Design of Substrate Integrated Coaxial Line (SICL) Fed Dipole Antenna for K Band Application

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***Abstract*—In this paper, design of Substrate Integrated Coaxial Line (SICL) fed printed dipole antenna for Ka band application is demonstrated. The proposed antenna efficiently utilizes the out of phase surface current in the central and outer conductor of the SICL to excite the dipole antenna. The use of SICL removes the need of using balun to feed the dipole antenna and makes the feeding network simpler. The metal plate at the top layer acts as reflector for the dipole antenna which helps to enhance the gain of the antenna upto 5.38 dBi with a broad bandwidth of 2.37 GHz. The antenna is implemented in low profile planar substrate making it suitable for practical application in Ka band.**

Keywords- coaxial line, dipole, SICL, planar, Ka band

I. INTRODUCTION

In recent years, studies on millimeterwave antennas have drawn much attention among the researchers due to its inherent advantages e.g. small size, higher bandwidth etc. [1]. Several millimeterwave applications e.g. 5G communication, automotive radar application etc. has emerged as potential technologies for modern wireless communication systems [2]. However, the conventional planar technologies e.g. microstrip, coplanar waveguide etc. have their inherent disadvantage of high radiation loss, surface wave loss etc. for operating in millimeterwave frequencies [3]. Recently a planar version of conventional waveguide technology named substrate integrated waveguide (SIW) has emerged as an alternative for implementing circuits at these frequencies [4].

However, the SIW technology has its inherent disadvantage of limited bandwidth single mode operation, large size etc. which makes it not suitable for compact broadband application. A similar technique named Substrate Integrated Coaxial Line (SICL) can be a good candidate which implements planar version of conventional rectangular coaxial line [5]. The SICL exhibits wideband single mode operation while maintaining compact size. Printed dipole antennas are extensively used over the years as efficient endfire radiators [6]. In this paper, a design of SICL fed printed dipole antenna for Ka band operation is demonstrated. The proposed antenna is implemented in planar substrate and exhibits a high gain and broad bandwidth making it suitable for practical applications.

II. DESIGN

The Substrate Integrated Coaxial Line (SICL) is shown in Fig. 1. The line consists of two layer of dielectric with metallic

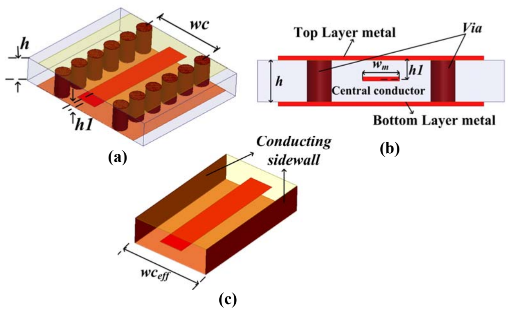

Figure 1. Substrate Integrated Coaxial Line (SICL); (a) 3D View; (b) front view; (c) equivalent rectangular coaxial line (h= 1 mm, $h1$= 0.5 mm, wc= 3 mm, wc_{eff}= 2.52 mm, w_m= 1.2 mm)

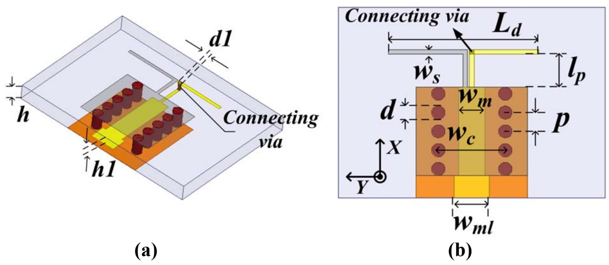

Figure 2. SICL fed printed dipole antenna; (a) side view; (b) top view (h= 1 mm, $h1$= 0.5 mm, w_c= 3mm, w_m= 1.2 mm , w_{ml}= 1.6 mm ,d= 0.6 mm, $d1$= 0.2 mm , p= 0.9 mm, l_p= 1.6 mm, l_d= 7.1 mm, w_s= 0.2 mm)

plate at top and bottom of the upper and lower layer respectively and a metallic strip in the middle sandwiched between the upper and lower dielectric layer. Two rows of metallic vias are placed to implement sidewall shielding as shown in Fig. 1(a) and (b). The structure implements rectangular coaxial line (RCL) in planar substrate as shown in Fig. 1(c). The effective width of the equivalent RCL can be determined from [5]. The dimensions of the SICL are chosen to keep its characteristic impedance of 50 Ω as shown in Fig. 1.

