Feasibility Study of a Stretchable Antenna Conformed on an Expandable Cylindrical Surface

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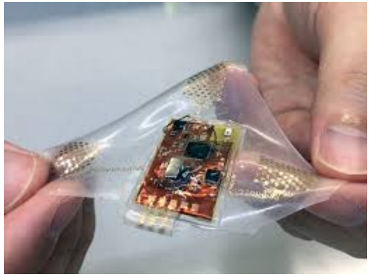
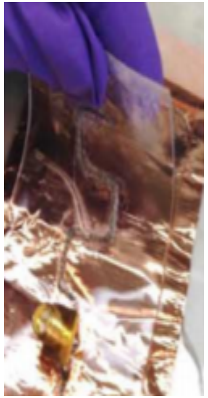
A Need for Stretchable Antennas

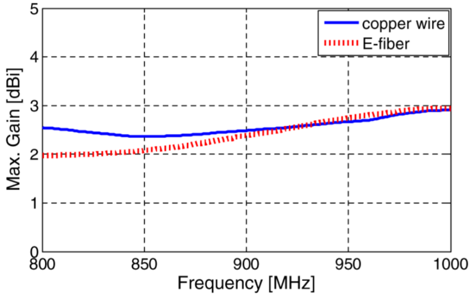
- Stretchable antennas have a wide range of applications
  - ➢ Inflatable Antennas in Weather Balloons
  - ➢ Smart Cars
  - ➢ Biomedical field such as monitoring human or animal joint's movement

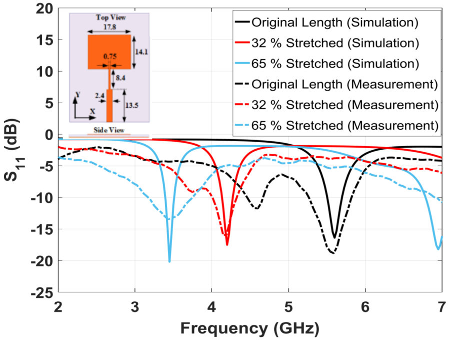


Survey on Stretchable Antennas

- Mainly focused on utilizing stretchable material such as composite conductor, liquid metal, stretchable ink, and thin film technology
- Utilizing material stretchability together with antenna geometry that is relatively immune to reshaping
- Limitations:
  - ➢ Low gain and efficiency
  - ➢ Limited Stretchability (~10%)







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[1] Asimina Kiourti, John L. Volakis, "Stretchable and Flexible E-Fiber Wire Antennas Embedded in Polymer," IEEE Antennas and Wireless Propagation Letters, vol. 13, pp. 1381-1384, 2014.
[2] H. Saghlatoon, M. Mahdi Honari, R. Mirzavand, P. Mousavi, A. Kumar, T. G. La, H. J. Chung, "A novel investigation on printed stretchable WLAN antennas," IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting, 2012.

Conductive Rubbers

- Good stretchability
- Some vendors: Shin-Etsu, MAJR Electronics, EMI Conductive Rubber.
- Each company has conductive rubber with conductivity at least 100 S/m at 0 Hz.
- Measurements may need to be done to see how this scales to higher frequencies, but from common knowledge, it may still be reasonably conductive.
- In this paper: *Silver Plated Aluminum-filled Fluorosilicone conductive elastomer* is used with stretchability of 350% and conductivity of 50000 S/m.

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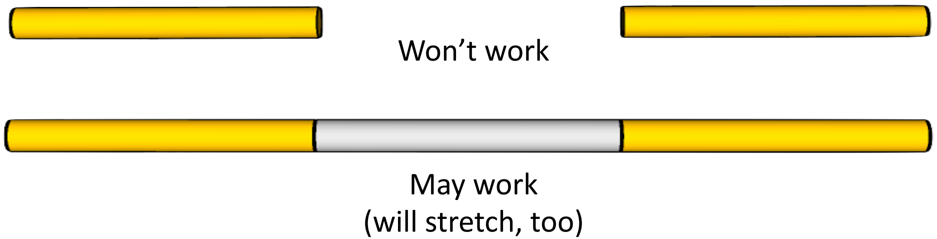
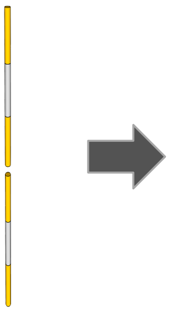
Design Philosophy

