# SIW Cavity-Backed Circularly Polarized Dual Loop Antenna with Broadband at Ka Band

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***Abstract* - An SIW cavity-backed dual loop antenna with broadband and circular polarization (CP) operation at Ka band is presented. The dual loop is on the top metal layer of the SIW and is coupled-fed by a longitudinal slot which is on the bottom metal layer. A microstrip-SIW transition is designed as the feed structure. Simulation results show that the antenna has a common bandwidth of 11.1% from 34 to 38 GHz for |S11| ≤ -10 dB as well as for the axial ratio (AR) ≤ 3 dB. A high broadside gain over 8.5 dBi is achieved within the operation band. This design yields good directional radiation patterns and low fabrication cost.**

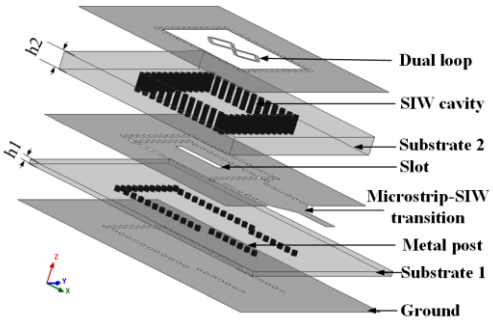
***Index Terms* — Circularly polarized antennas, substrate integrated waveguide (SIW), millimeter-wave antennas, broadband antenna.**

## 1. Introduction

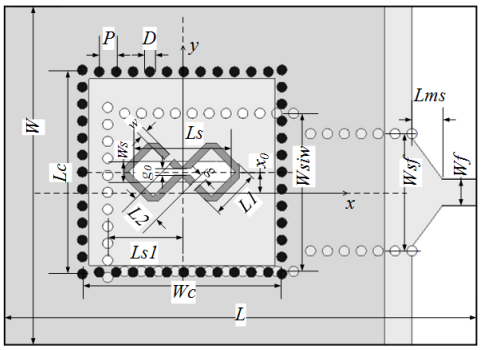
Circularly polarized (CP) antennas are now used in many systems, such as satellite communication, radar and microwave power transmission, etc. Dual loop antenna with CP operation becomes attractive because it has simple structure and a wider axial ratio bandwidth compared with microstrip antennas [1]-[2]. Ref. [1] proposed two types of dual rhombic loop antennas, which obtained the axial ratio (AR) bandwidth (≤3dB) more than 20% and the gain of 10dBi at L band. Ref. [2] suggested that the CP bandwidth of loop antennas could be enhanced by adding a parasitic loop and the AR (≤3 dB) bandwidths was improved up to 60% at C band. However, designing a CP antenna at millimeter-wave (MMW) bands by this way is infeasible owing to the high loss of the feeding structure.

Substrate integrated waveguide (SIW) with merits of low loss, none radiation, lost cost, planar structure and easy fabrication at MMW bands has been widely used as the feed structure of slot and microstrip antenna arrays [3]-[4]. Cavity-backed structures in antenna are noticed because of their excellent characteristics, such as high gain, high efficiency, and directional radiation pattern [5]-[6]. It can also reduce the surface wave and improve the isolation of antenna arrays at MMW bands [7].

In this work, a dual loop antenna for broadband CP operation at Ka band is proposed. To reduce the surface wave and improve the gain, the dual loop is surrounded by a square SIW cavity realized by the upper substrate layer. A microstrip-SIW transition is designed as the feed structure, which is realized by the lower substrate layer. The dual loop is coupled-fed by a longitudinal slot etched on the upper broad wall of an SIW. The proposed Ka band antenna yields advantages of wide bandwidth and low fabrication cost.




(a) 3-D view




(b) top view

(c) side view

Fig. 1. Geometry of the proposed antenna. h1 = 0.254, h2 = 1.016, $W$ = 12, $L$ = 15.6, $Wc$ = 6.3, $Lc$ = 6.3, $Ws$ = 0.6, $Ls$ = 2.9, $L1$ = 1.35, $L2$ = 0.8, $w$ = 0.2, $g$ = 0.2, $g_0$= 0.2, $x_0$ = 0.6, $Wsiw$ = 4.65, $Ls1$= 2.2, $Wsf$ = 3.45, $Lms$ = 0.9, $Wf$ = 0.78, $P$ = 0.5, $D$ = 0.3, in millimeter.

## 2. Antenna Configuration

The 3-D perspective view of the slot-coupled dual loop antenna is shown in Fig. 1(a). The antenna has two substrate layers and consists of a square SIW cavity, a dual loop etched on top layer of substrate 2, an SIW on substrate 1 with a longitudinal coupling slot and a microstrip to SIW transition for feed.

