Low Profile Stacked Patch Antenna for Satellite Communication

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ABSTRACT:

For satellite communication, circularly polarized antennas are often used since they have the ability to mitigate the multipath effects and provide additional freedom to the orientation angle of the transmitting and receiving antennas. A low-profile circularly polarized stacked patch antenna with U-slots was designed, fabricated and measured at 2 to 10 GHz for satellite and communications applications. T-slots on the driven patch is proposed and its design is optimized to improve the bandwidth of the antenna. In addition, the -10 dB return loss has been compromised in favor of a wider, stable and acceptable performance bandwidth. HFSS design software used to evaluate a performance

I. INTRODUCTION

A **patch antenna** is a type of radio antenna for a low profile, which can be fabricated on a flat surface. It contains of a flat rectangular sheet or "patch" of metal, mounted over a longer sheet of metal called a ground plane. The two metal sheets together shape a resonant bit of microstrip transmission line with a length of around one-half wavelength of the radio waves. The radiation system emerges from discontinuities at each truncated edge of the microstrip transmission line.

The radiation at the edges affects the antenna to act slightly larger electrically than its physical dimensions, so in order for the antenna to be work in resonant, a length of microstrip transmission line slightly should be shorter than one-half the wavelength at the frequency is used. The patch antenna is mostly practical at microwave frequencies, at which wavelengths are short enough that the patches are suitably small.

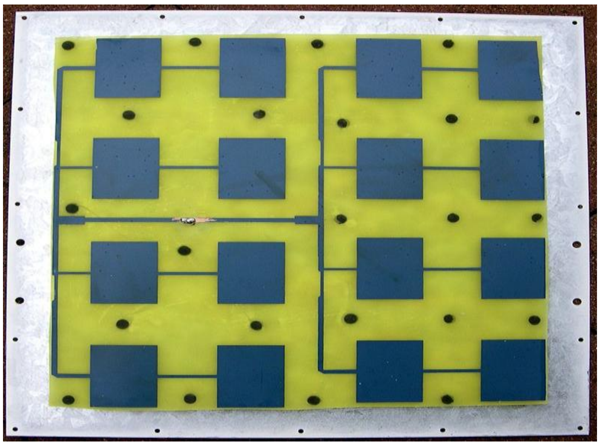

Fig 1.1 Patch antenna

It is usually used in portable wireless devices because of the ease of fabricating it on circuit boards. Multiple patch antennas fabricated on the same substrate *(fig 1.1)* called microstrip antennas, can be used to achieve high gain array antennas, and phased arrays in which the beam can be electronically directed.

A different type of the patch antenna commonly used in mobile phones is the shorted wave patch antenna, or planar inverted-F antenna (PIFA). In this type antenna, one corner of the patch is grounded with a ground pin. This different has better matching than the standard patch. Another variant of patch antenna with the partly etched ground plane, also known as printed monopole antenna, is a very versatile type antenna for dual-band operations

Microstrip patch antenna comprises of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 1.2. The patch is usually made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are frequently photo etched on the dielectric substrate.

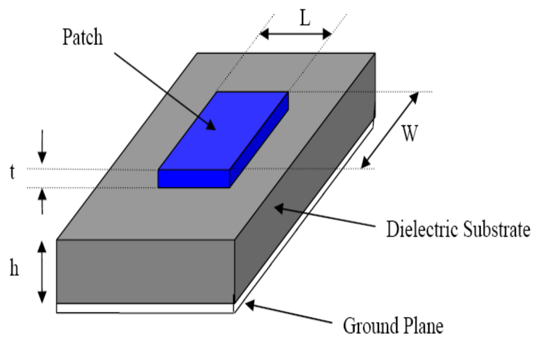

Figure 1.2 Structure of a Microstrip Patch Antenna

In order to simplify performance prediction and analysis , the patch is usually square, rectangular, triangular ,square, and elliptical or some other common shape as shown in Figure 3.2.For a rectangular patch, the length L of the patch is regularly 0.3333λ <*L* <0.5λ, where λ is the free-space wavelength of patch. The patch is designated to be very thin such that *o t* << λ (where *t* is thickness of patch).The height *h* of the dielectric substrate is typically 0.003 *o o*λ ≤ *h* ≤ 0.05λ. The dielectric constant of the substrate (*r*ε) is usually in the range 2.2 ≤ ≤ 12 *r* ε .

