



US009473269B2

(12) **United States Patent**
Walton et al.

(10) **Patent No.:** **US 9,473,269 B2**
(45) **Date of Patent:** **Oct. 18, 2016**

(54) **METHOD AND APPARATUS FOR PROVIDING AN EFFICIENT CONTROL CHANNEL STRUCTURE IN A WIRELESS COMMUNICATION SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 2225 days.

(21) Appl. No.: **10/725,904**

(22) Filed: **Dec. 1, 2003**

(65) **Prior Publication Data**

US 2005/0120097 A1 Jun. 2, 2005

(51) **Int. Cl.**

H04W 28/18 (2009.01)

H04L 1/06 (2006.01)

H04L 1/00 (2006.01)

H04L 27/26 (2006.01)

H04W 72/14 (2009.01)

H04B 7/26 (2006.01)

H04L 1/16 (2006.01)

H04L 25/02 (2006.01)

(52) **U.S. Cl.**

CPC **H04L 1/06** (2013.01); **H04L 1/0002** (2013.01); **H04L 27/261** (2013.01); **H04W 72/14** (2013.01); **H04B 7/2643** (2013.01); **H04L 1/0025** (2013.01); **H04L 1/16** (2013.01); **H04L 25/0204** (2013.01); **H04L 2001/0093** (2013.01); **H04W 28/18** (2013.01)

(58) **Field of Classification Search**

None

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,736,371 A	4/1988	Tejima et al.
4,750,198 A	6/1988	Harper
4,797,879 A	1/1989	Habbab et al.
5,239,677 A	8/1993	Jasinski
5,241,544 A	8/1993	Jasper et al.
5,295,159 A	3/1994	Kerpez
5,404,355 A	4/1995	Raith

(Continued)

FOREIGN PATENT DOCUMENTS

AU	2002259221	11/2002
CA	2690245 A1	10/2001

(Continued)

OTHER PUBLICATIONS

ETSI Standards, European Telecommunications Standards Institute, "Broadband Radio Access Networks (BRAN); IPERLAN Type 2; Data Link Control (DLC) Layer; Part 1: Basic Data Transport Functions", Dec. 2001, pp. 12-14, p. 16, p. 18-36, p. 48-53, pp. 82-86.

(Continued)

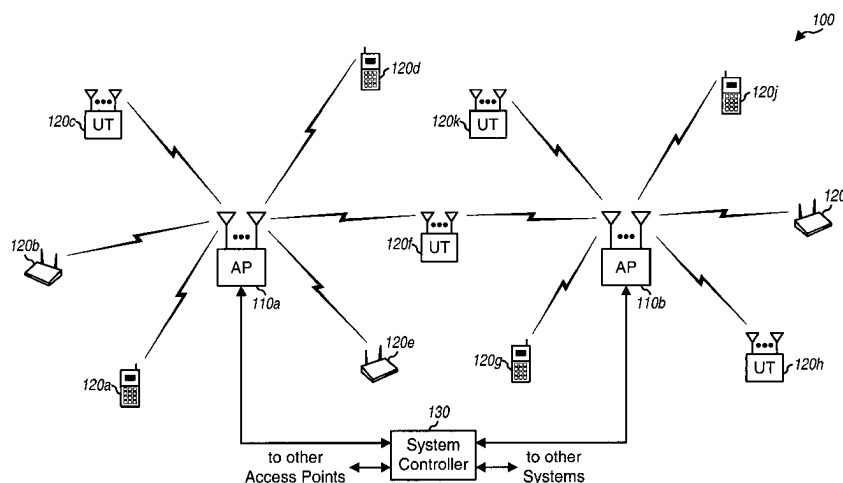
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(57)

ABSTRACT

According to one aspect of the invention, a method is provided in which a control channel used for transmitting control information is partitioned into a plurality of sub-channels each of which is operated at a specific data rate. For each of one or more user terminals, one of the subchannels is selected based on one or more selection criteria for transmitting control information from an access point to the respective user terminal. Control information is transmitted from the access point to a user terminal on a particular subchannel selected for the respective user terminal. At the user terminal, one or more subchannels are decoded to obtain control information designated for the user terminal.

45 Claims, 10 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

5,422,733	A	6/1995	Merchant et al.	6,348,036	B1	2/2002	Looney et al.
5,471,647	A	11/1995	Gerlach et al.	6,351,499	B1	2/2002	Paulraj et al.
5,479,447	A	12/1995	Chow et al.	6,363,267	B1	3/2002	Lindskog et al.
5,491,837	A	2/1996	Haartsen	6,369,758	B1	4/2002	Zhang
5,493,712	A	2/1996	Ramesh et al.	6,377,812	B1	4/2002	Rashid-Farrokhi et al.
5,506,861	A	4/1996	Bottomley	6,385,264	B1	5/2002	Terasawa et al.
5,509,003	A	4/1996	Snijders et al.	6,389,056	B1	5/2002	Kanterakis et al.
5,528,581	A	6/1996	De Bot	6,426,971	B1	7/2002	Wu et al.
5,606,729	A	2/1997	D'Amico et al.	6,452,981	B1	9/2002	Raleigh et al.
5,638,369	A	6/1997	Ayerst et al.	6,463,290	B1	10/2002	Stilp et al.
5,677,909	A	10/1997	Heide	6,473,467	B1	10/2002	Wallace et al.
5,729,542	A	3/1998	Dupont	6,478,422	B1	11/2002	Hansen
5,790,550	A	8/1998	Peeters et al.	6,492,942	B1	12/2002	Kezys
5,799,005	A	8/1998	Soliman	6,510,184	B1	1/2003	Okamura
5,818,813	A	10/1998	Saito et al.	6,512,737	B1	1/2003	Agee
5,822,374	A	10/1998	Levin	6,515,617	B1	2/2003	Demers et al.
5,832,387	A	11/1998	Bae et al.	6,532,225	B1	3/2003	Chang et al.
5,859,875	A	1/1999	Kato et al.	6,532,562	B1	3/2003	Chou et al.
5,867,478	A	2/1999	Baum et al.	6,545,997	B1	4/2003	Bohnke et al.
5,867,539	A	2/1999	Koslov	6,574,211	B2	6/2003	Padovani et al.
5,883,887	A	3/1999	Take et al.	6,574,267	B1	6/2003	Kanterakis et al.
5,886,988	A	3/1999	Yun et al.	6,574,271	B2	6/2003	Mesecher et al.
5,929,810	A	7/1999	Koutsoudis et al.	6,590,883	B1	7/2003	Kitade et al.
5,959,965	A	9/1999	Ohkubo et al.	6,594,473	B1	7/2003	Dabak et al.
5,963,589	A	10/1999	Nagano et al.	6,594,798	B1	7/2003	Chou et al.
5,973,638	A	10/1999	Robbins et al.	6,597,682	B1 *	7/2003	Kari H04J 3/1647 370/329
5,982,327	A	11/1999	Vook et al.	6,608,874	B1	8/2003	Beidas et al.
6,005,876	A	12/1999	Cimini, Jr. et al.	6,611,231	B2	8/2003	Crilly, Jr. et al.
6,011,963	A	1/2000	Ogoro	6,615,024	B1	9/2003	Boros et al.
6,014,429	A *	1/2000	LaPorta H04M 3/533 340/7.21	6,631,121	B1	10/2003	Yoon
6,049,548	A	4/2000	Bruno et al.	6,636,496	B1	10/2003	Cho et al.
6,067,290	A	5/2000	Paulraj et al.	6,636,568	B2	10/2003	Kadous et al.
6,072,779	A	6/2000	Tzannes et al.	6,654,590	B2	11/2003	Boros et al.
6,084,915	A	7/2000	Williams	6,654,613	B1	11/2003	Maeng et al.
6,097,771	A	8/2000	Foschini	6,668,161	B2	12/2003	Boros et al.
6,115,354	A	9/2000	Weck	6,683,916	B1	1/2004	Sartori et al.
6,122,247	A	9/2000	Levin et al.	6,690,660	B2	2/2004	Kim et al.
6,131,016	A	10/2000	Greenstein et al.	6,693,992	B2	2/2004	Jones et al.
6,141,388	A	10/2000	Servais et al.	6,694,155	B1	2/2004	Chin et al.
6,141,542	A	10/2000	Kotzin et al.	6,697,346	B1 *	2/2004	Halton et al. 370/335
6,141,555	A	10/2000	Sato	6,711,121	B1	3/2004	Gerakoulis et al.
6,141,567	A	10/2000	Youssefmir et al.	6,721,267	B2	4/2004	Hiben et al.
6,144,711	A	11/2000	Raleigh et al.	6,728,233	B1	4/2004	Park et al.
6,154,661	A	11/2000	Goldburg	6,731,668	B2	5/2004	Ketchum
6,163,296	A	12/2000	Lier et al.	6,735,188	B1	5/2004	Becker et al.
6,167,031	A	12/2000	Olofsson et al.	6,738,020	B1	5/2004	Lindskog et al.
6,175,588	B1	1/2001	Visotsky et al.	6,744,811	B1	6/2004	Kantschuk
6,178,196	B1	1/2001	Naguib et al.	6,751,187	B2	6/2004	Walton et al.
6,192,256	B1	2/2001	Whinnett	6,751,444	B1	6/2004	Meiyappan
6,205,410	B1	3/2001	Cai	6,751,480	B2	6/2004	Kogiantis et al.
6,222,888	B1	4/2001	Kao et al.	6,757,263	B1	6/2004	Olds
6,232,918	B1	5/2001	Wax et al.	6,760,313	B1	7/2004	Sindhushayana et al.
6,266,528	B1	7/2001	Farzaneh	6,760,388	B2	7/2004	Ketchum et al.
6,272,354	B1	8/2001	Saario	6,760,882	B1	7/2004	Gesbert et al.
6,275,543	B1	8/2001	Petrus et al.	6,768,727	B1	7/2004	Sourour et al.
6,278,726	B1	8/2001	Mesecher et al.	6,771,706	B2	8/2004	Ling et al.
6,292,917	B1	9/2001	Sinha et al.	6,785,341	B2	8/2004	Walton et al.
6,298,035	B1	10/2001	Heiskala	6,785,513	B1	8/2004	Sivaprakasam
6,298,092	B1	10/2001	Heath, Jr. et al.	6,788,948	B2	9/2004	Lindskog et al.
6,308,080	B1	10/2001	Burt et al.	6,792,041	B1	9/2004	Kim et al.
6,310,704	B1	10/2001	Dogan et al.	6,795,424	B1	9/2004	Kapoor et al.
6,314,113	B1	11/2001	Guemas	6,798,738	B1	9/2004	Do et al.
6,314,289	B1	11/2001	Eberlein et al.	6,801,790	B2	10/2004	Rudrapatna et al.
6,317,467	B1	11/2001	Cox et al.	6,802,035	B2	10/2004	Catreux et al.
6,317,612	B1	11/2001	Farsakh	6,804,191	B2	10/2004	Richardson
6,330,277	B1	12/2001	Gelblum et al.	6,821,535	B2	11/2004	Nurmi et al.
6,330,293	B1	12/2001	Klank et al.	6,842,460	B1	1/2005	Olkkonen et al.
6,330,462	B1	12/2001	Chen	6,847,828	B2	1/2005	Miyoshi et al.
6,333,953	B1	12/2001	Bottomley et al.	6,850,252	B1	2/2005	Hofberg
6,339,399	B1	1/2002	Andersson et al.	6,850,498	B2	2/2005	Heath et al.
6,345,036	B1	2/2002	Sudo et al.	6,859,503	B2	2/2005	Pautler et al.
6,346,910	B1	2/2002	Ito	6,862,440	B2	3/2005	Sampath
6,347,217	B1	2/2002	Bengtsson et al.	6,868,079	B1	3/2005	Hunt
6,347,234	B1	2/2002	Scherzer	6,873,651	B2	3/2005	Tesfai et al.
				6,879,578	B2	4/2005	Pan et al.
				6,879,579	B1	4/2005	Myles et al.
				6,882,868	B1	4/2005	Shattil
				6,885,708	B2	4/2005	Thomas et al.

(56)

References Cited

U.S. PATENT DOCUMENTS

6,888,809 B1	5/2005	Foschini et al.	7,187,646 B2	3/2007	Schramm
6,888,899 B2	5/2005	Raleigh et al.	7,190,749 B2	3/2007	Levin et al.
6,891,858 B1	5/2005	Mahesh et al.	7,191,381 B2	3/2007	Gesbert et al.
6,920,192 B1	7/2005	Laroia et al.	7,194,237 B2	3/2007	Sugar et al.
6,920,194 B2	7/2005	Stopler et al.	7,197,084 B2	3/2007	Ketchum et al.
6,927,728 B2	8/2005	Vook et al.	7,200,404 B2	4/2007	Panasik et al.
6,937,592 B1	8/2005	Heath, Jr. et al.	7,206,354 B2	4/2007	Wallace et al.
6,940,917 B2	9/2005	Menon et al.	7,218,684 B2	5/2007	Bolourchi et al.
6,950,632 B1	9/2005	Yun et al.	7,221,956 B2	5/2007	Medvedev et al.
6,952,426 B2	10/2005	Wu et al.	7,224,704 B2	5/2007	Lu et al.
6,952,454 B1	10/2005	Jalali et al.	7,231,184 B2	6/2007	Eilts et al.
6,956,813 B2	10/2005	Fukuda	7,233,625 B2	6/2007	Ma et al.
6,956,897 B1	10/2005	Honig	7,238,508 B2	7/2007	Lin et al.
6,956,906 B2	10/2005	Tager et al.	7,242,727 B2	7/2007	Liu et al.
6,959,171 B2	10/2005	Tsien et al.	7,248,638 B1	7/2007	Banister
6,963,741 B2	11/2005	Johansson et al.	7,248,841 B2	7/2007	Agee et al.
6,963,742 B2	11/2005	Boros et al.	7,254,171 B2	8/2007	Hudson
6,965,762 B2	11/2005	Sugar et al.	7,260,153 B2	8/2007	Nissani (Nissensohn) et al.
6,970,722 B1	11/2005	Lewis	7,260,366 B2	8/2007	Lee et al.
6,980,601 B2	12/2005	Jones	7,263,119 B1	8/2007	Hsu et al.
6,980,800 B2	12/2005	Noerpel et al.	7,269,127 B2	9/2007	Mody et al.
6,985,434 B2	1/2006	Wu et al.	7,272,162 B2	9/2007	Sano et al.
6,985,534 B1	1/2006	Meister	7,274,734 B2	9/2007	Tsatsanis
6,987,819 B2	1/2006	Thomas et al.	7,277,679 B1	10/2007	Barratt et al.
6,990,059 B1	1/2006	Anikhindi et al.	7,280,467 B2	10/2007	Smee et al.
6,992,972 B2	1/2006	Van Nee	7,280,625 B2	10/2007	Ketchum et al.
6,996,380 B2	2/2006	Dent et al.	7,283,508 B2	10/2007	Choi et al.
7,002,900 B2	2/2006	Walton et al.	7,283,581 B2	10/2007	Itoh
7,003,044 B2	2/2006	Subramanian et al.	7,289,570 B2	10/2007	Schmidl et al.
7,006,464 B1	2/2006	Gopalakrishnan et al.	7,298,778 B2	11/2007	Visoz et al.
7,006,483 B2	2/2006	Nelson, Jr. et al.	7,308,035 B2	12/2007	Rouquette et al.
7,006,848 B2	2/2006	Ling et al.	7,317,750 B2	1/2008	Shattil
7,009,931 B2	3/2006	Ma et al.	7,324,429 B2	1/2008	Walton et al.
7,012,978 B2	3/2006	Talwar	7,327,800 B2	2/2008	Oprea et al.
7,020,110 B2	3/2006	Walton et al.	7,333,556 B2	2/2008	Maltsev et al.
7,020,490 B2	3/2006	Khatrri et al.	7,342,912 B1	3/2008	Kerr et al.
7,023,826 B2	4/2006	Sjoberg et al.	7,356,004 B2	4/2008	Yano et al.
7,024,163 B1	4/2006	Barratt et al.	7,356,089 B2	4/2008	Jia et al.
7,031,671 B2	4/2006	Mottier	7,379,492 B2	5/2008	Hwang
7,035,359 B2	4/2006	Molnar et al.	7,386,076 B2	6/2008	Onggosanusi et al.
7,039,125 B2	5/2006	Friedman	7,392,014 B2	6/2008	Baker et al.
7,039,363 B1	5/2006	Kasapi et al.	7,403,748 B1	7/2008	Keskitalo et al.
7,042,858 B1	5/2006	Ma et al.	7,421,039 B2	9/2008	Malaender et al.
7,043,259 B1	5/2006	Trott	7,453,844 B1	11/2008	Lee et al.
7,054,378 B2	5/2006	Walton et al.	7,466,749 B2	12/2008	Medvedev et al.
7,058,367 B1	6/2006	Luo et al.	7,480,278 B2	1/2009	Pedersen et al.
7,062,294 B1	6/2006	Rogard et al.	7,492,737 B1	2/2009	Fong et al.
7,068,628 B2	6/2006	Li et al.	7,508,748 B2	3/2009	Kadous
7,072,381 B2	7/2006	Atarashi et al.	7,548,506 B2	6/2009	Ma et al.
7,072,410 B1	7/2006	Monsen	7,551,546 B2	6/2009	Ma et al.
7,072,413 B2	7/2006	Walton et al.	7,551,580 B2	6/2009	du Crest et al.
7,076,263 B2	7/2006	Medvedev et al.	7,573,805 B2	8/2009	Zhuang et al.
7,088,671 B1	8/2006	Monsen	7,599,443 B2	10/2009	Ionescu et al.
7,095,709 B2	8/2006	Walton et al.	7,603,141 B2	10/2009	Dravida
7,095,722 B1	8/2006	Walke et al.	7,606,296 B1	10/2009	Hsu et al.
7,099,377 B2	8/2006	Berens et al.	7,606,319 B2	10/2009	Zhang et al.
7,103,325 B1	9/2006	Jia et al.	7,623,871 B2	11/2009	Sheynblat
7,110,378 B2	9/2006	Onggosanusi et al.	7,636,573 B2	12/2009	Walton et al.
7,110,463 B2	9/2006	Wallace et al.	7,646,747 B2	1/2010	Atarashi et al.
7,113,499 B2	9/2006	Nafie et al.	7,653,142 B2	1/2010	Ketchum et al.
7,116,652 B2	10/2006	Lozano et al.	7,653,415 B2	1/2010	Van Rooyen
7,120,199 B2	10/2006	Thielecke et al.	7,656,967 B2	2/2010	Tirola et al.
7,120,657 B2	10/2006	Ricks et al.	7,778,337 B2	8/2010	Tong et al.
7,127,009 B2	10/2006	Berthet et al.	7,787,514 B2	8/2010	Shattil et al.
7,130,362 B2	10/2006	Girardeau et al.	7,822,140 B2	10/2010	Catreux et al.
7,133,459 B2	11/2006	Onggosanusi et al.	7,843,972 B2	11/2010	Nakahara et al.
7,137,047 B2	11/2006	Mitlin et al.	7,885,228 B2	2/2011	Walton et al.
7,149,190 B1	12/2006	Li et al.	8,134,976 B2	3/2012	Wallace et al.
7,149,239 B2	12/2006	Hudson et al.	8,145,179 B2	3/2012	Walton et al.
7,149,254 B2	12/2006	Sampath	8,169,944 B2	5/2012	Walton et al.
7,155,171 B2	12/2006	Ebert et al.	8,170,513 B2	5/2012	Walton et al.
7,158,563 B2	1/2007	Ginis et al.	8,213,292 B2	7/2012	Ma et al.
7,164,649 B2	1/2007	Walton et al.	8,254,246 B2	8/2012	Ma et al.
7,164,669 B2	1/2007	Li et al.	8,260,210 B2	9/2012	Esteve et al.
7,184,713 B2	2/2007	Kadous et al.	8,320,301 B2	11/2012	Walton et al.
			8,406,118 B2	3/2013	Ma et al.
			8,462,643 B2	6/2013	Walton et al.
			8,483,188 B2	7/2013	Walton et al.
			8,855,226 B2	10/2014	Medvedev et al.

