Compressive sampling (CS) is an emerging research area for the acquisition of sparse signals at a rate lower than the Shannon sampling rate. Recently, CS has been extended to the challenging problem of multidimensional data acquisition. In this context, block-sparse core tensors have been introduced as the natural multidimensional extension of block-sparse vectors. The (M1,..., MQ) block sparsity for a tensor assumes that Q support sets, characterized by Mq indices corresponding to the nonzero entries, fully describe the sparsity pattern of the considered tensor. In the context of CS with Gaussian measurement matrices, the Cramer-Rao bound (CRB) on the estimation accuracy of a Bernoulli-distributed block-sparse core tensor is derived. This prior assumes that each entry of the core tensor has a given probability to be nonzero, leading to random supports of truncated Binomial-distributed cardinalities. Based on the limit form of the Poisson distribution, an approximated CRB expression is given for large dictionaries and a highly block-sparse core tensor. Using the property that the mode unfolding matrices of a block-sparse tensor follow the multiple-measurement vectors (MMV) model with a joint sparsity pattern, a fast and accurate estimation scheme, called Beamformed mOde based Sparse Estimator (BOSE), is proposed in the second part of this paper. The main contribution of the BOSE is to "map" the MMV model onto the single MV model, thanks to beamforming techniques. Finally, the proposed performance bounds and the BOSE are applied in the context of CS to 1) nonbandlimited multidimensional signals with separable sampling kernels and 2) for multipath channels in a multiple-input multiple-output wireless communication scheme.