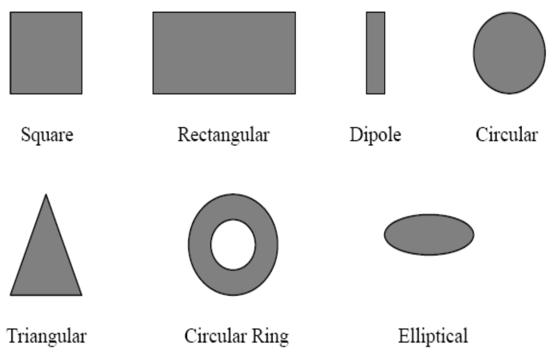

Figure 1.3 Common shapes for microstrip patch elements

Microstrip patch antennas emit radiation primarily because of the fringing fields between the patch edge and the ground plane. For good antenna, a thick dielectric substrate having a lower dielectric constant is desired since this delivers better efficiency, larger bandwidth and better radiation. However, such a configuration makes antenna size to a larger. In order to design a compact size of microstrip patch antenna, higher dielectric constants should be used which are less efficient and result in narrower bandwidth. Hence a compromise must be touched between antenna dimensions and antenna performance.

II. RELATED WORK

C. Borja, and J. Soler [3] presented a small H-shaped microstrip patch antenna (MPA) with improved bandwidth. First the H-shaped antenna is studied by a transmission line model and then is analyzed with a MoM code. A stacked patch configuration is suggested to increase the narrow bandwidth, directivity and radiation efficiency.

Pozar, [4] introduced a variation of the aperture-coupled stacked patch microstrip antenna, which greatly improves its bandwidth. Bandwidths of up to one octave have been attained. The impedance behavior of patch is compared with that of other wide-band microstrip radiators.

Nirmalathas [5] presented in this paper, an end fire printed-dipole antenna with broadband and low-mutual coupling characteristics is introduced for the millimeter-wave applications. The printed dipole is angled at 45° for a small size. To appreciate a wide frequency band of operation, the antenna is fed by an balun, which consists of a folded rectangular slot and a microstrip line.

Gupta [6] defines three new configurations for increasing the impedance bandwidth of the patch antennas. In these configurations, extra resonators are directly coupled through short sections of microstrip line to the radiating edges, non radiating edges, and all the four edges of the rectangular patches, respectively.

Wong and Hsu, [8] suggested a new broad-band design of a probe-fed rectangular patch antenna with a pair of widespread slits. The offered design is with an air substrate, and implementation results show that, simply by injecting a pair of wide slits at one of the radiating edges of the rectangular patch, better impedance matching over a wide bandwidth can easily be attained for the proposed antenna.

III. PROPOSED SCHEME

A. PROPOSED SYSTEM

A low-profile circularly polarized stacked patch antenna with U-slots was designed, fabricated and measured at 240 to 300 MHz for satellite and communications applications.In this project a novel low profile circularly polarized stacked patch antenna with two small S-slots is proposed for satellite communications at 240–300 MHz (22% bandwidth). A New material analysis for patch antenna has been designed with capabilities of both bandwidth enhancement and harmonic suppression.

Fig. work flow of proposed

In patch antenna design, air gap or substrate with low dielectric constant can help to improve the bandwidth of the antenna. This, however, results in an increase in patch's size, close to halfwavelength, which is too large for meeting miniaturization size requirements. To miniaturize the size of the antenna, substrate with high dielectric property was proposed for the antenna design. In addition, a stacked patch setup was used for wide S11 bandwidth. A dual fed configuration was also implemented in the proposed antenna design as dual fed or multiple fed techniques can provide wider axial ratio bandwidth. The initial design of the proposed dual-fed stacked patch antenna design. The driven patch and the parasitic patch were printed on the top of the substrates, where the driven patch was fed by two copper probes from the bottom. There was a small air gap in between the substrate layers. The air gap was for fabrication purpose, which provide space for the solder to bound the driven patch and the copper probes together. To determine which dielectric material is more suitable for the antenna design, different dielectric materials with high dielectric constant were examined, which include FR4, TC600 (Rogers), and TMM10i (Rogers). The dielectric materials have dielectric constant of 4.4, 6.15 and 9.8, respectively. Simulations of the patch antenna with different dielectric materials were performed in HFSS. The dimensions were adjusted accordingly so that the operating frequency of the antenna is close to the center frequency of the targeting frequency band. The simulation results of the patch antenna design on different substrate materials. Narrow S11 bandwidths (< 6%) were obtained in all

