Exploring Human Body Communications for IoT Enabled Ambulatory Health Monitoring Systems

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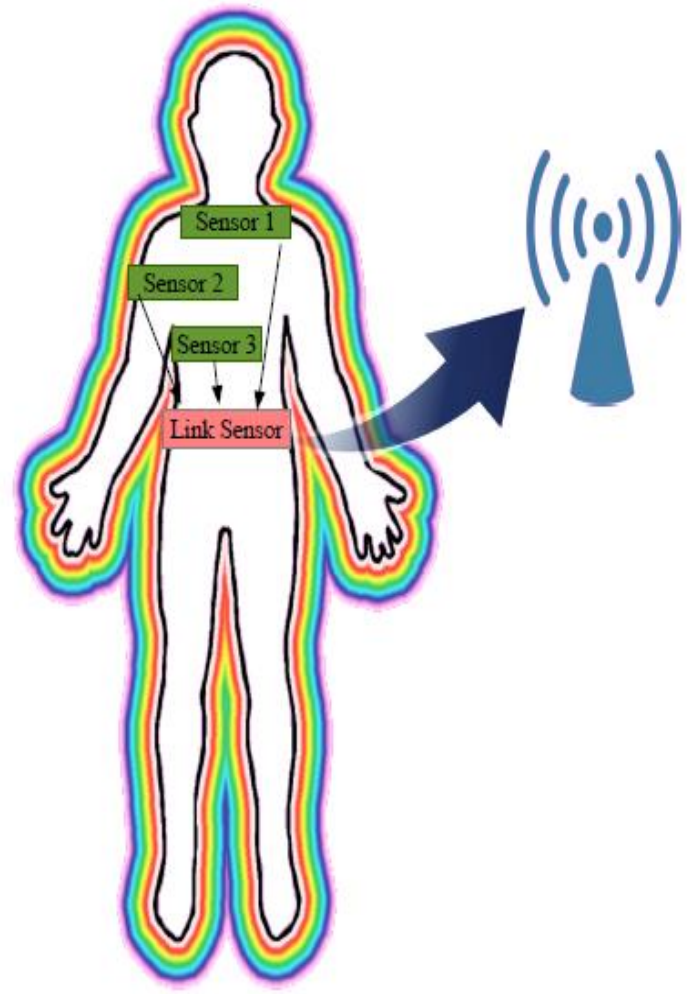
Outline of the talk

- Introduction and Motivation
- Novel Contributions
- Human Body Communication in IoT
- Proposed Ambulatory Health Monitoring System
- Implementation and validation of the design
- Conclusions and Future research

Introduction and Motivation

- With increasing features added to a design, there is a continuous need for energy efficient systems.
- Human Body communication (HBC) has proven to be a low power wireless data communication technology.
- Wearables designed using HBC can help in energy efficient personal area networks.



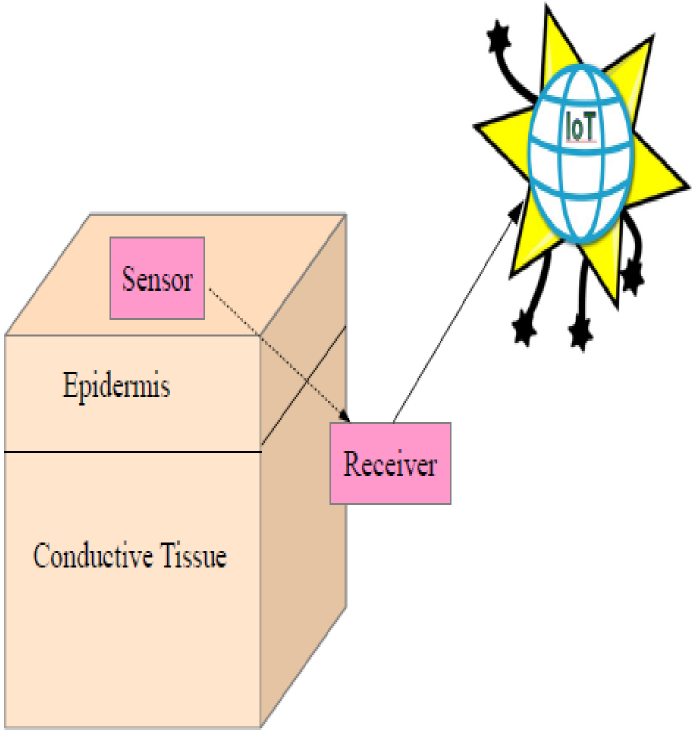
Introduction and Motivation

- In the healthcare domain, multiple sensors can be integrated to form a personal area network.
- Sensors are connected using wireless technologies such as Bluetooth, Wi-Fi, along with the RF components.
- The medium of network designed for smart healthcare can be anything depending upon the application.
- Using wireless components in such connected healthcare networks, can increase the power budget of the network.

Introduction and Motivation

✓ **Internet of Things**

- The Internet of Things is a network of devices where each device in the network is recognizable and connected.
- It can be thought of as the interconnection of uniquely identifiable smart objects and devices.
- An illustration of the application of HBC for IoT is shown in the Figure.



Introduction and Motivation

✓ **Smart Healthcare**

- Applications for IoT can range from a smart health care monitoring systems to efficient surveillance systems which are basic elements of building a smart city.

- In spite of having excellent infrastructures and cutting technologies, the medical services are not approachable to every individual.

- Energy efficient sensor systems such as monitoring systems, wearables and in-vivo sensors, empowers the users to manage emergency situations and maintain healthy lifestyle.

Introduction and Motivation

- Several communication methods have been employed in wearables technologies.
- Optical communication helps in realizing high speed links but it does not work for non line of sight communication.
- On the other hand, radio waves help in non line of sight communication but the electric power consumption is very high.
- Magnetic coupling has low electric consumption but the coils used to implement the same cannot be easily minimized.

Introduction and Motivation

- Sound waves help in non line of sight communication but it does not help in appropriate miniaturization of the transducers and offers very low energy conversion efficiency.