(56)	References Cited						
	U.S. PATENT DOCUMENTS						
2001/0017881	A1	8/2001	Bhatoolaul et al.		2003/0147371	A1	8/2003 Choi et al. 370/341
2001/0031621	A1 *	10/2001	Schmutz H04B 7/155		2003/0153320	A1	8/2003 Noerpel et al.
			455/7		2003/0153345	A1	8/2003 Cramer et al.
2001/0033623	A1	10/2001	Hosur		2003/0153360	A1	8/2003 Burke et al.
2001/0046205	A1	11/2001	Easton et al.		2003/0157953	A1	8/2003 Das et al. 455/522
2002/0003774	A1	1/2002	Wang et al.		2003/0157954	A1	8/2003 Medvedev et al.
2002/0004920	A1	1/2002	Cho et al.		2003/0161282	A1	8/2003 Medvedev et al.
2002/0018310	A1	2/2002	Hung		2003/0162519	A1	8/2003 Smith et al.
2002/0018453	A1	2/2002	Yu et al.		2003/0165189	A1 *	9/2003 Kadous 375/225
2002/0027951	A1	3/2002	Gormley et al.		2003/0174676	A1	9/2003 Willenegger et al.
2002/0041632	A1	4/2002	Sato et al.		2003/0174686	A1	9/2003 Willenegger et al.
2002/0044591	A1	4/2002	Lee et al.		2003/0185311	A1	10/2003 Kim
2002/0044610	A1	4/2002	Jones		2003/0186650	A1	10/2003 Liu
2002/0057659	A1	5/2002	Ozluturk et al.		2003/0190897	A1	10/2003 Lei et al.
2002/0062472	A1	5/2002	Medlock et al.		2003/0202492	A1 *	10/2003 Akella et al. 370/335
2002/0064214	A1	5/2002	Hattori et al.		2003/0202612	A1	10/2003 Halder et al.
2002/0071445	A1	6/2002	Wu et al. 370/441		2003/0206558	A1	11/2003 Parkkinen et al.
2002/0075830	A1	6/2002	Hartman, Jr.		2003/0210668	A1	11/2003 Malladi et al.
2002/0080735	A1	6/2002	Heath et al.		2003/0235147	A1	12/2003 Walton et al.
2002/0085620	A1	7/2002	Mesecher		2003/0235149	A1	12/2003 Chan et al.
2002/0085641	A1	7/2002	Baum		2003/0235255	A1	12/2003 Ketchum et al.
2002/0098872	A1	7/2002	Judson		2004/0005887	A1	1/2004 Bahrenburg et al.
2002/0105928	A1	8/2002	Kapoor et al.		2004/0013103	A1	1/2004 Zhang et al.
2002/0115467	A1	8/2002	Hamabe		2004/0017785	A1	1/2004 Zelst
2002/0115473	A1	8/2002	Hwang et al.		2004/0037257	A1	2/2004 Ngo
2002/0122381	A1	9/2002	Wu et al.		2004/0042439	A1	3/2004 Menon et al.
2002/0122393	A1	9/2002	Caldwell et al.		2004/0042556	A1	3/2004 Medvedev et al.
2002/0126803	A1	9/2002	Jones et al.		2004/0047284	A1	3/2004 Eidson
2002/0132600	A1	9/2002	Rudrapatna et al.		2004/0047292	A1	3/2004 Du Crest et al.
2002/0136271	A1	9/2002	Hiramatsu et al.		2004/0052228	A1	3/2004 Tellado et al.
2002/0147032	A1	10/2002	Yoon et al.		2004/0062192	A1	4/2004 Liu et al.
2002/0147953	A1	10/2002	Catreux et al.		2004/0071104	A1	4/2004 Boesel et al.
2002/0150182	A1	10/2002	Dogan et al.		2004/0071107	A1	4/2004 Kats et al.
2002/0154705	A1	10/2002	Walton et al.		2004/0076224	A1	4/2004 Onggosanusi et al.
2002/0163879	A1	11/2002	Li et al.		2004/0081131	A1	4/2004 Walton et al.
2002/0177447	A1	11/2002	Walton et al.		2004/0082356	A1	4/2004 Walton et al.
2002/0181390	A1	12/2002	Mody et al.		2004/0085939	A1	5/2004 Wallace et al.
2002/0183010	A1	12/2002	Catreux et al.		2004/0087324	A1	5/2004 Ketchum et al.
2002/0184453	A1	12/2002	Hughes et al.		2004/0120411	A1	6/2004 Walton et al.
2002/0191535	A1	12/2002	Sugiyama et al.		2004/0121730	A1	6/2004 Kadous et al.
2002/0193146	A1	12/2002	Wallace et al.		2004/0136349	A1	7/2004 Walton et al.
2002/0196842	A1	12/2002	Onggosanusi et al.		2004/0151108	A1	8/2004 Blasco Claret et al.
2003/0002450	A1	1/2003	Jalali et al.		2004/0151122	A1	8/2004 Lau et al.
2003/0003863	A1	1/2003	Thielecke et al.		2004/0156328	A1	8/2004 Walton
2003/0007463	A1	1/2003	Li et al.		2004/0160921	A1	8/2004 Kaipainen et al.
2003/0012308	A1	1/2003	Sampath et al.		2004/0160987	A1	8/2004 Sudo et al.
2003/0039217	A1	2/2003	Seo et al.		2004/0176097	A1 *	9/2004 Wilson H04B 7/0413
2003/0039317	A1	2/2003	Taylor et al.				455/452.2
2003/0043887	A1	3/2003	Hudson et al.		2004/0179627	A1	9/2004 Ketchum et al.
2003/0045288	A1	3/2003	Luschi et al.		2004/0184398	A1	9/2004 Walton et al.
2003/0045318	A1	3/2003	Subrahmanya		2004/0198276	A1	10/2004 Tellado et al.
2003/0048856	A1	3/2003	Ketchum et al.		2004/0252632	A1	12/2004 Bourdoux et al.
2003/0050069	A1	3/2003	Kogiantis et al.		2005/0002326	A1	1/2005 Ling et al.
2003/0060173	A1	3/2003	Lee et al.		2005/0047384	A1	3/2005 Wax et al.
2003/0072395	A1	4/2003	Jia et al.		2005/0047515	A1	3/2005 Walton et al.
2003/0073409	A1	4/2003	Nobukiyo et al.		2005/0099974	A1	5/2005 Kats et al.
2003/0076797	A1	4/2003	Lozano et al.		2005/0111599	A1	5/2005 Walton et al.
2003/0076812	A1	4/2003	Benedittis		2005/0128953	A1	6/2005 Wallace et al.
2003/0078024	A1	4/2003	Magee et al.		2005/0135284	A1	6/2005 Nanda et al.
2003/0086514	A1	5/2003	Ginis et al.		2005/0135295	A1	6/2005 Walton et al.
2003/0092456	A1	5/2003	Dent et al.		2005/0135318	A1	6/2005 Walton et al.
2003/0095197	A1	5/2003	Wheeler et al.		2005/0147177	A1	7/2005 Seo et al.
2003/0099306	A1	5/2003	Nilsson et al.		2005/0174981	A1	8/2005 Heath, Jr. et al.
2003/0103584	A1	6/2003	Bjerke et al.		2005/0185575	A1	8/2005 Hansen et al.
2003/0112745	A1	6/2003	Zhuang et al.		2005/0195915	A1	9/2005 Raleigh et al.
2003/0117989	A1	6/2003	Kim		2005/0208959	A1 *	9/2005 Chen et al. 455/515
2003/0119452	A1	6/2003	Kim et al.		2005/0220211	A1	10/2005 Shim et al.
2003/0123381	A1	7/2003	Zhuang et al.		2005/0227628	A1	10/2005 Inanoglu
2003/0123389	A1	7/2003	Russell et al.		2005/0245264	A1	11/2005 Laroia et al.
2003/0125040	A1	7/2003	Walton et al.		2005/0276343	A1	12/2005 Jones
2003/0128656	A1	7/2003	Scarpa		2006/0018247	A1	1/2006 Driesen et al.
2003/0128658	A1	7/2003	Walton et al.		2006/0018395	A1	1/2006 Tzannes
2003/0139194	A1	7/2003	Onggosanusi et al.		2006/0039275	A1	2/2006 Walton et al.
2003/0139196	A1	7/2003	Medvedev et al.		2006/0067417	A1	3/2006 Park et al.
2003/0142732	A1	7/2003	Moshavi et al.		2006/0072649	A1	4/2006 Chang et al.
					2006/0077935	A1	4/2006 Hamalainen et al.
					2006/0104196	A1	5/2006 Wu et al.
					2006/0104340	A1	5/2006 Walton et al.
					2006/0114858	A1	6/2006 Walton et al.

(56)	References Cited			EP	1175022	A2	1/2002
	U.S. PATENT DOCUMENTS			EP	1182799	A2	2/2002
				EP	1185001	A2	3/2002
				EP	1185015		3/2002
2006/0153237	A1	7/2006	Hwang et al.	EP	1207635		5/2002
2006/0159120	A1	7/2006	KIm	EP	1207645	A1	5/2002
2006/0176968	A1	8/2006	Keaney et al.	EP	1185048		6/2002
2006/0183497	A1*	8/2006	Paranchych et al. 455/522	EP	1223702	A1	7/2002
2006/0209894	A1	9/2006	Tzannes et al.	EP	1241824	A1	9/2002
2006/0209937	A1	9/2006	Tanaka et al.	EP	1265411		12/2002
2006/0285605	A1	12/2006	Walton et al.	EP	1315311	A1	5/2003
2007/0177681	A1	8/2007	Choi et al.	EP	1379020		1/2004
2007/0274278	A1	11/2007	Choi et al.	EP	1387545		2/2004
2008/0069015	A1	3/2008	Walton et al.	EP	1416688	A1	5/2004
2008/0267098	A1	10/2008	Walton et al.	EP	1447934	A1	8/2004
2008/0267138	A1	10/2008	Walton et al.	EP	1556984	A2	7/2005
2008/0285488	A1	11/2008	Walton et al.	GB	2300337		10/1996
2008/0285669	A1	11/2008	Walton et al.	GB	2373973	A	10/2002
2008/0285670	A1	11/2008	Walton et al.	JP	03104430		5/1991
2009/0129454	A1	5/2009	Medvedev et al.	JP	06003956		1/1994
2009/0161613	A1	6/2009	Kent et al.	JP	06501139		1/1994
2009/0291642	A1	11/2009	Cozzo et al.	JP	08274756		10/1996
2010/0067401	A1	3/2010	Medvedev et al.	JP	9135230		5/1997
2010/0119001	A1	5/2010	Walton et al.	JP	9266466		10/1997
2010/0142636	A1	6/2010	Heath, Jr. et al.	JP	9307526		11/1997
2010/0183088	A1	7/2010	Inanoglu	JP	09327073		12/1997
2010/0208841	A1	8/2010	Walton et al.	JP	9512156		12/1997
2010/0220825	A1	9/2010	Dubuc et al.	JP	10028077		1/1998
2010/0260060	A1	10/2010	Abraham et al.	JP	10051402	A	2/1998
2010/0271930	A1	10/2010	Tong et al.	JP	10084324		3/1998
2011/0096751	A1	4/2011	Ma et al.	JP	10209956		8/1998
2011/0216808	A1	9/2011	Tong et al.	JP	10303794	A	11/1998
2011/0235744	A1	9/2011	Ketchum et al.	JP	10327126		12/1998
2012/0134435	A1	5/2012	Kapoor et al.	JP	1132027		2/1999
2012/0140664	A1	6/2012	Walton et al.	JP	1141159		2/1999
2012/0176928	A1	7/2012	Wallace et al.	JP	2991167		3/1999
2012/0219093	A1	8/2012	Jia et al.	JP	11069431	A	3/1999
2013/0040682	A1	2/2013	Chang et al.	JP	11074863		3/1999
2013/0235825	A1	9/2013	Walton et al.	JP	11163823	A	6/1999
2013/0279614	A1	10/2013	Walton et al.	JP	11205273		7/1999
2014/0036823	A1	2/2014	Ma et al.	JP	11252037	A	9/1999
2014/0348258	A1	11/2014	Walton et al.	JP	11317723	A	11/1999
2015/0365147	A1	12/2015	Ketchum et al.	JP	2000068975	A	3/2000
				JP	2000078105		3/2000
				JP	2000092009	A	3/2000
				JP	2001044930	A	2/2001
				JP	200186045		3/2001
CA	2690247	10/2001		JP	2001103034	A	4/2001
CN	1086061	4/1994		JP	2001186051		7/2001
CN	1234661	11/1999		JP	2001510668	A	7/2001
CN	1298266	A	6/2001	JP	2001217896		8/2001
CN	1308794	8/2001		JP	2001231074		8/2001
CN	1314037	A	9/2001	JP	2001237751	A	8/2001
CN	1325198	12/2001		JP	200264879		2/2002
CN	1325243	A	12/2001	JP	2002504283		2/2002
CN	1339885	A	3/2002	JP	200277098		3/2002
CN	1347609	A	5/2002	JP	200277104		3/2002
CN	1469662	1/2004		JP	2002111627		4/2002
CN	1489836	A	4/2004	JP	2002118534	A	4/2002
CN	1537371	10/2004		JP	2002510932	A	4/2002
DE	19951525	A1	6/2001	JP	2002514033	A	5/2002
EP	0755090	1/1997		JP	2002164814		6/2002
EP	0762701	3/1997		JP	2002176379		6/2002
EP	0772329	5/1997		JP	2002204217		7/2002
EP	0805568	A1	11/1997	JP	2002232943	A	8/2002
EP	0869647	A2	10/1998	JP	2003504941		2/2003
EP	08095387	2/1999		JP	2003198442		7/2003
EP	0929172	A1	7/1999	JP	2003530010		10/2003
EP	0951091	A2	10/1999	JP	2004266586		9/2004
EP	0991221	A2	4/2000	JP	2004297172		10/2004
EP	0993211	4/2000		JP	2004535694		11/2004
EP	1061446	12/2000		JP	2005519520		6/2005
EP	1075093	2/2001		JP	2006504372		2/2006
EP	1087545	A1	3/2001	JP	4860925		11/2011
EP	1117197	A2	7/2001	KR	200011799		2/2000
EP	1126673	A2	8/2001	KR	20010098861		11/2001
EP	1133070	9/2001		KR	1020020003370		1/2002
EP	1137217	9/2001		KR	20030085040		11/2003
EP	1143754	10/2001		KR	2006-0095576		8/2006
EP	1170879	1/2002					

(56)

References Cited

FOREIGN PATENT DOCUMENTS

RU	2015281	C1	6/1994
RU	2111619		5/1998
RU	2134489		8/1999
RU	2139633		10/1999
RU	2141168		11/1999
RU	214509		5/2000
RU	2152132	C1	6/2000
RU	2157592		10/2000
RU	2158479	C2	10/2000
RU	2168277		5/2001
RU	2168278		5/2001
RU	2197781	C2	1/2003
RU	2201034		3/2003
RU	2335852		1/2006
TW	419912		1/2001
TW	496620		7/2002
TW	503347		9/2002
TW	200300636		6/2003
TW	545006	B	8/2003
TW	567689		12/2003
TW	567701		12/2003
TW	583842	B	4/2004
TW	1230525		4/2005
TW	1263449		10/2006
TW	1267251	B	11/2006
WO	WO8607223		12/1986
WO	9210890	A1	6/1992
WO	WO9307684	A1	4/1993
WO	WO9507578		3/1995
WO	9516319	A1	6/1995
WO	9521501	A1	8/1995
WO	9530316		11/1995
WO	9532567		11/1995
WO	WO9622662	A1	7/1996
WO	WO9635268		11/1996
WO	9702667		1/1997
WO	9719525		5/1997
WO	WO9736377	A1	10/1997
WO	WO9809381		3/1998
WO	WO9809395		3/1998
WO	WO9824192	A1	6/1998
WO	WO9826523		6/1998
WO	WO9830047		7/1998
WO	WO9857472		12/1998
WO	WO9903224		1/1999
WO	WO9914878		3/1999
WO	WO9916214		4/1999
WO	WO9929049	A2	6/1999
WO	9944379		9/1999
WO	WO9952224	A1	10/1999
WO	WO9957820		11/1999
WO	WO0011823	A1	3/2000
WO	WO0036764	A2	6/2000
WO	WO0062456		10/2000
WO	0105067		1/2001
WO	WO0126269		4/2001
WO	WO0163775	A2	8/2001
WO	WO0169801		9/2001
WO	WO0171928		9/2001
WO	0176110		10/2001
WO	WO0180510		10/2001
WO	WO0182521	A2	11/2001
WO	WO0195531	A2	12/2001
WO	WO0197400	A2	12/2001
WO	0205506		1/2002
WO	WO0201732	A2	1/2002
WO	WO0203557		1/2002
WO	WO0215433	A1	2/2002
WO	0225853		3/2002
WO	WO02060138	A2	8/2002
WO	WO02062002	A1	8/2002
WO	WO02065664		8/2002
WO	02069590		9/2002
WO	WO02069523		9/2002
WO	WO02073869	A1	9/2002

WO	WO02075955		9/2002
WO	02078211		10/2002
WO	WO02082689	A2	10/2002
WO	WO02088656		11/2002
WO	WO02093784	A1	11/2002
WO	WO02099992		12/2002
WO	WO 03/010984		2/2003
WO	WO03010994	A1	2/2003
WO	03019984		3/2003
WO	WO03028153		4/2003
WO	WO03034646	A2	4/2003
WO	WO03047140	A1	6/2003
WO	WO03075479		9/2003
WO	WO04002011		12/2003
WO	WO04002047		12/2003
WO	2004039011		5/2004
WO	WO2004038985	A2	5/2004
WO	WO2004038986		5/2004
WO	WO2004039022		5/2004
WO	WO2005041515		5/2005
WO	WO2005043855		5/2005
WO	WO2005046113	A2	5/2005

OTHER PUBLICATIONS

International Search Report-PCT/US04/038198, International Search Authority-European Patent Office, Apr. 4, 2005.

Alamouti, S.M., "A Simple Transmit Diversity Technique for Wireless Communications," IEEE Journal on Select Areas in Communications, vol. 16, No. 8, Oct. 1998, pp. 1451-1458.

Chen et al., "Novel Space-Time Processing of DS/CDMA Multipath Signal," IEEE 49th, Vehicular Technology Conference, Houston, Texas, May 16-20, 1999, pp. 1809-1813.

Choi et al., "MIMO Transmit Optimization for Wireless Communication Systems," Proceedings of the First IEEE International workshops on Electronic, Design, Piscataway, New Jersey, Jan. 29-31, 2002.

Haustein et al., "Performance of MIMO Systems with Channel Inversion," IEEE 55th, Vehicular Technology Conference, Birmingham, Alabama, May 6-9, 2002, pp. 35-39.

Hong et al., "Robust Frequency Offset Estimation for Pilot Symbol Assisted Packet CDMA with MIMO Antenna Systems," IEEE Communications Letters, vol. 6, No. 6:262-264 (Jun. 2002).

Joham et al., "Symbol Rate Processing for the Downlink of DS-CDMA Systems", IEEE Journal on Selected Areas in Communications, IEEE Service Center, Piscataway, US, vol. 19, No. 1, Jan. 1, 2001, XP011055296, ISSN: 0733-8716, paragraphs 1, 2, 4, 5.

Pautler et al., "On Application of Multiple-Input Multiple-Output Antennas to CDMA Cellular Systems," IEEE 54th, Vehicular Technology Conference Proceedings, Atlantic City, New Jersey, Oct. 7-11, 2001, pp. 1508-1512.

Tarighat et al., "Performance analysis of different algorithms for cdma2000 antenna array system and a new multi user beamforming (MUB) algorithm", Wireless Communications and Networking Conference, 2000. WCNC. 2000 IEEE E Sep. 23-28, 2000, Piscataway, NJ, USA, IEEE, vol. 1, Sep. 23, 2000, pp. 409-414. XP010532534. ISBN: 978-0-7803-6596-4. Paragraphs 2, 3.

