Inkjet Printing of a Wideband, High Gain mm-Wave Vivaldi Antenna on a Flexible Organic Substrate

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***Abstract*—A wideband, high gain mm-Wave Vivaldi antenna on a flexible substrate operating above 40 GHz with a realized gain greater than 9 dBi is demonstrated in this paper. This work presents both the highest frequency and highest gain antenna fabricated through inkjet printing to date. Inkjet printing allows for a rapid, low-cost, and environmentally advantageous fabrication of electronic components compared to traditional techniques and is currently advancing into mm-Wave operation for applications in high data-rate wireless communications.**

I. INTRODUCTION

Inkjet printing is a fabrication technology that has realized such electronic components as multilayer RF capacitors and high gain antenna arrays up to 24 GHz [1], [2]. The purely additive fabrication process is advantageous to typical fabrication methods in several areas, allowing for a low-cost, environmentally conscious, and robust line of emerging electronic devices, especially in the field of antenna fabrication. With the increasing congestion of typical RFID and UWB channels under 10 GHz, the current advancement of wireless technology is pushing for higher frequencies of operation [3]. Wideband inkjet printed antennas have been demonstrated up to 16 GHz with applications in high-precision tracking, distribution logistics, and high-speed personal area networks [4]–[6], yet higher frequency wideband operation is desired for the growing future of high data-rate local area networks.

This work introduces a multilayer wideband, high gain antenna fabricated on a flexible organic substrate through the process of inkjet printing. A Vivaldi antenna is designed and fabricated, exhibiting wideband mm-Wave operation beyond 40 GHz while preserving high end-fire gain, presenting the highest frequency and highest gain inkjet-printed antenna to date along with demonstrating the feasibility of inkjet printing for the rapid, low-cost fabrication of highly-directive wideband antennas in the mm-Wave range.

II. INKJET FABRICATION PROCESS

The inkjet fabrication process utilizes the Fujifilm Dimatix-2831 printing platform previously outlined in [2]. The host substrate is 100 um thick liquid crystal polymer (LCP) (Rogers Corporation, Rogers, CT, USA) absent of any copper cladding. This substrate exhibits a relative permittivity of 2.9 and a low loss tangent of 0.003 [7].

To pattern the metallic layers of the antenna, high-conductivity Cabot CCI-300 silver nanoparticle-based ink (Cabot Corporation, Boston, MA, USA) is used as received. After printing, the metallic layers are cured and sintered in an oven at 180 °C for 10 minutes. Each deposited layer of the silver nanoparticle ink yields a metal thickness of 500 nm with a conductivity of 1.1e7 S/m [8]. For this fabrication, 5 layers of conductive ink were deposited yielding a sheet resistance of 0.05 Ω/sq. Before printing, alignment marks were cut into the LCP substrate using a laser cutter to help assist with the alignment of the top and bottom metallic layers when printing.

III. VIVALDI ANTENNA DESIGN AND MEASUREMENT

In order to demonstrate the proficiency of inkjet printing for high frequency broadband antennas on flexible substrates, a multilayer Vivaldi antenna is chosen for design and fabrication. The Vivaldi design includes two stacked, negatively-symmetric metalized layers separated by a dielectric. Choosing the general dimensions for the desired wideband frequency range, the CST time domain solver is used to optimize the dimensions of the antenna to match a desired 50 Ω line. Fig. 1(a) shows the simulated model of the designed Vivaldi antenna. A photograph of the printed antenna is shown in Fig. 1(b) with the back of the substrate illuminated in order to show both front and back metallic layers.

Following the previously outlined fabrication, a clamp-mount end launch connector from Southwest Microwave is fastened to the antenna feedline. The S11 parameter of the fabricated antenna is measured with an Anritzu 37369A VNA and is shown in Fig. 2 along with the simulated results. The measured return loss from the fabricated antenna shows good

(a) (b)

Fig. 1. (a) Model simulation and (b) print of Vivaldi antenna.

