EuroEAP 2013
International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles
Dübendorf, 25-26 June 2013

Organized and supported by 'European Scientific Network for Artificial Muscles – ESNAM' (www.esnam.eu) COST Action MP1003

ESNAM
COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY
EUROPEAN SCIENCE FOUNDATION SETTING SCIENCE AGENDAS FOR EUROPE

Poster ID:
1.3.1

Towards reconfigurable RF devices based on dielectric elastomer actuators

Contact e-mail:
seun.araromi@epfl.ch

Oluwaseun Araromi (1), Pietro Romano (2), Samuel Rosset (1), Julien Perruisseau-Carrier (2), Herbert Shea (1)

(1) École Polytechnique Fédérale de Lausanne (EPFL), Microsystems For Space Technologies Laboratory, Neuchâtel, Switzerland; (2) École Polytechnique Fédérale de Lausanne (EPFL), Adaptive MicroNano Wave Systems Group, Lausanne, Switzerland

Abstract

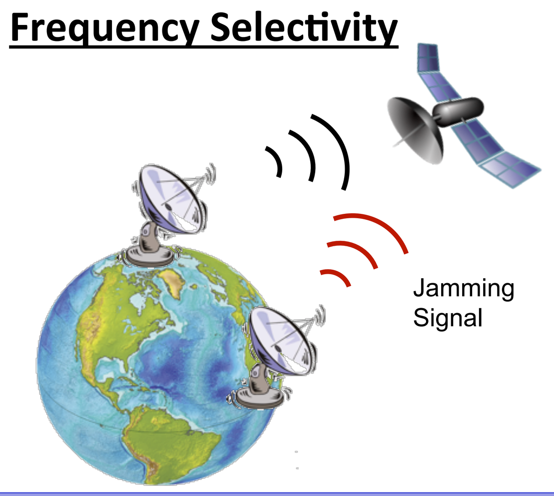
Radio Frequency (RF) devices generate or control the transmission or reception of electromagnetic (EM) waves such as are used in mobile phones, WIFI etc. Microwave (MW) and millimeter-wave (MMW) devices are used widely in satellite communications. Dynamic reconfiguration of MW/MMW devices and antennas is becoming a prime need in telecommunication applications, notably for updating in real time antenna characteristics such as coverage, polarization, or even operation frequency. However, available technologies (e.g. MMIC, RF-MEMS, ferrite, liquid crystals) can result in increasing cost and complexity when a reconfigurable device is needed. Moreover, many of the current technologies suffer from higher EM losses compared to their non-reconfigurable counterparts. We present a design for a tunable RF phase shifter based on a planar dielectric elastomer actuator (DEA). The design operates by laterally displacing conductors strips suspended above a coplanar waveguide. DEAs are compact, lightweight and are capable of generating large strains, hence such as device promises several advantages over current methodologies, principally low costs, low complexity and compactness. The design is also optimized to reduce losses compared to current methods. The design requires a lateral displacement of approximately 500 microns to achieve optimal phase shifting, our actuator meets this requirement whilst remaining as compact as possible. The phase shifter is the first step in the realization of fully reconfigurable antenna based on DEAs.

Reconfigurable RF Devices?

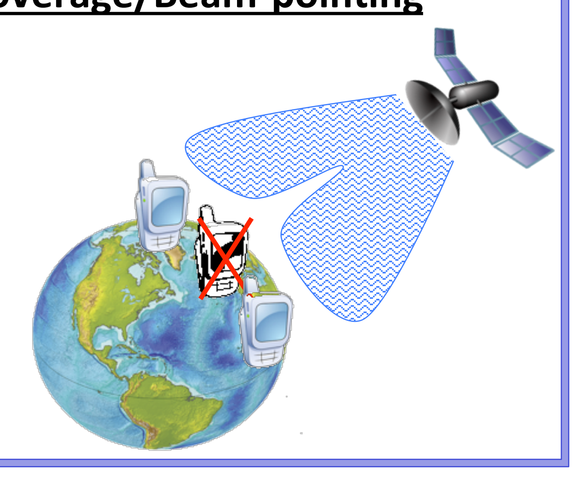
Wifi networks, cell phones, radios… anything which generates or controls electromagnetic wave transmission or reception embeds radio frequency (RF) devices.