The proposed design uses the SICL line as efficient feeding mechanism for the printed dipole antenna operating in Ka band. The side and top view of the antenna is shown in Fig. 2. The two arms of the printed dipole antenna are fed by top and middle layer conductor of the SICL. Just like conventional coaxial line, transverse electromagnetic (TEM) wave propagates through the SICL with 180^0 phase difference

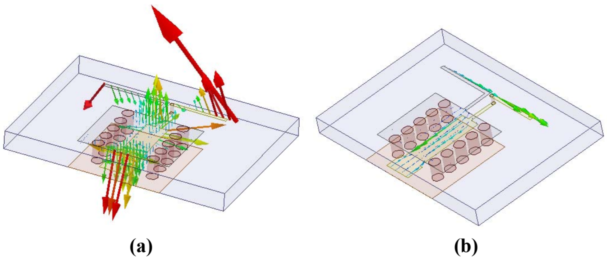

Figure 3. (a) Vector electric field; (b) vector surface current in top and middle layer of the proposed antenna

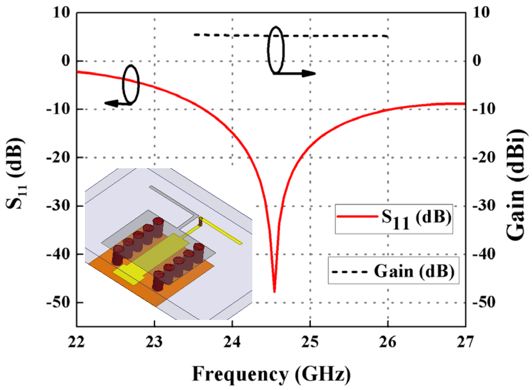

Figure 4. Reflection coefficient and gain of the antenna

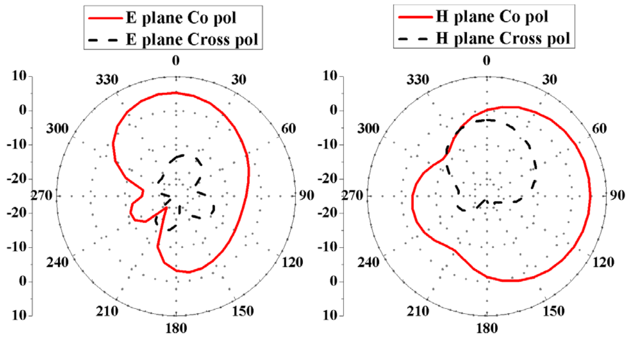

Figure 5. Radiation pattern of the antenna; (a) E plane; (b) H plane

between the surface current flowing through middle layer and top layer conductor. The two arms of the dipole are connected to the top and middle conducting plate using a small section of conducting line of width 'w_s' as shown in Fig. 2. To connect the middle layer conducting line to the left side arm of the dipole, a connecting via is placed as shown in Fig. 1. The diameter of the connecting via is optimized to improve the impedance matching performance of the proposed antenna. The efficient use of out of phase surface current distribution of the SICL removes the requirement of balun and makes the feeding network of the printed dipole much simpler. To excite the TEM wave in the SICL, a small section of microstrip line of 50 Ω is used at the end of the SICL as shown in Fig. 2. The printed dipole antenna is placed at a distance of l_p from the top metallic plate of the SICL. The distance l_p is optimized using Ansoft HFSS to get good impedance matching of the antenna. The top metal plate works as reflector which reflects the backside radiation of the dipole and helps to enhance gain of the antenna towards forwards direction ($\varphi = 0^0$). The vector electric field and surface current plot at the top and central conductor is shown in Fig. 3(a) and (b) respectively. The surface current at the both arm of the dipole antenna is out of phase as shown in Fig. 3(b) which helps to excite the antenna.

III. Simulation Result

The proposed antenna is designed using Rogers RT Duroid 5880 substrate of ε_r = 2.2. The performance of the antenna is shown in Fig. 4. The antenna resonates at 24.6 GHz with impedance bandwidth (-10 dB S_{11}) of 2.37 GHz (9.6%). The gain of the antenna is also shown in Fig. 4. The proposed dipole antenna radiates with a high gain of 5.38 dBi with very small variation throughout its operating bandwidth. The radiation pattern of the antenna is shown in Fig. 5. The presence of top metallic plate helps to reflect the backside radiation and enhances the gain of the antenna. As shown in Fig. 5, the crosspolar component of the antenna is below 19 dB towards the direction of maximum radiation. The front-to-back ratio (FTBR) of the antenna is approximately 9 dB.

IV. Conclusion

A compact planar design of printed dipole antenna fed by substrate integrated coaxial line is demonstrated. The efficient use of top and middle layer conductor of SICL with out of phase surface current to excite the dipole antenna helps to implement simple feeding network with good inherent shielding which makes it suitable for using in Ka band application. The use of top layer conductor as reflector helps the proposed antenna to exhibit higher gain while maintaining broad bandwidth making it suitable for practical applications.

Acknowledgment

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