- These problems are solved using human body coupled communication, which offers better non-line sight communication and multi-tasking .

- The main advantage of HBC, is that the electrode does not have to be present exactly over the sensor in order to measure the output.

Introduction and Motivation

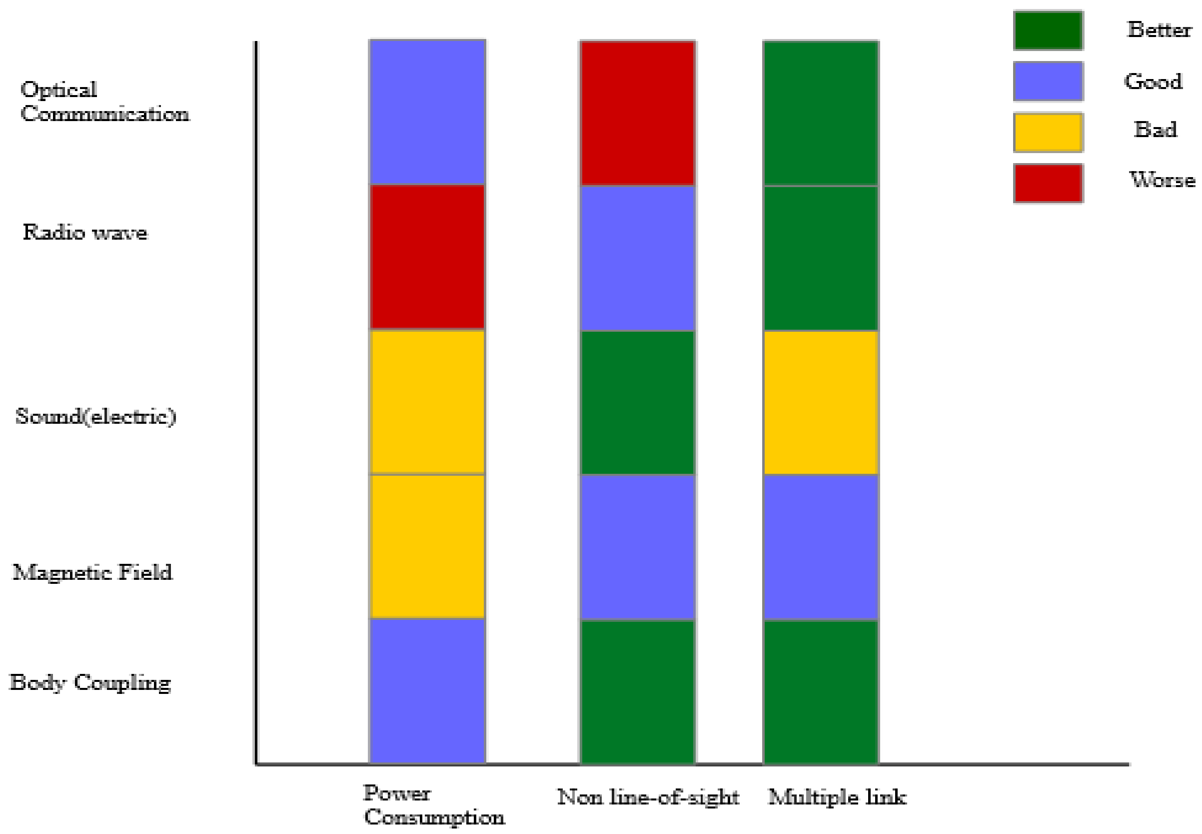


Fig. 4. Performance Comparison of different methods of wireless Communication [6]

[6] M. Fukumoto et al, “Body coupled fingering: Wireless wearable Keyboard”, CHI, 1997.

Novel Contributions of This Paper

1. A health monitoring system through HBC for IoT applications is presented.

2. An ambulatory monitoring system is proposed with an array of sensors.

3. A Simulink® based prototype of frequency selective baseband transmission is implemented.

4. An energy efficient monitoring system is proposed with low power communication channel for inter and intra sensor communication.

Human Body Communication in IoT

- The conductive tissue under the epidermis layer has some electrical conductivity.
- HBC can be achieved by creating a potential difference between any two points in the body.
- Body coupling helps in transmitting electrical signals via the human body but it is dangerous for excessive currents.
- Limitations on the amount of current that can be passed through the human body have been set by many countries.

Transceiver model for HBC

- A transceiver model for human body communication is presented in Figure 5.
- Human body can be modeled as capacitors in series with spreading resistance, leading to high pass filters.
- It acts as a communication channel from these sensors to the receiver, which is the communication module connected to Internet.

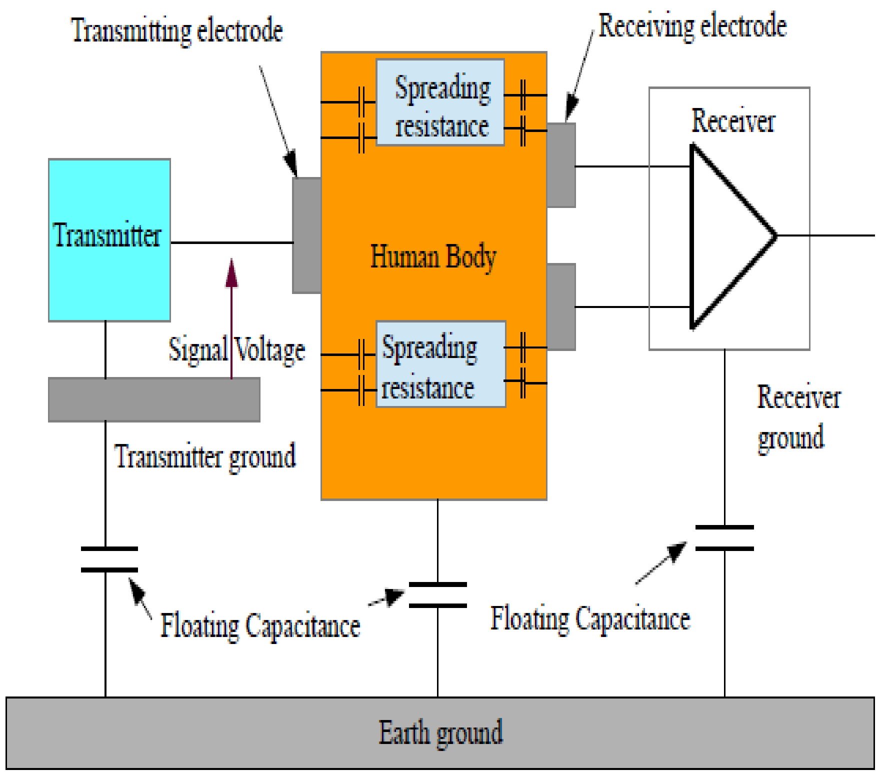


Fig. 5. Transceiver model for Human Body Communication.

