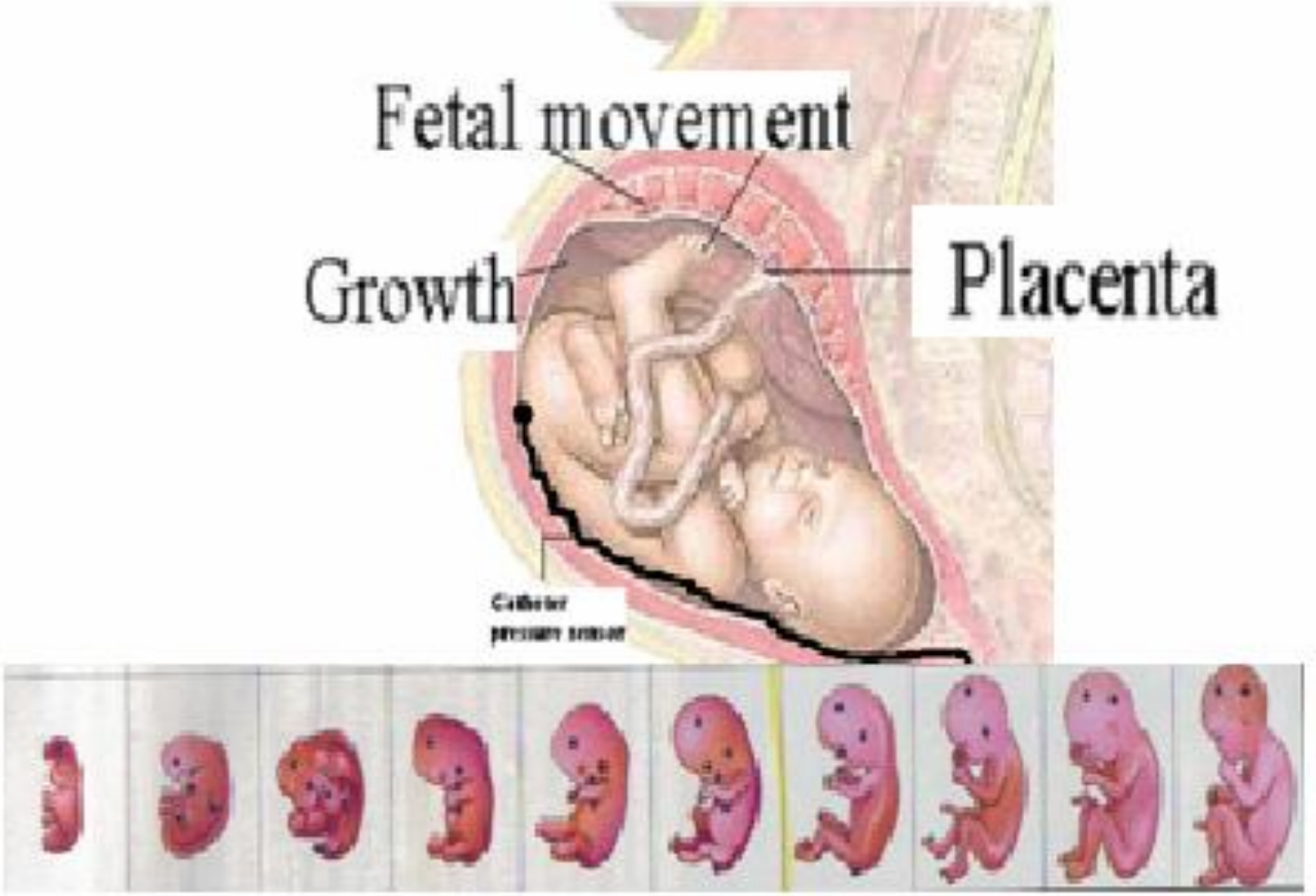
Real-Time Feto-Maternal Monitoring Using Electrical Impedance Approach: Hardware Design and Phantom Study

Sharvan Kumar


Fetal movement
Growth
Placenta

Present Status



Imaging

(FETO PLACENTAL IMAGING)

- FETAL POSITION
- PLACENTAL POSITION
- FETAL GROWTH MONITORING
- ANOMALY DETECTION

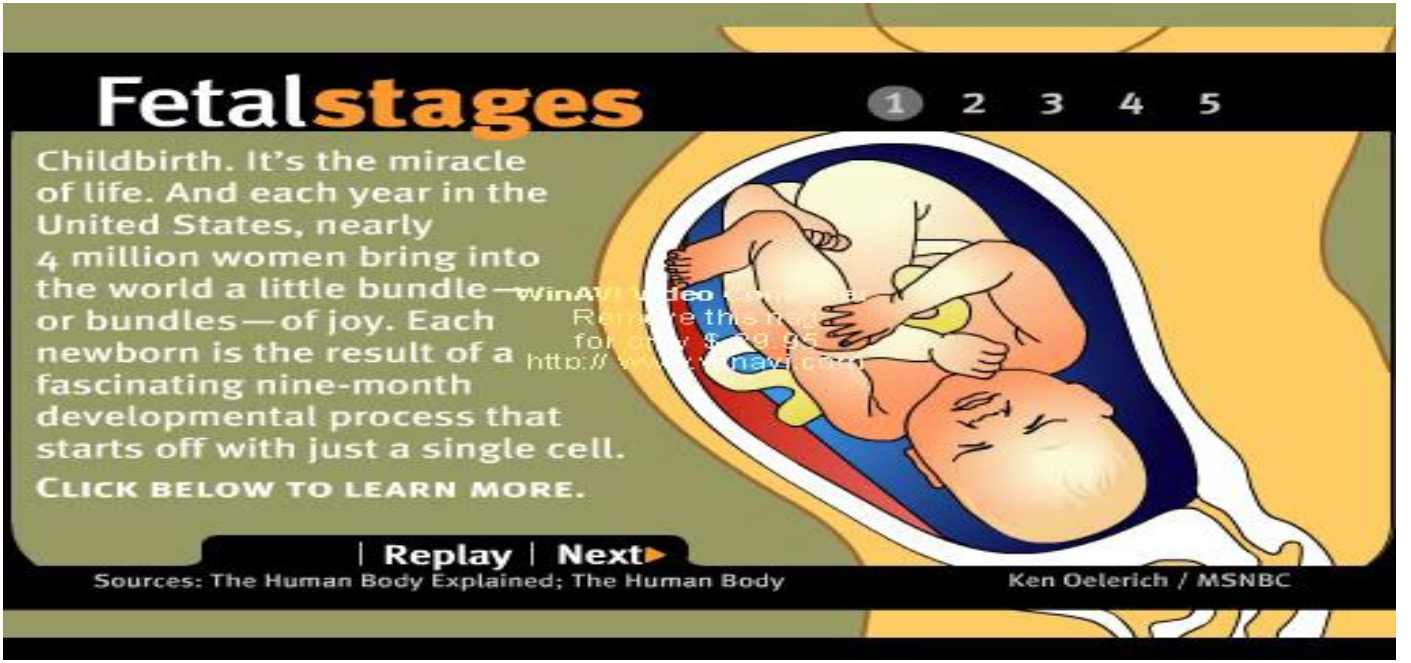
Bio physical monitoring

- Fetal Heart Rate
- Fetal Movements
- Uterine Contraction
- Blood flow
- Mother Heart Rate
- Amniotic Fluid volume

