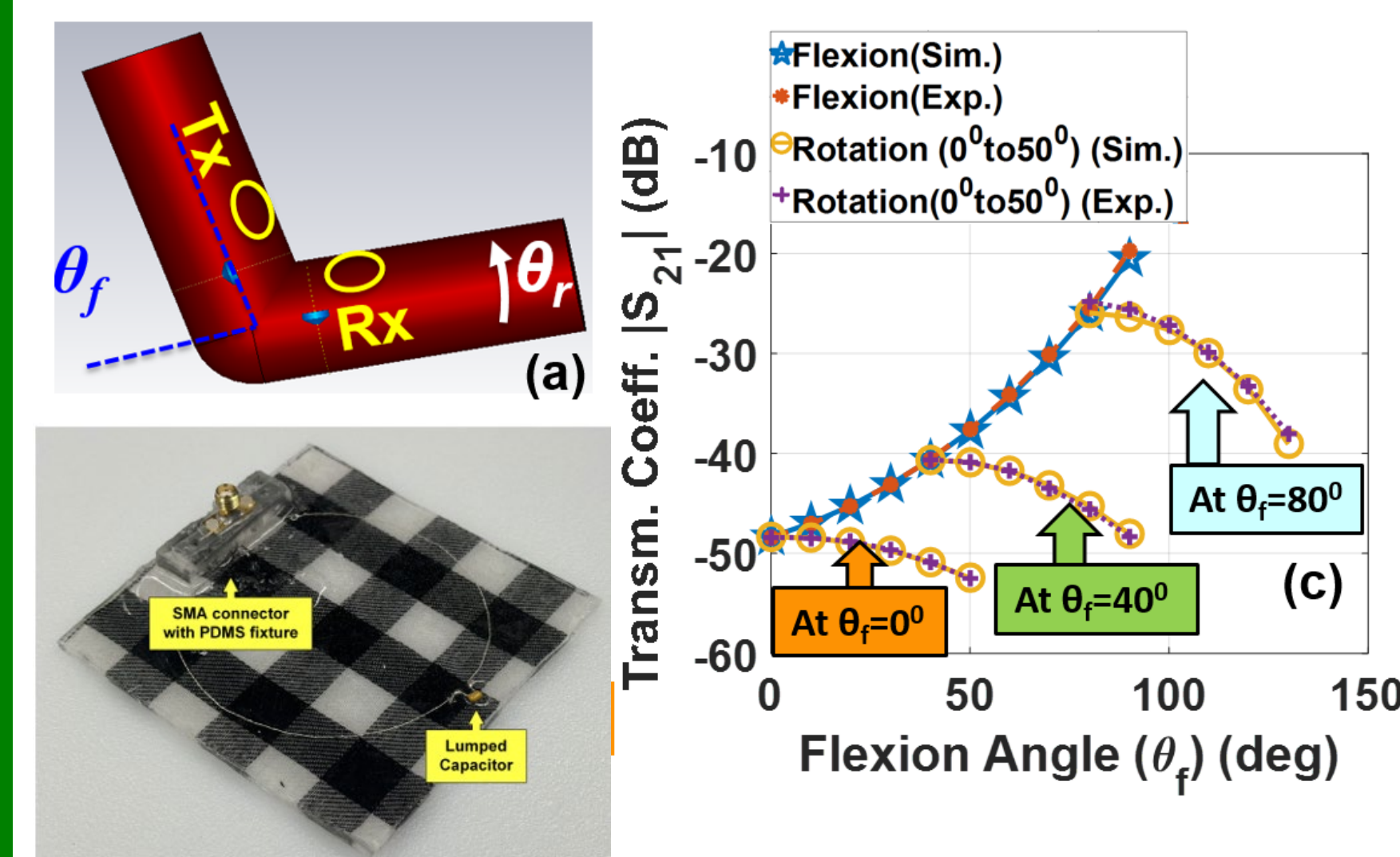# CAREER: Multi-Utility Textile Electromagnetics for Motion Capture and Tissue Monitoring Cyber-Physical Systems