Block level diagram of Ambulatory health monitoring through IoT

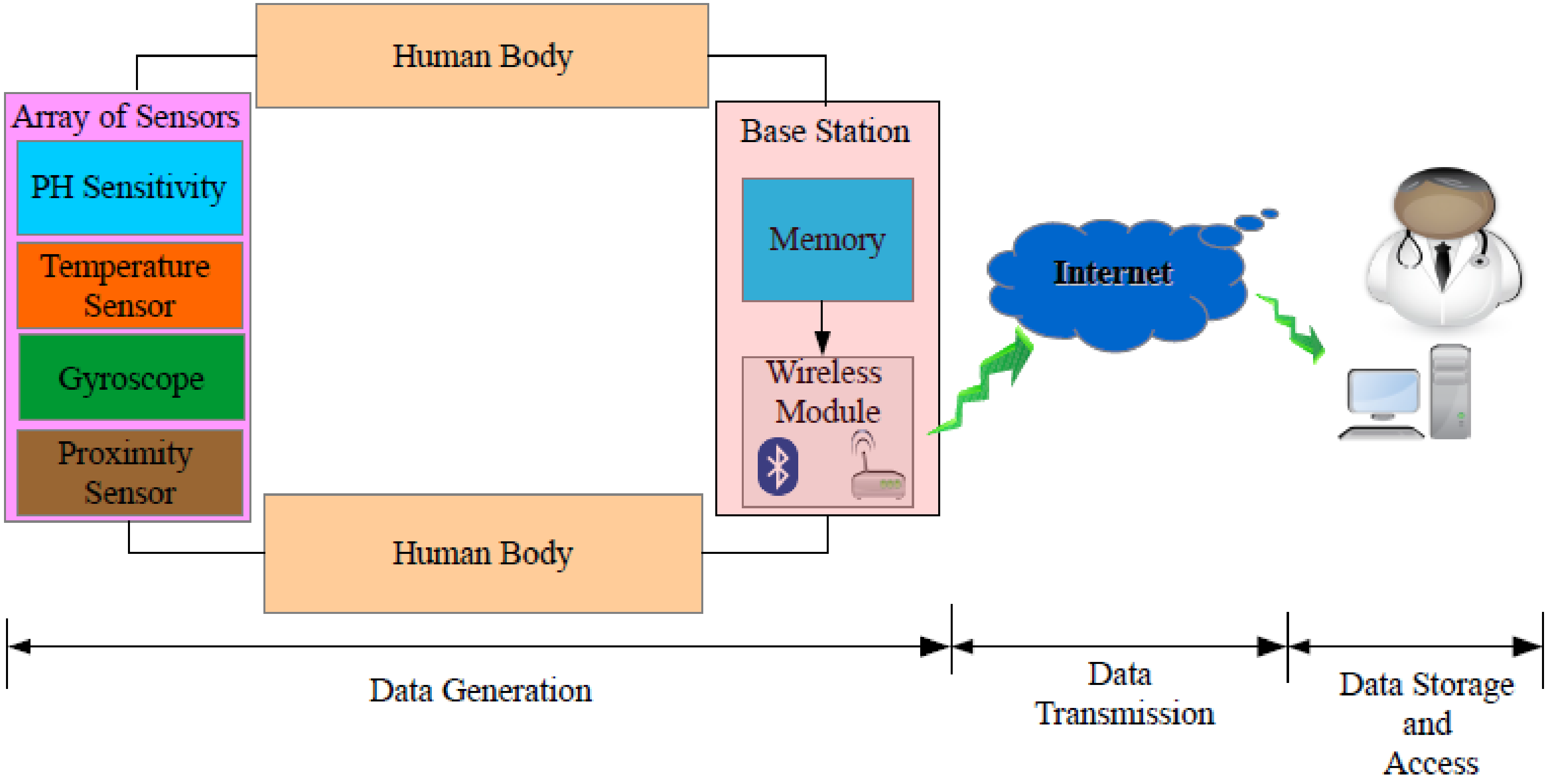


Fig. 3. Block level diagram indicating flow of data in ambulatory health monitoring through IoT.