Widely used

Ultrasonography & Cardiotocography

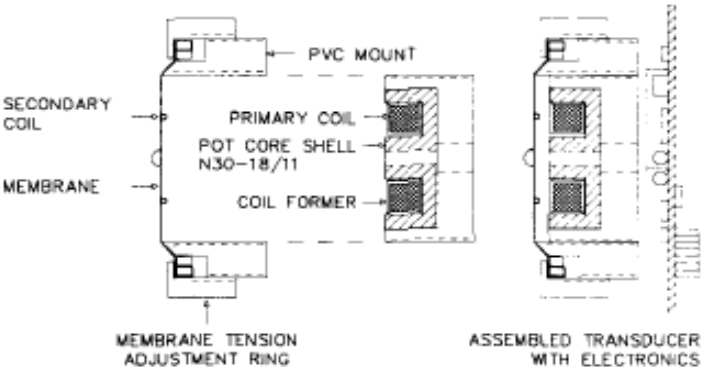
Fetal Movement



Measure of fetal movement

Pressure sensors used

- Strain gauge
- Inductive phonometer (INPHO)



Inductive phonometer (INPHO)

- **Monitoring of Fetus and Maternal health during labour are cardiotocogram, tocography, Ultrasound and Magnetocardiograpghy.**
- **Cause inconvenience to the patient and demand special attendance of the obstetrician.**
- **Cannot be used for continuously monitoring.**
- **Non-invasive electrical impedance approach is proposed.**

FETO-MATERNAL MONITORING

An appropriate and affordable, continuous, non- invasive, ambulatory point of care (PoC) feto-maternal monitoring system during labor and pregnancy is essential for better pregnancy outcome.

Accordingly, an effort has been made to develop an electrical conductivity based affordable screening tool for use by the health workers to monitor the vital physiological parameter necessary to assess fetal and maternal well being.

The technology remained unexplored in pregnancy monitoring. This technique helps electrical field distribution monitored on the surface and likely to provide information because of fetal movements

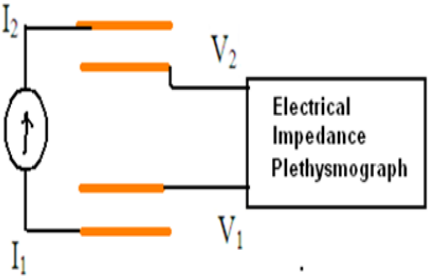
Impedance Plethysmography

- Theoretical model
- Physical model

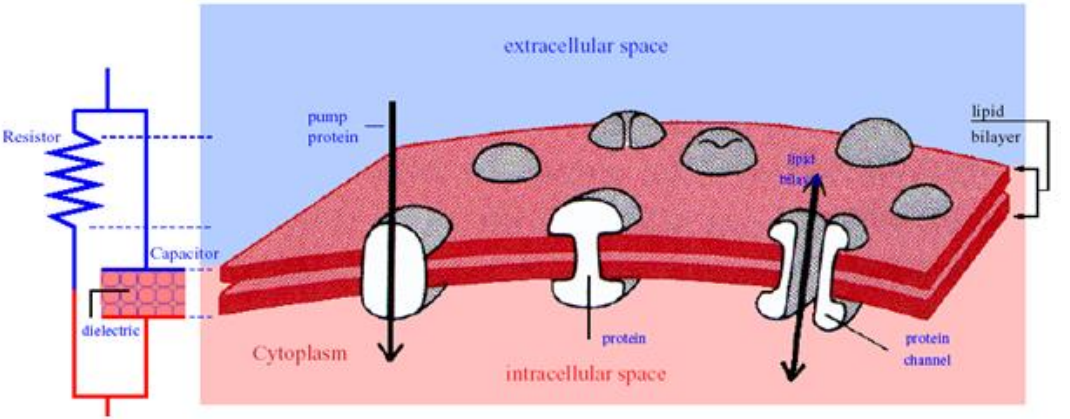
INTRODUCTION(IPG)

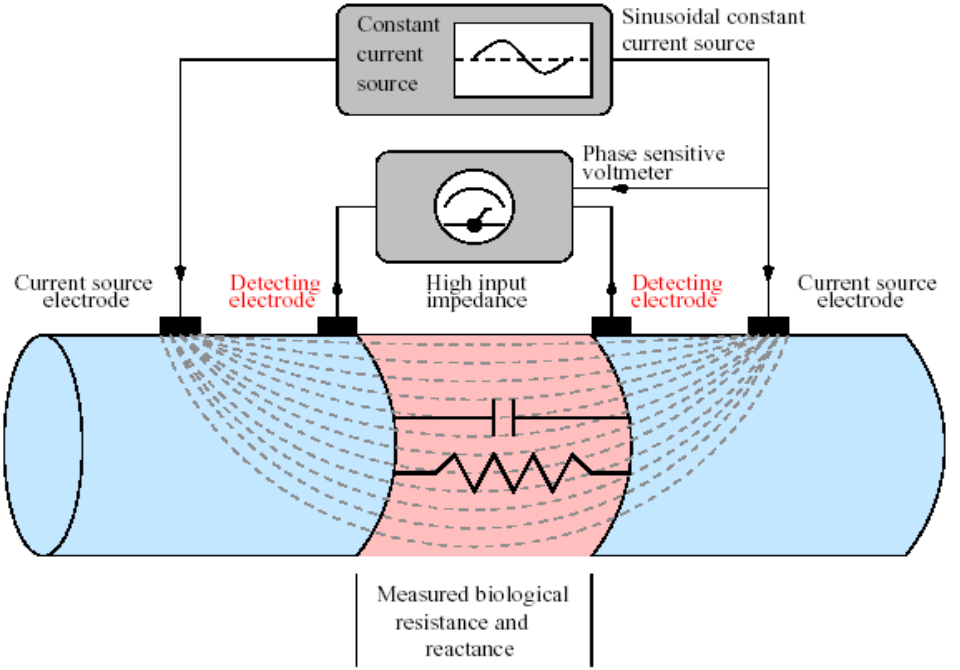
FOUR ELECTRODE IMPEDANCE MEASURING TECHNIQUE