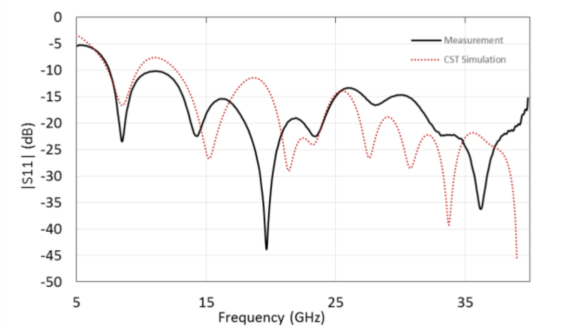
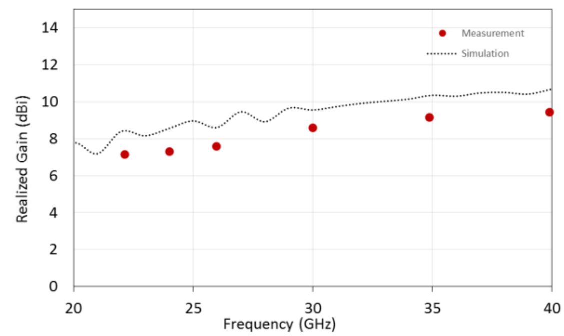


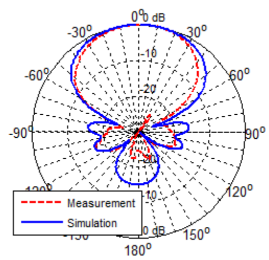
Fig. 2. Simulated and measured S11 of Vivaldi antenna.

agreement with the simulated results and demonstrates wideband operation from 15 to 40 GHz and beyond. The small discrepancies are likely the result of layer misalignment during fabrication in the order of tens of micrometers and the exclusion of the end launch connectors in the simulations.

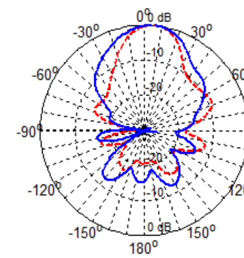
In order to measure the gain and radiation pattern of the antenna, a far-field anechoic chamber is utilized, calibrated to SA12A-18 standard gain horn antennas. The end-fire realized gain of the fabricated antenna is measured as a function of frequency over the range of 20 to 40 GHz and is plotted alongside simulation results in Fig. 3(a). Measured realized gain results are shown to follow the sloping trend of the simulation and experience an approximate 1 dB loss from the end launch connector interface. The measured and simulated normalized polar radiation plots at 24 and 40 GHz are displayed in Fig. 3(b)–(e), showing that the H-plane and E-plane cuts for each frequency are in good agreement with the simulations. The slight disagreements between the measured and simulated results are the result of the presence of the end launch connector in the measurements and its exclusion in simulation, which is predictably apparent at the 180° angle of each radiation plot. The agreement between simulated and measured results of the antenna indicates the practicality of realizing high gain wideband antennas through inkjet printing fabrication.



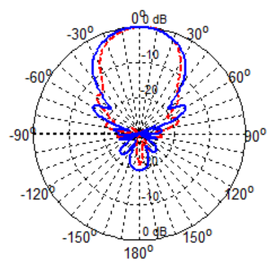
(a)



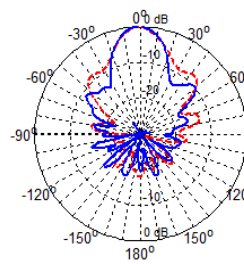
(b)



(c)



(d)



(e)

Fig 3. (a) Realized gain versus frequency, measured and simulated E and H planes for (b), (c) 24 and (d), (e) 40 GHz, respectively.

IV. CONCLUSION

Using the inkjet printing fabrication process, wideband, high gain mm-Wave Vivaldi antennas are realized with operation beyond 40 GHz and peak end-fire realized gain greater than 9 dBi, improving on previous wideband work up to 16 GHz and high gain antennas up to 7 dBi [2]. Through continued research into the fine-tuning of the inkjet printing process, this fabrication method shows a promising future for low-cost, environmentally friendly high frequency wideband wireless communication technology with inkjet printing.

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