Theon et al., "Improved Adaptive Downlink for OFDM/SDMA-Based Wireless Networks," IEEE VTS 53rd, Vehicular Technology Conference, Rhodes, Greece, May 6-9, 2001.

Tujkovic, "High bandwidth efficiency space-time turbo coded modulation", Institute of Electrical and Electronics Engineers. ICC 2001. 2001 IEEE International Conference on Communications, Conference Record, Helsinki, Finland, Jun. 11-14, 2001, IEEE International Conference on Communications, New York, NY: IEEE, US, vol. 1 of 10, Jun. 11, 2001, pp. 1104-1109, XP010553500.

Zelst et al., "Space Division Multiplexing (SDM) for OFDM Systems," IEEE 51st, Vehicular Technology Conference Proceedings, Tokyo, Japan, May 15-18, 2000.

IEEE 802.11a, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-Speed physical Layer in the 5GHz Band", Sep. 1999.

(56)

References Cited

OTHER PUBLICATIONS

- Written Opinion, PCT/US2004-038198—International Search Authority—European Patent Office—Apr. 4, 2005.
- International Preliminary Report on Patentability—PCT/US2004/038198—International Preliminary Examining Authority—US—Feb. 18, 2006.
- 3GPP2 TIA/EIA/IS-2000-2-A, “Physical Layer Standard for cdma2000 Spread Spectrum Systems”, (Nov. 19, 1999).
- B. Hassibi, et al. “High-Rate Codes that are Linear in Space and Time,” LUCENT Technologies, Murray Hill, NY (USA), Aug. 22, 2000, (pp. 1-54).
- Gao, et al. “On implementation of Bit-Loading Algorithms for OFDM Systems with Multiple-Input Multiple Output,” VTC 2002-Fall. 2002 IEEE 56th. Vehicular Technology Conference Proceedings. Vancouver, Canada, Sep. 24-28, 2002, IEEE Vehicular Technology Con.
- Hayashi, K, A New Spatio-Temporal Equalization Method Based on Estimated Channel Response, Sep. 2001, IEEE Transaction on Vehicular Technology, vol. 50, Issue 5, pp. 1250-1259.
- Bingham, “Multicarrier Modulation for Data Transmission: An Idea Whose Time Has Come,” IEEE Communications Magazines, May 1990 (pp. 5-13).
- Jongren et al., “Utilizing Quantized Feedback Information in Orthogonal Space-Time Block Coding,” 2000 IEEE Global Telecommunications Conference, 2(4): 995-999, Nov. 27, 2000.
- Kiessling, et al., “Short-Term and Long Term Diagonalization of Correlated MIMO Channels with Adaptive Modulation,” IEEE Conference, vol. 2, (Sep. 15, 2002), pp. 593-597.
- L. Deneire, et al. “A Low Complexity ML Channel Estimator for OFDM,” Proc IEEE ICC Jun. 2001 pp. 1461-1465.
- Miyashita, et al., “High Data-Rate Transmission with Eigenbeam-Space Division Multiplexing (E-SDM) in a MIMO Channel,” VTC 2002-Fall. 2002 IEEE 56th. Vehicular Technology Conference Proceedings. Vancouver, Canada, Sep. 24-28, 2002, IEEE Vehicular Technology.
- S. M. Alamouti “A Simple Transmit Diversity Technique for Wireless Communications” IEEE Journal on Select Areas in Communications, Oct. 1998, vol. 16, No. 8, pp. 1451-1458.
- Dae-Ko Hong, Young-Jo Lee, Daesik Hong, and Chang-Eon Kang. “Robust frequency offset estimation for pilot symbol assisted packet CDMA with MIMO antenna systems.” Communications Letters. IEEE. Jun. 2002.
- S.W. Wales, A MIMO technique within the UTRA TDD standard Jun. 22, 2005.
- Bong-Gee Song et al., “Prefilter design using the singular value decomposition for MIMO equalization” Signals, Systems and Computers, vol. 1, Nov. 3, 1996 (Nov. 3, 1996),-Nov. 6, 1996 (Nov. 6, 1996), pp. 34-38, XP010231388, IEEE, US DOI: 10.1109/ACSSC.1996.600812 ISBN: 978-0/8186-7646-8, p. 35, col. 2, paragraph 4—p. 36, col. 1.
- Chung, J. et al: “Multiple antenna systems for 802.16 systems.” IEEE 802.16 Broadband Wireless Access Working Group <<http://ieee802.org/16>>, IEEE 802.16abc-01/31, Sep. 7, 2001, pp. 1-5.
- Diggavi, S. et al., “Inter-carrier interference in MIMO OFDM,” IEEE International Conference on Communications, (Aug. 2002), vol. 1, pp. 485-489, doi: 10.1109/ICC.2002.996901.
- Fujii, M.: “Pseudo-Orthogonal Multibeam-Time Transmit Diversity for OFDM-CDMA” pp. 222-226 (2002).
- Gore, D. A., et al.: “Selecting an optimal set of transmit antennas for a low rank matrix channel,” 2000 IEEE International Conference on Acoustics, Speech, and Signal Processing. Proceedings. (ICASSP). Istanbul, Turkey, Jun. 5-9, 2000, New York, NY; IEEE, US, vol. 5 of 6, (Jun. 5, 2000), pp. 2785-2788, XP001035763, abstract.
- Grunheid et al., “Adaptive Modulation and Multiple Access for the OFDM Transmission Technique”, Wireless Personal Communications 13: May 13, 2000, 2000 Kluwer Academic Publishers, pp. 4-13.
- Iserte, P., et al., “Joint beamforming strategies in OFDM-MIMO systems,” Acoustics, Speech, and Signal Processing, 1993.
- ICASSP-93., 1993 IEEE International Conference on, vol. 3, sections 2-3, Apr. 27-30, 1993, doi: 10.1109/ICASSP.2002.1005279.
- Le Goff S et al: “Turbo-codes and high spectral efficiency modulation” Communications, 1994. ICC “94, SUPERCOMM/ICC ’94, Conference Record, “Serving Humanity Through Communications.” IEEE International Conference on New Orleans, LA, USA May 1-5, 1994, New York, NY, USA. IEEE, May 1, 1994 (May 1, 1994), pp. 645-649, XP010126658 ISBN: 978-0-78031825-0.
- Lebrun G., et al., “MIMO transmission over a time varying TDD channel using SVD,” Electronics Letters, 2001, vol. 37, pp. 1363-1364.
- Li, Ye et. al., “Simplified Channel Estimation for OFDM Systems with Multiple Transmit Antennas,” IEEE Transactions on Wireless Communications, Jan. 2002, vol. 1, No. 1, pp. 67-75.
- Office Action dated Aug. 13, 2008 for Australian Application Serial No. 2004223374, 2 pages.
- Office Action dated Jun. 27, 2008 for Chinese Application Serial No. 200480011307.6, 3 pages.
- Sampath, H., et al., “Joint transmit and receive optimization for high data rate wireless communication using multiple antennas,” Signals, Systems, and Computers, 1999. Conference Record of the Thirty-Third Asilomar Conference, Oct. 24, 1999 (Oct. 24, 1999), XP010373976, pp. 215-219, IEEE, Piscataway, NJ, US.
- Singapore Search Report—SG200718746-1—Hungary Intellectual Patent Office—Aug. 12, 2011 (050452SGD2).
- Taiwan Search Report—TW093135893—TIPO—Jul. 6, 2011.
- The Authoritative Dictionary of IEEE Standards Terms, Seventh Edition, IEEE Press: New York (Dec. 2000), p. 902.
- Warner, W. et al.: “OFDM/FM Frame Synchronization for Mobile Radio Data Communication”, IEEE Transactions on Vehicular Technology, Aug. 1993, vol. 42, No. 3, pp. 302-313.
- Wolniansky, P.W.; Foschini, G.J.; Golden, G.D.; Valenzuela, R.A.;, “V-BLAST: an architecture for realizing very high data rates over the rich-scattering wireless channel,” Signals, Systems, and Electronics, 1998. ISSSE 98. 1998 URSI International Symposium, pp. 295-300, (Sep. 29-Oct. 2, 1998), doi: 10.1109/ISSSE.1998.738086.
- Wong, et al., “Multiuser OFDM With Adaptive Subcarrier, Bit, and Power Allocation,” Oct. 1999, IEEE Journal on Selected Areas in Communications, vol. 17, No. 10, pp. 1747-1758.
- Wyglinski Physical Layer Loading Algorithms for Indoor Wireless Multicarrier Systems, p. 109 Nov. 2004.
- Li Lihua, et al., “A Practical Space-Frequency Block Coded OFDM Scheme for Fast Fading Broadband Channels” 13th IEEE International Symposium on Personal Indoor and Mobile Radio Communications. PIMRC 2002. Sep. 15-18, 2002, pp. 212-216, vol. 1, XP002280831.
- M.A. Kousa, et al., “Multichannel adaptive system,” IEE Proceedings-I, vol. 140, No. 5, Oct. 1993, pages 357-364.
- Yoshiki, T., et al., “A Study on Subcarrier Adaptive Demodulation System using Multilevel Transmission Power Control for OFDM/FDD System,” The Institute of Electronics, Information and Communications Engineers general meeting, lecture collection, Japan, Mar. 7, 2000, Communication 1, p. 400.
- Partial European Search Report—EP10012069—Search Authority—The Hague—Nov. 29, 2011.
- Supplementary European Search Report—EP06759443—Search Authority—Hague—Nov. 24, 2011.
- Vook, F. W. et al., “Adaptive antennas for OFDM”, Vehicular Technology Conference, vol. 1, May 18-21, 1998, pp. 606-610, XP010287858, New York, NY, USA, IEEE, US DOI: 10.1109/VETEC.1998.686646 ISBN: 978-0/7803-4320-7.
- G. Bauch, J. Hagenauer, “Smart Versus Dumb Antennas—Capacities and FEC Performance,” IEEE Communications Letters, vol. 6, No. 2, pp. 55-57, Feb. 2002.
- Heath et al., “Multiuser diversity for MIMO wireless systems with linear receivers”, Conference Record of the 35th Asilomar Conference on Signals, Systems, & Computers, Nov. 4, 2001, pp. 1194-1199, vol. 2, IEEE, XP010582229, DOI: 10.1109/ACSSC.2001.987680, ISBN: 978-0-7803-7147-7.
- Sampath et al., “A Fourth-Generation MIMO-OFDM Broadband Wireless System: Design, Performance and Field Trial Results”, IEEE Communications Magazine, Sep. 1, 2002, pp. 143-149, vol.

(56)

References Cited

OTHER PUBLICATIONS

40, No. 9, IEEE Service Center, XP011092922, ISSN: 0163-6804, DOI: 10.1109/MCOM.2002.1031841.

3rd Generation Partnership Project (3GPP); Technical Specification Group (TSG); Radio Access Network (RAN); RF requirements for 1.28Mcps UTRA TDD option, 3GPP Standard; 3G TR 25.945, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, No. V2.0.0, Dec. 20, 2000 (Dec. 20, 2000), pp. 1-144, XP050400193, [retrieved on Dec. 20, 2000], p. 126.

3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Radio Resource Control (RRC); Protocol Specification (Release 5), 3GPP Standard; 3GPP TS 25.331, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, No. V5.2.0, Sep. 1, 2002 (Sep. 1, 2002), pp. 1-938, XP050367950, pp. 124, 358 -p. 370.

"3rd Generation Partnership Project; Technical Specification Group Radio Access 6-18, Network; Physical channels and mapping of 21-24 transport channels onto physical channels (TDD) (Release 5)", 3GPP Standard; 3GPP TS 25.221, 3rd Generation Partnership Project (3GPP), Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, No. V5.2.0, Sep. 1, 2002 (Sep. 1, 2002), pp. 1-97, XP050366967.

European Search Report—EP10177175—Search Authority—Munich—Jul. 9, 2012.

Nogueroles R et al., "Performance of a random OFDMA system for mobile communications", Broadband Communications, 1998. Accessing, Transmission, Networking. Proceedings. 1998 International Zurich Seminar on Zurich, Switzerland Feb. 17-19, 1998, New York, NY, USA, IEEE, US, Feb. 17, 1998 (Feb. 17, 1998), pp. 37-43, XP010277032, DOI: 10.1109/IZSBC.1998.670242 ISBN: 978-0-7803-3893-7 * p. 1-p. 2 *.

S. Catreux, P.F. Droessen, L.J. Greenstein, "Simulation results for an interference-limited multiple input multiple output cellular system", Global Telecommunications letters. IEEE: U.S.A. Nov. 2000. vol. 4(11), pp. 334-336. <http://ieeexplore.i>.

Varanasi M K et al., "Optimum decision feedback multiuser equalization with successive decoding achieves the total capacity of the Gaussian multiple-access channel", Signals, Systems & Computers, 1997. Conference Record of the Thirty-First Asilomar Conference on Pacific Grove, CA, USA Nov. 2-5 1997, Los Alamitos, CA, USA, IEEE Comput. Soc, US, vol. 2, Nov. 2, 1997 (Nov. 2, 1997), pp. 1405-1409, XP010280667, DOI: 10.1109/ACSSC.1997.679134 ISBN: 978-0-8186-8316-9 * pp. 1,3,5; figures 1,3*.

Sakaguchi et al., "Comprehensive Calibration for MIMO System", International Symposium on Wireless Personal Multimedia Communications, IEEE, vol. 2, Oct. 27, 2002, pp. 440-443.

Coleri, S. et al: "Channel Estimation Techniques Based on Pilot Arrangement in OFDM Systems," IEEE Transactions on Broadcasting, Sep. 1, 2002, pp. 223-229, vol. 48, No. 3, IEEE Service Center, XP011070267, ISSN: 0018-9316.

Editor: 3GPP Draft; 3rd Generation Partnership Project (3GPP), Technical Specification Group (TSG) Radio Access Network (RAN); Working Group 4(WG4); base Station conformance and testing", TS 25.141 V0.1.1 (May 1995)", R4-99349, Mobile Competence Centre; 650, Route Des Lucioles; F-06921 Sophia-Antipolis Cedex; France, vol. RAN WG4, No. Miami; 20011024, Oct. 24, 2001 (Oct. 24, 2001), XP050166323.

EPO Communication pursuant to Article 94(3) EPC issued by the European Patent Office for Application No. 10174926.5 dated Aug. 1, 2013.

EPO Communication pursuant to Article 94(3) EPC issued by the European Patent Office for Application No. 10174932.3 dated Jul. 30, 2013.

Harada H., et al., "An OFDM-Based Wireless ATM Transmission System Assisted by a Cyclically ExtendedPN Sequence for Future Broad-Band Mobile Multimedia Communications", IEEE Transactions on Vehicular Technology, IEEE Service Center, Piscataway, NJ, US, vol. 50, No. 6, Nov. 1, 2001, XP011064321, ISSN: 0018-9545.

Lal D et al: "A novel MAC layer protocol for space division multiple access in wireless ad hoc networks", Computer Communications and Networks, 2002 Proceedings, Eleventh International Conference on Oct. 14, 2002 (Oct. 14, 2002), pp. 614-619.

Louvigne J.C., et al., "Experimental study of a real-time calibration procedure of a CDMA/TDD multiple antenna terminal," IEEE Antennas and Propagation Society International Symposium, 2002 Digest.APS. San Antonio, TX, Jun. 16-21, 2002, vol. 2, Jun. 16, 2002, pp. 644-647, XP010591780, DOI: 10.1109/APS.2002.1016729, ISBN: 978-0-7803-7330-3.

Technical Search Report issued by the Taiwan Patent Office for TW Application No. 098143050, dated Aug. 2, 2013.

Yamamura, T et al., "High Mobility OFDM transmission system by a new channel estimation and ISI cancellation scheme using characteristics of pilot symbol inserted OFDM signal", Vehicular Technology Conference, vol. 1, Sep. 19, 1999-Sep. 22, 1999, pp. 319-323, XP010352958 IEEE, Piscataway, NJ, USA, ISBN: 0-7803-5435-4.

* cited by examiner

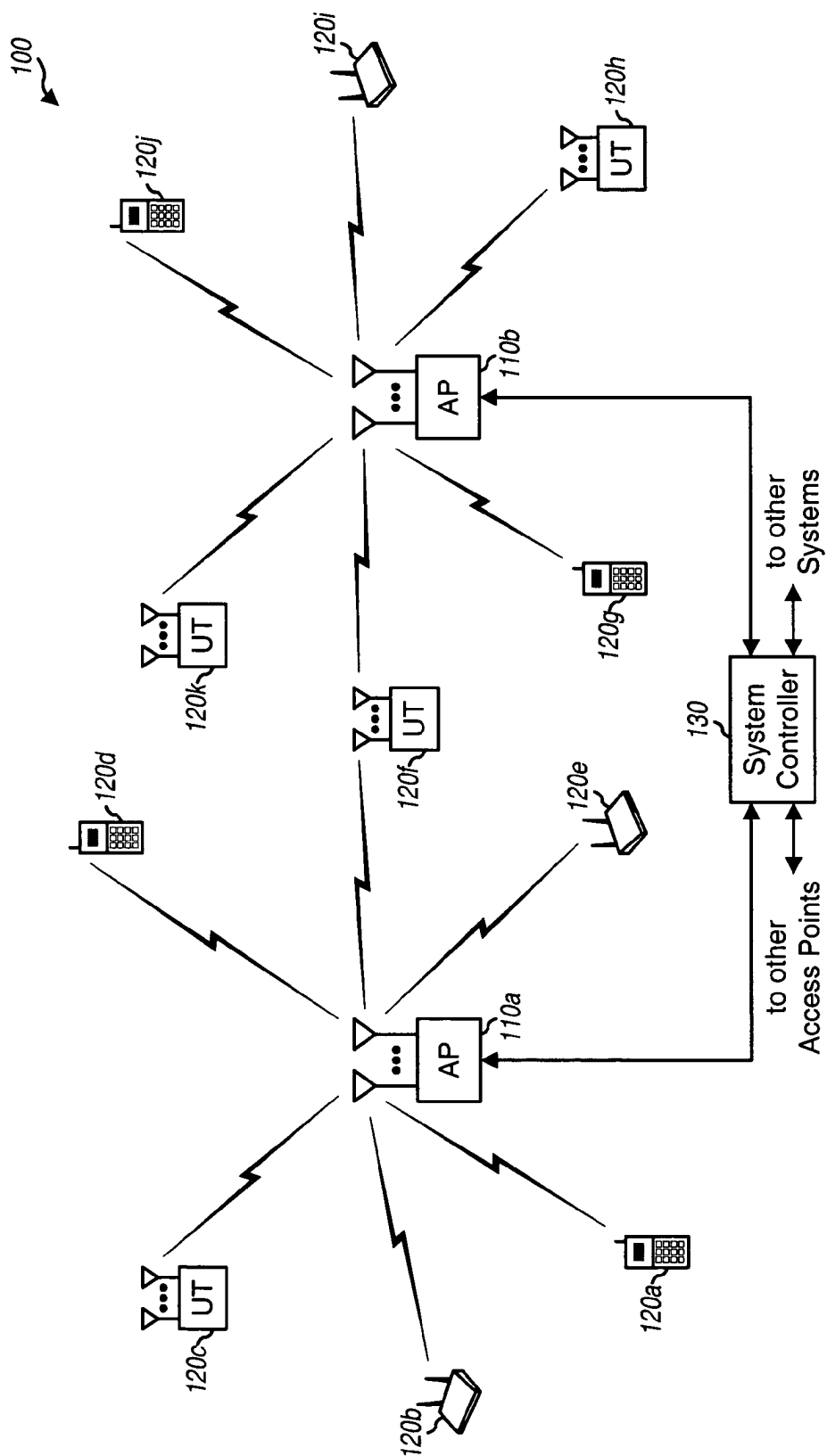
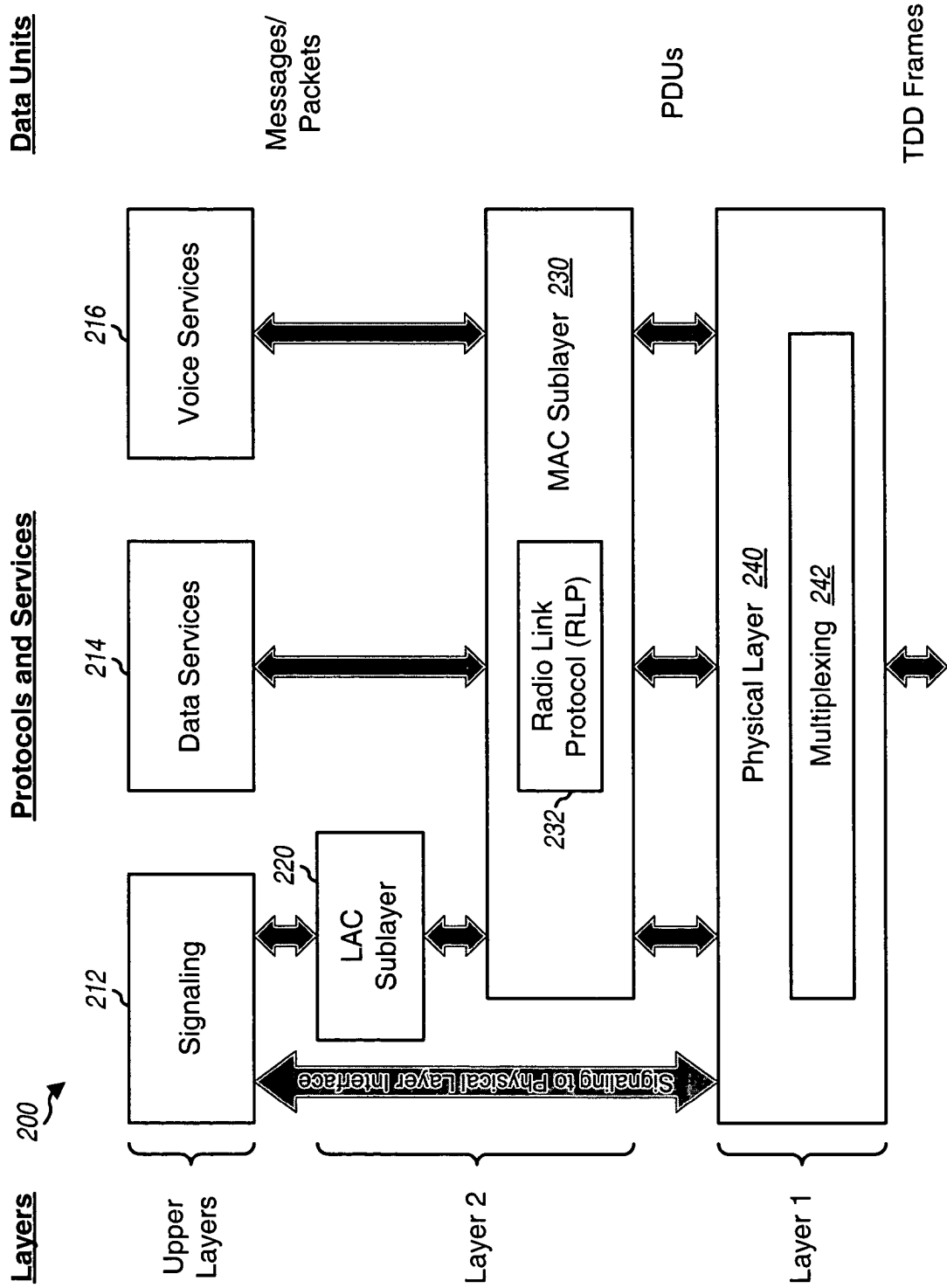