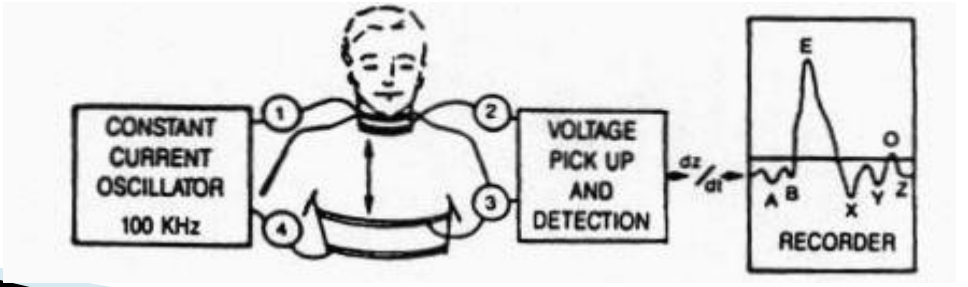
- AC Current or Voltage , frequency 20-100 KHz.
- The signal output α impedance.
- Impedance changes
  - Biomedical (medical imaging)
  - Non-Biomedical



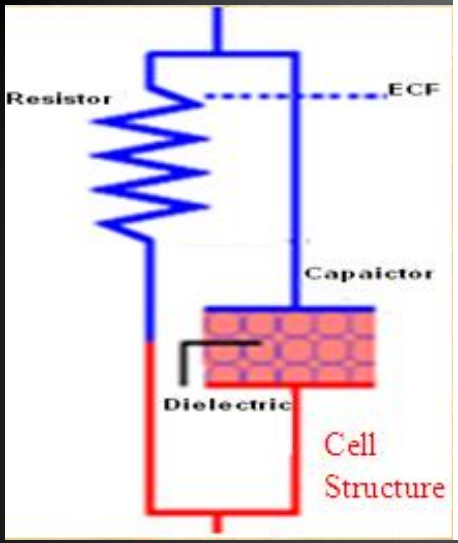
The Plasma Membrane of a Cell and its Electrical Equivalent

