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**Ma et al.**

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(54) **SCATTERED PILOT PATTERN AND CHANNEL ESTIMATION METHOD FOR MIMO-OFDM SYSTEMS**

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(51) **Int. Cl.**

**H04J 11/00** (2006.01)  
**H04Q 7/00** (2006.01)  
**H04B 7/216** (2006.01)  
**H04B 7/02** (2006.01)  
**H04L 27/00** (2006.01)

(52) **U.S. Cl.** ..... **370/208**; 370/328; 370/335; 370/342; 370/441; 375/299; 375/316; 455/101

(58) **Field of Classification Search** ..... 370/208, 370/203, 334, 435, 437, 465, 491, 500  
See application file for complete search history.

(56) **References Cited**

**U.S. PATENT DOCUMENTS**

5,867,478 A \* 2/1999 Baum et al. .... 370/203  
6,298,035 B1 \* 10/2001 Heiskala ..... 370/206  
6,359,938 B1 \* 3/2002 Keevill et al. .... 375/316

6,473,393 B1 \* 10/2002 Ariyavisitakul et al. .... 370/203  
6,654,429 B1 \* 11/2003 Li ..... 375/316  
2002/0003774 A1 \* 1/2002 Wang et al. .... 370/208  
2002/0034213 A1 \* 3/2002 Wang et al. .... 375/132  
2002/0080887 A1 \* 6/2002 Jeong et al. .... 375/295  
2002/0122383 A1 \* 9/2002 Wu et al. .... 370/210  
2002/0144294 A1 \* 10/2002 Rabinowitz et al. .... 725/139  
2002/0181390 A1 \* 12/2002 Mody et al. .... 370/208  
2003/0016621 A1 \* 1/2003 Li ..... 370/203

**OTHER PUBLICATIONS**

Fernández-Getino Garcia, M<sup>a</sup> Julia et al; Efficient Pilot Patterns for Channel Estimation in OFDM Systems Over HF Channels; pp. 2193-2197.

Jones, V.K.; Raleigh, Gregory G.; Channel Estimation for Wireless OFDM Systems; pp. 980-985.

\* cited by examiner

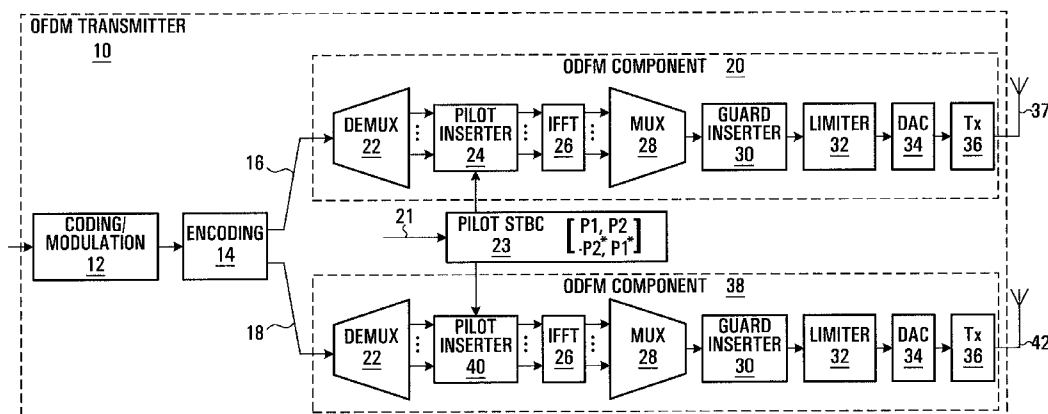
*Primary Examiner*—Chi Pham

*Assistant Examiner*—Melanie Jagannathan

(57) **ABSTRACT**

A method and apparatus are provided for reducing the number of pilot symbols within a MIMO-OFDM communication system, and for improving channel estimation within such a system. For each transmitting antenna in an OFDM transmitter, pilot symbols are encoded so as to be unique to the transmitting antenna. The encoded pilot symbols are then inserted into an OFDM frame to form a diamond lattice, the diamond lattices for the different transmitting antennae using the same frequencies but being offset from each other by a single symbol in the time domain. At the OFDM receiver, a channel response is estimated for a symbol central to each diamond of the diamond lattice using a two-dimensional interpolation. The estimated channel responses are smoothed in the frequency domain. The channel responses of remaining symbols are then estimated by interpolation in the frequency domain.