Fig. 1(b) shows the top view of the CP antenna. The dual loop consisting of two same square loops is etched on a Rogers RO4350 substrate (relative permittivity 3.66, loss tangent 0.004, thickness 1.016 mm). Each loop has a gap with a width of $g$ at the distance of $L2/2$ from the center of the

antenna. The two gaps are located symmetrically with respect to the antenna center. By means of combining an S-type dipole antenna with a straight dipole, the currents on the two dipoles produce two orthogonal modes with almost equal amplitude at the feed point. So the CP wave is excited [1]. An SIW cavity with metal via around the dual loop is designed in substrate 1 to block the surface waves. The cavity size of $W_c \times Lc$ is optimized for both AR bandwidth and impedance match. The SIW cavity can also improve the gain of the antenna at millimeter-wave bands.

The SIW feed structure is in Substrate 1 of Rogers RT/Duroid 5880 (permittivity 2.2, loss tangent 0.0002, thickness 0.254 mm). The diameter $D$ and the center distance $P$ of vias in the SIW are 0.3 mm and 0.5 mm, respectively. The width of the slot is important for energy coupling to the dual loop. The slot length affects the center frequency of the antenna. An SIW with smaller width of $W_{sf}$ is used to broaden the impedance bandwidth. A microstrip to SIW transition is designed to feed the SIW cavity-backed CP dual loop antenna.

## 3. Antenna Simulation Results

All simulations and optimizations are performed by the commercial software HFSS using the finite element method (FEM). The optimized parameters are shown in the caption of Fig. 2.

The simulated reflection coefficient |S11|, axial ratio, and broadside gain are shown in Fig. 3. The impedance band for |S11| ≤ -10 dB is from 33.7 to 38 GHz. The AR bandwidth for AR ≤ 3 dB is 19.8% from 34 to 41.5 GHz. So the common bandwidth of |S11| ≤ -10dB and AR ≤ 3 dB is 11.1% from 34 to 38 GHz, in which the center frequency is 36 GHz. The LHCP gain is over 8.5 dBi and gain variation within the operation bandwidth from 34 to 38 GHz is less than 0.5 dB. The highest gain is 9 dBi at 36 GHz.

The simulated radiation patterns of *xz*- and *yz*-plane at 35GHz, 36GHz and 37GHz are shown in Fig. 3 It could be found that the patterns are nearly the same at three frequencies, which exhibits good broadband performance. The cross polarization is better than 29 dB at 35 GHz. The front-back ratios are about 20dB, and the half power beam widths are about 60° at 35, 36, and 37GHz.

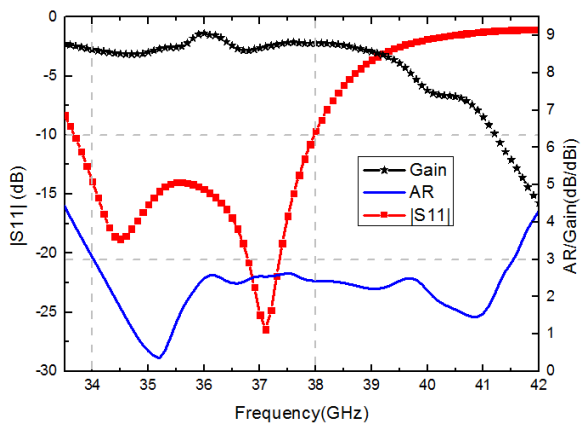



Fig. 2. Simulated |S11|, AR, and Gain.

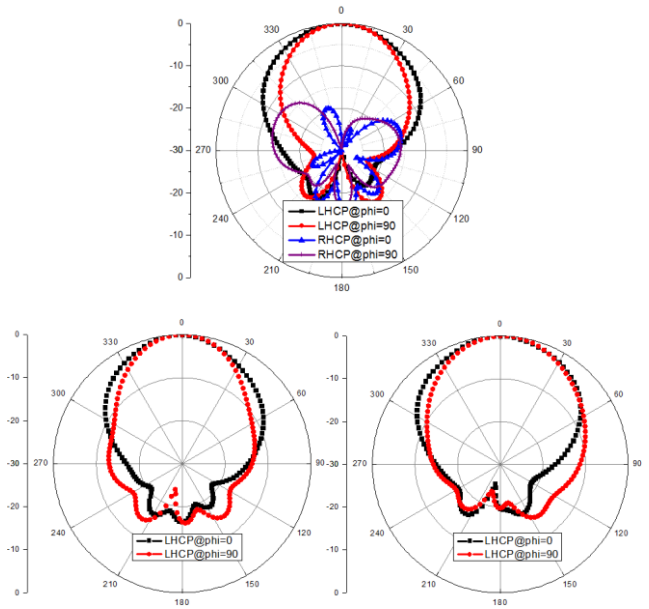



Fig. 3. Simulation radiation patterns of the proposed antenna at 35, 36, and 37 GHz, respectively.

## 4. Conclusion

A broadband CP dual loop antenna at Ka band is studied in this work. The dual loop is coupled-fed by a longitudinal slot on the top metallic surface of the SIW. The antenna presents a common bandwidth of 11.1% from 34 to 38 GHz for |S11| ≤ -10 dB and AR ≤ 3 dB, and a high broadside gain over 8.5 dBi is achieved within the operation band. The antenna has good radiation performance of symmetrical radiation patterns and low back radiation.


## Acknowledgment

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