Proposed Ambulatory health Monitoring System

✓ **Ideal Components**

- *Array of Sensors*

✓ Temperature sensor
✓ Proximity sensor
✓ Gyroscope
✓ pH sensitivity sensor

- *Communication channel*

✓ FSBT
✓ Body coupled communication

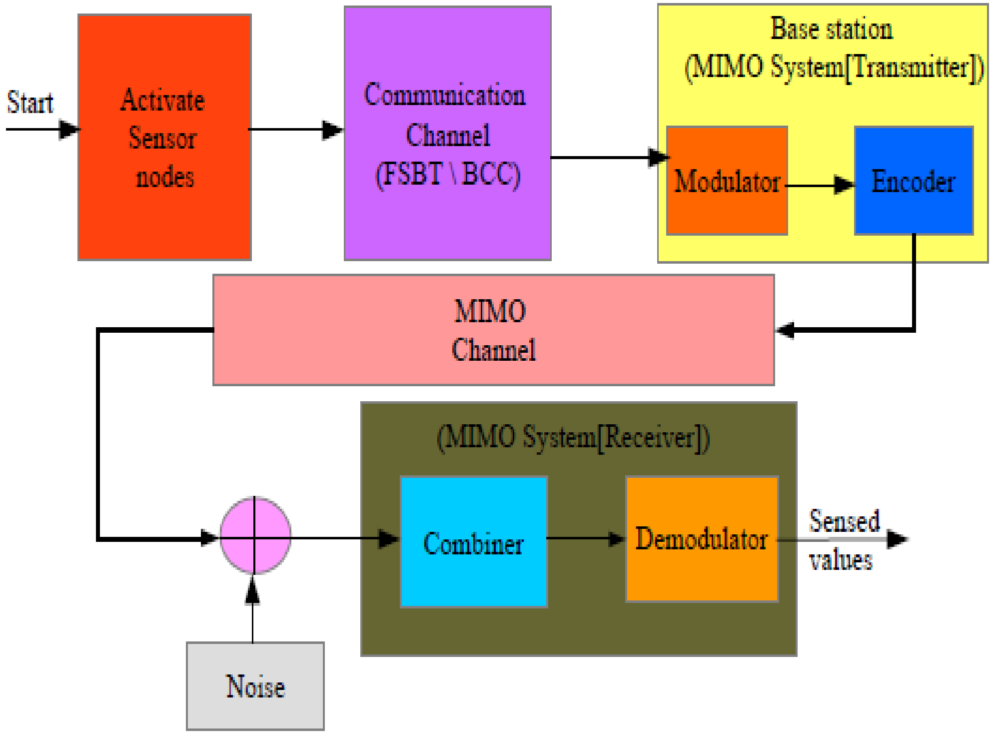


Fig. 6. Datapath across the health monitoring system.

Array of Sensors

1. Thermal Sensor

1. The temperature acquisition is done by using a ring oscillator.

2. In order to oscillate the ring should provide a 2π phase shift and have unity voltage gain at the oscillating frequency.

3. The oscillating frequency is given as

$$f = \frac{1}{N_{stage}(Tpd_{,LH} + Tpd_{,HL})}$$

where N_{stage} = number of stages in the ring oscillator
$T_{pd,L}\ and\ T_{pd,HL}$ = propagation delays

Array of Sensors

2. Proximity Sensor

1. The proximity sensor can also be called a simple distance sensor.

2. It helps in tracking the distance between the object and the sensor.

3. The proximity sensor helps in sensing the distance which is normal to the sensor surface.

4. In the given sensing distance, the sensor detects an object for a given radial offset R.

Array of Sensors

3. Gyroscope

1. A gyroscope sensor helps in analyzing the orientation of an object.

2. It can be used in a body area network to analyze the orientation of the patient or the sensor itself.

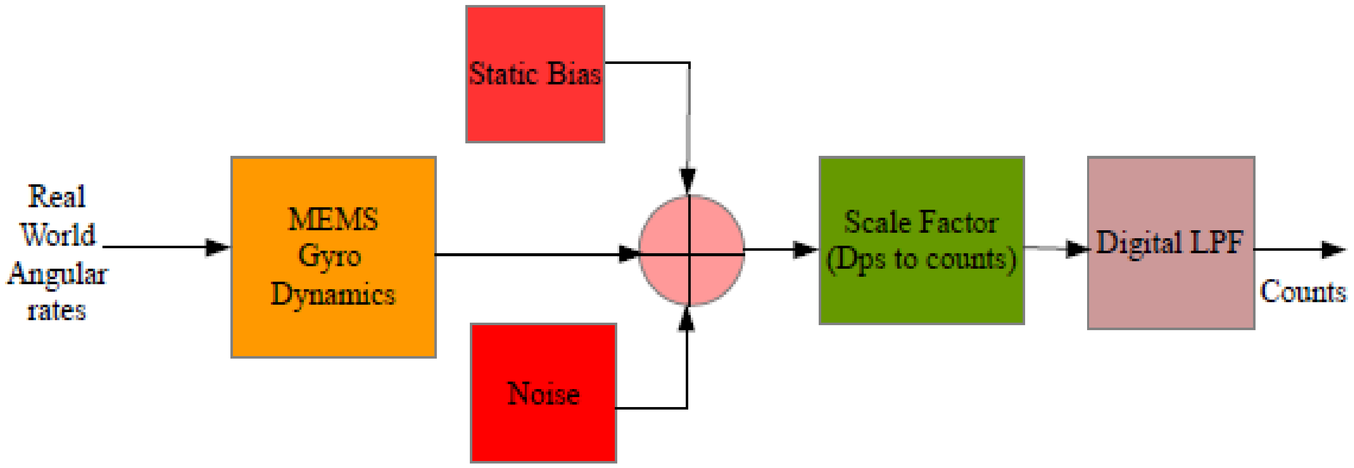


Fig. 7. Block Diagram of a simple MEMS based Gyroscope

Array of Sensors

4. pH Sensitivity sensor

1. Sweat analysis helps in monitoring vital signs such as glucose, sodium, vitamin deficiencies in a person.

2. The measurement of the acidity or alkalinity in sweat is done with the help of pH sensitive sensors.

3. In laboratories pH sensitivity is monitored using the potential difference between the reference electrode and the test electrode.

4. The sensor can be designed based on an operational amplifier.

Communication Channel

1. In the initial days of HBC, it was mainly considered as a way of transferring data through human body.

2. Continuous modulation schemes were used but these modulations do not aid in the touch and play mechanism.

3. Body Area Networks (BAN) can be implemented using low power radios, eTextiles and body coupled communication.

4. Low power radios and BCC have almost the same efficiency and give more flexibility.

Frequency Selective Baseband Transmission

1. Walsh (Hadamard) code helps in implementing Frequency selective baseband transmission.

2. A Walsh code consists of M_n matrix where n is an even integer. It has all 1s and 0s such that all rows differ from each other by exactly 1/2n positions.