PI: Asimina Kiourti, Associate Professor and Innovation Scholar Endowed Chair

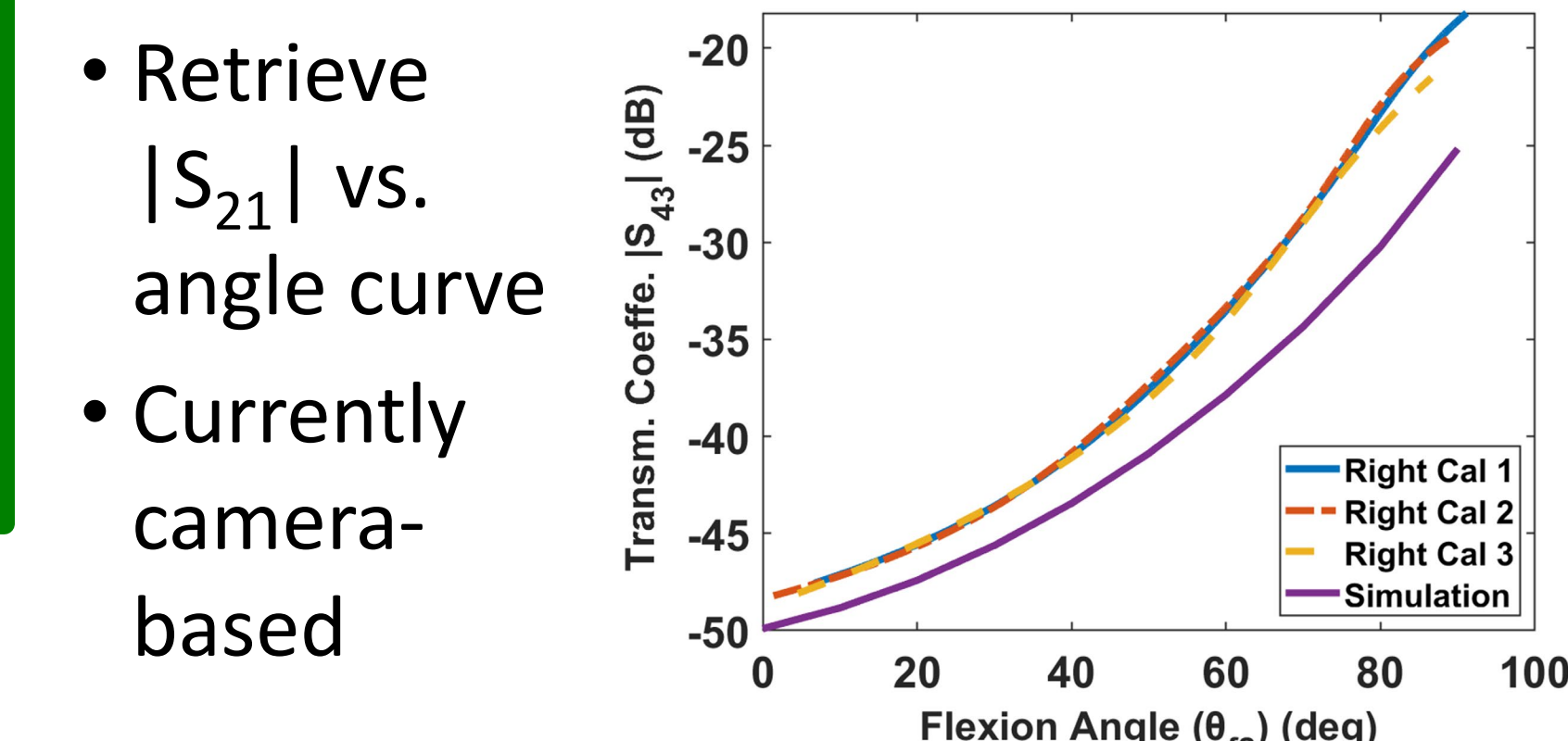ElectroScience Laboratory, Dept. of Electrical and Computer Engineering, The Ohio State University