Microwave/Millimeter-wave (MMW) antenna devices are typically used in satellite communications and reconfigurable versions of these devices are increasingly desired [1], particularly for:

Frequency Selectivity



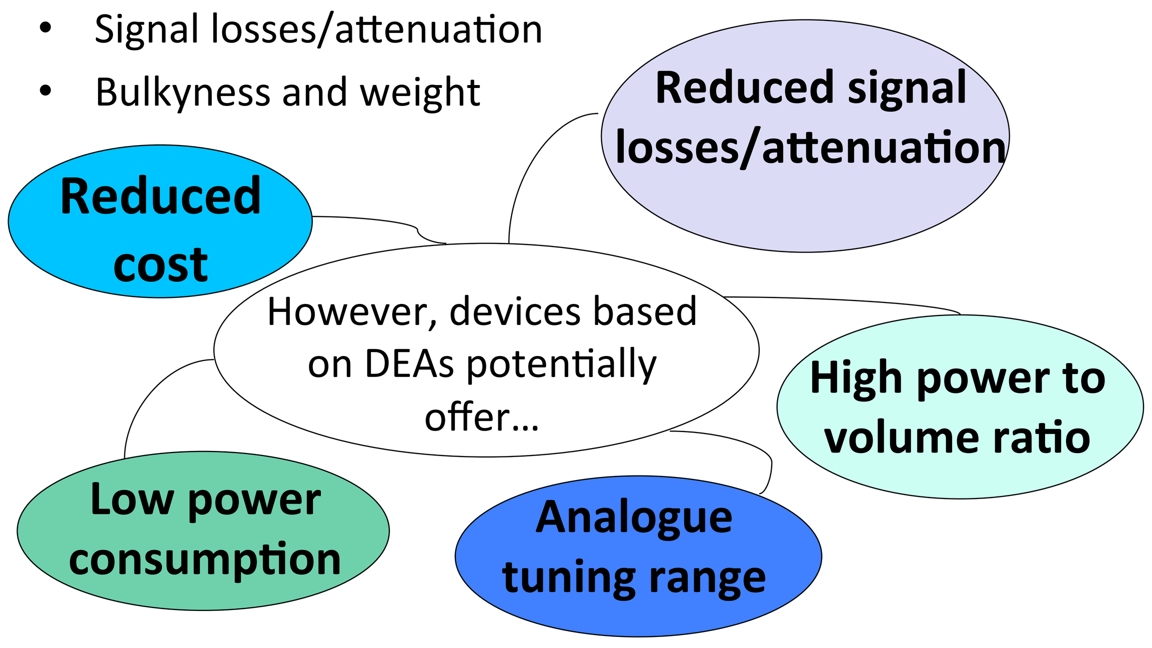
Coverage/Beam-pointing



Why use dielectric elastomer actuators?

Dynamically reconfigurable MMW RF devices exist currently but available technologies can result in increasing:

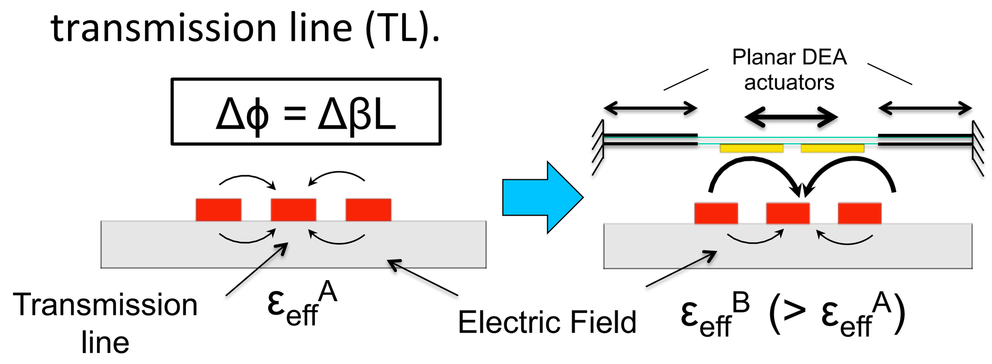
- Complexity and cost
- Signal losses/attenuation
- Bulkyness and weight



Initial concept…

We begin by designing a **phase shifter**, a fundamental subcomponent of many antenna systems. The principle:

