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(54) **PILOT DESIGN FOR OFDM SYSTEMS WITH FOUR TRANSMIT ANTENNAS**

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(51) **Int. Cl.**
H04J 11/00 (2006.01)

(52) **U.S. Cl.**
USPC **370/208; 370/328; 370/334; 370/437; 375/260; 375/267; 455/562.1; 455/101**

(58) **Field of Classification Search**
USPC 370/328, 334, 208, 437; 375/260, 375/267; 455/101, 562.1
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,867,478 A 2/1999 Baum et al.
6,298,035 B1 10/2001 Heiskala
6,359,938 B1 3/2002 Keevill et al.
6,473,393 B1 10/2002 Ariyavitakul et al.
6,473,467 B1 10/2002 Wallace et al.
6,654,429 B1 11/2003 Li

(Continued)

FOREIGN PATENT DOCUMENTS

WO 03/034642 4/2003
WO 03/034644 4/2003
WO 2004/077730 9/2004

OTHER PUBLICATIONS

Fernández-Getino Garcia, Ma Julia et al; Efficient Pilot Patterns for Channel Estimation in OFDM Systems Over HF Channels; IEEE Sep. 19, 1999; pp. 2193-2197; XP-000896002.

(Continued)

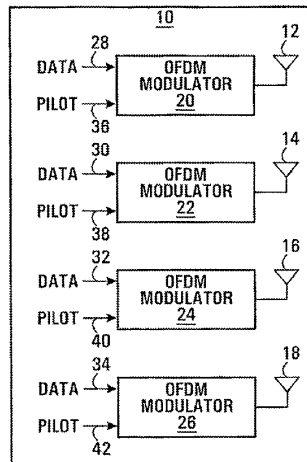
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(57) **ABSTRACT**

Pilot, preamble and midamble patterns are provided that are particularly suited for four transmit antenna OFDM systems. Pilots are inserted in a scattered manner for each of the four antennas, either uncoded, space-time coded in pairs, space-time frequency coded in pairs, or space-time-frequency coded.

30 Claims, 28 Drawing Sheets



U.S. PATENT DOCUMENTS

7,248,559	B2	7/2007	Ma et al.	
7,460,466	B2 *	12/2008	Lee et al.	370/208
7,545,734	B2	6/2009	Ma et al.	
7,848,438	B2 *	12/2010	Baum et al.	375/260
8,111,763	B2 *	2/2012	Ma et al.	375/260
2002/0003774	A1	1/2002	Wang et al.	
2002/0034213	A1	3/2002	Wang et al.	
2002/0080887	A1	6/2002	Jeong et al.	
2002/0122383	A1	9/2002	Wu et al.	
2002/0144294	A1	10/2002	Rabinowitz et al.	
2002/0181390	A1	12/2002	Mody et al.	
2003/0016621	A1	1/2003	Li	
2003/0072254	A1 *	4/2003	Ma et al.	370/208
2003/0072255	A1 *	4/2003	Ma et al.	370/208
2003/0072395	A1	4/2003	Jia et al.	
2004/0001429	A1	1/2004	Ma et al.	
2007/0053282	A1	3/2007	Tong et al.	
2009/0067534	A1 *	3/2009	Kwak et al.	375/267
2009/0238303	A1 *	9/2009	Mondal et al.	375/295

OTHER PUBLICATIONS

Jones, V.K.; Raleigh, Gregory G.; Channel Estimation for Wireless OFDM Systems; IEEE Nov. 8, 1998; pp. 980-985; XP-000825895.

Specification of U.S. Appl. No. 12/468,628, filed May 12, 2009.
 Mincai, Qiu; Wenyi, Guo; The Theories of W-CDMA and cdma2000 in the Third Mobile Communications System and the Draft for Implementation (II); Modern Science & Technology of Telecommunications, No. 11, pp. 24-26, Nov. 2000.
 EN 300 744 V1.1.2, Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television, Aug. 1997.
 Tong, et al.: "Enhancing MIMO features for OFDMA PHY layer" IEEE 802.16d-04/65, Apr. 15, 2004.
 Qinghua, et al: "Corrected pilot allocation for 4 BS transmit antennas" IEEE C802.16e-04/5311r2, Nov. 12, 2004.
 Siew, et al.; "A Channel Estimation Method for MIMO-OFDM Systems" Jul. 25, 2002, University of Bristol, UK.
 International Search Report dated Jul. 5, 2005 from International Patent Application No. PCT/CA2005/000387.
 "Extension of collaborative spatial multiplexing in OFDMA; C80216e-04/286r2", IEEE Draft; C80216E-04/286R2, IEEE-SA, Piscataway, NJ USA, vol. 802.16e, Aug. 29, 2004, pp. 1-6, XP017624418, [retrieved on Sep. 23, 2004].
 Communication in EP Application No. 05 714 626.8-2415, issued Nov. 14, 2012, pp. 1-6.

