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(54) **DIFFERENTIAL CODING AND CARRIER RECOVERY FOR MULTICARRIER SYSTEMS**

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(52) **U.S. Cl.** **375/346**
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(56) **References Cited**

U.S. PATENT DOCUMENTS

4,968,955 A	*	11/1990	Yoshida et al.	329/304
5,166,924 A	*	11/1992	Moose	370/289
5,202,643 A	*	4/1993	Sato	329/309
5,732,105 A	*	3/1998	Andren et al.	375/226
5,771,224 A		6/1998	Seki et al.	370/206
5,790,516 A	*	8/1998	Gudmundson et al.	370/210
5,889,759 A	*	3/1999	McGibney	370/207
5,946,292 A	*	8/1999	Tsujishita et al.	370/204
5,999,129 A	*	12/1999	Rose	342/394
6,292,777 B1	*	9/2001	Inoue et al.	704/230
6,377,683 B1	*	4/2002	Dobson et al.	379/406.12
6,466,958 B1	*	10/2002	Van Wechel et al.	708/422
6,574,283 B1	*	6/2003	Sakoda et al.	375/262
6,690,745 B1	*	2/2004	Horii et al.	375/316

FOREIGN PATENT DOCUMENTS

EP	1193934 A2	*	4/2002	.... H04L 27/26
JP	8265293		10/1996	

(Continued)

OTHER PUBLICATIONS

Moose, "Differentially Coded Multi-Frequency Modulation for Digital Communications", *Signal Processing V—Theories and Applications*, Proceedings of EUSIPCO-90 Fifth European Signal Processing Conference, Barcelona, Spain, vol. III, pp. 1807-1810 (Sep. 1990).
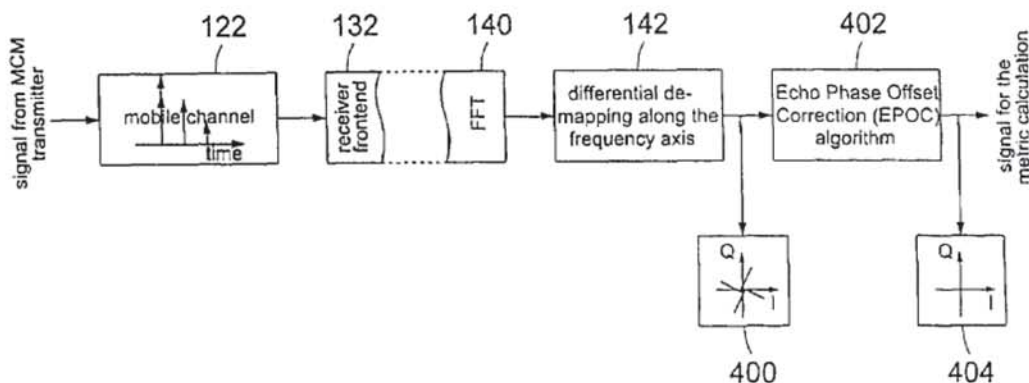
(Continued)

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(57) **ABSTRACT**

A method of performing an echo phase offset correction in a multi-carrier demodulation system involves the step of differential phase decoding phase shifts based on a phase difference between simultaneous carriers having different frequencies. An echo phase offset is determined for each decoded phase shift by eliminating phase shift uncertainties related to the transmitted information from the decoded phase shift. The echo phase offsets are averaged in order to generate an averaged offset. Finally, each decoded phase shift is corrected based on the averaged offset.

16 Claims, 7 Drawing Sheets

FOREIGN PATENT DOCUMENTS

JP	9149092	6/1997
JP	1041991	2/1998
WO	9205646	4/1992
WO	9800946	1/1998

OTHER PUBLICATIONS

Moose, "A Technique for Orthogonal Frequency Division Multiplexing Frequency Offset Correction", *IEEE Transactions on Communications,* vol. 42, No. 10, pp. 2908-2914 (Oct. 1994).

Keller and Hanzo; "Orthogonal Frequency Division Multiplex Synchronisation Techniques for Wireless Local Area Networks", *IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, pp. 963-967 (Oct. 1996).