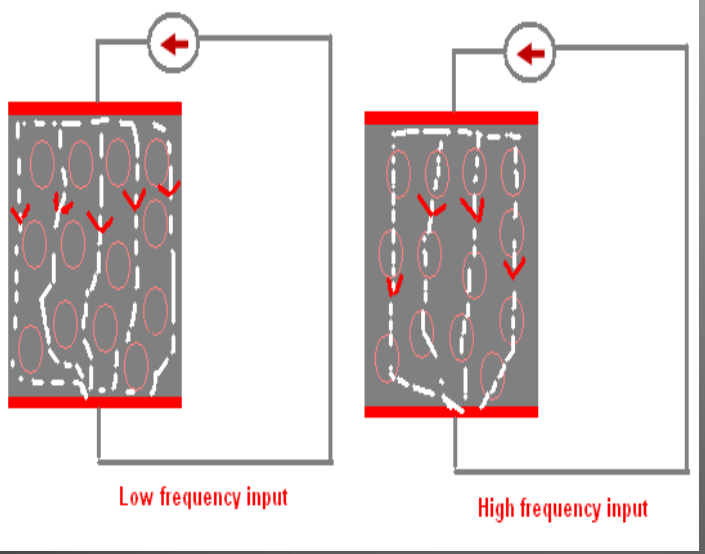


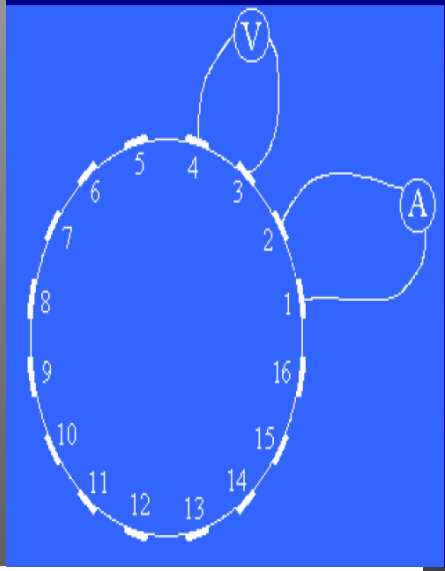




Four electrode impedance measuring Technique

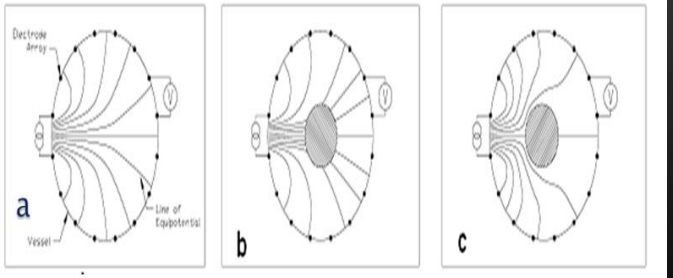






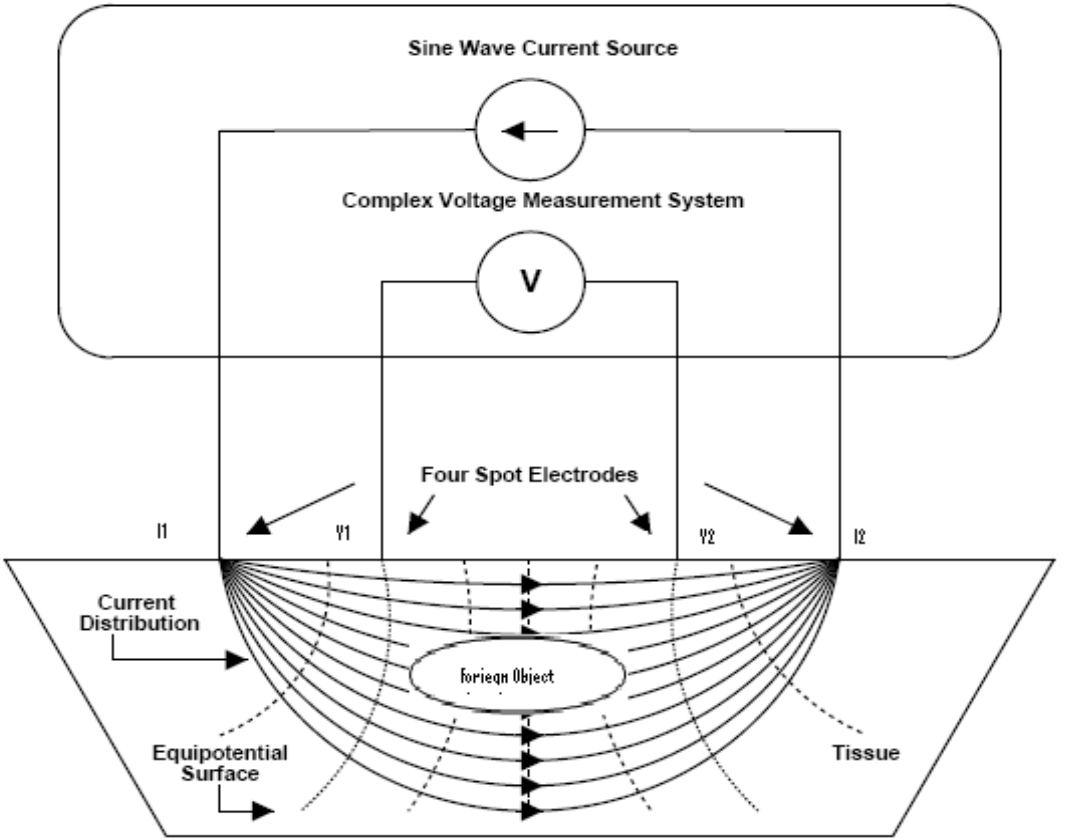
Tissue	Conductivity σ (S/m)
Bone	0.0201
Fat	0.0196
Heart	0.0827
Muscle	0.233
Skeleton muscle of fetus	0.0201
Soft tissues of fetus	0.216
Spinal cord	0.0274
Uterus	0.229

(a) Normal
(b) Conducting object
(c) Non-conducting object

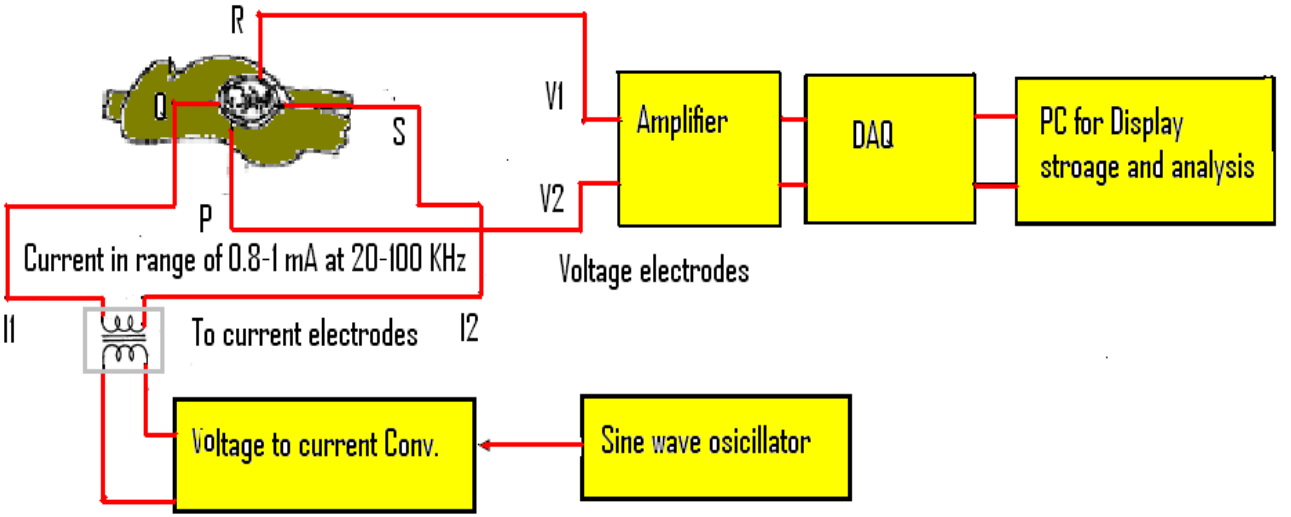


$Vc > Va$ $Vc > Vb$

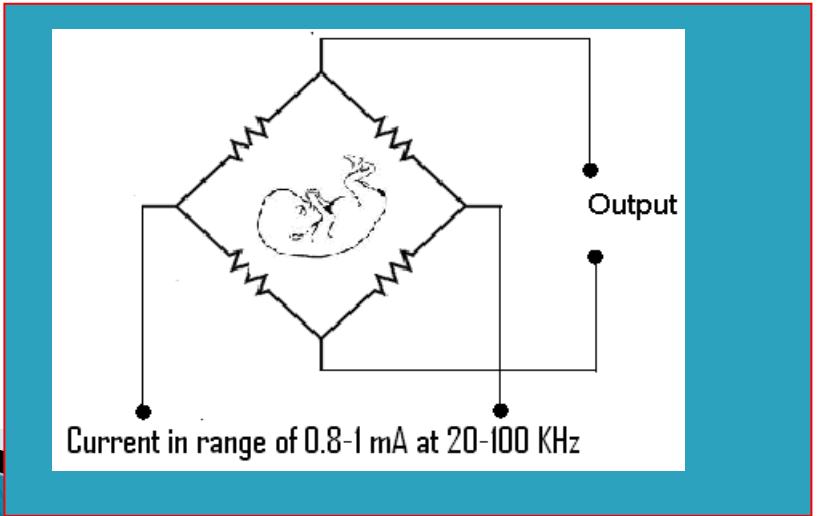
PROPOSED WORK



Four-electrode measurement system.

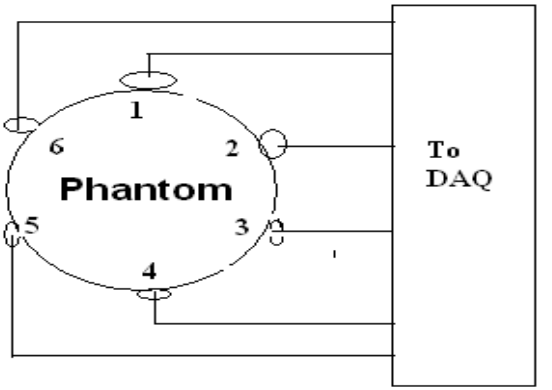


Block Diagram for measurement of various feto-maternal parameters

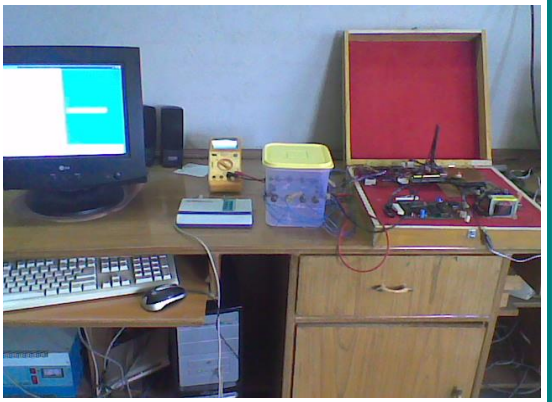


Material and Methods

- The high frequency low current is applied between I_1 , I_2 electrodes which gets uniformly distributed and the resulting voltage hence impedance is measured between V_1 and V_2 electrodes.
- Figure below shows the general block diagram of experimental setup.