**Challenge:** Reconcile human-in-the-loop CPS with conductive **e-textile sensors** operating in **complex** (human wearing a sensing fabric) and **dynamic** (real-world) environments.
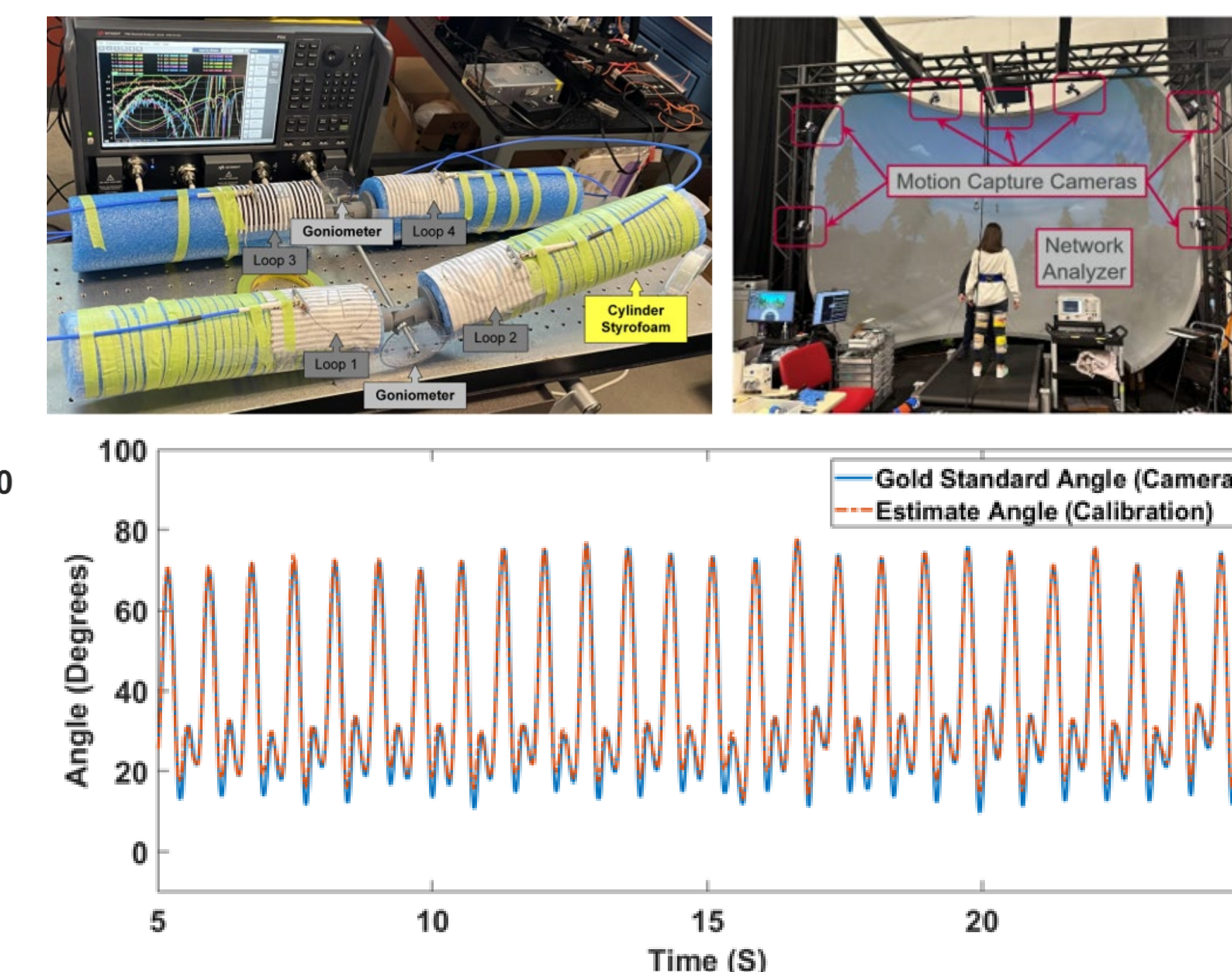
## Approach:



CPS · electro-magnetics · sensors · CAREER

Cognitive and Fully-Adaptive CPS

environment → Clinician / Cloud

**Multi-Utility Sensing**
- *Motion capture*
- *Monitoring of tissue properties*
- *Both of the above*

Tx / Rx

— — — **Wrap-Around Loops**
——— **Planar Loops**

### (a) E-textile sensor for kinematics monitoring



- Flexion(Sim.)
- Flexion(Exp.)
- Rotation($0^0$ to $50^0$) (Sim.)
- Rotation($0^0$ to $50^0$) (Exp.)

At $\theta_f = 0^0$ · At $\theta_f = 40^0$ · At $\theta_f = 80^0$

Transm. Coeff. $|S_{21}|$ (dB) vs. Flexion Angle ($\theta_f$) (deg)

### (b) Calibration



- Retrieve $|S_{21}|$ vs. angle curve
- Currently camera-based

Transm. Coeffe. $|S_{43}|$ (dB) vs. Flexion Angle ($\theta_{ex}$) (deg)
- Right Cal 1
- Right Cal 2
- Right Cal 3
- Simulation

### (c) Tissue-emulating phantoms and human subject testing



Loop 3, Loop 4, Goniometer, Loop 1, Loop 2, Cylinder Styrofoam, Motion Capture Cameras, Network Analyzer



