1. INTRODUCTION

Interest in low bit rate image compression is being stimulated by a variety of application areas in which acquisition, transmission, and storage demands are on the rise. Subband image coding is, unquestionably, one of the most popular methods for compression at this point in time, and much remains to be explored in the development of systems based on this approach. Given a certain level of reconstruction quality, the open-ended problem is to reduce the number of bits necessary for the representation. Subband image coding fairs well in this regard. But there are other aspects of the coding problem that are often important as well, such as speed, cost, control of the bit rate, robust performance over noisy channels, and progressive transmission capability.

It is difficult for a single system to achieve high marks in all of these categories, but good tradeoffs are certainly possible. In subband image coding, the quality and complexity of the analysis/synthesis filter banks can have significant impact on the system performance, its cost, and its flexibility. In addition, and perhaps even more important, is the method used to quantize and code the subband images. Schemes based on scalar quantization tend to offer simplicity and flexibility. Schemes based on vector quantization tend to yield higher performance, but require codebook storage, a higher level of computational complexity, and often impose rigidity in terms of bit rate control.

The subband image coding system discussed in this paper employs a computationally efficient analysis/synthesis system (in fact, the most efficient one known to the authors) in conjunction with vector quantization. The distinguishing features of this particular approach are that computational complexity is relatively small for a system of this class, the memory required for codebook storage is but a fraction of that required for conventional VQ, the use of larger (and more efficient) vector sizes is possible, control of the bit rate is flexible, and progressive transmission capability is built into the system. Moreover, the performance of the system is very high and competitive with the best reported methods in the literature.

This subband coder owes its performance and flexibility to recent advances in residual vector quantization (RVQ). In the next section, RVQ is discussed as a basis for coding subbands. In the following section, subband decomposition and bit allocation issues are discussed. These sections essentially define the system and the various permutations that are possible. The paper concludes with experimental results showing the quality achievable at low bit rates.

2. RESIDUAL VECTOR QUANTIZATION (RVQ)

Residual Vector Quantization (RVQ), which is also called multistage vector quantization in the literature, consists of a cascade of VQ stages, each operating on the "residual" of the previous stage. Typically an RVQ will have many stages, which can be indexed $i = 1, 2, \ldots, P$. Each stage codebook contains $N_i$ code vectors. Thus, the total number of vectors in the RVQ is $\sum_{i=1}^{P} N_i$; however, the number of direct sum code vectors uniquely