

# 60GHz Wire-Bond Helical Antennas in 130nm CMOS Technology

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**Abstract**—This paper presents an on-chip helical antenna concept using bond wires and the top metal layer in a standard 130nm CMOS technology. A row of top metal strips provide bonding pad positions for different antenna configurations. Two prototypes are fabricated targeting millimeter wave data link applications. The measured and simulated results show the center frequencies are 67.5 GHz and 85.0 GHz with -3.8 dBi and -4.9 dBi antenna gains, respectively. Both of the antennas occupy an area of  $166\mu\text{m} \times 1600\mu\text{m}$  with the same metal-strip pattern. However, different high-yield wire bonding patterns can lead to a variety of helical antenna options over a wide range of spectrum.

## I. INTRODUCTION

Recently wireless systems operating in the millimeter-wave range have been developed for large-bandwidth, short-range applications to meet the growing demand for high-speed communication [1]-[3]. CMOS technology is now capable of 100-GHz circuits operation [3], and considered as a promising platform because its low cost and ease of integration for full systems. However, its low resistive substrate ( $1\text{-}10\ \Omega\text{-cm}$ ) prohibits antennas from being integrated on chip due to significant power loss. Recently, wire-bond antennas have been proposed, showing improved efficiencies and antenna gains at millimeter wave range [1]-[5]. A loop configuration with a ground plane is popular among previous work. Given the simplicity for yield control and high performance, it is one of the best solutions for on-chip wire-bond antennas. However, its center frequency is mainly determined by the length of the bond wire, and there are constraints on the dimension such as the height and bending angles, therefore limiting the range of frequencies over which single-loop bond-wire antennas are practical.

In this paper, an on-chip helical antenna concept using the top metal layer of a 130nm CMOS process and wire bonds is proposed. The top metal layer offers an additional degree of freedom for the antenna design. Also, different wire-bond patterns are achievable with a simple bond-pad pattern. This allows various antenna configurations using short individual wire-bonds to cover a wide spectrum in millimeter wave range.

## II. WIRE-BOND HELICAL ANTENNAS DESIGN

Fig. 1 shows the proposed wire-bond helical antenna. The bond wires connect between top metal strips and form most of the segments of the helix for higher radiation efficiency. The

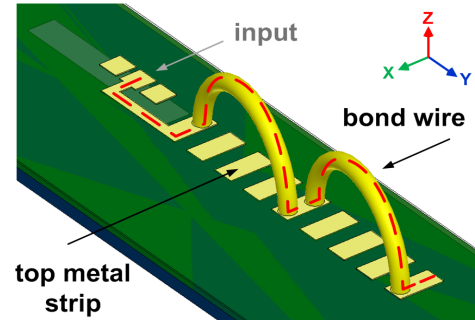


Fig. 1 The proposed wire-bond helical antenna concept.

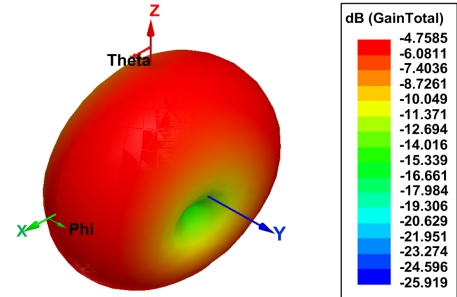


Fig. 2 The radiation pattern of the wire-bond helical antenna.

helical antenna operation mode and center frequency is determined by the helix diameter, spacing, and the total length. Helix diameter control is accomplished by choosing different bonding strips and bonding heights. The length of the strips and the gap between them are other critical factors for defining the helix diameter and spacing. Furthermore, to implement a lower-frequency antenna with high-yield, the unit helix can be duplicated along the Y-axis in Fig. 1 without challenging the mechanical limitations of a longer single bond wire. For miniaturized system integration purposes, the helix diameters of the two prototypes are small compared to the wavelength ( $>3.5\text{mm}$ ). Therefore, the radiation pattern is similar to a normal mode helix antenna as shown in Fig. 2 [6]. This is similar to those of dipoles and monopoles with more omnidirectional characteristics. However, with this design concept, we can also make the axial mode available by changing the top metal printed strips, targeting a helix diameter of  $\lambda/\pi$ , and a helix spacing of  $\lambda/4$  [6]. Fig. 3 shows the die photo of a prototype antenna in a 130nm CMOS