FIG. 1



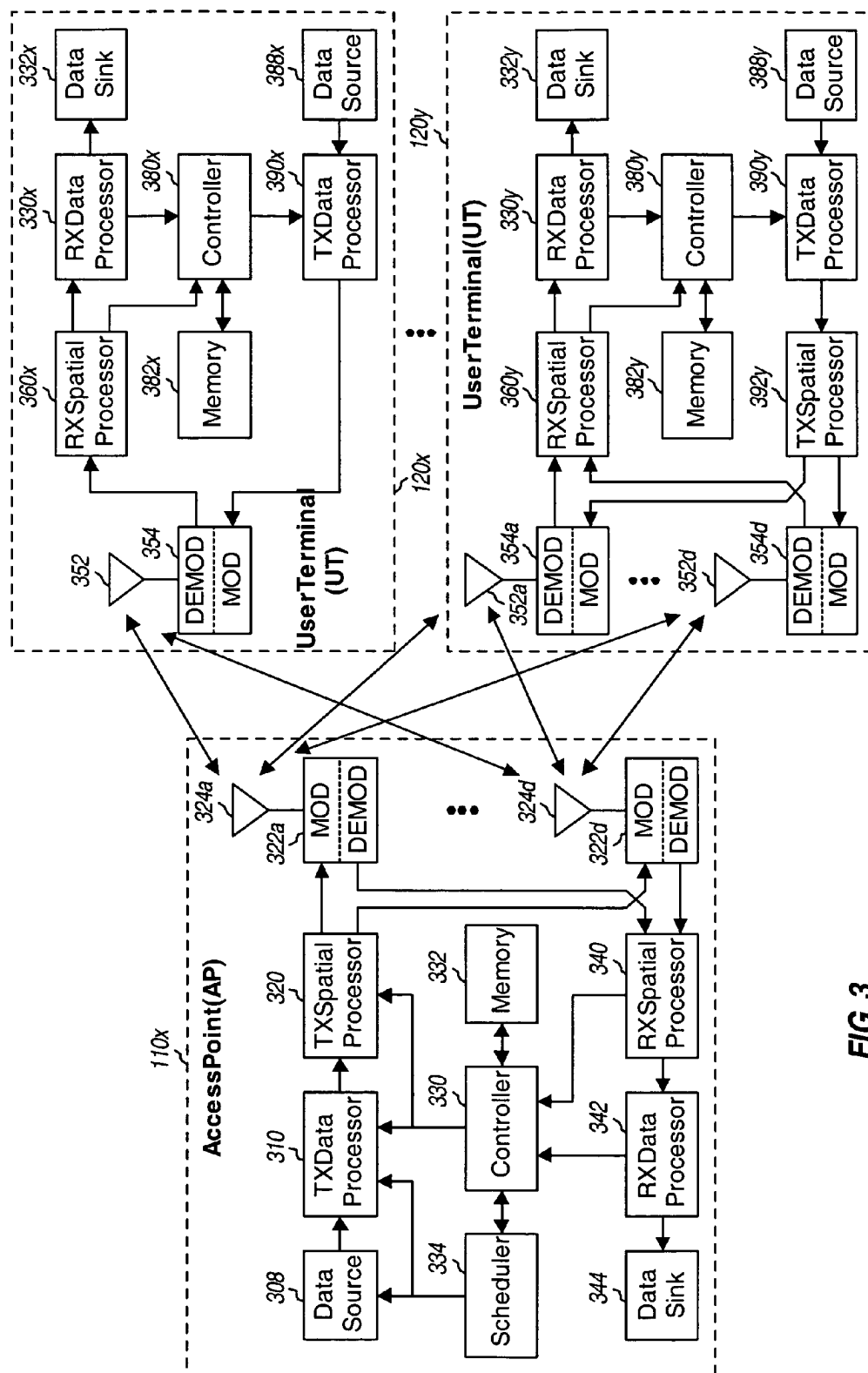


FIG. 3

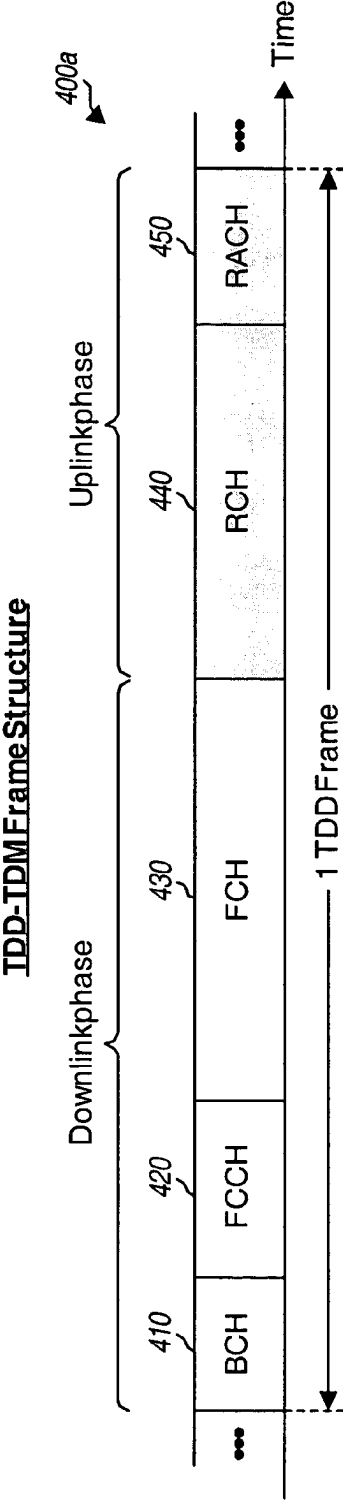


FIG. 4A

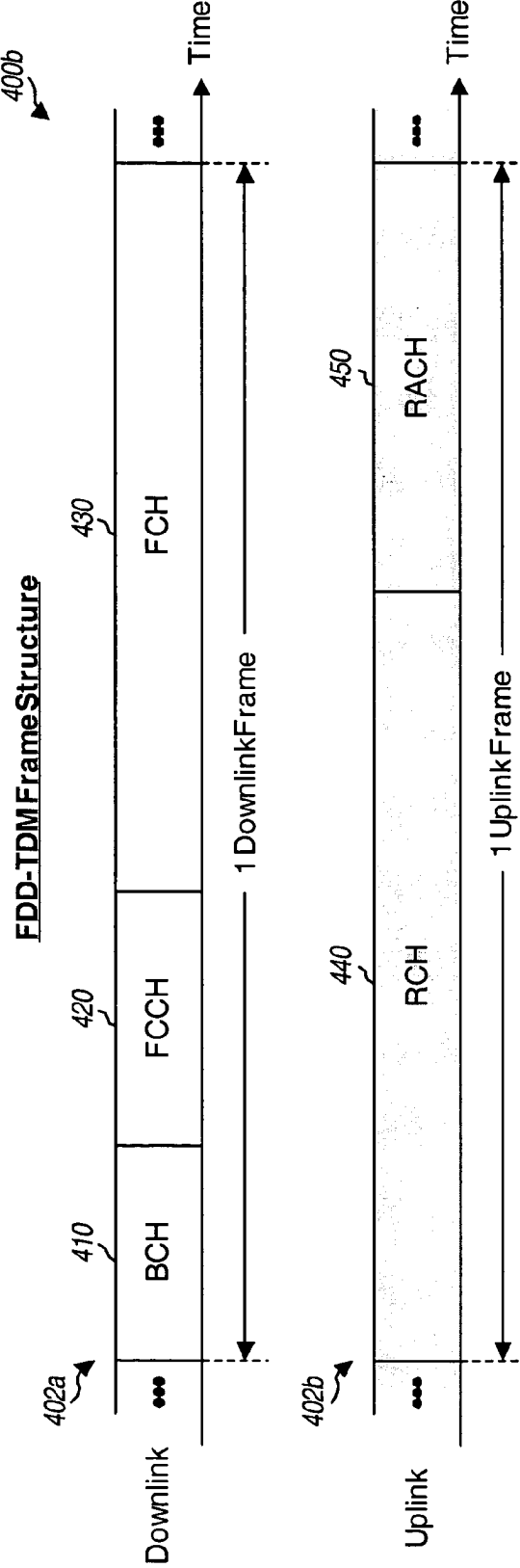
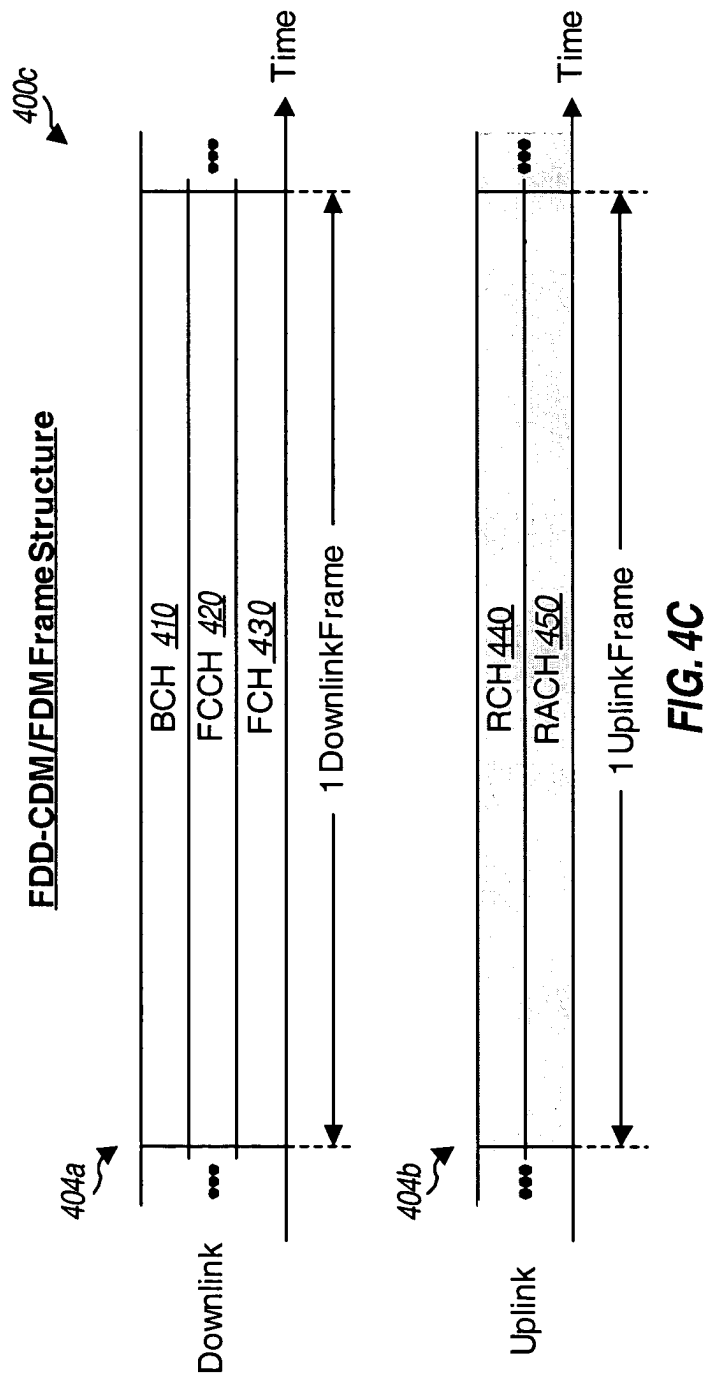


FIG. 4B



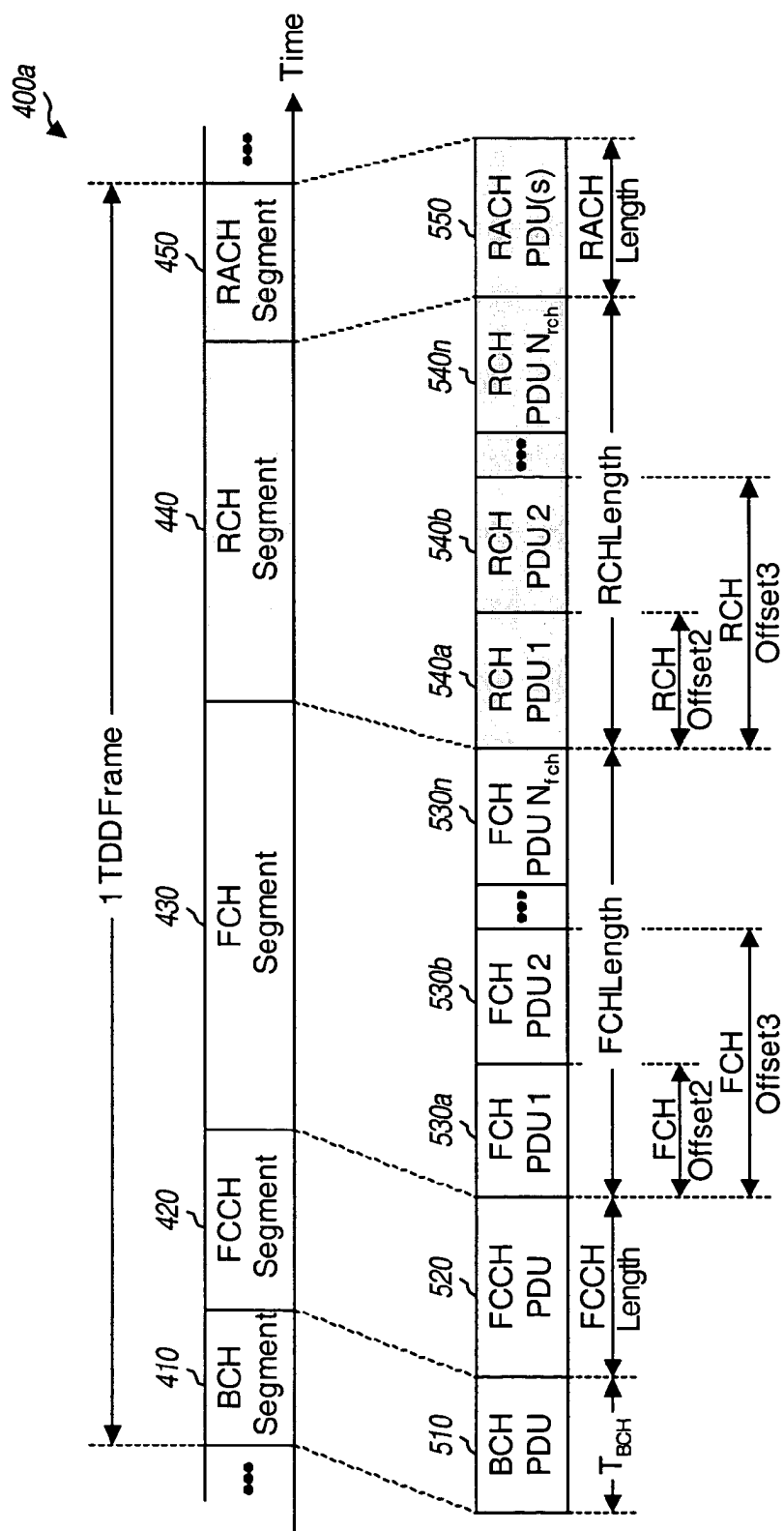
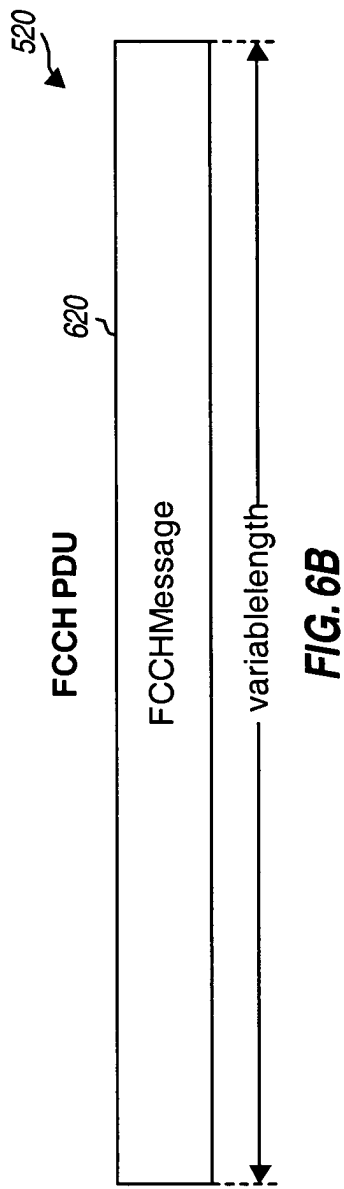
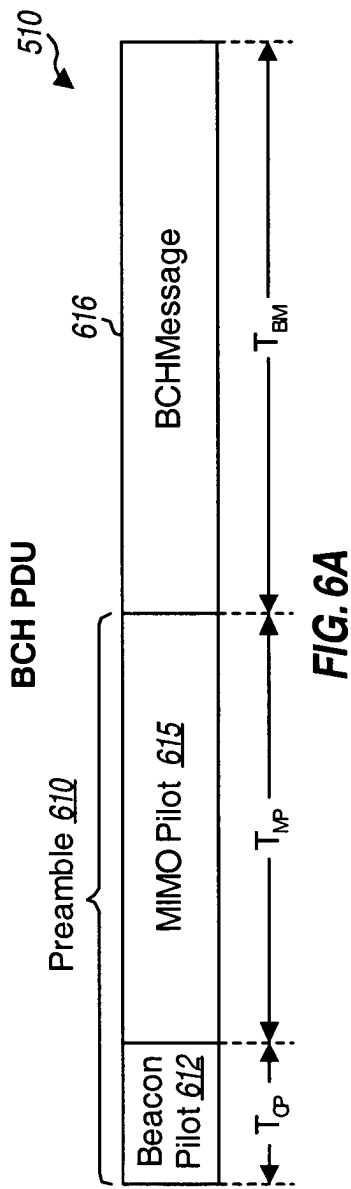


