Recent Developments in mm-Wave Technology and Applications

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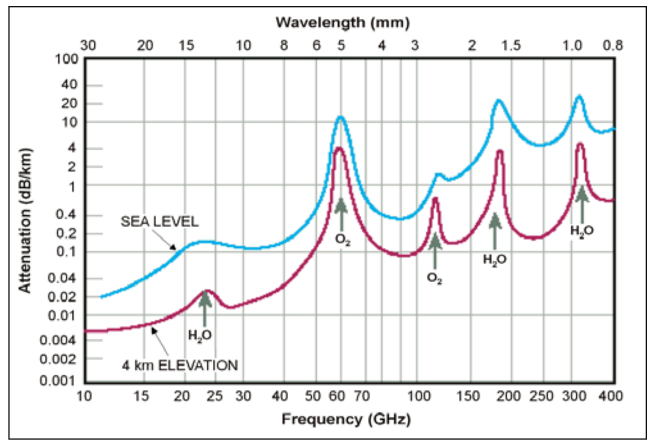
New wireless applications are being developed at the high end of the microwave region, where mm-wavelengths provide the means for wider bandwidths (and higher data rates) and offer new capabilities for sensors and imaging. Implementing mm-wave circuits and systems presents engineering challenges that do not exist at lower frequencies, due to both the physical dimensions defined by the wavelength, and device properties that are at the boundary of electronic and photonic behaviors.

In this report, we have collected news reports and other notes about mm-wave technology and its uses. The diversity of work illustrates the potential of mm-waves for present and future applications.



mm-wave atmospheric propagation characteristics include several molecular absorption frequencies.

60 GHz Development Work at IBM

The 60-GHz research group at IBM describes many potential applications for a band that offers ample license-free bandwidth. In the US, the range from 57 to 64 GHz is available, while in Japan, 59 to 66 GHz is available. With 7 GHz of bandwidth, there are many high data rate applications one can envision.

Wireless Personal Area Networks—60 GHz is ideally suited for high data rate personal area network (PAN) applications. A 60-GHz link could be used to replace various cables used in the office or home, including gigabit Ethernet (1000 Mbps), USB 2.0 (480 Mb/s), or IEEE 1394 (~800 Mb/s). Currently, the data rates of these connections have precluded wireless links, since they require so much bandwidth. The intended range of wireless PANs is ten meters or less, which covers the size of most offices, medium-size conference rooms, and rooms in the home. Wireless PANs could provide data transfer between various electronic devices, including laptops, cameras, PDAs, and monitors. Applications include wireless displays, wireless docking stations, and wireless streaming of data from one device to the other.

Wireless HDMI—The High-Definition Multimedia Interface (HDMI) appears be the preferred interface for high-definition TVs. This cable provides both video and audio information. Depending on the resolution of the display, the data rates required for an uncompressed HDMI signal can be substantial. The key advantage of 60-GHz is the ability to provide wireless, secure, and uncompressed high-definition video distribution.

Wireless interconnection allows the display to be located away from the information or programming source, which could change the way tuners, cable boxes, recording devices and displays are designed and used. A wireless monitor could be mounted like a picture frame on a wall, across the room from the off-air or satellite receiver, disk player, or other program sources.

Security is provided at 60-GHz due to the atmospheric and material properties at this frequency. Over long ranges, there is significant signal loss due to oxygen absorption. There is also significant attenuation through walls. These two facts prevent the HDTV signal from leaking into adjacent rooms and residences.

Point-to-Point Communication Links—Point-to-point links are used today for telecommunications backhaul from many cell sites to network switching centers. They employ high-gain antennas to increase the range of the link, and the electronic components are mainly implemented in III-V technologies. Silicon circuits, such as those being developed at IBM, promise to reduce the cost of system hardware, though the bulk of the system cost will still be installation on towers.

One drawback of 60-GHz for point-to-point communications is the oxygen absorption (~10 dB/km at sea level), which begins to play a role at distances as little as 100 m. Additionally, rainfall, fog and foliage adds additional attenuation (another ~5 dB/km for 1/2 inch per hour rainfall). Fortunately, at these short wavelengths, high gain antennas are not physically large, which helps to overcome these atmospheric effects.