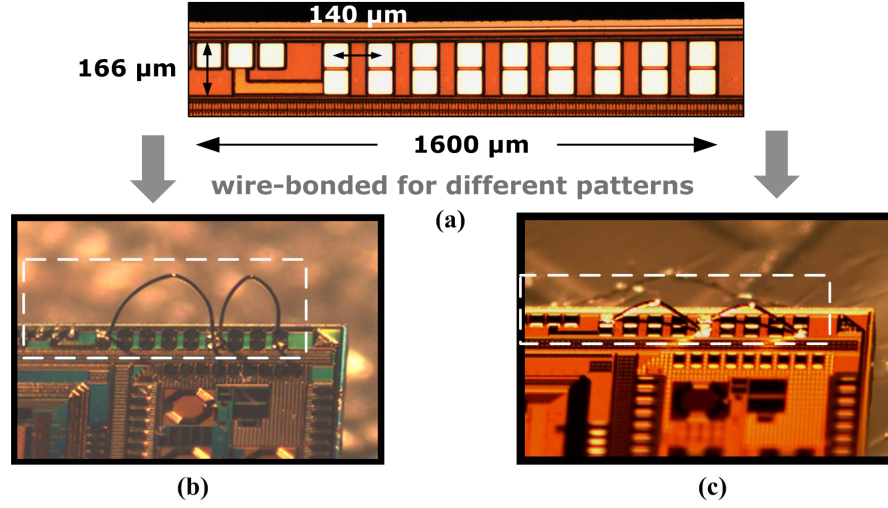


Fig. 3 Die photo (a) top metal strips and (b) helical antenna #1 (c) helical antenna #2.

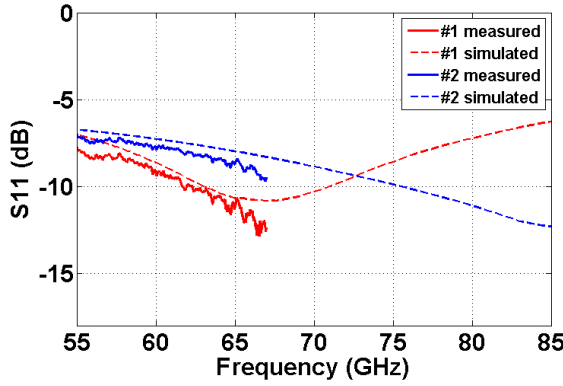


Fig. 4 S11 of helical antenna #1 and #2.

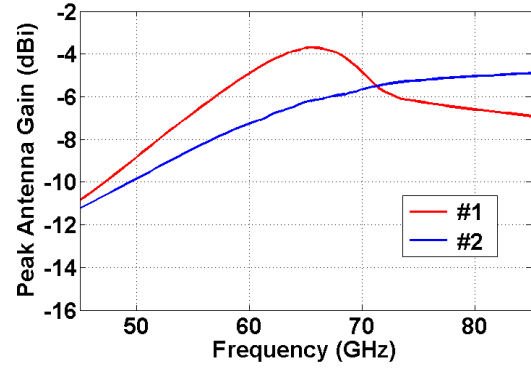


Fig. 5 Simulated peak antenna gain of helical antenna #1 and #2.

technology with design parameters of the metal strips and two wire-bond patterns. The length of the strip unit is  $166\mu\text{m}$  with a gap of  $60\mu\text{m}$ , and a row of 9 strips are printed. Antenna #1 has two helix units using  $500\mu\text{m}$  high 1mil diameter gold wires. Antenna #2 has a lower profile helix unit with a height of  $150\mu\text{m}$ .

### III. RESULTS

Fig. 4 shows the measured and the simulated S11 for antenna #1 and #2. The simulations have been performed in Ansoft HFSS. They are only measured up to 67 GHz due to limitations of our equipment. However, combining with the simulated result, the center frequencies can be predicted as 67.5 GHz and 85.0 GHz, respectively. This demonstrates different operation ranges are achievable by changing only the wire-bond patterns. Fig. 5 plots the simulated peak gain at right angles to the helix axis versus frequency, showing a maximum antenna gain of 3.8 dBi and 4.9 dBi for antenna #1 and antenna #2. The corresponding radiation efficiencies at the center frequencies are 24% and 19%, respectively. In summary, the results show that the wire-bond helical concept can be applied to a wide range of spectrum, and is suitable for RF SoC integration with high-yield.

### ACKNOWLEDGEMENT

The authors would like thank MOSIS and ProtoConnect for IC fabrication and wire bonding, and Dr. Anthony Grbic and Dr. Mona Jarrahi for measurement support. The work was supported by NSF under grant No. CNS-1111541.

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