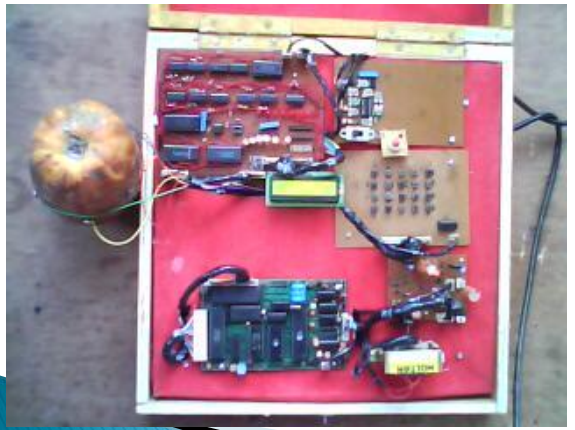
Results



ADC_NO	CHANNEL	CHANNEL_DATA
01	01	0.00
01	02	0.00
01	03	0.00
01	01	0.00
01	02	0.00
01	03	0.00
01	01	0.00
01	02	0.00
01	03	0.00
02	01	0.01
02	02	0.00
02	03	0.00
02	01	0.01
02	02	0.00
02	03	0.00
02	01	0.01
02	02	0.00
02	03	0.00
03	01	0.00
03	02	0.00
03	03	0.00
03	01	0.00
03	02	0.00
03	03	0.00
03	01	0.00
03	02	0.00
03	03	0.00

ADC_NO	CHANNEL	CHANNEL_DATA
01	01	0.64
01	02	0.01
01	03	0.02
01	01	0.67
01	02	0.10
01	03	0.02
02	01	0.02
02	02	0.02
02	03	0.02
02	01	0.01
02	02	0.02
02	03	0.11
03	01	0.01
03	02	0.11
03	03	0.01
03	01	0.01
03	02	0.02
03	03	0.01

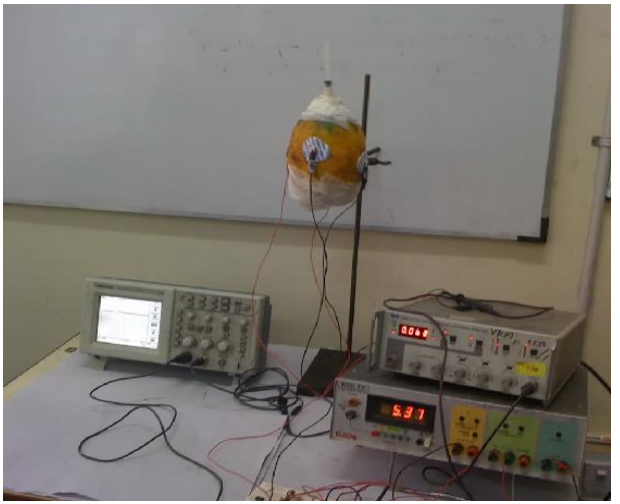
Processed Data (a) with empty Plastic Container (b) with water in Plastic Container