FIG. 5



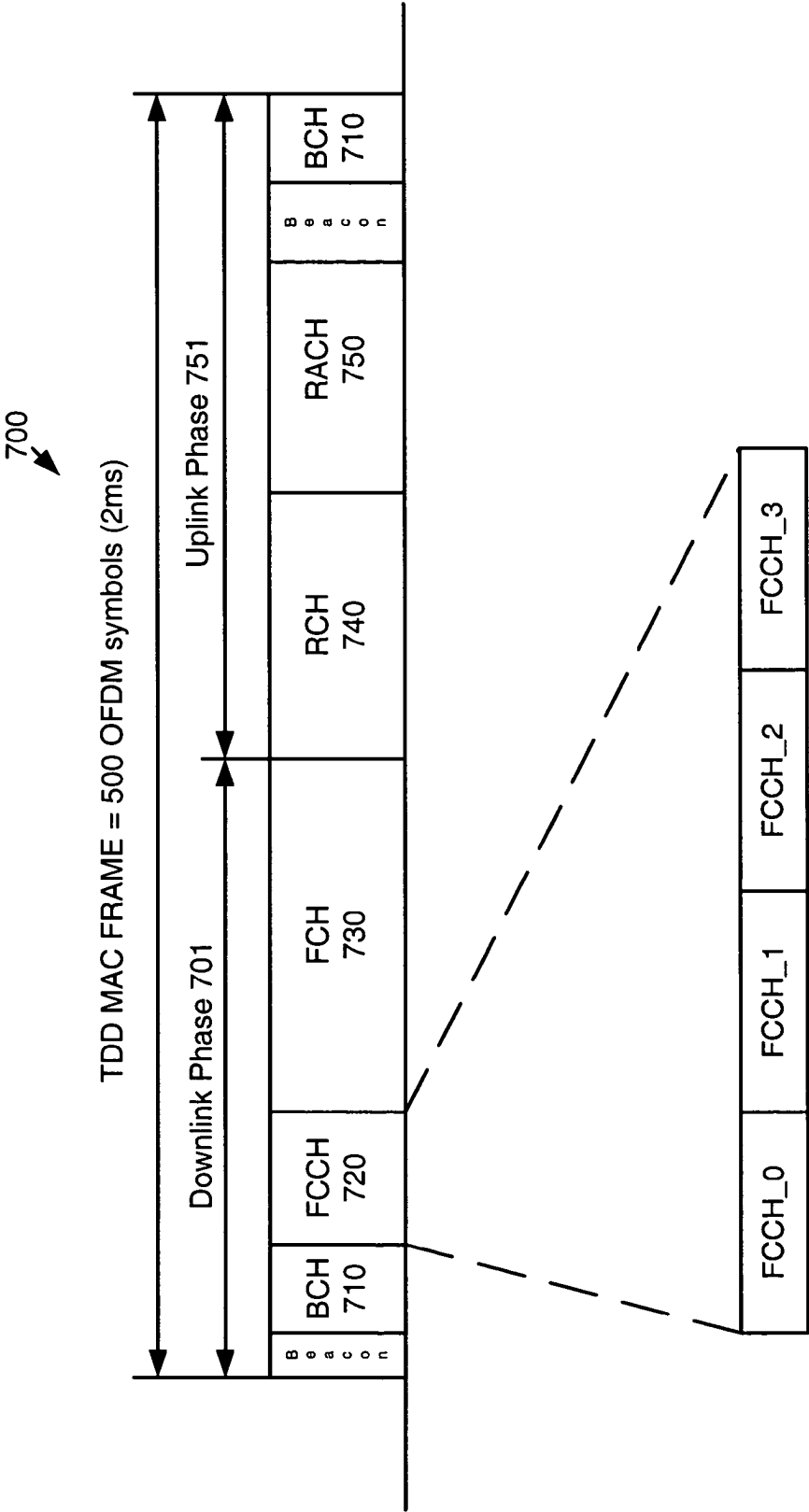
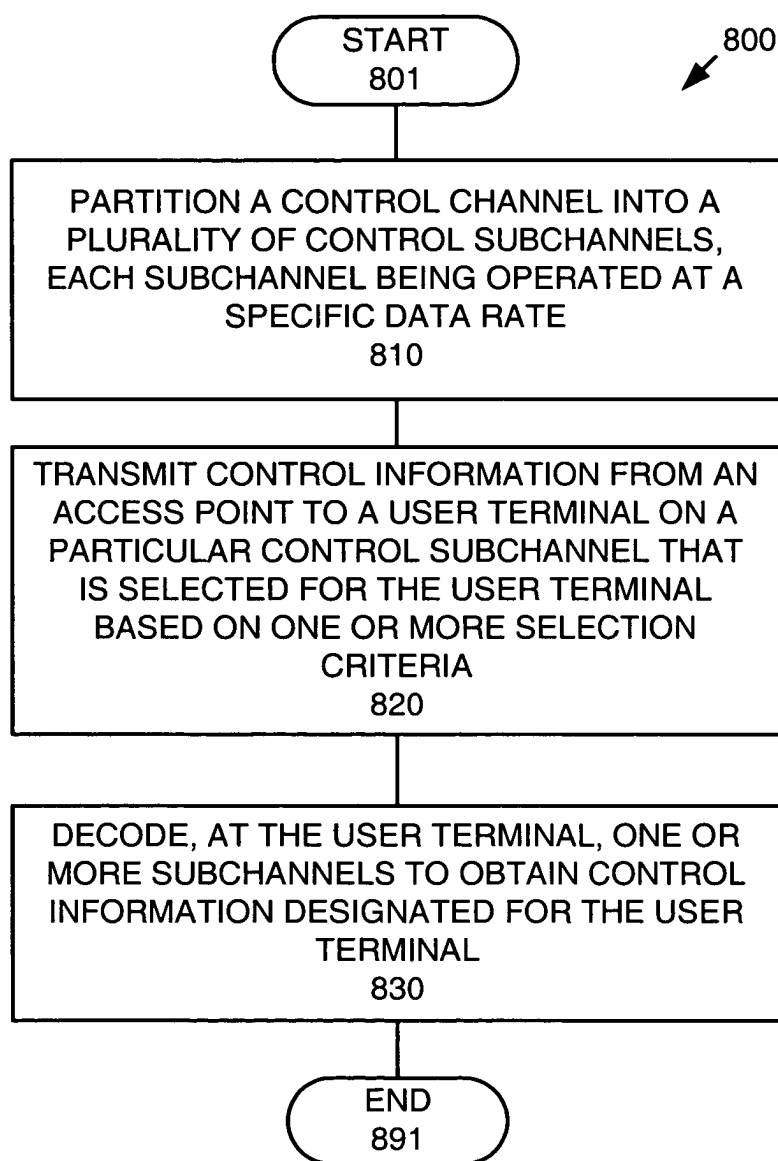
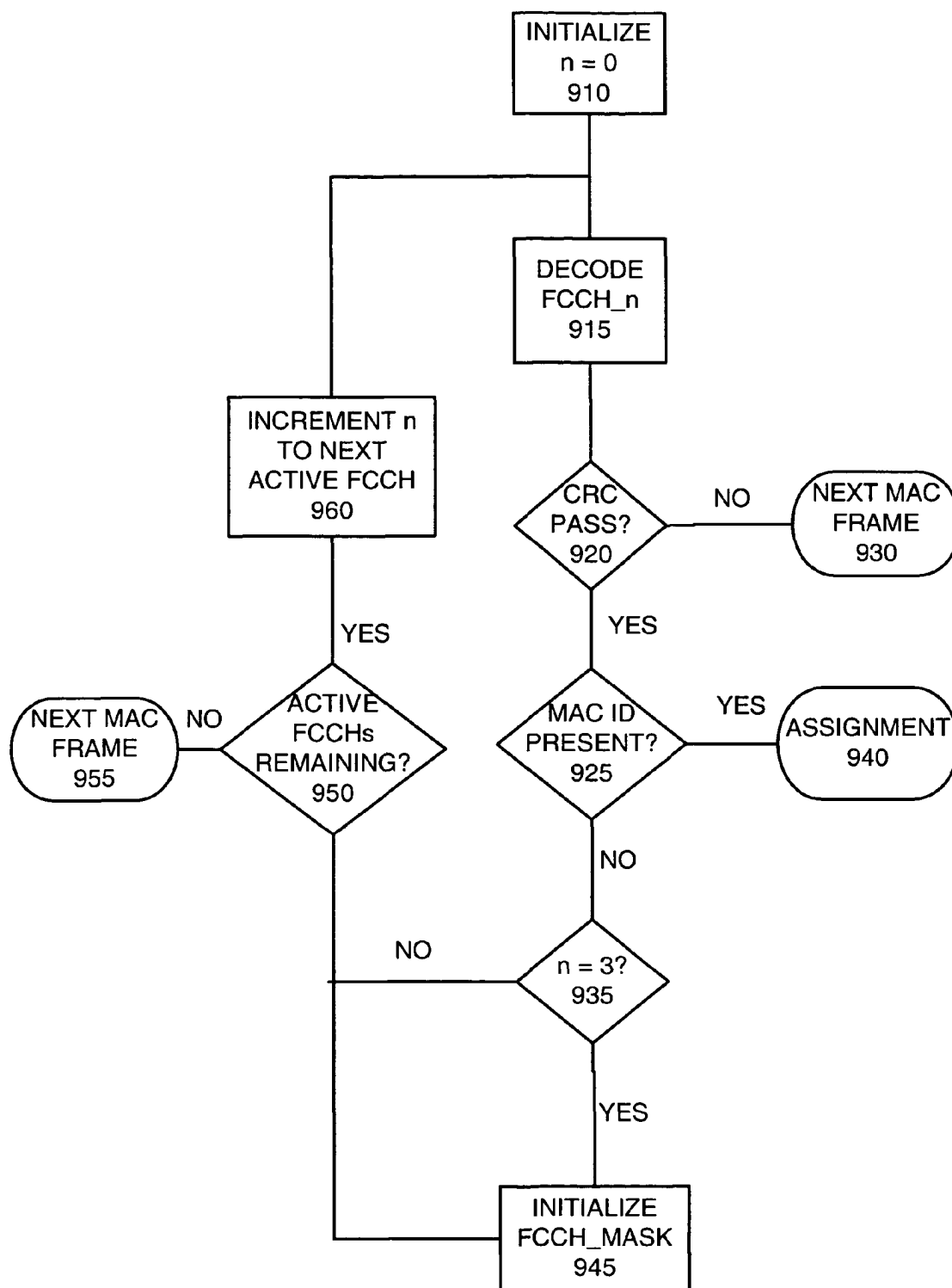


FIG. 7

**FIG. 8**

**FIG. 9**

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METHOD AND APPARATUS FOR PROVIDING AN EFFICIENT CONTROL CHANNEL STRUCTURE IN A WIRELESS COMMUNICATION SYSTEM

BACKGROUND

I. Field

The present invention relates generally to data communication and processing, and more specifically to a method and apparatus for providing an efficient control channel structure in a wireless local area network (WLAN) communication system.

II. Background

Wireless communication systems have been widely deployed to provide various types of communication such as voice, packet data, and so on. These systems may be multiple-access systems capable of supporting communication with multiple users sequentially or simultaneously by sharing the available system resources. Examples of multiple-access systems include Code Division Multiple Access (CDMA) systems, Time Division Multiple Access (TDMA) systems, and Frequency Division Multiple Access (FDMA) systems.

In recent years, wireless local area networks (WLANs) have also been widely deployed in accordance with various WLAN standards (e.g., IEEE 802.11a, 802.11b, and 802.11g, etc.) to enable communication among wireless electronic devices (e.g., computers) via wireless link. A WLAN may employ devices called access points (or base stations) that act like hubs and/or routers and provide connectivity for other wireless devices in the network (e.g., user terminals or user stations). The access points may also connect (or "bridge") the WLAN to wired LANs, thus allowing the wireless devices access to LAN resources.

In a wireless communication system, a radio frequency (RF) modulated signal from a transmitter unit may reach a receiver unit via a number of propagation paths. The characteristics of the propagation paths typically vary over time due to a number of factors, such as fading and multipath. To provide diversity against deleterious path effects and improve performance, multiple transmit and receive antennas may be used. If the propagation paths between the transmit and receive antennas are linearly independent (e.g., a transmission on one path is not formed as a linear combination of the transmissions on the other paths), then the likelihood of correctly receiving a data transmission increases as the number of antennas increases. Generally, diversity increases and performance improves as the number of transmit and receive antennas increases.

A MIMO system employs multiple (N_T) transmit antennas and multiple (N_R) receive antennas for data transmission. A MIMO channel formed by the N_T transmit and N_R receive antennas may be decomposed into N_S spatial channels, with $N_S \leq \min\{N_T, N_R\}$. Each of the N_S spatial channels corresponds to a dimension. The MIMO system can provide improved performance (e.g., increased transmission capacity and/or greater reliability) if the additional dimensionalities created by the multiple transmit and receive antennas are utilized.

An exemplary MIMO WLAN system is described in the aforementioned U.S. patent application Ser. No. 10/693,419, assigned to the assignee of the present invention. Such a MIMO WLAN system may be configured to provide various types of services and support various types of applications, and achieve a high level of system performance. In various embodiments, MIMO and orthogonal frequency division

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multiplexing (OFDM) may be employed to attain high throughput, combat deleterious path effects, and provide other benefits. Each access point in the system may be configured to support multiple user terminals. The allocation of downlink and uplink resources may be dependent on the requirements of the user terminals, the channel conditions, and other factors.

In one embodiment, the WLAN system as disclosed in the aforementioned U.S. patent application employs a channel structure designed to support efficient downlink and uplink transmissions. Such a channel structure may comprise a number of transport channels that may be used for various functions, such as signaling of system parameters and resource assignments, downlink and uplink data transmissions, random access of the system, and so on. Various attributes of these transport channels may be configurable, which allows the system to easily adapt to changing channel and loading conditions. One of these transport channels, called forward control channel (FCCH), may be used by the access point to allocate resources (e.g., channel assignments) on the downlink and uplink. The FCCH may also be used to provide acknowledgment for messages received on another transport channel.

As disclosed in the aforementioned U.S. patent application, in one embodiment, the FCCH can be transmitted or operable at different data rates (e.g., four different data rates). For example, the different data rates may include 0.25 bps/Hz, 0.5 bps/Hz, 1 bps/Hz, and 2 bps/Hz. However, in such a configuration, the rate employed on the FCCH is dictated by the worst case user in the system (i.e., the user that operates at the lowest data rate). This scheme is inefficient because a single user that cannot operate at a higher rate may reduce the efficiency and utilization of the FCCH, even though other users in the system may be able to operate at higher data rates.

There is, therefore, a need in the art for a method and apparatus to provide a more efficient control channel structure that is able to accommodate different users that may operate at different data rates.

SUMMARY

The various aspects and embodiments of the invention are described in further detail below. According to one aspect of the invention, a method is provided in which a control channel used for transmitting control information is partitioned into a plurality of subchannels each of which is operated at a specific data rate. For each of one or more user terminals, one of the subchannels is selected based on one or more selection criteria for transmitting control information from an access point to the respective user terminal. Control information is transmitted from the access point to a user terminal on a particular subchannel selected for the respective user terminal. At the user terminal, one or more subchannels are decoded to obtain control information designated for the user terminal.

BRIEF DESCRIPTION OF THE DRAWINGS

The various features and aspects of the invention can be understood from the detailed description set forth below in conjunction with the following drawings, in which:

FIG. 1 shows a block diagram of a MIMO WLAN system in which the teachings of the invention are implemented;

FIG. 2 shows a layer structure for the MIMO WLAN system;

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FIG. 3 is a block diagram illustrating various components of an access point and user terminals;

FIGS. 4A, 4B and 4C show a TDD-TDM frame structure, an FDD-TDM frame structure, and an FDD-CDM frame structure, respectively;

FIG. 5 shows the TDD-TDM frame structure with five transport channels—BCH, FCCH, FCH, RCH, and RACH;

FIGS. 6A and 6B illustrate various PDU formats for the various transport channels;

FIG. 7 shows a new FCCH structure, in accordance with one embodiment of the invention;

FIG. 8 shows a flow diagram of a method, in accordance with one embodiment of the invention; and

FIG. 9 shows a flow diagram of a decoding process in accordance with one embodiment of the invention.

DETAILED DESCRIPTION

The word “exemplary” is used herein to mean “serving as an example, instance, or illustration.” Any embodiment or design described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other embodiments or designs.

FIG. 1 shows a MIMO WLAN system 100 in which the teachings of the present invention are implemented. As shown in FIG. 1, MIMO WLAN system 100 includes a number of access points (APs) 110 that support communication for a number of user terminals (UTs) 120. For simplicity, only two access points 110 are shown in FIG. 1. An access point may also be referred to as a base station, access controller, or communication controller herein.

User terminals 120 may be dispersed throughout the system. Each user terminal may be a fixed or mobile terminal that can communicate with the access point. A user terminal may also be referred to as a mobile station, a remote station, an access terminal, a user equipment (UE), a wireless device, or some other terminology herein. Each user terminal may communicate with one or possibly multiple access points on the downlink and/or uplink at any given moment. The downlink (also called forward link) refers to transmission from the access point to the user terminal, and the uplink (also called reverse link) refers to transmission from the user terminal to the access point.

In FIG. 1, access point 110a communicates with user terminals 120a through 120f, and access point 110b communicates with user terminals 120f through 120k. Depending on the specific design of system 100, an access point may communicate with multiple user terminals simultaneously (e.g., via multiple code channels or subbands) or sequentially (e.g., via multiple time slots). At any given moment, a user terminal may receive downlink transmissions from one or multiple access points. The downlink transmission from each access point may include overhead data intended to be received by multiple user terminals, user-specific data intended to be received by specific user terminals, other types of data, or any combination thereof. The overhead data may include pilot, page and broadcast messages, system parameters, and so on.

In one embodiment, the MIMO WLAN system is based on a centralized controller network architecture. Thus, a system controller 130 couples to access points 110 and may further couple to other systems and networks. For example, system controller 130 may couple to a packet data network (PDN), a wired local area network (LAN), a wide area network (WAN), the Internet, a public switched telephone network (PSTN), a cellular communication network, etc. System controller 130 may be designed to perform a number

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of functions such as (1) coordination and control for the access points coupled to it, (2) routing of data among these access points, (3) access and control of communication with the user terminals served by these access points, and so on.