3. The input to the transmitter is divided into 4 subgroups where the input is spread using the Walsh code in the frequency spreader.

4. FSBT helps in implementing touch and play mechanism.

HBC Block Diagram with FSBT Modulator

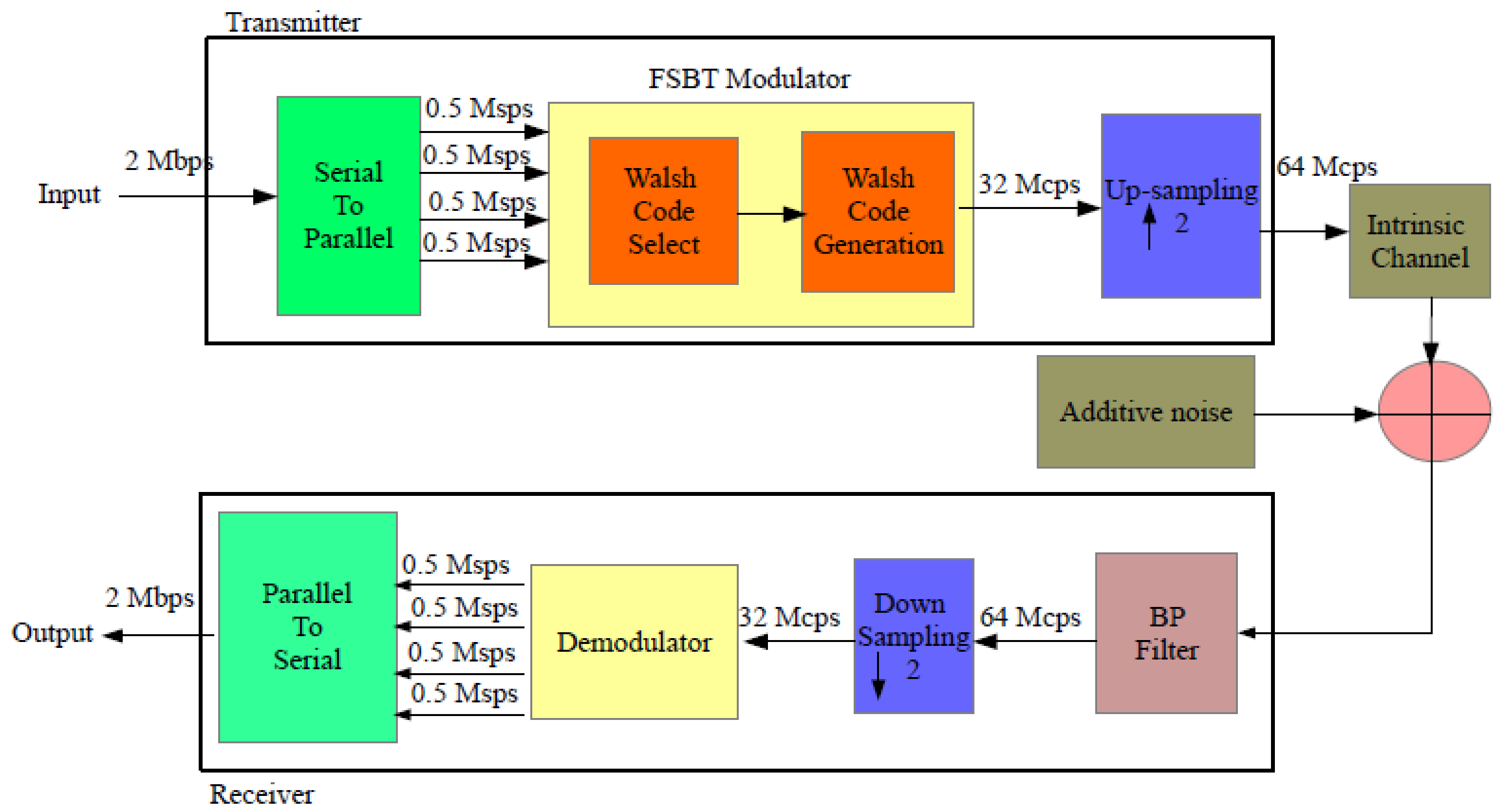


Fig. 8. HBC Block Diagram with FSBT Modulator

Body Coupled Communication (BCC)

1. BCC can be done by either capacitive coupling or galvanic coupling.

2. In galvanic coupling technique, the transmitter sends a signal through the human body and irrespective of the environment, the receiver receives it.

3. Both transmitter and receiver electrodes are directly placed in contact with the skin.

4. It is very robust and is used for wearables and implantable devices.

Body Coupled Communication (BCC)

5. In Capacitive coupling, the transmitter electrode is placed on the human skin and the other electrode is left floating.

6. The floating electrodes are coupled to ground through the air and create a return path, whereas the attached electrode creates a forward path.

7. Ideally the simplified BCC model can be implemented as a pair of High pass filters in case of Capacitive coupling and as a channel with one high pass filter for galvanic coupling.

Experimental results

1. The proposed system was implemented using Simulink® due to its available primitives and libraries.

2. Figure 10 shows the capacitive coupling in a human body which is modeled as spreading resistance.

3. As the input resistance increases, the level of passband increases which helps in improving the gain of the BCC channel.

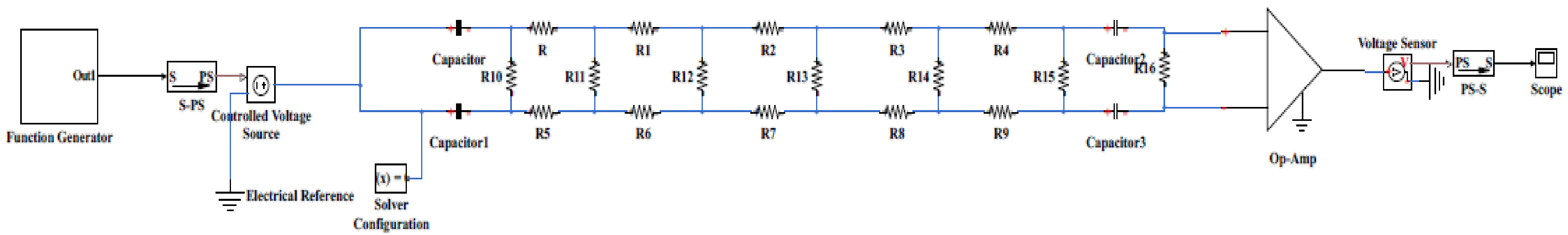


Fig. 10. Body modeled as a spreading resistance. The transmitter and receiver are capacitively coupled to the body.