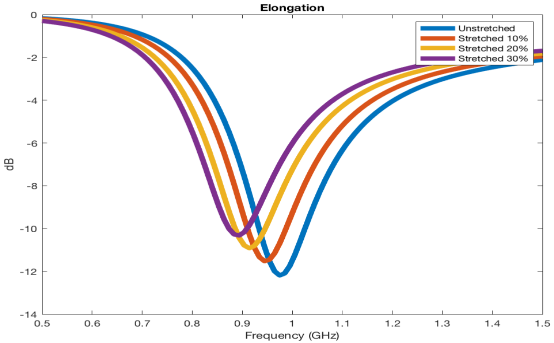
- Combing conductive rubber and copper to form the patch antenna
- Geometry of the rubber and copper has been kept as alternating strips
- Can be thought as rubber grids filled with small copper patches
- Although conductive rubber is not a great conductor, it may still act like a connecting agent.



Linear Geometry & Limitations

- A linear antenna constructed by alternating conductive rubber and copper was studied.
- Though it showed certain feasibility as a stretchable antenna, the conductive rubber is very lossy, and the antenna efficiency is low.
- Therefore, we decided to explore patch antenna because the patch surface mainly functions as forming a cavity, rather than conducting the current like a linear wire antenna.





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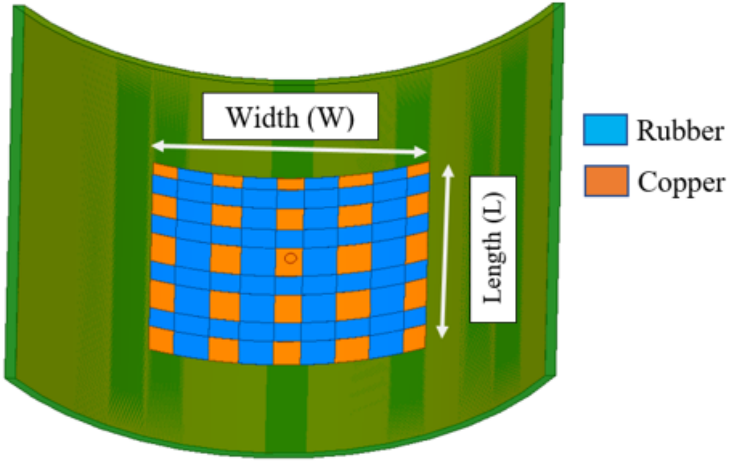
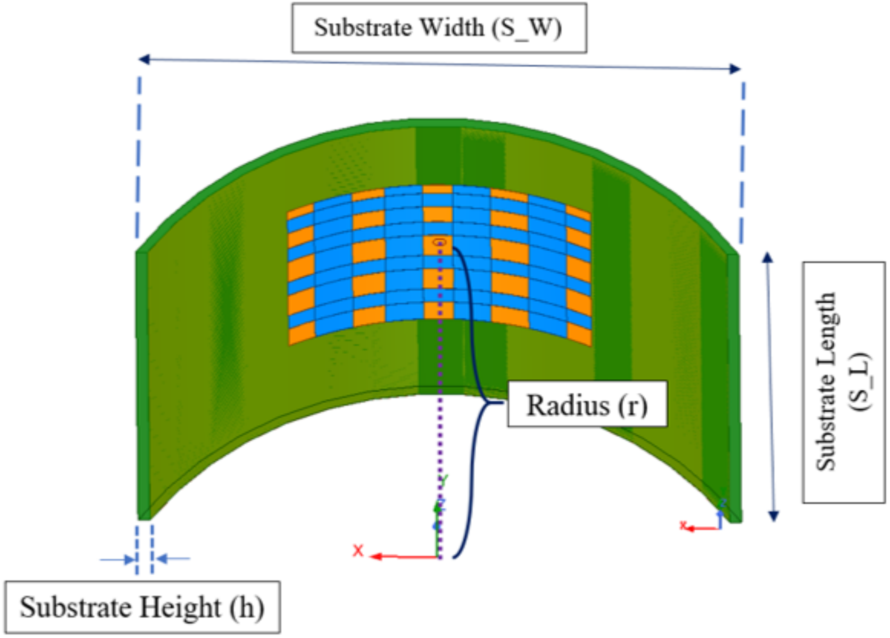
A Patch Antenna on A Cylinder