The MIMO WLAN system as shown in FIG. 1 may be operated in various frequency bands (e.g., the 2.4 GHz and 5.x GHz U-NII bands), subject to the bandwidth and emission constraints specific to the selected operating band.

In one embodiment, each access point may be equipped with multiple transmit and receive antennas (e.g., four transmit and receive antennas) for data transmission and reception. Each user terminal may be equipped with a single transmit/receive antenna or multiple transmit/receive antennas for data transmission and reception. The number of antennas employed by each user terminal type may be dependent on various factors such as, for example, the services to be supported by the user terminal (e.g., voice, data, or both), cost considerations, regulatory constraints, safety issues, and so on.

For a given pairing of multi-antenna access point and multi-antenna user terminal, a MIMO channel is formed by the N_T transmit antennas and N_R receive antennas available for use for data transmission. Different MIMO channels are formed between the access point and different multi-antenna user terminals. Each MIMO channel may be decomposed into N_S spatial channels, with $N_S \leq \min\{N_T, N_R\}$. N_S data streams may be transmitted on the N_S spatial channels. Spatial processing is required at a receiver and may or may not be performed at a transmitter in order to transmit multiple data streams on the N_S spatial channels.

The N_S spatial channels may or may not be orthogonal to one another. This depends on various factors such as (1) whether or not spatial processing was performed at the transmitter to obtain orthogonal spatial channels and (2) whether or not the spatial processing at both the transmitter and the receiver was successful in orthogonalizing the spatial channels. If no spatial processing is performed at the transmitter, then the N_S spatial channels may be formed with N_S transmit antennas and are unlikely to be orthogonal to one another.

The N_S spatial channels may be orthogonalized by performing decomposition on a channel response matrix for the MIMO channel, as described in the aforementioned U.S. patent application. For a given number of (e.g., four) antennas at the access point, the number of spatial channels available for each user terminal is dependent on the number of antennas employed by that user terminal and the characteristics of the wireless MIMO channel that couples the access point antennas and the user terminal antennas. If a user terminal is equipped with one antenna, then the four antennas at the access point and the single antenna at the user terminal form a multiple-input single-output (MISO) channel for the downlink and a single-input multiple-output (SIMO) channel for the uplink.

The MIMO WLAN system as shown in FIG. 1 may be designed and configured to support various transmission modes, as illustrated in Table 1 below.

TABLE 1

Transmission modes	Description
SIMO	Data is transmitted from a single antenna but may be received by multiple antennas for receive diversity.
Diversity	Data is redundantly transmitted from multiple transmit antennas and/or multiple subbands to provide diversity.

TABLE 1-continued

Transmission modes	Description
Beam-steering	Data is transmitted on a single (best) spatial channel at full power using phase steering information for the principal eigenmode of the MIMO channel.
Spatial multi-plexing	Data is transmitted on multiple spatial channels to achieve higher spectral efficiency.

The transmission modes available for use for the downlink and uplink for each user terminal are dependent on the number of antennas employed at the user terminal. Table 2 lists the transmission modes available for different terminal types for the downlink and uplink, assuming multiple (e.g., four) antennas at the access point.

TABLE 2

Transmission modes	Downlink		Uplink	
	Single-antenna user terminal	Multi-antenna user terminal	Single-antenna user terminal	Multi-antenna user terminal
MISO (on downlink)/ SIMO (on uplink)	X	X	X	X
Diversity	X	X		X
Beam-steering	X	X		X
Spatial multi-plexing		X		X

In an embodiment, the MIMO WLAN system employs OFDM to effectively partition the overall system bandwidth into a number of (N_F) orthogonal subbands. These subbands are also referred to as tones, bins, or frequency channels. With OFDM, each subband is associated with a respective subcarrier that may be modulated with data. For a MIMO system that utilizes OFDM, each spatial channel of each subband may be viewed as an independent transmission channel where the complex gain associated with each subband is effectively constant across the subband bandwidth.

In one embodiment, the system bandwidth can be partitioned into 64 orthogonal subbands (i.e., $N_F=64$), which are assigned indices of -32 to $+31$. Of these 64 subbands, 48 subbands (e.g., with indices of $\pm\{1, \dots, 6, 8, \dots, 20, 22, \dots, 26\}$) can be used for data, 4 subbands (e.g., with indices of $\pm\{7, 21\}$) can be used for pilot and possibly signaling, the DC subband (with index of 0) is not used, and the remaining subbands are also not used and serve as guard subbands. This OFDM subband structure is described in further detail in a document for IEEE Standard 802.11a and entitled "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: High-speed Physical Layer in the 5 GHz Band," September 1999, which is publicly available. In other embodiments, different numbers of subbands and various other OFDM subband structures may also be implemented for the MIMO WLAN system. For example, all 53 subbands with indices from -26 to $+26$ may be used for data transmission. As another example, a 128-subband structure, a 256-subband structure, or a subband structure with some other number of subbands may be used.

For OFDM, the data to be transmitted on each subband is first modulated (i.e., symbol mapped) using a particular modulation scheme selected for use for that subband. Zeros are provided for the unused subbands. For each symbol

period, the modulation symbols and zeros for all N_F subbands are transformed to the time domain using an inverse fast Fourier transform (IFFT) to obtain a transformed symbol that contains N_F time-domain samples. The duration of each transformed symbol is inversely related to the bandwidth of each subband. In one specific design for the MIMO WLAN system, the system bandwidth is 20 MHz, $N_F=64$, the bandwidth of each subband is 312.5 KHz, and the duration of each transformed symbol is 3.2 μ sec.

OFDM can provide certain advantages, such as the ability to combat frequency selective fading, which is characterized by different channel gains at different frequencies of the overall system bandwidth. It is well known that frequency selective fading causes inter-symbol interference (ISI), which is a phenomenon whereby each symbol in a received signal acts as distortion to subsequent symbols in the received signal. The ISI distortion degrades performance by impacting the ability to correctly detect the received symbols. Frequency selective fading can be conveniently combated with OFDM by repeating a portion of (or appending a cyclic prefix to) each transformed symbol to form a corresponding OFDM symbol, which is then transmitted.

The length of the cyclic prefix (i.e., the amount to repeat) for each OFDM symbol is dependent on the delay spread of the wireless channel. In particular, to effectively combat ISI, the cyclic prefix should be longer than the maximum expected delay spread for the system.

In an embodiment, cyclic prefixes of different lengths may be used for the OFDM symbols, depending on the expected delay spread. For the MIMO WLAN system described above, a cyclic prefix of 400 nsec (8 samples) or 800 nsec (16 samples) may be selected for use for the OFDM symbols. A "short" OFDM symbol uses the 400 nsec cyclic prefix and has a duration of 3.6 μ sec. A "long" OFDM symbol uses the 800 nsec cyclic prefix and has a duration of 4.0 μ sec. Short OFDM symbols may be used if the maximum expected delay spread is 400 nsec or less, and long OFDM symbols may be used if the delay spread is greater than 400 nsec. Different cyclic prefixes may be selected for use for different transport channels, and the cyclic prefix may also be dynamically selectable, as described below. Higher system throughput may be achieved by using the shorter cyclic prefix when possible, since more OFDM symbols of shorter duration can be transmitted over a given fixed time interval.

FIG. 2 illustrates a layer structure **200** that may be used for the MIMO WLAN system. As shown in FIG. 2, in one embodiment, layer structure **200** includes (1) applications and upper layer protocols that approximately correspond to Layer 3 and higher of the ISO/OSI reference model (upper layers), (2) protocols and services that correspond to Layer 2 (the link layer), and (3) protocols and services that correspond to Layer 1 (the physical layer).

The upper layers includes various applications and protocols, such as signaling services **212**, data services **214**, voice services **216**, circuit data applications, and so on. Signaling is typically provided as messages and data is typically provided as packets. The services and applications in the upper layers originate and terminate messages and packets according to the semantics and timing of the communication protocol between the access point and the user terminal. The upper layers utilize the services provided by Layer 2.

Layer 2 supports the delivery of messages and packets generated by the upper layers. In the embodiment shown in FIG. 2, Layer 2 includes a Link Access Control (LAC) sublayer **220** and a Medium Access Control (MAC) sublayer

230. The LAC sublayer implements a data link protocol that provides for the correct transport and delivery of messages generated by the upper layers. The LAC sublayer utilizes the services provided by the MAC sublayer and Layer 1. The MAC sublayer is responsible for transporting messages and packets using the services provided by Layer 1. The MAC sublayer controls the access to Layer 1 resources by the applications and services in the upper layers. The MAC sublayer may include a Radio Link Protocol (RLP) **232**, which is a retransmission mechanism that may be used to provide higher reliability for packet data. Layer 2 provides protocol data units (PDUs) to Layer 1.

Layer 1 comprises physical layer **240** and supports the transmission and reception of radio signals between the access point and user terminal. The physical layer performs coding, interleaving, modulation, and spatial processing for various transport channels used to send messages and packets generated by the upper layers. In this embodiment, the physical layer includes a multiplexing sublayer **242** that multiplexes processed PDUs for various transport channels into the proper frame format. Layer 1 provides data in units of frames.

It should be understood by one skilled in the art that various other suitable layer structures may also be designed and used for the MIMO WLAN system.

FIG. 3 shows a block diagram of one embodiment of an access point **110x** and two user terminals **120x** and **120y** within the MIMO WLAN system.

On the downlink, at access point **110x**, a transmit (TX) data processor **310** receives traffic data (e.g., information bits) from a data source **308** and signaling and other information from a controller **330** and possibly a scheduler **334**. These various types of data may be sent on different transport channels that are described in more details below. TX data processor **310** “frames” the data (if necessary), scrambles the framed/unframed data, encodes the scrambled data, interleaves (i.e., reorders) the coded data, and maps the interleaved data into modulation symbols. For simplicity, a “data symbol” refers to a modulation symbol for traffic data, and a “pilot symbol” refers to a modulation symbol for pilot. The scrambling randomizes the data bits. The encoding increases the reliability of the data transmission. The interleaving provides time, frequency, and/or spatial diversity for the code bits. The scrambling, coding, and modulation may be performed based on control signals provided by controller **330**. TX data processor **310** provides a stream of modulation symbols for each spatial channel used for data transmission.

A TX spatial processor **320** receives one or more modulation symbol streams from TX data processor **310** and performs spatial processing on the modulation symbols to provide four streams of transmit symbols, one stream for each transmit antenna.

Each modulator (MOD) **322** receives and processes a respective transmit symbol stream to provide a corresponding stream of OFDM symbols. Each OFDM symbol stream is further processed to provide a corresponding downlink modulated signal. The four downlink modulated signals from modulator **322a** through **322d** are then transmitted from four antennas **324a** through **324d**, respectively.

At each user terminal **120**, one or multiple antennas **352** receive the transmitted downlink modulated signals, and each receive antenna provides a received signal to a respective demodulator (DEMOD) **354**. Each demodulator **354** performs processing complementary to that performed at modulator **322** and provides received symbols. A receive (RX) spatial processor **360** then performs spatial processing

on the received symbols from all demodulators **354** to provide recovered symbols, which are estimates of the modulation symbols sent by the access point.

An RX data processor **370** receives and demultiplexes the recovered symbols into their respective transport channels. The recovered symbols for each transport channel may be symbol demapped, deinterleaved, decoded, and descrambled to provide decoded data for that transport channel. The decoded data for each transport channel may include recovered packet data, messages, signaling, and so on, which are provided to a data sink **372** for storage and/or a controller **380** for further processing.

For the downlink, at each active user terminal **120**, RX spatial processor **360** further estimates the downlink to obtain channel state information (CSI). The CSI may include channel response estimates, received SNRs, and so on. RX data processor **370** may also provide the status of each packet/frame received on the downlink. A controller **380** receives the channel state information and the packet/frame status and determines the feedback information to be sent back to the access point. The feedback information is processed by a TX data processor **390** and a TX spatial processor **392** (if present), conditioned by one or more modulators **354**, and transmitted via one or more antennas **352** back to the access point.

At access point **110**, the transmitted uplink signal(s) are received by antennas **324**, demodulated by demodulators **322**, and processed by an RX spatial processor **340** and an RX data processor **342** in a complementary manner to that performed at the user terminal. The recovered feedback information is then provided to controller **330** and a scheduler **334**.

In one embodiment, scheduler **334** uses the feedback information to perform a number of functions such as (1) selecting a set of user terminals for data transmission on the downlink and uplink, (2) selecting the transmission rate(s) and the transmission mode for each selected user terminal, and (3) assigning the available FCH/RCH resources to the selected terminals. Scheduler **334** and/or controller **330** further uses information (e.g., steering vectors) obtained from the uplink transmission for the processing of the downlink transmission.

As mentioned above, a number of services and applications may be supported by the MIMO WLAN system and various transport channels may be defined for the MIMO WLAN system to carry various types of data. Table 3 lists an exemplary set of transport channels and also provides a brief description for each transport channel.

TABLE 3

Transport channels		Description
Broadcast channel	BCH	Used by the access point to transmit pilot and system parameters to the user terminals.
Forward control channel	FCCH	Used by the access point to allocate resources on the downlink and uplink. The resource allocation may be performed on a frame-by-frame basis. Also used to provide acknowledgment for messages received on the RACH.
Forward channel	FCH	Used by the access point to transmit user-specific data to the user terminals and possibly a reference (pilot) used by the user terminals for channel estimation. May also be used in a broadcast mode to send page and broadcast messages to multiple user terminals.

TABLE 3-continued

Transport channels		Description
Random access channel	RACH	Used by the user terminals to gain access to the system and send short messages to the access point.
Reverse channel	RCH	Used by the user terminals to transmit data to the access point. May also carry a reference used by the access point for channel estimation.

As shown in Table 3, the downlink transport channels used by the access point includes the BCH, FCCH, and FCH. The uplink transport channels used by the user terminals include the RACH and RCH. It should be recognized by one skilled in the art that the transport channels listed in Table 3 represent an exemplary embodiment of a channel structure that may be used for the MIMO WLAN system. Fewer, additional, and/or different transport channels may also be defined for use for the MIMO WLAN system. For example, certain functions may be supported by function-specific transport channels (e.g., pilot, paging, power control, and sync channel channels). Thus, other channel structures with different sets of transport channels may be defined and used for the MIMO WLAN system, within the scope of the invention.

A number of frame structures may be defined for the transport channels. The specific frame structure to use for the MIMO WLAN system is dependent on various factors such as, for example, (1) whether the same or different frequency bands are used for the downlink and uplink and (2) the multiplexing scheme used to multiplex the transport channels together.

If only one frequency band is available, then the downlink and uplink may be transmitted on different phases of a frame using time division duplexing (TDD). If two frequency bands are available, then the downlink and uplink may be transmitted on different frequency bands using frequency division duplexing (FDD).

For both TDD and FDD, the transport channels may be multiplexed together using time division multiplexing (TDM), code division multiplexing (CDM), frequency division multiplexing (FDM), and so on. For TDM, each transport channel is assigned to a different portion of a frame. For CDM, the transport channels are transmitted concurrently but each transport channel is channelized by a different channelization code, similar to that performed in a code division multiple access (CDMA) system. For FDM, each transport channel is assigned a different portion of the frequency band for the link.

Table 4 lists the various frame structures that may be used to carry the transport channels. Each of these frame structures is described in further detail below.

TABLE 4

	Shared frequency band for downlink and uplink	Separate frequency bands for downlink and uplink
Time division	TDD-TDM frame structure	FDD-TDM frame structure
Code division	TDD-CDM frame structure	FDD-CDM frame structure

FIG. 4A illustrates an embodiment of a TDD-TDM frame structure **400a** that may be used if a single frequency band is used for both the downlink and uplink. Data transmission occurs in units of TDD frames. Each TDD frame may be defined to span a particular time duration. The frame duration may be selected based on various factors such as, for

example, (1) the bandwidth of the operating band, (2) the expected sizes of the PDUs for the transport channels, and so on. In general, a shorter frame duration may provide reduced delays. However, a longer frame duration may be more efficient since header and overhead may represent a smaller fraction of the frame. In one embodiment, each TDD frame has a duration of 2 msec.

As shown in FIG. 4A, each TDD frame can be partitioned into a downlink phase and an uplink phase. The downlink phase is further partitioned into three segments for the three downlink transport channels—the BCH, FCCH, and FCH. The uplink phase is further partitioned into two segments for the two uplink transport channels—the RCH and RACH.

The segment for each transport channel may be defined to have either a fixed duration or a variable duration that can change from frame to frame. In one embodiment, the BCH segment is defined to have a fixed duration, and the FCCH, FCH, RCH, and RACH segments are defined to have variable durations.

The segment for each transport channel may be used to carry one or more protocol data units (PDUs) for that transport channel. In the embodiment shown in FIG. 4A, a BCH PDU is transmitted in a first segment **410**, an FCCH PDU is transmitted in a second segment **420**, and one or more FCH PDUs are transmitted in a third segment **430** of the downlink phase. On the uplink phase, one or more RCH PDUs are transmitted in a fourth segment **440** and one or more RACH PDUs are transmitted in a fifth segment **450** of the TDD frame.

Frame structure **400a** represents one arrangement of the various transport channels within a TDD frame. This arrangement can provide certain benefits such as reduced delays for data transmission on the downlink and uplink. The BCH is transmitted first in the TDD frame since it carries system parameters that may be used for the PDUs of the other transport channels within the same TDD frame. The FCCH is transmitted next since it carries resource allocation (e.g., channel assignment) information indicative of which user terminal(s) are designated to receive downlink data on the FCH and which user terminal(s) are designated to transmit uplink data on the RCH within the current TDD frame. Other TDD-TDM frame structures may also be defined and used for the MIMO WLAN system.

FIG. 4B illustrates an embodiment of an FDD-TDM frame structure **400b** that may be used if the downlink and uplink are transmitted using two separate frequency bands. Downlink data is transmitted in a downlink frame **402a**, and uplink data is transmitted in an uplink frame **402b**. Each downlink and uplink frame may be defined to span a particular time duration (e.g., 2 msec). For simplicity, the downlink and uplink frames may be defined to have the same duration and may further be defined to be aligned at the frame boundaries. However, different frame durations and/or non-aligned (i.e., offset) frame boundaries may also be used for the downlink and uplink.

As shown in FIG. 4B, the downlink frame is partitioned into three segments for the three downlink transport channels. The uplink frame is partitioned into two segments for the two uplink transport channels. The segment for each transport channel may be defined to have a fixed or variable duration, and may be used to carry one or more PDUs for that transport channel.

In the embodiment shown in FIG. 4B, the downlink frame carries a BCH PDU, an FCCH PDU, and one or more FCH PDUs in segments **410**, **420**, and **430**, respectively. The uplink frame carries one or more RCH PDUs and one or more RACH PDUs in segments **440** and **450**, respectively.

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This arrangement may provide the benefits described above (e.g., reduced delays for data transmission). Other FDD-TDM frame structures may also be defined and used for the MIMO WLAN system, and this is within the scope of the invention.

FIG. 4C illustrates an embodiment of an FDD-CDM/FDM frame structure 400c that may also be used if the downlink and uplink are transmitted using separate frequency bands. Downlink data may be transmitted in a downlink frame 404a, and uplink data may be transmitted in an uplink frame 404b. The downlink and uplink frames may be defined to have the same duration (e.g., 2 msec) and aligned at the frame boundaries.

As shown in FIG. 4C, the three downlink transport channels are transmitted concurrently in the downlink frame, and the two uplink transport channels are transmitted concurrently in the uplink frame. For CDM, the transport channels for each link are “channelized” with different channelization codes, which may be Walsh codes, orthogonal variable spreading factor (OVSF) codes, quasi-orthogonal functions (QOF), and so on. For FDM, the transport channels for each link are assigned different portions of the frequency band for the link. Different amounts of transmit power may also be used for different transport channels in each link.

Other frame structures may also be defined for the downlink and uplink transport channels, and this is within the scope of the invention. Moreover, it is possible to use different types of frame structure for the downlink and uplink. For example, a TDM-based frame structure may be used for the downlink and a CDM-based frame structure may be used for the uplink.

In one embodiment, the transport channels as described above are used to send various types of data and may be categorized into two groups: common transport channels and dedicated transport channels.