Experimental results

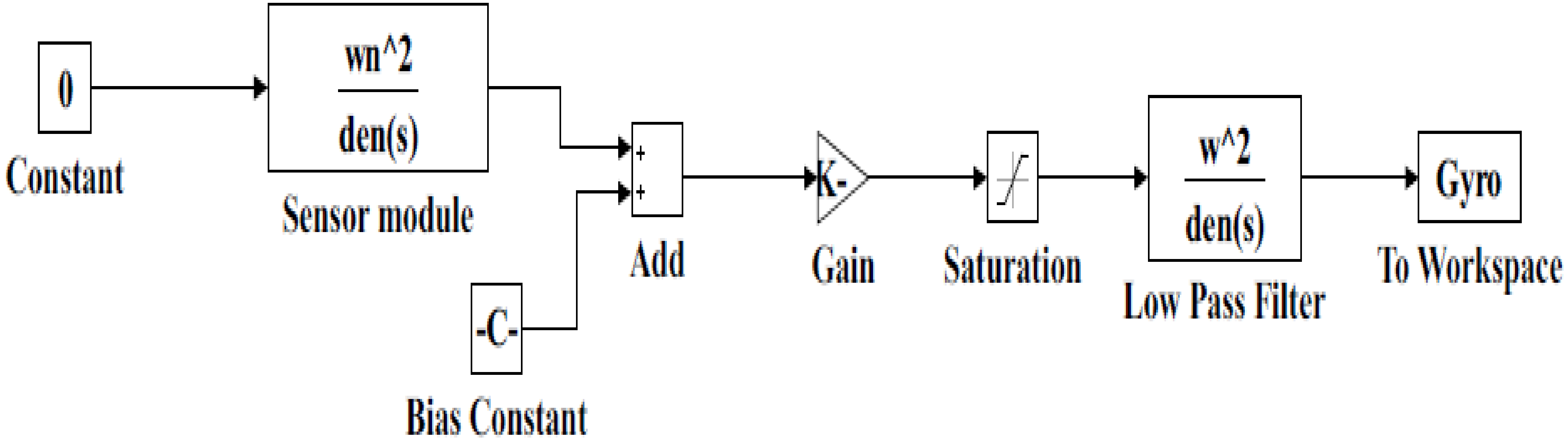


Fig. 9. Gyroscope Block Diagram in Simulink®.

Experimental results

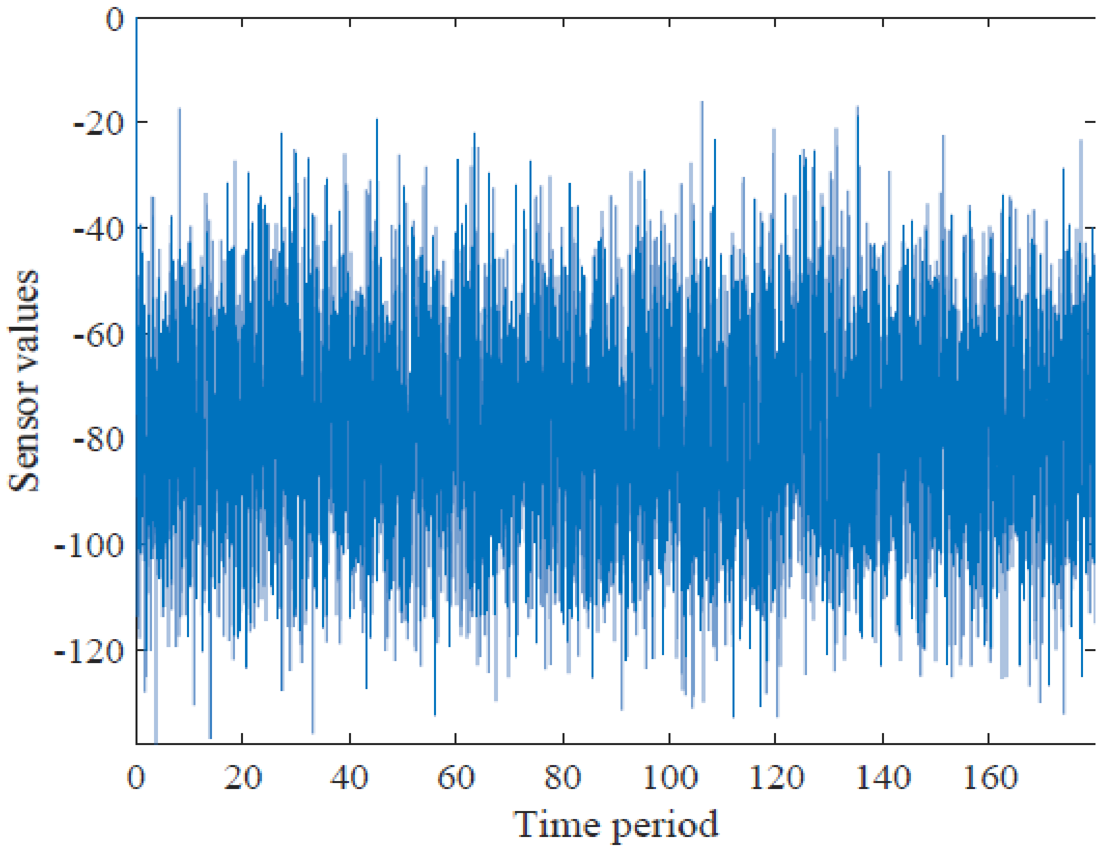


Fig. 11. Output of Gyroscope sensor module with white noise.

