New Mechanism for Feeding Integrated Elevated Patch Antennas

Adel Saad Emhemmed(1), Abdulmagid A. Aburwein(1), Nasar-Aldian Ambark Shashoa(2)
(1)Electrical and Electronics Engineering Department, University of Tripoli, Tripoli, Libya
(2)Electrical and Electronics Engineering, Azzaytuna University, Trhouna, Libya.
adel@ee.edu.ly

ABSTRACT

A new concept for feeding an elevated patch antenna is presented for first time. The antenna scheme maximizes the antenna radiation performance on high dielectric substrates. The elevated antenna patch is excited by feeding a metal post directly connected with the radiator, and it also vertically mounted at the end of the centre conductor of the covered coplanar waveguide (C-CPW) line underneath the patch. Our results show that the bandwidth is 4.3 GHz, determined from 10 dB return loss and the gain is about 6.3 dB at G-band frequencies (140GHz-220GHz) with nearly constant broadside radiation pattern over its bandwidth.

KEYWORDS

Integrated antenna, mm-wave, surface wave, CPW, planar transmission line.

1 INTRODUCTION

The growing global demand for broadband wireless communication systems motivates the need for new antenna structures with high radiation efficiency, large bandwidth, small size, and integrated with MMICs at ever higher frequencies. G-band frequencies (140-220 GHz) have been currently stimulating great commercial and academic interest as many systems have been allocated or are proposing to use frequencies within this operating band. Such applications include high-data rate wireless indoor communication systems, direct detection radiometers for remote atmospheric sensing, high-resolution passive and active mm-wave imaging applications, systems for detection of concealed weapons, automotive radar, and aircraft navigation in zero visibility conditions [1-3]. These applications have intensified the demand for integrated millimetre-wave antennas with high performance. Traditionally, horn antennas are considered for high gain solutions, however, their overall size and the associated losses resulting from routing signals off-chip to a transition from the active MMICs to the horn make these antennas unattractive[3, 4].

Integrating microstrip patch antennas directly with MMICs in a single package at G-band frequencies offers potential advantages of low cost, reduced parasitic, shrunken transceiver size and increased design flexibility compared with systems based on discrete antennas, since the shorter wavelength of G-band frequencies results in reduced antenna size and increased bandwidth [4]. However, integrating the antenna directly with MMICs at millimetre-wave frequencies above 140GHz is a very challenging task when the substrate thickness become large compared with λ/4. This results in a strong moding effect and high dielectric loss due to surface wave excitation which leads to lower efficiency, reduced bandwidth, degraded radiation patterns and undesired coupling between the various elements in array configurations. This has limited their applications in broadband modules and they are difficult to successfully apply at millimetre-wave frequencies [5, 6]. It has been demonstrated that the surface wave propagation in high dielectric substrates can be reduced by using elevated structures [4, 5, 6]. A reduction in surface waves is very important in millimetre-wave antenna design for it not only improves the efficiency of antenna but also weakens the side-lobe level which is produced by surface wave diffraction around the antenna substrate.

The elevated patch antenna approach can be considered as an alternative to the integration of antenna with MMICs, and has concomitant
advantages over conventional antenna designs such as broader bandwidth and reduced influence of substrate moding effects [7, 8, 9]. To date, undesirable feeding radiation coupling has prevented elevated patch antennas from being efficiently implemented in integrated form. Therefore, this paper proposes a new antenna design that uses covered coplanar waveguide (C-CPW) to feed elevated patch antennas. The main goal of this design is to enhance the antenna gain and reduce the back lobes and substrate effects with emphasis on antenna integration with other MMICs at G-band.

2 C-CPW FEED LINE

The feeding technique of integrated antennas plays a very important role in achieving desirable antenna characteristics. For good antenna performance, a low loss and less radiation feed is desirable since this will provide better radiation efficiency. There are many transmission lines available to meet various applications. The most popular one at higher frequencies is coplanar waveguide CPW, this is because a CPW structure has many interesting advantages over conventional transmission lines. For instance, CPW has inherently less losses at millimetre-wave frequencies due to a large proportion (approximately half) of the field existing outside the dielectric, as a result, the dielectric loss is lower and the dispersion of the signal is considerably less. Also, the CPW line has a uniplanar construction which implies that all of the signal lines and ground planes are on the same surface of the substrate. This attribute simplifies manufacturing by eliminating the need for backside via holes [11]. However, CPW suffers from the excitation of the parasitic slot-line mode, this because the two ground planes of CPW are different potentials [12, 13]. This mode propagates at a different velocity from the dominant even CPW mode and causes more radiation to free space as shown on Figure 1-a.

In this paper, a new technique is propose to eliminate the unwanted radiation mode by covering the CPW using metal cover to shield its field and to equalize potential of the ground planes along the feed line as shown in Figure 1-b.

