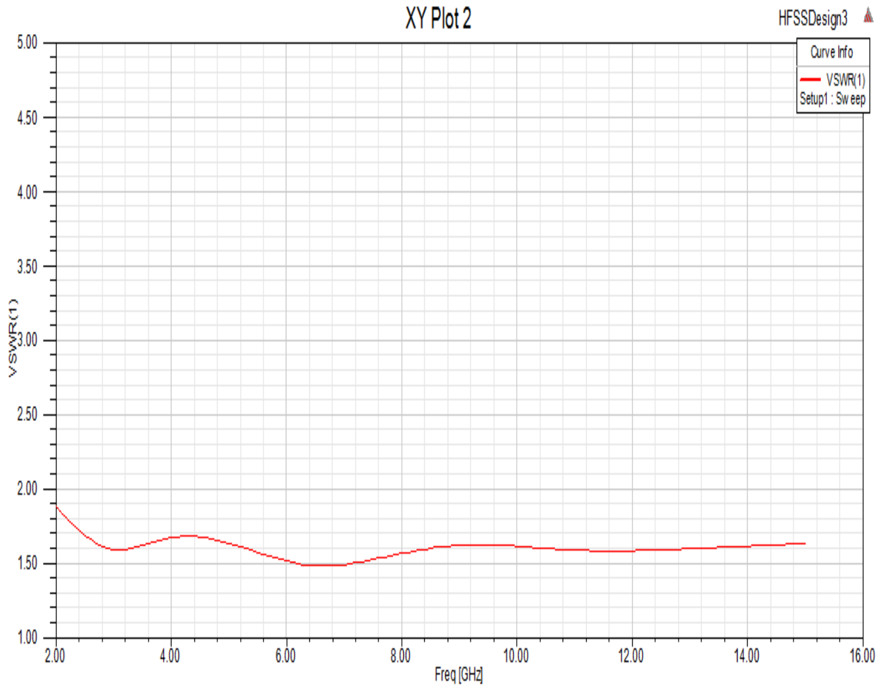


Figure (3):- Simulated VSWR of proposed antenna

Radiation Pattern:-Radiation pattern represents the energy radiated by antenna. It is the diagrammatical representation of distribution of radiated energy into space as a function of direction. The 2D radiation pattern of proposed antenna is shown in Figure (4).The simulated result shows Omni directional radiation pattern in H-plane at 6 GHz frequency. The simulated 3-D radiation pattern of antenna is shown in figure (5). The 3D figure shows the clear visualization in which direction antenna radiate, In this case the radiation is maximum in Y-Z plane.