- Conductive rubber and copper stripes were alternated to form a patch surface on a Rogers RT/duroid 5880 substrate
- The rubber strip was made taller than copper and its height reduces when being stretched.

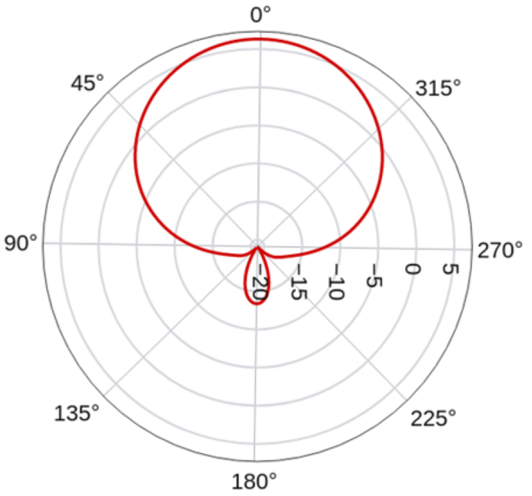
Antenna Dimensions



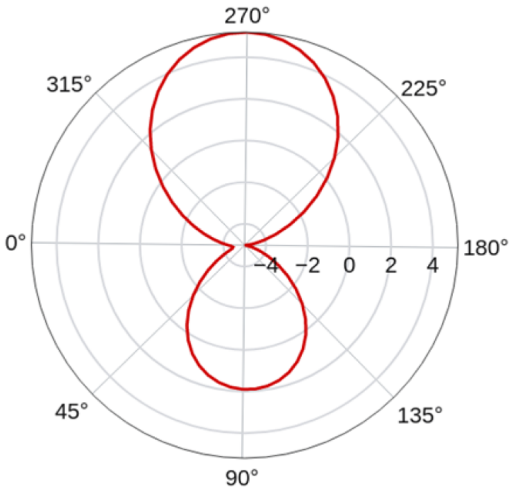
Dimensions (mm) of the Antenna

r	S_L	S_W	h	L	W