IBM is also studying licensed E-band point-to-point communications. In the US, bands have been set aside at

71-76, 81-86 GHz, and 92-95 GHz. As compared to 60 GHz, the benefits of licensed E-band are (1) the license itself, which protects a registered link from interference and (2) operation in a band free from oxygen absorption. Other areas of work include vehicular radar in the 76-77 GHz band, and future applications in the 94-GHz band, where many materials (such as clothing) are transparent. This provides an opportunity for security applications such as airport screening, provided privacy rights are maintained.

Photonic Technologies for mm-Wave

With much of the mobile world yet to migrate to 3G mobile communications, let alone 4G, European researchers are already working on a new technology able to deliver data wirelessly up to 12.5Gb/s. The technology—known as mm-wave or microwave photonics—has commercial applications not just in telecommunications but also in instrumentation, radar, security, radio astronomy and other fields. Despite the leap in performance made possible by combining the radio and optics technologies to produce mm-wave components, it will probably only be a few years before there are real benefits for the average citizen. The research and development work is being done by the EU-funded project IPHOBAC (www.ist-iphobac.org), which brings together partners from both academia and industry with the aim of developing a new class of components and systems for mm-wave applications.

IPHOBAC is not simply technology research, but is very much a practical exercise to develop and commercialize a new class of products. While several companies in Japan and the USA have been working on merging optical and radio frequency technologies, IPHOBAC is a fully integrated European effort in the field, with a lot of different companies involved.

It recently unveiled a tiny component, a transmitter able to transmit a continuous signal not only through the entire mm-wave band but beyond. Its full range is 30 to 325 GHz, with even higher frequency operation under investigation. Other components developed by the project include 110 GHz modulators, 110 GHz photodetectors, 300 GHz dual-mode lasers, 60 GHz mode-locked lasers, and 60 GHz transceivers.

The technology has been demonstrated for full wireless HDTV and access telecom networks, and has delivered data rates of up to 12.5 Gb/s over short- to medium-range wireless spans. Future applications include space-based communications systems for the European Space Agency and a number of imaging applications for medicine, research and security.

Additional information on European research efforts can be obtained from the source of this news item, ICT Results (http://cordis.europa.eu/ictresults).

Integrated Fiber/ww-wave Systems

Since propagation characteristics limit the range of mm-wave wireless links, their combination with high bandwidth fiber optic interconnections seems obvious for many data distribution applications. Wireless transmission allows flexibility in connecting individual devices, while fiber optics avoids the problems of interference and poor propagation when exchanging high rate data between rooms, buildings, or with an outside network.

According to a research report from Stanford University, this type of hybrid network could solve the problem of reduced data rate transmission as the destination becomes further removed from the Internet backbone. Presently, a ~10 Gb/s Internet connection is reduced to 1 or 2 Gb/s in local fiber and CATV distribution. When delivered from the local network to the end user, the maximum available rate is in the tens of Mb/s, and is often much less. Hybrid fiber/mm-wave has the potential to minimize the data rate reduction, delivering 1 Gb/s to 2.5 GB/s to individual users.

Additional Notes on mm-Wave Applications

In addition to the communications applications described above, there are many radar, scanning and imaging applications that make use of the precision that can be achieved with short wavelengths, or use the ability of various mm-wave frequencies to penetrate different distances and types of materials.

A few specific radar applications include high precision proximity location for aircraft and helicopter landing systems, runway debris detection systems and automotive collision avoidance systems. Imaging applications range from ground-penetrating radar (including explosives detection) to full-body scanning at security checkpoints. Imaging for medical diagnosis, materials research and industrial process control are other applications. The high resolution of mm-wave imaging make it possible to create holographic images, which provide much more information for analysis.

In the more speculative realm, at wavelengths of 1-10 mm, resonance occurs in objects and structures in the same size range as many biological structures: cells and single-cell organisms, membranes, and proteins such as amino acids. There is significant research into thermal effects, both for safety and for therapeutic applications, but there is also speculation—and some early research—into biological manipulation applications, where mm-wave energy would either trigger or suppress biological activities.

One basis for this work is the possibility that these biological structures are especially sensitive to low levels of mm-wave radiation, due to the combination of resonances in the structures' physical size and their lack of exposure to natural radiation because of oxygen absorption. There are similar conjectures about the behavior of non-biological molecules that may allow new materials analysis techniques using frequencies in the mm-wave and THz range.

With a wide range of applications, mm-wave technology has great potential for scientific advances as well as commercial business opportunities.