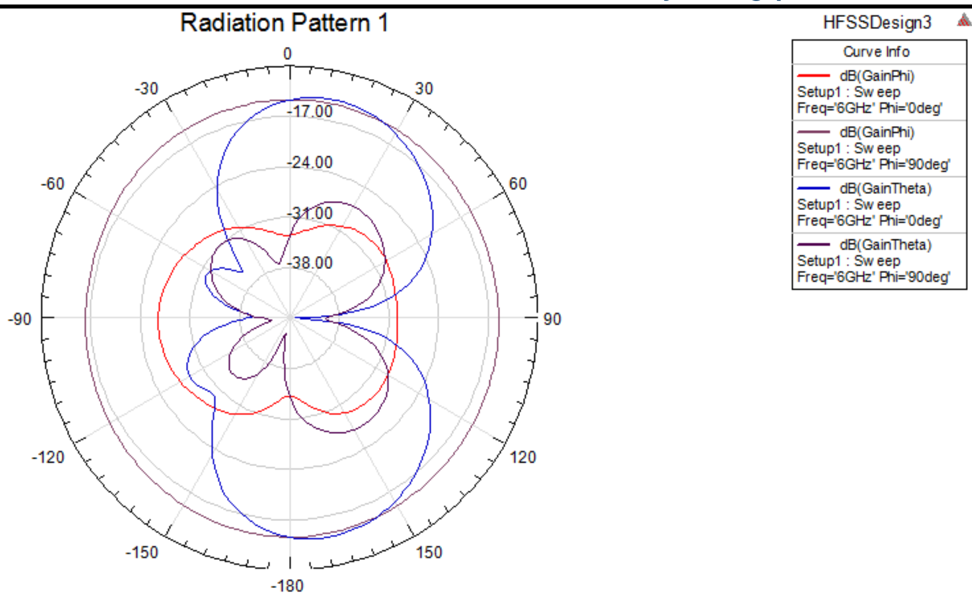


Figure (4):- 2D-Radiation Pattern of Proposed Antenna

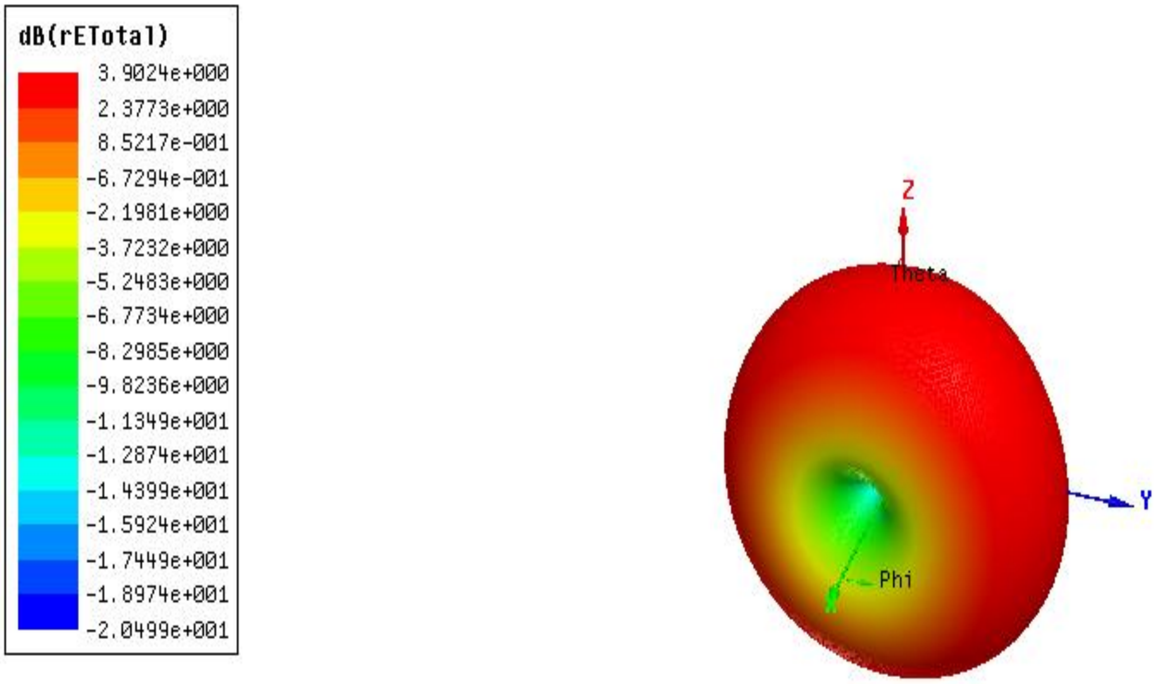


Figure (5):- 3D Radiation Pattern of Proposed Antenna

IV. Conclusion

A novel design and analysis of a coplanar wave guide (CPW) fed ultra wide band microstrip patch antenna is presented here for UWB Applications. The proposed patch antenna is elliptical in structure which gives larger degree of freedom and flexibility in the design, compare to circular configuration and can also provide circular polarization by means of proper selection of feed line of ellipse while CPW fed provide good impedance matching. The antenna is overall size of 50×35×1.6 mm3 and assumed to fabricate on RT Duroid substrate whose dielectric constant is 2.32.The proposed antenna is simulated by using Ansoft HFSS (High Frequency Structure Simulator) v14 and exhibit impedance bandwidth of 2.4 GHz to 10.6 GHz (8.04 GHz) for S11≤ -12 dB with stable radiation patterns, better impedance matching, low VSWR and reasonable gain over UWB.

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