cases. The difference in bandwidth between the substrate materials is around 1%. Nevertheless, antenna design with FR4 has the widest bandwidth. However, for a slight reduction in size and to avoid the variation of FR4, the TC600 substrate was chosen in the further development of the antenna design.

C. EQUIVALENT CIRCUIT

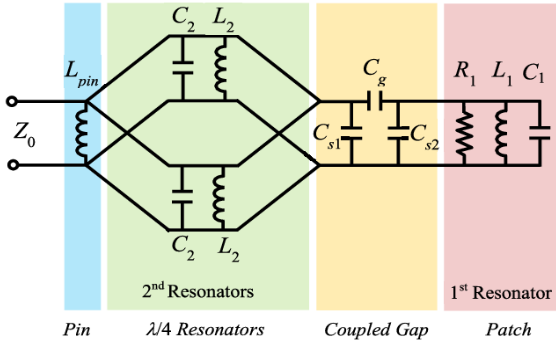

Fig. 2. Equivalent circuit model of the novel patch antenna

Fig. 2 shows the equivalent circuit model of the proposed patch antenna. the rectangular patch is denoted by a lossy resonator of $R1L1C1$, whose parameter values calculated by the transmission-line or cavity model. For each λ /4 resonator, The 2nd resonator, is denoted by a lossless resonator of $L2C2$, whose design values can be calculated. Since the two λ /4 resonators use a common shorting pin, they are denoted by two identical branches in parallel.

A small gap is allowed between the paired λ /4 resonators and the radiating patch to offer a capacitive coupling. Its equivalent circuit can be demonstrated by a λ -type network with three capacitances values ,Cg, $Cs1$, and $Cs2$. These capacitances can be arithmetically de-embedded. The effect of the gap in the proposed antenna will be deliberated in the following section.

The shorting pin is an significant component. In our method, the reactance introduced by this pin is taken into attention and it is modeled as a reactance L_{pin}, which approximated as

$$L_{pin} \approx \frac{\eta}{2\pi} kh \left[\ln\left(\frac{2}{kr}\right) - \gamma \right]$$

Where η and k is the wave impedance and wave number, h and r is height and radius of the shorting pin, and γ is the Euler's constant with $\gamma = 0.5772$.

Design Method

Because of the compact size and symmetrical geometry of the proposed antenna, there are only a few parameters to be calculated in our antenna design. The design procedure includes the following two steps. The first step is to calculate the sizes of the patch (*Lp*× *Wp*) and λ /4 resonators (*Lr*× *Wr*) according to the specified central frequency *f*0. Resonant frequencies of the patch and λ /4 resonator are mostly dependent on their lengths, *Lp*and *Lr*, respectively, which estimated as:

$$L_p = \frac{1}{2 f_0 \sqrt{\varepsilon_{rp}} \sqrt{\mu_0 \varepsilon_0}} - 2\Delta L$$

$$L_r = \frac{1}{f_0 \sqrt{\varepsilon_{rr}} \sqrt{\mu_0 \varepsilon_0}}$$

Where Δ*L* is effective extended length because of the parasitic effects at the two edges of a rectangular patch. $\mu_0$andε_0 are permeability and permittivity in free space, respectively. ε_{rp} andε_{rr} are the effective permittivities for the patch and λ /4 resonators, which can be calculated by using

$$\varepsilon_{ri} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \frac{1}{\sqrt{1 + 12h / W_i}} \qquad i = p, r$$

IV. SIMULATION RESULTS

High Frequency Structure Simulator (HFSS) is a high-performance full-wave Electro Magnetic (EM) field simulation software for arbitrary 3D volumetric passive device modeling that uses the advantage of familiar Microsoft Windows graphical user interface(GUI). It mixes simulation, visualization, solid modeling, and automation in an easy-to-learn environment where solutions to your 3D EM problems are accurately solved and obtained. An soft HFSS works by Finite Element Method(FEM), adaptive meshing, and brilliant graphics to give us unparalleled performance and insight to all of your 3D EM problems. Ansoft HFSS can be used to find parameters such as S Parameters, Resonant Frequency, and Fields.

