Electronic Design

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What is Incident Power Density?

When measuring the amount of electromagnetic energy incident on a surface, engineers refer to the "incident power density" metric.

Incident power density (IPD) is a metric that's used to assess the exposure of humans to electromagnetic fields (EMFs) in the frequency range from 6 to 300 GHz.

IPD is typically spatially averaged over an averaging area. Two quantities can be used to define spatially averaged IPD:

1. Using the normal component of IPD vectors crossing the surface.
2. The magnitude of IPD vectors (norm) averaged over an area independent of the orientation.

The Hertzian Dipole

IPD is often determined from the radiation of the Hertzian dipole in the frequency range of 5G mobile communication systems.[1,3]

The IPD is used to derive a new metric called "absorbed/epithelial power density" based on thermal modeling. It defines the permissible incident power density for frequencies between 6 and 300 GHz.1 It's also used in the compliance assessment of wireless products operating in millimeter-wave frequencies.[1]

EMF Exposure

With 5G devices, the dosage level of ionizing radiation from EMF exposure[2] is the IPD above 6 GHz in place of the specific absorption rate (SAR) below 6 GHz. However, when being exposed to radiation from sub-6-GHz antennas, along with above-6-GHz antennas simultaneously, the total exposure ratio (TER) may be used to evaluate EMF exposure.

Skin and Surface Temperature Elevation Due to IPD

Because of the transition from the SAR to IPD, TER may not have a good correlation with temperature increase (ΔT) in human tissue.[5,6,7] To avoid this alignment difficulty, an approximate expression of TER is proposed based on the Gaussian distribution approximation of the SAR and IPD on the skin surface. which is caused by acceptable procedure in dipoles. In addition, to keep a good correlation between TER and ΔT, the temperature-based TER (TBTER) should be used.

5G devices will typically work in both sub- and above-6-GHz ranges, and the simultaneous exposure to the EMF in these two frequency ranges must be considered. TER is defined as:

$$\mathrm{TER}(x,y) = \mathrm{ER}_{\mathrm{SAR}}(x,y) + \mathrm{ER}_{\mathrm{IPD}}(x,y) = \frac{\mathrm{SAR}(x,y)}{\mathrm{SAR}_L} + \frac{\mathrm{IPD}(x,y)}{\mathrm{IPD}_L}$$

In the above equation, x and y are the coordinates, $\mathrm{ER}_{\mathrm{SAR}}$ and $\mathrm{ER}_{\mathrm{IPD}}$ are defined as exposure ratios (ERs) of SAR and IPD, respectively, and SAR_L and IPD_L are the limits of SAR and IPD, respectively.

The Federal Communications Commission (FCC) identifies SAR as 1.6 W/kg averaged over 1g of tissue, and IPD_L is 10 W/m^2 for the spatial peak value, which has recently been proposed to be averaged over 1 cm^2.

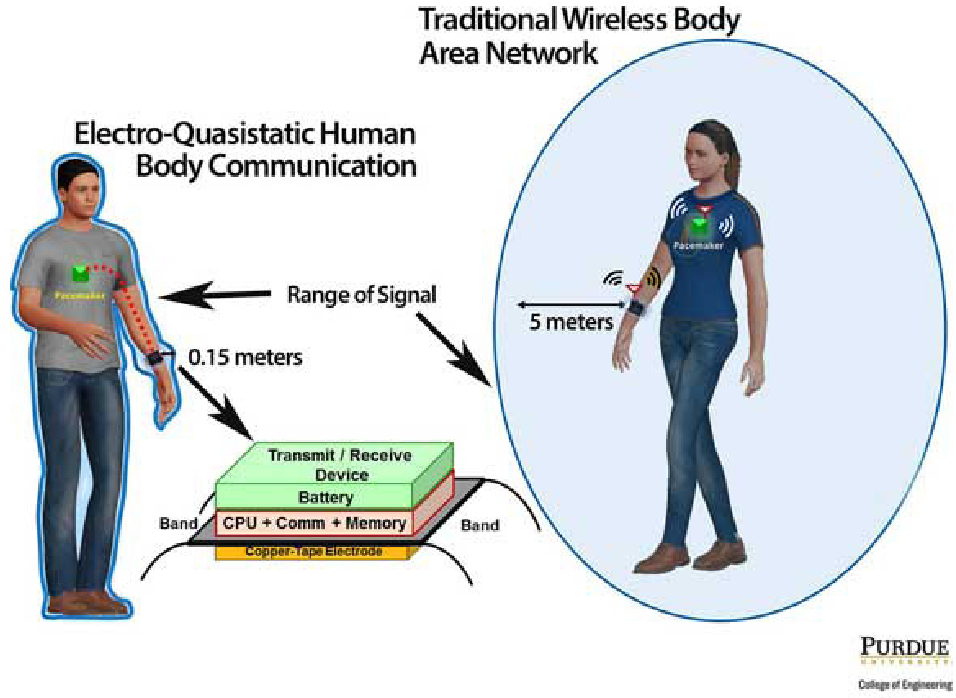
EMF Exposure with 6- and 10-GHz User-Equipment Antennas