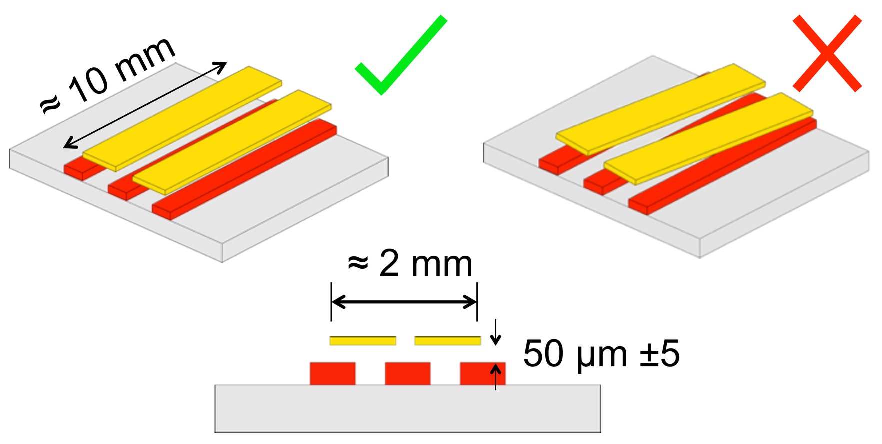
1) Take a coplanar waveguide (red) and suspend metallic loading lines (yellow) above it. This changes the propagation constant $\beta=f(\varepsilon_{eff})$ of the central transmission line (TL).



2) Moving the conductor strips laterally over the TL, using **planar dielectric elastomer actuators** (DEAs), varies the change in ε_{eff} and therefore the phase ϕ by the relationship above.

Device Requirements

Device dimensions and requirements (derived from simulation):



Requirements:

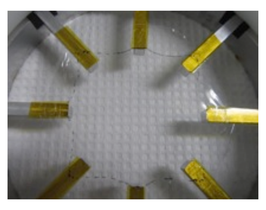
- Total lateral displacement approx. **500 um**
- **50 µm ±5** spacing between metallic loading lines
- Good in-plane alignment necessary between the metallic loading and the waveguide
- Overall size be minimised

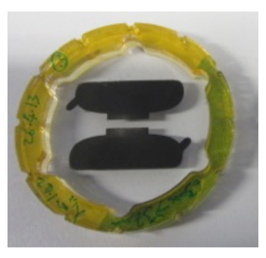
Actuator Design

Prestretch: A biaxial prestretch sufficiently large to avoid electromechanical instability (EMI), a common failure mode for DEAs [2], whilst also avoiding loss of tension [3] is desirable.

One electrode or two?: A passive region is required to minimise loss of tension, hence probably more optimal to divide the active region in two.

Fabrication and Assembly

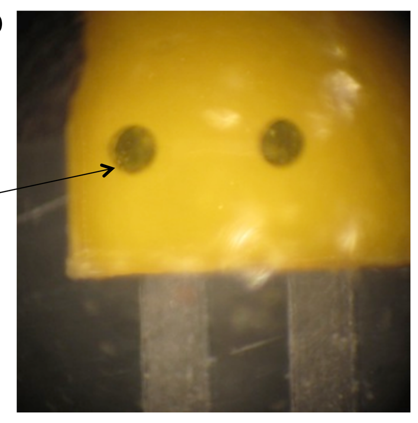




Membrane – Approx. **50 µm** PDMS (Sylgard 186, Dow Corning) prestretched approx. **1.4 times biaxially** [3].

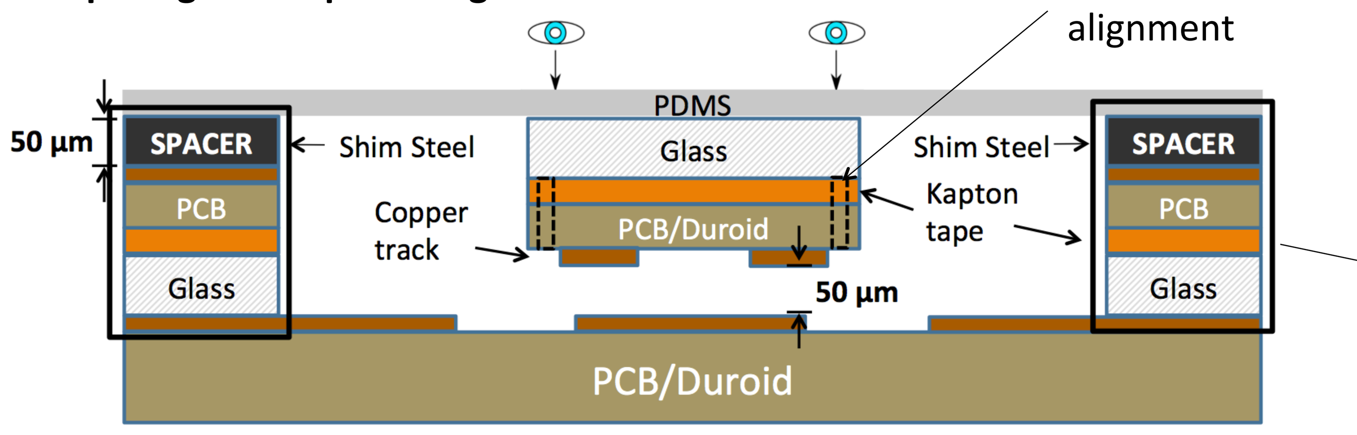
Electrode – Pad printed carbon powder in silicone elastomer matrix.

