Ultra-Broad-Band Communications for Electromagnetic Nanonetworks in the THz Band

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Graphene-Based Nano-Antennas (II) Several quantum phenomena determine the propagation speed of EM waves in graphene (kinetic inductance, quantum capacitance, contact resistance).

As a result, the EM wave propagation speed can be up to 100 times below that of speed of light in vacuum.

For all this, a 1 μm long antenna radiates in the Terahertz Band (0.1 – 10.0 THz).

First Resonant Frequency

Input Resistance

Ultra-Broad-Band Communications (I) The terahertz channel supports very large transmission bandwidths, up to tens of Terabits/second, for very short transmission distances, i.e., below 1 meter.

In light of the state of the art in molecular electronics, we envision a new communication technique based on the exchange of femtosecond-long pulses.

A pulse like this has its main frequency components in the terahertz band.

There already exists a few femtosecond pulse generators used for sensing and imaging in the terahertz band.

Ultra-Broad-Band Communications (II) Due to technological constraints, these very short pulses cannot be transmitted in very long bursts, but spread in time.

As a result, the individual transmission rate that a nano-device can achieve is far below the theoretical channel capacity.

However, we can use the time between pulses to interleave users, maximizing the total network capacity.

If the time between pulses is known in advance, a user can track the input pulse stream of the transmitter while ignoring the other pulses or even do multiple receptions.

At this point, it is clear that new Medium Access Control protocols, able to efficiently use the channel properties but aware of the limitations of nano-devices are required. Then efficient routing and transport protocols should follow.

Two Nanocommunication Alternatives

Nano-electromagnetic communications and molecular communications have been envisaged as feasible nanocommunication alternatives for nanonetworks.

<table>
<thead>
<tr>
<th>Features</th>
<th>Nano-Electromagnetic</th>
<th>Molecular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carrier</td>
<td>EM waves in the Terahertz Band</td>
<td>Molecules</td>
</tr>
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</tr>
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<td>Propagation speed</td>
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Terahertz Channel Capacity

Because of molecular absorption, the terahertz channel is highly frequency selective.

The channel information capacity depends on the molecular composition of the channel, the total system noise, and the power spectral density (p.s.d.) of the transmitted signal.

Ultra-Broad-Band Communications

The Optimal power allocation scheme obtained by means of the water filling principle.

Flat p.s.d between 100 GHz and 10 THz.

70 GHz wide transmission window at 300 GHz (macroscale perspective).

Femtosecond – long Gaussian pulses.

Nano-technology, Nanomaterials, Nano-electronics


Nano-technology is enabling the development of electronic components in a scale ranging from one to a few hundred nanometers, such as nano-processors, nano-memories, nano-batteries or nanosensors, amongst others.

The integration of these nano-components in a single device, just a few micrometers in size, will result in autonomous nano-devices able to perform specific tasks at the nano-level, such as computing, data storing, sensing or actuation.

Novel nanomaterials such as graphene and its derivatives, i.e., Carbon Nanotubes (CNTs) and Graphene Nanoribbons (GNRs), have been proposed as the building material of novel nano-antennas.

By accounting for the interactions between every single atom in the graphene structure, we accurately model the transmission line properties of nano-antennas.

The terahertz channel is an unlicensed frequency range (0.1 – 10.0 THz).

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In light of the state of the art in molecular electronics, we envision a new communication technique based on the exchange of femtosecond-long pulses.

A pulse like this has its main frequency components in the terahertz band.

There already exists a few femtosecond pulse generators used for sensing and imaging in the terahertz band.

This technique is more capacity-efficient than just using one of the absorption-defined transmission windows around 350 GHz.

This is what is being done for short range communications in the macroscale (see above).

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Terahertz Propagation Model


The terahertz band is an unlicensed frequency range between 100 GHz and 10 THz.

The terahertz channel is mainly determined by molecular absorption, i.e., the conversion of the wave energy into kinetic energy in several gas molecules. This determines path-loss and molecular noise.

Ultra-Broad-Band Communications

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