An empirical model for field-effect transistor (FET) based power detectors is presented. The electrical model constitutes a Volterra analysis based on a Taylor series expansion of the drain current together with a linear embedding small-signal circuit. It is fully extracted from S-parameters and IV curves. The final result are closed-form expressions for the frequency dependence of the noise equivalent power (NEP) in terms of the FET intrinsic capacitances and parasitic resistances. Excellent model agreement to measured NEP of coplanar access graphene FETs with varying channel dimensions up to 67 GHz is obtained. The influence of gate length on responsivity and NEP is theoretically and experimentally studied.