The centre conductor width W and the gap S between the centre conductor and the ground planes of the CPW were designed to have a characteristic impedance of 50Ω. The CPW dimensions are calculated using LineCalc in Agilent ADS and optimized with HFSS simulation software as follows: W/S=20μm/15μm. Figure 1-b. shows the configuration of the CPW.

The simulation results of return loss for this transmission line is shown in Figure 2 and can be seen to be in good performance at W-band and G-band frequencies.

![Figure 1: Excitation of the parasitic slot-line in a coplanar waveguide](image1)

![Figure 2: a 50Ω C-CPW transmission line return loss.](image2)
Comparing C-CPW and conventional that reported in [3] in terms of substrate loss is achieved by simulating S12 of CPW with cover. A 50 C-CPW transmission line insertion loss is shown in Figure 3. The CPW loss at 220GHz is about 8.4dB, the C-CPW with the same ground size and the same impedance has an only 2.25 dB. This means the C-CPW is more efficient than conventional CPW for antenna feeding at G-band. Since the field efficiently confine inside the cover of CPW as a result the radiation field of C-CPW less than conventional CPW as shown in Figure 4. This characteristic can be beneficial as it provides control over signal leakage and reduces undesirable coupling and crosstalk effect between adjacent monolithic circuits.

### 3 ANTENNA DESIGN

An important principle for antenna design is to avoid the undesirable coupling between the feed line and antenna radiator. The undesirable coupling will decrease the antenna radiation efficiency, hence our design is based on elevated antenna structures. However, elevated patch antennas on high dielectric substrate at G-band have been already demonstrated in [3, 6, 10], exhibiting a significant improvement in the antenna performance. Specifically in [3]. In this paper, the undesirable coupling effect of elevated patch antenna in [10] is further reduced by using C-CPW connected with metal post to feed the antenna. The antenna design takes advantage of the elevated patch antenna approach to eliminate surface waves, and advantage of the undesirable coupling between the feed and radiator to enhance the antenna gain and radiation efficiency.

Figure 5 shows a schematic of the antenna structure. The elevated antenna patch is excited by feeding a metal post directly connected with the radiator, and it also vertically mounted at the end of the centre conductor of the covered coplanar waveguide (C-CPW) line underneath the patch on gallium arsenide substrate. The metal post can be adjusted to an appropriate location below the patch to obtain a suitable input impedance. Therefore, the antenna can be directly matched to various input impedances without using any kinds of transformers. The main advantage of this feed technique is that it provides very high gain, reduce the back to front ratio, and reduces the substrate effects. The rectangular patch is elevated above C-
CPW by posts, which offer a strong and rigid mechanical performance. C-CPW ground plane on the substrate will completely shield the antenna from the underlying elements and vice versa. The cover of CPW will shield the radiated patch from feed line field.

**Figure 5:** A schematic of the antenna structure

The antenna was designed and simulated using the HFSS simulator, which is based on the finite element technique. A waveport at the antenna input terminal was used for the simulation with meshing at \( \lambda/4 \) to obtain higher simulation resolution.

For operation at G-band for radiometer applications at 178.7GHz simulation suggested the geometry of the rectangular patch antenna to be \( Wp \times Lp \) of 806 \( \mu \)m \( \times \) 738 \( \mu \)m, with a groundplane extent, \( Ws \times Ls \), of 1.5 mm \( \times \) 2.0 mm, which is large enough to reduce diffraction at the edges for reducing ripples in the main pattern and backward radiation. The antenna can be fabricated using a standard III-V MMIC airbridge technology.

**4 RESULTS**

The antennas were characterized using HFSS software. Figure 6 shows the simulated return loss of the antenna. The simulation results show an excellent match of -32 dB at 196 GHz and bandwidth of 4.5 GHz from 176.5 GHz to 181 GHz (return loss<-10 dB).

Simulation predicts a nearly constant broadside radiation pattern (beamwidth of 60° in the E-plane and 45° in the H-plane with gain of 6.38dB) with low side lobes, and good the front-to-back ratio of 17.2dB as shown in Figure 7 and Figure 8. This indicates a high radiation efficiency structure across the designed bandwidth. It can be clearly observed that there is a high improvement in the gain for the proposed antenna compared with [10] due to a reduction in the losses of the feed network.

**Figure 6:** Simulated return loss of the antenna.

**Figure 7:** E-plane and H-plane of antenna radiation pattern
CONCLUSION

A novel G-band C-CPW fed elevated patch antenna has been proposed for the first time. By using CPW with the metal cover, the field can efficiently confine inside the cover. This characteristic can be beneficial as it provides control over signal leakage and unwanted parasitic coupling. The antenna operates with a bandwidth of 4.5GHz and gain of 6.38dB. The feed network reduces undesired coupling and substrate moding effects, and shows a viable route to higher levels of integration and functionality. The performance exhibited by the antenna makes it an attractive candidate for antenna arrays applications.

REFERENCES