59.2	80	93	1.575	49.3	40

Radiation Patterns after Bending



(a) Flat rubber-copper antenna



(b) Antenna bent to conform on a cylinder

Effect conforming the patch antenna to a cylinder from being flat

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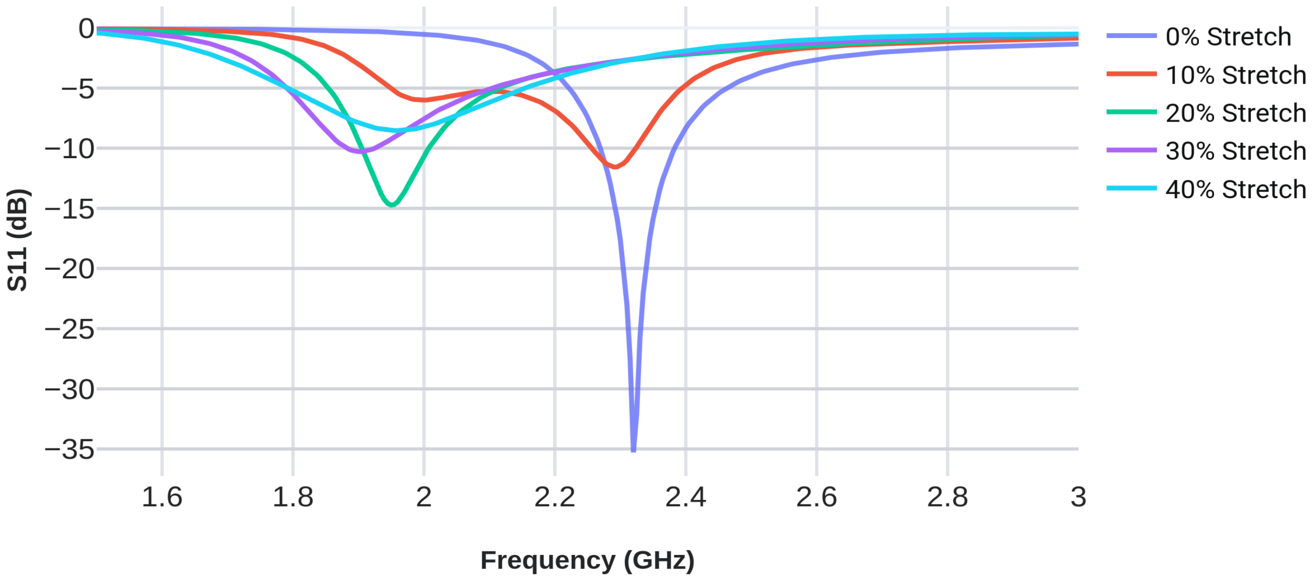
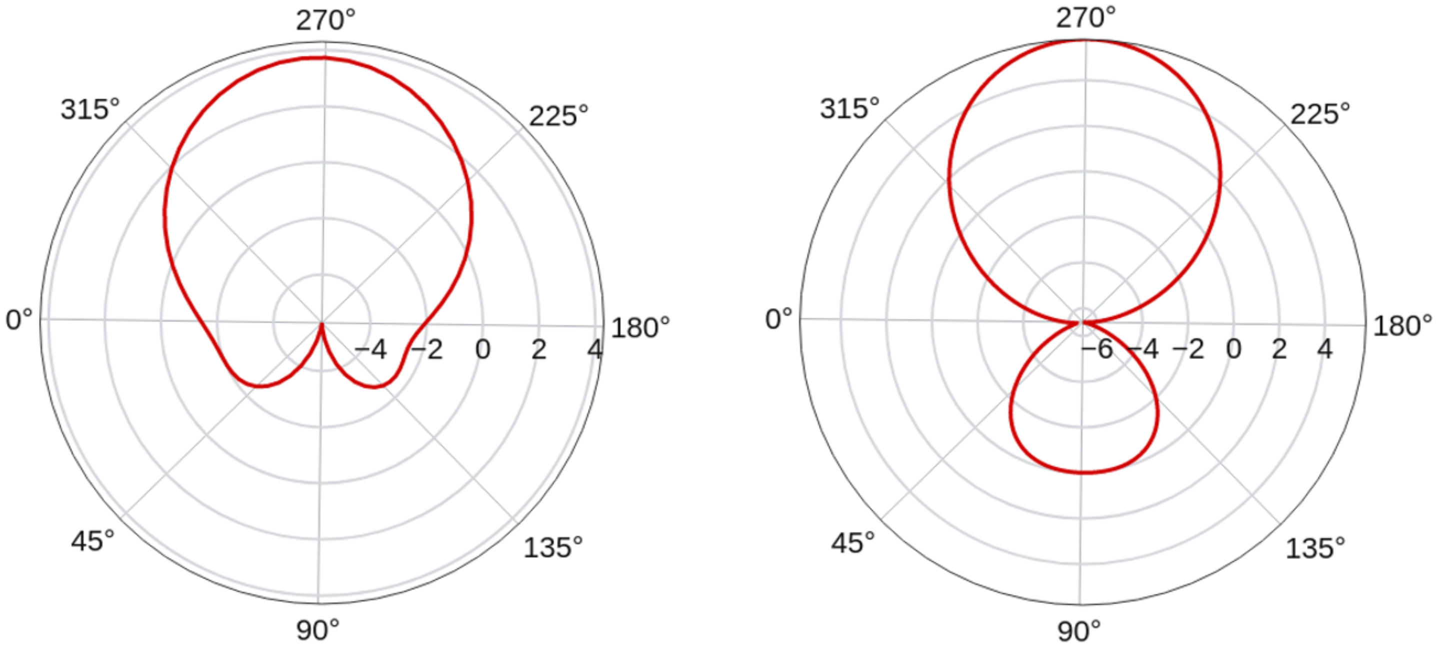
Results (Frequency vs Stretching)

