LATERAL PNP TRANSISTOR MODELING WITH SPICE MODELS

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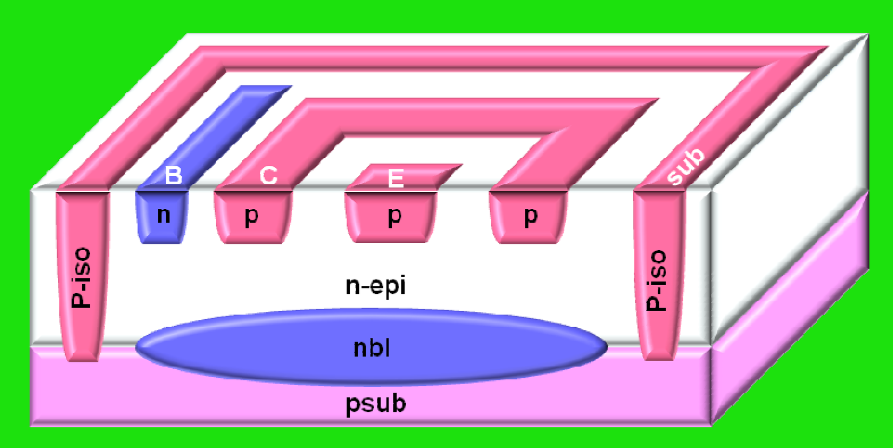
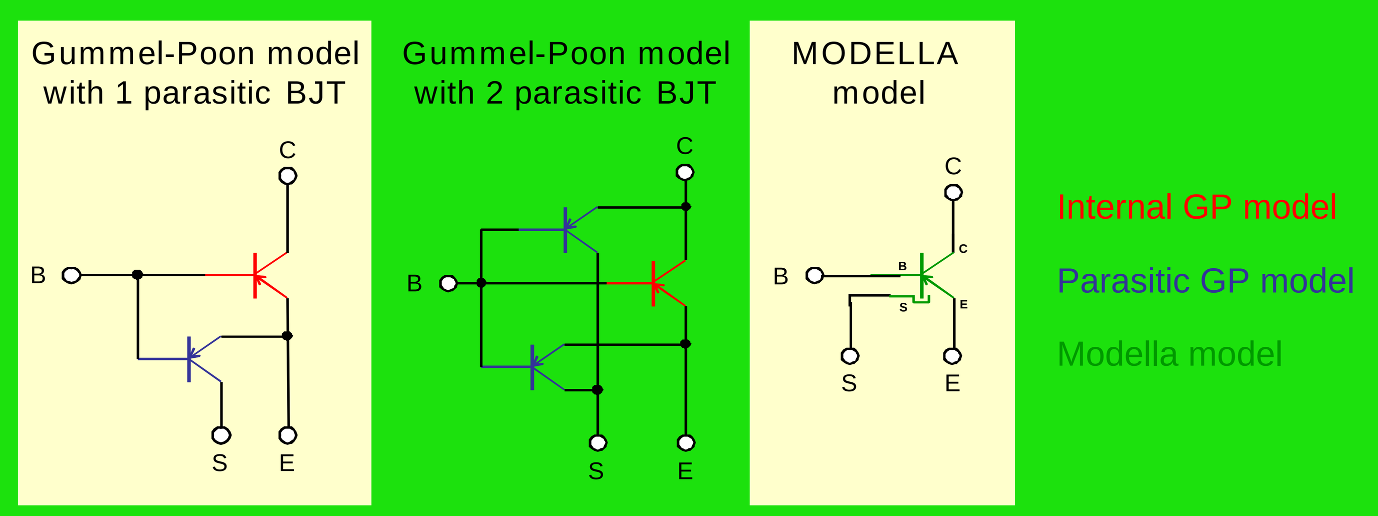
Goal of the contribution

More flexibility in integrated circuit design can be achieved, if it is possible to use both types of transistors – NPN and PNP. However, this means more semiconductor layers have to be added so that a vertical PNP structure can be created. A PNP transistor can be also created as a lateral PNP structure from the same layers as a vertical NPN transistor without addition of any layers. In this case the emitter and the collector are formed from a P type layer that is used for base in a NPN transistor.



Lateral PNP transistor modeling

Adapted models of vertical NPN transistor are still mostly used for lateral PNP transistor modeling. Behavior of laterally arranged PN junctions is different than that of a vertically arranged PN junction. Using adapted models of a vertical NPN transistor for modeling lateral PNP transistor causes inaccurate modeling. Possible models of lateral PNP transistor are shown in figure on the right. The Gummel-Poon model does not include parasitic components therefore one Gummel-Poon model is used for intrinsic component and one or two for parasitic components. The Modella model already includes parasitic transistors.