Zou and Wu, "COFDM: An Overview", *IEEE Transactions on Broadcasting*, vol. 41, No. 1, pp. 1-8 (Mar. 1995).
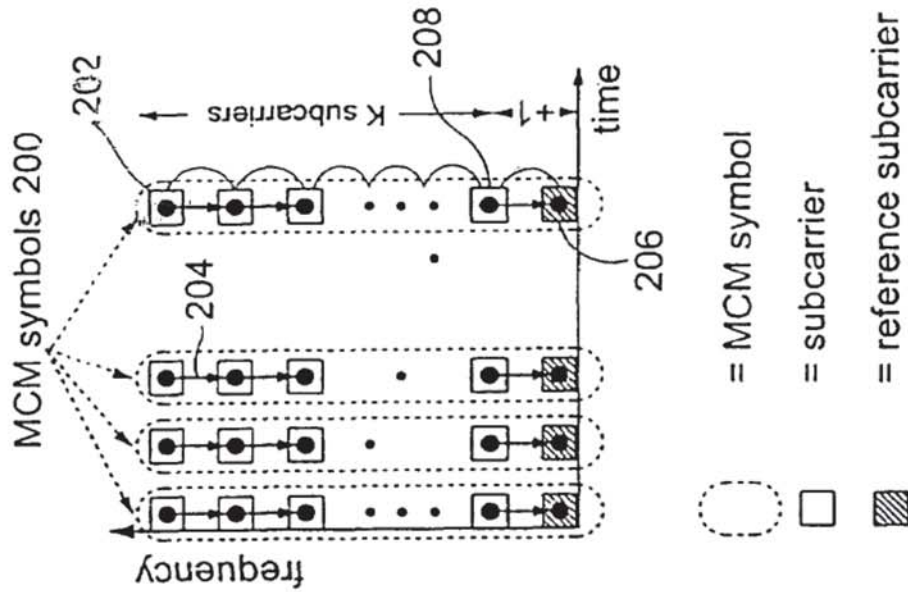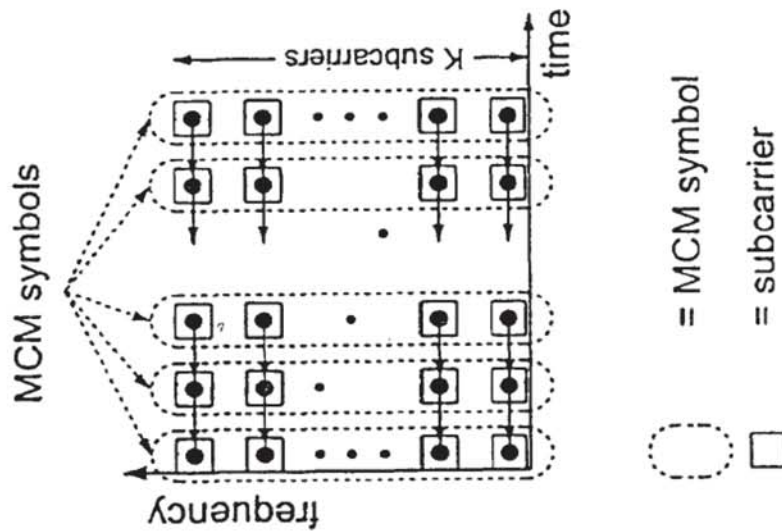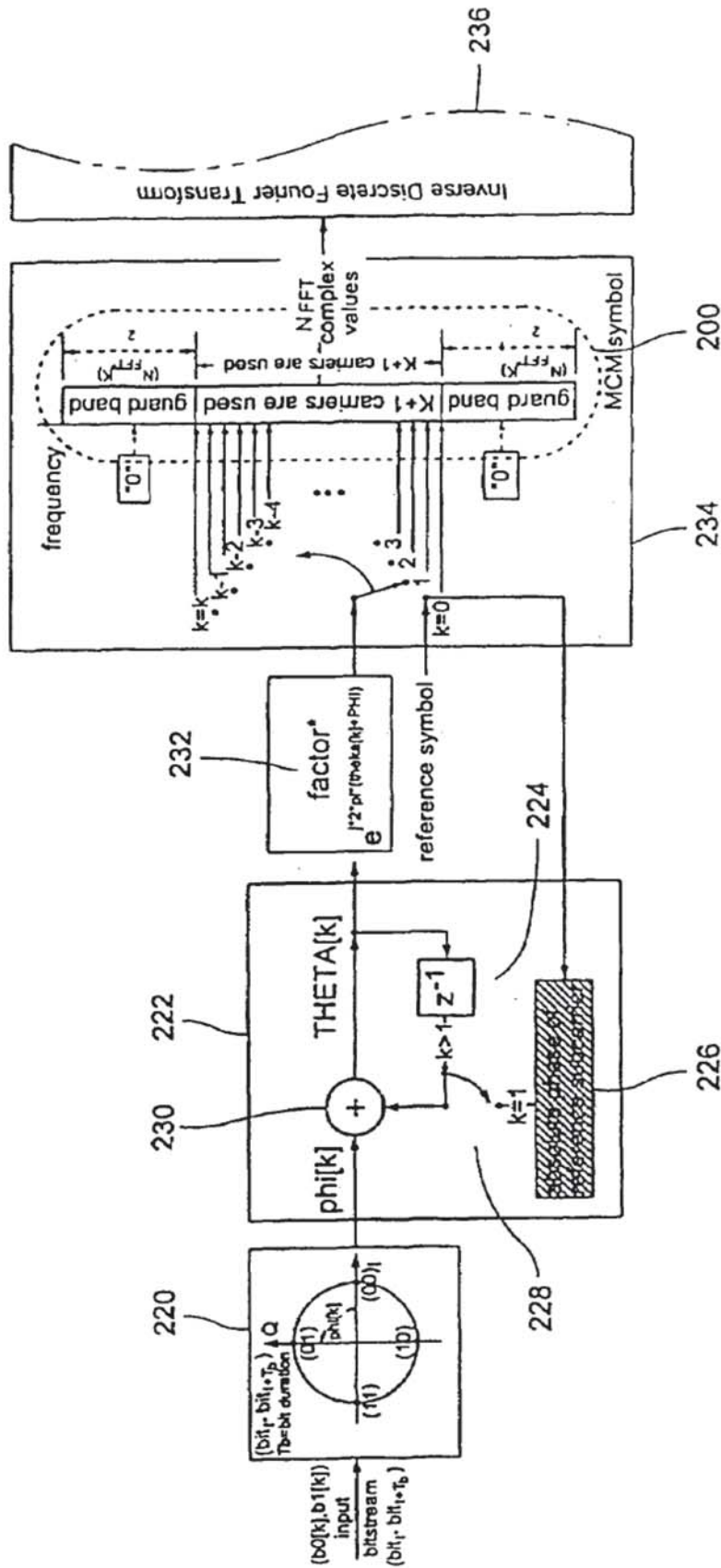
* cited by examiner