The antenna was stretched proportionally in length and width to 10%, 20%, 30%, and 40%. The ground was also proportionally enlarged in order to maintain a constant curvature.

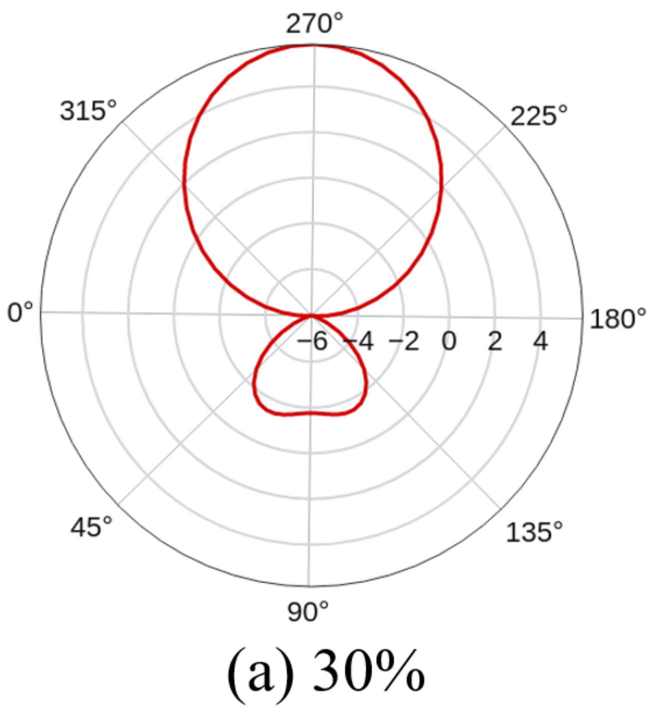


Results (Radiation Pattern vs Stretching)



(a) 10% (b) 20%

Results (Radiation Pattern vs Stretching)



Stretch Ratio and Antenna Gain

Since the stretching in this study was performed in two dimensions, it is necessary that we compute the overall stretch ratio. Letting α being the stretch percentage along the length of the antenna (the stretch ratio in width is the same because we stretched the antenna proportionally), then the stretch ratio in area is $2\alpha + \alpha^2$

Stretch Ratio		Frequency	Gain
0	0%	2.32 GHz	5.2 dB
21%	10%	2.29 GHz	4.0 dB
44%	20%	1.95 GHz	5.8 dB
69%	30%	1.90 GHz	5.8 dB
96%	40%	1.955 GHz	5.4 dB

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Discussion

- The antenna consistently functions well after being stretched to 96% in area. The data point for 10% was not quite fit in with the other numbers, and the reasons most likely were due to lack of further tuning.

- When the rubber was stretched for more than 20%, the geometry of the antenna differed significantly from the original because only the rubbers were stretched, and the copper remained the same. This could be the reason for the increase of the gain for higher stretch ratio.

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Future Work

- For the future design and studies, we may consider printing copper patches on a conductive rubber.
- The feed design will also be replaced with a wide-band matching method in the future studies.
- As stated earlier in this presentation, for wether balloon applications, the antenna needs to be stretched 5 times in diameter. This remains a major future challenge for us.
- Although in the study, we enlarged the ground proportionally, and this can be not realistic if the ground is made of copper, the examination on the ground will be performed in the follow up work.

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Thank you!

- Thank you very much for this opportunity to present my work.
- Please feel free to contact us for any future questions.

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