A novel hybrid large-signal model of GaAs pseudomorphic HEMTs (pHEMTs) is proposed for monolithic microwave integrated circuit design. This new model is based upon accurate electromagnetic (EM) description and creative multi-path artificial neural network (ANN) optimization. To precisely describe the EM effect in the high-frequency range, the extrinsic part of this model includes both lumped and distributed components. In order to re-grid the discrete data, the bias-dependent intrinsic elements are determined by ANNs rather than traditional interpolations. The dispersion effect is represented by nonlinear sources with the multi-path-dependent integration technique, which is described by processed multi-bias S-parameters. This proposed approach can be applicable to different bias conditions, which is also verified by different types of GaAs pHEMTs with good agreement. In addition, a class-AB Ka-band power amplifier and a Ka-band switch using a 0.15-μm GaAs pHEMT process were designed based on the novel hybrid model for further practical verification.