MCM symbols 200

202

204

208

l+1

K subcarriers

206

frequency

time

☐ = MCM symbol

☐ = subcarrier

▨ = reference subcarrier

FIG.1

MCM symbols

K subcarriers

frequency

time

☐ = MCM symbol
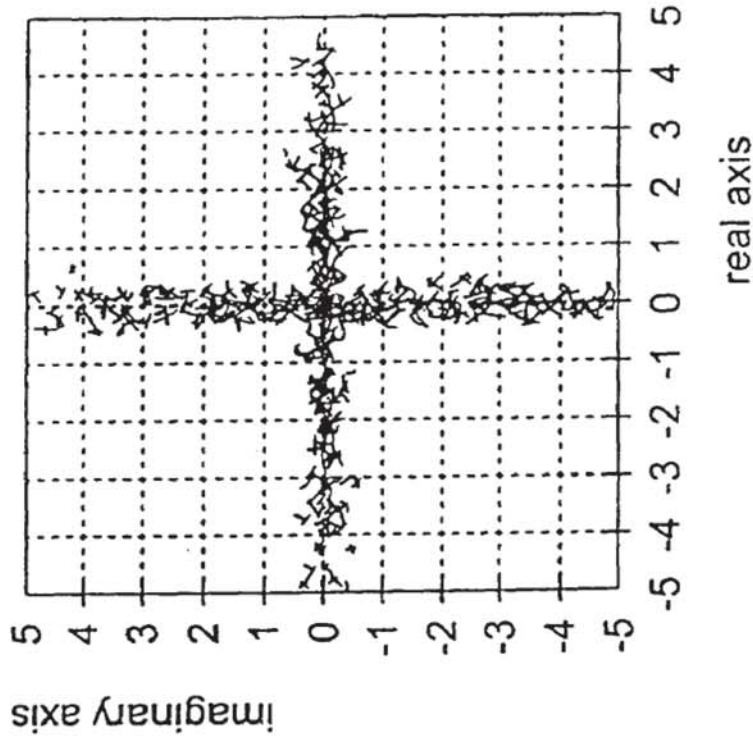
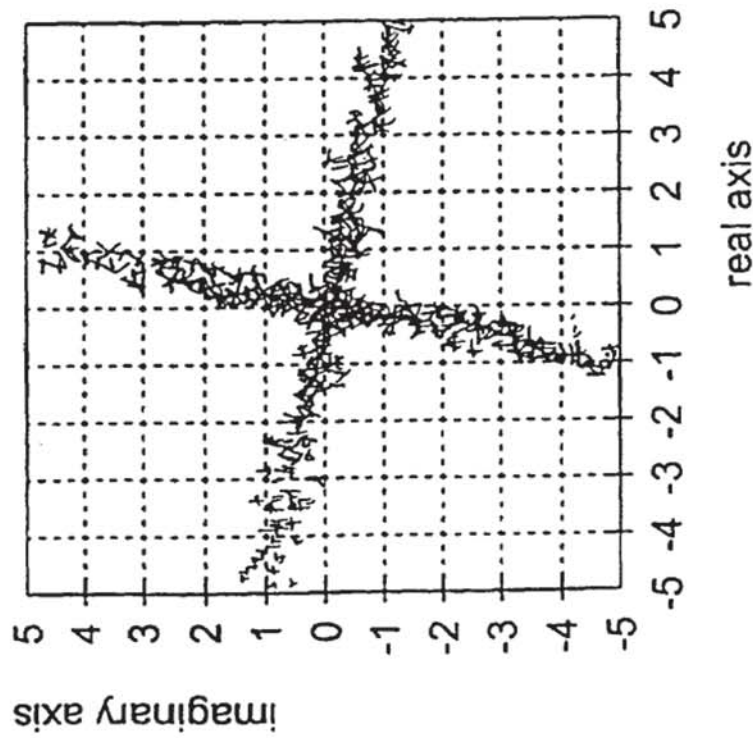☐ = subcarrier

FIG.8

FIG.2

FIG.3B

FIG.3A

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