Just about every person has some sort of user-equipment (UE) device for 5G in today's world.[8] 5G has two frequency ranges: FR1 (sub-7-GHz) and FR2 (from 24.25 to 71.0 GHz). The spectrum around 10 GHz is now being looked at as potential bands for future cellular networks.

Antenna radiation and the human body

UE antenna transmit/receive signals become deteriorated when passing through the lossy tissue within the human body. The antenna input impedance will change in this scenario and affect the matching and operating bandwidth. A fraction of the radiated power is absorbed into the human tissue, reducing the antenna radiation efficiency. In addition, the radiation pattern will become distorted because of the human body blocking the signals.

Electromagnetic (EM) radiation, such as radio waves, may induce a current in conducting bodies. Such induced



The device shown keeps communication signals within the human body. This method is used so that no one can hack into medical equipment like pacemakers. (Purdue University image/ Debayan Das)

current will in turn generate an EMF, or even may cause EM waves to be emitted. When a human hand is close to a radio, emitted EM waves from that hand will interfere with the RF waves received by the radio antenna.

EM waves can be scattered. When placing a hand near a radio antenna, RF waves will scatter off the hand, causing interference patterns that can be constructive or destructive.

Internet of Body Coupling

A differentiating feature for Internet of Body (IoB) devices, as compared to Internet of Things (IoT) devices, is that IoB devices share a common medium—the body itself.[9,10]

Electro-quasistatic Human Body Communication (EQS-HBC) has been demonstrated, using the human body's conductive properties to communicate without radiating the signals outside of the body. Unlike traditional wireless body area network (WBAN) devices, frequencies used in EQS-HBC are below 1 MHz, such that the corresponding wavelength is large with respect to the human body, making the communication EQS in nature *(see figure)*.

Some previous experiments demonstrated that an attack, with an antenna, wasn't successful when at a distance further than 1 cm from the human body surface while 15 cm from an EQS-HBC device.

No Need for Smartphones in the Future?

Shreyas Sen, a Purdue University engineer, is involved in developing leading-edge solutions for the post-smartphone era. In this future idea, people will be able to participate with technology, instead of just co-existing with wireless devices like smartphones that are now encased behind screens.[11,12]

"We're connecting more and more devices to the human body network, from smart watches and fitness trackers to head-mounted virtual-reality displays," said Sen.

Right now, the challenge hasn't solely been keeping this kind of communication inside the body so that no one can intercept it, but also enabling higher bandwidth along with less battery consumption.

Bodily fluids can carry electrical signals quite well. In today's technology, so-called "body area networks" have employed Bluetooth technology to send signals on or around the body. These electromagnetic waves can be detected within at least a 10-meter radius of a person.

Sen's team demonstrated a means for human body communication that can happen more securely while not going beyond a centimeter away from human skin, while using 100X less energy than traditional Bluetooth communication. This was made possible via a device that's able to couple signals in the EQS range, operating much lower on the electromagnetic spectrum. Sen's group works with industry and government to incorporate this device into a dust-sized IC.

Doctors, using such a device, may be able to reprogram medical devices without having invasive surgery. Closed-loop bioelectronic medicine could use wearable or even implantable medical devices that would function like a drug without any side effects.

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