* cited by examiner

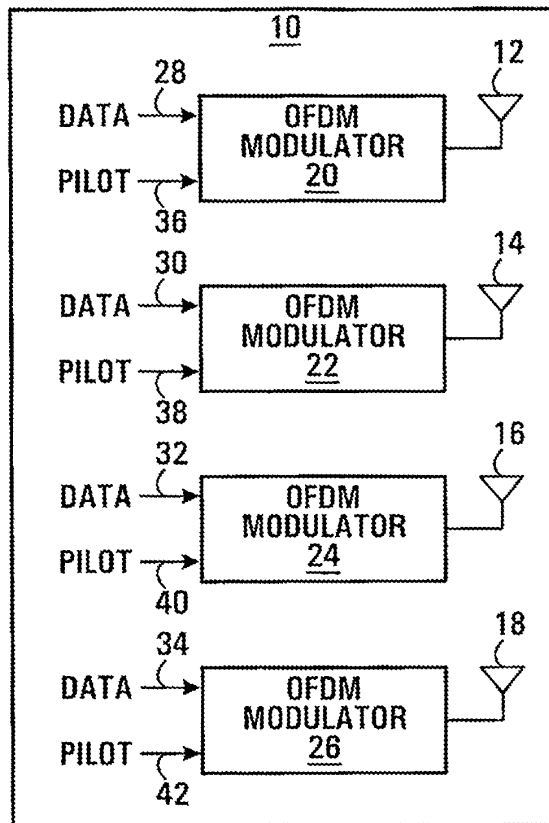


FIG. 1

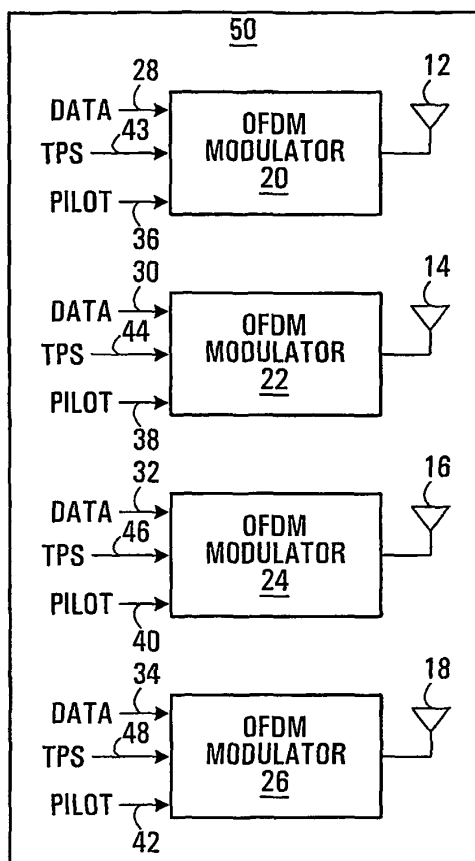


FIG. 2

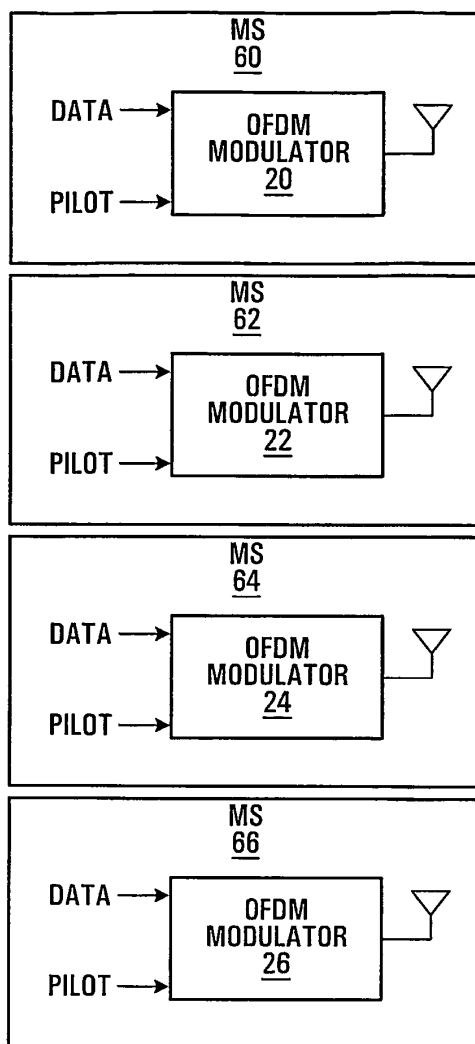


FIG. 3

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