Flexible Hybrid Electronic Circuits for Microwave Frequency Applications

S3IP A New York State Center of Excellence BINGHAMTON UNIVERSITY

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Introduction

Flexible hybrid electronics are especially useful for wearable electronics and applications where conformal circuits are needed to fit non-planar surfaces. These include applications such as monitoring the health and vital signs of humans, as well as critical infrastructure and equipment. With the rapid expansion of the Industrial Internet of Things (IIOT), there will be an enormous demand for advanced electronics incorporating wireless communication and power transfer operating in the microwave frequency range, while still being flexible and conformable.

In this poster, a variety of passive circuits designed for 2.4 GHz are fabricated on polyimide using conventional copper plating and precision printing. The performance of the different fabrications are measured and compared.

Test Circuits

- Test frames were fabricated at i3 Electronics, Inc, in Endicott, NY on 2 mil Kapton with 14μm thick plated copper.
- Test elements include transmission lines, couplers, filters, inductors, resonators with copper structures. Printed elements were added.

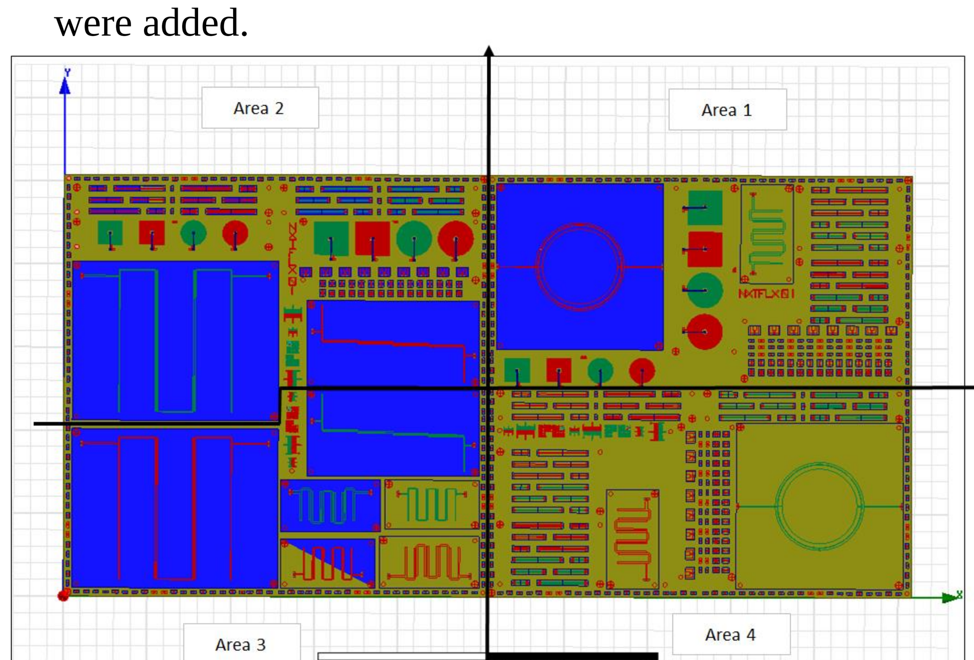

Fig. 1 CAD design of test frame, with structures fabricated only in copper and pads for the addition of printed elements.

Circuit Printing

- Microwave circuits were printed on the same test frames using Optomec AJ-300 system.
- Align and print to Cu GSG pads with 100μm wide, 4 – 5μm thick printed lines.
- Paru PG-007AP ink used with pneumatic atomizer.
- Ink sintered at 200°C for 60min in convection oven.

