Global Limitation on Fast Switching by Semiconductor Devices

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One of the important problem of UWB short pulse Electromagnetic is the pulse generation. The core of a pulse generator is a fast switch, a device, which could be switched between two states "off" and "on" with low and high conductance. Difference between the conductances must be as large as possible. Many types of semiconductor devices could be used for the switching. For many of them figures of merit, which shows their limitations, are well known (for an example – time of flight limitations).

In this work global limitations, which could be applied to any kind of a switch are considered. In reality any limitation is connected with some physical process or combination of several processes and with the geometry under consideration. Switching processes consist in the filling of semiconductor volume by electron-hole plasma (turn on) and its removal (turn off). Plasma gets in and gets out by only two ways:

- injection/extraction through the borders of the volume;
- generation/recombination inside the volume.

Generation could be performed by external radiation or by impact ionization.

For mentioned above ways the next physical processes are considered, which leads to a variety of limitations. All corresponding figures of merit are estimated.

1. Space charge build up limits current density rise rate.
2. Sharply changed current and corresponding change of electromagnetic field limits the working width of the area where the current flows. For linear case this leads to well known skinning in conductors. For nonlinear case skin layer is limited by current density rise rate, which is determined above.
3. Fast heating due to transient dissipation of energy and corresponding shock wave generation in semiconductor limits current density.
4. Heating plus skinning limit current density per length of the switch perimeter.
5. During switch off and on processes EM field changes its configuration: gets inside and out the semiconductor volume, which leads to "time of EM wave flight" limitation.

For the most promising type of devices – Drift Step Recovery Devices the limits for different types of semiconductors (Si, GaAs, SiC) are evaluated. Family tree of known switching devices with relation to considered above physical processes are shown.