The common transport channels, in one embodiment, may include the BCH, FCCH, and RACH. These transport channels are used to send data to or receive data from multiple user terminals. The BCH and FCCH can be transmitted by the access point using the diversity mode. On the uplink, the RACH can be transmitted by the user terminals using the beam-steering mode (if supported by the user terminal). The BCH can be operated at a known fixed rate so that the user terminals can receive and process the BCH without any additional information. As described in more details below, the FCCH support multiple rates to allow for greater efficiency. Each “rate” or “rate set” may be associated with a particular code rate (or coding scheme) and a particular modulation scheme.

The dedicated transport channels, in one embodiment, include the FCH and RCH. These transport channels are normally used to send user-specific data to or by specific user terminals. The FCH and RCH may be dynamically allocated to the user terminals as necessary and as available. The FCH may also be used in a broadcast mode to send overhead, page, and broadcast messages to the user terminals. In general, the overhead, page, and broadcast messages are transmitted prior to any user-specific data on the FCH.

FIG. 5 illustrates an exemplary transmission on the BCH, FCCH, FCH, RCH, and RACH based on TDD-TDM frame structure 400a. In this embodiment, one BCH PDU 510 and one FCCH PDU 520 are transmitted in BCH segment 410 and FCCH segment 420, respectively. FCH segment 430 may be used to send one or more FCH PDUs 530, each of which may be intended for a specific user terminal or multiple user terminals. Similarly, one or more RCH PDUs

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540 may be sent by one or more user terminals in RCH segment 440. The start of each FCH/RCH PDU is indicated by an FCH/RCH offset from the end of the preceding segment. A number of RACH PDUs 550 may be sent in RACH segment 450 by a number of user terminals to access the system and/or to send short messages.

In one embodiment, the BCH is used by the access point to transmit a beacon pilot, a MIMO pilot, and system parameters to the user terminals. The beacon pilot is used by the user terminals to acquire system timing and frequency. The MIMO pilot is used by the user terminals to estimate the MIMO channel formed by the access point antennas and their own antennas. The system parameters specify various attributes of the downlink and uplink transmissions. For example, since the durations of the FCCH, FCH, RACH, and RCH segments are variable, the system parameters that specify the length of each of these segments for the current TDD frame are sent in the BCH.

FIG. 6A illustrates an embodiment of BCH PDU 410. In this embodiment, BCH PDU 410 includes a preamble portion 510 and a message portion 516. Preamble portion 510 further includes a beacon pilot portion 512 and a MIMO pilot portion 514. Portion 512 carries a beacon pilot and has a fixed duration of $T_{CP}=8 \mu\text{sec}$. Portion 514 carries a MIMO pilot and has a fixed duration of $T_{MP}=32 \mu\text{sec}$. Portion 516 carries a BCH message and has a fixed duration of $T_{BM}=40 \mu\text{sec}$. A preamble may be used to send one or more types of pilot and/or other information. A beacon pilot comprises a specific set of modulation symbols that is transmitted from all transmit antennas. A MIMO pilot comprises a specific set of modulation symbols that is transmitted from all transmit antennas with different orthogonal codes, which then allows the receivers to recover the pilot transmitted from each antenna. Different sets of modulation symbols may be used for the beacon and MIMO pilots.

In one embodiment, the BCH message carries system configuration information. Table 5 lists the various fields for an exemplary BCH message format.

TABLE 5

BCH Message

Fields/ Parameter Names	Length (bits)	Description
Frame Counter	4	TDD frame counter
Net ID	10	Network identifier (ID)
AP ID	6	Access point ID
AP Tx Lvl	4	Access point transmit level
AP Rx Lvl	3	Access point receive level
FCCH Length	6	Duration of FCCH (in units of OFDM symbols)
FCCH Rate	2	Physical layer rate of FCCH
FCH Length	9	Duration of FCH (in units of OFDM symbols)
RCH Length	9	Duration of RCH (in units of OFDM symbols)
RACH Length	5	Duration of RACH (in units of RACH slots)
RACH Slot Size	2	Duration of each RACH slot (in units of OFDM symbols)
RACH Guard Interval	2	Guard interval at the end of RACH
Cyclic Prefix Duration	1	Cyclic prefix duration
Page Bit	1	“0” = page message sent on FCH “1” = no page message sent
Broadcast Bit	1	“0” = broadcast message sent on FCH “1” = no broadcast message sent
RACH Acknowledgment Bit	1	“0” = RACH acknowledgment sent on FCH “1” = no RACH acknowledgment sent

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TABLE 5-continued

BCH Message		
Fields/ Parameter Names	Length (bits)	Description
CRC	16	CRC value for the BCH message
Tail Bits	6	Tail bits for convolutional encoder
Reserved	32	Reserved for future use

The Frame Counter value may be used to synchronize various processes at the access point and user terminals (e.g., the pilot, scrambling codes, cover code, and so on). A frame counter may be implemented with a 4-bit counter that wraps around. This counter is incremented at the start of each TDD frame, and the counter value is included in the Frame Counter field. The Net ID field indicates the identifier (ID) of the network to which the access point belongs. The AP ID field indicates the ID of the access point within the network ID. The AP Tx Lvl and AP Rx Lvl fields indicate the maximum transmit power level and the desired receive power level at the access point, respectively. The desired receive power level may be used by the user terminal to determine the initial uplink transmit power.

The FCCH Length, FCH Length, and RCH Length fields indicate the lengths of the FCCH, FCH, and RCH segments, respectively, for the current TDD frame. In one embodiment, the lengths of these segments are given in units of OFDM symbols. The OFDM symbol duration for the BCH can be fixed at 4.0 μ sec. The OFDM symbol duration for all other transport channels (e.g., the FCCH, FCH, RACH, and RCH) is variable and depends on the selected cyclic prefix, which is specified by the Cyclic Prefix Duration field. The FCCH Rate field indicates the rate used for the FCCH for the current TDD frame.

The RACH Length field indicates the length of the RACH segment, which is given in units of RACH slots. The duration of each RACH slot is given by the RACH Slot Size field, in units of OFDM symbols. The RACH Guard Interval field indicates the amount of time between the last RACH slot and the start of the BCH segment for the next TDD frame.

The Page Bit and Broadcast Bit indicate whether or not page messages and broadcast messages, respectively, are being sent on the FCH in the current TDD frame. These two bits may be set independently for each TDD frame. The RACH Acknowledgment Bit indicates whether or not acknowledgments for PDUs sent on the RACH in prior TDD frames are being sent on the FCCH in the current TDD frame.

The CRC field includes a CRC value for the entire BCH message. This CRC value may be used by the user terminals to determine whether the received BCH message is decoded correctly or in error. The Tail Bits field includes a group of zeros used to reset the convolutional encoder to a known state at the end of the BCH message.

As shown in Table 5, the BCH message includes a total of 120 bits. These 120 bits may be transmitted with 10 OFDM symbols. Table 5 shows one embodiment of the format for the BCH message. Other BCH message formats with fewer, additional, and/or different fields may also be defined and used, and this is within the scope of the invention.

In one embodiment, the access point may allocate resources for the FCH and RCH on a per frame basis. The

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FCCH is used by the access point to convey the resource allocation information for the FCH and RCH (e.g., the channel assignments).

FIG. 6B illustrates an embodiment of FCCH PDU 420. In this embodiment, the FCCH PDU includes only a portion 520 for an FCCH message. The FCCH message has a variable duration that can change from frame to frame, depending on the amount of scheduling information being carried on the FCCH for that frame. The FCCH message duration is in even number of OFDM symbols and given by the FCCH Length field on the BCH message. The duration of messages sent using the diversity mode (e.g., BCH and FCCH messages) is given in even number of OFDM symbols because the diversity mode transmits OFDM symbols in pairs.

In an embodiment, the FCCH can be transmitted using four possible rates. The specific rate used for the FCCH PDU in each TDD frame is indicated by the FCCH Phy Mode field in the BCH message. Each FCCH rate corresponds to a particular code rate and a particular modulation scheme and is further associated with a particular transmission mode.

An FCCH message may include zero, one, or multiple information elements (IEs). Each information element may be associated with a specific user terminal and may be used to provide information indicative of the assignment of FCH/RCH resources for that user terminal. Table 6 lists the various fields for an exemplary FCCH message format.

TABLE 6

FCCH Message		
Fields/ Parameter Names	Length (bits)	Description
N_IE	6	Number of IEs included in the FCCH message N_IE information elements, each including:
IE Type	4	IE type
MAC ID	10	ID assigned to the user terminal
Control Fields	48 or 72	Control fields for channel assignment
Padding Bits	Variable	Pad bits to achieve even number of OFDM symbols in the FCCH message
CRC	16	CRC value for the FCCH message
Tail Bits	6	Tail bits for convolutional encoder

The N_IE field indicates the number of information elements included in the FCCH message sent in the current TDD frame. For each information element (IE) included in the FCCH message, the IE Type field indicates the particular type of this IE. Various IE types are defined for use to allocate resources for different types of transmissions, as described below.

The MAC ID field identifies the specific user terminal for which the information element is intended. Each user terminal registers with the access point at the start of a communication session and is assigned a unique MAC ID by the access point. This MAC ID is used to identify the user terminal during the session.

The Control Fields are used to convey channel assignment information for the user terminal and are described in detail below. The Padding Bits field includes a sufficient number of padding bits so that the overall length of the FCCH message is an even number of OFDM symbols. The FCCH CRC field includes a CRC value that may be used by the user terminals

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to determine whether the received FCCH message is decoded correctly or in error. The Tail Bits field includes zeros used to reset the conventional encoder to a known state at the end of the FCCH message. Some of these fields are described in further detail below.

A number of transmission modes are supported by the MIMO WLAN system for the FCH and RCH, as indicated in Table 1. Moreover, a user terminal may be active or idle during a connection. Thus, a number of types of IE are defined for use to allocate FCH/RCH resources for different types of transmissions. Table 7 lists an exemplary set of IE types.

TABLE 7

FCCH IE Types			
IE Type	IE Size (bits)	IE Type	Description
0	48	Diversity Mode	Diversity mode only
1	72	Spatial Multiplexing Mode	Spatial multiplexing mode - variable rate services
2	48	Idle Mode	Idle state - variable rate services
3	48	RACH Acknowledgment	RACH acknowledgment - diversity mode
4		Beam Steering Mode	Beam steering mode
5-15	—	Reserved	Reserved for future use

For IE types 0, 1 and 4, resources are allocated to a specific user terminal for both the FCH and RCH (i.e., in channel pairs). For IE type 2, minimal resources are allocated to the user terminal on the FCH and RCH to maintain up-to-date estimate of the link. An exemplary format for each IE type is described below. In general, the rates and durations for the FCH and RCH can be independently assigned to the user terminals.

IE type 0 and 4 are used to allocate FCH/RCH resources for the diversity and beam-steering modes, respectively. For fixed low-rate services (e.g., voice), the rate remains fixed for the duration of the call. For variable rate services, the rate may be selected independently for the FCH and RCH. The FCCH IE indicates the location of the FCH and RCH PDUs assigned to the user terminal. Table 8 lists the various fields of an exemplary IE Type 0 and 4 information element.

TABLE 8

FCCH IE Type 0 and 4		
Fields/Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to the user terminal
FCH Offset	9	FCH offset from start of the TDD frame (in OFDM symbols)
FCH Preamble Type	2	FCH preamble size (in OFDM symbols)
FCH Rate	4	Rate for the FCH
RCH Offset	9	RCH offset from start of the TDD frame (in OFDM symbols)
RCH Preamble Type	2	RCH preamble size (in OFDM symbols)
RCH Rate	4	Rate for the RCH
RCH Timing Adjustment	2	Timing adjustment parameter for RCH
RCH Power Control	2	Power control bits for RCH

The FCH and RCH Offset fields indicate the time offset from the beginning of the current TDD frame to the start of

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the FCH and RCH PDUs, respectively, assigned by the information element. The FCH and RCH Rate fields indicate the rates for the FCH and RCH, respectively.

The FCH and RCH Preamble Type fields indicate the size of the preamble in the FCH and RCH PDUs, respectively. Table 9 lists the values for the FCH and RCH Preamble Type fields and the associated preamble sizes.

TABLE 9

Preamble Type			
Type	Bits	Preamble Size	
0	00	0 OFDM symbol	
1	01	1 OFDM symbol	
2	10	4 OFDM symbols	
3	11	8 OFDM symbols	

The RCH Timing Adjustment field includes two bits used to adjust the timing of the uplink transmission from the user terminal identified by the MAC ID field. This timing adjustment is used to reduce interference in a TDD-based frame structure where the downlink transmissions are time division duplexed. Table 10 lists the values for the RCH Timing Adjustment field and the associated actions.

TABLE 10

RCH Timing Adjustment	
Bits	Description
00	Maintain current timing
01	Advance uplink transmit timing by 1 sample
10	Delay uplink transmit timing by 1 sample
11	Not used

The RCH Power Control field includes two bits used to adjust the transmit power of the uplink transmission from the identified user terminal. This power control is used to reduce interference on the uplink. Table 11 lists the values for the RCH Power Control field the associated actions.

TABLE 11

RCH Power Control	
Bits	Description
00	Maintain current transmit power
01	Increase uplink transmit power by δ dB, where δ is a system parameter.
10	Decrease uplink transmit power by δ dB, where δ is a system parameter.
11	Not used

The channel assignment for the identified user terminal may be provided in various manners. In an embodiment, the user terminal is assigned FCH/RCH resources for only the current TDD frame. In another embodiment, the FCH/RCH resources are assigned to the terminal for each TDD frame until canceled. In yet another embodiment, the FCH/RCH resources are assigned to the user terminal for every n-th TDD frame, which is referred to as “decimated” scheduling of TDD frames. The different types of assignment may be indicated by an Assignment Type field in the FCCH information element.

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IE type 1 is used to allocate FCH/RCH resources to user terminals using the spatial multiplexing mode. The rate for these user terminals is variable, and may be selected independently for the FCH and RCH. Table 12 lists the various fields of an exemplary IE type 1 information element.

TABLE 12

FCCH IE Type 1		
Fields/ Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to the user terminal
FCH Offset	9	FCH offset from end of FCCH (in OFDM symbols)
FCH Preamble Type	2	FCH preamble size (in OFDM symbols)
FCH Spatial Channel 1 Rate	4	Rate for the FCH for spatial channel 1
FCH Spatial Channel 2 Rate	4	Rate for the FCH for spatial channel 2
FCH Spatial Channel 3 Rate	4	Rate for the FCH for spatial channel 3
FCH Spatial Channel 4 Rate	4	Rate for the FCH for spatial channel 4
RCH Offset	9	RCH offset from end of FCH (in OFDM symbols)
RCH Preamble Type	2	RCH preamble size (in OFDM symbols)
RCH Spatial Channel 1 Rate	4	Rate for the RCH for spatial channel 1
RCH Spatial Channel 2 Rate	4	Rate for the RCH for spatial channel 2
RCH Spatial Channel 3 Rate	4	Rate for the RCH for spatial channel 3
RCH Spatial Channel 4 Rate	4	Rate for the RCH for spatial channel 4
RCH Timing Adjustment	2	Timing adjustment parameter for RCH
Reserved	2	Reserved for future use

For IE type 1, the rate for each spatial channel may be selected independently on the FCH and RCH. The interpretation of the rates for the spatial multiplexing mode is general in that it can specify the rate per spatial channel (e.g., for up to four spatial channels for the embodiment shown in Table 12). The rate is given per eigenmode if the transmitter performs spatial processing to transmit data on the eigenmodes. The rate is given per antenna if the transmitter simply transmits data from the transmit antennas and the receiver performs the spatial processing to isolate and recover the data (for the non-steered spatial multiplexing mode).

The information element includes the rates for all enabled spatial channels and zeros for the ones not enabled. User terminals with less than four transmit antennas set the unused FCH/RCH Spatial Channel Rate fields to zero. Since the access point is equipped with four transmit/receive antennas, user terminals with more than four transmit antennas may use them to transmit up to four independent data streams.

IE type 2 is used to provide control information for user terminals operating in an Idle state. In an embodiment, when a user terminal is in the Idle state, steering vectors used by the access point and user terminal for spatial processing are continually updated so that data transmission can start quickly if and when resumed. Table 13 lists the various fields of an exemplary IE type 2 information element.

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TABLE 13

FCCH IE Type 2		
Fields/ Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to the user terminal
FCH Offset	9	FCH offset from end of FCCH (in OFDM symbols)
FCH Preamble Type	2	FCH preamble size (in OFDM symbols)
RCH Offset	9	RCH offset from end of FCH (in OFDM symbols)
RCH Preamble Type	2	RCH preamble size (in OFDM symbols)
Reserved	12	Reserved for future use

IE type 3 is used to provide quick acknowledgment for user terminals attempting to access the system via the RACH. To gain access to the system or to send a short message to the access point, a user terminal may transmit an RACH PDU on the uplink. After the user terminal sends the RACH PDU, it monitors the BCH to determine if the RACH Acknowledgement Bit is set. This bit is set by the access point if any user terminal was successful in accessing the system and an acknowledgment is being sent for at least one user terminal on the FCCH. If this bit is set, then the user terminal processes the FCCH for acknowledgment sent on the FCCH. IE Type 3 information elements are sent if the access point desires to acknowledge that it correctly decoded the RACH PDUs from the user terminals without assigning resources. Table 14 lists the various fields of an exemplary IE Type 3 information element.

TABLE 14

FCCH IE Type 3		
Fields/ Parameter Names	Length (bits)	Description
IE Type	4	IE type
MAC ID	10	Temporary ID assigned to user terminal
Reserved	34	Reserved for future use

A single or multiple types of acknowledgment may be defined and sent on the FCCH. For example, a quick acknowledgment and an assignment-based acknowledgment may be defined. A quick acknowledgment may be used to simply acknowledge that the RACH PDU has been received by the access point but that no FCH/RCH resources have been assigned to the user terminal. An assignment-based acknowledgment includes assignments for the FCH and/or RCH for the current TDD frame.

A number of different rates are supported for the transport channels. Each rate is associated with a particular code rate and a particular modulation scheme, which collectively results in a particular spectral efficiency (or data rate). Table 15 lists the various rates supported by the system.

TABLE 15

Rate Word	Spectral Efficiency (bps/Hz)	Code Rate	Modulation Scheme	Info bits/OFDM symbol	Code bits/OFDM symbol
0000	0.0	—	off	—	—
0001	0.25	1/4	BPSK	12	48

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TABLE 15-continued

Rate Word	Spectral Efficiency (bps/Hz)	Code Rate	Modulation Scheme	Info bits/ OFDM symbol	Code bits/ OFDM symbol
0010	0.5	$\frac{1}{2}$	BPSK	24	48
0011	1.0	$\frac{1}{2}$	QPSK	48	96
0100	1.5	$\frac{3}{4}$	QPSK	72	96
0101	2.0	$\frac{1}{2}$	16 QAM	96	192
0110	2.5	$\frac{3}{8}$	16 QAM	120	192
0111	3.0	$\frac{3}{4}$	16 QAM	144	192
1000	3.5	$\frac{7}{12}$	64 QAM	168	288
1001	4.0	$\frac{2}{3}$	64 QAM	192	288
1010	4.5	$\frac{3}{4}$	64 QAM	216	288
1011	5.0	$\frac{5}{6}$	64 QAM	240	288
1100	5.5	$\frac{11}{16}$	256 QAM	264	384
1101	6.0	$\frac{3}{4}$	256 QAM	288	384
1110	6.5	$\frac{13}{16}$	256 QAM	312	384
1111	7.0	$\frac{7}{8}$	256 QAM	336	384

While the FCCH channel structure as described above can be operable at different data rates, this structure may not be efficient because the rate employed on the FCCH is dictated or limited by the worst-case user in the system (e.g., the user that operates at the lowest data rate). For example, if one of the users can only receive and decode information on the FCCH at a low data rate of 0.25 bps/Hz, other users in the system will be adversely affected even though they are capable of operating at higher data rates. This is because the rate employed on the FCCH structure will be limited to that of the worst-case user, which is 0.25 bps/Hz. Thus, the FCCH performance and efficiency may be reduced by a single user. As described in more details below, the present invention provides a novel and more efficient FCCH channel structure that can be used to accommodate different users operable at different data rates.