**44 Claims, 7 Drawing Sheets**



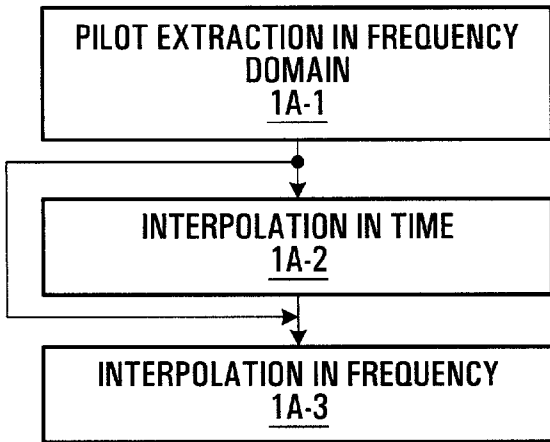


FIG. 1A  
(PRIOR ART)

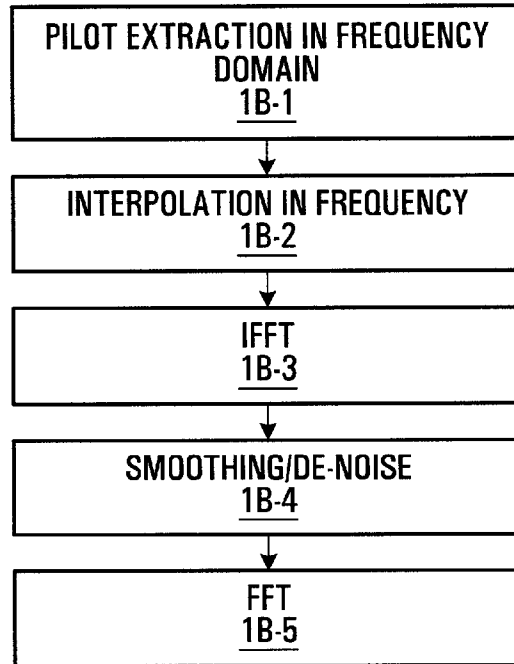


FIG. 1B  
(PRIOR ART)

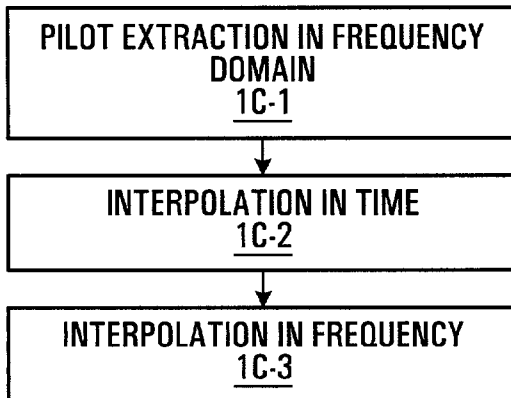


FIG. 1C  
(PRIOR ART)