S. No	Property	Value
1	Dielectric loss tangent	0.0013
2	Bulk conductivity	1
3	Relative permittivity	3
4	Thickness	17.5um
5	Length	2.29
6	Width	4.42
7	Height	0.254
8	Land G factor	2

Table 4.1 Material property

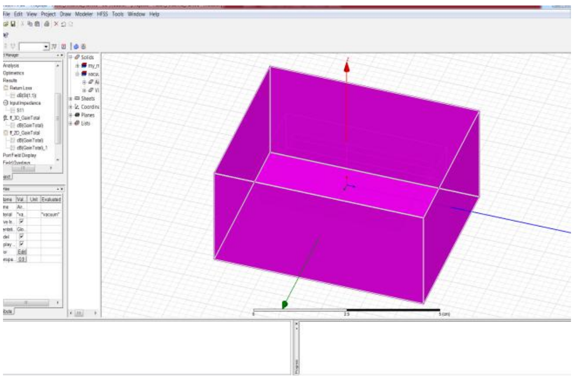

Fig4.1 Air box creation

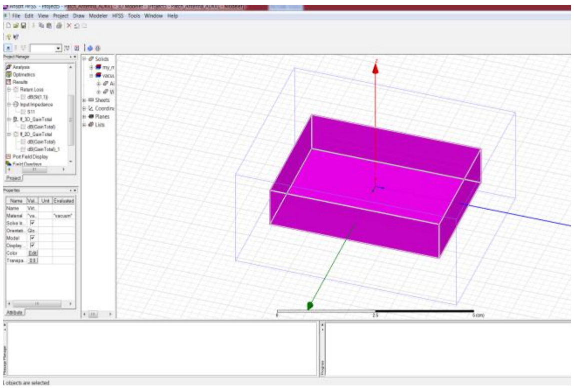

Fig4.2 Virtual radiation

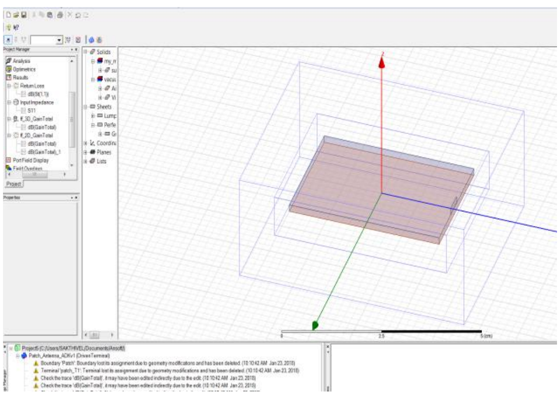

Fig4.3 Ground

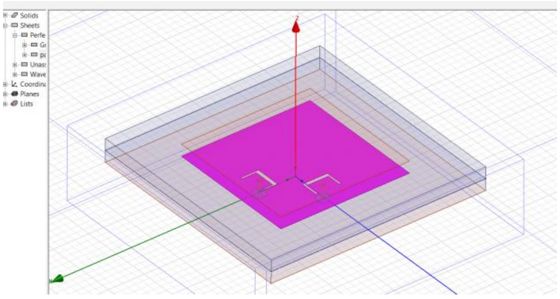

Fig4.4 Outdoor portion of patch antenna

V. CONCLUSION

A novel low-profile circularly polarized and electrically compact patch antenna with U-slots was designed at the 10-12 GHz frequency band for satellite communication. By compromising the - 10 dB S11 for a wider bandwidth with stable and acceptable performance, an antenna with various material was designed, tested using HFSS. In addition, U-slots and 90° hybridcoupler were used to improve the bandwidth of the antenna. This antenna has gain of 8.6 dBic with operating frequency of 10Ghz. Moreover, the proposed antenna has similar performance but much wider bandwidth than the other published low-profile designs of similar dimensions.

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