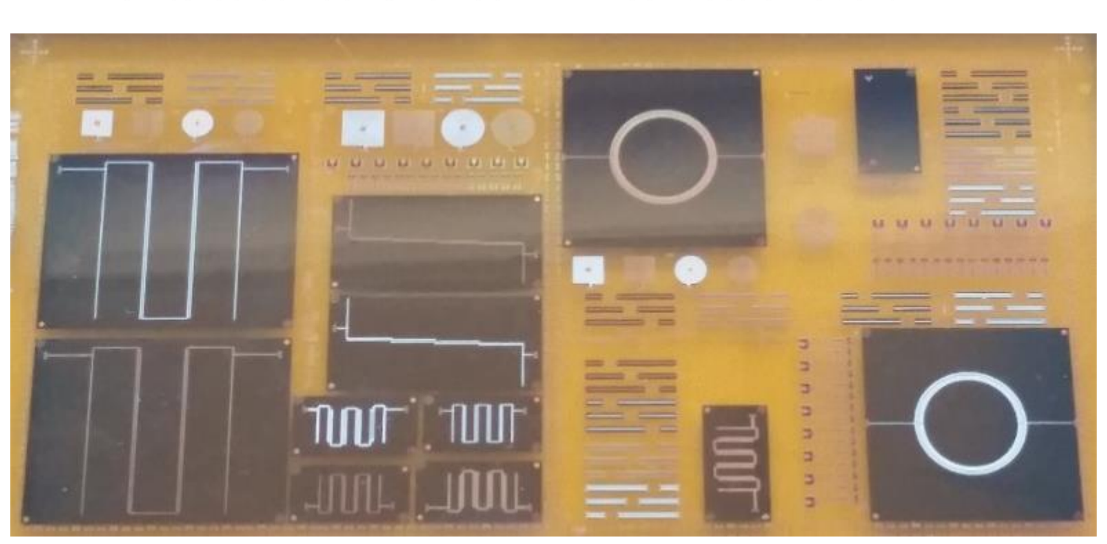

Fig. 2 Photograph of plated copper and printed silver structures.

DC Resistance

- Asses resistance per length and bulk resistivity with cross sectional area.
- Measure resistance of 5.5, 3.5, and 1.5mm signal lines on probe station-linear fit of 0.15 ohm/mm.
- Cross sectional area from integrating profile – 479 μm^2
- Overall bulk resistivity estimate: 7.05261E-08 ohm-m, ~4.4x bulk Ag.