In one embodiment, the new FCCH structure, also referred to as a tiered control channel structure or segregated control channel structure herein), comprises multiple control channels (e.g., 4 distinct control channels). Each of these distinct control channels, also called control subchannel or FCCH subchannel herein, can operate at one of the multiple overhead data rates (e.g., one or four different data rates as mentioned above).

FIG. 7 illustrates a diagram of a new FCCH structure within a TDD MAC frame, in accordance with one embodiment of the invention. It should be understood by one skilled in the art that while TDD-TDM frame structure is used in this example for the purposes of illustration and explanation, the teachings of the present invention are not limited to TDD frame structure but can also be applied to various other frame structures of various durations (e.g., FDD-TDM, etc.). As shown in FIG. 7, the TDD MAC frame is partitioned into a downlink phase (also called downlink segment) 701 and an uplink phase (also called uplink segment) 751. In this embodiment, the downlink phase is further divided into three segments for the three corresponding transport channels—the BCH 710, the FCCH 720, and the FCH 730. The uplink phase is further partitioned into two segments for the two corresponding transport channels—the RCH 740 and the RACH 750.

As shown in FIG. 7, the FCCH segment is divided or partitioned into multiple distinct FCCH segments or subchannels, each of which may operate at a specific data rate. In this example, the FCCH segment is divided into four FCCH subchannels (FCCH_0, FCCH_1, FCCH_2, and FCCH_3). In other embodiments of the invention, the FCCH segment may be divided into different numbers of subchannels (e.g., 8 subchannels, etc.), depending on the particular

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applications or implementations of the invention. In one embodiment, each FCCH subchannel may be associated with a specific set of operating and processing parameters (e.g., code rate, modulation scheme, SNR, etc.). For example, Table 16 below illustrates the code rates, modulation scheme, SNR, etc., that are associated with each FCCH subchannel. In this example, STTD is employed for each of the subchannels, in which case the length of each subchannel is a multiple of two OFDM symbols.

TABLE 16

FCCH Subchannel Data Rates (STTD)					
FCCH Sub-channel	Efficiency (bps/Hz)	Code Rate	Modulation	Information Bits Per STTD OFDM symbol	Total SNR for 1% Frame Error Rate (FER)
FCCH_0	0.25	0.25	BPSK	24	-2.0 dB
FCCH_1	0.5	0.5	BPSK	48	2.0 dB
FCCH_2	1	0.5	QPSK	96	5.0 dB
FCCH_3	2	0.5	16 QAM	192	11.0 dB

As shown in Table 16, each FCCH subchannel has a distinct operating point (e.g., SNR and other processing parameters) associated with it. A user terminal (UT) that is assigned a specific FCCH subchannel (e.g., FCCH_n at a particular rate) can correctly decode all lower rate subchannels, but not those operating at the higher rates. For example, if a particular user terminal is assigned subchannel FCCH_2, that user terminal can decode FCCH_0 and FCCH_1 subchannels because FCCH_0 and FCCH_1 operate at the lower rates. However, that user terminal cannot decode FCCH_3 because FCCH_3 operates at a higher rate. In one embodiment, the access point (AP) decides which FCCH subchannel to send control data to a UT based on various factors or selection criteria. These various factors or selection may include link quality information or operating conditions of the user terminals (e.g., C/I, Doppler, etc.), quality of service (QoS) requirements associated with the user terminals, and control subchannel preference indicated by the user terminals, etc. As described in more details below, the user terminals then attempt to decode each of the FCCH subchannels to determine if they have been allocated resources (e.g., FCH/RCH channel resources).

Table 17 illustrates the structure for the various FCCH subchannels, in accordance with one embodiment of the present invention. As shown in Table 17, the FCCH subchannel structure for subchannel FCCH_0 is distinct from the structure used for other FCCH subchannels (FCCH_1, FCCH_2, and FCCH_3). In one embodiment, the FCCH_MASK field in the FCCH_0 structure is used to indicate the presence/absence of higher rate FCCH subchannels in a particular order. For example, the FCCH_MASK field may comprise three bits each of which corresponds to a particular subchannel and is used to indicate whether the particular subchannel is present in an order from subchannel 1 (MASK bit 0), subchannel 2 (MASK bit 1), and subchannel 3 (MASK bit 2). The corresponding subchannel MASK bit is set to a particular value (e.g., 1) to indicate the presence of the respective subchannel. For example, if the value of MASK bit number 0 (the least significant MASK bit) is set to "1", this indicates the presence of FCCH_1 subchannel. Pad bits are provided to achieve an even number of OFDM symbols in each subchannel. In one embodiment, each FCCH subchannel is capable of providing scheduling infor-

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mation for multiple user terminals (e.g., 32 users). The IE types described above can be used for the FCCH subchannels.

TABLE 17

FCCH Subchannel Structure	
	Bits
<u>FCCH_0:</u>	
FCCH MASK	3
No. IE Rate 0	5
Rate 0 IE's	
0 Padding	
CRC	16
Tail	6
<u>FCCH_1:</u>	
No. IE Rate 1	5
Rate 1 IE's	
0 Padding	
CRC	16
Tail	6
<u>FCCH_2:</u>	
No. IE Rate 2	5
Rate 2 IE's	
0 Padding	
CRC	16
Tail	6
<u>FCCH_3:</u>	
No. IE Rate 3	5
Rate 3 IE's	
0 Padding	
CRC	16
Tail	6

FIG. 8 illustrates a flow diagram of a method 800 in accordance with one embodiment of the present invention. At block 810, as described above, a control channel is segregated or partitioned into a plurality of subchannels each of which being operable at a specific data rate. At block 820, control information including resource allocation information is transmitted from an access point to a user terminal on a particular subchannel of the plurality subchannels selected for the user terminal, based on one or more selection criteria, as described above. At block 830, at the user terminal, one or more subchannels of the plurality of subchannels are decoded to obtain control information (e.g., channel assignments) designated for the user terminal. In one embodiment, as explained in more details below, the decoding procedure performed at the user terminal starts with the FCCH subchannel operated at the lowest data rate (FCCH_0 in this example) and continues until at least one of a plurality of conditions is satisfied.

FIG. 9 shows a flow diagram of a decoding procedure 900 performed by a user terminal in decoding the new FCCH structure, in accordance with one embodiment of the present invention. The user terminal starts by decoding the subchannel FCCH_0. In one embodiment, decoding is considered successful if the CRC test passes. The user terminal terminates FCCH decoding process whenever any of the following events occurs:

- (i) Failure to correctly decode an FCCH subchannel;
- (ii) Receipt of an assignment;
- (iii) Decoding of all active FCCH subchannels without receiving an assignment.

Referring again to FIG. 9, at block 910, the process begins by initializing n to 0. In this example, n is a variable used to indicate the current FCCH subchannel being decoded in the

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current iteration of the process. At block 915, the current FCCH_n subchannel is decoded. For example, in the first iteration, FCCH_0 is decoded at block 915. At block 920, it is determined whether the CRC test with respect to the current FCCH_n subchannel passes. If the CRC test passes, the process proceeds to block 925 to determine whether the corresponding MAC ID is present, otherwise the process proceeds to block 930 to process the next MAC frame. At block 925, if the corresponding MAC ID is present, the process proceeds to block 940 to obtain the assignment information provided by the access point. Otherwise, the process proceeds to block 935 to check if n is equal to 3. At block 935, if n is equal to 3, the process proceeds to block 945 to initialize the FCCH_MASK field to indicate that all FCCH subchannels have been processed. As described above, in one embodiment, the FCCH_MASK field in the FCCH_0 subchannel structure comprises three bits each of which is used to indicate the presence/absence of a corresponding higher rate FCCH subchannel. For example, the first bit (bit 0 or the least significant bit) of the FCCH_MASK field is used to indicate the presence/absence of subchannel 1, the second bit (bit 1 or the next significant bit) of the FCCH_MASK field is used to indicate the presence/absence of subchannel 2, and so on. The process then proceeds to block 950 to determine whether there are any active FCCH subchannels remaining to be decoded. If there are more active FCCH subchannels to be decoded, the process proceeds to block 960 to increment n to the next active FCCH subchannel. Otherwise the process proceeds to block 955 to process the next MAC frame.

Various parts of the MIMO WLAN system and various techniques described herein may be implemented by various means. For example, the processing at the access point and user terminal may be implemented in hardware, software, or a combination thereof. For a hardware implementation, the processing may be implemented within one or more application specific integrated circuits (ASICs), digital signal processors (DSPs), digital signal processing devices (DSPDs), programmable logic devices (PLDs), field programmable gate arrays (FPGAs), processors, controllers, micro-controllers, microprocessors, other electronic units designed to perform the functions described herein, or a combination thereof.

For a software implementation, the processing may be implemented with modules (e.g., procedures, functions, and so on) that perform the functions described herein. The software codes may be stored in a memory unit and executed by a processor. The memory unit may be implemented within the processor or external to the processor, in which case it can be communicatively coupled to the processor via various means as is known in the art.

Headings are included herein for reference and to aid in locating certain sections. These headings are not intended to limit the scope of the concepts described therein under, and these concepts may have applicability in other sections throughout the entire specification.

The previous description of the disclosed embodiments is provided to enable any person skilled in the art to make or use the present invention. Various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without departing from the spirit or scope of the invention. Thus, the present invention is not intended to be limited to the embodiments shown herein but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

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What is claimed is:

1. A method for processing information in a communication system, comprising:
 - partitioning, at an access point, a control channel used for transmitting control information into a plurality of subchannels;
 - selecting, for each of at least two user terminals, one of the subchannels to be used for transmitting the control information from the access point to the respective user terminal, based on one or more selection criteria; and
 - transmitting the control information on the control channel from the access point, wherein at least two of the subchannels are operated at different data rates.
2. The method of claim 1 wherein the control information is transmitted in a segment of a data frame specifically allocated for the control channel.
3. The method of claim 1 wherein each different data rate is associated with a different set of operating parameters.
4. The method of claim 3 wherein the operating parameters are selected from the group consisting of a code rate, a modulation scheme, and a signal-to-noise ratio (SNR).
5. The method of claim 1 wherein the control information is transmitted on the plurality of subchannels sequentially in an order from a subchannel with a lowest data rate to a subchannel with a highest data rate.
6. The method of claim 5 wherein the control information transmitted on one of the subchannels includes a field to indicate whether the control information is also transmitted on other subchannels.
7. The method of claim 6 wherein the field comprises a plurality of bits each of which corresponds to a particular subchannel and is used to indicate whether the corresponding subchannel is present in the segment allocated for transmitting the control information.
8. The method of claim 1 wherein the one or more selection criteria are selected from the group consisting of a first criterion corresponding to a link quality associated with the respective user terminal, a second criterion corresponding to quality of service requirements associated with the respective user terminal, and a third criterion corresponding to a subchannel preference indicated by the respective user terminal.
9. A method for processing information in a communication system, comprising:
 - segregating, at an access point, a control channel into a plurality of subchannels;
 - transmitting control information on the control channel, wherein at least two of the subchannels are operated at different data rates, the control information including resource allocation information from the access point to a user terminal on a particular subchannel of the plurality of subchannels selected for the user terminal, based on one or more selection criteria; and
 - decoding, at the user terminal, one or more subchannels of the plurality of subchannels to obtain control information designated for the user terminal.
10. The method of claim 9 wherein decoding comprises: performing a decoding procedure to decode the one or more subchannels, starting with a subchannel operated at a lowest data rate, until at least one of a plurality of conditions is met.
11. The method of claim 10 further comprising: terminating the decoding procedure if one of the plurality of conditions is met.
12. The method of claim 11 wherein the plurality of conditions includes a first condition indicating a failure to correctly decode one of the plurality of subchannels.

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13. The method of claim 11 wherein the plurality of conditions includes a second condition indicating that the control information designated for the user terminal has been obtained from one of the plurality of subchannels.

14. The method of claim 11 wherein the plurality of conditions includes a third condition indicating that all subchannels have been processed.

15. The method of claim 10 wherein performing the decoding procedure comprises:

determining whether information transmitted on a subchannel has been correctly received, based on a quality metric corresponding to the respective subchannel.

16. The method of claim 15 wherein the quality metric comprises a cyclic redundancy check (CRC).

17. The method of claim 10 wherein performing the decoding procedure comprises:

determining whether the control information designated for the user terminal is present in the respective subchannel, based on an identifier associated with the user terminal.

18. The method of claim 17 wherein the identifier comprises a Medium Access Control (MAC) identifier.

19. The method of claim 9 wherein the one or more selection criteria are selected from the group consisting of a first criterion corresponding to operating conditions of the respective user terminal, a second criterion corresponding to quality of service requirements associated with the respective user terminal, and a third criterion corresponding to a subchannel preference indicated by the respective user terminal.

20. An apparatus for processing information in a communication system, comprising:

means for partitioning, at an access point, a control channel that is used for transmitting control information into a plurality of subchannels;

means for selecting, for each of one or more user terminals, one of the subchannels to be used for transmitting the control information from the access point to the respective user terminal, based on one or more selection criteria; and

means for transmitting the control information on the control channel, wherein at least two of the subchannels are operated at different data rates.

21. The apparatus of claim 20 wherein each subchannel is associated with a distinct set of operating parameters including a code rate, a modulation scheme, and an SNR.

22. The apparatus of claim 20 wherein the plurality of subchannels are transmitted sequentially in an order from a subchannel with a lowest data rate to a subchannel with a highest data rate.

23. The apparatus of claim 22 wherein a subchannel that is transmitted first in the plurality of subchannels includes a field to indicate whether other subchannels are also being transmitted.

24. The apparatus of claim 20 wherein the one or more selection criteria including a first criterion corresponding to a link quality associated with the respective user terminal, a second criterion corresponding to quality of service requirements associated with the respective user terminal, and a third criterion corresponding to a subchannel preference indicated by the respective user terminal.

25. An apparatus for processing information in a communication system, comprising:

means for segregating, at an access point, a control channel into a plurality of subchannels;

means for transmitting control information on the control channel, wherein at least two of the subchannels are

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operated at different data rates, the control information including resource allocation information from the access point to a user terminal on a particular subchannel of the plurality of subchannels selected for the user terminal, based on one or more selection criteria; and means for decoding, at the user terminal, one or more subchannels of the plurality of subchannels to obtain control information designated for the user terminal.

26. The apparatus of claim 25 wherein the means for decoding comprises:

means for performing a decoding procedure to decode the one or more subchannels, starting with a subchannel operated at a lowest data rate, until at least one of a plurality of conditions is met.

27. The apparatus of claim 26 wherein the plurality of conditions includes a first condition indicating a failure to correctly decode one of the plurality of subchannels, a second condition indicating that the control information designated for the user terminal has been obtained from one of the plurality of subchannels, and a third condition indicating that all subchannels have been processed.

28. The apparatus of claim 25 wherein the means for performing a decoding procedure comprises:

means for determining whether information transmitted on a subchannel has been correctly received, based on a quality metric corresponding to the respective subchannel; and

means for determining whether the control information designated for the user terminal is present in the respective subchannel, based on an identifier associated with the user terminal.

29. The apparatus of claim 25 wherein the one or more selection criteria including a first criterion corresponding to operating conditions of the respective user terminal, a second criterion corresponding to quality of service requirements associated with the respective user terminal, and a third criterion corresponding to a subchannel preference indicated by the respective user terminal.

30. An apparatus for processing information in a communication system, comprising:

a controller configured to select, at an access point, at least one of a plurality of control subchannels of a control channel to send control information to each of at least two user terminals, based on one or more selection criteria; and

a transmitter configured to transmit the control information on the control channel from the access point, wherein at least two of the control subchannels are operated at different data rates, the control information including resource allocation information from the access point to a user terminal on a particular control subchannel of the plurality of control subchannels selected for the user terminal, based on the one or more selection criteria.

31. The apparatus of claim 30 wherein each control subchannel is associated with a specific set of operating parameters, including a data rate at which the control information is transmitted, a code rate, a modulation scheme, and an SNR.

32. The apparatus of claim 30 wherein the plurality of control subchannels are transmitted sequentially in an order from a control subchannel with a lowest data rate to a control subchannel with a highest data rate.

33. The apparatus of claim 30 wherein the one or more selection criteria including a first criterion corresponding to a link quality associated with the respective user terminal, a second criterion corresponding to quality of service require-

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ments associated with the respective user terminal, and a third criterion corresponding to a control subchannel preference indicated by the respective user terminal.

34. An apparatus for processing information in a communication system, comprising:

a receiver configured to receive information on one or more control subchannels, at least two of which being operated at different data rates; and

a decoder configured to decode the one or more control subchannels to obtain control information designated for a particular user terminal, starting with a control subchannel operated at a lowest data rate, until at least one of a plurality of conditions is met.

35. The apparatus of claim 34 wherein the plurality of conditions includes a first condition indicating a failure to correctly decode one of the one or more control subchannels, a second condition indicating that the control information designated for the user terminal has been obtained from one of the one or more control subchannels, and a third condition indicating that all of the control subchannels have been processed.

36. The apparatus of claim 34 wherein the decoder is configured to determine whether the information received on a control subchannel has been correctly received, based on a quality metric corresponding to the respective control subchannel and to determine whether the control information designated for the user terminal is present in the respective control subchannel, based on an identifier associated with the user terminal.

37. A memory unit having software codes stored thereon, the software codes being executed by a processor for:

partitioning a control channel used for transmitting control information into a plurality of subchannels;

selecting, for each of one or more user terminals, one of the subchannels to be used for transmitting the control information from an access point to the respective user terminal, based on one or more selection criteria; and transmitting the control information on the control channel, wherein at least two of the subchannels are operated at different data rates.

38. The memory unit of claim 37 wherein each subchannel is associated with a set of operating parameters, including a data rate at which the control information is transmitted, a code rate, a modulation scheme, and an SNR.

39. The memory unit of claim 37 wherein the one or more selection criteria includes a first criterion corresponding to a link quality associated with the respective user terminal, a second criterion corresponding to quality of service requirements associated with the respective user terminal, and a third criterion corresponding to a subchannel preference indicated by the respective user terminal.

40. A memory unit having software codes stored thereon, the software codes being executed by a processor for:

receiving information on one or more control subchannels, at least two of which being operated at different data rates; and

decoding the information received on the one or more control subchannels to obtain control information designated for a particular user terminal, starting with a control subchannel operated at a lowest data rate, until at least one of a plurality of conditions is met.

41. The memory unit of claim 40 wherein the plurality of conditions includes a first condition indicating a failure to correctly decode the information received on one of the one or more control subchannels, a second condition indicating that the control information designated for the user terminal has been obtained from one of the one or more control

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subchannels, and a third condition indicating that all of the control subchannels have been processed.

42. The memory unit of claim 40 wherein the decoding comprises determining whether the information received on a control subchannel has been correctly received, based on a quality metric corresponding to the respective control subchannel and to determine whether the control information designated for the user terminal is present in the respective control subchannel, based on an identifier associated with the user terminal.

43. A method for processing information in a system, comprising:

receiving, at a user terminal, information on one or more control subchannels, at least two of which being operated at different data rates; and

decoding the information received on the one or more control subchannels to obtain control information designated for a particular user terminal, starting with a control subchannel operated at a lowest data rate, until at least one of a plurality of conditions is met.

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44. The method of claim 43 wherein the plurality of conditions includes a first condition indicating a failure to correctly decode one of the one or more control subchannels, a second condition indicating that the control information designated for the user terminal has been obtained from one of the one or more control subchannels, and a third condition indicating that all of the control subchannels have been processed.

45. The method of claim 43 wherein decoding comprises:

determining whether the information received on a control subchannel has been correctly received, based on a quality metric corresponding to the respective control subchannel; and

determining whether the control information designated for the user terminal is present in the respective control subchannel, based on an identifier associated with the user terminal.

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