White noise is added to the sensor values as it becomes easier to transmit.

Experimental results

A 64 Walsh code is shown in Figure 13 which can be used for human body communication.

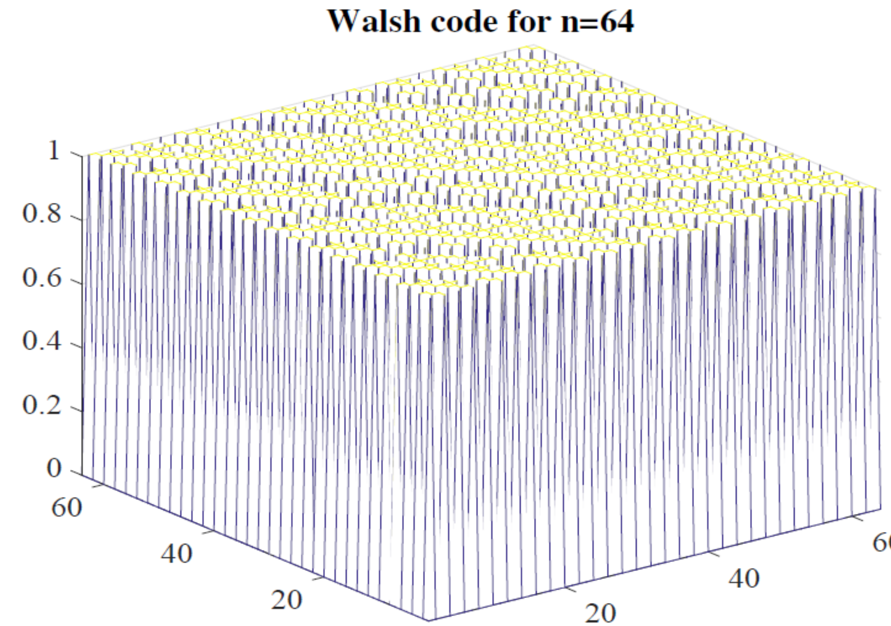


Fig. 13. A mesh of Walsh code for n=64, i.e. $M_{64\times 64}$ of all 1s and 0s.

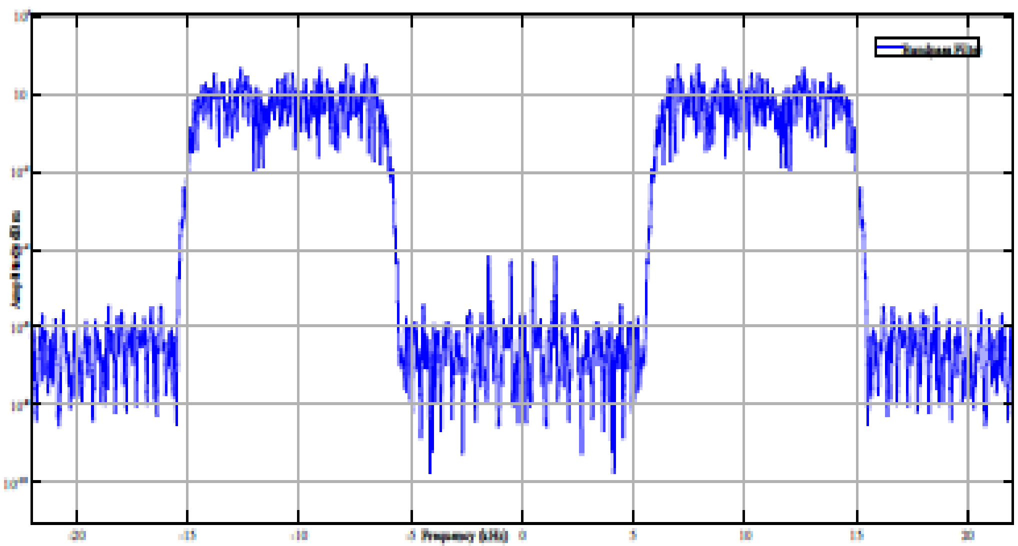


Fig. 12. Frequency spectrum after BPF in HBC implementation.

The bandpass filter is used to remove the noise components and to pass the main energy of the signal as shown in Figure 12.

Experimental results

- The performance of HBC in FSBT implementation is evaluated based on Average Signal to Noise Ratio and Bit error rate.

- Figure 15 shows the BCC channel gain for capacitively coupled human arm model for input resistance 50 Ohms and 250 Ohms.

- It can be observed that as input resistance increases, the gain increased but the slope gradually decreased, indicating a variation in corner frequency.

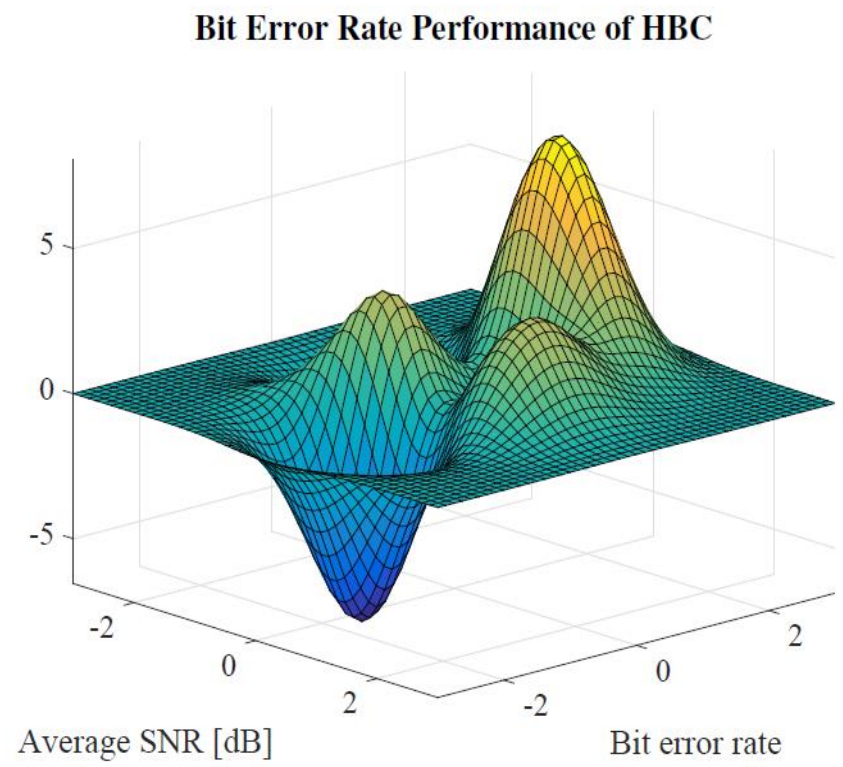


Fig. 14. Performance of HBC with FSBT.