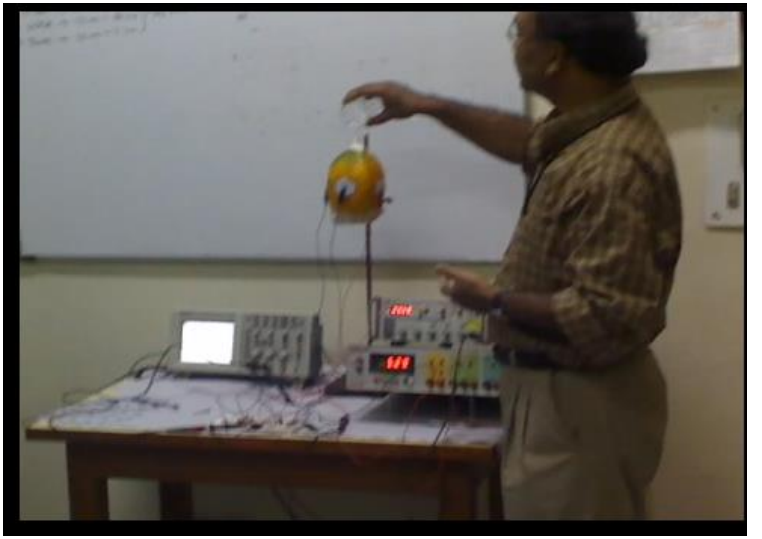


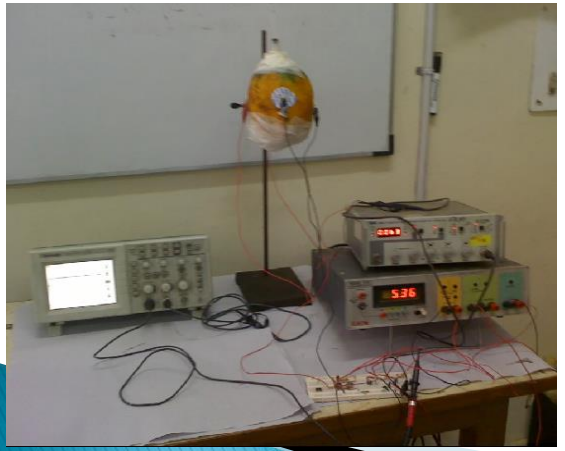
Capturing and Processing of Data

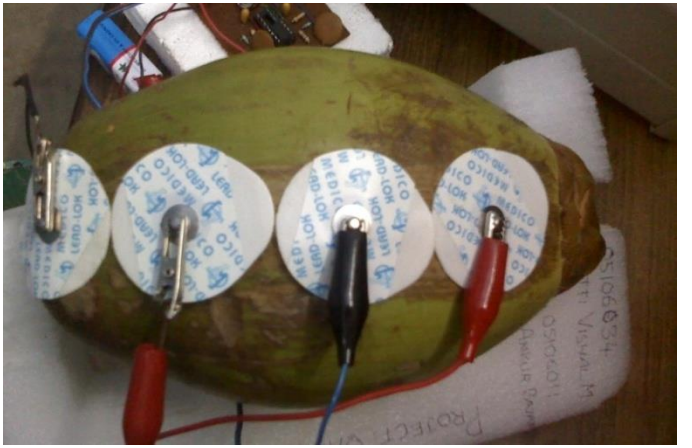
ADC_NO	CHANNEL	CHANNEL_DATA
01	01	0.83
01	02	0.11
01	03	0.08
01	01	0.88
01	02	0.11
01	03	0.11
01	01	0.83
01	02	0.10
01	03	0.34
02	01	0.08
02	02	0.06
02	03	0.07
02	01	0.08
02	02	0.18
02	03	0.23
02	01	0.08
02	02	0.18
02	03	0.23
03	01	0.02
03	02	0.10
03	03	0.18
03	01	0.03
03	02	0.10
03	03	0.06
03	01	0.03
03	02	0.11
03	03	0.19

Snap shot of the papaya phantom



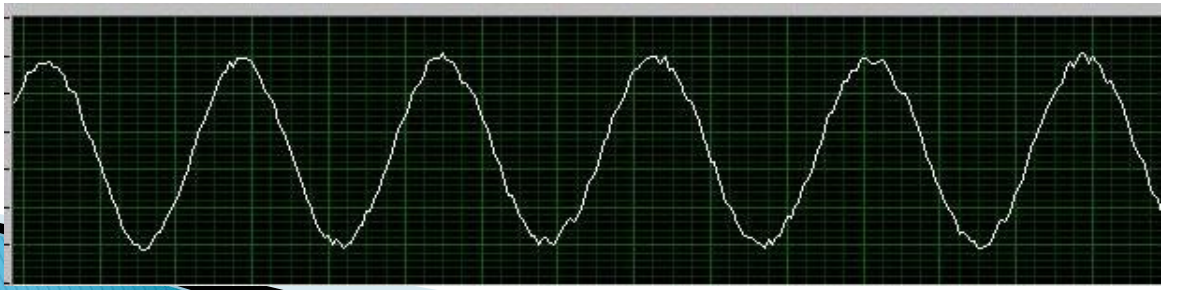


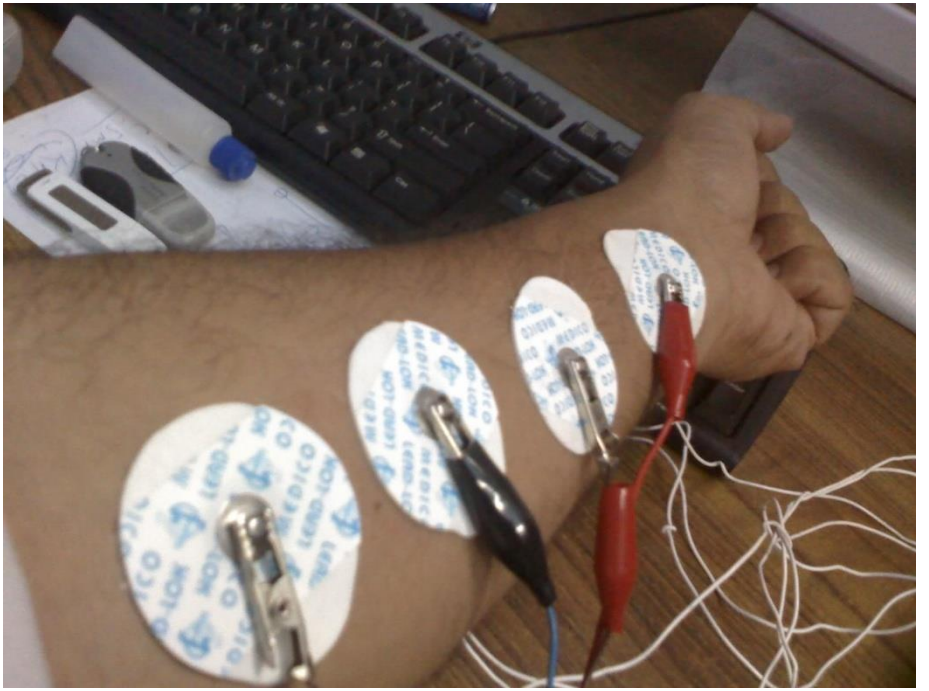




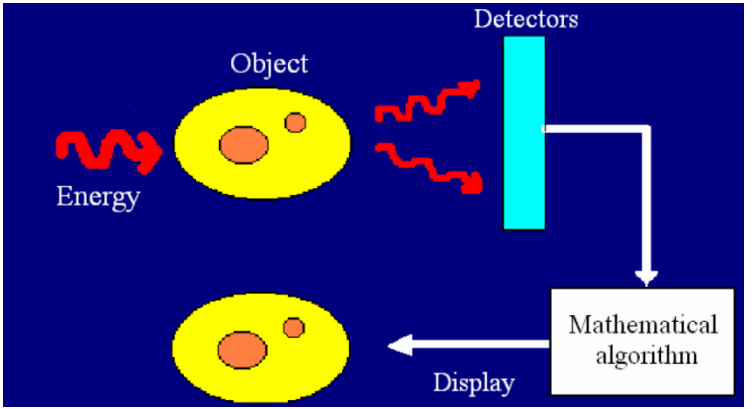
Impedance Plethysmo-graph of a Phantom (melon)