Angle (Degrees) vs. Time (S)
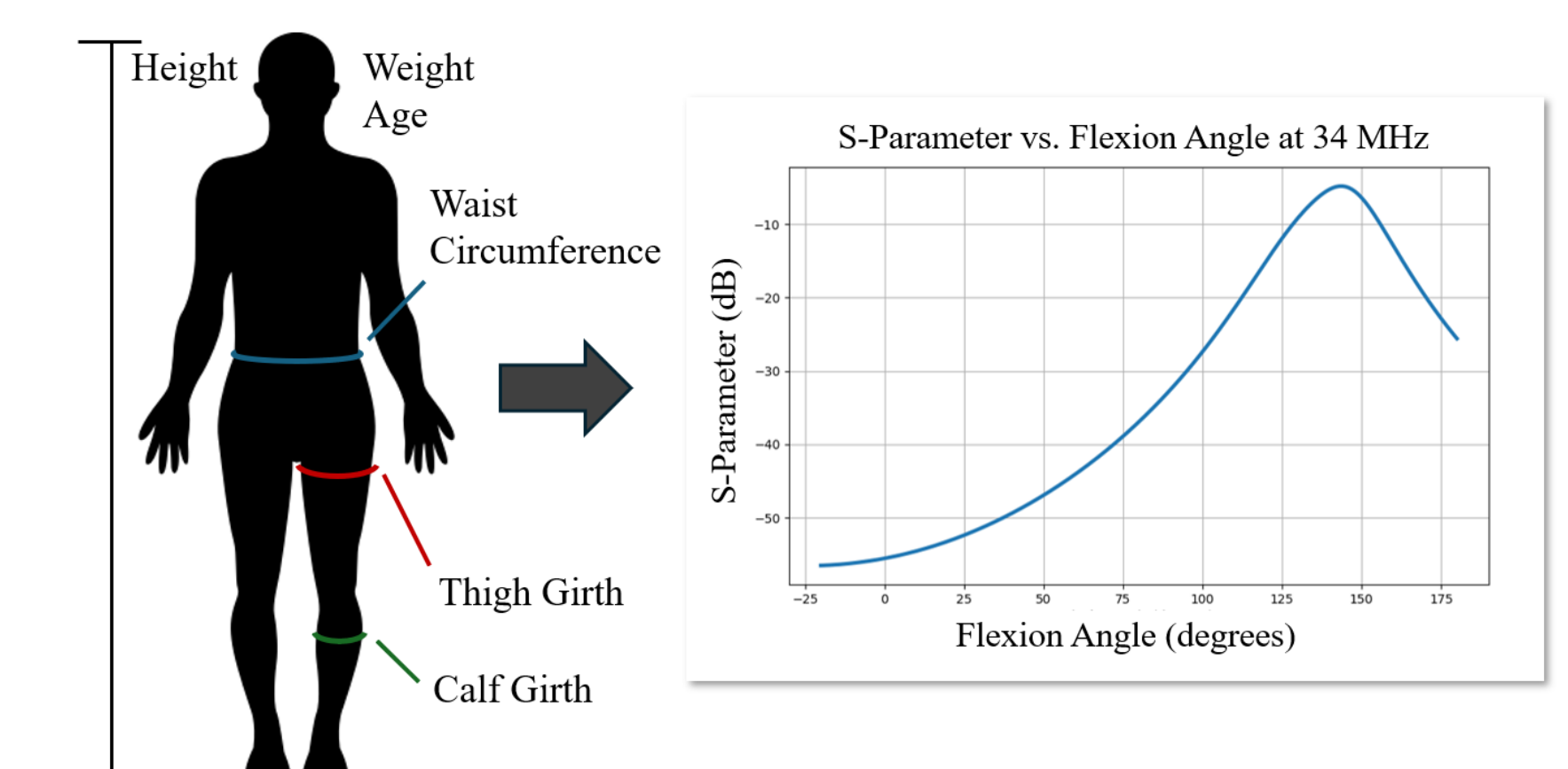- Gold Standard Angle (Camera)
- Estimate Angle (Calibration)

- Currently, 2 to 3 deg of RMSE → adequate for several clinical applications (with room for improvement)

### (d) Machine learning for optimized performance

- Reduce the effect of fabric drift

| Motion Type | RMSE (deg) (with ML) | RMSE (deg) (without ML) |
|---|---|---|
| Brisk Sleeved | 7.07 | 52.00 |
| Jog Sleeved | 5.82 | 51.08 |
| Walk Sleeved | 6.30 | 52.15 |
| Slow Sleeved | 8.21 | 35.07 |

- Predict calibration curves based solely on body measurements



Height, Weight, Age, Waist Circumference, Thigh Girth, Calf Girth →

S-Parameter vs. Flexion Angle at 34 MHz
S-Parameter (dB) vs. Flexion Angle (degrees)

## Scientific Impact:

- Revolutionize performance of wearable CPS "in the wild"
- Redefine wearables from bulky sensors to seamless fabrics
- Establish core expertise in electromagnetic-enabled garments that monitor motion and/or tissue abnormalities with unique merits over the state-of-the-art

## Broader Impact:

**Healthcare**
Rehabilitation, Treatment, Baseline data, Diagnosis

**Sports**
Training, Injury prevention, Data analytics

Wearable Human-in-the-Loop CPS

**Defense / Emergency**
Training, Injury detection, Performance metrics

**Entertainment**
Human-machine interfaces,