Experimental results

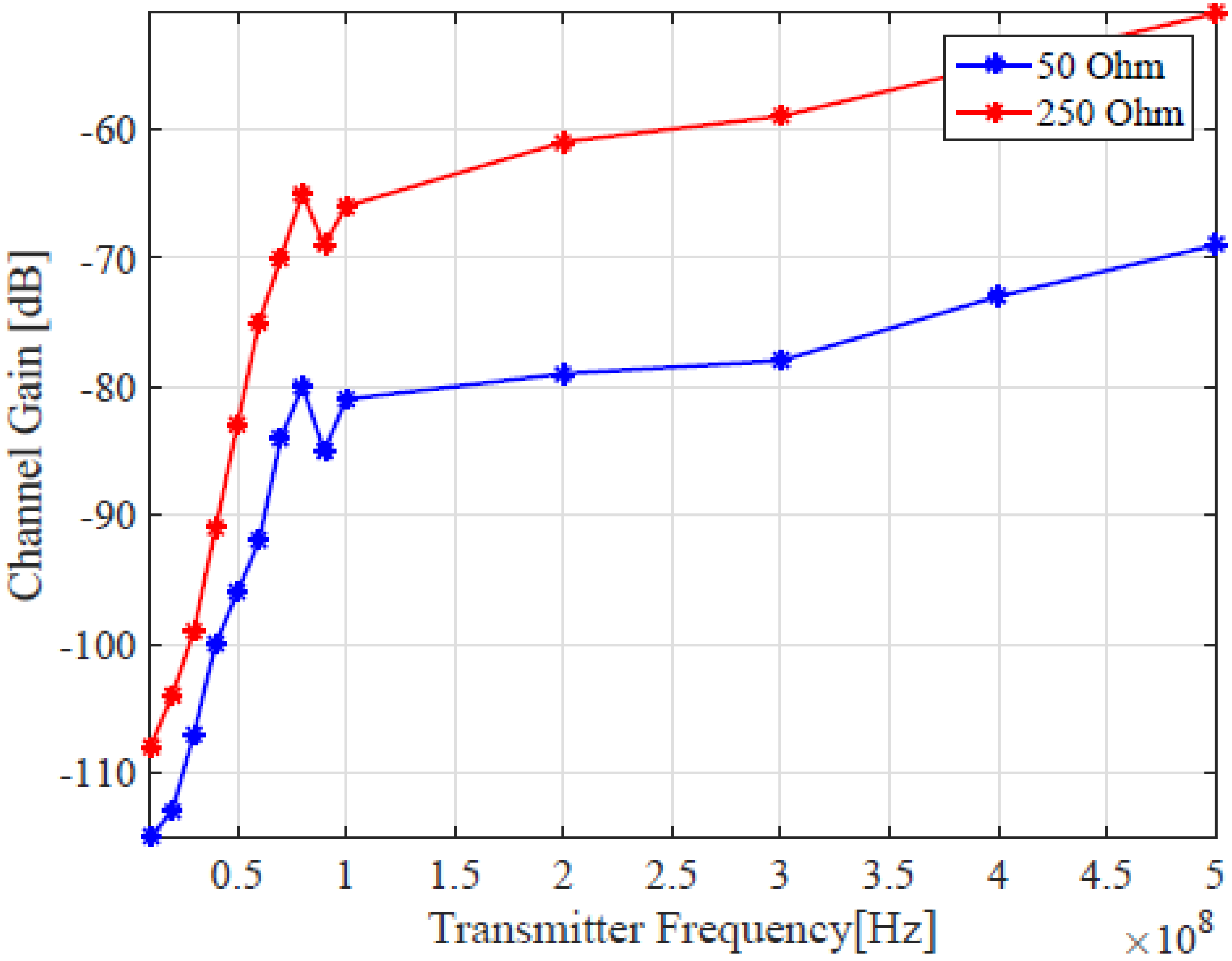


Fig. 15. Frequency response for BCC Channel.

Experimental results

Characteristics	Methods/ values
Frequency Band	Frequency Selective Baseband
Spreading	Frequency Selective Walsh Modulation
Communication Environment	Intra Body Communication
MIMO Encoder	Orthogonal Space Time Block Code
MIMO Channel	Rayleigh distribution
MIMO Combiner	Orthogonal Space Time Block Code
Walsh Code Size	64
BCC Coupling method	Capacitively coupled
Frequency range of operation	1 – 100 MHz
Power consumption	3.14 mW

Table 1. Characterization Table

Conclusions and Future work

- An Ambulatory health monitoring system using FSBT and BCC is proposed. The proposed system is prototyped in Simulink®.

- Human body communication helps in reducing the system complexity and power consumption as additional RF components are not used.

- A Multiple Input Multiple Output System was used in order to employ the design in IoT applications.

Conclusions and Future work

- It was observed that in independent applications such as touch-based intuitive service, FSBT plays an important role whereas for inter sensor communication, BCC helps in reducing power budget.

- Future research involves developing smaller prototypes of the HBC such that it can be used for integrating real time sensors to Simulink®.

- Further exploring more communication methods to reduce power consumption in BAN is also part of future work.

THANK YOU