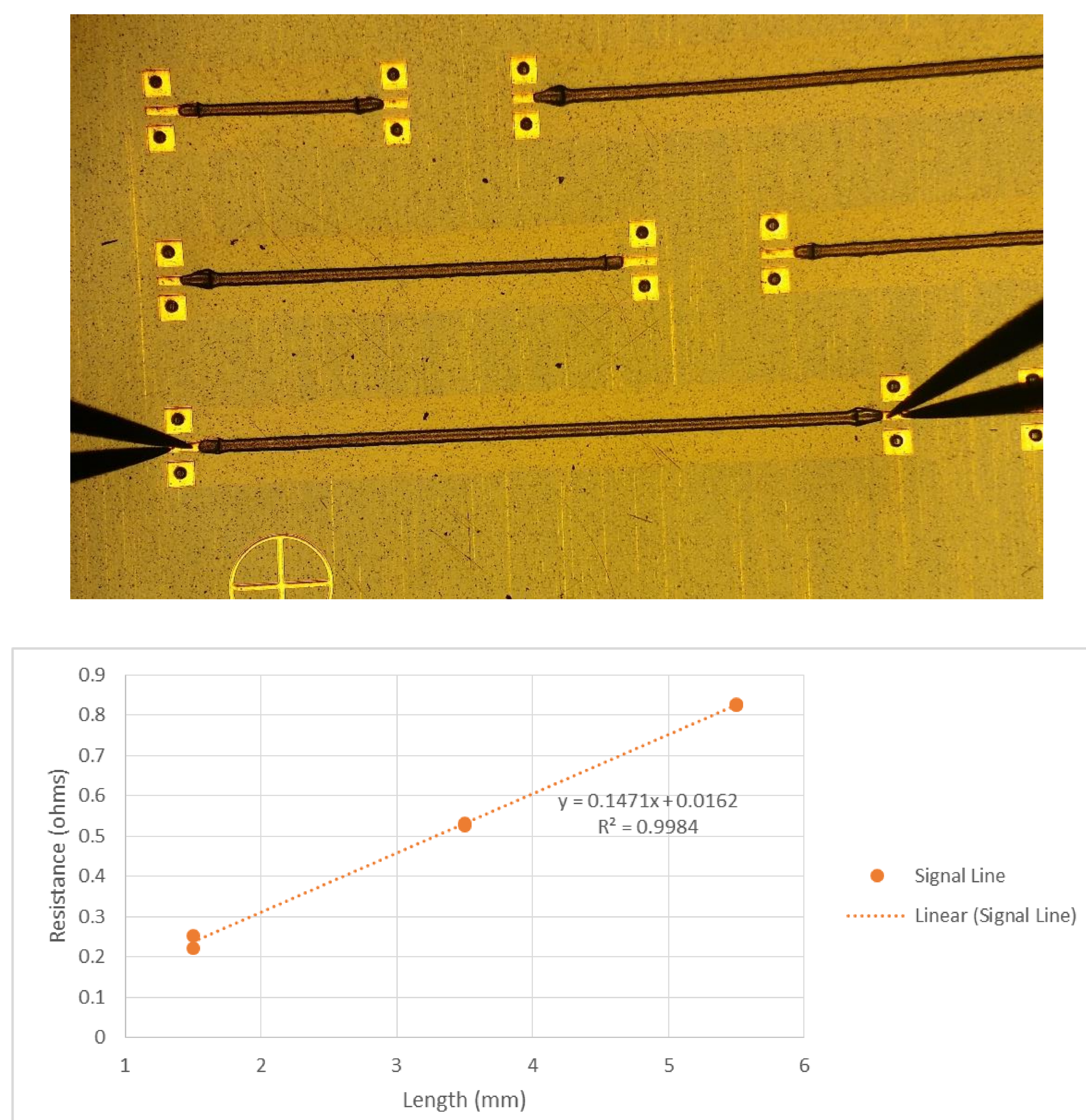

Fig. 3 DC measurements using a 4-wire technique on microstrip lines (top) and plot of resistance versus line length with linear fit to measure conductivity of printed lines (bottom).

RF Measurements

- Microwave measurements made with network analyzer, 0-20GHz
- 2 port measurements for transmission lines and resonators

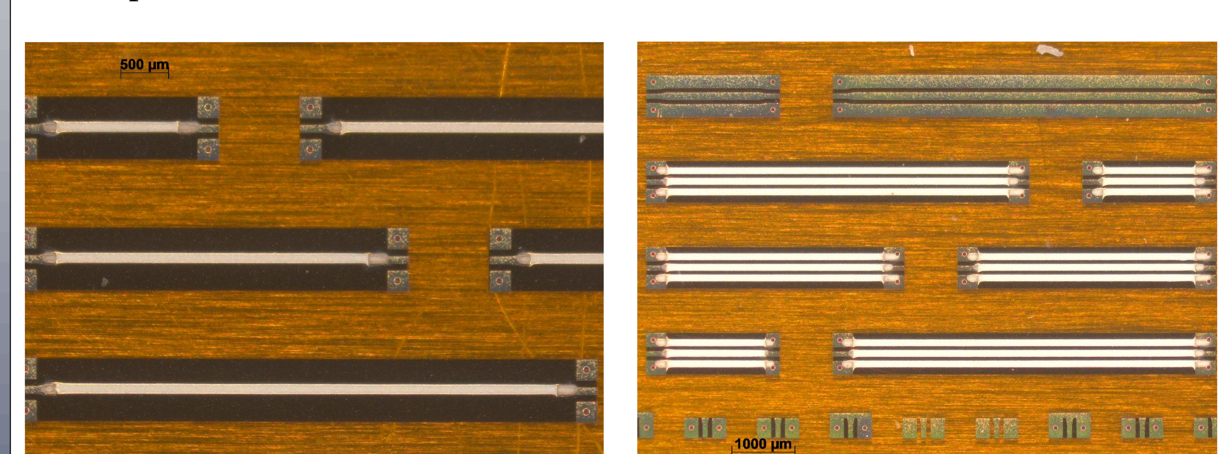

Fig. 4 Printed microstrip with plated GSG launch (left) and printed co-planar waveguides with plated GSG launch (right). Note that both have plated ground planes and vias.