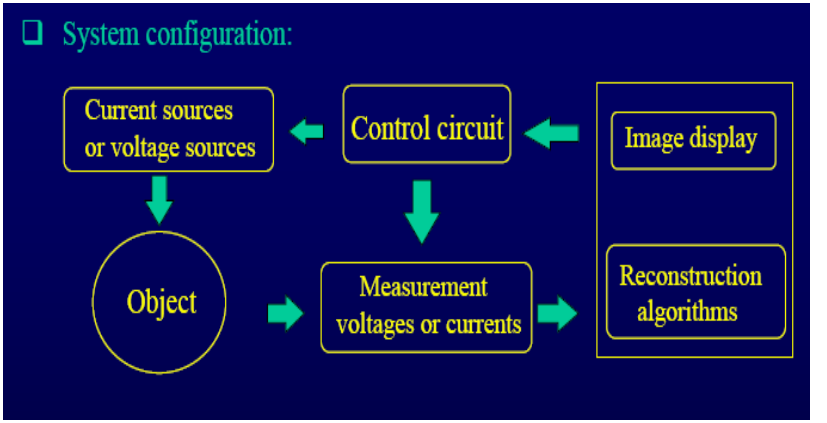


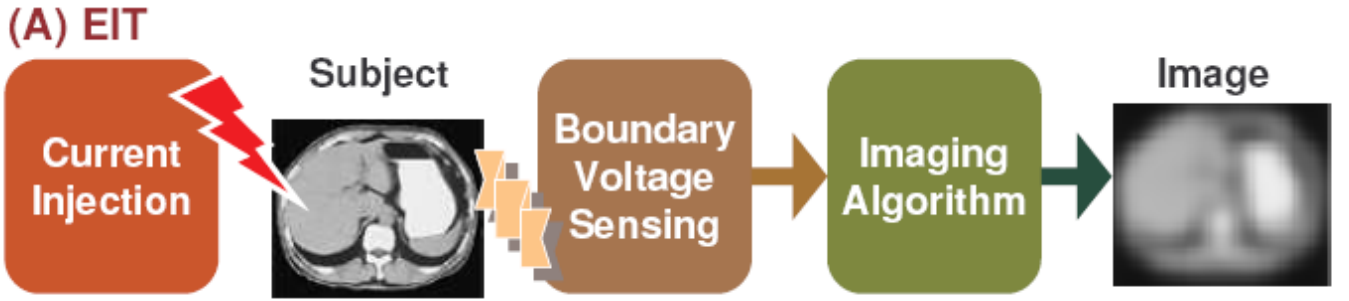




Block diagram of a Medical Imaging System





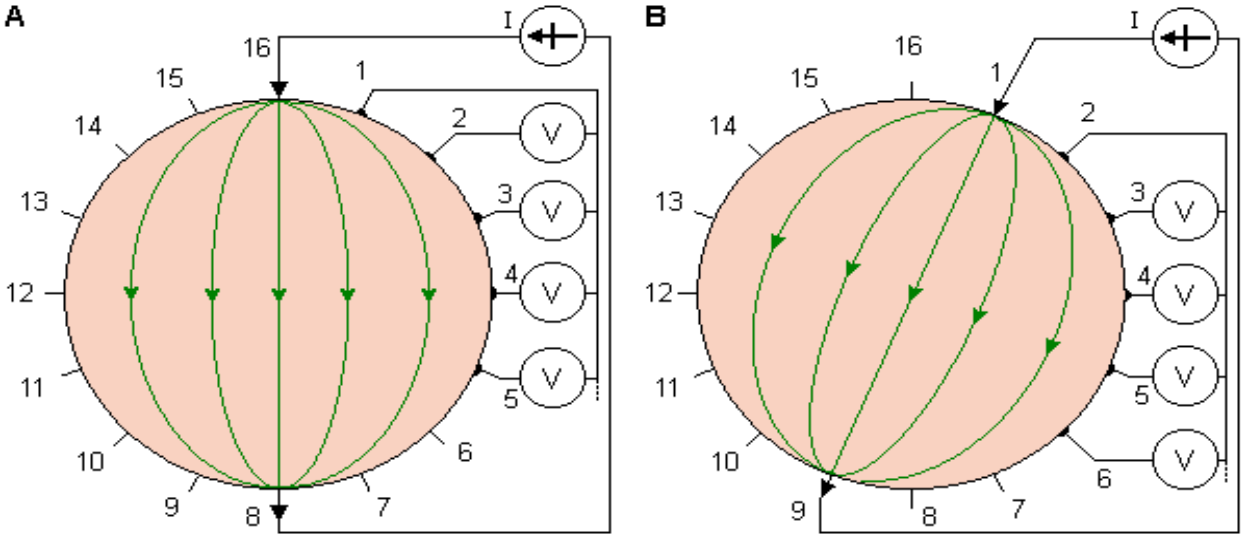


Medical Applications

Area	Applications	Researchers
Central nervous system	The investigation of human brain function	*H. McCann et al. 2005* *D S Holder et al. 2003*
	The measurement of brain and skull resistivities	*R M Heethaar et al. 2003*
Respiratory system	The investigation of lung ventilation	*G Hedenstierna et al. 2003*
Cardiovascular system	The measurement of blood flows using microelectrodes	*K K Haase et al. 2005*
	The monitoring of blood loss in animal study	*N H Secher et al. 2000*
Digestion system	The monitoring of gastric emptying	*T Kondo et al. 2000*

DATA ACQUISITION METHODS

- *OPPOSITE METHOD*



Total measurements : 8×13 = 104

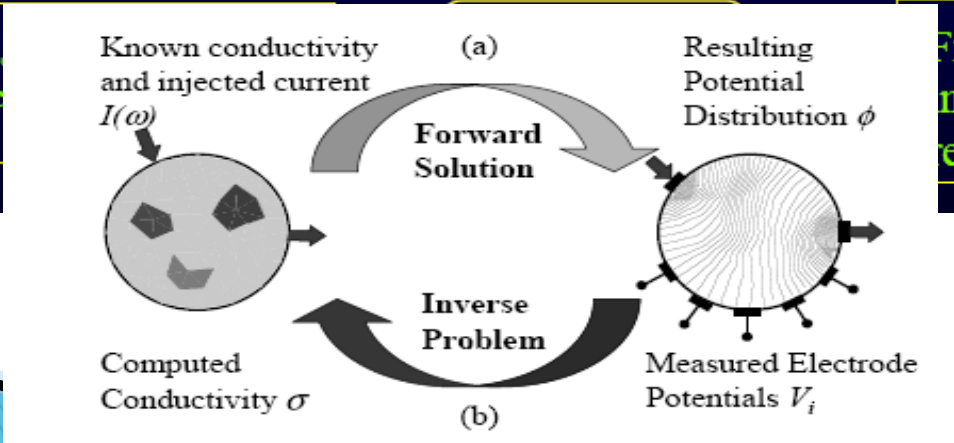
Image Reconstruction Algorithm

- **Forward problem**

Given internal resistivity ρ
boundary current density J_o → Solver → Find voltage V

