This paper presents a novel Block Iterative Bayesian Algorithm (Block-IBA) for reconstructing block-sparse signals with unknown block structures. Unlike the existing algorithms for block sparse signal recovery which assume the clustered nonzero elements of the unknown signal to be independent and identically distributed (i.i.d.), we use a more adequate Bernoulli-Gaussian hidden Markov model (BGHMM) to characterize the non-i.i.d. block-sparse signals commonly encountered in practice. The Block-IBA iteratively estimates the amplitudes and positions of the block-sparse signal using the steepest-ascent based Expectation-Maximization, and effectively selects the nonzero elements of the block-sparse signal by a diminishing threshold. The global convergence of Block-IBA is analyzed and proved based on the non-i.i.d. property of BGHMM and error vector method. The effectiveness of Block-IBA is demonstrated by simulations on synthetic and real-life data.