Microwave S-parameters

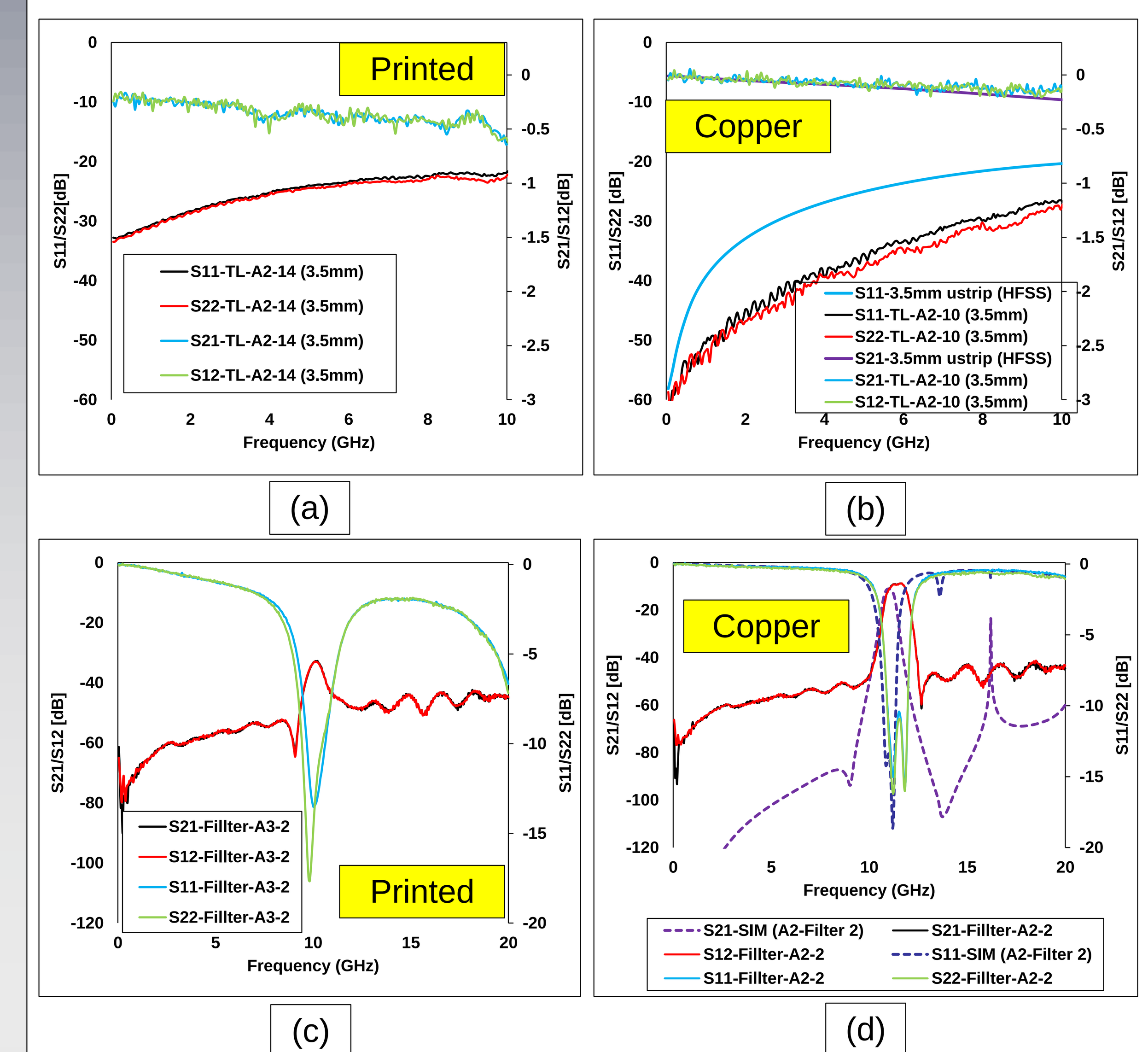

Fig. 5 Comparisons of: (a) and (b) transmission lines; (c) and (d) filters.

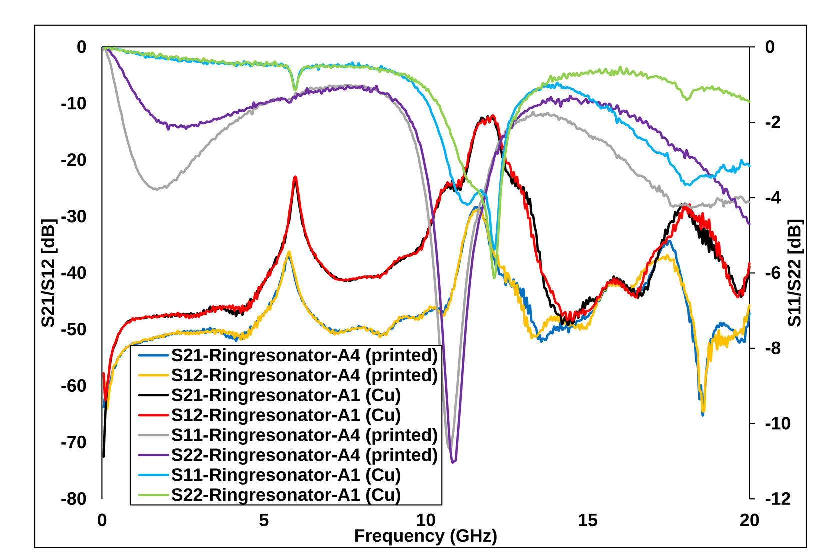

Fig. 6 S-parameters of two printed and copper ring resonators.

Printed Antenna

- Design planar inverted F antenna on polyimide.
- Use commercially available polyimide with copper foil.
- Printed antenna aligned to copper foil ground plane.

Fig. 7 Printed Inverted F Antenna mounted for testing.