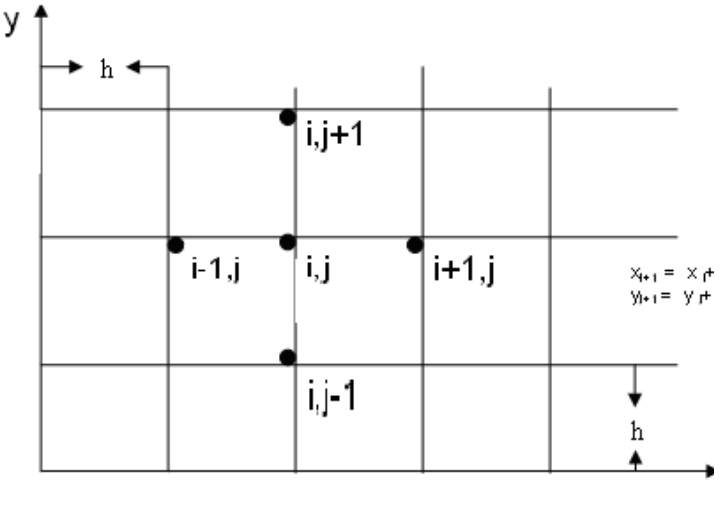
- **Inverse problem**

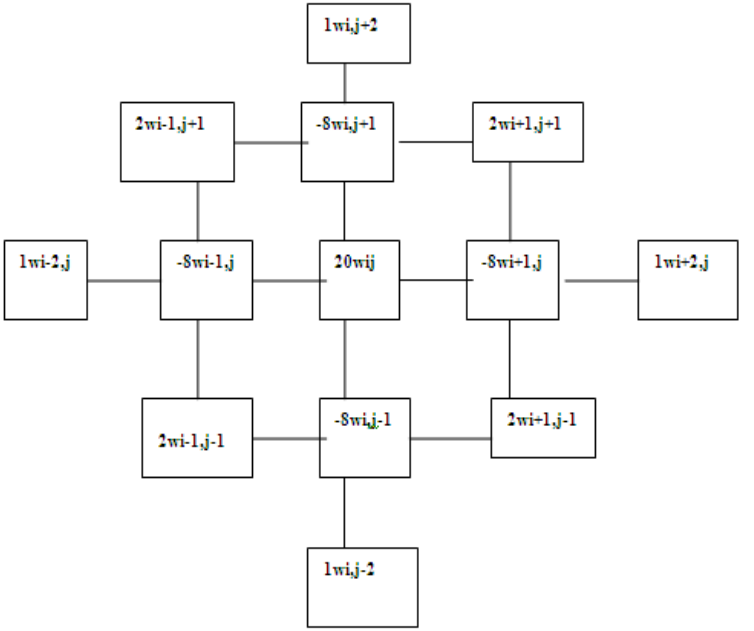
Given b… and c… → Find …nternal ρ …esistivity



Finite Difference Method (FDM)

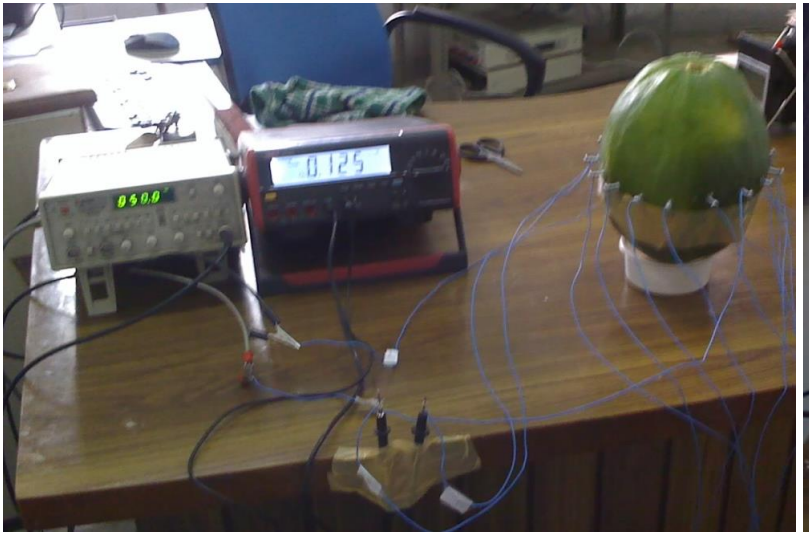
- $W_{ij} = 0.5x(8(W_{i+1,j} + W_{i-1,j}, W_{i,j+1}, W_{i,j-1}) - 2(W_{i+1,j+1} + W_{i-1,jJ+1} + W_{i-1,j-1} + W_{i+1,j-1}) - W_{i,J+2} + W_{i,J-2} + W_{i-2,J} + W_{i+2,J}) = 0$



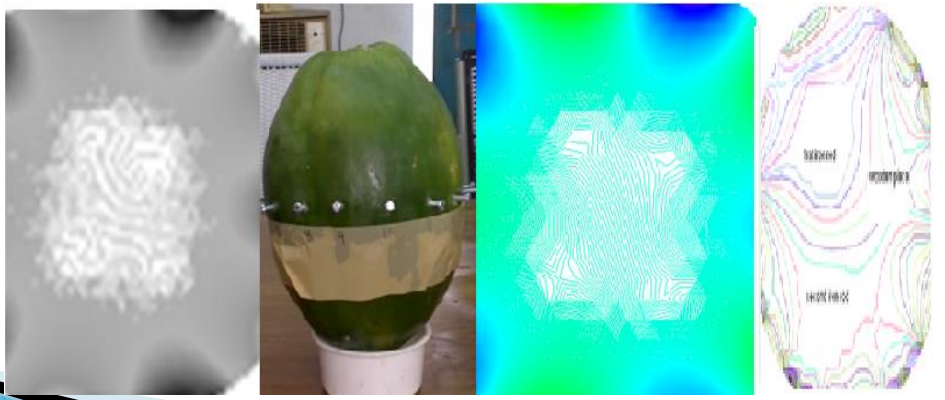


Contains four neighboring points around the central point (xi, yj)

Result







Conclusion

- Series of experiments done in the phantom and other mechanical model of similar conditions.
- Results clearly showed that the electrical impedance tomography can be used to image as well as detect relevant bio physiological parameters of mother and fetus growing inside the gravid uterus.
- Further it can be translated into actual field condition in pregnancy after taking ethical clearance for pre clinical and clinical trials.
- As a non-ionizing [27] and inexpensive method, electric impedance tomography can be an addendum to the existing feto-maternal monitoring medical imaging methods.

► Day to day monitoring

► Ambulatory monitoring 24x7 during and labor and pregnancy.

► For mass health care.

► As a scaling down technology as mass health care tool for screening and monitoring purpose as an alternative system in the absence of known conventional monitoring technology.

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[9] Terry Tressler, DO, Monica Bernazzoli, RDMS, James Hole, DO and Francis Martinez, DO, ", The Effects of Maternal Position on the Amniotic Fluid Index" , J Ultrasound Med 25:445-447 .

Thank you