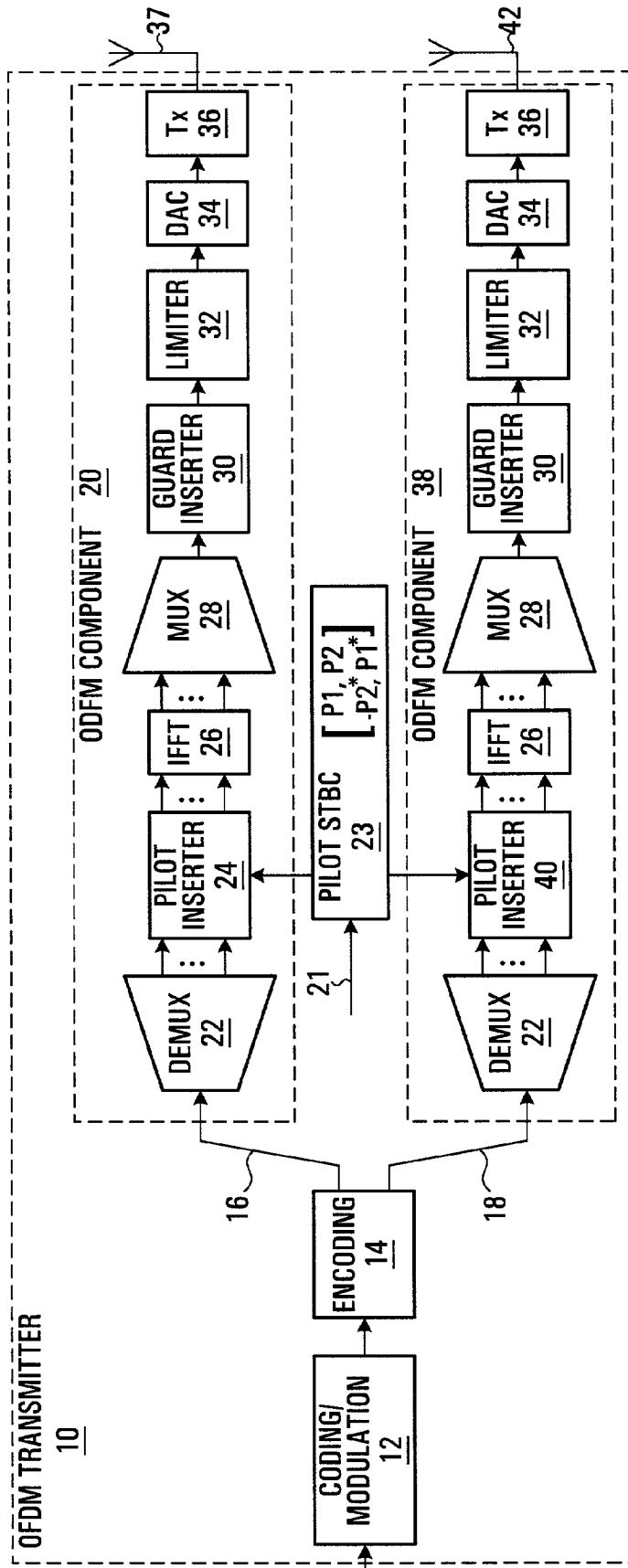


FIG. 2

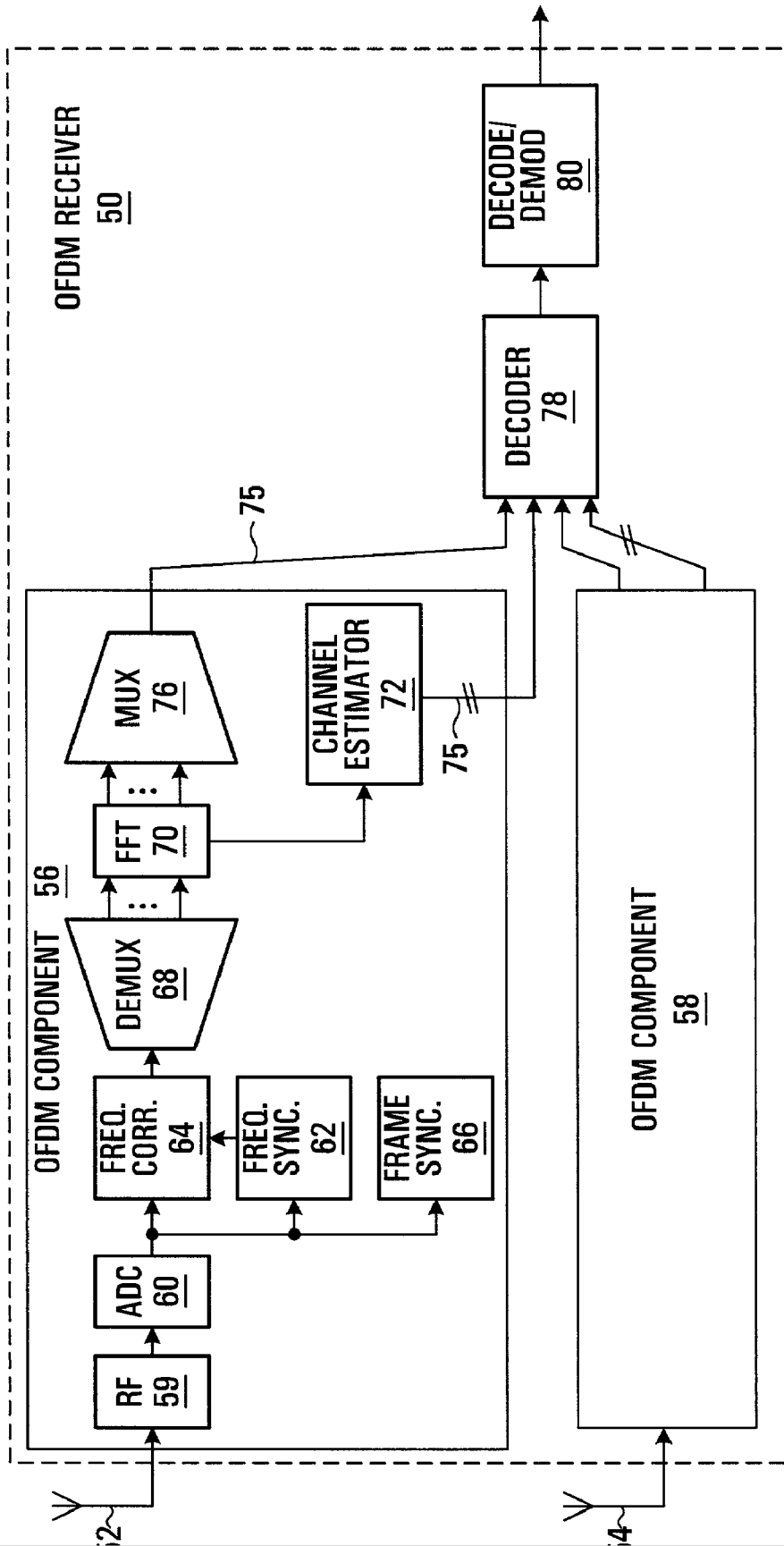


FIG. 3

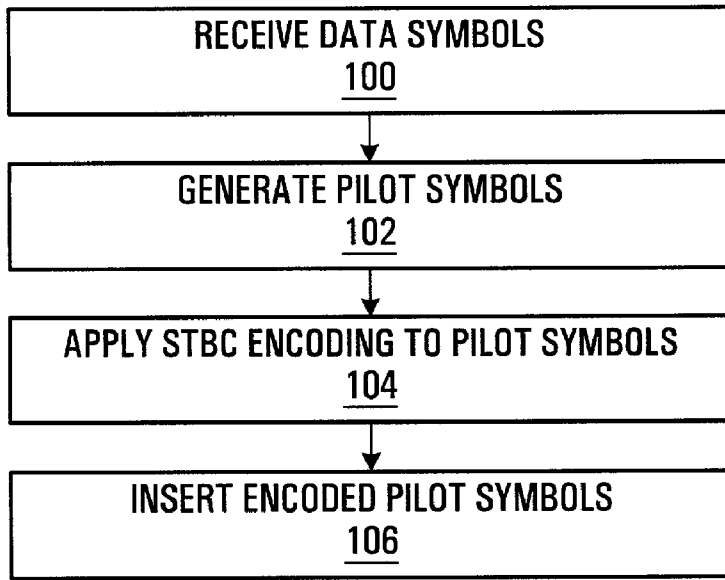


