In this paper, we have investigated the electron transport and frequency response of the state-of-the-art single-InAs nanowire (NW) FETs using a full-band Monte Carlo simulator. InAs transistors using a single NW as the channel reveal excellent properties such as high current densities, high transconductance, and superior mobility when compared with silicon devices. One aspect that has been neglected until now is the high-frequency (HF) response of such devices. We perform a detailed HF analysis, calibrating our simulations with the experimental measurements that are successfully reproduced. We are able to make predictions about the electron distribution inside the NW transistor, and via a small signal analysis, we determine the intrinsic cutoff frequency and maximum frequency of oscillation. We compare these with the extrinsic measured figures of merit and observe a large discrepancy, which we are able to attribute to the parasitic elements. We finally perform a large signal analysis and investigate the nonlinearity of the device and the power transfer to the harmonics.