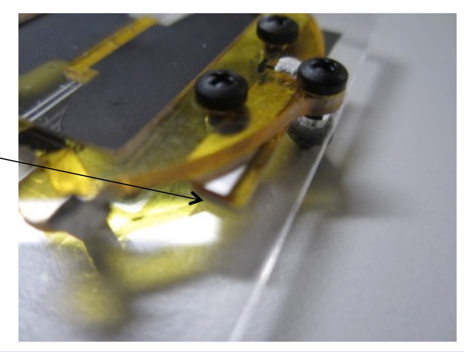
Metallic loading – Etched copper on a Duroid substrate and bonded to PDMS membrane by O2 plasma activation.



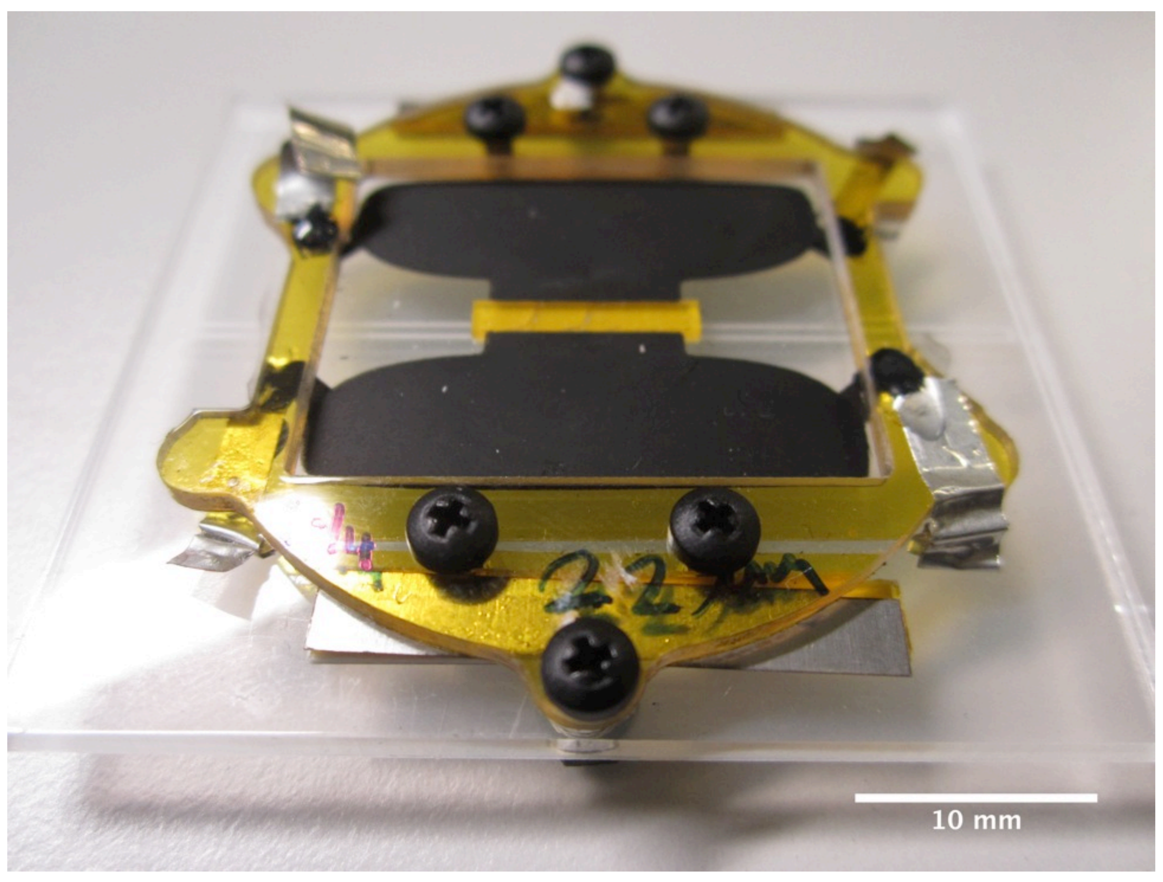
Holes to facilitate manual in-plane alignment