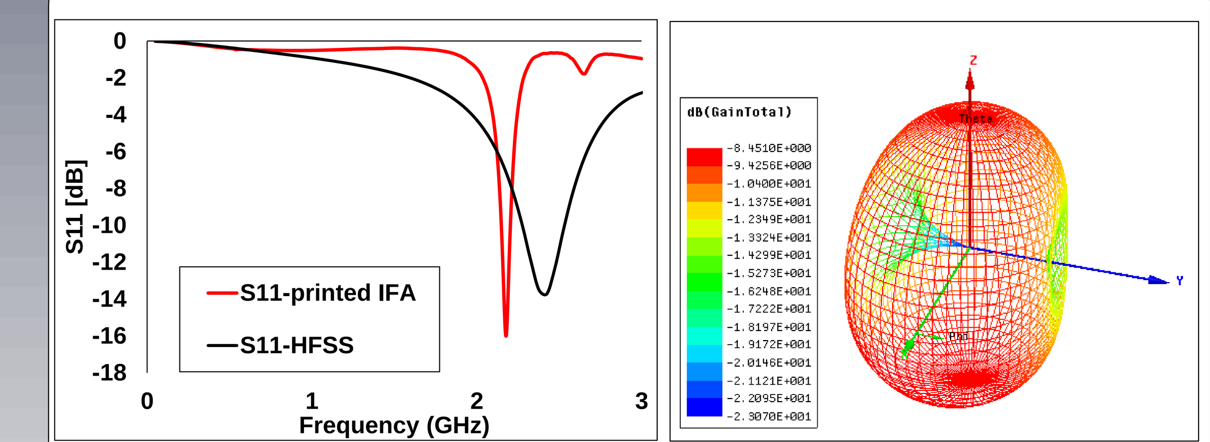

Fig. 8 Measured and simulated S11 for the antenna (left) and radiation gain pattern from HFSS simulation (right).

Wilkinson Coupler

- Design Wilkinson coupler using previous RF measurements.
- Printed silver on 5mil polyimide with 1μm copper ground plane.
- Dispenser print resistive carbon paste for resistor.

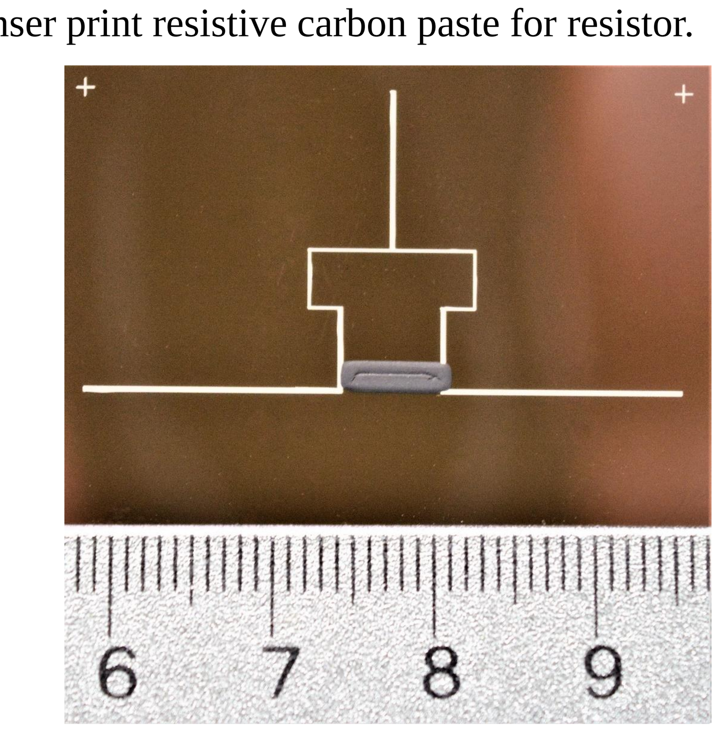

Fig. 9 Printed Wilkinson coupler with a 100Ω printed resistor on polyimide.

Summary

- The DC and microwave properties of printed circuit elements were measured and compared to copper circuit elements on 2mil thick polyimide.
- The measured S-parameters for printed circuit elements compare well with copper elements except for some additional losses due to the lower conductivity of printed lines.
- The losses could be reduced by printing thicker lines. In this study, the printed lines were 4-5μm thick, and the copper lines were 13μm thick.
- Accurate models for printed lines were developed from the DC and RF characteristics.
- Printed planar inverted F antennas and Wilkinson couplers were designed and fabricated based on previous RF measurements.

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