Popular Science Summary

Advancement in technology has made the fabrication of miniature electronic chips possible that consumes less power and can be used for wireless connectivity. This has resulted in many small and compact wireless devices that are either implantable or wearable. Hearing aids and the more recently developed Google Glass are examples of wearable devices and the pacemaker is an example of an implantable device. As these examples suggest, the user of these devices are patients as well as healthy persons. A doctor may place wireless devices like a temperature sensor, a heart-rate monitor or a blood-pressure monitor on a patient to monitor his or her vital parameters. These devices collect the health parameters and may send them to a central control unit also located on the body. The central control unit may then send these data to the doctor's computer using Wi-Fi or Bluetooth. Such network of the communicating wireless devices that are implantable, wearable or in a close proximity of a body is called wireless body area network (WBAN). Athletes and sportsmen can also use the WBAN for monitoring their health parameters. The WBAN have the possibility to make the users' life comfortable by giving them freedom from wires and increasing their mobility.

As these devices are small, the space for the antenna is limited. An antenna is the part of the wireless device that receives and transmits a wireless signal. The wireless communication between the devices in the WBAN takes place either through the body as in the implants or over the body as for the wearable devices. This is different from the communication between two mobile phones where the communication channel is mostly through the air. When the communication channel is through the body or over the body, the signal loss is much higher than through the air. The reason for this is that the tissues of the human body absorb and attenuate the signal radiated by the antennas. A reliable wireless link between the devices in the WBAN can be achieved by the knowledge of the signal loss in the communication channel, and the use of a proper antenna. Usually it is not possible to test the devices on an actual human due to ethical and safety issues. Hence, to calculate the signal loss or test the antenna, a phantom is used. A phantom could be a computer model of actual human or a physical phantom mimicking the tissues. This thesis present the research work done for antennas and the communication channel for various applications in the wireless body area network. Phantoms have been used for the investigation. The investigated applications are: (1) Binaural Hearing Aids (2) Sensors placed around the body (3) Wireless Capsule Endoscopy (4) In-Mouth Device. These are explained below.

(1) Binaural Hearing Aids: Binaural hearing aids are a system where there is a hearing aid in both of the ears. Such system helps a user in identifying the direction of sound. The binaural hearing aids communicate wirelessly with each other for functions like adjusting the volume or changing the program for the listening environment. In this research, small antennas suitable in size and performance were designed for the hearing aids. Further, a mathematical model of the signal loss for the wireless signal from the hearing aid in one ear to the hearing aid in the other ear was developed. The model can calculate the signal loss for different head sizes. The main advantage of the model is that it is faster in calculating the loss when compared to calculating it by using computer simulations.

(2) Sensors placed around the body: A mathematical model for the signal loss between the sensors/devices placed around the torso was developed. The influence of the arms on the signal loss was also included in the model. It was found that there is a temporal variation in the signal level received by the devices placed around the torso when the arms swing while walking. Using this fact, we developed an approach to analyze the arm movements while walking using three wearable wireless devices. The variation in the received signal power was found symmetric for the receivers, one placed on the left side and the other on the right side of the torso for the normal swinging of the arms. The transmitter was placed at the central back position. An asymmetric power variation was found when the left arm and the right arm moved differently while walking. A high degree of asymmetric arm movements is an early sign of Parkinson's disease. Hence, the developed approach could be useful for such an analysis.

(3) Wireless Capsule Endoscopy: Endoscopy is a medical diagnosis method where the interior of the gastro-intestinal tract is inspected. In conventional endoscopy, a tube with a lens is inserted through the mouth or the rectum to observe the interior of the tract. However, it is uncomfortable and do not reach the entire small intestine. These problems of the conventional endoscopy can be overcome by using wireless capsule endoscopy. A wireless capsule endoscope is a swallow-able pill like device with a camera and a transmitter. The camera captures the picture as it passes through the gastro-intestinal tract. The transmitter sends the picture to the sensors located on the body. However, one of the major challenges associated with the wireless capsule is that the location of the capsule cannot be identified by viewing the picture alone. The knowledge of the location is important so that if some abnormality is observed, an operation can be performed at the correct location. In this research work, algorithms were developed to find the location of the capsule.

(4) In-Mouth Device: Spinal cord or brain injury may result in movement disabilities. It can result in paraplegia where lower portions of the body are paralyzed. It may also results in more severe situation called quadriplegia where both torso and limbs are paralyzed. Such patients may have to depend upon someone else for moving their wheelchair or using a computer. Fortunately, the muscles above their neck like tongue are often healthy. The in-mouth device is a wireless device placed in the mouth of such patients. The device is controlled by the movement of the tongue. The signal transmitted by the device can then control the movements of the wheelchair having a receiver. In this research work, antennas suitable in performance and size for such devices were developed.

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