FIG. 4

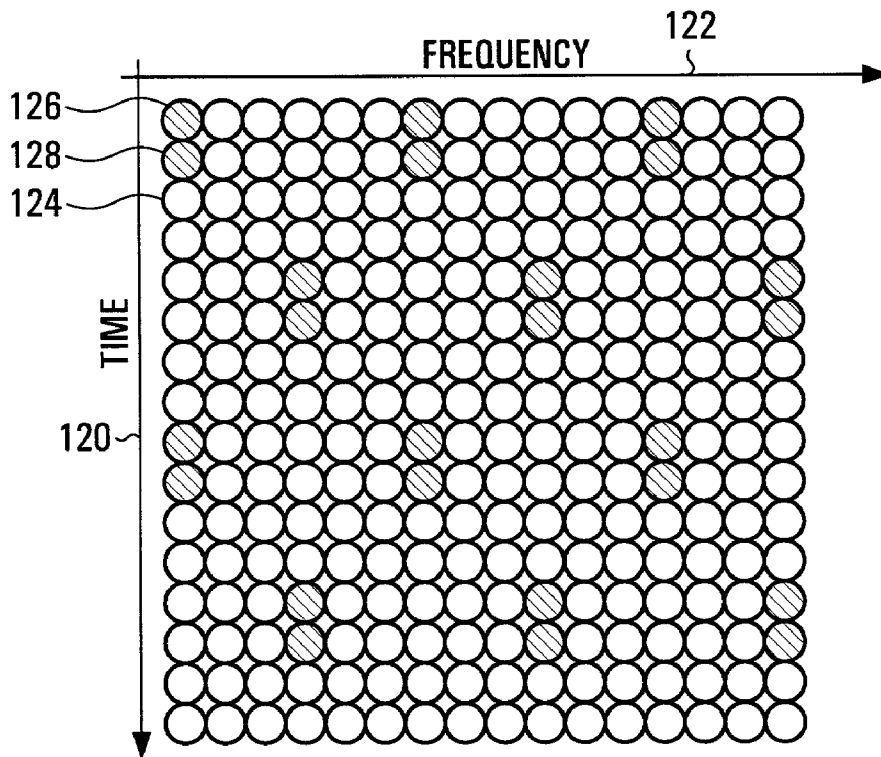


FIG. 5

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