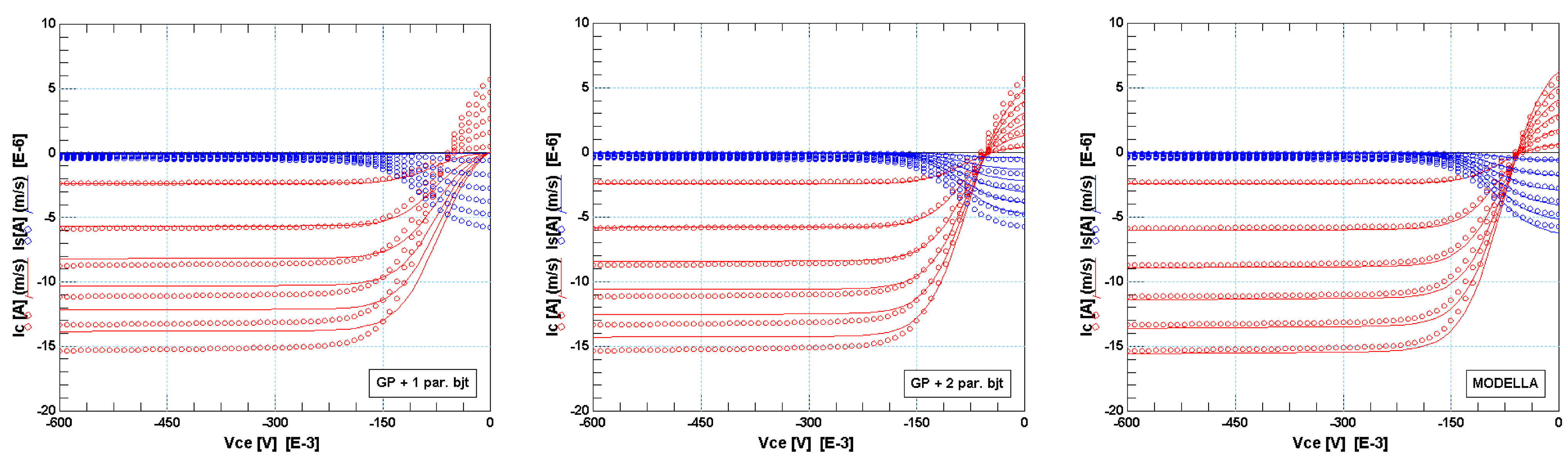


In first case one transistor is used for intrinsic transistor and one for parasitic emitter-base-substrate transistor. Parameter extraction of both transistors is relatively easy. In second case one transistor is used for intrinsic transistor, one for parasitic emitter-base-substrate transistor and one for parasitic collector-base-substrate transistor. Parameter extraction of tree transistors together is relatively complicated, mostly extraction in AC mode. Modella has big advantage against Gummel-Poon models during parameters extraction because extraction of one set of parameters is easier.