Spacing and in-plane alignment:

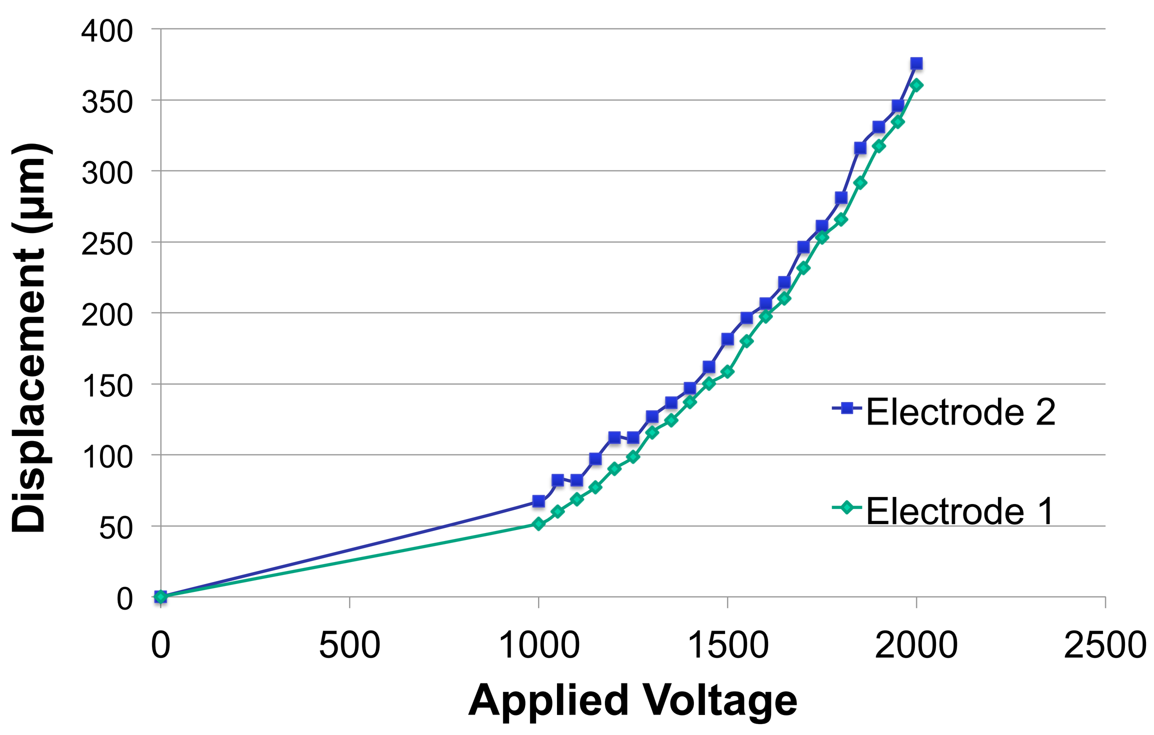




Results



- Over 700 um total displacement achieved with current devices
- Desired displacement achieved within a safe applicable voltage



Looking ahead…

Near Future:

Full device characterization – Place the device under a RF probe station and measure the change of phase! We expect a phase shift of approx. 150 degrees for the current actuator design.

Actuator optimisation and miniaturization – Further optimisation of the prestretch and electrode design required to reach the highest displacements possible whilst keeping the overall device size small.

Long Term:

Alignment: Active in-plane self-alignment capabilities

Inclusion of vertical actuation: Planar and vertical actuation capabilities desirable for even greater phase shifting capabilities.

Reconfigurable antenna: 3D deformable antenna based on DEAs.

Acknowledgments

Participation to this conference was partially supported by COST (European Cooperation in Science and Technology) in the framework of ESNAM (European Scientific Network for Artificial Muscles) - COST Action MP1003. This research activity is partially funded by the ESA project REACT.

References

[1] Pietro Romano, "Reconfigurable millimeter-wave antennas based on micro-fabricated electroactive actuators", Research plan (2013)
[2] Zhao, Hong, Suo. Physical Review B, **76**, 134113 (2007)
[3] Akbari, Rosset, and Shea, Appl. Phys. Lett., **102**, 071906 (2013)