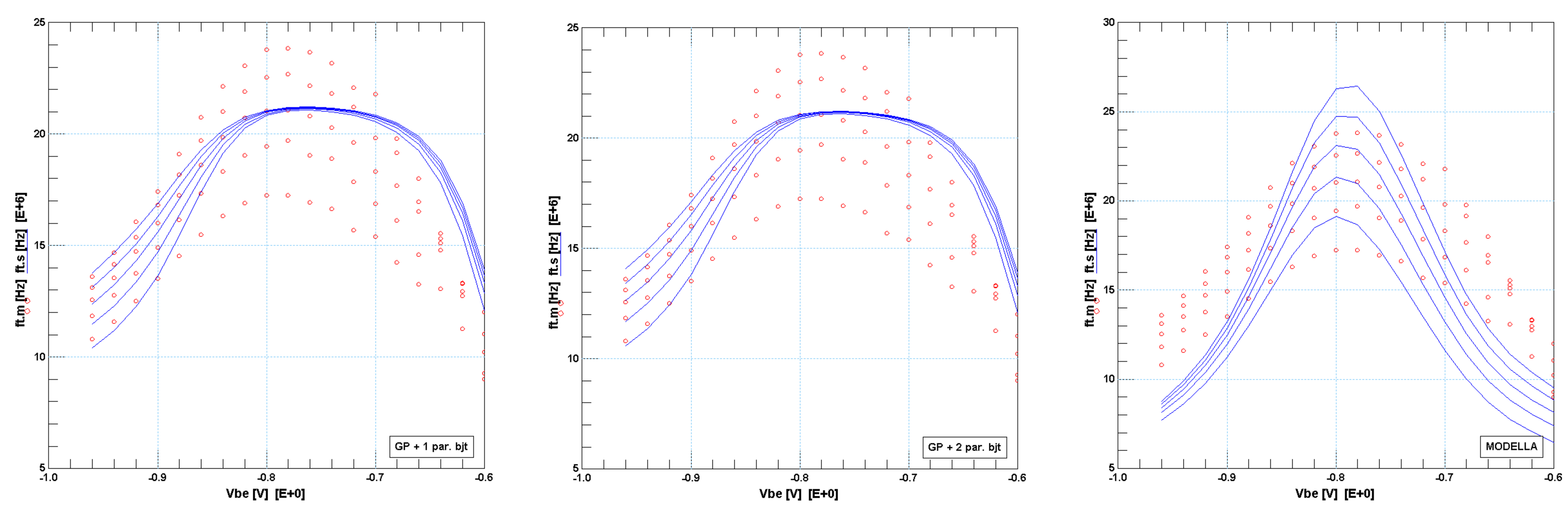
Model comparison

At first the parameters of all these models are extracted on chosen lateral PNP transistors in the BCD 0.8 µm technology. Next, differences among models are identified in DC/AC modes. A special attention is paid to the saturation region and models capabilities to describe scattering parameters (S parameters). Simultaneously, measured data are compared with simulated data for each model.

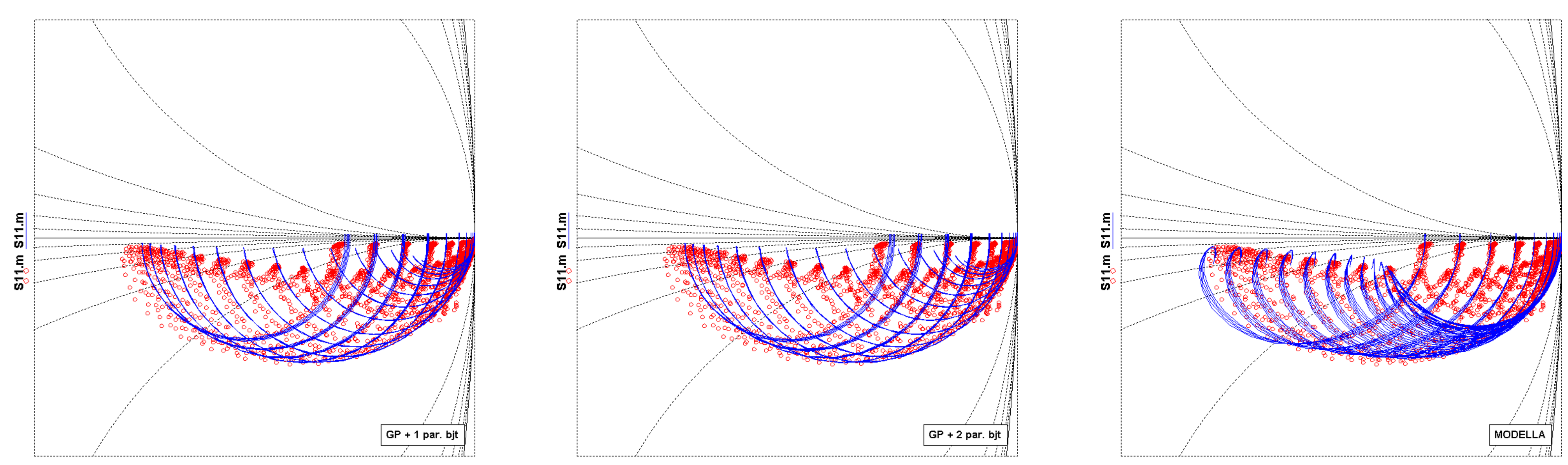
The Gummel-Poon model, whether with one or two parasitic transistors, does not model quasi-saturation region. Modella contains at least partial distribution of collector resistors therefore it is possible to better optimize saturation and quasi-saturation region by tuning of these resistors. Thanks to distribution of emitter, collector and base resistors Modella is more accurate. Modella also very accurately models substrate current in saturation region. Gummel-Poon model with one parasitic transistor is not able to do this. Only model with two parasitic transistors is able to model saturation.



Output characteristics in saturation region



Forward transit frequency



S11 in Smith chart

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